Draft Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (*Salmo salar*)

June, 2004

DRAFT

Prepared by

National Marine Fisheries Service
(NOAA Fisheries)
Silver Spring, Maryland

and

Northeastern Region
U.S. Fish and Wildlife Service
Hadley, Massachusetts

DISCLAIMER

Recovery plans delineate actions that are believed to be required to recover and/or protect endangered species. Recovery plans are prepared by the National Marine Fisheries Service (NOAA Fisheries) and the U.S. Fish and Wildlife Service (FWS) and sometimes with the assistance of recovery teams, contractors, state agencies and others. This draft Recovery Plan for the Gulf of Maine (GOM) Distinct Population Segment (DPS) of Atlantic Salmon (*Salmo salar*) was prepared by an interagency writing committee composed of staff from the Northeast Regional Offices of NOAA Fisheries, FWS and the Maine Atlantic Salmon Commission (ASC). While the State of Maine provided recommendations for this plan, it was developed using federal guidelines and policies pertaining to recovery plans for federally listed species. Recovery plans are not regulatory or decision documents -- that is, the recommendations in a recovery plan are not considered final decisions unless and until they are actually proposed for implementation. Objectives will only be attained and funds expended contingent upon appropriations, priorities and other budgetary constraints. Nothing in this plan should be construed as a commitment or requirement that any federal agency obligate or pay funds in contravention of the Anti-Deficiency Act, 31 U.S.C. 1341, or any other law or regulation. Recovery plans do not necessarily represent the views nor the official positions or approval of any individuals or agencies, other than those of NOAA Fisheries and FWS. They will represent the official positions of NOAA Fisheries and FWS only after they have been signed as approved by the NOAA Assistant Administrator for Fisheries and FWS Regional Director. Approved recovery plans are subject to modification as dictated by new findings, changes in species status and the completion of Recovery Actions.

LITERATURE CITATION SHOULD READ AS FOLLOWS:

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 2004. Draft Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (*Salmo salar*). National Marine Fisheries Service, Silver Spring, MD.

ADDITIONAL COPIES MAY BE OBTAINED FROM:

NOAA Fisheries
One Blackburn Drive
Gloucester, Massachusetts 01930
978-281-9328

Recovery plans can be downloaded via the Internet at:
http://www.nmfs.noaa.gov/pr/
http://endangered.fws.gov.

ACKNOWLEDGMENTS

This draft Recovery Plan was prepared by a recovery plan writing team comprised of staff from the Northeast Regional Offices of the National Marine Fisheries Service (NOAA Fisheries) and the United States Fish and Wildlife Service (FWS) (the Services) and the Maine Atlantic Salmon Commission (ASC). Mark Minton, NOAA Fisheries' Atlantic Salmon Recovery Plan Coordinator, served as the primary author. Efforts to develop a recovery plan for the Gulf of Maine Distinct Population Segment (DPS) of Atlantic salmon began immediately after the listing of the DPS in December 2000.

This recovery plan builds on and expands recovery actions identified in the State of Maine's Atlantic Salmon Conservation Plan for Seven Maine Rivers (MASCP). The MASCP (1997) provides the basis for many important on-going Atlantic salmon conservation and recovery activities. The Services intend to maintain and expand ongoing collaborative recovery efforts implemented as part of the MASCP. The MASCP is further discussed in section VIII of the recovery plan.

The Atlantic salmon recovery plan writing committee sought the individual review and input of a number technical experts from a variety of fields, agencies and organizations in the development of this draft recovery plan. The draft plan has undergone extensive internal technical review by NOAA Fisheries (NEFSC, NWFSC, NERO, F/PR), ASC[1] and FWS staff. This draft recovery plan has also been reviewed by the technical staff of many other state and federal agencies including the Maine Department of Environmental Protection (DEP), Maine Department of Inland Fish and Wildlife (IFW), the Maine Forest Service (MFS), the Maine Department of Marine Resources (DMR) and the U.S. Geological Survey (USGS). The comments received from these agencies and groups have been fully considered.

The writing committee solicited feedback from the Maine Atlantic Salmon Technical Advisory Committee (TAC) regarding draft recovery criteria. In addition, the writing committee held public meetings in Maine to seek individual stakeholder input on recovery strategies that provide overarching principles that will guide all recovery activities conducted under the plan. Furthermore, NOAA Fisheries published a Federal Register notice on September 12, 2001 (66 FR 47452), requesting public input on threats and information that should be considered in the development of the recovery plan.

The authors of this plan would like to thank the many individuals that have contributed material used in its development and who have reviewed and commented on this plan. These have improved the accuracy and usefulness of the draft plan. The authors of this plan would like to specifically thank the following individuals for their contributions in the preparation of this recovery plan:

---

[1] The ASC distributed the draft plan for review to all the state agencies and organizations that were involved in the development and implementation of the Atlantic Salmon Conservation Plan for Seven Maine Rivers.

Brad Allen (Maine IFW)
Marty Anderson (NOAA Fisheries)
Jessica Anthony (NOAA Fisheries)
Martha BalisLarsen (FWS)
Michael Bartlett (FWS)
Ed Baum (ASU)
David Bean (NOAA Fisheries)
Ken Beland (Maine ASC)
Dana Belden (NOAA Fisheries)
Russ Brown (NOAA Fisheries)
Sara Brusila (Maine, DOC)
Kenneth Carr (FWS)
Mary Colligan (NOAA Fisheries)
Charlie Corliss (Maine, DOC)
Julie Crocker (NOAA Fisheries)
Monica Daniels (NOAA Fisheries)
Scott Dickerson (CMLT)
Brian Dresser (NOAA Fisheries)
Norm Dube (Maine ASC)
Ken Elowe (Maine IFW)
Andrew Fisk (Maine DMR)
Kevin Friedland (Umass)
Rachel Friedman (NOAA Fisheries)
Elizabeth Gaar (NOAA Fisheries)
Merry Gallahger (Maine IFW)
Jim Gilbert (UMaine)
Jaime Geiger (FWS)
Ruth Haas-Castro (NOAA Fisheries)
Terry Haines (USGS)
Melissa Halsted (SRWC)
Jamie Hardage (NOAA Fisheries)
Ed Hastings (NOAA Fisheries)
James Hawkes (NOAA Fisheries)
Anne Hecht (FWS)
Dan Kimball (FWS)
Tom King (FWS)
Dan Kircheis (NOAA Fisheries)
Fred Kircheis (Maine ASC)
John Kocik (NOAA Fisheries)
Steve Koenig (SHARE)
George LaPointe (Maine DMR)
Chris Legault (NOAA Fisheries)
Nicole Libby (NOAA Fisheries)
George Liles (NOAA Fisheries)
Jim Loftin (NOAA Fisheries)
Greg Mackay (Maine ASC)
Sharon MacLean (NOAA Fisheries)
Wende Mahaney (FWS)
Chris Mantzaris (NOAA Fisheries)
Jerry Marancik (FWS)
Joe McKeon (FWS)
Richard Merrick (NOAA Fisheries)
Steve Mierzykowski (FWS)
Mike Millard (FWS)
Martin Miller (FWS)
Morten Moesswilde (Maine FS)
Sherry Morgan (FWS)
Marta Nammack (NOAA Fisheries)
Willa Nehlsen (FWS)
Henry Nichols (Maine ASC)
Paul Nickerson (FWS)
David O'Brien (NOAA Fisheries)
Mary Parkin (FWS)
Nate Pennell (SWCD)
Dave Perkins (FWS)
Lee Perry (Maine IFW)
Ralph Pisapia (FWS)
Susan Pultz (NOAA Fisheries)
Gordon Russell (FWS)
Rory Saunders (NOAA Fisheries)
Pat Scida (NOAA Fisheries)
Steve Shepard (ASA)
Tim Sheehan (NOAA Fisheries)
Peter Steenstra (FWS)
Barry Thom (NOAA Fisheries)
Joan Trial (Maine ASC)
Robin Waples (NOAA Fisheries)
Gordon Waring (NOAA Fisheries)
Mark Whiting (MDEP)
Fred Whorisky (ASF)
Carolyn Woodhead (NOAA Fisheries)
Jed Wright (FWS)

EXECUTIVE SUMMARY FOR THE GULF OF MAINE DPS OF ATLANTIC SALMON

Current Species Status: The Gulf of Maine Distinct Population Segment (DPS) of Atlantic salmon was listed as endangered on December 17, 2000. The DPS includes all naturally reproducing remnant populations of Atlantic salmon from the Kennebec River downstream of the former Edwards Dam site, northward to the mouth of the St. Croix River. DPS salmon taken for hatchery rearing for broodstock purposes and any captive progeny from these salmon are also included as part of the DPS. These hatchery-held fish, however, do not count toward a delisting or reclassification goal as this goal refers to the status of naturally-spawned salmon in the wild.

The historic geographic range of the DPS extends from the Androscoggin River in the south, northward to the mouth of the St. Croix River at the United States-Canada border including tributaries to the lower portion of the Penobscot River (below the former site of the Bangor dam) and the Kennebec River (below the former site of the Edwards Dam). In the listing determination, the Services deferred a decision whether the Gulf of Maine DPS range included the mainstem of the Penobscot River and its tributaries above the former site of the Bangor dam (65 FR 69459). Presently a status review is underway to determine the relationship of large river systems (e.g., Penobscot, Kennebec) to the DPS as currently delineated. This review will also determine the status of current salmon populations within these large river systems, as well as any other additional salmon populations present within the geographic range of the DPS. Decisions regarding the status of these populations may have significant implications for the recovery strategy and recovery criteria. The Services will consider the implications of these decisions for the overall recovery program and revise the recovery plan accordingly.

At the time of listing, there were at least eight rivers in the geographic range of the DPS known to still support wild Atlantic salmon populations (Dennys, East Machias, Machias, Pleasant, Narraguagus, Ducktrap and Sheepscot rivers and Cove Brook). In addition to these eight rivers, there are at least fourteen small coastal rivers within the historic range of the DPS from which wild salmon populations have been extirpated.

The Gulf of Maine DPS has declined to critically low levels. Adult returns, juvenile abundance estimates and survival have continued to decline since the listing. In 2002, total adult returns to the eight rivers still supporting wild Atlantic salmon populations within the DPS were estimated to range from 23 to 46 individuals. No adults were documented in three of the eight rivers. Declining smolt production has also been documented in recent years, despite fry stocking. For example, from 1996 through 1999, annual smolt production in the Narraguagus River was estimated to average about 3,000 fish. Smolt production declined significantly in 2000 and for the past three years has averaged only about 1,500 fish per year. Overwinter survival in the Narraguagus River since 1997 has only averaged about 12%, approximately half of the survival rate of previous years and significantly less than the 30% previously accepted for the region.

Habitat Requirements and Limiting Factors: The Atlantic salmon is an anadromous fish, spending its first two to three years in freshwater, migrating to the ocean where it spends typically two years, and returning to its natal river to spawn.

Suitable spawning habitat consists of coarse substrate (gravel or rubble) in areas of moving water. Eggs incubate slowly due to cold winter water temperatures, hatch in March or April and become fry. Fry remain buried in the gravel for about six weeks. The fry emerge from the gravel about mid-May and start feeding on plankton and small invertebrates. Emergent fry quickly disperse from the redd, develop parr marks along their sides and enter the parr stage. Parr habitat (often called "nursery habitat") is typically riffle areas characterized by adequate cover (gravel and rubble up to 20 cm), moderate water depth (10-60 cm) and moderate to fast water flow (30-90 cm/sec).

Salmon parr spend two to three years in the freshwater environment then undergo a physiological transformation called smoltification that prepares them for life in a marine habitat. Atlantic salmon leave Maine rivers in the spring and reach Newfoundland and Labrador by mid-summer. They spend their first winter at sea in the area of the Labrador Sea south of Greenland. After the first winter at sea, a small percentage return to Maine while the majority spend a second year at sea, feeding off the southwest or (to a much lesser extent) southeast coast of Greenland. Some Maine salmon are also found in waters along the Labrador coast. After a second winter in the Labrador Sea, most Maine salmon return to rivers in Maine, with a small number returning the following year as three sea winter (3SW) fish.

The habitat within the range of the DPS is generally characterized as being free-flowing, medium gradient, cool in-water temperature and suitable for spawning in gravel substrate areas. The watershed structure, available Atlantic salmon habitat, and abundance of Atlantic salmon stocks at various life stages are best known for the seven largest salmon rivers with remnant Atlantic salmon populations. There is less known about the habitat of smaller rivers within the historic range of the DPS, with the exception of Cove Brook.

Reasons for Listing

Among the numerous factors that led to the endangered designation of Atlantic salmon populations in the Gulf of Maine DPS were the following:

- Critically low adult returns make the DPS especially vulnerable and susceptible to threats
- Continued low marine survival rates for U.S. stocks of Atlantic salmon
- Excessive or unregulated water withdrawal
- Multiple factors that are likely affecting the quality of freshwater habitat in the DPS
- Continuation of the commercial fishery in Greenland
- The threat of disease to the DPS from Infectious Salmon Anemia (ISA) and Salmon Swimbladder Sarcoma (SSS)
- Increased likelihood of predation because of low numbers of returning adults and increases in some predators
- Existing aquaculture practices, including the use of European Atlantic salmon, pose ecological and genetic risks

These threats, which were key factors in the listing determination, continue to imperil the continued existence of Atlantic salmon.

In addition to the threats that were integral to the listing decision, several other threats that have the potential to adversely affect the DPS have been identified during the implementation of the listing and the development of this recovery plan. These factors include:

- Low overwinter survival
- Acidified water and associated aluminum toxicity which decrease juvenile survival
- Endocrine disrupting chemicals
- Poaching of adults in DPS streams
- Incidental capture of adults and parr by recreational fishermen
- Competition with native and non-native species

Threat Assessment: An evaluation of the geographic extent and life stage affected by threats, and the severity of these effects, resulted in the following threats being identified as high priority for action to reverse the decline of Atlantic salmon populations in the Gulf of Maine DPS:

- Aquaculture practices, including the use of European Atlantic salmon, which pose ecological and genetic risks
- Acidified water and associated aluminum toxicity which decrease juvenile survival
- Poaching of adults in DPS rivers
- Incidental capture of adults and parr by recreational fishermen
- Predation
- Excessive or unregulated water withdrawal

Recovery Strategy: The initial focus of the recovery program will be on the eight populations in the DPS that were extant at the time of the listing. Without immediate action to conserve and protect these core populations and the remnant genetic variation they represent, long-term success and attainment of self-sustaining populations will be severely compromised.

Certain categories of actions will be high priority for the first phase of recovery plan implementation. The cornerstone of the initial phase of recovery will be the immediate implementation of priority 1 recovery actions that will reduce the severest threats. In addition, actions that can be initiated quickly and have the potential to significantly improve survival, thereby helping to reverse the decline of DPS populations, also will receive high priority for expeditious implementation. Actions to address critical information needs are a third category of actions that are high priority for immediate implementation. Research is needed to increase understanding of certain threats and how best to address them.

After the initial phase of recovery plan implementation is completed, efforts will focus on addressing remaining threats and information needs. Throughout all phases of recovery plan implementation, an adaptive management approach will be used.

Recovery Goal, Objectives and Criteria: The goal of the recovery program is removal of the Gulf of Maine DPS of Atlantic salmon from the Federal List of Endangered and Threatened Wildlife and Plants. Recovery will be achieved when conditions have been attained that allow self-sustaining populations to persist under minimal ongoing management and investment of resources. In order to achieve the goal of recovery, a stepwise approach will be adopted which addresses the critically low numbers of adult Atlantic salmon returns then builds toward full recovery.

The Services have concluded that it is not practicable at this time to establish final demographic criteria for reclassification and delisting of the DPS. The Recovery Plan does, however, contain both preliminary demographic and threat reduction recovery criteria.

The first objective of the plan is to halt the decline of the DPS and demonstrate a persistent increase in population abundance trends such that the overall probability of long-term survival is increased. To meet Objective 1 of the plan, the following criteria must be met:

Criterion 1. Atlantic salmon are perpetuated in at least the eight rivers within the Gulf of Maine DPS that had extant populations at the time of listing; and

Criterion 2. The replacement rate (5-year geometric mean) of adult salmon within DPS rivers is greater than 1.0.

Once Objective 1 has been achieved, the second step or objective necessary to achieve the recovery goal is to establish self-sustaining populations, and the third is to ensure that threats have been diminished such that the self-sustaining populations will remain viable over the long-term. These last two objectives relate to conditions necessary for reclassification and delisting.

Actions Needed: The major areas of action are designed to stop and reverse the downward population trends of the remnant eight wild Atlantic salmon populations and minimize the potential for human activities to result in the degradation or destruction of Atlantic salmon habitat essential to survival and recovery. For full recovery the following actions are needed:

1. Protect and restore freshwater and estuarine habitat
2. Minimize potential for take in freshwater, estuarine and marine fisheries
3. Reduce predation and competition on all life stages of Atlantic salmon
4. Reduce risks from commercial aquaculture operations
5. Supplement wild populations with hatchery-reared DPS salmon
6. Conserve the genetic integrity of the DPS
7. Assess stock status of key life stages

8. Promote salmon recovery through increased public and government awareness
9. Assess effectiveness of recovery actions and revise as appropriate

Total Estimated Cost of Recovery: The total cost of recovery is undeterminable at this time. The Implementation Schedule, however, does contain cost estimates for individual tasks. The total estimated minimum cost of recovery actions identified for year 1 to year 3 is $33.2 million.

Estimated Date of Recovery: It is impossible to estimate the date of recovery for the DPS. The species continues to decline and its status is precarious. Even with a complete reversal of downward trends and population growth, it is not possible to estimate the date of recovery of the DPS.

LIST OF ABBREVIATIONS

ABF	Aquatic Base Flow
ACOE	Army Corps of Engineers (U.S.)
ASA	Atlantic Salmon Authority (Maine)
ASC	Atlantic Salmon Commission (Maine)
ASCP	Atlantic Salmon Conservation Plan (Maine)
ASRSC	Atlantic Sea Run Salmon Commission (Maine)
ATV	All Terrain Vehicle
BKD	Bacterial kidney disease
BMP	Best management practice
BPC	Board of Pesticides Control (Maine)
BRT	Biological Review Team
CBNFH	Craig Brook National Fish Hatchery
CCP	Critical Control Points
CFR	Code of Federal Regulations (U.S.)
CMLT	Coastal Mountains Land Trust
CMS	Containment Management System
COSEWIC	Committee on the Status of Endangered Wildlife
CPUE	Catch per Unit Effort
CSE	Conservation Spawning Escapement
CWD	Coldwater Disease
DEP	Department of Environmental Protection (Maine)
DFO	Department of Fisheries and Oceans (Canadian)
DMR	Department of Marine Resources (Maine)
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon

DPS	Distinct Population Segment, Gulf of Maine
DRESS	Dennys River Eastern Surplus Superfund
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
ESA	Endangered Species Act
EPA	Environmental Protection Agency
ERM	Enteric redmouth disease
FAMP	Finfish Aquaculture Monitoring Program
FMP	Fishery Management Plan
FWS	U.S. Fish and Wildlife Service
GLNFH	Green Lake National Fish Hatchery
GOM	Gulf of Maine
HACCP	Hazard Analysis Critical Control Point
HCP	Habitat Conservation Plan
ICES	International Council for the Exploration of the Sea
ICM	Integrated Crop Management
IFIM	Instream Flow Incremental Methodology
IFW	Inland Fisheries and Wildlife, Department of (Maine)
IPN	Infectious Pancreatic Necrosis
HKS	Hemorrhagic Kidney Syndrome
HMSC	Huntsman Marine Science Center
ISA	Infectious Salmon Anemia
LCP	Loss Control Plans
LFHC	Lamar Fish Health Center (FWS)
LMF	Land for Maine’s Future (Program)
LURC	Land Use Regulation Commission (Maine)
LWRC	Land and Water Resource Council (Maine)

MBTA	Migratory Bird Treaty Act
MDOT	Maine Department of Transportation
MEPDES	Maine Pollutant Discharge Elimination System
MFS	Maine Forest Service
MGS	Maine Geological Survey
MNAP	Maine Natural Areas Program
MMPA	Marine Mammal Protection Act
MOA	Memorandum of Agreement
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
NGO	Non-Governmental Organization
NAC	North American Committee
NASSG	North American Salmon Study Group (ICES)
NASWG	North Atlantic Salmon Working Group (ICES)
NANFH	North Attleboro National Fish Hatchery (Massachusetts)
NASCO	North Atlantic Salmon Conservation Organization (international)
NEST	Northeast Salmon Team (NOAA Fisheries)
NFWF	National Fish and Wildlife Foundation
NEFMC	New England Fishery Management Council
NMFS	National Marine Fisheries Service (NOAA Fisheries)
NPDES	National Pollutant Discharge Elimination System
NWFSC	Northwest Fisheries Science Center (NOAA Fisheries)
NPS	Non-point Source
OBD	Overboard Discharge
PCR	Polymerase Chain Reaction
PIT	Passive Integrated Transponder
PVA	Population Viability Analysis
SFI	Sustainable Forest Initiative

SWCD	Soil and Water Conservation Districts (Maine)
SSSV	Salmon swimbladder sarcoma vrius
SST	Sea surface temperature
SFI	Sustainable Forestry Initiative
TAC	Technical Advisory Committee (Maine)
USASAC	United States Atlantic Salmon Assessment Committee
USDA/APHIS	U.S. Department of Agriculture/Animal and Plant Health Inspection Services
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WUMP	Water Use Management Plan (Maine)

LIST OF FIGURES AND TABLES

TABLE OF CONTENTS

PART ONE: BACKGROUND

The overall goal of the Endangered Species Act of 1973 (Act) is to recover species listed as endangered or threatened to the point at which they are no longer in danger of extinction and are unlikely to become so in the foreseeable future. To help achieve this goal, the Act requires a recovery plan for each listed species unless such a plan will not promote its conservation. The Act also says that each recovery plan must contain criteria for assessing recovery progress, management actions needed to recover and/or protect the listed species and the ecosystem upon which it depends, and time and cost estimates for reaching recovery objectives.

The subject of this recovery plan is the Gulf of Maine (GOM) distinct population segment (DPS) of Atlantic salmon. The National Marine Fisheries Service (NOAA Fisheries) and the U.S. Fish and Wildlife Service (FWS) listed the Atlantic salmon GOM DPS as endangered on December 17, 2000 (65 FR 69459). The listing was made in accordance with both the Act, which defines distinct population segments of vertebrate fish or wildlife as “species” eligible for protection, and the 1996 DPS policy issued by the U.S. Fish and Wildlife Service and the National Oceanic and Atmospheric Administration (USFWS-NOAA 1996).

The following Background sections describe the Gulf of Maine distinct population segment of Atlantic salmon and assess its current status, continuing threats to its survival and recovery, and conservation efforts to date. The intent is to provide the context for the recovery objectives and actions recommended in Parts Two and Three of this plan.

I. GULF OF MAINE DISTINCT POPULATION SEGMENT

Historically, the geographic range of the DPS within the U.S. extended from the Androscoggin River in the south, northward to the mouth of the St. Croix River on the United States-Canada border (NMFS-USFWS 1999)(figure 1). This delineation was based on examination of life history, biogeographical, genetic, and environmental information. Zoogeographic maps helped identify boundaries between areas that likely exert different selective pressures on Atlantic salmon populations and have substantial differences in riverine-marine ecosystem structure and function. Key elements to the delineation included: (1) spatial arrangements of river systems to create isolation, and (2) watershed location within ecological provinces and subregions that affect the productivity and ecology of riverine-marine ecosystem complexes (NMFS and FWS 1999).

The Gulf of Maine DPS includes all naturally reproducing remnant populations of Atlantic salmon from the Kennebec River downstream of the former Edwards dam site, northward to the mouth of the St. Croix River. The Penobscot and its tributaries downstream from the site of the Bangor Dam are included in the range of the Gulf of Maine DPS (65 FR 69459). At the time of the listing, there were at least eight rivers within the geographic range of the Gulf of Maine DPS

Gulf of Maine DPS of Atlantic Salmon

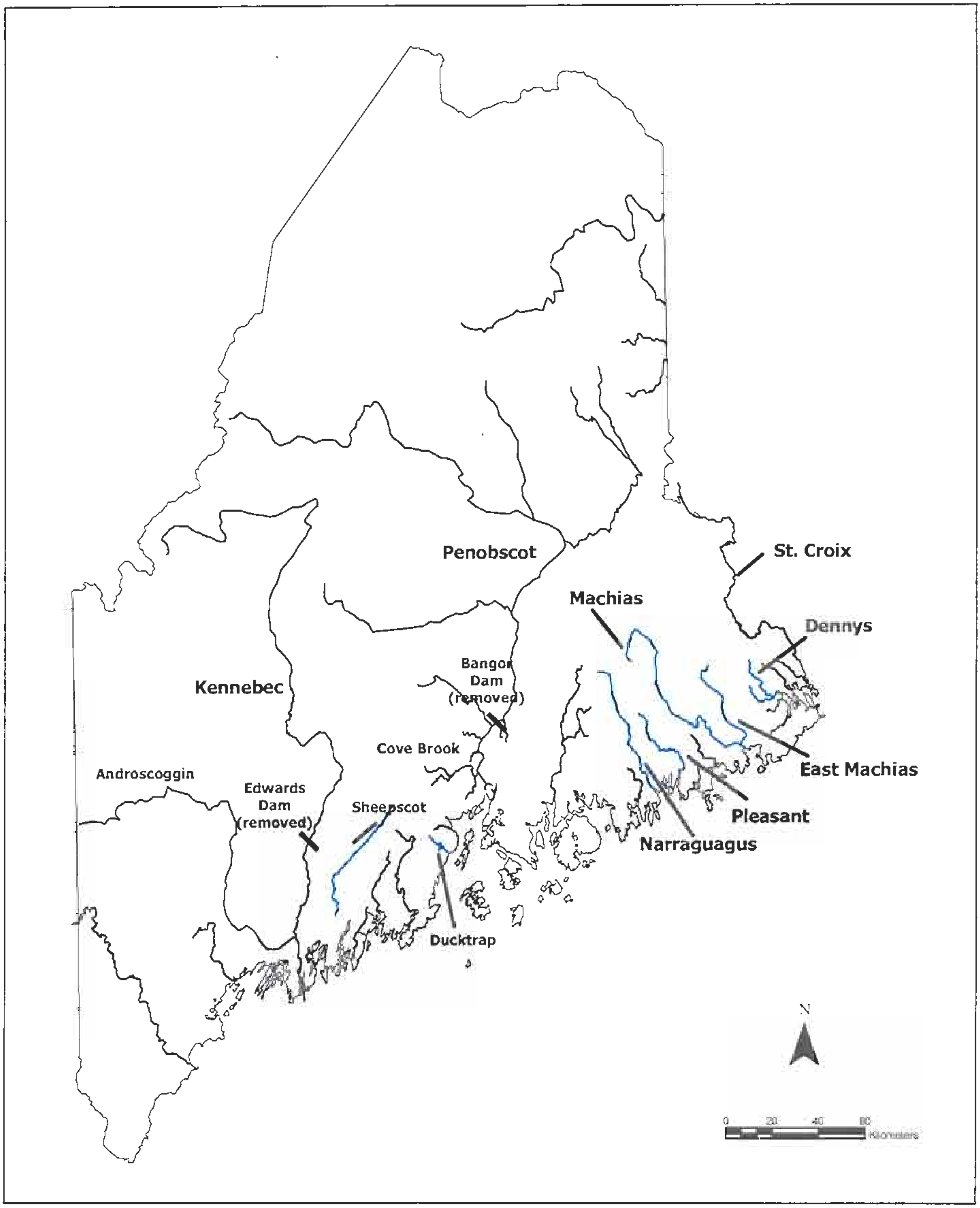


Figure 1

that still contained functioning wild salmon populations, although at substantially reduced abundance levels (65 69459)(hereinafter referred to as “DPS rivers”). The core of these remnant populations is located in the Dennys, East Machias, Machias, Pleasant, Narraguagus, Ducktrap and Sheepscot rivers and Cove Brook (65 FR 69459). DPS salmon taken for hatchery rearing for broodstock purposes, and any captive progeny of these salmon, are included as part of the DPS; however, these hatchery-held fish do not count toward a delisting or reclassification goal as this goal refers to the status of the salmon in the wild (see Part Three).

At the time of the listing, the Services deferred a decision whether the Gulf of Maine DPS range included the mainstem of the Penobscot River and its tributaries above the former site of the Bangor dam (65 FR 69459). Presently a status review is underway to determine the relationship of large river systems (e.g., Penobscot, Kennebec) to the DPS as currently delineated. This review will also determine the status of current salmon populations within these large river systems, as well as any other additional salmon populations present within the geographic range of the DPS. Decisions regarding the status of these populations may have significant implications for the recovery strategy and recovery criteria. The Services will consider the implications of these decisions for the overall recovery program and revise the recovery plan accordingly.

II. TAXONOMY AND DESCRIPTION

The Atlantic salmon, *Salmo salar*, is of the order Salmoniformes and family Salmonidae. Atlantic salmon is one of only two members of the genus *Salmo* found in North America. The Atlantic salmon is an anadromous fish, spending its first two to three years in freshwater, migrating to the ocean where it spends typically two years, and returning to its natal river to spawn. A non-anadromous variety (recognized in the past by some taxonomists as the subspecies *S. salar sebago*) is found in some lakes and rivers, but for purposes of this Recovery Plan the term “Atlantic salmon” refers to the anadromous form while “landlocked salmon” refers to members of the non-anadromous populations. The other member of the genus *Salmo* is *Salmo trutta*, brown trout, which was introduced from Europe.

Atlantic salmon have a fusiform body shape, i.e., like a spindle, rounded, broadest in the middle and tapering at each end. The shape is somewhat flattened towards the sides which is typical of salmonids in general. The head is relatively small, comprising approximately one-fifth of body length. Ventral paired fins are prominent, especially on juveniles.

Parr (juvenile salmon before they enter salt water) have eight to eleven vertical dark bars (known as “parr marks”) on silvery sides. After smoltification - the physiological process that enables juvenile salmon to transition from freshwater to salt-water and enter the sea - the typical silver coloration with small, dark dorsal spots of the sea-run pre-adult predominates. Spawning adults darken to a bronze color after entering freshwater and darken further after spawning. They are often referred to as “black salmon” at this stage. The silver coloring returns after re-entering the sea.

Outmigrating Atlantic salmon smolts in Maine average 14-18 cm in length. The size of returning adults depends on the time spent at sea. Grilse, young salmon returning to freshwater after one winter at sea (1SW), average 50-60 cm and weigh 1-2 kg while 2SW salmon (adult salmon returning after two years at sea) range from 70-80 cm and 3.5-4.5 kg. Salmon that are 3SW (adult salmon returning after three years at sea) are 80-90 cm long and often weigh more than 7 kg (Baum 1997).

III. DISTRIBUTION AND ABUNDANCE

Atlantic salmon reproduce in coastal rivers of northeastern North America, Iceland, Europe and northwestern Russia and migrate through various portions of the North Atlantic Ocean. There are three generally recognized groups of Atlantic salmon: North American, European and Baltic.

The North American group historically ranged from the Ungava area of northern Quebec, southeast to Newfoundland and southwest to Long Island Sound. It includes Canadian populations (e.g., St. Lawrence River Basin, outer Maritimes, Bay of Fundy and Newfoundland-Labrador) and U.S. populations, including the Gulf of Maine DPS of Atlantic salmon as described above.

In Canada, significant reproducing populations remain throughout the historic range, though many populations are severely depleted. In May 2001, Atlantic salmon populations in several rivers in the upper Bay of Fundy were designated as endangered by the Canadian Committee on the Status of Endangered Wildlife[2] (COSEWIC).

In the U.S., nearly every major coastal river north of the Hudson river historically supported an Atlantic salmon population (figure 2). These populations have been divided into three Distinct Population Segments: Long Island Sound, Central New England and Gulf of Maine (NMFS-FWS 1999). At one time, at least eight rivers in the Long Island Sound DPS had Atlantic salmon runs. The Central New England DPS ranged from the Merrimack River in the south to the Royal River (Yarmouth, Maine) in the north. All wild populations in the Long Island Sound and Central New England DPS's have been extirpated. Efforts to restore these salmon runs (e.g., Saco, Merrimack, Pawcatuck and Connecticut rivers) have been underway for the past thirty years.

Persistent reproducing wild populations of Atlantic salmon occur within the Gulf of Maine DPS (see Section I), but have declined to critically low levels. Since the listing, adult returns, as well as, juvenile abundance estimates and survival have continued to decline. In 2002, the total number of adult returns to the eight rivers still supporting wild Atlantic salmon populations within the DPS was estimated to range from 23 to 46 (USASAC 2003). No adults were

---

[2] COSEWIC is an independent committee of experts that assesses the status of species suspected of being at risk of extinction. While Canadian federal, provincial and territorial governments recognize COSEWIC as the source of independent advice on the status of species at risk and to work cooperatively to protect these species, COSEWIC designations have no legal standing.

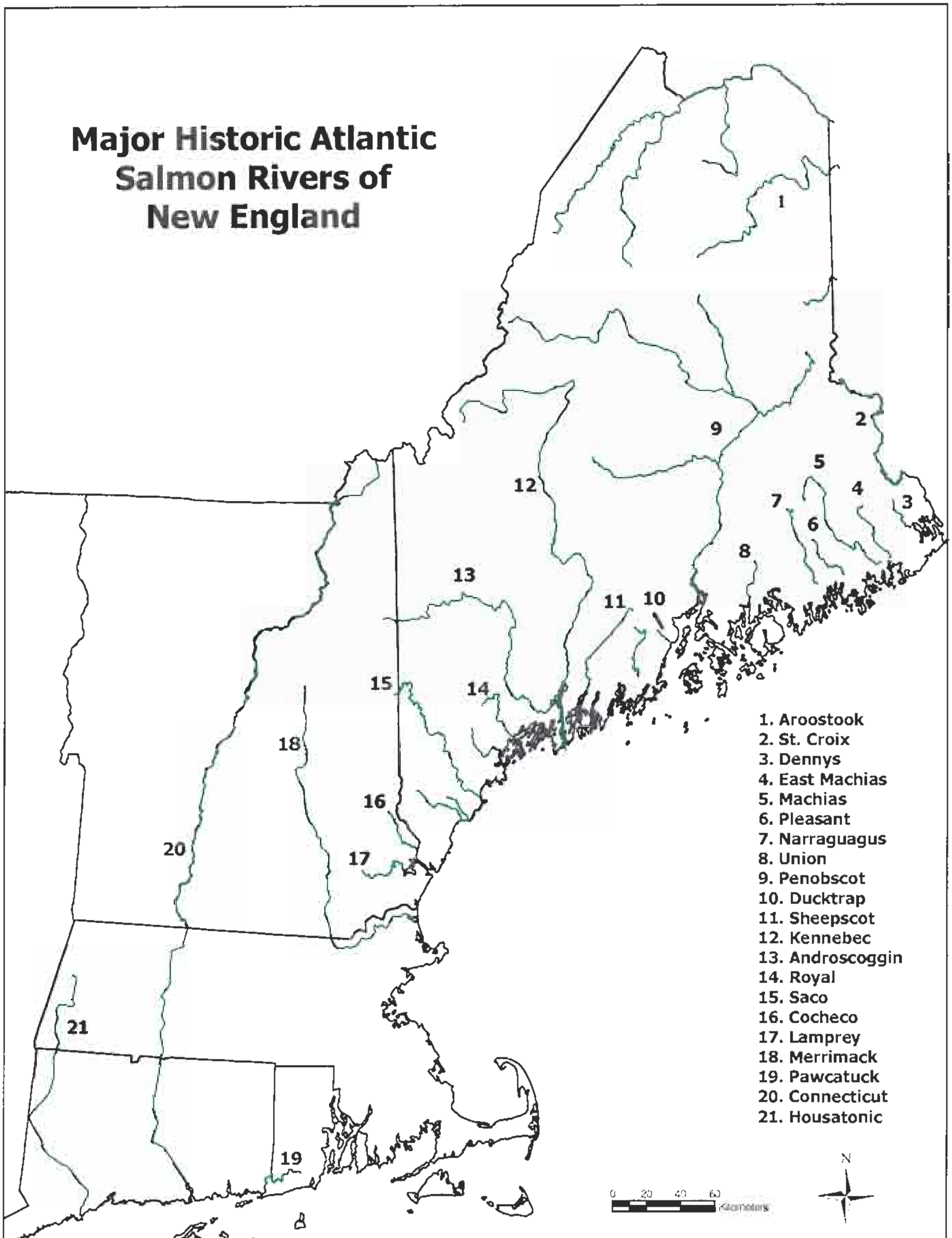

Major Historic Atlantic
Salmon Rivers of
New England
1. Aroostook
2. St. Croix
3. Dennys
4. East Machias
5. Machias
6. Pleasant
7. Narraguagus
8. Union
9. Penobscot
10. Ducktrap
11. Sheepscot
12. Kennebec
13. Androscoggin
14. Royal
15. Saco
16. Cocheco
17. Lamprey
18. Merrimack
19. Pawcatuck
20. Connecticut
21. Housatonic
N
0 20 40 60

Figure 2

documented in three of the eight DPS rivers. The best long-term data for adult DPS returns is for the Narraguagus River, which indicates greatly reduced numbers since 1967 (Figure 3). The estimated number of adult returns to other DPS rivers over the past 11 years indicates a similar decline (Figure 4). Replacement rates of adult salmon in the Narraguagus River for the years 1996 to 2002 all averaged less than 1.0, with the lowest value of 0.2 occurring in 2002 (Figure 5). Population assessments on the DPS by USASAC show a current 5-year geometric mean replacement rate of 0.54 (USASAC 2004, http://www.nefsc.noaa.gov/USASAC/).

IV. LIFE HISTORY AND HABITAT REQUIREMENTS

Differences in life history among United States and Canadian stocks of Atlantic salmon were identified as early as 1874 (Atkins 1874). Both environmental and genetic factors make the DPS markedly different from other populations of Atlantic salmon in their life history and ecology (NMFS and FWS 1999). Differences in life history characteristics have contributed to making the Gulf of Maine DPS distinct (NMFS and FWS 1999). Remnant DPS populations have maintained the most characteristic of these factors: smoltification at a mean age of two and predominant adult returns at age four after two winters at sea (2SW fish).

Wild salmon in Maine DPS rivers are genetically different from European and Canadian Atlantic salmon (NRC 2002, and references therein). U.S. Atlantic salmon stocks are composed of predominately 2SW salmon (> 80%) (Atkins 1874; Kendall 1935; USASAC 1999), while many Canadian and several European stocks have a much higher grilse component and a lower 2SW component (frequently <50%) (Hutchings and Jones 1998). Since the proportion of 2SW fish in an Atlantic salmon stock has a documented genetic basis (Glebe and Saunders 1986; Ritter *et al*. 1986; Hutchings and Jones 1998; Palm and Ryman 1999), the BRT concluded that the Gulf of Maine DPS has unique life history characteristics that have a heritable basis (NMFS and FWS 1999). The pattern of homing to their natal streams leads to a variety of local adaptations in life history features such as timing of spawning runs and growth rates (NRC 2002 and references cited therein). The NRC Committee on Atlantic salmon in Maine concluded that the large genetic differences among populations suggest biologically important genetic isolation and that the genetic differences among tributaries within large watersheds are suggestive of local adaptations (NRC 2002).

The occurrence of at least some straying among locally-adapted populations allows the development of a metapopulation[3] structure. Genetic data on Atlantic salmon in Maine indicate that they may constitute one or more metapopulations, which are distinct from other populations in North America (Spidle et al. 2003).

[3] A metapopulation is a set of populations (sometimes referred to as subpopulations) connected by straying at low to moderate rates.

Figure 3: Documented Adult Returns to the Narraguagus River

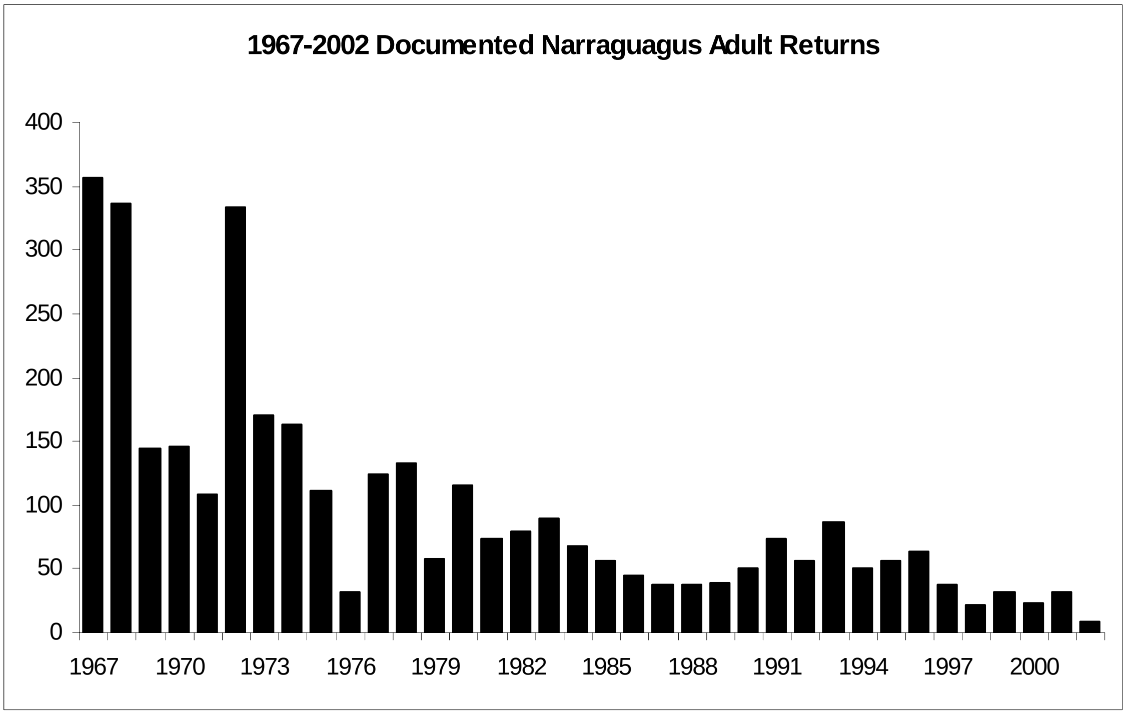


Figure 4: Estimated Adult Returns to rivers within the DPS (1991-2002)

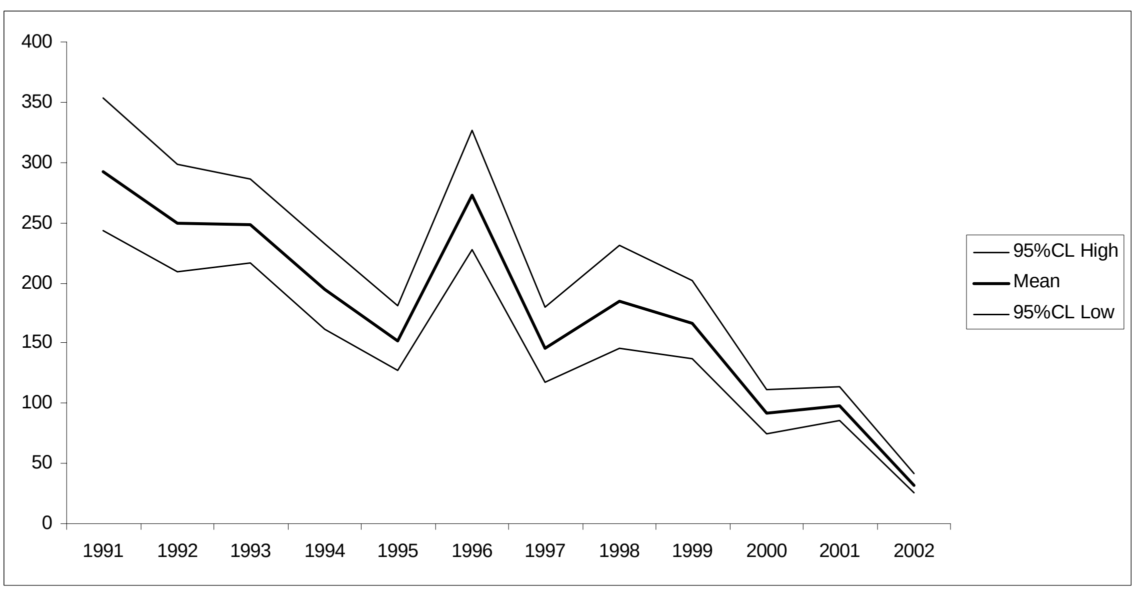
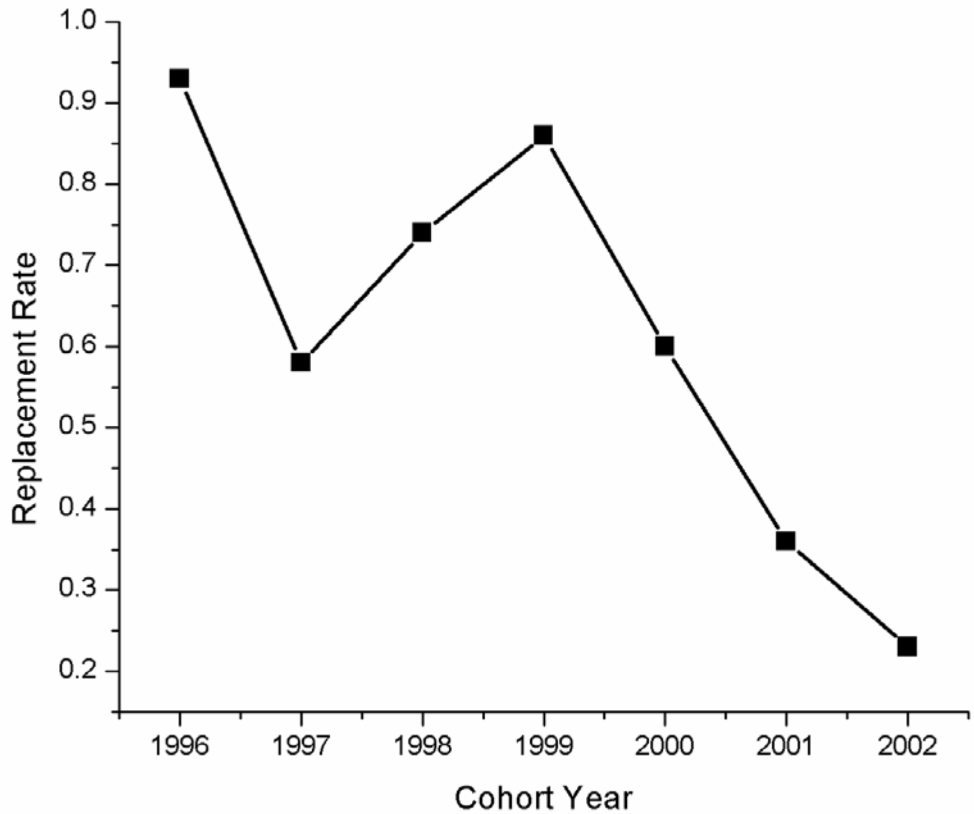


Figure 5: Replacement Rate for Narraguagus River



The relatively complex life cycle of anadromous Atlantic salmon is described in the Status Review (NMFS and FWS 1999) and is extensively treated by Baum (1997)(figure 6). The typical cycle for Maine salmon is summarized below by life stage.[4]

A. Adult Spawning

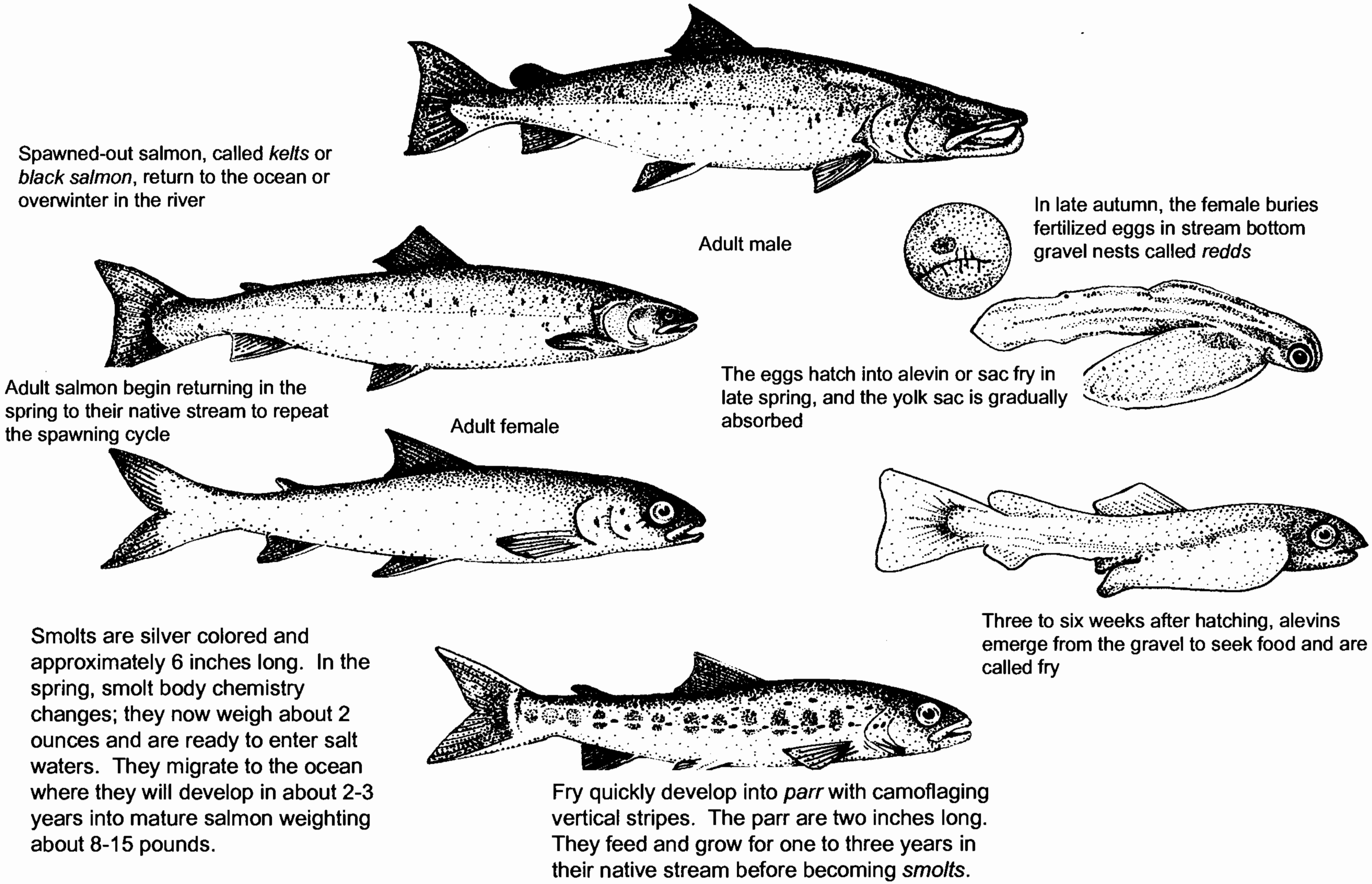
Historically (through the early 1980s), salmon runs in Maine were comprised of approximately 5% 1SW fish and 3SW fish, or repeat spawners, were more prevalent than today (Ed Baum, Atlantic Salmon Unlimited, personal communication). Presently, the majority of returning adult salmon are 2SW fish (80%) while approximately 15 to 20% of the run are 1SW fish. A small proportion of the run is comprised of 3SW fish and repeat spawners. While most 1SW fish are male, the older returning salmon are predominantly females at approximately a 2:1 ratio.

Spawning adults return from the sea to Maine rivers from May through October. The majority of a spawning run (60-70%) enter freshwater before August. The predominance of 2SW fish influences spawning-run timing because they typically enter rivers earlier than grilse (1 SW). Historically, the majority of salmon in the Penobscot, Dennys, East Machias, Narraguagus, Kennebec, Androscoggin and Saco rivers entered freshwater between May and mid-July and were therefore called "early run," whereas the majority of those returning to the St. Croix, Machias and Ducktrap rivers entered freshwater after mid-July and were called "late run" (Baum 1997). Some rivers, such as the Sheepscot and Pleasant, had both an early run and late run of Atlantic salmon (Baum 1997). The current trend in spawning-run timing is difficult to discern due to low abundance and the lack of collection facilities on all rivers. Analysis of historic recreational catch data in some Maine rivers indicates that the timing has changed little in the past fifty years (Baum 1997).

The upstream migration of adult Atlantic salmon is a complex response to different environmental stimuli at different times in the migration. Increasing water flows and temperatures stimulate upstream migration. Solomon *et al.* (1999) describe two Atlantic salmon migration phases: the first includes river entry and a period of holding, the second includes instream movement to spawning areas. Olfaction is important in the first phase of migration, when salmon locate and enter their natal river. Once in the river, olfaction is overshadowed by the influence of flow and temperature. The low flows that are typical of Maine rivers in late summer constrain movement. As a result of these constraints, Maine salmon typically hold for long periods before the second migration phase. In the second migration phase, flow becomes increasingly important as the salmon move to smaller tributaries farther upstream in the watershed (Solomon *et al.* 1999). Salmon may await the fall rains that typically occur in Maine before making their final move to spawning reaches. Water temperatures above 22.8^{o}C or dissolved oxygen levels below 5 ppm will inhibit migration (DeCola 1970). In Maine rivers, high summer temperatures constrain adult salmon movements and result in mortality (Shepard 1995).

[4] See appendix 2 for glossary of terms relating to the life history of Atlantic salmon.

Figure 6: Life Cycle of the Atlantic Salmon (*Salmo salar*)



Spawning occurs predominantly from mid-October to mid-November when water temperatures are between 7-10ºC. The female seeks gravel substrate within riffle areas and digs out a redd (nest or depression) with her tail. She deposits 7,000-8,000 eggs in several redds 12-20 centimeters (cm) under the gravel with 22-76 cm of water flowing over them at 27-83 centimeters per second (cm/sec). The eggs are fertilized by milt released from nearby males, which may include several different age groups (possibly five to six), including precocious parr that have never gone to sea. While the homing fidelity of salmon tends to limit the exchange of genetic material between populations of different rivers (particularly distant rivers), the participation of several age groups in a single spawning season promotes genetic exchange among generations within a river.

The downstream movement of post-spawned adults (kelts) may be triggered by increased water temperatures or flows. Some migrate toward the sea immediately, either moving partway downstream or returning to the ocean (Ruggles 1980; Don Pugh, U.S. Geological Survey (USGS) personal communication). The majority, however, overwinter in the river and migrate to sea in the spring as "black salmon." Kelts that remain in the river appear to survive well through the winter (Ruggles 1980; Jonsson *et al.* 1990). After reaching the ocean, few kelt survive. Few rivers have a spawning run with a significant proportion of repeat spawners.

B. Early Freshwater Development

Atlantic salmon deposit their eggs 12-20 cm under the gravel in redds. As noted, water depths of 22-76 cm and flow rates of 27-83 cm/sec are needed to provide adequate protection and water movement for the developing embryos. Eggs incubate slowly due to cold winter water temperatures and hatch in March or April. The newly hatched pre-emergent fry (alevins) rely on their yolk sac for nourishment while remaining deeply buried in the gravel. The fry emerge from the gravel about mid-May and start feeding on plankton and small invertebrates. Studies in Maine indicate less than 10% of the eggs spawned in the autumn will survive to emerge as feeding fry the following spring (Baum 1997). Sources of egg mortality include de-watering, freezing, mechanical destruction (i.e., sedimentation) and predation. From the egg through the juvenile stages, salmon need clean gravel and cobble substrate through which water can easily flow (Stanley and Trial 1995).

The timing of hatching and emergence, relative to spring runoff, affects egg to fry mortality and survival. Low flows in the thirty days prior to spring runoff may cause high mortality among pre-emergent alevins (Frenette *et al.* 1984). Unusually high spring runoff may scour redds, causing pre-emergent alevins to drift downstream prematurely. High flows within one week after emergence can cause fry mortality or displace fry to sub-optimal habitats (Jensen and Johnson 1999).

C. Parr Stage

Emergent fry quickly disperse from the redd, develop parr marks along their sides and enter the parr stage. The parr stage may last for one to three years in Maine rivers, with two years being typical. Parr habitat (often called "nursery habitat") is typically riffle areas characterized by adequate cover (gravel and rubble up to 20 cm), moderate water depth (10-60 cm) and moderate to fast water flow (30-90 cm/sec) (Symons and Heland 1978). Parr are very territorial and spend much time on the bottom, holding their position in the current aided by large pectoral fins. They feed on invertebrates and some small fish.

The growth rate of juvenile salmon is determined by the productivity of the water (nutrient supply) and temperature. Temperatures during the growing season range from around 7-25°C (Elson 1975; Symons 1979). Temperatures above 28°C can be harmful to juvenile salmon (Fry 1947). While environmental factors have a strong influence on juvenile growth and maturation, genetic differences between stocks also influence growth and performance (Kincaid *et al.* 1994; Hutchings and Jones 1998).

The low flows that typically occur in late summer in Maine salmon rivers can limit parr populations (Havey 1974; Power 1981; Gibson and Myers 1988; Frenette *et al.* 1984). Parr growth and survival during the summer are positively correlated with various flow rates, demonstrating that the low flows limit parr populations. Population reductions during low flows probably occur because of reduction in habitat quantity and quality and possibly reduced foraging opportunities (Frenette *et al.* 1984). This reduction in habitat quantity and quality can cause salmon parr to shift to sub-optimal habitat, reducing foraging opportunities and thereby impairing growth and survival. Frenette *et al.* (1984) found that the abundance of large parr (generally 2+ parr[5] in their study) was significantly correlated with mean July flow the preceding year and mean August flow two years earlier. Power (1981) found correlations between the abundance of adult salmon returning to Canadian rivers and low summer flows as parr.

Similarly, low flows in winter are associated with reduced parr and pre-smolt abundance (Hvidsten 1993). Low winter flows can reduce habitat quantity and exacerbate ice conditions that cause parr mortality (Whalen and Parrish 1999).

D. Smolt Stage

Parr larger than 12 cm undergo a physiological transformation called smoltification that prepares them for life in a marine habitat. In Maine, this usually occurs the second spring after hatching. The outward signs include a color transformation with the loss of the parr marks and silvering of the body (except along the back), a more streamlined body form (less weight per unit of length), a decline in territorial behavior and a change in swimming orientation from facing upstream to facing downstream. Fundamental physiological changes also occur, especially with osmoregulatory processes, that enable the transition from the freshwater environment to the marine environment.

Migration to sea is triggered by a number of environmental cues including water flow, temperature and photoperiod changes. Smolt migrations in Maine rivers occur primarily at night

---

5 The period from July 1 to December 31 two years after hatching.

after peak spring flows and at temperatures above about 10°C (Ruggles 1980; Shepard 1991). In Maine rivers, downstream migration occurs primarily from mid-April through mid-June (Baum 1997). Migrating smolts swim actively in the river and the estuary, but the migration also includes periods of holding and may include periods of passive drift with the current (LaBar *et al.* 1978; Shepard 1991; Peake and McKinley 1998). Higher flows accelerate the timing of the migration and shorten the duration. Differences in the timing of smolt migration occur between rivers.

E. Marine Stage

The marine stage of Atlantic salmon life history is the least understood. Post-smolts leaving Maine rivers in spring migrate northeasterly, reaching Newfoundland and Labrador by mid-summer (figure 7). They spend their first winter at sea in the area of the Labrador Sea south of Greenland. After the first winter at sea, a small percentage will return to Maine while the majority will spend a second year at sea, feeding off the southwest or, to a much lesser extent, southeast coast of Greenland. Some Maine salmon are also found in waters along the Labrador coast. After a second winter in the Labrador Sea most Maine salmon return to rivers in Maine, with a small number returning the following year as 3SW fish. The homing instinct is high for Maine Atlantic salmon; generally less than 2% have been observed to stray to non-natal rivers (Baum 1997).

V. HISTORICAL STOCKING OF SALMON WITHIN THE DISTINCT POPULATION SEGMENT RANGE

A. Stocks Used for Artificial Propagation

The first stocking of Atlantic salmon within the range of the Gulf of Maine DPS (see page 1-1) occurred in 1871 with the release of 1,500 parr of Canadian origin into the Sheepscot River. At the same time, a hatchery was established in the lower Penobscot River drainage and the practice of purchasing wild adult salmon harvested by commercial trap-netters for use as broodstock was initiated. The Penobscot River was the primary source of Atlantic salmon eggs for artificial propagation within the region for the next fifty years. Between 1871 and 1886 about 24 million eggs were taken from wild Penobscot sea-run salmon. Most of these eggs were used to stock waters outside of the DPS area, including inland lakes to create or enhance landlocked salmon populations (Baum 1997).

In the early 20th century, declining salmon runs and price disputes with commercial trap-netters resulted in a decline of Penobscot eggs available for artificial salmon propagation. As a result,

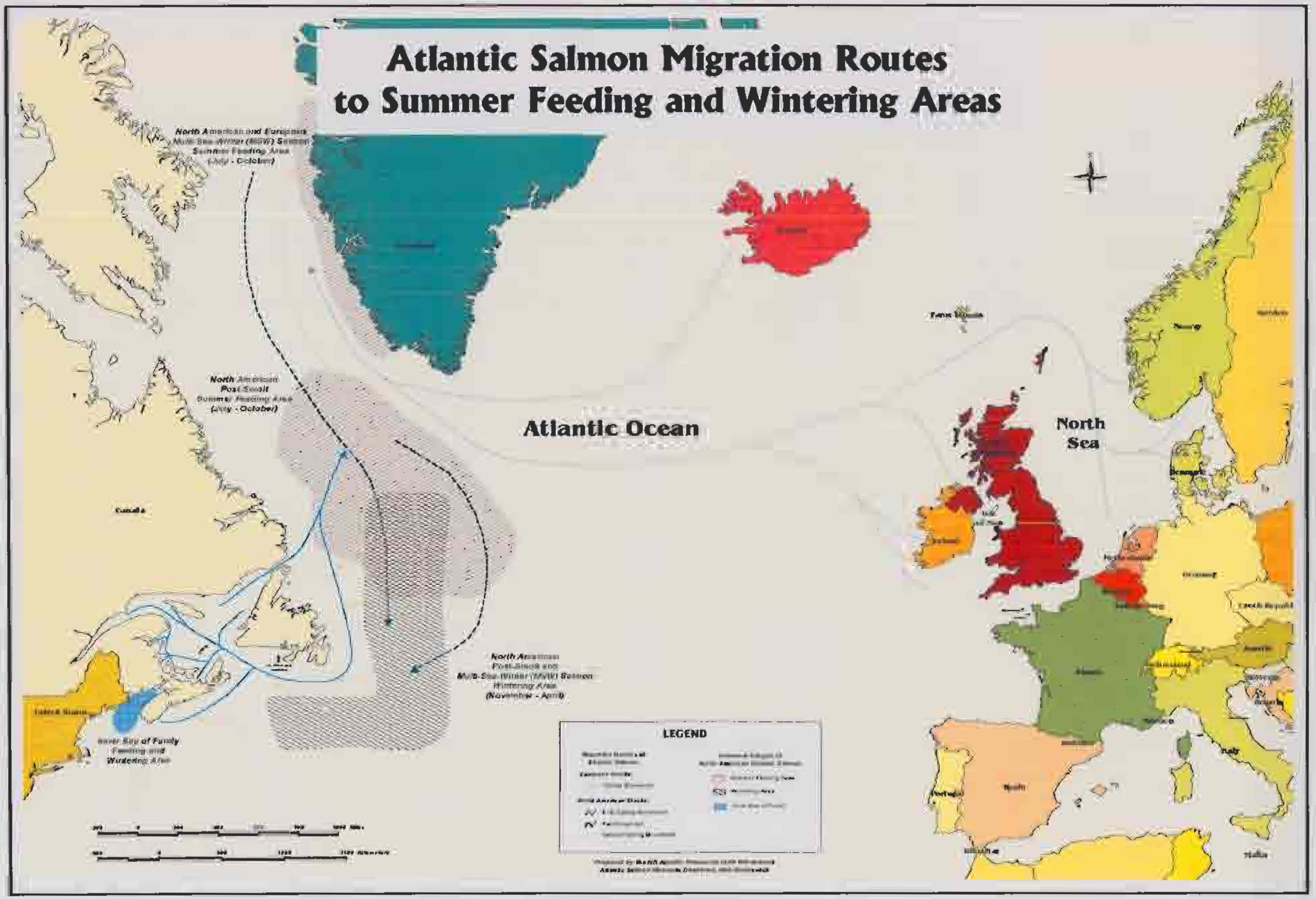

Atlantic Salmon Migration Routes
to Summer Feeding and Wintering Areas
North American
Post Smolt
Summer Feeding Area
(July - October)
Atlantic Ocean
North
Sea
LEGEND

Figure 7

Canadian salmon stocks, primarily from the Miramichi and Gaspé rivers, were used throughout the 1920s and 1930s as a source of eggs for the Craig Brook National Fish Hatchery (CBNFH) in East Orland, Maine. The use of Canadian eggs declined in the 1940s when the Machias River and, for a brief time the Penobscot River, became sources of broodstock. During the 1950s and 1960s, a lack of Penobscot River fish once again resulted in Canadian salmon being used as the primary source of eggs. These were supplemented with Atlantic salmon eggs from adults collected from the Machias and Narraguagus rivers.

In the late 1960s, efforts to rehabilitate the Penobscot salmon run were initiated through a combination of construction of new and/or improved fish passage facilities, improved water quality[6] and restocking utilizing smolts of mostly Machias and Narraguagus River origin (Baum 1997). By the 1970s, the adult returns made the Penobscot River propagation program self-sufficient for eggs and enabled it to support the egg needs of all hatcheries in Maine. Since 1992, rivers within the range of DPS still supporting wild salmon populations have been stocked only with juvenile salmon that are the offspring of parr taken from that specific river and raised to broodstock or mature fish (i.e., river-specific stocking).

B. Life Stages and Numbers Stocked

The stocking strategy in the U.S. from the start of the artificial propagation program in the 1870s through the 1930s depended heavily on releasing fry. Most records indicate that early fry stocking methods were dominated by cluster stocking in limited areas of a river. After a sixty-year period of predominantly fry releases, with unsatisfactory success, the strategy shifted to parr stocking which continued through the 1950s. By the mid-1960s, due to poor results from the parr stocking program, a smolt stocking program was implemented (Baum 1997).

The numbers of fish produced and stocked varied greatly depending on the stocking strategy (i.e., fry vs. parr vs. smolt). The greatest numbers of fish were stocked between 1896 and 1936. Fry were the focus of the stocking program during this period, with millions of fry stocked each year. In the 1930s, hatcheries began retaining fry for rearing to the parr stage. As a result of this change in stocking strategy, the number of fish stocked annually fell from one to three million fry to 100,000-300,000 parr. This reduction was due to hatchery capacity limitations. During the 1940s and 1950s, adult returns were poor despite the stocking of hundreds of thousands of hatchery-reared fry and parr (Baum 1997).

Beginning in the early 1960s, the stocking program shifted to smolt production. The construction of Green Lake National Fish Hatchery (GLNFH) in 1974 and a change in rearing regime from 2-year-old smolts to 1-year-old smolts increased production capacity to 600,000 annually. Nearly all these smolts are stocked into the Penobscot River.

---

[6] These improvements were made under the auspices of the Anadromous Fish Conservation Act of 1965, and Clean Water Act of 1972.

In 1991, based on the recommendation of the Maine Atlantic Salmon Technical Advisory Committee (TAC)[7], the current river-specific stocking program was initiated. The river-specific stocking program stocks fish at the fry life-stage as the primary management strategy to recover Atlantic salmon populations in the DPS (see Recovery Action 5). This program stocks the progeny of salmon collected from DPS rivers into the river of origin (i.e., river-specific stocking). This strategy was intended to help protect the genetic integrity and metapopulation structure of the DPS and restore declining numbers of wild salmon.

C. Impacts of Past Stocking

Despite previous stocking efforts, the natural populations remaining in Maine rivers are distinguishable from each other with a level of genetic distinctiveness typical of that found in natural salmon populations in other parts of the world (NRC 2002). Historic stocking practices may have had an adverse effect upon the genetic integrity of the wild stocks persisting in rivers within the DPS (i.e., the geographic range, see page 1-1)(NMFS-USFWS 1999). These early programs, however, were limited in technology, distribution capabilities and knowledge of stocking strategies. Evidence suggests that these early efforts probably resulted in only negligible adult returns. For example, a recent study found no evidence of genetic influence on the Penobscot River salmon population from Miramichi stocks introduced in the late 1960s (Spidle *et al.* 2001). Poor hatchery return rates coupled with remnant natural stocks suggest that while some negative effects upon the genetic integrity of these stocks are possible, there is no evidence that stocks of hatchery origin have supplanted or homogenized the wild populations existing in these rivers. Genetic studies and review of these data (King *et al.* 2000, 2001; NRC 2002) have demonstrated that genetic structure continues to exist among the wild populations in the DPS rivers.

In June 2001, a multi-disciplinary committee was formed by the National Research Council (NRC), the principal operating agency of the National Academies of Science, to review the available scientific information on the status of wild Atlantic salmon populations in Maine. Part of the committee's charge was to assess how Maine salmon populations differ from other Atlantic salmon populations. The NRC committee was tasked with assessing whether North American Atlantic salmon are genetically different from European salmon, whether Maine salmon are genetically different from Canadian salmon and the level of genetic distinctiveness, if any, between Atlantic salmon populations in the Gulf of Maine DPS. The committee concluded that North American populations of Atlantic salmon are clearly genetically distinct from European Atlantic salmon populations; Atlantic salmon in Maine are genetically distinct from Atlantic salmon in Canada; and, there is considerable genetic divergence among the remnant populations of Atlantic salmon in the Gulf of Maine DPS (NRC 2002). In addition, the

---

7 The Maine TAC provides scientific and technical advice concerning Maine Atlantic salmon to the Regional Administrator of the National Marine Fisheries Service, Regional Director of the U.S. Fish and Wildlife Service and the Chair of the Maine Atlantic Salmon Commission. The TAC is comprised of representatives of the Maine ASC, Maine DMR, Maine IFW, NOAA Fisheries, FWS and the Penobscot Indian Nation.

committee concluded that the pattern of genetic divergence among Maine streams is similar to patterns seen elsewhere and is the degree of genetic divergence expected in natural salmon populations in the Northern hemisphere (NRC 2002). The NRC committee on Atlantic salmon in Maine reviewed the available scientific information on this subject and concluded that, despite many years of non-river specific stocking, substantial genetic divergence remains among populations (NRC 2002). The committee also concluded that the remnant stocks in the Gulf of Maine DPS are not simply hatchery products, rather they display typical metapopulation structure. Wild salmon populations in Maine display the degree of genetic divergence characteristic of wild salmon populations where stocking has not occurred or has been minimal.

VI. REASONS FOR LISTING

Documented adult returns of Maine salmon declined significantly in the 1980s and remain at critically low levels of abundance. Among the numerous factors that led to the endangered designation of Atlantic salmon populations in the Gulf of Maine DPS were the following:

- Critically low adult returns make the DPS especially vulnerable and susceptible to threats
- Continued low marine survival rates for U.S. stocks of Atlantic salmon
- Excessive or unregulated water withdrawal
- Multiple factors that are likely affecting the quality of freshwater habitat in the DPS
- Continuation of the commercial fishery in Greenland[8]
- The threat of disease to the DPS from Infectious Salmon Anemia (ISA) and Salmon Swimbladder Sarcoma (SSS)
- Increased likelihood of predation because of low numbers of returning adults and increases in some predators
- Existing aquaculture practices, including the use of European Atlantic salmon[9], pose ecological and genetic risks

These threats, which were key factors in the listing determination, continue to imperil the continued existence of Atlantic salmon.

---

8 The Services determined that at the time of listing the continuation of the internal use fishery in Greenland posed a reduced but continuing concern to the DPS. However, the Services concluded that the best available data did not show that overutilization was creating a danger of extinction. In August 2002, commercial fishing for Atlantic salmon within Greenland territorial waters was provisionally suspended for five years (see page 1-38). The internal use fishery is not included in the agreement.

9 In May 2003, U.S. District Judge Gene Carter issued a ruling prohibiting the use of European salmon by Atlantic Salmon of Maine and Stolt Sea Farm Inc. The ruling was part of a lawsuit brought against the aquaculture industry under the Clean Water Act for operating without a NPDES permit as required under the Act. Heritage Salmon, the other major salmon producer in Maine, had already agreed to not stock any non-North American salmon as part of an earlier consent degree. In 2003, the Maine DEP issued a MEPDES general permit for Atlantic salmon aquaculture. The permit contains conditions for finfish aquaculture operations including the prohibition of the use of non-North American strains of Atlantic salmon.

In addition to the threats that were integral to the listing decision, several other threats that have the potential to adversely affect the DPS have been identified during the implementation of the listing and the development of this recovery plan. These factors include:

- Low overwinter survival
- Acidified water and associated aluminum toxicity which decrease juvenile survival
- Endocrine disrupting chemicals
- Poaching of adults in DPS rivers
- Incidental capture of adults and parr by recreational fishermen
- Competition with native and non-native species

No single factor can be pinpointed as the cause of the continuing decline of the DPS, rather, all the threats that were key factors in the listing determination in addition to other recently identified threats, have the potential to adversely affect Atlantic salmon and/or their habitat. Continuing research and assessment is needed to understand the impacts and interactions of all of the threats faced by the DPS. Not all threats are pervasive throughout DPS rivers (e.g., excess nutrients may only be a threat in the Sheepscot River) and not all threats would be expected to adversely affect the DPS if populations were stable (i.e., predation and competition would not be expected to be a threat if Atlantic salmon populations were not at critically low levels). The discussion of threats below includes identification of threats, the impact the threat has on the species and/or its habitat, and the source of the threat.

A. PRESENT OR THREATENED DESTRUCTION, MODIFICATION OR CURTAILMENT OF HABITAT OR RANGE

Many historical land and water use activities have altered, and in some cases destroyed, the habitat needed by Atlantic salmon for spawning, growth and migration. The effects are evident from the headwater lakes, streams and springs that feed the rivers all the way to the estuaries and into the Gulf of Maine. Atlantic salmon habitat in Maine has changed dramatically over the last two hundred years due to a number of factors including accelerated sedimentation, dams, stream channelization, road crossings and log drives. These factors have altered important habitat features including channel widths and depths, pool-to-pool spacing and substrate composition. Salmon habitat is directly and indirectly affected by changes to riparian lands. Excessive removal of riparian vegetation can accelerate erosion and sedimentation and can also contribute to thermal loading. Upland and wetland vegetation help prevent NPS pollutants from entering streams.

Historically, timber harvests likely had a significant impact on Atlantic salmon populations and habitat. Salmon and their habitat were likely impacted through direct and indirect effects of timber removal and transport. Historical practices such as log driving, channel clearing and large-scale clear cutting have largely been eliminated. Forest management activity, including timber and pulpwood harvesting, is still common in the DPS river watersheds. The Maine Forest Service (MFS; a bureau within the Maine Department of Conservation) estimates that 1-2% of the area of these watersheds are harvested annually, slightly below the statewide average of approximately 3.3%. Natural regeneration of harvested areas is typically profuse on most sites in Maine and planting is relatively uncommon.

The Services believe that current forest management activities, including timber harvesting, do not represent a significant threat under current management measures and harvest practices. However, the potential for negative impact on salmon and their habitat remains. For example, during preparation of this recovery plan, the Services became aware of changing land-use patterns that may impact the DPS rivers in the Downeast region. Forestry is the current dominant land use in the five Downeast watersheds (Dennys, East Machias, Machias, Pleasant and Narraguagus). International Paper (IP) Corporation, a private forestry company, is the largest landowner within the five Downeast watersheds. IP has recently begun to sell forest lands in this region. The sale of this property has reportedly attracted liquidation timber harvesters and developers, known for intensive logging, followed quickly by subdivision and resale of property. The potential extent and impact on salmon of this activity should be evaluated.

Human activities have affected salmon habitat in all watersheds within the range of the Gulf of Maine DPS. Current smolt population and survival studies strongly suggest that habitat-related factors in freshwater may significantly impact smolt production and survival (NMFS and FWS 1999). Incongruity between the increases in early juvenile abundance due to fry stocking and the corresponding parr and smolt survival rates suggest that the quality of the freshwater habitat may be negatively impacted by multiple factors within the rivers.

Despite the impacts of past human activities, the habitat within the DPS is generally characterized as being free-flowing, medium gradient, cool in-water temperature, and suitable for spawning in gravel substrate areas. Based on habitat surveys, estimates of the total amount of Atlantic salmon habitat are currently available for the eight rivers within the DPS known to still support wild salmon populations. With a few other minor exceptions, most other rivers within the historic range of the DPS have not been surveyed. While habitat quantity is generally known for DPS rivers, the quality of existing salmon habitat has not been fully assessed.

1. Water Use

Water withdrawals for agricultural irrigation have been identified as a key threat to Atlantic salmon (65 FR 69459; NMFS and FWS 1999; MASCP 1997). Water extraction has the potential to expose or reduce salmon habitat. It is the most immediate habitat threat posed in some DPS rivers (65 FR 69475). Adequate water quantity and quality are critical to all life stages of Atlantic salmon, including spawning, egg survival, fry emergence, juvenile survival and smolt emigration. Water quantity and quality can be affected by the withdrawal of water for irrigation and other purposes.

In the Pleasant, Narraguagus and Machias river watersheds, commercial blueberry growers irrigate with water withdrawn from streams supporting wild Atlantic salmon. These water withdrawals pose a threat to Atlantic salmon and their habitat (65 FR 69477). This threat, if not adequately addressed, is likely to grow based on industry projections of expansion of berry production and processing. Approximately 6,000 acres of blueberries are irrigated annually. The blueberry industry reportedly plans to double its production by the year 2005 and will likely need more water for irrigation, frost protection and berry processing (NMFS and FWS 1999).

The potential impacts of water withdrawals from DPS rivers and streams include limiting summer habitat for parr, low winter flow effects on redds and egg incubation as well as adult immigration (requires fall increases in flows) and smolt emigration. Timing of emigration is cued by day length, temperature and discharge. Speed of out movement may be related to discharge. If reservoirs are to be used, the effects of capturing spring flows on the emigration of smolts needs to be evaluated. Changes in streamflow due to withdrawal can change basic sediment transport functions and result in stream channel changes.

The State of Maine and its partners have completed a water use management plan (WUMP) for the Narraguagus and Pleasant rivers and for Mopang Stream (MSPO 2001)[10]. The WUMP concludes that withdrawal of surface water during low flows poses the greatest risk to Atlantic salmon habitat. Surface water withdrawals during low flow periods pose a significant risk to salmon rearing habitat. The WUMP also concludes that "...irrigation of existing acreage with a well replacing the major direct withdrawal seems to affect habitat only at the lowest flows."

As a result of the WUMP, there has been a net reduction in the number of large growers withdrawing water directly from streams covered under the WUMP (Nate Pennell, Washington County Soil and Water Conservation Service, personal communication). In recent years, blueberry growers have begun to move away from withdrawing water directly from rivers in these watersheds, relying instead on groundwater withdrawals to meet their needs. Little information is available to assess the potential impacts of these withdrawals on water quality in DPS rivers. Water withdrawal from groundwater aquifers may affect cold groundwater discharge rates from springs. During periods of elevated water temperatures typical of summer conditions, salmon rely on cold water refugia to survive. Numerous smaller blueberry growers continue to rely on direct water withdrawals from rivers to meet their irrigation needs.

The Maine Land Use Regulation Commission (LURC; a bureau of the Maine Department of Conservation) regulates water withdrawals from surface waters and groundwater within unorganized territories in the State of Maine. The LURC must approve requests for withdrawals for irrigation and can curtail withdrawals if water levels fall below what is considered necessary for the well being of fish and wildlife or other natural resources. In 1999, LURC limited the amount of water that could be drawn from the Pleasant, Narraguagus and Machias rivers based on instream flow incremental methodology (IFIM) studies of Mopang Stream (a major tributary of the Machias River), Narraguagus and Pleasant rivers. Maine DEP has the authority to regulate

---

10 The WUMP identifies a hierarchical approach for using water intended to ensure adequate stream flows that are protective of Atlantic salmon while addressing the irrigation needs of the blueberry industry within the watersheds for which the plan was developed.

water withdrawals from organized municipalities within the State. Water withdrawals in organized municipalities are not currently regulated. This multi-jurisdictional arrangement results in situations where water withdrawals from a water body whose shores are located in both organized and unorganized towns can be regulated on one bank and not on the opposite bank.

In addition to the agricultural demand for water, population growth and development in Maine has accelerated in recent years, especially in the mid-coast region. This trend is projected to continue (Gulf of Maine, Council on Environmental Quality 2001) and will undoubtedly result in increased municipal water use demands. This change in land use patterns and resource demands, including water use, will need to be managed in order to protect salmon and their habitat.

2. Water Quality

There are a number of water quality issues that have the potential to adversely affect the recovery of the DPS. Non-point source (NPS) pollution problems occur on all DPS rivers. Sources of NPS pollution include agriculture, airborne pollutants (e.g., acid rain), livestock grazing, septic systems, forestry, public and private roads, overboard discharges (OBD, a type of waste water treatment system), stream channel alteration and urban runoff. The most common NPS pollutants are sediment and nutrients. Other NPS pollutants include agricultural pesticides, heavy metals, pathogens (bacteria and viruses) and toxic chemicals. The prevailing land use patterns and disturbances within DPS river watersheds result in varying amounts of NPS pollution within DPS rivers. While NPS pollution issues are noticeable in all rivers within the DPS, the cumulative effect on water quality is most evident in the Sheepscot River watershed (Maine TAC 2002). The Sheepscot River has elevated levels of nutrients, bacteria, organic loading, temperature and also has depressed dissolved oxygen (Maine TAC 2002). Local watershed councils, with assistance from state and federal agencies, have identified and remediated numerous non-point source pollution sites in DPS river watersheds.

There are few point sources of pollution on the eight salmon rivers. Maine DEP issues permits for licensed discharges. These permits are conditioned to maintain the existing water quality classification. The Maine DEP has issued discharge permits to blueberry processors on the Narraguagus River, a municipal waste treatment facility in Machias, the Maine Department of Inland Fisheries and Wildlife (IFW) Palermo Rearing Station (Sheepscot River) and commercial salmon aquaculture hatcheries operated by Heritage Salmon (Connors Brothers) located on the Narraguagus River in Deblois and on Chase Mills Stream (tributary to East Machias River).

In 2001, the Signatories to the Maine Atlantic Salmon Cooperative Agreement (ASC, NOAA Fisheries, FWS) asked the Maine TAC to assess whether water quality issues threaten the recovery of the DPS. The Maine TAC (2002) concluded that sufficient evidence exists that several water quality issues are affecting DPS Atlantic salmon populations in Maine. The TAC Water Quality Committee concluded that acidification and endocrine disruption are the most significant water quality threats to the DPS.

i. Acidified water and aluminum

Acidified Water and Acid Rain

The physiological effects of chronically low pH on freshwater life stages of Atlantic salmon are well documented. Exposure to pH less than 4.5 causes rapid plasma ion loss and death, apparently from circulatory collapse. Alevins (sac-fry) are the most susceptible life stage. This transitional life stage experiences high mortality even in healthy populations with high quality habitat. Chronic exposure to depressed pH results in reduced feeding and growth of juvenile Atlantic salmon (Haya *et al.* 1985). Chronically low pH also results in altered behavior and gill damage (Jagoe and Haines 1990). Perhaps the most severe effect of low pH is the disruption of osmoregulatory ability, particularly after smolts enter seawater (Staurnes *et al.* 1993). Like alevins, the smolt stage is a life cycle bottleneck for stocks of Atlantic salmon, even healthy stocks experience high mortality during the transition to a marine environment. Low pH further stresses smolting salmon during a critical physiological transition period.

Atlantic salmon populations cannot persist in chronically low pH environments. The effects are most severe in river systems that have a low buffering capacity, such as the granitic bedrock watersheds of Nova Scotia. By 1980, the mean annual pH in nine Nova Scotia rivers that historically contained salmon populations had dropped below 4.7 and as a result, the salmon were extirpated (Watt 1981). Large portions of the DPS river watersheds share this poor buffering capacity and chronically low pH has been documented in streams such as the West Branch Narraguagus River (Beland *et al.* 1994).

In addition to chronic low pH levels, recent research has shown that pulses of low pH can impact some life stages of Atlantic salmon. Acidity in DPS rivers varies in predictable geographic and seasonal patterns. Seasonally, the most significant pH depression occurs during spring runoff when acidity stored in the snow pack is released into rivers and the greater volume of water dilutes the river's acid neutralizing capacity. This low pH pulse occurs as smolts are beginning to migrate and are altering their physiology in preparation for life in marine habitats and when alevins are preparing to emerge from the gravel as fry. Pulses of low pH can also occur in response to stormwater runoff (Staurnes *et al.* 1993), such as during fall rains that typically increase the flows in the DPS rivers.

Geographically, the DPS rivers that are located east of the Penobscot River have a lower pH than those located west of the Penobscot (Haines 1981; Haines *et al.* 1990). This is due to the granitic bedrock underlying much of eastern Maine and the low acid neutralizing capacity of the overlying soils. Within a given river system, pH is typically lower in headwater streams and at higher elevations (Schofield 1981). This is evident in the Narraguagus River, where pH measurements from 1990 through 1993 in tributaries such as Sinclair Brook were often below 5.0, while the main stem Narraguagus consistently remained above 5.0 (Beland *et al.* 1994). West Kerwin Brook, a tributary of the Machias River, also has lower pH relative to the main stem (Haines 1981).

Studies of eastern Maine coastal watersheds have shown that these rivers are becoming more dilute (i.e., fewer dissolved solids), with very little bicarbonate acid neutralizing capacity. Bicarbonate buffering will typically maintain pH 6-7 in receiving waters, while the depletion of bicarbonates can lead to pH levels below 5.0 in aquatic systems (Schofield 1981; Haines *et al.* 1990; Stoddard *et al.* 1999; Norton *et al.* 1999). Previously, it was believed that over time acid rain depleted the bicarbonate-based acid-neutralizing capacity of forest soils, shifting the buffering system to other chemical reactions (Schofield 1981; Haines *et al.* 1990). More recent evidence suggests that soil capacity to absorb sulfate and nitrate is the most important factor controlling acidity of surface waters, along with cation exchange and mineral weathering (Driscoll *et al.* 2001; Galloway 2001; Terry Haines, USGS, personal communication).

Exposure to acid rain has been responsible for the decline and extirpation of Atlantic salmon populations from certain Norwegian and Canadian rivers (Watt 1981; Watt *et al.* 1983; Watt *et al.* 2000; Sandøy and Langåker 2001). In Nova Scotia, chronically depressed pH linked to anthropogenic sources, specifically airborne sulfates and nitrates that originate largely from fossil fuel combustion, is the likely cause of salmon mortalities (Terry Haines, USGS, personal communication). In Norway, however, the mortalities are primarily caused by aluminum and occur at much higher pH levels, as high as pH 5.8 to 6.2 as compared to the pH levels in Nova Scotia ranging from pH 4.2 to 4.7 (Terry Haines, USGS, personal communication).

Runoff from peat deposits (bogs) also depresses pH in DPS rivers. For example, in the Pleasant River pH is lower downstream of the Great Heath relative to upstream monitoring locations (Beland *et al.* 1994). This also occurs in the West Branch Narraguagus River where pH was found to be lower downstream of Denbo Heath than upstream of this peat bog (Beland *et al.* 1994).

Historically, runoff from peat mining operations may have exacerbated depressed pH in rivers within the DPS (NMFS and FWS 1999). The only peat mining operation in the DPS river watersheds is the Downeast Peat plant in Deblois, which is in the West Branch of the Narraguagus River. Recent improvements in state and federal licensing programs have greatly improved the water quality from drainage ditches in peat mining operations. Ownership of the peat mining facility changed control in the early 1990s. With the assistance of the DEP, the facility was brought into compliance with stormwater and other water discharge standards. Analysis of upstream and downstream sites on the West Branch and on McCoy Brook (a tributary to the main stem) have shown no difference in water quality since monitoring began in 1994 (Mark Whiting, Maine DEP, personal communication).

Current integrated crop management (ICM) programs for blueberries recommend that soil pH be maintained at 4.5 for weed control (the desired range is pH 4.3 to 4.8). If the soil pH is not already low, Maine Cooperative Extension recommends the addition of sulfur. If the soil is too acidic, growers are advised to use lime. Either of these practices can affect surface water pH. Some tributaries (e.g., Big Springy Brook in the Machias River drainage) have a springtime pH that is more acidic than rainfall (the volume weighted average pH of rainfall in Maine is 4.7). This suggests that soil acidity might also have a role in governing pH in streams (Mark Whiting, Maine DEP, personal communication). While the addition of sulfur to blueberry fields to lower soil pH is a standard Cooperative Extension recommendation, reportedly neither Cherryfield Foods or Jasper Wyman and Sons, Inc., the two largest blueberry growers in Downeast Maine, engage in this practice (Fred Olday, Jasper Wyman & Son, personal communication). It is not known whether, or to what extent, small growers apply this practice.

Acidified Water and Aluminum

Laboratory and field studies demonstrate that low pH leaches aluminum and increases its toxicity to fish. Aluminum's solubility increases exponentially as pH declines below 7.0 (Haines 2001). The aqueous chemistry of aluminum is complex, the most toxic species are collectively termed labile forms[11]. Dissolved organic carbon (DOC) readily binds with labile aluminum (as well as other metals) and these organic carbon/aluminum complexes are not toxic.

Osmoregulatory failure seems to be the most significant impact of acidified water and aluminum. This toxic effect is significant for developing alevins and migrating smolts, life stages that are undergoing significant physiological transitions and already experience high mortality. This critical period directly affects adult return rates to the DPS rivers.

The toxic effects of aluminum have been well studied in Norwegian salmon rivers. Salmon populations in twenty-four rivers were not affected by labile aluminum less than 8 ug/l, pH greater than 6.0 and at least 50 ueq/l of acid neutralizing capacity (Staurnes *et al.* 1995). Varying degrees of impact were observed in twenty-six Norwegian streams with intermediate pH (5.2 to 6.2), greater amounts of labile aluminum (10 to 60 ug/l), and acid neutralizing capacity between 20 and 40 ueq/l (Staurnes *et al.* 1995). Salmon were extirpated from twenty-two Norwegian rivers with pH less than 5.7, labile aluminum levels in excess of 20 ug/l and acid neutralizing capacity less than 10 ueq/l (Staurnes *et al.* 1995). Laboratory experiments using Norwegian salmon stocks showed that smolts experienced osmoregulatory failure and 60 to 75% mortality in 24-hour seawater challenges at pH 5 with 50ug labile aluminum (Staurnes *et al.* 1993; Rosseland *et al.* 2001; Kroglund *et al.* 2001).

In contrast to the Norwegian salmon studies, North American studies have shown smolts to be more tolerant of low pH and elevated aluminum. Pauwels (1990) recorded a significant reduction of plasma chloride concentration but no mortality of smolts exposed for eleven days to pH 4.6-5.5 with 20-84ug labile aluminum. About 4% mortality occurred on the thirteenth day with no additional mortality occurring until the twenty-first day. However, these fish were never challenged with seawater. Magee *et al.* (2001) found no mortality occurred after a fourteen-day exposure to stream water with pH declining from 6.0 to 5.1 and an acidic pulse of pH 4.5. There was substantial mortality observed when smolts were placed in seawater and exposed to both a constant low pH and pulsed exposure (Magee *et al.* 2001). Saunders *et al.* (1983) reported ionoregulatory disruption within four weeks but only 24% mortality after ten weeks at pH 4.2-4.7. Farmer *et al.* (1989) reported that pH 5.0 elicited no significant reduction

[11] These include $AlOH^{++}$, $AlOH^{2+}$, AlF^{++}, AlF^{2+} and Al^{+++} (hereafter referred to as labile aluminum).

in plasma osmolality, hematocrit, chloride concentration, branchial Na+/K+ ATPase activity, or mortality during a 112-day period in spring. In contrast, fry growth was reduced and mortality increased when pH was decreased to 5.5 with aluminum causing little increase in mortality above acid addition alone (Haines *et al.* 1990).

The mean pH of precipitation falling in Maine is about 4.6 and large amounts of aluminum are mobilized from Maine soils to the aquatic environments of DPS rivers. The synergistic effect of aluminum toxicity exacerbates the stress from acidity (Kroglund *et al.* 2001). DPS river watersheds located east of Penobscot Bay are dilute with very little acid-neutralizing capacity and low pH, which mobilizes toxic aluminum. The pH depression that accompanies spring runoff may exacerbate this toxic effect.

Increased gill sodium/potassium ATPase activity is associated with smoltification and recent research has demonstrated that smolts in DPS rivers have unusually low levels of sodium/potassium ATPase activity relative to Maine hatchery smolts and smolts from several New Brunswick and Newfoundland rivers (McCormick *et al.* 2002). This is an area that requires additional study, but it may indicate that conditions in the DPS rivers produce smolts that are poorly equipped for the marine environment. These impacts are associated with the extirpation of salmon from many Norwegian rivers. The relatively high levels of DOC in some of the DPS rivers may mitigate the toxic effects of labile aluminum and acidity. More study is needed on the synergistic effect of these water chemistry parameters, particularly the seasonal variation and influence of precipitation.

ii. Agricultural Pesticides (insecticides, herbicides and fungicides)

Agricultural chemicals include insecticides, fungicides and herbicides. Of these, insecticides are generally the most toxic to Atlantic salmon, followed by fungicides and herbicides (Maine TAC 2002). Improper applications of pesticides may introduce agricultural chemicals into DPS rivers and streams.

The effects of pesticide exposure to Atlantic salmon have not been fully investigated. The effects of agricultural chemicals on salmonids may range from acute (i.e., lethal), to chronic (i.e., sublethal). Effects on aquatic life depend primarily on the concentration and duration of exposure. Specific effects on Atlantic salmon depend on a number of factors including concentration, toxicity of the pesticide in question, water quality (i.e., pH, temperature, conductivity, alkalinity) and stream flow velocity. Salmonid LC50's (lethal concentration to 50% of the individuals in a given time) are known for most of the pesticides used in Maine agriculture. All available data show that pesticides occur in the DPS rivers at concentrations that are several orders of magnitude less than published thresholds for acute toxicity (Mark Whiting, Maine DEP, personal communication).

The effects of chronic sublethal exposure at critical life stages such as fry emergence and smoltification are not well understood. New data on endocrine disruption suggests that significant physiological effects are possible at sub-lethal doses (Mark Whiting, Maine DEP, personal communicaton). In general, endocrine effects occur at levels that are an order of magnitude greater than observed values in the DPS rivers (Mark Whiting, Maine DEP, personal communication). Sublethal concentrations of pesticides may impair behavior or physiological functions in fish (Trial 1986). Endocrine disruptors are believed to affect smoltification in juvenile Atlantic salmon thereby impairing smolt's ability to successfully transition to seawater (Fairchild *et al.* 1999; Maine TAC 2002). For example, Fairchild *et al* (1999) documented a decline in returning adult Atlantic salmon to rivers in areas where the insecticide Matacil 1.8D had been sprayed to control an outbreak of spruce budworm. Matacil 1.8D contains 4-nonylphenol (4-NP), a compound known to have estrogenic effects. These researchers also documented a significant relationship between Matacil 1.8D application and smolt mortality. It is unlikely that Matacil will be used in future spruce budworm outbreaks. Spruce budworm outbreaks are cyclical over 40-80 year periods and are not expected in the next 10-20 years (Maine DOC, personal communication). A variety of endocrine disrupting chemicals have been found in DPS rivers (Beland *et al.* 1995, Mierzykowski and Carr 1998; Maine DEP 1999; Chizmas 1999; Chizmas 2000; Magee 2001).

There are a number of pesticides used by the blueberry industry in Maine (brand or trade names in parentheses). Insecticides include azinophos-methyl (Guthion, Sniper 2E), *Bacillus thuringiensis* (Javeline, Biobit), carbaryl (Sevin), diazinon, malathion (Cythion), methoxychlor (Marlate) and phosmet (Imidan). Herbicides include fluazifo-p butyl (Fusilade), glyphosate (Roundup), hexazinone (Velpar), sethoxydim (Poast), terbacil (Sinbar) and 2,4-D ester. Fungicides include propiconazole (Orbit), chlorothalonil (Bravo), benomyl (Benlate), captan and captec (Captan) and triflorine (Funginex) (MASCP 1997). Most of these chemicals have not been routinely detected in historical water samples from the DPS rivers with the exception of hexazinone and DDT, phosmet, guthion, propiconazole and chlorothalonil that have been detected intermittently at low concentrations. It should be noted that the absence of pesticides in historical sampling data does not infer absence of contamination. Increased joint monitoring by DEP and the Maine Board of Pesticides Control (BPC) is needed to accurately detect levels of pesticides in DPS river watersheds and detect modes of contamination, contaminant fate and toxicity.

Hexazinone, a herbicide used in the spring for blueberry farming, has been detected at numerous sites in trace amounts in the Narraguagus, Pleasant and Machias rivers (Beland *et al*. 1995; Chizmas 1999; Chizmas 2000, Maine TAC 2002). Many fields are treated aerially with this chemical and drift to adjacent waters has been documented. Sprays are applied May through June but hexazinone has been detected in water samples year-round. The pervasive presence of hexazinone in surface water sampled at low flow periods suggests that it is entering the river through groundwater flow rather than storm runoff (Beland *et al.* 1993). The herbicide was initially detected during routine water sampling for an array of pesticides conducted in the spring and fall of 1991. Hexazinone was subsequently detected in additional locations and samples in 1994 (Beland *et al.* 1994). Although hexazinone has been detected in surface water samples in the range of 4-9 ppb, concentrations are typically less than 1 ppb. Some groundwater (e.g., wells) samples have hexazinone levels approaching 30 ppb. Groundwater does not appear to be an important pathway for other pesticides that have been reported in DPS rivers (Maine TAC 2002).

The forestry industry uses pesticides on a site specific basis. The forest industry periodically uses insecticides to control outbreaks of insects, most commonly budworm. Insecticides applied to control outbreaks of defoliating insects employ primarily biological agents (*Bacillus thuringiensis* or Bt). These agents are specific to the target organisms (e.g. moth larvae). Herbicides are occasionally used to control hardwood regrowth after a timber harvest to promote softwood regeneration and during site preparation for planting. There is the potential for these chemical compounds to enter streams through runoff and drift. Herbicide use can be reduced through best management practices (BMP). Use of forestry herbicides statewide has been declining in recent years. There are no current broad-scale forest insect control efforts known in the salmon watersheds.

The Maine BPC regulates the application, storage and disposal of pesticides in Maine. The BPC has the authority to designate areas where pesticide use is restricted to protect health, welfare and environment. Through the BPC, the State of Maine has encouraged farmers to adopt integrated crop management practices including integrated pest management. These integrated management practices have reduced the rates and frequency of agricultural chemical applications. For example, the use of hexazinone in recent years is about one third of historic application rates (Mark Whiting, Maine DEP, personal communication). Maine has developed a State Management Plan for Pesticides and Groundwater, a strategy for Managing Nonpoint Source Pollution from Agricultural Sources, Best Management System Guidelines and a Coast Nonpoint Source Control Program. These water quality programs address potential pollution associated with pesticides, sediments, nutrients, manure, grazing management and wastewater from confined animal facilities.

iii. Sedimentation

The final rule listing Atlantic salmon as endangered concludes that sedimentation from a variety of sources may be altering habitat and rendering it incapable of supporting Atlantic salmon. While a thorough assessment of habitat conditions has not been conducted, field evidence suggests that elevated levels of sediment have compromised spawning habitat along certain reaches in several DPS rivers (65 FR 69459). For example, large sections of the Sheepscot River turn cloudy in the spring and fall; turbidity can last for four to six weeks during the spring freshet. This watershed has the highest density of year-round roads in DPS river watersheds (Maine TAC 2002).

Generally, sediment can impact salmon habitat in a number of ways. Sediment changes the physical structure of a river’s substrate, a critical factor in salmon survival. Sediment may result in direct mortality of Atlantic salmon through the burial of salmon redds and the suffocation of eggs and newly hatched salmon sac-fry prior to emergence. Documented effects of sedimentation include direct mortality to early life stages (e.g., eggs and fry due to smothering)(Shaw and Maga 1943; Shelton 1955; Hall and Lantz 1969; Platts *et al.* 1979;

Bjornn and Reiser 1991); increased embeddedness (the degree in which the rocks and cobble are stuck in the stream) of aquatic substrate that may affect benthic macroinvertebrates (Bjornn *et al.* 1974, 1977 and McClelland and Brusven 1980); direct loss of juvenile and adult habitat through the filling of pools, interstitial spaces and other habitat; temperature change; reduced primary production; and excess nutrient loading (Cordone and Kelley 1961). Sedimentation can cause severe damage to benthic invertebrate populations. The affected organisms consist mainly of insect orders which are generally the forms most readily available to foraging fish (Waters 1995).

Filling of interstitial spaces and reduction of water depth in pools can affect Atlantic salmon habitat (Waters 1995). McCrimmon (1954) compared several factors (temperature, food, sediment) affecting stocked Atlantic salmon fry. He concluded that sedimentation had the most significant deleterious effect on the survival of fry. Bjornn *et al.* (1974, 1977) found that embedding cobble substrates in sediment reduced the amount of habitat available for juvenile salmonids (salmon and trout) affecting their density and distribution. Excess sediments can fill pools, resulting in decreased depths and total area, thus reducing the amount of habitat available for juveniles and adults during the summer months (Cordone and Kelley 1961). The loss of shelter in interstitial gravel and cobble spaces due to filling by sediment can result in increased predation and lower overwinter survival rates (Cordone and Kelley 1961; Bjornn *et al.* 1974). Excess sedimentation in pools has been cited as a reason for numerous salmonid population declines (Saunders and Smith 1965; Peters 1967; Elwood and Waters 1969; Barton 1977).

Examples of specific sources within DPS rivers include improperly constructed culverts, poor agricultural practices, road construction and maintenance, timber harvest in the riparian zone, stream crossings, dredging, recreational all terrain vehicles (ATVs) and salt and sand from winter road maintenance[12].

Poorly designed and placed bridges and culverts may constrict natural stream channels and increase sedimentation. This can result in altered fish habitat and restricted fish passage. Inadequately stabilized road shoulders surrounding bridge and culvert crossings can have similar impacts (Choctawhatchee, Pea and Yellow Rivers Watershed Management Authority 2000). Until recently, the construction of road ditches that ran directly into rivers and streams was common. In some cases this practice still continues. This practice can result in unnaturally elevated stream levels during rain events. This can result in increased erosion and flooding.

Concerns exist about the impacts caused by ATVs on salmon habitat. Recreational vehicles crossing rivers or streams can threaten salmon and their habitats through direct mortality, destruction of redds and increased bank erosion and sedimentation.

---

[12] The Maine Department of Transportation (MDOT) is currently implementing a new winter road maintenance program expected to reduce sand applications by 80% minimizing this potential input of sediment to salmon rivers.

Pasturing livestock near or adjacent to a river or stream can adversely affect instream salmon habitat, including degrading water quality and adjacent riparian zones. Overgrazing and direct access to the river or stream can expose soils, increase soil erosion, promote invasion of undesirable terrestrial and aquatic plants and destroy fish habitat (EPA 1996).

Dredging activities have the potential to adversely affect Atlantic salmon habitat in DPS rivers. The removal of large amounts of sediment causes the creation of a sediment plume, which may adversely affect water clarity and quality. There is also the potential for resuspension of toxic chemicals or other harmful compounds from the sediment. Dredging can alter natural flow regimes and impact salinity levels within the estuary. Dredging has the potential to harm Atlantic salmon both as outmigrating smolts by creating a migration barrier and as returning adults by disrupting the olfactory cues used by the fish to identify and ascend natal rivers. There are several existing federal navigation projects maintained by the ACOE within the range of the DPS.

Cooperative efforts among landowners and watershed councils have identified and remediated chronic NPS sites (most related to forest roads) where sedimentation of streams was a concern. Regulatory authority over water quality issues related to forestry resides with DEP and LURC. MFS field staff assist by conducting routine harvest inspections. MFS has made a priority of conducting inspections in the areas near important salmon habitat.

ii. Excess Nutrients

Excessive nutrient enrichment of a river can increase growth of aquatic vegetation and may reduce the carrying capacity for Atlantic salmon. Increased respiration and decomposition of plants may cause dissolved oxygen to fall below levels optimal for Atlantic salmon. Increased algae in the water column can decrease visibility for sight feeding salmon.

Excess nutrients can enter a river either in surface runoff or groundwater. Sources of excess nutrients include agricultural facilities, sewage treatment plants, failing septic systems, manufacturing or processing plants and hatcheries. Increased nutrients from improper manure storage and manure spreading can significantly impact water quality making habitats less suitable for the spawning, rearing and migration of Atlantic salmon. As long as manure spreading is done in accordance with existing state regulations and with proper oversight, there is minimal potential for deleterious water quality effects (Maine TAC 2002). Passage of the Nutrient Management Act with the requirement for nutrient management plans and funding for the construction of manure storages has helped reduce the potential for deleterious water quality effects (MDAFRR personal observations).

The available water quality data for DPS rivers indicate that excess nutrients are not a problem, except for in the Sheepscot River. The relative contribution of agricultural uses versus suburban development and runoff is not known (Mark Whiting, Maine Department of Environmental Protection (DEP), personal communication 2001).

v. Elevated Water Temperatures

Water temperature may be an important factor limiting Atlantic salmon rearing habitat in Maine rivers (Maine TAC 2002). Even relatively minor increases in water temperature may result in sub-lethal and lethal physiological effects and reduce habitat suitability for adult and juvenile salmon (Maine TAC 2002). Increased water temperature may adversely affect the production potential of a river or stream (Maine TAC 2002). Factors that may contribute to elevated water temperature include broad climatic changes, unregulated or improper land use practices, impoundment of free-flowing river and stream reaches and discharges of cooling or processing water (Maine TAC 2002). Summer water temperatures can exceed 22°C in large portions of the Sheepscot River. In addition, dissolved oxygen (DO) levels often drop below 7 milligrams per liter (mg/l) coinciding with high bacteria counts in the Sheepscot River (Maine TAC 2002). Summer oxygen levels below 6 mg/l are not suitable for salmonids (Maine TAC 2002).

The temperature requirements of the various salmon life stages are well understood. Table 1 summarizes published optimal temperature ranges along with maximum and minimum thermal tolerance criteria. The optimal temperature range for juvenile salmon feeding and growth in streams is 15-19°C and the maximum limit for feeding is 22.5°C (DeCola 1970; Elson 1975; Danie *et al.* 1984; Elliott 1991). Juvenile salmon can survive for several days at temperatures of 26-27°C (Garside 1973; Elliott 1991). However, adult salmon mortalities have often been observed at temperatures of 26-27 °C and temperatures above 23°C inhibit spawning migrations (Elson 1969; DeCola 1970; Danie *et al.* 1984; Hawkins 1989; Shepard 1995).

Water temperatures in DPS rivers fluctuate daily with the lowest temperatures in the morning and highest temperatures in the late afternoon. The ASC has recorded continuous water temperatures at several sites on the Narraguagus River (Figure 8). Daily maximum water temperatures often exceed the feeding threshold of 22.5°C in warm years, but only occasionally in cool years such as 1992 and 1996. Daily maximum temperatures seldom exceeded 26°C in cool years, but exceeded this level on about ten days during the warmer years.

Table 1 – Atlantic salmon temperature (°C) requirements for freshwater life stages. Data are from published studies on Atlantic salmon, including experimental data and in situ measurements over the range of the species (North America and Europe).

Life Stage	Optimum Range	Min.[1]	Max.	References
Spawning	5-8	4.4	10	DeCola '70; Danie *et al.* '84; McLaughlin and Knight '87
Incubation	4-7.2	0.5	12	DeCola '70; Gunnes '79; Danie *et al.* '84; McLaughlin and Knight '87
Early Fry	8-19	0.5	23.5	Danie *et al.* '84; Jensen *et al.* '91
Juveniles				
Feeding	15-19	3.8	22.5 [2]	DeCola '70; Elson '75; Danie *et al.* '84; Elliott '91
Survival	0.5-20	0	29.0 [3]	Garside '73; Elliott '91
River Migration				
Smolt	7-14.3	5	19	Bakshtansky *et al.* '76; LaBar *et al.* '78; Ruggles '80; Jonsson and Rudd-Hansen '85; Duston *et al.* '91; Shepard '91
Adult	14-20	8	23 [4]	Elson '69; DeCola '70; Danie *et al.* '84; Hawkins '89; Shepard '95

Notes:

1. Minimum water temperatures reflect the requirements of southern populations and include winter temperature requirements. Northen populations have lower minima for some life stages (not included).
2. Highest temperature for feeding after acclimation at 20.0 °C.
3. Highest temperature for 1000 minute survival after acclimation at 25.0-27.0 °C.
4. Highest temperature for normal upstream migration. The lethal temperature for adult salmon is approximately 27.0 °C, depending upon acclimation and duration of exposure.

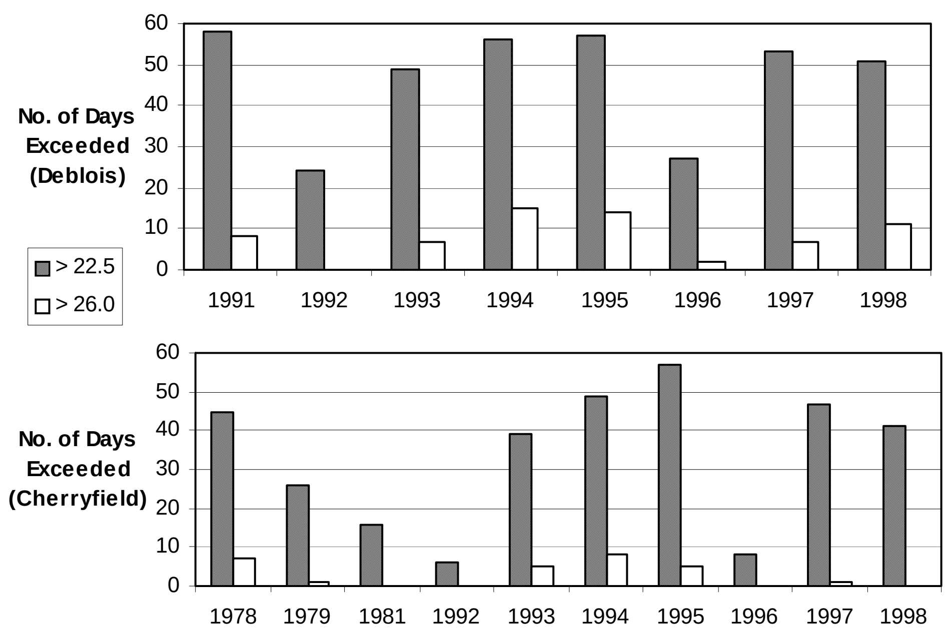


Figure 8 – Number of days when the Narraguagus River daily maximum water temperature exceeded 22.5 or 26 °C at Deblois (upper) and Cherryfield (lower). Data from the Maine ASC.

Water temperatures in the DPS rivers may have increased in the last decade or more as a result of regional/global climate changes that have increased both air and water temperatures. The period of record for water temperature data, however, is not adequate to assess long-term trends. Staff reports from the Atlantic Salmon Authority (ASA; predecessor agency to ASC) indicate that elevated water temperatures may affect habitat in some DPS rivers (Beland *et al.* 1995; Horton *et al.* 1995). Specifically, available data indicates that high water temperature may be a problem in some years in Cathance Stream in the Dennys River and certain sections of the mainstem of the East Machias River (ASA 1998). Localized temperature changes may occur as a result of decreased stream shading, low flows that increase net insolation (exposure to sun) or thermal discharges to the DPS rivers.

The potential for water temperature elevation in the vicinity of berry processing water discharges has been identified as a water quality issue (MASCP 1997). Two berry processing plants on the Narraguagus River and one on the Machias River discharge water used in the processing of blueberries directly into the river (MASCP 1997). Processing plants are allowed to discharge 627,000 gallons of agricultural process water in to the Narraguagus River per day (0.97 cfs). Up to 100,000 gallons per day (0.15 cfs) is allowed to attain a discharge temperature of 26˚ C. Up to 70,000 gallons per day (0.11 cfs) of agricultural process water is allowed to be discharged into the Machias River with a maximum temperature of 32˚C, a temperature lethal to both juveniles and adult salmon. No monitoring of the effect of these discharges on the river temperature and Atlantic salmon has been conducted. In addition to lethal effects, areas of elevated water temperature may adversely affect salmon by acting as a thermal barrier to passage thereby inhibiting migration.

3. Obstruction to Passage

i. Manmade Barriers

Historically, dams were a major cause of the decline of Atlantic salmon runs in many Maine rivers and streams (Baum 1997). At one time, dams existed at various times on virtually all eight rivers within the DPS known to still support wild Atlantic salmon. Dams were constructed to produce electricity, operate mills, transport logs and as ice control structures. Historic records indicate that many of the old, low-head timber crib dams had significant leakage and were not complete barriers to fish passage.

In the late 1940s, the presence of dams on the Narraguagus, Machias, East Machias and Pleasant rivers was identified as a threat to the continued existence of Atlantic salmon in those rivers (Rounsefell and Bond 1949). According to Rounsefell and Bond (1949), the Atlantic salmon run in the Dennys River was almost always in peril during the 1880s because of dams. In the Sheepscot River, twenty-four obstructions, including a dam at the head of tide in Alna, threatened salmon returns until the early 1960s (Meister 1982).

Today, most of these dams have either been removed or breached and no longer threaten salmon migration. Coopers Mills Dam on the Sheepscot River and the Stillwater Dam on the

Narraguagus are the only remaining dams with potential to significantly obstruct access to valuable spawning and rearing habitat. The Head Tide Dam on the Sheepscot River was effectively breached on the eastern shore in 1968 to allow free passage into the river (Meister 1982). Today, most of the structure still exists and though it no longer obstructs fish passage, it still impacts spawning and rearing habitat by altering normal flow conditions. All other obstructions on these rivers (e.g., ice-control dam in Cherryfield, Meddybemps Lake outlet dam) have fishways. The efficiency of these fishways has not been well documented (Baum *et al.* 1992).

The Coopers Mills Dam, located below the long pond on the mainstem of the Sheepscot River, was retrofitted in 1960 with a Denil fishway, which IFW maintains (Meister 1982). In recent years, the dam has developed leaks that reduce attraction to the fishway. In addition, a screen in the fishway to block lamprey passage and to assist in the alewife fishery, in combination with the deterioration of the dam's structural integrity, greatly reduces or prevents the passage of migrating salmon during the spring migration period.

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

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

ii. Natural Barriers

Natural geological falls occur in most of the rivers within the DPS known to still support wild salmon populations and sometimes act as temporary barriers or deterrents to fish passage during certain flow conditions. Fish ladders have been constructed at Bad Little Falls on the Machias River in Machias (Fletcher *et al.* 1982) and at Saco Falls on the Pleasant River (Dube and Jordan 1982). The Bad Little Falls fishway provides passage around the dam that was constructed at the head of the Machias Gorge. In 1970, the dam was breached by the spring freshets and now fish most often use the west channel to pass above the falls rather than the fishway, which is in the center channel (Fletcher *et al.* 1982). On the Pleasant River a fish ladder was constructed at Saco Falls in 1955 to improve fish passage around this natural obstruction (Dube and Jordan 1982). The Saco Falls fish ladder is in disrepair and is no longer functional.

Beaver dams and debris jams are perennial events on Maine rivers. These dams are typically temporary partial obstructions (Havey and Fletcher 1956). They can temporarily alter habitat and block access to spawning habitat, thereby reducing salmon productivity. While Atlantic salmon and beavers have always coexisted, the problems associated with beaver dams are exacerbated by very high beaver populations and very low salmon populations. Beaver populations in Maine have expanded in the absence of natural predators. Beaver populations have also increased as demand for their fur has decreased. In many DPS river watersheds, ideal beaver habitat now exists due to past logging practices, i.e., the harvesting of timber (pine, spruce, hemlock and firs) and the subsequent successional regrowth of alder and poplars.

Generally, beaver dams do not limit upstream migration for adult Atlantic salmon in the main stem of the Dennys, East Machias, Machias and Narraguagus rivers. Tributaries to the East Machias, Machias and Narraguagus rivers contain some spawning habitat that may be blocked by beaver dams. In years of low water conditions, beaver dams may prevent access to some spawning areas on these rivers (ASA 1998). Beaver dams generally pose a greater threat on smaller tributaries that often provide valuable spawning and rearing habitat but are also essential sources of cold water. Small tributaries can quickly become choked with beaver dams that can adversely alter salmon habitat by inundating riffle-pool complexes and runs, reduce flow, increase stream depth, increase water temperature and block sediment transport. Beaver dams can inundate salmon spawning and rearing habitat. Further, they may increase levels of predation on salmon parr and out-migrating smolts. Conversely, the impoundments created by beaver dams store water which may be beneficial in low water years.

B. OVERUTILIZATION FOR COMMERCIAL, RECREATIONAL, SCIENTIFIC OR EDUCATIONAL PURPOSES

Commercial and Recreational Fisheries

Both commercial and recreational fisheries, especially marine, have historically played a role in the decline of the DPS. Today, U.S. fishery regulations prohibit commercial and recreational harvest of sea-run Atlantic salmon in state and federal waters. Canadian regulations prohibit all commercial harvest of Atlantic salmon off Labrador and Newfoundland. In Greenland, commercial harvest of Atlantic salmon is regulated through cooperative international management. Currently, the only marine fishery not under state, federal or international management that poses a potential threat to Endangered salmon occurs in the French territory of St. Pierre et Miquelon off the coast of Newfoundland.

1. U.S. Fisheries

In 1987, the New England Fishery Management Council (NEFMC), pursuant to its authority under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) (16 USC. 1801 *et seq*.) prepared and implemented a federal Fishery Management Plan (FMP) for Atlantic salmon. The FMP prohibits possession of Atlantic salmon in the U.S. exclusive economic zone (EEZ). The FMP was intended to safeguard U.S. Atlantic salmon, protect the U.S. investment in the state-federal restoration program and strengthen the U.S. position in international negotiations. In addition, Section 9 of the ESA prohibits the take of endangered Atlantic salmon. The term take means to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct."

The State of Maine currently prohibits all recreational and commercial harvest of wild Atlantic salmon in state waters. From the 1960s through the early 1980s, the estimated average recreational catch[13] rate in Maine rivers ranged from approximately 20% to more than 25% of the run (Beland 1984; Baum 1997). This level of harvest was likely too high, especially in light of the extensive commercial marine harvest at that time. In response to declining salmon returns, the State of Maine enacted new regulation of the recreational harvest of salmon. These measures included reducing the allowable annual harvest from ten salmon in the 1980s to one salmon in 1994. In 1995, regulations were implemented permitting only catch-and-release fishing for Atlantic salmon in Maine, closing the last remaining recreational harvest opportunities for wild Atlantic salmon in the U.S. In December 1999, the State of Maine adopted regulations prohibiting all angling for sea-run salmon statewide.

Despite these strict state and federal regulations, both juvenile and adult Atlantic salmon remain vulnerable to injury and mortality due to incidental capture by recreational anglers and as bycatch in commercial fisheries. Returning adult sea-run Atlantic salmon are particularly vulnerable to capture by recreational anglers when holding in deep, cold water pools during the summer months prior to spawning. The best available information indicates that Atlantic salmon are still often incidentally caught by recreational anglers in many of these pools.

In addition to inadvertent capture by recreational fishermen, Atlantic salmon are vulnerable to intentional capture. Documented poaching in 1998 and 2000 indicate that poaching continues to pose a threat to Atlantic salmon. In 2003, two Atlantic salmon kelts were reportedly taken by a fisherman on the Sheepscot River. Reports of the deliberate targeting and capture of Atlantic salmon in the Narraguagus and Machias rivers by recreational fishermen also raise serious concerns.

In August 2003, the Maine IFW closed all fishing in the portion of the Narraguagus River from the ice control dam to the Railroad Bridge in Cherryfield through an emergency measure. This river reach includes that includes the Stillwater, Cable and Maple Pools. Atlantic salmon were being fished for and hooked under the guise of angling for shad on the Narraguagus River. ASC biologists monitoring returning adults at the fishway trap at the ice control dam documented hooking and line wounds on 3 of 12 Atlantic salmon captured (25%). The Atlantic Salmon Commission received a request from the Narraguagus and Pleasant River Watershed Councils to pursue this closure. The Maine IFW is currently considering adopting a rule that would permanently close the Cable and Maple Pools to all fishing while leaving open, for the time period that shad are migrating, (May 1 to June 10) the Stillwater Pool (100 and 450 feet from the ice control dam) where shad are more likely to be caught than Atlantic salmon.

---

[13] During this period catch and release was generally not practiced.

The potential also exists for recreational anglers to keep juvenile Atlantic salmon misidentified as brook trout, brown trout or landlocked salmon. To reduce the potential for keeping salmon parr misidentified as other salmonid species, the State established a minimum size (8 inches) restriction on trout caught after June 30 of each year in the DPS river watersheds. Atlantic salmon kelts may also be kept by ice fishermen who misidentify them as landlocked salmon. In an attempt to avoid this potential source of accidental sea-run Atlantic salmon harvest, a maximum length for landlocked salmon and brown trout (25 inches) was implemented by the State. There is no way to accurately estimate the number of Atlantic salmon caught as recreational bycatch or the resultant mortality (LWRC 1999).

The biological effects that incidental catch and subsequent release may have on Atlantic salmon are not well understood (Brobbel *et al.* 1996). Several studies have concluded that exhaustive exertion associated with angling may result in significant physiological disturbances including mortality (Bouck and Ball 1966; Beggs *et al.* 1980; Graham *et al.* 1982; Wood *et al*. 1983; Brobbel *et al.* 1996). For example, Brobbel *et al.* (1996) compared the effects of catch and release fishing on kelts and bright salmon on the Miramachi River in New Brunswick. It was determined that compared to kelts, bright salmon[14] were more disturbed by angling and were more likely to suffer mortality. Several factors, such as degree of starvation, osmoregulatory status and environmental temperature, probably influenced the physiological response of Atlantic salmon at different life-stages. In contrast, other researchers have found that extreme exertion does not always result in significant levels of mortality (Wydoski *et al.* 1976; Tufts *et al.* 1991; Booth *et al.* 1995).

While studies conducted under controlled or laboratory settings have resulted in zero mortality to Atlantic salmon caught and properly released, it is highly unlikely that such favorable conditions would be consistently present in the natural environment. Conditions that contribute to mortality include elevated water temperatures, exposure of the fish to air after it has been captured, extremely soft water, low oxygen levels, low river flow and improper handling (Booth *et al.* 1995). Given current wild Atlantic salmon population levels, any bycatch mortality would adversely affect the DPS and its recovery.

The potential also exists for juvenile and adult Atlantic salmon to be incidentally taken as bycatch in commercial fisheries. Commercial fisheries deploying small mesh active gear (pelagic trawls and purse seines within ten meters of the surface) have the potential to incidentally take post-smolts. Results from a 2001 and 2002 post-smolt trawl survey in Penobscot Bay and the nearshore waters of the Gulf of Maine indicate that Atlantic salmon post-smolts are prevalent in the upper water column throughout this area in mid-to-late May (Russell Brown, NOAA Fisheries, personal communication). The potential also exists for returning adults to be taken as bycatch in commercial fisheries. For example, in 2001 a commercial fishing vessel captured an adult salmon subsequently determined to be an escaped aquaculture fish. While a review of existing commercial fishery records does not indicate that bycatch of Atlantic salmon is a significant threat, additional investigation is warranted.

---

[14] a salmon that has entered its natal stream upon return from the sea.

In addition to marine fisheries, commercial fisheries in estuarine and freshwater environments have the potential to incidentally take Atlantic salmon. For example, a commercial elver (juvenile eels) fishery harvests small eels returning to Maine rivers from their ocean spawning areas. Intense market demand in the Far East (Japan, China, Taiwan and Korea) makes elvers a highly valuable commercial catadromous species. In Maine, elvers begin to migrate into Gulf of Maine watersheds in March with peak migrations occurring in April and May. Elver harvest methods are restricted to fyke nets (a funnel shaped net) and hand dip nets. Regulation of the elver fishery includes a season from March 22 to May 31, a ban on harvest of elvers upriver of the head-of-tide and limits on the length of fyke nets that can be set in waterways. Regulations also prohibit nets from the middle third of any waterway and require finfish excluder panels to minimize bycatch and adverse impacts on non-target species. Fishing effort for elvers has decreased in recent years due to license restrictions and a significant reduction in the market price (65 FR 69470). In recent years, no incidental take of juvenile or adult Atlantic salmon has been documented in this fishery.

A recent event highlights the potential for other commercial fisheries to adversely affect Atlantic salmon and the need to continue to monitor these fisheries. In 2001, in violation of existing regulations, access to the Dyer River (a tributary to the Sheepscot River) was entirely blocked by an alewife net. The problem was brought to the attention of state and federal agencies by a member of a local conservation organization.

2. Canadian Fisheries

In February 1999, the Canadian Department of Fisheries and Oceans (DFO) instituted a three-year moratorium on the commercial harvest of Atlantic salmon in Newfoundland and Labrador. This moratorium has been extended indefinitely. In addition, the DFO implemented regulations for recreational fisheries, including the requirement to use only barbless hooks in Newfoundland and Labrador. Currently, recreational fisheries for Atlantic salmon are regulated through in-season adjustments to the total allowable catch rates based on salmon returns. Since these recreational fisheries occur in Canadian rivers, they do not impact DPS fish.

3. West Greenland Fishery

Until recently, the West Greenland fishery was one of the last directed Atlantic salmon fisheries in the Northwest Atlantic. In August 2002, commercial fishing for Atlantic salmon within Greenland territorial waters was provisionally suspended for five years (see page 1-17). The internal use fishery is not included in the agreement. In 2002, the internal use fishery landed an estimated 19 metric tons (mt) (reported and unreported catch). This fishery is a mixed stock fishery, catching both North American and European fish. The North American component of this mixed stock includes both Canadian and United States salmon. Maine-origin salmon including Endangered salmon are taken in low numbers by this fishery[15]. Based upon tag

[15] In 2002, based on reported and unreported catch estimates, one DPS fish may have been caught in the fishery (Chris Legault, NOAA Fisheries, personal communication).

returns, the commercial fisheries of Newfoundland and Labrador historically intercepted far greater number of Maine-origin salmon than the West Greenland fishery (Baum 1997). Nevertheless, concerns exist about the potential of the West Greenland fishery to harvest endangered U.S. salmon.

Beginning in 1982, Atlantic salmon catch has been sampled from the West Greenland fishery to determine continent of origin. The information is used in the scientific model that predicts pre-fishery abundance and to make science-based management decisions for this fishery. The results of this research are integral to the completion of stock assessments of Atlantic salmon through the ICES North Atlantic Salmon Working Group.

Historically, the overall proportion of European to North American fish taken was roughly 50/50 (Baum 1997). In recent years, the proportion of North American fish taken in this fishery has increased. Based on discriminant analysis of characteristics from scales sampled in the fishery, 91% of fish harvested in 1999 were of North American origin, the highest proportion on record (ICES 2000). The reasons for this are not understood but may relate to changes in the fish migration patterns of Atlantic salmon, or differential rates of decline in the stocks of long-range migrating Atlantic salmon originating from North American and European sources. The proportion of North American salmon dropped to 65% in 2000 and 67% in 2001. In 2000 and 2001, fishing effort shifted southward along the coast of West Greenland relative to 1999, with fishing effort disproportionately distributed in the southern divisions (NAFO subareas 1D & 1F).

In view of elimination of the directed commercial fishery in Maine and changes in the high seas fishery, the existing fishery off West Greenland is not thought to be limiting the survival of the DPS. The best available data indicate that, while a potential impediment to the recovery of the DPS, the West Greenland commercial fishery is not currently jeopardizing the continued existence of the species.

4. St. Pierre et Miquelon Fishery

A small commercial fishery occurs off St. Pierre et Miquelon, a French territory off the coast of Newfoundland. Historically, the fishery has been very limited in scope (2-3 mt per year). There is great interest by the U.S. and Canada in sampling this catch to gain more information on stock composition. In recent years there has been a reported small increase in the number of fishermen participating in this fishery. Efforts to establish a sampling program to determine the composition of the catch have so far been unsuccessful although efforts are continuing through the North Atlantic Salmon Conservation Organization (NASCO). Without these data it is not possible to estimate the level of take and potential threat this fishery may pose to the continued survival and recovery of the DPS.

C. DISEASE

Atlantic salmon are susceptible to a number of diseases that can result in direct or indirect mortality. Indirect mortality involves debilitation that leads to increased mortality from other sources and causes. Disease-related mortality is more apparent and easier to document in fish culture facilities than in the wild. The final rule listing the DPS as endangered identified disease as a serious threat to the continued survival and recovery of the species (65 FR 69459). The Maine TAC Water Quality Committee (2002) concluded that fish pathogens may be a significant factor affecting recovery of Atlantic salmon populations, particularly in rivers with salmon net-pen facilities at their mouth or hatcheries in the watershed.

The Atlantic Salmon Status Review (NMFS and FWS 1999) provides a detailed description of common salmonid diseases that may adversely affect wild salmon populations in Maine. These diseases include both viral and bacterial pathogens. There are at least a dozen common fish diseases that are a threat to Atlantic salmon. To some degree, the immediacy of the threat and the basic approach for control are related to geographic proximity and frequency of occurrence of the disease relative to the DPS population. For convenience of discussion, these diseases are grouped below on that basis.

There are three basic categories of disease: (a) those not endemic to the geographic range of the DPS; (b) those commonly occurring within the geographic range of the DPS; and (c) those present to a limited extent within the geographic range of the DPS. The significance of each disease within a group, relative to management and severity of threat, depends on a number of characteristics of the particular pathogen. These factors include the rate of mortality, ease of control, ease of detection and method and rate of spread. Diseases not endemic to the DPS include Viral Hemorrhagic Septicemia (VHS), Infectious Hematopoietic Necrosis (IHN), Oncorhynchus Masou Virus Disease, Whirling Disease and Ceratomyxosis. Those commonly occurring within the geographic range of the DPS include Bacterial Kidney Disease (BKD), Infectious Pancreatic Necrosis (IPN), Enteric Redmouth (ERM), Furunculosis, Coldwater Disease (CWD) and Vibrio. Those present to a limited extent within the geographic range of the DPS include Infectious Salmon Anemia (ISA) and Salmon Swimbladder Sarcoma (SSS) (Mills 1971; Gaston 1988; Olafsen and Roberts 1993; Egusa 1992).

The threats posed by diseases in group (a) are best controlled through strict importation and transfer regulations and protocols. State regulations in Maine are some of the most restrictive in the U.S.. The State's current salmonid fish health inspection and importation regulations (09-137 Code of Maine Rules Chapter 2.03-A) identify exotic and endemic infectious pathogens of regulatory concern. These regulations also prohibit the transfer of live salmonids or gametes among culture facilities until the fish are tested and certified pathogen free, outlaws the sale of clinically ill fish, outlines a standardized annual testing and monitoring protocol for all salmonids in public and private facilities and requires that fish taken from the wild be isolated until inspected for diseases. These regulations also outline stringent regulations for salmonid importation into the State and outline a standard protocol for action in the case of a confirmed disease outbreak. Applicable federal import regulations (Title 50) apply only to a limited number of pathogens and need to be revised to include the ISA virus. Guidelines and protocols, such as the New England Salmonid Fish Health (NESFH) Guidelines (1995) and the North American Commission of NASCO Protocols for Salmonid Introductions and Transfers (1992), provide guidance to control the introduction and spread of group (a) pathogens beyond their current distribution.

The relatively common diseases found in group (b) are most often a problem in fish culture situations (hatchery and pens) of high population densities. Mitigation of the disease threats posed by group (b) pathogens primarily requires proper fish culture practices. In addition to impacting hatcheries and net-pens, group (b) diseases can also impact salmon in the wild. For example, furunculosis is a bacterial disease that is more common under crowded hatchery conditions but also occurs in the wild. The bacterium causing this disease, *Aeromonas salmonicida*, is highly infectious in freshwater and sufficiently salt tolerant for transmission to occur in seawater. This disease can cause mortality if not recognized and treated at an early stage. In New England, furunculosis is the only documented epizootic source of mortality in wild Atlantic salmon (Bley 1987). Outbreaks of this disease are most common when environmental conditions become stressful, such as during high water temperature situations that can occur with low water levels. Thus, this threat needs to be considered as a factor in maintaining proper flow levels in DPS rivers. In Norway, furunculosis was found for the first time after the importation of rainbow trout from Denmark (Heggberget *et al.* 1993). Another example of how group (b) diseases can be a problem in culture situations would be with *Flavobacterium psychrophila*, the bacterium causing cold water disease (CWD). Although this bacterium is considered ubiquitous in the aquatic environment, in the artificial environmental conditions of the fish culture facility it can spread among adults to a higher than normal prevalence and subsequently it has been demonstrated to be passed to the eggs where it has been associated with early fry mortality syndrome.

The concern about disease raised in the final listing rule (65 FR 69459) relates primarily to the recent occurrence of two salmonid diseases previously unknown in the geographic range of the DPS: ISA and SSS; these diseases are discussed below.

1. Infectious Salmon Anemia (ISA)

ISA is a contagious and untreatable viral disease that affects a fish’s kidneys and circulatory system with a variable mortality rate from 3% to more than 50% in one production cycle (USDA APHIS 2001). Atlantic salmon infected with clinical ISA are anemic, typically lethargic, swim near the surface and fail to swim upright. Experimental studies have demonstrated that the virus is transmissible through mucous, feces and blood of infected/diseased fishes. This results in cultured fishes being particularly susceptible to exposure to ISAV by infected cagemates. Studies in Norway indicate that penned salmon populations held within five kilometers (km) of each other or the discharge of slaughter wastes are at greatest risk of contracting ISA. There is no evidence that the virus spreads vertically (from parents to offspring) although poor disinfection of fertilized eggs may allow for external transfer of the virus. Poor culture practices in fish hatcheries and net-pens in an Atlantic salmon watershed could increase the risk of a wild population's exposure to disease.

ISA is the most significant known disease threat to the DPS. The threat of ISA to the recovery of the DPS is both direct, through infection of wild fish, and indirect by compromising hatchery supplementation of the DPS. The infection of emigrating smolts or adults passing near infected net-pens may cause mortality. This risk is greatest in those rivers whose approaches are nearest the highest concentration of net-pens, specifically the Dennys, East Machias and Machias. Other DPS river populations may also be at risk if they migrate through areas where aquaculture facilities are concentrated.

ISA has the potential to compromise CBNFH and the GLNFH if ISA-infected fish are inadvertently brought into one of these facilities. For example, an ISA-infected salmon brought into CBNFH for broodstock purposes could potentially infect other fish at the facility. In fact in 2001, a Penobscot sea run salmon brought to CBNFH for use as broodstock initially tested positive for ISA. Subsequent tests were negative and no additional fish were found to be infected. The potential for juveniles that have never entered salt water to be carriers of the virus is currently unknown.

ISA has already had an impact on Atlantic salmon recovery efforts. An adult stocking experiment (see page 4-65) was not fully optimized due to ISA concerns. These concerns resulted in more than 50% of the net-pen reared broodstock being destroyed. This decision was made because fish health experts felt the close proximity of these fish to fish infected with the ISA virus (ISAV) in commercial aquaculture pens was a substantial risk to wild populations. This concern was later affirmed by the outbreak of ISA in marine pens in the Cobscook Bay region (see page 1-42).

ISA was first reported in Norway in 1984 (Thorud and Djupvik 1988). In more recent years, cases of the disease have been reported from eastern Canada (Mullins *et al.* 1998), Scotland (Rodger *et al.* 1998), the Faroe Islands (OIE 2000), and in Cobscook Bay, Maine (Bouchard *et al.* 2001). The virus has also been associated with disease in cultured coho salmon in Chile (Kibenge *et al.* 2001) and very recently has been detected in cultured rainbow trout in Ireland.

The ISA virus has been known to cause disease in cultured fishes, principally in Atlantic salmon, although other species may act as carriers of the virus without signs of the disease. Species other than Atlantic salmon can become infected with ISAV and must be considered in the epizootiology of outbreaks and management of ISA. In laboratory studies, brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) have been shown to be asymptomatic carriers of the ISA virus that can transmit the virus to salmon by co-habitation (Nylund and Jakobsen 1995; Nylund *et al.* 1995; Nylund *et al.* 1997). Escaped or caged rainbow trout may pose a threat to wild Atlantic salmon by serving as a reservoir of ISAV.

Recent studies in the United States and Canada indicate non-salmonids (i.e., gadids) can become infected with ISAV. Whether these species act as reservoirs in wild populations remains to be determined. Assays of non-salmonid fishes taken from pens containing ISA-diseased cultured Atlantic salmon resulted in isolation of virus from tissues of asymptomatic cod (MacLean *et al.* 2003).

Results of recent studies conducted in Scotland and Canada indicate that ISAV exists at a low level in wild salmonids. ISAV has been found in Atlantic salmon aquaculture escapees (Olivier 2002; Raynard *et al.* 2001). There has been one case of wild salmon exhibiting ISA in Canada, but these wild fish were confined in a trapping facility with infected salmon of aquaculture origin.

At the time of the listing of the DPS as endangered in December 2000 (65 FR 69459), some U.S. net-pen sites in Cobscook Bay, the location of Maine's greatest concentration of salmon aquaculture pens, were within five km of Canada's ISA positive sites, raising concerns about the potential for this disease to infect U.S. aquaculture and wild salmon stocks. Subsequent to the listing of the Gulf of Maine DPS of Atlantic salmon as endangered, the disease spread to U.S. aquaculture sites within Cobscook Bay. The first known case of ISA in Cobscook Bay involved a salmon aquaculture net-pen site. The infection probably occurred in 2000 and was confirmed in February 2001. By September 2001, 50% of the net-pen sites in Cobscook Bay were ISAV-infected or diseased.

In January 2002, in an effort to control a catastrophic outbreak of ISA in Cobscook Bay, the Maine Department of Marine Resources (DMR), with the assistance of the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (USDA/APHIS), ordered the destruction of an estimated 1.5 million salmon in the Bay. The industry was required to remove all fish from the Bay and a fallowing period, between sixty and ninety days, was imposed for the entire Bay in an attempt to eradicate the disease. The industry was also required to remove, clean and disinfect all the associated net-pens, barges and equipment at all the farms. The January 2002 order followed the voluntary removal by the aquaculture industry of nearly one million ISA-infected or exposed fish. In March 2002, ISA was also detected in an aquaculture facility in Passamaquoddy Bay. In response, the DMR issued an eradication order for the approximately 140,000 fish at the site.

In response to the ISA outbreak in Cobscook Bay, Maine DMR implemented new fish health regulations. The new DMR rules include mandatory surveillance and reporting of all test results for ISAV in salmon culture facilities. Sites with confirmed presence of ISAV are automatically subject to a remedial action plan developed by the DMR. Under the new regulations, the movement of vessels and equipment is also restricted. Prior to the rule changes, surveillance was not mandatory and reporting was only required when a case of the disease was confirmed.

The new rules require monthly sampling for all active finfish facilities in Cobscook Bay and quarterly testing for aquaculture facilities elsewhere in Maine. Reporting of results is mandatory and reports are provided to DMR. The DMR can require monthly testing for finfish facilities outside of Cobscook Bay if a positive case of ISAV is detected. The new rules expand DMR's authority to take action at not only infected facilities, but also those exposed to ISAV. The rules require DMR to consult with all relevant state and federal entities with expertise in ISA control to keep ISA from spreading and prevent further outbreaks.

In response to the ISA outbreaks, the USDA/APHIS also implemented an ISA control and indemnity program for farm-raised salmon in the U.S.. The funds provided by the USDA were used to help the State of Maine with epidemiology, surveillance and to indemnify the industry for their losses due to ISA. Under the DMR rule, all salmon growers in Maine must participate in the program. The goal of this program is to control and contain the disease through rapid detection and depopulation of salmon that have been infected with or exposed to the ISA virus.

In Spring 2002, Maine DMR authorized the restocking of Cobscook Bay. The Bay had laid fallow since January 2002. This authorization followed USDA approval of the cleaning and disinfection of equipment and the fallowing period. Subsequent to approval, the aquaculture industry stocked 1.9 million smolts on seven farms in Cobscook Bay. The number of smolts stocked was 30% lower than the amount historically stocked in this area (DMR 2002). New husbandry standards have also been put in place as part of the ISA control program. These new standards will be administered by DMR.

The ISA control program divides Cobscook Bay into two management areas, a southern and a northern zone. The southern zone will be stocked in even years beginning in Spring 2002. The northern zone will be stocked only in odd years, beginning in Spring 2003. DMR estimates that by 2003 there will be approximately 25% fewer fish in Cobscook Bay compared to recent levels. In addition to these management zones, several conditions will be required for each lot of smolts that are introduced into net-pens from freshwater hatcheries. All aquaculture facilities in Cobscook Bay will only be permitted to raise a single-year class of fish. A minimum thirty-day fallowing period between production cycles is required. No more than 10% of the fish at a site may be carried over between production cycles and then only upon approval by DMR. This approval will require that no ISA was detected at the site during the production cycle, that general fish health is satisfactory, that fish are removed by September 1, and that there be a biweekly surveillance of the site by a fish health professional. Movement of fish between farms in the same zone will require a permit and verification that ISAV has not been detected at either site in the four weeks prior to movement. There will be no moving of fish between zones. In addition, farms, aquaculture vessels and processing plants will be subject to routine third-party biosecurity audits. The introduction of these standards and the coordination of DMR with USDA should allow for better detection and control of ISA. In June 2003, additional cases of ISAV, were detected at aquaculture sites in Cobscook Bay.

The DMR's bay management program is being developed following an evaluation of other bay management and ISA control programs in Canada, Ireland, Scotland and Norway. These nations have developed control programs intended to prevent further outbreaks of the disease. The DMR plans to codify bay management husbandry standards in a rule and establish other bay management areas where finfish leases are located. Successful sea lice management and control is a necessary component of bay area management as sea lice have been shown to retain the ISA virus after feeding on infected salmon (Nylund *et al.* 1993).

2. Salmon Swimbladder Sarcoma (SSS)

Salmon swimbladder sarcoma virus (SSSV) is a pathogen recently reported in North America. A similar (perhaps identical) virus was first reported from sub-adult farmed Atlantic salmon in Scotland in the 1970s (Duncan 1978; McKnight 1978). The disease has not been reported from Scotland since and the relationship between this and the Maine retrovirus has not been determined.

The level of threat posed by SSSV is more difficult to assess than ISAV. In 1996, this retrovirus was detected in sub-adult salmon collected as parr from the Pleasant River for river-specific broodstock development. These fish were being held at the North Attleboro National Fish Hatchery (NANFH) in Massachusetts. Mortalities were first observed in 1997 and continued to occur in 1998. Necropsies revealed massive tumors in the swimbladder. The detection of the virus and the outbreak of disease resulted in a decision to destroy all captive broodstock for the Pleasant River. Pleasant River fish being held at a private hatchery in Deblois, Maine were also found to be positive for the virus, although no disease was present and no mortality occurred. As a precaution, all these fish were destroyed. The destruction of these broodstock have significantly affected efforts to develop river-specific broodstock for the Pleasant River.

No disease symptoms have ever been observed in wild populations or in the captive populations held in Maine. No fish at CBNFH have ever demonstrated symptoms of the disease in the seven years wild stocks have been held at that hatchery.

It is not known if SSSV contributes to salmon mortality in natural conditions either directly through disease, indirectly through debilitation of immune system and resultant decrease in fitness and survival or if it has no substantial impact on survival in the wild. Assays done on Atlantic salmon adults and smolts from other Downeast DPS rivers revealed positive results in a small number of fish from the Machias, East Machias and Narraguagus rivers, although there were no signs of disease. These results indicate that the virus may be widespread at a low level in the environment.

D. PREDATION AND COMPETITION

Predation would not be expected to threaten the continued existence of a healthy population. The threat of predation on endangered salmon is significant because of the very low numbers of adults returning to spawn and the increased population levels of some predators. Known predators of Atlantic salmon include marine mammals (e.g., seals, porpoises, dolphins), terrestrial mammals (e.g., otters, minks), birds, fish and sharks. Predation is a naturally occurring factor affecting salmon populations. Anthony (1994), the Atlantic Salmon Status Review (NMFS and FWS 1999) and Baum (1997) review the significant predators of Atlantic salmon and identify the various life stages of salmon they prey upon.

Estimating predation rates is difficult because of the wide spatial and temporal distribution of Atlantic salmon at low densities and the large number and variety of potential predators. The final rule listing the DPS as endangered concludes that there are insufficient data at this time to show that predation threatens the continued existence of the DPS (65 FR 69459). Nonetheless, the threat from predation is significant because of low numbers of adult salmon.

In addition to predation, the potential exists for interspecific competition between salmon and other species of fish including non-native species. Interspecific competition may result in adverse impacts to the DPS. Adverse effects of competition are exacerbated by the small size of the Atlantic salmon population. The introduction of non-native fish can endanger or threaten the continued existence of native species of fish (Lassuy 1999). For example, long-term stocking of non-native rainbow trout into streams in the Western U.S. has resulted in the widespread extinction of native trout populations through introgressive hybridization (Behnke and Zarn 1976; Leary *et al.* 1995). Introduced brown trout have replaced subspecies of cutthroat trout in large streams throughout the same region (Behnke 1992).

1. Marine Mammals

Since the passage of the Marine Mammal Protection Act (MMPA) in 1972, seal populations have increased in Maine. Five species of seals are found in the Gulf of Maine region: the harbor seal (*Phoca vitulina*), gray seal (*Halichoeurs grypus*), hooded seal (*Cystophora cristata*), harp seal (*Phoca groenlandica*) and ringed seal (*Phoca hispida*). Harbor seals and gray seals are the only seal species that have a year-round presence in Maine. Harp and hooded seal sightings and strandings have increased in recent years in New England (NMFS 1996). The apparent increase in the number of harp and hooded seals is largely based on strandings and fishery bycatch data. These species are ice seals and usually occur in Maine from January to May. No systematic surveys document population trends of these two species in U.S. waters. Sightings of ringed seals are too few to infer anything regarding population increases in U.S. waters (Gordon Waring, NOAA Fisheries, personal communication).

The growth of seal populations in Maine has led to speculation that declining salmon populations can be attributed, in part, to seal predation. Populations of both harbor and gray seals have grown since the early 1980s. Harbor seal populations along the coast of Maine have increased from 10,540 in 1981 to 30,990 in 1997; an average annual increase of 4.2%. Similarly, the number of pups along the Maine coast has increased at an annual rate of 12.9% over the 1981-1997 period (Gilbert and Guldager 1998). Gray seal abundance is also increasing in the U.S. but the rate of increase is unknown (Waring *et al.* 2000). In 1996, the estimated gray seal population in eastern Canada was 143,000 (Mohn and Bowen 1996). Gray seal populations in eastern Canada have experienced a 7.4% annual growth in the Gulf of St. Lawrence and a 12.6% increase at Sable Island (Hammill *et al.* 1998). Gray seal numbers in Maine increased from an estimated thirty animals in the early 1980s to between 500-1,000 animals in 1993 (Waring *et al.* 2001).

Seals are opportunistic feeders and will target both benthic and schooling pelagic fish species. Harbor seal prey include herring, alewife, capelin, clam, sand lance, cod, haddock, pollock, hake, ocean pout, flounder, squid and mackerel (Boulva and McLaren 1979; Katona *et al.* 1993; Williams 1999). Gray seals feed primarily on squid, herring, hake and cod (Mansfield 1988;

Katona *et al.* 1993; USASAC 2000). Seal predation on salmonids has been documented in Europe and in the Pacific Northwest. Rae (1960, 1965, 1973) reported that seal predation on salmonids was significant around Scotland. These findings must be considered in light of the fact that these seals were caught in salmon nets. More recent studies employing improved dietary analysis techniques suggest that salmonids are of minor importance (NOAA AFSC 2001-04).

There are only two documented cases of gray seal predation on Atlantic salmon in the Gulf of St. Lawrence (USASAC 2000). There have been no documented instances of Atlantic salmon being found in harbor seal stomachs in U.S. waters in the Western North Atlantic. The U.S. Atlantic Salmon Assessment Committee (USASAC) notes that if one-hundred percent of the Atlantic salmon biomass in the Atlantic Ocean were consumed by harp seals[16], Atlantic salmon would account for only 0.01 % of their annual diet. This illustrates the difficulty in documenting Atlantic salmon predation by seals (USASAC 2000).

Evidence suggests that seal predation is not a function of population size, but rather is a function of habitat and individual rogue animals (NMFS 1996). For instance, Rae (1960, 1965) found that seal attacks on salmon nets in Scotland were not related to population size. Seal attacks at river mouths are likely attributable to a few individuals that have learned how to catch salmon there (James Gilbert, University of Maine, personal communication).

During fish trapping operations in Maine, incidences of scarring and injury on adult Atlantic salmon have been observed. ASC staff records suggest that on the Penobscot River as many as 11% of adults entering the trap at the fishway have apparent seal bites (several hundred fish are examined each year) (MASCP 1997). These injuries could also be due to attempts to ascend the fishway and rocks around the Veazie Dam, as well as, prior to closure by the State in December 1999, catch and release angling (USASAC 2000). Anglers and biologists have reported apparent seal bites on adult Atlantic salmon caught in Washington County rivers during the past twenty years. In 1986, members of the Two Rivers Salmon Club reported that 70% of the salmon caught in the East Machias River had seal bites (Baum 1997). In Scotland, approximately 20% of returning salmon displayed predator damage (Thompson and Mackay 1999). The majority of the observed injuries were determined to be caused by odontocetes (primarily porpoises), not seals. These findings highlight the difficulty of using observed apparent predator damage in assessing the impact of different predators on salmon populations. Further, it is not possible to quantify the numbers of salmon that did not survive an attack.

It has been suggested that expanding harp seal populations may indirectly impact salmon population abundance in the North Atlantic by their consumption of large amounts of capelin (Anthony 1994). The current available evidence on this impact is inconclusive. Capelin are a major prey item of Atlantic salmon off the coast of West Greenland and on the Canadian shelf (Hislop and Shelton 1993). Reddin and Carscadden (1982) conclude that an important biological

[16] The Northwest Atlantic harp seal population is comprised of approximately 5.2 million animals. These seal populations consume approximately 3+ million tons of fish annually.

link exists between salmon and capelin. Hislop and Shelton (1993) report that capelin comprised 72% of the diets of Atlantic salmon in West Greenland and 73% in Canada. They note, however, that Atlantic salmon, as opportunistic predators, are not very sensitive to interannual variation in the availability of any specific prey item.

In Atlantic Canada, researchers have attempted to model the trophic impacts of seal predation on fish stocks (Stenson *et al.* 1997; Hammill and Stenson 2000). While estimates of consumption rates indicate that seals in Atlantic Canada do consume large quantities of fish, seal predation is only one of many sources of fish mortality. Estimating the relative impact of seal predation on fish stock abundance will not be possible until other sources of natural mortality are quantified (Hammill and Stenson 2000). In order to fully assess the significance of this possible competition, a complete analysis of the food web in the Gulf of Maine and the Atlantic would be required. While multispecies predation models offer great potential to assess the impacts of predation, the data requirements make the use of such an approach unlikely in the near future (Hammill and Stenson 2000).

2. Avian Predators

A number of bird species are known to prey on juvenile Atlantic salmon including the double-crested cormorant, mergansers, belted kingfisher, great black-backed gulls, gannets and owls. Among these, cormorants are often cited as a major predator contributing to declining salmon populations, although mergansers are also known to be significant predators. Avian predators of adult salmon include ospreys and eagles (NMFS 2000).

i. Double-crested Cormorant

Cormorants were extirpated from New England by the early European settlers (Baum 1997) and did not begin to recolonize areas along the Maine coast until the 1920s (Krohn *et al.* 1995). In 1972, cormorants became a protected species under the Migratory Bird Treaty Act (MBTA). The MBTA regulates killing of protected birds and destruction of their nests and eggs. Cormorant populations increased rapidly through the mid-1980s (Krohn *et al.*1995). By the early 1990s, population growth had stabilized and there were an estimated 28,000 breeding pairs in 135 colonies in Maine (Krohn *et al.* 1994). In 1995, an aerial survey conducted by IFW biologists as part of an FWS funded colonial waterbird inventory recorded approximately 20,000 cormorant nests in 125 colonies in Maine.

Several recent papers provide summaries of double-crested cormorant predation and its potential impact on Atlantic salmon populations in Maine (Blackwell and Krohn 1997; Blackwell *et al.* 1997; see also Baum 1997). Cormorants are highly opportunistic and voracious feeders that typically feed on mid-water schooling fish (Duffy 1995; Blackwell *et al.* 1997; Derby and Lovvorn 1997). They consume between 16-30% of their body weight of fish per day (Anthony 1994). In addition to Atlantic salmon, cormorants are known to feed on at least forty other species of fish (Baum 1997).

Much of the published research reveals that cormorant predation on salmon is limited both temporally and spatially (Anthony 1994). Krohn *et al.* (1995) found that cormorant predation can reduce fish populations in localized feeding areas, including dams where migrating Atlantic salmon smolts can be congregated (Blackwell and Krohn 1997). Cormorants can consume large numbers of emigrating hatchery-reared salmon smolts during spring migration (Meister and Gramlich 1967; Kennedy and Greer 1988). The presence of manmade obstructions to passage, such as dams, weirs and fish traps, may exacerbate predation rates.

Cormorant predation is reported to be generally higher on hatchery-reared than wild smolts (Anthony 1994; Baum 1997; NMFS 2000). There is little evidence, despite thirty years of study and the sampling of thousands of cormorant stomachs, of cormorant predation on wild Atlantic salmon smolts (Baum 1997). A number of factors may account for this observation, including method and timing of hatchery-reared smolt release, conspicuous external tags (i.e, carlin tags) on the backs of hatchery fish and behavioral differences between hatchery and wild smolts (i.e., predator avoidance behavior). Factors that likely serve to minimize cormorant predation on wild salmon smolts include predator avoidance behavior, the fact that smolts migrate primarily at night while cormorants forage primarily during the day and run timing (Baum 1997).

Studies of cormorant predation conducted by the Atlantic Sea Run Salmon Commission (ASRSC; predecessor agency to ASC) and FWS (1972 to1982; 1986 to 1988) in the Penobscot River found predation rates of between 1-2% for hatchery smolts (Baum 1997). Meister and Gramlich (1967) studied salmon predation by cormorants in the Machias River estuary. The results of this study documented that cormorants consumed an estimated 8,000 tagged hatchery smolts during the period 1966-1967 in the Machias River. This study suggests that cormorants can be significant predators of Atlantic salmon and may adversely affect the abundance of hatchery-reared salmon smolt in a river. Predation rates on migrating hatchery-reared salmon smolts were found to be as high as 13.4% in the Machias River in the mid-1960s (Meister and Gramlich 1967). More recently, Blackwell (1996) documented cormorant predation rates of up to 7% for hatchery-reared smolts in the Penobscot River. Much of the predation was observed in the headwater ponds of several hydropower dams (Blackwell 1996).

ii. Mergansers

Common and red-breasted mergansers are known to prey on juvenile Atlantic salmon. The common merganser preys on salmon parr in streams throughout the summer while the red-breasted merganser is a marine species that feeds more heavily on migrating smolts primarily in the spring (Anthony 1994).

Studies in Canada found mergansers consumed more juvenile Atlantic salmon than did cormorants. White (1957) found that salmon parr were consistently the major food item of mergansers in the ten rivers in New Brunswick and the six rivers in Nova Scotia he studied. Elson (1975) concludes that smolt production was higher in the Maramichi River in Canada when mergansers were scarce. The DFO (1998) concludes that mergansers likely take substantial numbers of juvenile salmon in some maritime rivers (DFO 1998). The report notes that repeated experiments have failed to show that bird control increases juvenile salmon abundance (DFO 1998).

Mergansers, like cormorants, are protected under the Migratory Bird Treaty Act (16 USC Sec. 590q-1). Current state regulations permit hunting of this species. Hunters are permitted to shoot up to five mergansers per day (MIFW 2003).

3. Piscine Predators and Competitors

i. Freshwater

Juvenile salmon are preyed on by a number of fish species. These include both native and non-native fish species. Native species include brook trout (*Salvelinus fontinalis*), American eel (*Anguilla rostrata*), chain pickerel (*Esox niger*) and landlocked salmon (*Salmo salar sebago*). Non-native species include smallmouth bass (*Micropterus dolomieui*), largemouth bass (*Micropterus salmoides*), brown trout (*Salmo trutta*), splake (hybrid cross of brook and lake trout), and rainbow trout (*Oncorhynchus mykiss*)(Godfrey 1957; Warner 1972; Larsson 1985; Anthony 1994).

The introduction of non-native species of fish may adversely affect native species through predation, competition for food and available habitat, interbreeding and hybridization and the introduction of disease and parasites (Kohler and Courtenay 1986; ANS Task Force 1994; Lassuy 1999). Interactions between Atlantic salmon and non-salmonids, especially introduced species, are poorly understood. Most research on competition has focused on interactions between species of salmonids (Hearn 1987; Fausch 1988). Competitive interactions are often more harmful when they are between native and non-native species that have not co-evolved (Hearn 1987; Fausch 1988).

Interspecific competition between Atlantic salmon and other salmonid species are dependent on a number of factors including the availability of food and habitat. Ecological interactions between salmonids can lead to increased mortality and decreased growth (Fausch and White 1986). Survival rates from eggs to the fry stage are affected by a number of factors (i.e., stream gradient, overwintering temperatures, water flows) including the level of predation and competition (Bley and Moring 1988). The growth rate of parr has been shown to be influenced by the level of competition and predation (Hearn 1987).

The Maine IFW stocks a number of native and non-native salmonids into rivers, lakes and ponds within DPS river watersheds. In addition, many non-native species of fish have been introduced illegally in DPS river watersheds by individuals that wish to fish for these species.

Chain pickerel (*Esox niger*) is native to the State of Maine. It was introduced into the Penobscot River watershed in 1819 and rapidly dispersed throughout the State including into DPS rivers (Baum 1997). Predation by pickerel on migrating Atlantic salmon smolts can be significant, particularly in lakes, ponds and other impoundments (Barr 1962; Warner 1972; Van den Ende 1993; Baum 1997). Barr (1962) found that 21% of the pickerel sampled in Beddington Lake on the Narraguagus River contained salmon smolts. Van den Ende (1993) found that Atlantic salmon are the most common prey item of chain pickerel in the Penobscot River. Nearly one-third of twenty-three pickerel captured in this study were found to contain Atlantic salmon.

Smallmouth bass (*Micropterus dolomieui*) are known to prey on juvenile Atlantic salmon (Baum 1997). This species, first introduced into Maine waters in the 1860s, now occurs in all the DPS rivers with remnant populations of wild Atlantic salmon (MASCP 1997; Baum 1997). While smallmouth bass have been present in some DPS rivers for a number of decades (i.e., the Narraguagus and Machias), it has been introduced relatively recently to the Pleasant River. In the mid-1970s, this species was illegally introduced into Pleasant River Lake, a headwater lake of the Pleasant River. By 1995, smallmouth bass were found in the lower reaches of the river all the way to Columbia Falls at the head-of-tide (Scott 2002). The continued expansion and possible interactions between smallmouth bass and Atlantic salmon should be closely monitored.

Van den Ende (1993) studied predation of Atlantic salmon smolts by smallmouth bass in the Penobscot River. Field investigations of the food habits of this species found that insects, fishes (golden shiners, white sucker, creek chub, brook trout) and crawfish were the most important prey items of smallmouth bass (Van den Ende 1993). No Atlantic salmon smolts were found in any of the 127 smallmouth bass sampled (Van den Ende 1993). Van den Ende (1993) found that smallmouth bass were inactive and did not feed at 5°C, responded to prey at 10°C and fed most actively at 15°C. By the time temperatures reach these levels, most salmon smolts have already migrated out of the river. Van den Ende concluded that smallmouth bass were probably not a major predator on Atlantic salmon smolts in the Penobscot River. This is due to a number of factors including: low feeding rates during the beginning of the smolt run, morphological constraints (small mouth), differential habitat use by each species (smolts generally utilize areas of high current velocity; smallmouth bass prefer current edges and other low velocity areas), anti-predator behavior of smolts and observed selection of small prey rather than large prey by smallmouth bass. It is more likely that smallmouth bass prey on salmon fry and parr, which are found in similar habitats as bass (Baum 1997). ASC electrofishing data from juvenile salmon rearing areas in DPS rivers indicate that smallmouth bass commonly occur in these areas at sizes capable of consuming juvenile Atlantic salmon (Ken Beland, ASC, personal communication).

Largemouth bass (*Micropterus salmoides*) are present in the Sheepscot, Ducktrap and East Machias rivers and Cove Brook. This species was introduced into Maine sometime during the early 1900s although the exact date of introduction is not known. Largemouth bass are known to prey on salmon (Warner 1972, Anthony 1994). The potential level of predation on Atlantic salmon is currently unknown. There is currently no viable way to control these populations.

Brown trout (*Salmo trutta*) are not indigenous to the waters of Maine. The first stocking of this species in Maine occurred in 1885 at Branch Lake, Ellsworth (Maine IFW 2001). Brown trout predation has been implicated in the decline of native salmonid populations in North America (Moyle 1976; Sharpe 1962; Alexander 1977; 1979; Taylor *et al.* 1984). Brown trout are known to eat large numbers of stocked Atlantic salmon fry (Maine ASC and Maine IFW 2002). Brown trout have been stocked into a number of headwater lakes within DPS river watersheds in Washington County including the East Machias and Machias watersheds (MASCP 1997). The Sheepscot River is the only salmon river within the DPS where brown trout have been captured during stream assessments (MASCP 1997)[17]. Stocked brown trout in the Sheepscot River have established a self-sustaining population. Although the potential exists for brown trout to prey on juvenile Atlantic salmon in the Sheepscot River, most brown trout reside in the headwater section below Sheepscot Lake where few Atlantic salmon spawn (LWRC 1997).

Brown trout are capable of hybridizing with other salmonids (Brown 1966; Schwartz 1972, 1981; Dangel *et al.* 1973; Chevassus 1979; Taylor *et al.* 1984; Beall *et al.* 1997). Studies in Sweden (Nilsson 1965), Scotland (Hearn 1987), and Canada (Beall *et al.* 1997) have documented brown trout/Atlantic salmon hybrids. One study that examined the incidence of hybrids in salmonid populations in Northern Spain and Southwestern France determined that significant proportions of salmonid populations were locally affected by hybridization. Hybridization was found to occur in the absence of conspecific males and due to the modification of spawning behavior by females (Beall *et al.* 1997) Hybridization has also been witnessed in the Connecticut River where salmon fry were stocked into a headwater tributary, where no adult salmon were present. The stream had a self-sustaining population of brown trout and enzyme electrophoresis later demonstrated the presence of one hybrid. Given that the maternal species was identified as a brown trout, it was concluded that the male parent had to have been a mature male Atlantic salmon parr (Gephard *et al.* 2000). Evidence also suggests that the number of hybrids increases with increasing population densities (Maine ASC and Maine IFW 2002).

Brown trout and Atlantic salmon demonstrate similar spawning site preferences and spawn at about the same time in the fall. Evidence also suggests that brown trout females may prefer to spawn on existing redd sites. This creates the potential for superimposition of redds in spawning areas (Maine ASC and Maine IFW 2002). Interspecific competition between brown trout and Atlantic salmon also has the potential to negatively affect Atlantic salmon. Habitat use by Atlantic salmon has been found to be restricted through interspecific competition with brown trout that are more aggressive (Heggenes et al. 1999; Kennedy *et al.* 1986; Hearn 1987; Fausch 1998). Furthermore, Harwood et al. determined that competition is not limited to the summer months, instead competition for food and resources observed during overwintering indicates potential affects on both the long-term and short term growth of wild Atlantic salmon (Harwood *et al.* 2001). Also, at lower water temperatures, Atlantic salmon fry may compete less effectively than brown trout. However in Europe, Brown trout and Atlantic salmon are sympatric and habitat segregation allows them to remain genetically isolated (Hethagen 1988; Hearn 1987). The extent of predation and competition between brown trout and Atlantic salmon has not been well documented in salmon rivers within the range of DPS.

---

[17] The Maine IFW raises brown trout at the Palermo hatchery on the Sheepscot River for stocking purposes. Brown trout escaping from this hatchery contribute to resident populations of brown trout already established in the Sheepscot river.

Splake (*Salvelinus namaycush* x *Salvelinus fontinalis*) is another potential predator and competitor of Atlantic salmon found in DPS rivers. In 1995, IFW stocked splake in seven lakes within the Sheepscot, Narraguagus, Pleasant and Machias river watersheds. In 2001, splake were stocked into Mopang Stream, Second Old Stream, Beddington Lake, Keeley Lake, Burntland Lake, Pleasant River, Sheepscot River and Peaked Mountain Pond. Splake stocking has been successful only where an adequate volume of cool water (12-16°C) is available.

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

Splake are non-reproductive in Maine waters. Therefore, future adverse interactions between splake and Atlantic salmon may be mitigated by termination of splake stocking. To date, neither splake reproduction nor naturally produced juveniles have been observed. Observations during the fall spawning period are ongoing and will continue. Little information is currently available to assess the level and significance of splake predation upon Atlantic salmon.

Rainbow trout (*Oncorhynchus mykiss*) is native to the Western United States. Rainbow trout have been introduced into Maine through stocking for recreational fishing and for use in aquaculture operations. In terms of genetics, habitat, size, growth and life cycle, rainbow trout is the most similar species to the sea-run Atlantic salmon (Bley and Mooring 1988).

Rainbow trout can be a significant competitor with Atlantic salmon. The potential for interactions between the two species exists as Atlantic salmon and rainbow trout exploit similar resources. Early life stages of the Atlantic salmon and rainbow trout are remarkably similar in habitat preferences, behavior and feeding (Bley and Mooring 1988). In areas where Atlantic salmon and rainbow trout co-occur, significant niche overlap is expected. Under limiting circumstances, vigorous competition for resources is likely (Volpe *et al.* 2001). Interactions between Atlantic salmon and rainbow trout are most likely to occur during the juvenile life stages of these species (Gibson 1981). Interspecific competition during juvenile stages may be an important factor affecting growth and survival of Atlantic salmon (Fausch 1998). The potential also exists for Atlantic salmon redds to be superimposed by spring-spawning rainbow trout (Volpe *et al.* 2001).

Experiments done by Hearn and Kynard (1998) demonstrate that rainbow trout are better adapted to pools and habitats with low current velocities. In such habitats, rainbow trout are more aggressive and out-compete Atlantic salmon parr. These interspecific interactions may cause reductions in salmon populations. In a study done by Volpe *et al* (2001), rainbow trout performance was superior to Atlantic salmon. Should rainbow trout colonize freshwater habitats within DPS rivers through either intentional introduction or escapement from aquaculture facilities it could have adverse affects on wild salmon populations. Numerous reports (Bley and Moring 1988; Gibson 1981; Hearn and Kynard 1986; Volpe. *et al.* 2001) state that the potential exists for interspecific competition between the two species to have negative consequences for native Atlantic salmon. Currently rainbow trout are raised for aquaculture purposes at one site in Sheepscot Bay on the east side of Birch point.

The Maine IFW does not currently stock rainbow trout in salmon rivers within the DPS. Private landowners with farm ponds may obtain rainbow trout or brook trout through the United States Department of Agriculture (USDA). The State requires a stocking permit for private ponds. On the basis of an informal intra-agency agreement between the ASC and IFW, IFW biologists deny permits for rainbow trout in DPS rivers, except in private ponds with no outlet streams (Ken Beland, ASC, personal communication).

Brook trout (*Salvelinus fontinalis*) are indigenous to all Atlantic salmon rivers and have coevolved with Atlantic salmon. Brook trout are not thought to be a significant predator on Atlantic salmon because most trout do not attain the size where piscivorous foraging greatly increases (> 10 inches) (MASCP 1997). Once salmon eggs are deposited by the female, both brook trout and Atlantic salmon parr may feed on them (White 1939). Recent studies have documented brook trout feeding on large numbers of stocked Atlantic salmon fry (Maine ASC and Maine IFW 2002).

Competition is most intense between juveniles of these species. While juvenile Atlantic salmon and brook trout are often found in the same stream, salmon are found predominately in riffles and trout in pools (Gibson 1973; Gibson 1981). This habitat partitioning (use of different habitat) during most of the growing season limits the opportunity for interaction between brook trout and juvenile salmon. Brook trout will out-compete Atlantic salmon in deep pools while Atlantic salmon will out-compete brook trout in riffles and flats (Gibson 1973; Gibson 1981). When Atlantic salmon fry do co-occur with brook trout fry, the growth of salmon is suppressed (Maine ASC and Maine IFW 2002).

Landlocked salmon (*Salmo salar sebago*) are present in lakes within the Sheepscot, Narraguagus, Pleasant, Machias, East Machias and Dennys river watersheds. Predation on juvenile salmon by adult landlocked salmon may occur either during periods of cool water temperatures before landlocked salmon move to nearby lakes or during periods of high flows when larger landlocked salmon might temporarily reside near nursery habitat (MASCP 1997). It is believed that the extent of predation of wild Atlantic salmon by landlocked salmon is relatively minor (MASCP 1997). Because sea-run and landlocked Atlantic salmon are the same species, direct competition for food and space is inevitable when the fish are in the same area (Maine ASC and Maine IFW 2002). The Meddybemps lake outlet on the Dennys River is an area where competition between landlocked and sea-run Atlantic salmon could occur (Maine ASC and Maine IFW 2002). The Meddybemps Lake population of landlocked Atlantic salmon is stocked and natural spawning of landlocked salmon is known to occur. The success of this reproduction is not known but may result in hybridization, redd superimposition and ecological competition between juvenile life-stages.

American eel (*Anguilla rostrata*) is commonly found in rivers within the range of the DPS. Eels are known to prey upon many fish species (Sinha and Jones 1967; Daniels 1999). The potential exists for predation on fry, parr and smolts as juvenile Atlantic salmon habitat overlaps with eel habitat (Ken Beland, ASC, personal communication). There has been little directed research on predation of Atlantic salmon by eels. Baum (1997) and Godfrey (1957) report some eel predation on Atlantic salmon fry and parr. The remains of 429 salmon fry were once documented in one eel (Baum 1997). Sinha and Jones (1967) report unidentified salmonids in many eel stomachs. Larger eels are active piscivores, with eel foraging activity greatest in spring and early summer (Merry Gallagher, IFW, personal communication). During late summer sampling of juvenile salmon rearing habitats, ASC staff commonly encounter eels 20-70 cm in length, occasionally in abundance (Ken Beland, ASC, personal communication). Eels are not thought to pose a threat to adult salmon.

ii. Estuarine and marine

Smoltification occurs in the spring when juvenile salmon move downstream to the ocean. 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 including striped bass, cod, American pollock and whiting (Bley 1987; Carlin 1954; Bigelow and Schroeder 1953; Thurow 1966; Rae 1966 and 1967; 1973; Hvidsten and Mokkelgjerd 1987; Hvidsten and Lund 1988; Barrett *et al.* 1990; Greenstreet *et al.* 1993, Massachusetts Cooperative Fish and Wildlife Research Unit, unpublished data).

Atlantic salmon grow rapidly while in the ocean and increasing size reduces vulnerability to predators. Little is known about the predator-prey interactions involving salmon and piscine predators in the ocean, as documented below.

Striped bass (*Morone saxatilis*) has been cited as a potentially significant predator of Atlantic salmon (MASCP 1997; Baum 1997; Beland *et al.* 2001). In a study on the Merrimack River, striped bass were found to prey on Atlantic salmon just below the Essex Dam. In 1997, stomach content analysis of 41 striped bass revealed 32 documented and 28 suspected salmon smolts. Only 16 of the 389 striped bass stomachs analyzed in 1998 contained salmon smolts. The difference between the two years may be explained by the timing and availability of river herring as an alternative prey species (USASAC 1999). Striped bass seem to be arriving in New England waters earlier in the spring and more fish may even be overwintering in New England (USASAC 1999).

In Maine, striped bass populations have increased over the last ten years, extending their range into Downeast river estuaries. There is evidence that striped bass are now spawning in the Kennebec River and it is possible that spawning could expand to other northern river systems (USASAC 1999). The timing of the smolt migration (April-May) and the arrival of striped bass in Maine waters (May-June) may serve to minimize the potential for predator-prey interactions between these two species. Striped bass abundance in eastern Maine rivers is highly variable between years (Beland *et al.* 2001).

Gadoid fishes such as cod and pollock are known to feed on post-smolts (Rae 1966, 1967; Hvidsten and Mokkelgjerd 1987; Hvidsten and Lund 1988). Research on the food habits of thousands of cod in Newfoundland indicates that salmon is not a common prey item (DFO 1998).

Benthic feeders, including shark, skate and ling prey on Atlantic salmon (Hislop and Shelton 1993). Wheeler and Gardner (1974) report that sharks are the most significant predator of adult Atlantic salmon in the marine environment.

E. INADEQUACY OF EXISTING REGULATORY MECHANISMS

A variety of state and federal statutes and regulations seek to address threats to Atlantic salmon and their habitat. These laws are complemented by international actions under NASCO, many interagency agreements and state-federal cooperative efforts. Existing regulatory mechanisms either lack the capacity or have not been implemented adequately to decrease or remove all threats to wild Atlantic salmon.

The final rule listing the DPS identified two important concerns about existing regulations relating to salmon: 1) either they were inadequate or 2) were not being effectively implemented. Although there are still areas of concern, progress has been made (65 FR 69459). Maine has closed all angling for Atlantic salmon, including catch and release. The State has developed a water use management plan for the Pleasant, Narraguagus rivers and Mopang Stream (a tributary of the Machias River).

Regarding aquaculture, comprehensive solutions to minimize the threat of interaction between wild and aquaculture salmon have not yet been fully implemented. The Services have worked extensively with the aquaculture industry, the State of Maine and the Army Corps of Engineers (ACOE) to eliminate the use of pure European strain and North American/European hybrids in marine cages. On June 19, 2003, the Maine DEP issued a general permit for salmon aquaculture under its delegated CWA authority. The DEP general permit includes conditions that will eliminate the use of non-North American strains of Atlantic salmon, improve containment measures, and require marking of salmon placed in net pens so that escapes, if they occur, can be traced. Similarly, the ACOE is proposing permit conditions that would eliminate European strain fish in sea cages, require marking, and would improve containment measures. On November 21, 2003, NOAA Fisheries completed Section 7 consultation with the ACOE on the proposed permit modifications. The ACOE is currently in the process of issuing revised permits with the new conditions. Although importation of European milt is still allowed under state law, the progeny created from this milt could not be stocked in Maine waters under the existing state general permit and the proposed ACOE permit conditions.

The lack of regulatory measures to address and prevent escapes from aquaculture hatcheries has also been a concern. Two commercial hatcheries are located on DPS rivers (Heritage Salmon hatcheries in East Machias, Maine at Gardner Lake and in Deblois, Maine), and cases of chronic and large escapements from freshwater hatcheries in Maine have been documented. Recent improvements (e.g., installation of drum filter and screens) have been made at both of these hatcheries to help minimize escapement. Moreover, the industry has developed a hatchery management system that includes a Hazard Analysis Critical Control Point (HAACP)-based plan for each hatchery that follows the hatchery production cycle from arrival of eggs to smolt transport. The effectiveness of HAACP plans, filters, and screens in eliminating escapes from the two hatcheries has not yet been fully analyzed. Escapes of juvenile salmon from commercial hatcheries could still occur from catastrophic events (e.g., floods, icing of the water intake, and power outages). Escapement of juvenile aquaculture salmon from hatcheries into DPS river watersheds could negatively contribute to the status of the DPS, although with recent hatchery improvements, escape events are much less likely to occur.

Ocean harvest is still occurring off West Greenland and St. Pierre et Miquelon, though it is much reduced. One concern related to that harvest is the increased percentage of North American origin fish that comprise it.

F. OTHER NATURAL AND ANTHROPOGENIC FACTORS AFFECTING THE SPECIES' CONTINUED EXISTENCE

1. Salmon Aquaculture

The salmon aquaculture industry has grown rapidly in the last two decades in Maine. The Maine Atlantic salmon aquaculture industry is currently composed of twelve companies at 43 sites with over 750 cages that cover approximately 800 leased acres of water. Farms are concentrated in Cobscook Bay near Eastport, Maine but are located as far south as the Sheepscot River, although that site currently does not grow Atlantic salmon. Annual Atlantic salmon aquaculture production in Maine increased from an estimated 20 mt in 1984 to more than 16,400 mt. (>36 million pounds) in 2000 (Honey *et al.* 1993; Baum 2001). Since 2000, annual production of Atlantic salmon in Maine has decreased 28% to 26 million pounds in 2001 (Sebastian Belle, Maine Aquaculture Association, personal communication). In 2002, the industry produced 15 million pounds. In Maine, pen-rearing of salmon to harvestable size requires 18 months, yielding an average standing crop of about ten million salmon in two-year classes. Most salmon are harvested from October through March, although some salmon are harvested throughout the year. The aquaculture industry in Canada is approximately twice the size of the Maine industry.

Until recently five commercial freshwater hatcheries in the U.S. produced up to three million Atlantic salmon smolts for aquaculture net-pens annually. As mentioned above, two of these hatcheries (Gardner Lake and Deblois) are on DPS rivers. The Gardner Lake hatchery is on Chase Mill Stream, a tributary of the East Machias River, and the Deblois Hatchery (a state owned facility leased and operated by Heritage Salmon) is located on Beaver brook, a tributary to the Pleasant River. The Gardner Lake hatchery produces one million smolts annually and the Deblois hatchery produced 500,000 smolts annually until its closure in summer 2002.

Atlantic salmon broodstock lines used in aquaculture production include fish from the Penobscot River and the St. John River of North American origin and an industry strain from Scotland. The

North American lines used in production have been used since the mid-1980s. The Scottish strain was imported into the U.S. in the early 1990s and is composed primarily of Norwegian strains, often referred to as "Landcatch." In 1991, the State of Maine (PL 1991 c381 sub section 2) prohibited the importation of non-North American fish and eggs but failed to restrict the importation of European milt. Some Maine industry companies continued to import salmon milt of European origin. The imported gametes from Europe were crossed with gametes from North America to produce a hybridized strain of Atlantic salmon referred to as the "Maine Strain." Norwegian-origin milt (obtained from Icelandic sources) has been imported as recently as 1999. It is estimated that at least 50% of the production fish (fish destined for market or harvest) in Maine are either pure or hybridized Landcatch strains (Baum 2001). As noted (see page 1-17), a recent ruling issued by the United States District Court, District of Maine prohibits the use of European salmon by Atlantic Salmon of Maine and Stolt Sea Farm Inc. The other major salmon producer in Maine (Heritage Salmon) had previously agreed to not stock any non-North American salmon as part of a consent degree.

Interactions between wild Atlantic salmon and salmon aquaculture

The potential for interactions between wild Atlantic salmon and aquaculture escapees represents a significant threat to the continued existence of endangered salmon in Maine (65 FR 69459; NMFS and FWS 1999). Comprehensive protective solutions to minimize the threat of interactions between wild and aquaculture salmon have not been implemented. The threats posed by existing aquaculture practices and aquaculture escapees and the lack of progress in resolving these concerns were a major consideration in the final listing decision.

Escaped farmed salmon may adversely affect wild salmon through ecological and genetic effects. Escaped aquaculture fish have the potential to disrupt redds of wild salmon and compete with wild salmon for food and/or habitat. Escaped aquaculture salmon may also interbreed with wild salmon, leading to disruption of local adaptations, threatening stock viability and decreasing recruitment, thereby leading to the extinction of wild salmon populations (Fleming *et al.* 2000; Utter *et al.* 1993; Verspoor 1997; Youngson and Verspoor 1998). Escaped aquaculture salmon may also transfer disease and/or parasites to wild salmon (Clifford 1997; Youngson *et al.* 1993; Webb *et al.* 1993; Windsor and Hutchinson 1990; Saunders 1991). Farm-raised Atlantic salmon have been documented in the wild (Bergan *et al.* 1991; Lura and Saegrov 1991; NASCO 1993; Hansen *et al.* 1993; ICES-NASWG 1994; Skaala and Hindar 1997; Stokesbury and Lacroix 1997; USASAC 1999).

Escaped aquaculture salmon pose a significant threat to the Gulf of Maine DPS because even at low numbers they can represent a substantial portion of fish in some rivers. Aquaculture escapees have been detected annually in Maine rivers since 1990. Aquaculture fish have been found in the Dennys, East Machias, Narraguagus, Pennamaquan, Penobscot and St. Croix rivers and Boyden and Hobart streams (Baum 1991; USASAC 1996, 1997). In recent years, escaped aquaculture fish have accounted for 2% to 100% of the total salmon returns to some DPS rivers (NMFS and FWS 1999). The first sexually mature aquaculture salmon escapees were documented in 1996. In the St. Croix River, 5 of 17 escapees (30%) examined in September

1998 exhibited evidence of sexual maturation. In 1999, all three aquaculture escapees captured in the Narraguagus River were sexually mature (USASAC 2000).

It is not possible to assess the full extent of marine aquaculture escapees entering DPS rivers because 1) several DPS rivers have no counting or interception facilities, 2) escapees are not currently marked (aquaculture escapees are currently identified by physical characteristics such as fin deformities and body shape and size and scale samples[18] and 3) existing counting facilities do not operate year-round[19]. An accurate count of U.S. origin escapees is further confounded by the fact that some of the escapees detected in the DPS rivers may have come from nearby Canadian marine cages.

In Maine, escapes of large numbers of aquaculture fish have occurred. In November 2000, approximately 13,000 fish escaped from a net-pen near Eastport, Maine when a vessel, transferring fish from one site to another, accidently hit one of the cages, tearing a hole in the pen. In December 2000, approximately 100,000 aquaculture salmon escaped in Machias Bay when a storm wrecked a steel cage.

Seals are known to attack net-pens where farmed salmon are raised. These attacks may damage net-pens and result in the escape of farmed raised fish (Morris 1996; NMFS 1996). For example, in Canada, it is estimated that minimally 61,600 fish escaped per year due to predator damage in New Brunswick between 1988 and 1998 (Jacobs and Terhune 2000).

In Atlantic Canada, most aquaculture occurs in the lower Bay of Fundy, where there are an estimated sixty aquaculture facilities. These facilities are in close proximity to the DPS. Since the aquaculture industry began in the Canadian Maritimes in 1979, escapees have been documented in fourteen rivers in New Brunswick and Nova Scotia (DFO 1998). Large scale escapes due to cage failure, storm events, anchor system failure, human error and vandalism have been documented in Canada (Fred Whorisky, Atlantic Salmon Federation, personal communication).

Juvenile salmon of commercial hatchery-origin have been documented in DPS rivers in Maine. In 1999, 707 smolts were captured in a smolt trap on the Pleasant River during salmon population assessments. Of the fish collected, 31 had fin deformities and coloration and body form suggesting that they were of commercial hatchery-origin (USASAC 2000). The Deblois Hatchery is located upstream of the sampling site. Scale and tissue samples were collected for DNA analysis. Based on fin deformities, scale pattern analysis and genetic assignment tests, it

---

[18] The use of scale characteristics (i.e., circuli patterns) and body morphology to identify escaped farmed salmon are well established techniques. The use of these techniques to identify aquaculture escapees is more problematic if fish have escaped early in their life cycle from freshwater hatcheries.

[19] Fish weirs are installed in late April to early May, depending on river flow and ice conditions. Weirs are removed in mid- to late November depending on ice conditions.

was determined that approximately 20 to 25% of the 1999 Pleasant River smolt run was of commercial hatchery origin.

Subsequent electrofishing surveys were conducted within Beaver Meadow Brook at the outflow of the Deblois Hatchery. These surveys documented 87 salmon parr near the vicinity of the hatchery outflow. The hatchery is located at the upstream end of Beaver Meadow Brook which does not have salmon habitat. The nearest reach of the Pleasant River is dead water habitat, unsuitable for spawning or rearing of salmon. Consequently, the Maine TAC concluded that hatchery-origin Atlantic salmon were escaping into the Pleasant River drainage from the Deblois Hatchery and that the escaped fish represent a threat to wild Atlantic salmon in the Pleasant River drainage (Maine TAC, 2000). As a result of these findings, Heritage Salmon upgraded the discharge systems for the hatchery. Modifications included adding rotary drum filters to remove solids, a solids collection area and screened outlets from the hatchery. The secondary treatment of hatchery effluent should effectively eliminate escape from the hatchery once completed.

Since 1989, annual population assessments conducted by ASC on Chase Mill Stream have resulted in the capture of suspected aquaculture-origin juvenile salmon in the vicinity of the Gardner Lake hatchery discharge. These fish had deformed fins and were typically larger than wild parr, characteristics associated with aquaculture fish. Until 1999, no attempt was made to assess the origin of these fish. In October 1999, Chase Mill Stream was specifically electrofished in the vicinity of the hatchery outlet and, based on fin condition, twenty-eight suspected aquaculture origin salmon were collected (USASAC 2000).

Ecological Effects

Ecological interactions between farmed and wild salmon can occur through transfer of disease and parasites, competition for food and habitat, disturbance of reproductive habitat (i.e., redd superimposition) and increased predation. Ecological interactions between salmonids can lead to reduced reproductive success, increased mortality and decreased growth (Fausch and White 1986; Webb *et al.* 1991)(see page 1-50).

<u>Disease transfer and Parasites</u>

Wild salmon may be vulnerable to exposure and infection with disease when passing in close proximity to infected aquaculture sites. The potential for disease transfer is a concern as both post-smolts and adult salmon migrate past aquaculture sites (DFO 1998; Crozier 1993; Skaala and Hindar 1997; Carr *et al.* 1997; Lura and Saegrov 1991). While fish pathogens exist in the wild concentrations of individuals magnify the level of any pathogen present and the rate and extent of any resultant epizootic (Finlay and Falkow 1989). The presence of the ISAV in the geographic range of the DPS and the existence of extensive concentrations of net-pens is a significant threat to the DPS.

ISAV

The outbreak of ISAV in Cobscook Bay and the close proximity of high density fish farms to DPS rivers raises concerns about transference of this disease to wild salmon. A significant portion of endangered salmon must swim near U.S. net-pens in Cobscook Bay and Machias Bay, the establishment of ISA in and around U.S. net-pen sites and its presence in nearby Canadian aquaculture sites pose a risk to wild salmon.

ISA poses a threat to both endangered wild and hatchery populations. The potential exists for infected escaped farmed salmon to spread disease to endangered salmon populations. There are no documented instances of this occurring except in Canada, where wild fish held in a weir with aquaculture escapees were found to be positive for ISAV. In this instance it is not clear if the wild fish were positive prior to the confinement with escaped farmed salmon.

Sea Lice

The potential exists for transfer of parasites between aquaculture facilities and wild salmon. The sea louse (*Lepeophtheirus salmonis*) is a small parasitic copepod found only on salmonids. It is one of the more common marine parasites of Atlantic salmon. Sea lice undergo a series of ten life stages, from egg to mobile, feeding adult (Johnson and Albright 1991). Sea lice normally die and fall off salmon within twenty-four hours of entry into freshwater (Baum 1997).

Normally, the generally low numbers of sea lice typically found on wild salmon do not pose a health risk (Nolan *et al*.1999). Sea lice normally do not cause widespread mortality or severe pathological effects in Atlantic salmon (Wooten *et al.* 1982). While the prevalence of sea lice is often high on farmed salmon, the total number on individual fish is generally low (Wooten *et al.* 1982). However, a heavy burden of sea lice can kill an Atlantic salmon. Finstad *et al.* (2000) reports that a sea lice burden of eleven lice per fish is lethal to a juvenile salmon smolt of 15 g or less. In addition, as few as five adult sea lice can cause significant pathological damage to fish (Wooten *et al*. 1982).

Sea lice may also be a vector of disease, including possibly ISA. An experimental study conducted in Norway by Nylund *et al.* (1993) concludes that sea lice on Atlantic salmon can function as a vector transmitting the ISAV. ISAV was shown to be present in the gut of the lice further substantiating this evidence. This study shows that the presence of just four infected sea lice can cause mortality to adult Atlantic salmon and that sea lice may transmit ISAV from one host to another (Nylund *et al.* 1993).

Wild salmon are vulnerable to sea lice infestation originating from aquaculture facilities. In Norway, the level of sea lice infestation on wild fish in some areas where Atlantic salmon farming is concentrated has been found to be ten times greater than in areas where there are no salmon farms (NASCO 1993). Outmigrating salmon may acquire sea lice infestations if they migrate close to infected salmon aquaculture facilities. For adult salmon returning to their natal streams to spawn, the threat is likely lower because when fish enters freshwater sea lice die and fall off within twenty-four hours.

It is difficult to estimate the population effects of sea lice infestations on seaward migrating wild Atlantic post-smolts. In Norway, surveys of emigrating post-smolt salmon found high numbers of sea lice on wild salmon migrating past salmon aquaculture sites. Minimum mortality rates for wild salmon smolts in this study were estimated at 95% (Institute of Marine Research 2001). In 2001, NMFS researchers initiated research to sample outmigrating smolts in Penobscot Bay and the adjacent nearshore marine environment. So far, this research has not detected significant burdens on North American fish. Sampling of salmon taken in the West Greenland fishery has found some fish carrying significant sea lice burdens - fish with fifty or more lice concentrated around the vent of the fish (Russell Brown, NMFS, personal communication). The potential of sea lice to adversely effect the DPS and the role of salmon aquaculture sites as a reservoir for this parasite should be further investigated (see page 4-60).

<u>Competition</u>

Competition for food and habitat has the potential to regulate salmon populations because carrying capacity of streams is limited for various life stages (White 1995). Competition may play an important role in regulating salmon population dynamics shortly after fry emerge from redds, when fry densities are at their highest (Hearn 1987). Because of artificial selection in the hatchery, farmed salmon are expected to be less fit than wild salmon; however, they may have competitive advantages at certain life stages (Gross 1998). McGinnity *et al*. (1997) conducted a study to compare the performance of farmed and wild Atlantic salmon progeny in the Burrishoole River in western Ireland. The experiment found that the progeny of farmed fish grew faster and displaced native fish downstream. In Norway, Fleming *et al*. (1997) found that the progeny of escaped farmed salmon grew faster than the offspring of wild fish. In Ireland, Ferguson *et al*. (1997) found that farmed salmon displaced wild salmon into sub-optimal habitat where feeding rates were lower. Jonsson (1997) reports that the progeny of cultured salmon are generally more aggressive then wild salmon offspring. The results of theses studies suggest that aquaculture escapees and their progeny can outcompete wild salmon under certain conditions thereby adversely affecting wild Atlantic salmon populations.

Escaped aquaculture fish may reduce the spawning success of wild salmon by digging up the redds of wild salmon (Lura and Saegrov 1991; Webb *et al.* 1991). Escaped farmed salmon have been documented to spawn later in the season than wild salmon (Lura and Saegrov 1991; Jonsson *et al*. 1991; Webb *et al* 1991; Jonsson 1997). This increases the potential for escaped farmed salmon to limit the success of wild spawners through redd superimposition (Webb *et al* 1991).

In addition, it has been speculated that salmon net-pens may aggregate predators (e.g., seals) of Atlantic salmon increasing the potential for predation of outmigrating wild post-smolts or returning sea-run adults.

Genetic Effects

Atlantic salmon populations at low levels, such as those in the Gulf of Maine DPS, are particularly vulnerable to genetic intrusion or other disturbance caused by escapees (DFO 1998; Hutchings 1991; NRC 2002). These introgression events may be one of the most significant ways in which aquaculture salmon affect wild populations. While natural selection may be able to purge wild populations of maladaptive genetic traits, regularly-occurring interaction between aquaculture fish and wild salmon makes this considerably less likely. Interactions between wild and aquaculture salmon may lead to decreased numbers of wild Atlantic salmon and, in the extreme, to extirpation of wild stock (Einum and Fleming 1997; Fleming and Einum 1997; Grant 1997; Saegrov *et al.* 1997).

There is a positive relationship between the reproductive success of cultured fish and the time the fish has lived in nature before reaching sexual maturity (Jonsson 1997). Consequently, escapees from freshwater hatcheries may pose a larger genetic threat to wild populations than escapees from net-pens. Cases of chronic and large escapements from freshwater hatcheries in Maine have been documented (see above).

The industry's continued use of non-North American origin Atlantic salmon increases the threat posed by commercially cultured salmon. The use of reproductively viable European strains (pure and hybrid) of Atlantic salmon within North America poses a threat to the DPS. Genetic studies demonstrate that there are significant differences between North American and European Atlantic salmon (NRC 2002, and the references therein). Breeding between genetically divergent populations may adversely affect natural populations (Utter *et al.* 1993; Verspoor 1997; Youngson and Verspoor 1998; ISAB 2002). The introgression by non-North American stocks with endangered Atlantic salmon presents a substantial threat to the genetic integrity of North American stocks and threatens fitness through outbreeding depression. The ACOE permit holders have continued to use European strains or hybrids despite their commitment not to do so when obtaining permits (i.e., many permit applications stated that no European strains or hybrids would be placed in cages)(see page 1-56).

In January 2001, the EPA delegated authority to the State of Maine to administer the CWA, National Pollutant Discharge Elimination System (NPDES) program[20]. An MEPDES general permit for Atlantic salmon aquaculture was finalized in 2003, the permit contains conditions for finfish aquaculture operations in four primary areas; (1) Fish husbandry and culture, (2) loss prevention through audited containment practices, (3) marking cultured fish to identify the origin of escapes, and (4) use of only North American strains of Atlantic salmon.

There is evidence that escaped salmon of non-North American origin have spawned successfully in the wild with either native or other escaped aquaculture fish. In five of the six populations of DPS river broodstocks held at the CBNFH, parr collected from the wild had alleles and

[20] The EPA retains oversight of this program.

multilocus genotypes indicative of non-Maine origin. These fish were culled out of the hatchery population.

In addition to the threats identified above from current aquaculture practices, the potential use of transgenic salmonids in aquaculture poses additional unknown, but possibly significant, genetic and ecological risks to wild Atlantic salmon populations. Transgenic salmonids include fish species of the genus *Salmo*, *Oncorhynchus* or *Salvelinus* in the family Salmonidae that contain stably integrated recombinant DNA in all their cells. The "new" DNA typically contains a gene obtained from another species[21]. By 1989, production of fourteen species of transgenic fish had been reported (Kapuscinski and Hallerman 1990). Research and development efforts on transgenic forms of Atlantic salmon and rainbow trout are currently being directed toward their potential use for net-pen aquaculture. Research has focused on enhancement of growth and increased tolerance of low water temperature through the transfer of genetic material from cold-tolerant species, such as flounder. Transgenic fish have probably undergone severe "genetic bottlenecking" in their production. Thus, it is not possible to generically predict the impacts on Atlantic salmon if these transgenic fish were to escape into the wild. Any specific proposal to rear transgenic salmon must be evaluated to determine the potential impact on the listed population.

Transgenic fish produced for culture in marine net-pens are bred to survive under nearly natural physical and chemical environmental conditions; thus, if they escape, it is likely that a portion of them will survive. The transmission of novel genes to wild fish could lead to physiological and behavioral changes and traits other than those targeted by the insert gene are likely to be affected (Kapuscinski and Hallerman 1990). Ecological effects are expected to be greatest where transgenic fish exhibit substantial altered performance. Such fish could destabilize or change aquatic ecosystems. Juvenile salmon of domesticated aquaculture strains have been shown to grow faster and be more aggressive than wild strains; they impact wild salmon through competition for food and space (Einum and Fleming 1997). It is reasonable to expect that genetically modified salmonids, possessing a greatly accelerated growth potential and occupying the same habitat as wild fish, could have a greater displacement impact on wild fish than non-transgenic domestic strains.

2. Marine Survival

Marine survival rates continue to be low for U.S. stocks of Atlantic salmon, impeding the recovery of the DPS. Based on a review of twenty studies, reported survival rates of Atlantic salmon during the marine phase range from 0% to 20% (Bley and Moring 1988). In the United States, return rates for hatchery stocked salmon were generally less than 1.5% for the Penobscot River from 1970 to 1998 (NMFS and FWS 1999). The most current estimates indicate that since 1990 return rates have been below 0.5% and in the most recent three years, below 0.2% (Russell

---

[21] Transgenic organisms can also be called genetically modified organisms. Transgenic is usually used to refer to animals while genetically modified is usually used to refer to plants or microorganisms.

Brown, NOAA Fisheries, personal communication). The return rates of wild salmon are usually higher than hatchery stocked salmon (Bley and Moring 1988; Friedland 1994). Preliminary estimates for the Narraguagus River indicate that total marine survival (emigrating smolt to returning adult) of DPS salmon are less than 2% (John Kocik, NOAA Fisheries, personal communication). The number of naturally reproducing Atlantic salmon in DPS rivers is at a historic low, placing the DPS in danger of extinction. In 2002, only an estimated 23 to 46 adult salmon returned to DPS rivers to spawn (USASAC 2003).

The production potential and population dynamics of Atlantic salmon may be determined by year-to-year variability in oceanic natural mortality as well as the average level of natural mortality in the marine environment (NMFS and FWS 1999). On an interannual basis, marine survival rates can be more variable than freshwater survival rates (NMFS and FWS 1999). Reddin (1988) found that overall marine survival rates were typically higher (5.51%) than freshwater (1.67%). However, the variability in survival during the marine phase is approximately four times higher then during the freshwater phase of salmon's life-history (Reddin 1988). Bley and Moring (1988) report that Atlantic salmon stocks that undertake longer migrations, such as those from DPS rivers, typically have lower marine survival. This hypothesis is consistent with an observed north to south gradient of decreasing marine survival rates. This theory is also consistent with typically high survival rates seen in several of the northern (Icelandic, Irish and Baltic) stocks of Atlantic salmon with limited migratory routes (Bley and Moring 1988). 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 may offset the higher marine mortality.

The factors affecting the survival of salmon during the marine phase of their life history are not well understood. Marine survival is determined by a combination of factors, including predation, starvation, disease/parasites, abiotic factors, and commercial fisheries. Based on the current level of knowledge of the marine ecology of Atlantic salmon, it is not possible to partition mortality into specific categories.

Scientists have concluded that post-smolt survival accounts for a significant proportion of the variation in recruitment or return rate (i.e., total marine survival). It has been theorized that the transition from freshwater to the marine environment accounts for a high proportion of the total at-sea mortality. However, the factors responsible for reduced post-smolt survival are not well understood. Recent research on the effects of acid rain has shown that pulses of acidity can result in mortality in smolts during the transition from the freshwater to marine life phase of their life cycle (Magee *et al.* 2001; Rosseland *et al.* 2001)(see page 1-22). Survival can also be affected by exposure to endocrine disruptors that may also impair the smolts' ability to successfully transition from the freshwater to the marine environment (Haines *et al.* 1990; Magee *et al.* 2001; Moore and Lower 2001). Migrating salmon smolts survival is also affected by predation and exposure to new disease pathogens and parasites.

Sea surface temperature (SST) appears to be an important feature of the marine environment that affects Atlantic salmon survival. Survival appears to also be closely related to marine temperatures in the overwintering area, indicating that variation in the quality or quantity of food supply may play a significant role in survival (Friedland *et al.* 1993; Reddin *et al.* 1993). Atlantic salmon are found in waters ranging from 3°C to 13°C (38°F to 56°F)(Baum 1997). The optimal water temperature range for Atlantic salmon is 4°C to10°C (40°F to 46°F) waters, a temperature range thought to be ideal for growth (Saunders 1986).

Saunders (1986) and Reddin and Shearer (1987) found that SST influenced Atlantic salmon marine distribution. Reddin and Shearer (1987) concluded that below-normal surface temperatures in the Labrador Sea over the winter were responsible for low catches in West Greenland in 1983 and 1984. Friedland *et al.* (1993) and Reddin *et al.* (1993) found that the pattern of stock production was related to the area of winter habitat available to North American post-smolts. The lack of a relationship for spring, summer and autumn suggests that habitat during these seasons may not be limiting. While these investigations have indicated the importance of SST to Atlantic salmon recruitment, the mechanisms responsible for reduced survival are still unknown. Mortality could arise from stress, starvation, predation, disease or other unknown mechanisms. The model used until recently to estimate the pre-fishery abundance (PFA) of non-maturing 1SW salmon available for harvest shows improving thermal habitat condition and predicts increased numbers of returning adults. The predicted increases in the number of returning adult Atlantic salmon have not occurred.

Large scale oceanographic processes likely affect Atlantic salmon survival rates (Dunbar 1993; Friedland 1994). Correlations have been found between SST and marine survival for Atlantic salmon (Scarnecchia 1984; Martin and Mitchell 1985; Scarnecchia et al. 1989; Friedland et al 1993; Friedland et al 1996; Friedland 1998). The North Atlantic Oscillation (NAO) is one possible causal mechanism for this relationship. The NAO is responsible for variation of the pressure gradient over the North Atlantic and thus changes in weather patterns. A direct link has not been established between Atlantic salmon survival and the NAO. However, many other salmon species exhibit cyclic patterns of marine survival linked to large scale oceanographic processes. For example, marine survival of Pacific salmon species have been shown to vary with El Niño Southern Oscillation (ENSO) events (Johnson 1988; Beamish and Bouillon 1993; Francis and Hare 1994).

Friedland *et al.* (1993) report that year-to-year variation in return rates of U.S. stocks, although at lower absolute levels, are generally synchronous with other Atlantic salmon stocks. Recent return rates have been decreasing for several North American Atlantic salmon stocks. The correlations between the survival rates of multiple stocks suggest that an important cause of mortality may act upon the stocks when they are mixed and utilizing a shared habitat. This observation suggests that although significant natural mortality may occur in the riverine and estuarine environment, it may not be the patterning source of mortality observed in North American salmon stocks (Larsson 1985; Wood 1987; Hvidsten and Lund 1988; Magnhagen 1988). Friedland *et al.* (1993) found the survival rate for the Penobscot River stock was correlated to growth rates during the first winter at sea, suggesting that this period regulates annual recruitment. This observation suggests an association between growth rates and survival rates (NMFS and FWS 1999). In years of poor growth, a greater proportion of the stock died; when growth was better, so was survival (Friedland *et al.* 1993).

The directed commercial fishery off the coasts of West Greenland and Canada was a major source of mortality from the 1960s to early 1990s. These commercial fisheries have been significantly reduced in Canada through voluntary and regulatory measures and in West Greenland by internationally negotiated quotas that are greatly reduced from past levels of exploitation (see page 1-38). As noted (see page 1-38), a small commercial fishery occurs off St. Pierre et Miquelon, a French territory off the coast of Newfoundland. Thus, ocean interception by fisheries has not been completely eliminated as a source of mortality to salmon of Maine origin.

VII. THREATS ASSESSMENT

As part of the recovery planning process, the threats facing the listed species have been assessed with regard to their geographic extent, severity, life stage affected and responsiveness to management. The more critically the threats can be assessed, the more refined and targeted the recovery strategy can be, increasing the probability for successful recovery.

To conduct a threats assessment, it is important to understand the difference between vulnerabilities and threats and their effect on the listed entity. A vulnerability is a weakness that can influence how various threats affect the resource. The Gulf of Maine DPS of Atlantic salmon is extremely vulnerable due to the very low number of returning adults. Due to this small population size, the DPS is less able to withstand natural and human-caused outside forces, which could range from genetic intrusions to catastrophic events. As populations within DPS rivers increase and recovery proceeds, the vulnerability of the DPS will decrease.

A threat is any circumstance or event with the potential to cause harm to the resource. Threats can come in a variety of forms, including those causing direct mortality of one or more life stages; indirect mortality through genetic, ecological or behavioral effects; impairing natural movement or life history functions; or degrading habitat.

A threats assessment includes consideration of both natural and human threats, which can result from either intentional or unintentional actions. The current or potential impact of each threat on the DPS is affected by a variety of characteristics of that threat including the geographic extent of the threat (i.e., how many populations are impacted by the threat) and consideration of the specific life stage(s) affected by that threat. The greater the geographic extent of a threat, the higher the concern over that specific threat. The later in the life cycle that a threat impacts the DPS, the greater the effect to the persistence and recovery of the DPS overall. For example, a threat that affects all populations in the DPS and affects returning adults would be assessed a higher risk than a threat affecting fry in only one population.

An assessment of an individual threat not only includes consideration of the geographic extent and life stage affected, but also the responsiveness of that threat to management actions and the feasibility of implementing those actions. While there may be great concern over a particular threat to a species, if there are no effective measures that can be implemented to minimize or mitigate that threat, then abatement of this threat may not be a high priority recovery action. Based on the best available scientific information, actions specific to this threat may be limited to additional research and experimentation. The ability to implement management actions to address a threat and the likelihood that those actions will be effective are critical considerations when formulating a strategy for the recovery of a listed species.

An assessment of threats must also recognize the interrelationship between various threats. There may be synergistic effects that must be taken into consideration. For example, while slightly lower dissolved oxygen (DO) may be tolerable for juvenile Atlantic salmon, in combination with elevated water temperatures it may result in more significant impacts, including mortality. Evaluation of individual threats in isolation may lead to an underestimate of their impact on Atlantic salmon. Attention needs to be paid to cumulative impacts of threats or interrelationships between threats in order to ensure an accurate assessment.

Given the extremely low numbers of returning adult salmon to the Gulf of Maine DPS, priority should be given to those threats that alone, or in combination with other factors, pose a high risk to one or more life stages of Atlantic salmon. An evaluation of the geographic extent and life stage affected by threats, and the severity of these effects, resulted in the following threats being identified as high priority for action to reverse the decline of Atlantic salmon populations in the Gulf of Maine DPS:

- Aquaculture practices, including the use of European Atlantic salmon, which pose ecological and genetic risks
- Acidified water and associated aluminum toxicity which decrease juvenile survival
- Poaching of adults in DPS rivers
- Incidental capture of adults and parr by recreational fishermen
- Predation
- Excessive or unregulated water withdrawal

Commercial aquaculture of Atlantic salmon poses high risks to all life stages of Atlantic salmon through genetic, disease and ecological interactions. For this reason, actions to minimize the potential interaction between wild and farmed fish should continue to receive a high priority for implementation.

Acidified water and associated aluminum toxicity has been identified as potentially having severe effects on parr and smolts. For this reason, actions to address the source of acid rain and lowered bicarbonate buffering should be treated as priority implementation actions as well as mitigation measures that may ameliorate the impacts to parr and smolt. Increases in parr and smolt survival are critical in order to halt the decline and reverse the population trend.

Direct mortality at various life stages of Atlantic salmon can significantly impede recovery of populations within DPS rivers, and actions to reduce mortality should receive a high priority in implementation. Sources of direct mortality of parr and returning adults include incidental capture by recreational fishermen, poaching and predation. For example, recreational fisheries for trout pose the greatest threat to parr. Any mortality of a returning adult has the most serious and immediate impact on the population, and therefore actions to prevent adult mortality by poaching should receive the highest priority.

Predators also have the potential to cause direct mortality to various life stages of Atlantic salmon, including returning adults. Marine mammals have been identified as a possible source of mortality of returning adults, and focused actions to minimize vulnerability of returning adults to marine mammal predators should be implemented. Smolt outmigration occurs in a relatively narrow time window and along a narrow pathway exposing outmigrating smolts to predation by double-crested cormorants. Successful recovery is dependent on our ability to increase the numbers of outmigrating smolts and therefore actions to reduce vulnerability of smolts to predation by double-crested cormorants should be a high priority.

Decreases in instream flows likewise have the potential for high impacts to adult spawners, early freshwater life stages and parr. Water extractions have the potential to impede or prohibit access to spawning habitat, dewater redds, or reduce the quantity of habitat available for fry and parr. Interference with spawning or direct mortality of juveniles could have serious consequences for population recovery.

In addition, to the highest priority threats discussed above, moderate threats to adult spawners warrant elevation for priority action due to the extremely low population numbers. Low dissolved oxygen due to excess nutrients from agriculture, sewage treatment, septic systems, processing/manufacturing facilities, and/or hatcheries has the potential to cause impact adult spawners. Elevated water temperatures due to land use practices, impoundment of free-flowing reaches of rivers, low flows, thermal discharges and/or decreased stream shading also has the potential to impact adult spawners. Impacts to adult spawners are also possible from obstructions to passage that may be caused by man-made barriers (e.g. dams, poorly designed roads and culverts) or natural barriers (e.g. geological falls, beaver dams and debris dams). Although these threats are not now categorized as high, the fact that they impact adult spawners justifies the elevation of concern such that actions to address these threats should be prioritized.

In addition to the threats which are currently known to affect Atlantic salmon, there are factors that have the potential for significant adverse effects; however, the information needed to fully assess the severity of these factors is lacking. As such, additional research on the following factors is a critical recovery need: the effect of diseases, sedimentation and chemical contaminants on all life stages; the effect of acidified water and associated aluminum toxicity on the early freshwater life stages; the effect of marine mammal predation; and the effect of bycatch in U.S. commercial fisheries on adult spawners, smolts and in the marine environment.

VIII. CURRENT CONSERVATION EFFORTS

Atlantic salmon conservation and restoration efforts involving private citizens as well as state, federal, local and international organizations have been underway for more than 150 years. Baum (1997) provides an excellent summary of historic restoration activities. The majority of these efforts is related to hatchery fish production and stocking activities. It has only been in the last two decades that a greater emphasis has been placed on the issue of quality, quantity and accessibility of Atlantic salmon habitat. The following section provides an overview of recent conservation efforts and accomplishments. Many of these are described in more detail in other sections of this plan.

State of Maine Conservation Plan

In 1997, the State of Maine established the Atlantic Salmon Conservation Plan for Seven Maine Rivers (MASCP). The MASCP (1997) provides the basis for many important on-going Atlantic salmon conservation and recovery activities. This plan was developed with extensive participation of state and local agencies, industry, conservation groups and other stakeholders and with the input of NOAA Fisheries and FWS staff. This plan is administered by the Maine Atlantic Salmon Commission. The MASCP identifies fourteen goals for successful Atlantic salmon conservation (MASCP amendment). These goals fall under four major categories: fishery management, habitat protection, habitat enhancement and species protection. Key elements and factors addressed by the plan include: water quality and quantity, riparian habitat, fishing activities, predation, aquaculture, disease and stocking. The MASCP and progress reports on its implementation are important sources of information about recent and ongoing conservation efforts for the Gulf of Maine DPS of Atlantic salmon and can be accessed at ASC website (www.state.me.us/asa/).

Many significant conservation efforts have been accomplished under the auspices of the MASCP. These include improving juvenile and adult salmon population assessment; construction of weirs and traps; mapping of spawning and nursery habitat and completion of riparian buffer methodology; habitat protection efforts including acquisition of riparian habitat, improvement of road crossings and evaluation of non-point source pollution; habitat enhancement activities including improving fish passage, water use management planning and upgrading road crossings, ditches and culverts; species protection efforts including work with the aquaculture industry and recreational fishing interests (MASC 2000). Ongoing conservation activities that fall under the framework of the MASCP are detailed in other sections of this recovery plan.

This recovery plan builds on and expands recovery actions identified in the MASCP. The Services intend to maintain and expand ongoing collaborative recovery efforts implemented as part of the MASCP. The recovery program will build on and complement continuing conservation efforts identified in the MASCP.

Other Ongoing Conservation Efforts

Many public and private organizations and agencies have been involved in Atlantic salmon conservation. The Services recognize and acknowledge the ongoing efforts of these groups and accomplishments to date. Many of the ongoing efforts by these groups are outlined throughout the recovery plan.

Several departments within Maine state government are involved in Atlantic salmon conservation. These include: Maine Atlantic Salmon Commission; Maine Department of Inland Fisheries & Wildlife; Maine Department of Environmental Protection; Maine Department of Agriculture, Food, and Rural Resources; Maine Department of Transportation; Maine Department of Conservation; Maine Department of Marine Resources; Maine Land Use Regulation Commission; Maine State Planning Office.

Federal agencies involved in Atlantic salmon conservation in Maine include: Army Corps of Engineers; National Marine Fisheries Service; USDA Natural Resource Conservation Service; United States Geological Survey (USGS); U.S. Environmental Protection Agency (EPA); and the U.S. Fish and Wildlife Service.

The recovery process for endangered species incorporates all the elements of the ESA; regulatory protection, research, management and education and outreach. Regulatory actions, such as Section 7 consultations or Habitat Conservation Plans, for a listed species, should be conducted in such a manner that furthers the recovery process. In addition to independent federal conservation efforts, many federal actions are cooperative and require collaborative efforts with the State of Maine and the many organizations acting to fulfill the goals of the MASCP. These efforts are discussed in more detail throughout the recovery plan.

In addition to state and federal government initiatives, there are many private and public organizations involved in Atlantic salmon conservation efforts. These include: Atlantic Salmon Federation – Maine Council; Atlantic Salmon Unlimited; Cherryfield Foods Inc.; Coastal Mountain Land Trust; Cove Brook Watershed Council; Dennys River Watershed Council; Dennys River Sportsman's Club; Downeast Rivers Coalition; Ducktrap Coalition; East Machias River Watershed Council; Eight Rivers Roundtable; Fish Friends; Fishing in Maine; Friends of the Kennebec; Kennebec County Soil & Water Conservation District; Knox/Lincoln County Soil & Water Conservation District; Machias River Watershed Council; Maine Rivers; Maine Environmental Research Institute; Maine Wild Blueberry Commission; Narraguagus River Watershed Council; Natural Resources Council of Maine; Northern Penobscot Salmon Club; Penobscot Riverkeepers; Pleasant River Watershed Council; Pleasant River Fish and Game Conservation Association; Pleasant River Hatchery; Project SHARE; Quoddy Regional Land Trust; Saco River Salmon Club; St. Croix International Waterway Commission; Sheepscot River Watershed Council; Sheepscot Valley Conservation Association; Trout Unlimited Maine Council; Trout Unlimited Merrymeeting Bay Chapter; University of Maine Cooperative Extension Service; Veazie Salmon Club; Waldo County Soil & Water Conservation District; Washington County Soil & Water Conservation District; Wild Salmon Resource Center; Wyman

& Son Inc. The education and outreach section of the recovery plan includes a more detailed discussion of the ongoing efforts of the Watershed Councils.

International Atlantic salmon conservation efforts are largely pursued through NASCO. Since the early 1990s, NASCO has drastically reduced harvest of Atlantic salmon on the high seas and from foreign fisheries. Ongoing efforts by NASCO are discussed in several of the following sections of this recovery plan. In addition, other groups involved in international Atlantic salmon issues include the North Atlantic Salmon Trust, the Atlantic Salmon Federation, Trout Unlimited, World Wildlife Fund, the Maine Aquaculture Association and other industry groups.

PART TWO: RECOVERY STRATEGY

The Gulf of Maine DPS continues to face a drastic population decline and severe threats to its persistence. Recovery actions must be implemented in a focused and strategic way to achieve the greatest benefits for recovery of the DPS. To accomplish this, three categories of actions will be high priority for the first phase of recovery plan implementation (i.e., the first five years):

1) Implementation of the Priority 1 recovery actions (see Part Five: Implementation Schedule) that will reduce the severest threats (i.e., salmon aquaculture, acidified water and associated aluminum toxicity, poaching, incidental capture by recreational fishermen, predation and decreased instream flows).

2) Actions that can be initiated quickly and have the potential to significantly improve survival and reverse the decline of DPS populations. One such action is stream liming; others will be identified at the beginning of the recovery plan implementation.

3) Actions that address critical information needs. One such action is completion of a population viability analysis (PVA)[22] that will help develop final reclassification and delisting criteria (see Part Three: Recovery Goal, Objectives and Criteria). Other actions include research to better understand threats and how best to address them; these threats include disease, chemical contaminants, acidified water, aluminum toxicity, predation, sedimentation, low marine survival and potential commercial fisheries bycatch.

Presently a status review is underway to determined the relationship of large river systems to the DPS as currently delineated. This review will also determine the status of salmon populations within these large river systems, as well as any other additional salmon populations present within the geographic range of the DPS. Decisions regarding the status of these populations may have significant implications for the recovery strategy.

The initial focus of the recovery program will be on the eight populations in the DPS that were extant at the time of the listing (see page 1-1). Without immediate action to conserve and protect these core populations and the remnant genetic variation they represent, long-term success and attainment of self-sustaining populations will be severely compromised.

After the initial phase of recovery plan implementation is completed, efforts will focus on addressing remaining threats and information needs. Throughout all phases of recovery plan implementation, recovery actions will be designed as experiments, results will be monitored and

---

[22] Population viability analysis (PVA) is a tool used to estimate the probability of persistence over time of given stock sizes. There are a wide range of modeling approaches used in PVA, from simple extrapolation of current trends to complex individual-based models. Whatever approach is taken, the purpose is the same, to predict the probability of the population persisting into the future. PVA is used to explore potential consequences of management actions in the light of uncertainty.

future actions modified accordingly, following an adaptive management approach. In addition, the following principles will be used to bring focus to longer-term recovery efforts:

1. *Maintain and expand on-going collaborative conservation and recovery efforts.* The recovery program will build on and complement continuing conservation efforts, most notably actions described in the 1997 Atlantic Salmon Conservation Plan for Seven Maine Rivers (MASCP). A number of multi-organizational groups (e.g., Atlantic Salmon Collaborative, Project SHARE, Maine Technical Advisory Committee, industry/government) are actively engaged in cooperative Atlantic salmon conservation activities. Local watershed councils, formed under the auspices of the MASCP, will also continue to play an important role in recovery activities in their respective DPS watersheds, particularly the planning and implementation of watershed-specific habitat protection and restoration, consistent with general habitat conservation actions outlined in this plan. Federal recovery efforts will strive to complement and enhance the expertise and commitment of this diverse group of agencies, organizations and interested parties, consistent with the principles of sound science and the mandates of the ESA. Recovery implementation will be coordinated with local Indian Tribes in accordance with Secretarial Order 3206.

2. *Utilize the river-specific hatchery populations as a temporary "bridge" through the present period of low returns of adult spawners, with the goal of attaining self-sustaining wild-spawning populations.* While the recovery hatchery program serves an important role in preserving river-specific stocks until factors currently depressing survival rates and adult returns can be addressed, the purpose of the recovery process under the ESA is to restore self-sustaining populations in the wild. Thus, recovery of the Gulf of Maine DPS will require the recovery of secure wild-spawning Atlantic salmon populations that are able to live their entire lives and meet all of their requirements in the wild. The river-specific hatchery fish are also listed and protected under the ESA, but only naturally-spawned adult spawners that have spent their life-cycle in the wild will be counted towards reclassification and delisting criteria (65 FR 69459).

Management of hatchery stocks outlined in this plan (as in the MASCP) is predicated on river-specific management, as "the most scientifically prudent approach in order to protect any local adaptations, consistent with the long-established management for these rivers ... From ecological and evolutionary perspectives, river-specific stocking is currently viewed by the scientific community as the best available strategy to promote restoration of the resource."(MASCP 1997). The river-specific hatchery stocking program adopted in 1991 and efforts to prevent introgression of farmed fish into the wild salmon populations are both based on the goal of conserving the natural diversity of genetic traits of DPS stocks that have evolved over time in response to local conditions, and on maximizing the ability of these stocks to exploit their native habitat. Conservation of river-specific stocks reflects "evidence ... that restocking efforts are most likely to succeed when donor fish come from the river to be stocked" (MASCP 1997), and maximizes potential for retention of genetic traits needed to respond to long-term local environmental variation. This recovery plan supports that goal and also recognizes and strives to minimize risks to the natural genetic integrity of the wild stocks from selective pressures and inbreeding in the captive environment. In the event that significantly reduced genetic diversity or indications of inbreeding depression are observed in any river-specific population, carefully planned crossing of stocks during artificial propagation or via stocking may be required to increase population viability.

3. *Restore, maintain, and ensure long-term protection of freshwater, estuarine, and marine habitats and natural processes in sufficient quantity and quality to support self-sustaining wild-spawning populations.* Consistent with the central purpose of the ESA (section 2(b)): "to provide a means whereby the ecosystems upon which endangered species and threatened species may be conserved"), recovery efforts described in this plan are premised on the long-term protection and restoration of habitats for all stages of the Atlantic salmon life-cycle. This "ecosystem approach," also reflected in the MASCP, recognizes the fundamental interdependence of aquatic, riparian, and upland habitats within DPS river watersheds. A variety of mechanisms, including (but not limited to) cooperative agreements, State and local land and water use regulations, habitat conservation plans (under Section 10 of the ESA), landowner incentive programs, conservation easements, and land acquisition may be employed to accomplish habitat restoration and protection. The ESA listing also recognizes the potential role of factors in the marine environment in the recent low adult returns. The Services are committed to prompt and appropriate response to any marine factors that may be identified and for which management is feasible.

4. *Seek long-term reductions in risks of disease transmission, genetic introgression, and ecological impacts from aquaculture-bred Atlantic salmon and non-indigenous fish species.* Current low numbers render the DPS Atlantic salmon especially vulnerable to threats posed by aquaculture fish. Even when the DPS population attains numbers and distribution that satisfy the delisting criteria, however, the large numbers of farmed fish in hatcheries and marine cages within some DPS river watersheds will pose a substantial continuing risk to the persistence and integrity of the wild fish. Full recovery of the DPS will require long-term commitments to practices that minimize potential threats to the DPS from disease transmission, genetic introgression, and ecological impacts from farmed fish. Stocking of non-indigenous fish species poses risks due to competition, and measures must be instituted to limit current and future stocking unless robust data indicates that a particular non-indigenous species does not pose a threat to Atlantic salmon.

5. *Employ appropriate and effective measures to reduce mortality of Gulf of Maine DPS Atlantic salmon due to international commercial fisheries, predation, and poaching until populations become self-sustaining.* Atlantic salmon populations should be able to withstand natural predation rates and some controlled level of harvest. The current low number of Gulf of Maine DPS Atlantic salmon have elevated their vulnerability to even very small increments in mortality rates. Near-term recovery efforts, therefore, may include efforts to reduce predation-induced mortality, especially where human activities increase the salmon's natural vulnerability to predation (e.g., by impeding salmon movements) or where predator populations are at historical high levels that are likely to pose a detriment to salmon survival and recovery. Likewise, efforts to minimize take due to poaching and harvest in international waters are warranted in light of the severely low current population numbers. Once populations have

recovered to self-sustaining levels, the need for predator management should be reevaluated, along with the potential for the DPS to support carefully regulated sustainable harvest.

6. *Expand the distribution and increase the abundance of Atlantic salmon populations within the historic range of the DPS*. The viability of the entire DPS is served by preventing formation of any further gaps in the range of the DPS and by restoring demographically secure and genetically secure diverse populations within each many watersheds. Promoting recovery across rivers within the historic range of the DPS will help conserve the remaining genetic variability of populations, reduce the vulnerability of the DPS to catastrophic events and provide opportunities for research. Expanded distribution of Atlantic salmon stocks within the DPS could be achieved through natural recolonization or use of experimental population designations to introduce DPS fish from other rivers (see Section 5.1.4).

PART THREE: RECOVERY GOAL, OBJECTIVES AND CRITERIA

The goal of the recovery program is removal of the Gulf of Maine DPS of Atlantic salmon from the Federal List of Endangered and Threatened Wildlife (50 CFR 17.11). Recovery will be achieved when conditions have been attained that allow self-sustaining populations to persist under minimal ongoing management and investment of resources. Achievement of recovery does not require the return of a species to all of its historic range, nor does it require attainment of full carrying capacity of available habitat if a smaller population is demonstrably secure. In order to achieve the goal of recovery, a stepwise approach will be adopted which first addresses the critically low number of adult Atlantic salmon returns then builds toward full recovery. Although the objectives are presented in a stepwise fashion, it is recognized that there is an inherent linkage among the objectives in that specific recovery actions will often help achieve all objectives.

Objective 1: Immediately halt the decline of the DPS and demonstrate a persistent increase in population abundance such that the overall probability of long-term survival is increased.

The initial focus of the recovery program will be on the 8 rivers within the DPS with extant populations at the time of the listing. To maintain a viable population for recovery, the first step is reversing these trends and conserving these extant populations. Without immediate action to conserve and protect these core populations and the remnant genetic variation they represent, long-term success and attainment of self-sustaining populations will be severely compromised. To achieve this first objective, the following criteria must be met:

Criterion 1. Atlantic salmon are perpetuated in at least the eight rivers within the Gulf of Maine DPS that had extant populations at the time of listing; and

Criterion 2. The replacement rate (5-year geometric mean) of adult salmon within DPS rivers is greater than 1.0[23].

Criterion 1 recognizes that conserving the relatively broad geographic distribution in the extant populations is important for the reasons outlined in the Recovery Strategy. Achievement of this criterion may require stocking in rivers that are not stocked currently to enhance the demographic survival probabilities. Criterion 2 provides a quantitative measure of recovery, showing that the decline has been halted, and that integrates the results of recovery actions that have been implemented and changes in habitat and survival that may occur. The replacement rate describes the rate at which each subsequent generation, or cohort, replaces the previous one (NMFS 1995). The replacement rate will be calculated based on returning DPS adults. The 5-year time period represents the general time needed for an adult spawner's offspring to complete

[23] As noted, Replacement rates of adult salmon in the Narraguagus River for the years 1996 to 2002 all averaged less than 1.0, with the lowest value of 0.2 occurring in 2002. Population assessments on the DPS by USASAC show a current 5-year geometric mean replacement rate of 0.54 (USASAC 2004, http://www.nefsc.noaa.gov/USASAC/).

its life cycle and return as an adult spawner. Progress towards achieving criteria 2 above will be annually assessed using available information on adult returns.

Although the criteria are based on numbers and distribution of fish, they encompass evaluation of threat reduction. Success in increasing adult returns for the DPS to a level such that the five-year geometric mean is greater than 1.0 is achieved is dependent on, and reflective of, our ability to adequately address threats to the Gulf of Maine DPS, as described in the Threats Assessment (see pages 1-66 to1-68).

The purpose of the recovery process under the ESA is to restore self-sustaining populations in the wild. Recovery of the Gulf of Maine DPS will require the recovery of secure wild-spawning Atlantic salmon populations that are able to live their entire lives and meet all of their requirements in the wild. The river-specific hatchery fish are included in the DPS and protected under the ESA, but only naturally-spawned adult spawners that have spent their life-cycle in the wild will be counted towards reclassification and delisting criteria (65 FR 69459). Once Objective 1 has been achieved, recovery actions necessary to achieve the second and third objectives of the recovery program will be concurrently implemented.

Objective 2: Achieve the conditions necessary for the establishment of self-sustaining populations.

Objective 3: Ensure that threats have been diminished such that the self-sustaining populations will remain viable over the long-term future. Objectives 2 and 3 relate to conditions necessary for reclassification and delisting discussed below.

Preliminary Reclassification and Delisting Criteria

In order to reclassify the Gulf of Maine DPS of Atlantic salmon from endangered to threatened, the Services must determine that the species' abundance, survival, and distribution, taken together with the ESA listing factors, no longer render the species "in danger of extinction throughout all or a significant portion of its range." Removal of ESA protection (i.e., delisting) requires demonstration that the threats that occurred at the time of listing have been removed or sufficiently reduced so the Gulf of Maine DPS of Atlantic salmon is no longer "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." Any new factors identified since listing must also be addressed in this analysis to ensure that the species no longer requires protection as a threatened or endangered species.

The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria which, when met, would result in a determination in accordance with the provisions of the ESA that the species be removed from the Federal List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12). The recovery criteria comprise the standards upon which the decision to reclassify or delist a species will be based. As discussed further below, final demographic (e.g., abundance and distribution) recovery criteria are in the process of development. As noted, the Services deferred a decision whether the Gulf of Maine DPS range included the mainstem of the Penobscot River and its tributaries above the former site of the Bangor dam (65 FR 69459). Presently a status review is underway to determine the relationship of large river systems (e.g., Penobscot, Kennebec) to the DPS as currently delineated. This review will also determine the status of current salmon populations within these large river systems, as well as any other additional salmon populations present within the geographic range of the DPS. Decisions regarding the status of these populations may have significant implications for the development of final recovery criteria.

Preliminary Reclassification Criteria

A. Population Demographics

In order to reclassify the Gulf of Maine DPS of Atlantic salmon from endangered to threatened, the DPS' demographics must be consistent with a stable or increasing wild population not in danger of extinction.

1. Population demographics, including but not limited to total population size, population structure and geographic distribution, as informed by modeling results, indicate that the DPS is not in danger of extinction throughout all or a significant portion of its range; and

2. Atlantic salmon populations in the DPS are stable or increasing.

B. Control of Threats

It is imperative that threats to the species be controlled prior to reclassification. This includes all threats identified at the time of listing, as well as any new factors identified since listing. Factors cited in the determination of endangered status for Atlantic salmon were disease, aquacultural practices, inadequate regulation of water withdrawal and low marine survival (65 FR 69479, see page 1-17). Preliminary criteria have also been provided to address several other current or potential threats including degradation of riparian habitat areas adjacent to freshwater habitats, acidification of freshwater habitats, angling and competition with non-indigenous fish.

In order to reclassify the Gulf of Maine DPS from endangered to threatened, the following threats-based criteria must be met through any regulatory or other means, including use of mechanisms available under the ESA.

1. *Water withdrawals*: Long-term mechanisms are in place to effectively regulate existing and new water withdrawals, and to prevent excessive water withdrawals in the event of severe drought. These mechanisms should maintain suitable habitat quality and quantity for all life stages of Atlantic salmon within DPS rivers and tributaries.

2. *Acidification of freshwater habitats*: Mechanisms are in place to ensure that pH is maintained at levels that provide suitable habitat quality and quantity for all life stages of Atlantic salmon within DPS rivers and tributaries.

3. *Loss or degradation of riparian habitat*: Adequate native vegetation is maintained as a means of controlling siltation and sedimentation, providing woody debris for instream structure and providing a shade canopy.

4. *Marine harvest*: Domestic and international regulatory mechanisms are in place that will prevent adverse effects to the long-term viability of the DPS from marine harvest.

5. *Recreational angling*: Regulatory mechanisms are in place to assure that angling for other species will not adversely affect the long-term viability of the DPS.

6. *Disease*: Disease detection and response plans for existing and newly discovered fish diseases are in place and fully implemented at all federal, state and private aquaculture facilities (freshwater and marine).

7. *Competition with non-indigenous fish species*:

    a. Stocking of non-indigenous fish species is prohibited if it may adversely affect the long-term viability of the DPS.

    b. All other stocking is accompanied by an ongoing monitoring program to detect and assess any adverse impacts to the long-term viability of the DPS. Mechanisms to prevent any future threats from stocking of non-indigenous fish are in place.

8. *Aquaculture*:

    a. There is no stocking of reproductively viable non-North American strains of Atlantic salmon.

    b. Aquaculture facilities (freshwater and marine) have established a fully functional containment management systems (CMS) designed, constructed, and operated so as to prevent the accidental or consequential escape of fish to open water.

Preliminary Delisting Criteria

A. Population Demographics

    1. Population demographics, including but not limited to total population size, population structure and geographic distribution, as informed by modeling results, indicate that the DPS is not likely to become an endangered species in the foreseeable future throughout all or a significant portion of its range; and

    2. Atlantic salmon populations in the DPS are stable or increasing.

When the final demographic recovery criteria (e.g. total population size, population structure and geographic distribution) are developed, those for delisting will differ from the criteria for reclassifying the DPS as threatened. This difference in demographic criteria will reflect the fact that a threatened population is still protected by the ESA, whereas a delisted population is not. A higher degree of confidence in the continued viability of the DPS is required, based on population demographics and the control of threats (as indicated below), before delisting it and completely removing the protections of the ESA.

B. Control of Threats

To delist the Gulf of Maine DPS of Atlantic salmon, the same threats as those described under "Preliminary Downlisting Criteria" will have to be controlled. Because a delisted population would no longer receive protection under the ESA, it is imperative that threats to the continued viability of the DPS be controlled by means other than mechanisms available under the ESA (e.g., state or local management mechanisms) before delisting could occur.

Development of Final Recovery Criteria

The Atlantic salmon recovery planning process has involved considerable efforts to develop reclassification and delisting criteria. The Services and State partners have explored several approaches to establishing final demographic recovery criteria for the Gulf of Maine DPS of Atlantic salmon, but have concluded that all available methods are insufficient for purposes of this plan. As a result, the Services have concluded that it is not practicable at this time to establish final demographic criteria for reclassification and delisting criteria of the DPS. The reasons for this and the anticipated timeline necessary to develop such criteria are discussed below.

The primary approach considered for establishing demographic reclassification and delisting criteria was the use of Conservation Spawning Escapement (CSE) targets[24]. While the increases in population abundance required to attain CSE targets for DPS rivers would reflect a healthier population than is currently present in the Gulf of Maine DPS, this method does not provide an indication of the probability of persistence (i.e., extinction risk) of the DPS. For example, CSE targets could substantially under or over-represent the abundance of adult spawners needed to ensure a high probability of species persistence. In the first case, populations might remain highly vulnerable even at or above the theoretically attainable CSE. In the latter case, recovery could be reached well before CSE targets are met. The size and distribution of the recovered population must be sufficient for the DPS to withstand the natural environmental fluctuations that should be expected even under favorable environmental conditions.

[24] A CSE target is the number of returning adult spawners that will theoretically fully seed currently available juvenile rearing habitat. CSE is calculated using a number of factors, including average female fecundity, ratio of returning males to females, available freshwater habitat and target egg-deposition rates per unit of habitat needed to fully seed a river (Elson 1975).

The Services also considered other potential approaches to establishing recovery criteria, including the use of criteria established by the World Conservation Union (IUCN 1994), and the use of a basic stock/recruitment curve and the concept of limit and target reference points similar to Canadian salmon management models[25]. The IUCN criteria are not species-specific and their application could result in delisting criteria that exceed the capacity of the habitat in the eight rivers, even taking into consideration all reasonable habitat restoration options. The limit and target reference point approach would require the use of a PVA model to define the stock/recruitment relationship for the DPS and to generate extinction probability curves for individual DPS river population and the DPS as a whole. This approach does not provide a measure of the long-term viability of the DPS and therefore was deemed to be insufficient for the development of recovery criteria.

The Services and their State partners have concluded, as a result of the unsuitability of the available approaches, that the development of final demographic recovery criteria would be facilitated by the development of a PVA model specific to the Gulf of Maine Atlantic salmon DPS. A life history PVA model has been developed for the eight rivers within the DPS still supporting wild salmon populations at the time of the listing. This model, which was developed by NOAA Fisheries, Northeast Fisheries Science Center (NEFSC) in cooperation with other state and federal partners, has undergone technical review[26]. A life history modeling approach was selected for the Gulf of Maine DPS due to the large amount of data available for the species. This approach has the benefit of higher biological realism but requires many more input parameters and distributions relative to simpler PVA models. Complex features of Atlantic salmon biology, such as anadromy, precocious parr, kelting and hatchery supplementation, are captured in the model.

The Services will use the results of the PVA to assist in the development of final measurable reclassification and delisting criteria for the DPS. The Services will integrate the existing PVA model with the comprehensive Viable Salmonid Populations Approach (VSP)[27] approach to determine appropriate scenarios for effective and dynamic conservation. Atlantic salmon recovery criteria will focus on achieving population levels consistent with their probability to

---

25 A limit reference point is a biological reference point, usually expressed in terms of spawning population numbers, that represent a lower threshold that represents a point where a population below it is considered collapsing towards extinction. A target reference point is a biological reference point that is a desirable minimum population target to reach and maintain.

26 The PVA model has been reviewed by internally as well as by a number of technical groups including the Maine TAC, the USASAC, ICES North Atlantic Salmon Working Group, NOAA Fisheries NEFSC, NWFSC and the SWFSC.

27 McElhany *et al.* (2000) introduces the concept of viable salmonid populations (VSP). The VSP approach identifies attributes of viable salmonid populations and provides guidance on assessing the conservation status of Pacific salmonid populations and larger-scale salmonid groupings (i.e., Evolutionarily Significant Units (ESUs)). There are four parameters that are key to determining the viability of salmonid populations: abundance, population growth rate, population spatial structure and diversity.

avoid extinction, rather than a general rule of thumb for salmon production. The integration of the VSP approach with the results of the PVA will require scientists and managers to address the complex issues of 1) the role of vacant habitat; 2) mixing of stocks with current geographic juxtaposition of populations and other scenarios; and 3) the current and future habitat quality, quantity, and locations, among other equally complex issues. The Services will develop these criteria through scientific and management panels that will outline appropriate risk levels and develop a case study of likely scenarios for recovery. The Services anticipate that the consideration of VSP attributes and parameters will be an integral element in developing recovery criteria for the DPS. The proposed final reclassification and delisting criteria will be reviewed by the scientific community and disseminated for formal public comment prior to final approval by the Services. The Services anticipate the development of final reclassification and delisting criteria to be complete within three years of the finalization of this recovery plan, including technical, peer and formal public review of the criteria. As noted above, the Services deferred the decision whether to include the mainstem of the Penobscot River and its tributaries above the former site of the Bangor dam at the time of listing pending further analysis. The outcome of this decision could have major implications for the development of final recovery criteria, the overall recovery strategy and the status of Atlantic salmon in other rivers within the range of the DPS.

PART FOUR: RECOVERY PROGRAM

A. RECOVERY ACTION OUTLINE

1. Protect and restore freshwater and estuarine habitats

- 1.1 Protect hydrologic conditions to ensure instream flows (volume, velocity, depth, temperature) adequate for Atlantic salmon
  - 1.1.1 Determine instream flow requirements for Atlantic salmon in additional DPS rivers
    - 1.1.1A Conduct IFIM studies on additional DPS rivers to determine flow requirements of juveniles
    - 1.1.1B Determine flow requirements of adult Atlantic salmon in DPS rivers
  - 1.1.2 Monitor surface and groundwater hydrology for DPS rivers
    - 1.1.2A Continue analyses of historical flow data for salmon rivers within the DPS to assess changes over time or hydrologic differences between the rivers that may affect salmon recovery efforts.
    - 1.1.2B Maintain existing USGS stream gauges on DPS rivers
    - 1.1.2C Develop and implement an effective flow monitoring program in addition to gauge-sites to monitor stream flow and discharge data at points along rivers
    - 1.1.2D Monitor and assess the potential for groundwater withdrawals to impact stream flow and cold water discharges
    - 1.1.2E Continue ongoing multi-year study of low flow characteristics of streams in eastern and northern Maine
  - 1.1.3 Assess the impact of current water withdrawals on instream flows and Atlantic salmon and monitor future water use and demand
    - 1.1.3A Implement the Downeast Salmon Rivers Water Use Management Plan (WUMP) for the Pleasant and Narraguagus rivers and Mopang Stream
    - 1.1.3B Determine the effects of current irrigation withdrawals by all growers in the watersheds on flow and Atlantic salmon
    - 1.1.3C Assess and monitor other agricultural water use needs and demands within DPS river watersheds
    - 1.1.3D Develop water use management plans for other DPS rivers
    - 1.1.3E Continue periodic assessments of irrigation methods and water demands and their potential effects on hydrology and Atlantic salmon habitat
  - 1.1.4 Ensure that water withdrawals do not adversely affect Atlantic salmon
    - 1.1.4A Ensure that water withdrawal permit requirements protect stream flows required for the recovery and conservation of Atlantic salmon
    - 1.1.4B Issue and enforce all appropriate permits for water withdrawals
- 1.2 Ensure water quality to support healthy and productive salmon populations

- 1.2.1 Review existing water quality standards for each river within the range of the DPS to determine adequacy to meet needs of Atlantic salmon
- 1.2.2 Identify and mitigate water quality threats to Atlantic salmon within the DPS
  - 1.2.2A Evaluate the impacts of acid rain on juvenile Atlantic salmon survival in DPS rivers
  - 1.2.2B Identify available management measures and techniques to mitigate the potential impacts of acid rain on the DPS. Experimentally evaluate stream acidification mitigation techniques in a natural river system within the DPS
  - 1.2.2C Identify point sources of airborne pollutants contributing to acid precipitation that may be adversely affecting the DPS and reduce to levels that will not adversely affect or jeopardize the recovery of the DPS
  - 1.2.2D Model the impact on air and water quality issues, especially acid precipitation, on productivity of salmon in DPS rivers
  - 1.2.2E Evaluate current agricultural practices such as soil acidity management practices to determine whether they may affect pH levels in DPS rivers
  - 1.2.2F Evaluate the biological effects of low pH and aluminum and its toxicity on Atlantic salmon
  - 1.2.2G Sample resident fish from all DPS rivers and analyze them for tissue residues and bio-chemical factors indicative of exposure to endocrine disrupting chemicals.
  - 1.2.2H Evaluate the chronic and acute effects of agricultural chemicals on Atlantic salmon and how they may impact salmon recovery efforts
  - 1.2.2I Identify and consider appropriate management measures and techniques to mitigate the potential impacts of agricultural chemicals and other contaminants on the DPS
  - 1.2.2J Evaluate the link between pesticides and endocrine disruption
  - 1.2.2K Conduct research on the mechanisms of non-pesticide organochlorines exposure, uptake and effect in rivers where these contaminants are known to occur including, the Dennys below the Superfund site
  - 1.2.2L Continue State program to replace overboard discharges (OBDs)
- 1.2.3 Develop and implement a water quality monitoring program for DPS rivers
  - 1.2.3A Implement a comprehensive and integrated long-term water chemistry monitoring program on all DPS rivers
  - 1.2.3B Monitor water temperatures in the vicinity of blueberry process water discharge sites on the Machias and Narraguagus rivers to assess the potential impact on Atlantic salmon
- 1.2.4 Prepare and implement plans to reduce pollution

1.2.4A Prepare and implement NPS pollution reduction plans for DPS rivers

1.2.4B Prepare and implement PS pollution reduction plans for DPS rivers

1.2.4C Fully implement EPA aquaculture wastewater and effluent discharge regulations

1.2.4D Continue monitoring of the remediation efforts at the Eastern Surplus Superfund site in Meddybemps

1.2.4E Address any ground water problems at the Smith junkyard on the Dennys River and restore the site

1.3 Ensure timely passage for each life-stage, including connectivity of spawning and nursery habitats, downstream passage for smolts and upstream passage for returning spawners

1.3.1 Assess fish passage at dams, fishways and weirs currently in place and repair or improve as needed

1.3.1A Repair or remove the Coopers Mill Dam to improve fish passage around the dam

1.3.1B Evaluate the need to repair the existing fishway at Saco Falls

1.3.2 Identify and improve culverts or other road crossings that impede salmon passage

1.3.3 Identify and manage natural debris jams (including beaver dams) that impede salmon passage

1.3.4 Condition permits for activities within the estuaries of DPS rivers so as to minimize potential effects on migration of juveniles and adults

1.4 Secure long term protections for freshwater and estuarine habitats

1.4.1 Ensure long-term protection of riparian habitat

1.4.1A Provide long-term protection for riparian buffers through fee acquisition, conservation easements, conservation and management agreements, and other appropriate tools

1.4.1B Promote the adoption and use of BMPs by landowners and compliance with these voluntary standards

1.4.1C Evaluate the impacts on Atlantic salmon of activities that may affect riparian buffer zones

1.4.1D Evaluate current state and local land use regulations to determine adequacy of existing measures protecting riparian habitat and revise if appropriate

1.4.1E Enhance protection of riparian areas where necessary through expanded enforcement and modifications to the Natural Resource Protection Act, Forest Practices Act, LURC Zoning standards, and/or Municipal Shoreland Zoning

1.4.2 Protect estuarine habitat used by Atlantic salmon

1.4.2A Evaluate the potential for activities in estuaries to adversely affect Atlantic salmon

1.4.2B Condition permits for activities within the estuaries of DPS rivers so as to minimize potential effects on Atlantic salmon

1.5 Restore degraded stream and estuarine salmon habitat
   1.5.1 Create regional hydraulic geometry curves and a reference reach database
   1.5.2 Identify, catalogue and prioritize habitat restoration needs
      1.5.2A Identify, catalogue and prioritize habitat restoration needs in DPS rivers
      1.5.2B Identify, catalogue and prioritize habitat restoration needs in estuarine habitat of DPS rivers
   1.5.3 Conduct high priority restoration projects
   1.5.4 Evaluate the potential of stream flow augmentation as a recovery tool to help meet Atlantic salmon flow needs and increase juvenile production and survival

2. Minimize potential for take in freshwater, estuarine, and marine fisheries

2.1 Prevent Directed Take of Atlantic salmon
   2.1.1 Maintain and enforce the closure of the directed sport fishery for Atlantic salmon
   2.1.2 Maintain current FMP that restricts directed harvest of Atlantic salmon in U.S. estuarine and marine waters
   2.1.3 Continue international efforts to reduce threats from commercial fisheries outside of U.S. jurisdiction
      2.1.3A Participate in international salmon management with the goal of ensuring any quotas set are based on the best available scientific data and provide adequate protection of U.S. stocks
      2.1.3B Continue U.S. participation in the international sampling program at West Greenland
      2.1.3C Continue efforts to implement a biological sampling program at St. Pierre et Miquelon to determine the origin of Atlantic salmon captured in this fishery

2.2 Avoid bycatch of Atlantic salmon
   2.2.1 Monitor, assess and develop methods to avoid bycatch in recreational and commercial freshwater fisheries
      2.2.1A Assess the level of incidental take of Atlantic salmon by recreational anglers.
      2.2.1B Prohibit all recreational fishing in select areas utilized by Atlantic salmon as holding areas to all fishing where Atlantic salmon may be taken as bycatch or poached
      2.2.1C Develop a Section 10(a)(1)(B) habitat conservation plan for recreational fishing permitted by the State that may incidentally take Atlantic salmon
      2.2.1D Continue to monitor commercial freshwater fisheries where the potential for incidental take of Atlantic salmon exists
   2.2.2 Monitor, assess and develop methods to avoid bycatch in other estuarine or marine fisheries under U.S. jurisdiction
      2.2.2A Assess the potential risk for incidental take of Atlantic salmon in marine and estuarine fisheries

2.2.2B Develop appropriate management strategies and regulatory measures to avoid bycatch of Atlantic salmon in estuarine and marine fisheries where significant potential for bycatch has been identified

3. Reduce predation and competition on all life-stages of Atlantic salmon

3.1 Assess impacts of predation on wild and hatchery-reared river-specific salmon populations and develop methods for reducing adverse affects from predation

3.1.1 Evaluate salmon population management practices, habitat features and water management practices that may exacerbate predation rates

3.1.1A Identify and catalogue locations that restrict passage and/or concentrate salmon and thereby increase the vulnerability of salmon to predation

3.1.1B Review existing salmon population management practices to determine if they increase the vulnerability of juvenile salmon to cormorant predation

3.1.1C Document and monitor the presence and abundance of potential salmon predators at natural and man-made concentration sites

3.1.1D Assess the potential of land and water use practices to exacerbate predation rates

3.1.2 Implement integrated management of cormorants to reduce predation on Atlantic salmon

3.1.2A Evaluate the potential of cormorant predation to adversely affect the recovery of the DPS.

3.1.2B Identify specific cormorant colonies within the DPS that may inflict significant levels of depredation on DPS salmon populations and implement appropriate experimental management measures

3.1.2C Evaluate the potential of conserving and restoring runs of anadromous forage species to provide a buffer against predation on salmon

3.1.3 Evaluate the need for integrated management of seals to reduce predation on Atlantic salmon

3.1.3A Evaluate the effect of seal predation on the recovery of the DPS

3.1.3B Identify sites where seals are concentrated and Atlantic salmon predation is exacerbated

3.1.3C Conduct research to determine the role of net pen sites in seal aggregation and salmon predation

3.1.3D Evaluate the potential of alternative research techniques and food habit sampling methodologies to help assess seal predation on Atlantic salmon

3.1.3E Develop and implement appropriate management measures to mitigate the impact of documented seal predation on wild salmon populations

3.1.4 Assess potential effects of other predators

3.2 Reduce predation and competition between Atlantic salmon and other freshwater fish species

3.2.1 Review and monitor potential impacts of existing stocking programs fro other fish

3.2.1A Review existing stocking programs and assess the potential impacts of these introductions on Atlantic salmon populations and ways to minimize potential adverse affects

3.2.1B Monitor potential adverse interactions of existing stocking programs for freshwater salmonids in Atlantic salmon river drainages and fully assess the potential impacts of these programs on the DPS

3.2.1C Suspend stocking of brown trout immediately in all DPS rivers until the potential impacts of these introductions can be fully assessed

3.2.1D Monitor potential adverse interactions of existing stocking programs for freshwater salmonids (i.e., splake, landlocked salmon, brook trout) in headwater lakes of DPS rivers to determine the potential impacts of these programs on the DPS

3.2.1E Assess the need to develop a Section 10(a)(1)(B) habitat conservation plan for existing stocking programs and if warranted, develop and implement

3.2.2 Monitor populations of introduced non-salmonid species and implement management controls when appropriate and feasible

4. Reduce risks from commercial aquaculture operations

4.1 Improve containment at existing and future marine sites

4.1A Evaluate new aquaculture lease and permit applications to ensure that net pens and equipment are adequate for site location and potential storm impact

4.1B Develop fully functional containment management systems for the containment of farmed salmon at marine sites. Operate marine containment systems so that no farmed salmon escape to open water

4.1C Develop and implement integrated loss control plans for all salmon aquaculture facilities

4.1D Develop and maintain an inventory tracking system for all marine aquaculture facilities

4.1E Assess, document and monitor damage caused by seal predation that may lead to the escapement of farmed salmon into the environment

4.2 Minimize the effects of escaped farmed salmon

4.2.1 Develop and implement contingency measures in case of accidental release of farmed fish

4.2.2 Maintain existing weirs on DPS rivers and establish additional sites as needed

4.2.2A Maintain existing weirs on DPS rivers to exclude aquaculture escapees, enable data collection and collect broodstock

4.2.2B Construct weirs on DPS rivers, including the East Machias and Machias rivers, where necessary to exclude aquaculture escapees, enable data collection and collect broodstock

4.2.3 Mark all farmed salmon prior to placement into marine net-pens

4.2.4 Discontinue the culture of non-North American salmon

4.2.5 Prohibit the placement into marine net-pens of reproductively viable transgenic salmon

4.2.6 Continue research into developing strains of aquaculture fish that cannot interbreed with wild fish

4.3 Minimize risks of disease and parasite transmission from farmed fish in marine pens to wild fish

4.3.1 Minimize risk of disease transmission

4.3.1A Develop and implement a comprehensive disease management plan that includes siting and standard operational procedures to minimize outbreaks of ISA.

4.3.1B Develop and implement comprehensive integrated bay management plans that include coordination of stocking densities, harvesting and fallowing and disease treatment and management

4.3.1C Revise federal import regulations (Title 50) to include the ISA virus

4.3.1D Maintain and update existing fish health guidelines and protocols as necessary, to control the introduction of new pathogens and continue to provide protection from disease

4.3.1E Expand the FWS Wild Fish Health Survey to include all DPS rivers

4.3.2 Conduct research on endemic and exotic salmonid pathogens to reduce the potential of disease transfer from farmed fish to wild Atlantic salmon

4.3.2A Determine the modes of transmission of the ISA virus

4.3.2B Continue to investigate the role of wild fish species as potential reservoirs and vectors of ISA

4.3.2C Initiate screening and long-term monitoring of resident and migratory fish in aquaculture production bays for endemic and exotic salmonid pathogens.

4.3.2D Continue active research programs on immunization of farmed fish

4.3.2E Develop an effective diagnostic technique for the SSS virus and determine the distribution of SSS virus within the geographic range of the DPS

4.3.3 Reduce the potential for sea lice outbreaks in farmed and wild salmon populations

4.3.3A Investigate the potential of sea lice to adversely affect the DPS and the role of salmon aquaculture sites as a reservoir for this parasite

4.3.3B Regularly test and report sea lice burdens at individual net-pen facilities.

4.3.3C Continue treatment for sea lice at aquaculture facilities

4.4 Reduce risk of juvenile escapement from freshwater aquaculture facilities into DPS rivers

4.4.1 Ensure containment at existing and future freshwater aquaculture facilities accessible to DPS rivers

4.4.1A Develop and operate fully functional containment management systems for the containment of farmed salmon at freshwater hatchery sites.

4.4.1B Develop integrated loss control plans for all salmon aquaculture hatchery facilities Conduct independent audits of freshwater hatcheries once loss control plans are in place

4.4.1C Develop and maintain an inventory tracking system that facilitates the accurate tracking of total numbers of salmon smolts being produced by the hatchery

4.4.2 Develop contingency plans to reduce adverse impacts if containment measures fail

5. Supplement wild populations with hatchery-reared DPS salmon

5.1 Stock cultured fish in natal rivers to supplement contributions of wild-spawned fish

5.1.1 Maintain river-specific hatchery broodstock and continue to stock cultured fish in natal rivers

5.1.1A Continue operation of federal fish rearing facilities needed for recovery of the DPS, including maintenance of river-specific broodstock

5.1.1B Continue stocking cultured fish to supplement wild salmon populations

5.1.2 Monitor and evaluate the current stocking program

5.1.3 Evaluate and implement, as appropriate, new stocking strategies

5.1.3A Evaluate the role of alternate stocking strategies to supplement wild salmon populations

5.1.3B Continue to assess and evaluate the results of the adult stocking program

5.1.3C Evaluate the role of streamside incubation facilities to supplement wild salmon populations

5.1.4 Evaluate the potential role of reintroduction in the recovery of the DPS

5.1.4A Evaluate the need to re-establish populations of Atlantic salmon in rivers within the DPS’s historic range from which river populations have been extirpated

5.1.4B Evaluate whether the use of experimental populations will facilitate the recovery of the GOM DPS of Atlantic salmon

5.2 Maintain Fish Health Practices to Minimize Potential Introduction of Disease to Hatchery Stocks and transmission to Wild Populations

5.2.1 Continue fish culture management practices at federal hatcheries to minimize the potential for disease

- 5.2.2 Continue fish health surveillance efforts and implementation of fish health practices at federal hatcheries
- 5.2.3 Continue research on fish health issues, detection and prevention
  - 5.2.3A Conduct research on ISA and SSS detection and prevention
  - 5.2.3B Conduct research on other pathogens to identify potential threats to the DPS
  - 5.2.3C Initiate screening and long-term monitoring of resident fish species in DPS rivers for endemic and exotic salmonid pathogens

5.3 Maintain practices to prevent escapement from federal hatcheries
- 5.3A Develop and implement procedures at federal hatcheries to identify potential escape sources and implement the appropriate modifications
- 5.3B Implement discharge and effluent management protocols for all hatcheries with the goal of controlling and minimizing release of juveniles

6. Conserve the genetic integrity of the DPS

6.1 Ensure that culture and stocking programs conserve the genetic integrity of the DPS
- 6.1.1 Develop broodstock management plans, including brood fish collection, genetic management and program evaluation protocols
- 6.1.2 Continue to genetically characterize and screen all brood fish and to track parentage of all fish produced

6.2 Ensure that management plans consider and avoid negative genetic effects of management actions

6.3 Explore methods for long-term preservation of gametes and genes for future use

6.4 Monitor genetic diversity, including parentage of smolts and returning adults

7. Assess stock status of key life stages

7.1 Assess abundance and survival of Atlantic salmon at key freshwater and marine life-stages
- 7.1.1 Monitor adult returns and spawning escapement
  - 7.1.1A Monitor adult returns at existing fishways and weirs
  - 7.1.1B Construct weirs on the East Machias and Machias rivers to monitor adult returns
  - 7.1.1C Conduct intensive redd counts on all DPS rivers to index spawning escapement
  - 7.1.1D Continue development of DPS-level estimates of spawning escapement
  - 7.1.1E Develop accurate extrapolation methods to estimate abundance in areas where traditional redd counts are not feasible or practical
- 7.1.2 Conduct basinwide assessment of large parr abundance and biological characteristics
  - 7.1.2A Continue basinwide assessment of large parr abundance and measurement of biological characteristics in the Narraguagus and Dennys river systems
  - 7.1.2B Expand assessments of large parr abundance to a third DPS river

7.1.2C Establish 6-10 index sites to assess large parr abundance and biological characteristics in the remaining DPS rivers

7.1.3 Conduct quantitative assessments of Atlantic salmon smolt production

7.1.4 Monitor estuarine and coastal survival, ecology, and distribution of smolts using telemetry and surface trawling

7.1.4A Continue telemetry studies of smolt migration from the Dennys and Narraguagus rivers

7.1.4B Expand spatial coverage of detection arrays to better assess movements of post-smolts in the Gulf of Maine and the Bay of Fundy

7.1.4C Continue post-smolt surface trawling assessment programs and expand the temporal and spatial extent of coverage

7.1.5 Continue to participate and contribute to international cooperative research and assessment efforts to improve our understanding of salmon at sea

7.1.6 Continue to develop and apply population viability analysis model

8. Promote salmon recovery through increased public and government awareness

8.1 Develop a comprehensive Education and Outreach Program for the Gulf of Maine DPS of Atlantic salmon

8.1A Develop a comprehensive Education and Outreach Plan for the Gulf of Maine DPS of Atlantic salmon

8.1B Continue efforts to educate anglers on the difference between trout and juvenile salmon

8.1C Develop updated educational programs for schools

8.1D Evaluate use of public display of salmon as outreach tool

8.2 Maintain, and if necessary increase, coordination/communications between government and local agencies on issues pertaining to Atlantic salmon recovery

9. Assess effectiveness of recovery actions and revise as appropriate

9.1 Appoint a Recovery Team to coordinate implementation of recovery plan objectives

9.2 Review implementation of Recovery Plan tasks annually and assess need for revisions, including changes in priorities

9.2A Conduct an annual review of the implementation schedule

9.2B Complete a biennial progress report on completion of recovery actions

9.3 Complete necessary addenda, updates and revisions to the Recovery Plan

9.4 Continue to evaluate Atlantic salmon populations in other rivers within the range of the DPS and the appropriateness of their protection under the ESA

B. RECOVERY ACTION NARRATIVE

The recovery actions outlined below reflect the best scientific and commercial information currently available. Following the narrative description of each recovery action and sub-action is a list of recovery actions items needed for salmon recovery. A thorough discussion of each proposed action can be found within the text of the appropriate recovery action or sub-action. The action items are intended to make proposed actions more readily identifiable to readers of this recovery plan. Estimated time and cost required, task priority and those responsible for carrying out each recovery action are identified in the Implementation Schedule (see pages 5-1 to 5-11). A comprehensive list of all threats and the corresponding recovery actions follows at the end of the recovery plan in Appendix 1.

Following recovery plan approval and subsequent implementation, the Services and the State of Maine will monitor recovery action implementation. The effectiveness of various recovery measures will be assessed and appropriate modifications implemented to accelerate progress towards the recovery goal. While many factors can confound efforts to evaluate the effects of discrete actions on wild populations, carefully designed monitoring is key to assessing and improving the effectiveness of recovery actions. Habitat improvement, predator management, stocking of hatchery-raised fish and efforts to reduce threats from commercial aquaculture are all appropriate subjects for monitoring and evaluation. Results of this type of monitoring will be considered during annual reviews of recovery plan implementation (under task 9) to assure timely adjustment of ongoing efforts and priorities. All recommended recovery actions should incorporate monitoring and evaluation to assess their effectiveness in furthering the recovery of the DPS. The results of research tasks described below will be used to evaluate and refine other recovery actions. The response of populations to recovery measures will be used to revise research priorities.

The Services intend to maintain and expand ongoing collaborative conservation efforts conducted under the auspices of the Maine Atlantic Salmon Conservation Plan. Proposed recovery actions will be evaluated and revised, as appropriate, in light of the findings of the NRC's report on Atlantic Salmon in Maine, as well as public comment and independent peer review of the draft recovery plan.

1. Protect and restore freshwater and estuarine habitats

Atlantic salmon habitat is comprised of several interrelated features. They include stream structure, substrate material, water flow, riparian cover and water chemistry. The following recovery actions are necessary to restore or protect one or more critical features of Atlantic salmon habitat.

1.1 Protect hydrologic conditions to ensure instream flows (volume, velocity, depth, temperature) adequate for Atlantic salmon

The rivers within the range of the DPS have inherent hydrologic differences. For example, there are significant groundwater sources within the Narraguagus River watershed but not in the Machias, East Machias and Dennys watersheds (MSPO 2001). In addition, each of the DPS river watersheds has different land usage patterns. The five salmon DPS river watersheds in eastern Maine are dominated by forestry and agriculture, including blueberry production. The Ducktrap and Sheepscot river watersheds have a greater proportion of agricultural land, including numerous dairy farms. Dams are found on some of the DPS rivers, particularly near the headwaters. For example, the flow of the Dennys River has historically been managed to enhance salmon habitat using releases from a headwater dam located at the outlet of Meddybemps Lake. The annual flow cycle for DPS rivers includes the following general seasonal trends:

- peak flows in April in response to snow-melt and spring runoff
- decreasing flows from the spring runoff through late August
- lowest flows from late July to mid September
- increasing flows in response to typical fall rains (October-December)
- decreased runoff in January and February, when most precipitation remains on the ground as snow

Figure 9 illustrates annual flow patterns in four of the DPS rivers as relative flow (mean monthly flow expressed as a proportion of the mean annual flow). Peak runoff occurs in April in all four rivers with a mean April discharge that is nearly 2.5 times the annual mean except in the Sheepscot River, where relative flows are somewhat higher. Summer flows in all of these rivers fall to well under half the mean annual flow, with August and September flows in the Sheepscot River at about twenty percent of the mean annual flow. The Dennys River has the highest summer flow in relation to the annual mean. Relative flows increase through the fall and peak at 1.3 times the mean in December, except for the Dennys River which has a somewhat lower relative flow. January and February flows in all four rivers are, on average, very close to the mean annual flow.

The potential impacts of hydrologic manipulation for irrigation was identified as a primary threat to the DPS in the final listing determination (see page 1-17; 65 FR 69459; NMFS and FWS 1999; MASCP 1997). The potential for water withdrawal to adversely affect the adequacy of instream flows for Atlantic salmon (volume, velocity, depth, temperature) should be assessed and continuously monitored.

Currently available techniques to assess and monitor the impacts of water withdrawals on Atlantic salmon include: standard setting method (FWS instream flow policy-aquatic based flow), incremental flow instream studies (IFIM), Habitat Suitability Index (HSI) models, stream gage data, low flow studies, stream flow analysis conducted as part of Maine's water use management planning (WUMP) iniative and precipitation and rainfall data.

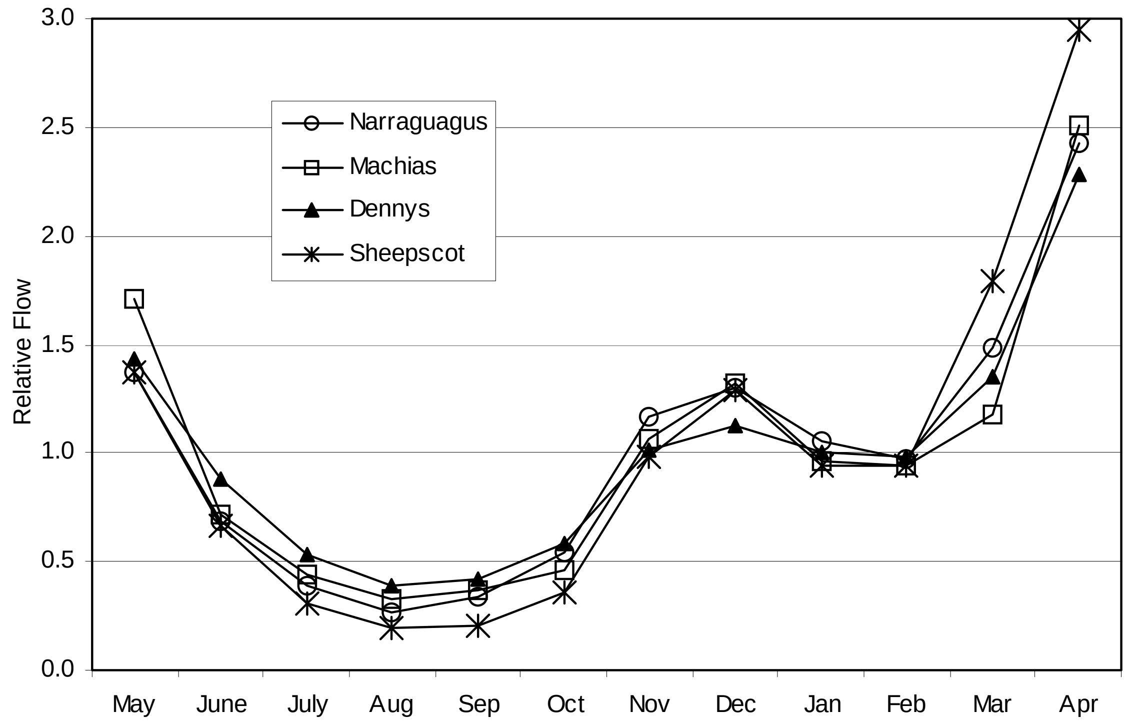


Figure 9: Mean monthly flows for the Narraguagus, Machias, Dennys and Sheepscot Rivers, normalized as relative flow. Relative flow is the mean monthly flow expressed as a proportion of the mean annual flow for each river (Q_M/Q_A). Mean monthly flow data are USGS flow statistics from 1949-2000 (Narraguagus), 1949-1977 (Machias), 1955-1998 (Dennys) and 1939-2000 (Sheepscot).

Standard setting techniques, including FWS' New England Flow Policy, use historical flow records to establish protective flows. The FWS uses the median August flow (often estimated to be 0.5 cfs/sq.mi. of drainage area in the absence of actual long-term gaging records). This is commonly referred to as the Aquatic Base Flow (ABF). Similarly, FWS uses a standard fall/winter flow to protect spawning adults and overwintering eggs and larvae.

Instream flow incremental methodology (IFIM) studies utilize morphological characteristics of the stream channel in representative river reaches to predict the availability of habitat at various water levels. IFIM studies have been conducted for Mopang Stream (a major tributary of the Machias River), Narraguagus and Pleasant rivers (see page 1-20). Within an IFIM study, only variables related to the channel morphology and discharge (depth, velocity, cover, substrate embeddedness) are used. ABF or other standard setting techniques can be pro-rated based on drainage area, and applied over a wider geographic area than IFIM.

Habitat Suitability Index (HSI)[28] models are used within the IFIM study to evaluate salmon habitat at the reaches where hydraulic modeling was done for various flow regimes (e.g., low, medium, high). HSI models were developed as part of the FWS' Habitat Evaluation Procedures (HEP). HSI models cannot be used independently, they require data from the stream reaches being evaluated. HSI models include habitat quality assessments for water quality variables (temp, pH, turbidity) that are not used in classic IFIM studies. HEP evaluations are typically conducted for habitats other than rivers and streams (e.g., wetlands). IFIM techniques are the more commonly used approach for evaluating the relationship between habitat and changing flows. The results of IFIM and HSI studies help establish the relationship between stream flow and habitat availability.

Stream gages provide real time stream flow data. Stream gages can be used to determine when stream flow is nearing levels inadequate for Atlantic salmon if the gages are located in stream reaches where IFIM studies have been conducted. Stream flow conditions can only be assessed directly for habitat near stream gages. If stream gages are used to evaluate the effect of irrigation, the distance between the withdrawal reach/point and the stream gage must be known. The USGS, in cooperation with ASC and the Maine Geological Survey (MGS; a bureau within the Maine Department of Conservation), is conducting a multi-year study of low-flow characteristics of streams in eastern and northern Maine. The purpose of the study is to develop regression equations that can be used to estimate low-flow statistics at any ungaged location. The regional low-flow criteria for aquatic habitat currently in use may not be applicable to streams in specific areas of Maine. The low-flow data collection by USGS/MGS will help build the database on historic flows, from which long-term averages can be obtained and applied. Management and effective utilization of water resources could be improved if more accurate, locally-based, low-flow estimation techniques were available (USGS 2002).

As part of the State of Maine's WUMP initiative, Horsley and Witten (H & W), a private consulting firm, was retained by the ACOE to model the likely impacts of water withdrawals on Atlantic salmon habitat. The H&W model provides estimates for baseflow and total flow in the watershed basins covered by the WUMP. The results of the H&W model were used by the WUMP advisory group to help develop the hierarchical water use strategy for water withdrawal recommended by the WUMP (see below).

An evaluation of currently available hydrologic data should be conducted to ensure the data currently being collected is adequate to assess and monitor the potential impacts of water withdrawals on the DPS. This analysis should include consideration of what additional data are needed to ensure effective monitoring and management of water withdrawal impacts on Atlantic salmon.

[28] HSI models are developed based on a number of relevant factors including water quality and observed densities of juveniles. Habitat is ranked on a 0 (unsuitable) to 1(optimally suitable) scale. HSI models can be used as a hypothesis of species-habitat interactions and are based on the assumption that high quality habitat is correlated with a high carrying capacity.

1.1.1 Determine instream flow requirements for Atlantic salmon in additional DPS rivers

The flow requirements of Atlantic salmon need to be determined for all DPS rivers. Instream flow requirements for juvenile Atlantic salmon have been determined for rivers where IFIM studies were undertaken. The State of Maine, through the WUMP initiative, conducted IFIM studies to evaluate the effects of low, medium and high flow discharge periods on availability of juvenile habitat. Using IFIM, the flow requirements of juvenile Atlantic salmon have been assessed in the Narraguagus and Pleasant rivers and Mopang Stream as part of the WUMP (MSPO 2001). In addition, ASC completed an IFIM study for the Dennys River in 2002. The report will be used to help manage river flows to protect salmon habitat. IFIM studies may need to be conducted on additional rivers within the DPS. Conducting IFIM studies in additional DPS rivers will allow researchers to determine flow requirements for juvenile Atlantic salmon in these rivers. Conducting additional IFIM studies will help establish flows protective of Atlantic salmon needs, particularly if done in connection with proposed permits (i.e., site-specific).

The information collected through these studies will assist in determining both Atlantic salmon flow requirements and natural hydrographic conditions for DPS rivers. Knowing Atlantic salmon flow requirements will enable managers to set water withdrawal permit requirements that are protective of Atlantic salmon (see below). This information is also an integral component of determining the effect of water withdrawal on flows in DPS rivers.

The effect of alternative flow regimes on adult habitat currently cannot be assessed through IFIM studies. The available data are for juvenile rearing habitat. There are no HSI models for adults to be used in an IFIM study. There are general ways to model the effect of discharge on adult passage and holding zones. The need to conduct studies to determine flow requirements of adult Atlantic salmon in DPS rivers should be evaluated.

Recovery Actions:

1.1.1A Conduct IFIM studies on additional DPS rivers to determine flow requirements of juvenile Atlantic salmon

1.1.1B Determine flow requirements of adult Atlantic salmon in DPS rivers

1.1.2 Monitor surface and groundwater hydrology for DPS rivers

Surface and groundwater hydrology should be analyzed and monitored for all DPS river watersheds with the DPS. The collection of hydrological and habitat/flow data is needed to assist in recovery and conservation efforts. The USGS has collected flow data at locations on many of the DPS rivers for different periods of record. The most extensive and up-to-date data are for sites on the Narraguagus, Machias, Dennys and Sheepscot rivers. Some data are also available for the East Machias and Pleasant rivers. Analyses of these flow data are ongoing and should be continued to assess and enable detection of changes over time or hydrologic differences between the rivers that may affect salmon recovery efforts. For example, analyses of these data by the USGS document an earlier spring runoff in recent years (Dudley and Hodgkins 2002).

The USGS maintains stream gages on several of the DPS rivers. Stream gages provide important data about hydrological conditions. The USGS stream gages on the Narraguagus, Pleasant, Machias, Sheepscot, Dennys and Ducktrap rivers should continue to be maintained. These gages are needed to determine whether minimum flow requirements are being met. Monitoring data should be compiled in a single database. These data should be compiled in a timely manner to facilitate assessment of stream flow conditions. The need for a stream gage on the East Machias River should be evaluated.

An effective flow monitoring strategy should be developed and implemented. This flow monitoring program should include river specific monitoring plans to assess stream discharge data at points along the rivers in addition to gage-sites. A quality control plan should be developed and implemented to assure standard methods for data collection and reporting at all monitoring sites. In addition to providing hydrological information, gage data can help managers monitoring water withdrawal permits to determine if conditions are being met.

Groundwater monitoring programs should be developed and implemented for all DPS river watersheds. As irrigation shifts to groundwater sources and ponds that are hydrologically distant from riverine surface waters the effects are more subtle and may be spatially and temporally distant from the withdrawal. While there are data on stream discharge, well levels, irrigation withdrawals and rainfall at a variety of locations throughout the DPS river basins Downeast, there are no analyses that link these monitoring points together to help determine if and how stream discharge may be affected by irrigation. Without that analysis the effect on habitat cannot be evaluated. Groundwater monitoring data should be archived in a central database accessible to state and federal managers.

Currently, LURC requires permits for groundwater withdrawals. Permits should require impact assessments (well tests) and monitoring to avoid adverse effects on nearby surface waters. Groundwater monitoring programs should focus on aquifer connectivity. Shifts in irrigation techniques by the blueberry industry from direct withdrawals from rivers to wells makes groundwater withdrawal an important consideration when collecting hydrological information in the DPS. The potential for groundwater withdrawals to impact stream flow and cold water discharges should be evaluated and monitored.

Recovery Actions:

1.1.2A Continue analyses of historical flow data for DPS rivers to assess changes over time or hydrologic differences between the rivers that may affect salmon recovery efforts

1.1.2B Maintain existing USGS stream gages on DPS rivers

1.1.2C Develop and implement an effective flow monitoring program in addition to gage-sites to monitor stream flow and discharge data at points along rivers

1.1.2D Monitor and assess the potential for groundwater withdrawals to impact stream flow and cold water discharges

1.1.2E Continue ongoing multi-year study of low flow characteristics of streams in eastern and northern Maine

1.1.3 Assess the impact of current water withdrawals on instream flows and on Atlantic salmon and monitor future water use and demand

The threat of insufficient water in DPS rivers is significant and may be exacerbated water withdrawals in summer months when natural flow conditions are already low. Irrigation is the most common use of water withdrawn from DPS river watersheds. Excessive withdrawal of water directly from rivers or from groundwater connected to rivers has the potential to adversely affect Atlantic salmon. The effect of water withdrawals on Atlantic salmon should be continually assessed and monitored. Water use and demand should also be monitored.

The State of Maine has developed a water use management plan (WUMP)[29] for the Narraguagus and Pleasant rivers and for Mopang Stream (MSPO 2001)(see page 1-20). Current demand for irrigation water by large blueberry growers is estimated in the WUMP for the three river basins covered by the plan. While there are too many factors involved to project future water demand with any confidence, it is likely that irrigation in the Pleasant, Narraguagus and Mopang river basins will increase. The WUMP should be fully implemented. The effectiveness of the WUMP in ensuring that water withdrawals are adequately managed and protective of Atlantic salmon should be continually monitored and evaluated.

As noted, the WUMP provides estimated water demand for large blueberry growers within the river basins covered by the plan. Limited data are available on the current irrigation water demand of small and medium sized blueberry growers. In order to effectively manage and minimize adverse affects on Atlantic salmon and their habitat, total water demand should be assessed for all users. The State of Maine should prepare an annual report on current and projected water withdrawals each year as part of efforts to monitor and assess all water withdrawals within the three river basins addressed by the WUMP.

---

[29] As noted (page 1-20) the WUMP identifies a hierarchy of water supply alternatives and ranks these alternatives based on an assessment of potential threats each poses to Atlantic salmon habitat. Based on this assessment, the WUMP recommends utilizing groundwater sources first, followed by water storage options. Under the WUMP, surface water withdrawal is the least preferable alternative. The WUMP relies primarily on non-regulatory voluntary actions of water users in carrying out irrigation strategies intended to minimize potential impacts on instream flows.

While there is currently little or no water withdrawn from rivers outside the three covered by the WUMP (with the possible exception of the Sheepscot) this could change over time. Water management plans for other watersheds should be developed. These plans should be a means to assess current water use and demand and estimate effects on salmon and salmon habitat. Consideration should be given to balance the needs of water users with natural resources, including salmon. Water management plans should include information on natural hydrological conditions, current water demand projected growth and proposed means to manage for sustainable water withdrawals. As noted, population growth and development in Maine has accelerated in recent years, especially in the mid-coast region. This trend will undoubtedly result in changes in land use patterns and resource demands, including water use, that will need to be managed in order to protect salmon and their habitat.

The State of Maine has recently enacted legislation (LD 1488) that requires the Maine DEP to work with state, regional and local agencies to develop water use policies that protect the environment from excessive drawdown of water sources during low flow periods. This bill requires annual water use reporting beginning in December 2003. The bill also directs the Maine Board of Environmental Protection to establish water use standards protective of instream flows needed by aquatic life by January 2005. This bill should be fully implemented.

Recovery Actions:

1.1.3A Implement the Downeast Salmon Rivers Water Use Management Plan (WUMP) for the Pleasant and Narraguagus rivers and Mopang Stream

1.1.3B Determine the effects of current irrigation withdrawals by all growers on flow and Atlantic salmon

1.1.3C Assess and monitor other agricultural water use needs and demands within DPS river watersheds

1.1.3D Develop water use management plans for other DPS rivers

1.1.3E Continue periodic assessments of irrigation methods and water demands and their potential effects on hydrology and Atlantic salmon habitat

1.1.4 Ensure that water withdrawals do not adversely affect Atlantic salmon

Water withdrawal permits should be conditioned so that they are protective of Atlantic salmon habitat[30]. Permitees should not be authorized to withdraw water to a level where flow is below what is needed by Atlantic salmon. In rivers where IFIM studies have been completed, the information to set protective permit requirements is available. Some blueberry producers have

[30] Existing water withdrawal permits issued by LURC and the ACOE for blueberry growers use the FWS ABF flows.

voluntarily agreed to cease withdrawals when flows drop below a critical level identified by IFIM studies. The results of IFIM studies should be incorporated in state/federal permits and monitored for compliance. No withdrawals should be authorized if stream flow is at or below the August median.

Water withdrawal permits are issued by LURC in unorganized territories. In organized townships, Maine DEP has the authority to issue water withdrawal permits but does not currently do so. This results in unregulated water withdrawals in areas under DEP's jurisdiction. Maine DEP should issue water withdrawal permits with requirements protective of Atlantic salmon. Water withdrawal permits issued by LURC require that water withdrawal reports be submitted weekly. LURC should review these reports as they are submitted in order to detect any violations. All water withdrawal permits should require a monitoring/reporting component.

Recovery Actions:

1.1.4A Ensure that water withdrawal permit requirements protect stream flows required for the recovery and conservation of Atlantic salmon

1.1.4B Issue and enforce all appropriate permits for water withdrawals

1.2 Ensure water quality to support healthy and productive salmon populations

The ranges of water quality parameters that impact Atlantic salmon mortality and behavior are generally known (see Part One).

1.2.1 Review existing water quality standards for each river within the range of the DPS to determine adequacy to meet needs of Atlantic salmon

Existing water quality standards should be reviewed for each river within the range of the DPS to determine their adequacy to meet the needs of Atlantic salmon. The Maine DEP currently classifies all streams (third order and higher) according to coliform bacterial levels, aquatic life criteria and dissolved oxygen levels required to support biological functions (e.g., fish spawning). Aquatic life criteria are numeric measures of the diversity and abundance of benthic macroinvertebrate communities. In addition to numeric criteria there are provisions that apply to existing and designated uses and prohibitions against "anti-degradation". Existing Maine water quality regulations also specify criteria for discharges that alter pH, temperature and nutrient levels. All DPS salmon rivers maintain AA ratings, the State's highest water quality classification. The Sheepscot River meets the AA rating but did not attain satisfactory standards for bacteria and dissolved oxygen levels due to non-point source pollution.

The State of Maine does not have regulatory water quality standards specific to Atlantic salmon, with the exception of the provisions pertaining to designated uses and anti-degradation. The adequacy of current water quality standards as they relate to Atlantic salmon needs should be assessed. The need to develop standards (e.g., temperature, dissolved oxygen, turbidity, pH, alkalinity, nutrients and other important parameters) specific to Atlantic salmon requirements should be evaluated.

1.2.2 Identify and mitigate water quality threats to Atlantic salmon within the DPS

Research is needed on water quality threats such as the threat posed by non-pesticide organochlorines, other chlorine compounds, the link between pesticides and endocrine disruption and the link between acid deposition and toxic levels of aluminum. Acidification and endocrine disruption are two of the most significant water quality threats to Atlantic salmon in Maine (Maine TAC 2002). Research should include the following water quality issues:

- acid rain's effect on juvenile Atlantic salmon
- toxicity of low pH and aluminum
- agricultural practices and pH
- pesticides and endocrine disruption links
- chronic and acute effect of agrochemicals.

Stream acidification due to acid rain has a high likelihood of adversely affecting the recovery of Atlantic salmon in at least some Maine rivers (Maine TAC 2002). Acidification potentially affects the DPS through effects on parr/smolt transformation and smolt adaptation to seawater (see page 1-22). The impacts of acid rain on juvenile Atlantic salmon survival in DPS rivers should be evaluated. The best available data indicates that a risk to Atlantic salmon recovery is present (Maine TAC 2002). The Narraguagus, Pleasant, Machias, East Machias and Dennys rivers are the most vulnerable to acidification (Maine TAC 2002). Acidification of Maine Atlantic salmon rivers has been periodically investigated since the 1980s. Current data collection efforts are inadequate to fully characterize the risks. The TAC water quality committee recommended an intensive long-term water chemistry monitoring program on representative rivers. The measurement of water chemistry parameters is necessary to interpret the implications of changes in acidity on Atlantic salmon (Maine TAC 2002).

Potential opportunities to mitigate the effects of stream acidification should be identified. Various methods have been successful in the U.S., Canada and Norway. Available methods to mitigate acid rain require adding carbonate materials to the river or watershed. These mitigation techniques have been used in Canada to restore Atlantic salmon rivers. Lacroix (1996) applied crushed limestone to a small acidified brook in eastern Canada to assess the efficacy of this technique to mitigate the impacts acid rain on Atlantic salmon populations. Lacroix reported a lasting small increase in pH in the limed section of the brook and downstream over eight years (Lacroix 1996). Lacroix (1996) found that Atlantic salmon consistently dug more redds in the limed section of the brook. He found that age-0 salmon and brook trout densities were always greater in the limed sections of the stream versus the unlimed portion. Lacroix suggested that, alternatively, this preference might be due to the physical enhancement of spawning habitat rather than decreased acidity.

Most acid mitigation methods are expensive (such as the addition of lime to the entire watershed to increase the buffering capacity of the soils) or require that structures be built in streams (limestone infiltration beds). There are some low cost and low-tech approaches, such as the use of shells (such as mussel or clam shells from local seafood industries) in headwater streams. The shells decompose by physical and biological processes and increase pH buffering capacity and ambient calcium concentrations. The use of these techniques should be evaluated in Maine. The Services should work with ASC to identify a potential site to evaluate the mitigation of acid rain on Atlantic salmon populations. These mitigation techniques are short term solutions; the addition of carbonate to headwaters or to watershed soils only treats the symptoms of acid rain.

Control of air pollution is necessary to reduce the impacts of acid rain on the DPS. Available air and water quality data should be reviewed and sources of airborne pollutants, such as sulfur and nitrogen dioxides, identified. The impact of acid precipitation on the productivity of salmon in DPS rivers should be modeled. The Services should consult with the EPA to ensure all measures necessary to reduce sources of acid rain to levels that do not adversely affect the DPS are initiated.

In addition to acid precipitation, other human activities have the potential to alter the pH of DPS rivers and their tributaries. For example, the Maine Cooperative Extension recommends to blueberry growers the addition of sulfur to reduce soil pH if it is not within desired range of pH 4.3-4.8 (see page 1-23). Conversely, if the soil is too acidic growers are advised to use lime. Either of these practices can affect surface water pH. The available data suggests that soil acidity might also have a role in governing pH in streams (Mark Whiting, Maine DEP, personal communication). The potential effect of soil pH adjustments on stream water pH should be evaluated. The extent of the use of these practices by blueberry growers should be assessed. The ASC and FWS should work with the Maine Cooperative Extension Service to ascertain the extent to which this practice is employed by local landowners and monitor its potential to affect pH in adjacent salmon streams the DPS. Prior to modifications of soil acidity within DPS river watersheds, blueberry growers should notify appropriate state and federal agencies to enable appropriate monitoring of the potential impacts on the pH of adjacent streams.

Laboratory and field studies have demonstrated that low pH leaches aluminum and increases its toxicity to fish (see page 1-24). More study is needed on the biological effects of low pH and aluminum, particularly how it affects critical life stages such as smolts. Research is also needed on the synergistic effects of water chemistry parameters (pH, dissolved organic carbon, river discharge, water temperature, alkalinity), particularly the seasonal variation and influence of precipitation. This research will help in understanding the dynamics of pH/aluminum toxicity.

The effects of chemical contaminants on the DPS need further study. Based on the results of this research, strategies should be developed to mitigate and minimize any harmful effects from these contaminants. Some of these chemicals (e.g., propiconozol, hexazinone and methoxychlor) are known to be estrogen mimics that may disrupt the normal physiology of Atlantic salmon.

Endocrine disruption is a new field of study and many pesticides have not been studied. In addition, research has often focused on the active ingredient in the pesticide formulation. Some of the inert ingredients, including spreaders and emulsifiers (e.g., nonylphenols and phthalates) used in chemical formulations as carriers are now known to have endocrine effects. Because they are generally water soluble, these chemicals may get into the DPS rivers more readily than the active ingredient (Mark Whiting, Maine DEP, personal communication). More testing is needed of the effects of whole formula applications on fish. In addition, more sampling is needed to assess the occurrence of additional carrier compounds in DPS rivers.

Endocrine disrupting chemicals have been detected in DPS rivers. Given the wide-spread occurrence of known endocrine disrupting chemicals in Maine Atlantic salmon rivers, these chemicals have a high probability of adversely affecting Atlantic salmon recovery (Maine TAC 2002). While there are not sufficient water quality data to ascertain the extent of exposure of Atlantic salmon in Maine rivers and the potential affects these chemicals may have on the recovery of the DPS, the available evidence suggests that this issue may be important in recovery efforts (Maine TAC 2002).

Research is also needed to understand the chronic and acute effects of agricultural chemicals. Water quality monitoring has documented that hexazinone persists in the Narraguagus River at all times of the year and may come from contaminated groundwater. The other Downeast DPS rivers may have similar chronic hexazinone contamination. Resident fish from all DPS rivers should be sampled and analyzed for tissue residues and bio-chemical factors indicative of exposure to endocrine disrupting chemicals. Based on these results, additional investigations should be conducted.

Other agricultural chemicals may be present at low levels following typical application periods or after stormwater runoff events. The Board of Pesticides Control (BPC) and DEP are collaborating to assess the importance of pesticide drift in transporting trace amounts of pesticides into the DPS rivers. Initial results from 2001 suggest that pesticides are quickly diluted and transported away by stream currents (Mark Whiting, Maine DEP, personal communication). These results need to be confirmed by more quantitative and longterm monitoring. Water quality monitoring should document temporal and spatial patterns of agricultural chemical contamination in the DPS rivers (see below). Additional research is needed to identify which chemicals have physiological effects and how these effects may impact salmon recovery efforts, including the link between pesticides and endocrine disruption.

The Maine Cooperative Extension Service is developing Best Management Practices to help reduce spray drift from blueberry fields. The establishment of vegetated buffers could greatly reduce pesticide drift and bank erosion. This is recommended by draft BMP’s for spray applications, but there are currently no regulatory requirements or BMP standards for such buffers. The DEP should monitor and assess the efficacy of existing BMPs. DEP staff should work with blueberry growers and spray applicators prior to spraying to help ensure BMPs are employed to reduce spray drift. Cherryfield Foods, Inc., the largest of the blueberry growers in Downeast Maine, is planting evergreen buffers between blueberry fields and adjacent areas. The

State should consider providing more assistance to blueberry growers to help them with environmental compliance issues.

Maine Department of Transportation (MDOT) does not use herbicides for the control of roadside brush in the Downeast DPS rivers. This policy should be implemented in the other salmon river watersheds as well.

Non-pesticide organochlorines have been identified as a potential threat to Atlantic salmon (Maine TAC 2002). These compounds include furans, dioxins and planar polychlorinated biphenyls (PCBs). In the DPS, non-pesticide organochlorines are known to be present in the Dennys Rivers below the Dennys River Eastern Surplus Superfund (DRESS) site (see page 4-27). A NOAA Fisheries study is slated to examine the role of pesticides in amplified gene expression in Atlantic salmon parr from affected and unaffected sites on the Dennys River. Further research on the mechanisms of exposure, uptake and effect of non-pesticide organochlorines on Atlantic salmon should be undertaken (Maine TAC 2002).

The effects of chlorine compounds on salmon olfactory senses and homing behavior is currently unknown and should be studied (Maine TAC 2002). While the potential effects of chlorine compounds on Atlantic salmon are unknown, the density of overboard discharges (OBD)[31] in Cherryfield on the Narraguagus River, is a matter of concern to salmon recovery efforts in this watershed (Maine TAC 2002). OBDs use chlorine tablets (calcium hypochlorite) in the chlorinator unit.   There are thirty-seven OBD units in Cherryfield. OBDs in rivers other than the Narraguagus should also be assessed to determine the extent and level of threat to the DPS.

Since 1987, the construction of new OBDs has been prohibited in Maine. In 1990, the Maine OBD program was initiated by the State legislature (38 MRSA Section 411-A) to help fund replacement systems that would eliminate OBDs in certain areas. Currently, the focus of the replacement program is in shellfish areas that would be open to shellfishing if the OBDs were removed. Maine DEP is responsible for annually inspecting all OBD systems and generating a priority list for replacement. In addition to DEP, the Farmers Home Administration and the Maine State Housing Authority can provide grants or low interest loans to towns or community groups for replacement of OBDs. This program to replace OBDs with less environmentally harmful wastewater treatment systems should be continued.

Recovery Actions:

1.2.2A Evaluate the impacts of acid rain on juvenile Atlantic salmon survival in DPS rivers

---

31 An overboard discharge (OBD) is an alternative wastewater treatment system for sites where municipal sewer connection is not possible and where a traditional septic system is not feasible. The simplest kind of overboard discharge (OBD) is a holding tank with a chlorinator for the overflow pipe (Maine TAC 2002).

1.2.2B Identify available management measures and techniques to mitigate the potential impacts of acid rain on the DPS. Experimentally evaluate stream acidification mitigation techniques in a natural river system within the range of the DPS

1.2.2C Identify point sources of airborne pollutants contributing to acid precipitation that may be adversely affecting the DPS and reduce to levels that will not adversely affect or jeopardize the recovery of the DPS

1.2.2D Model the impact on air and water quality issues, especially acid precipitation, on productivity of salmon in DPS rivers

1.2.2E Evaluate current agricultural practices such as soil acidity management practices to determine whether they may affect pH levels in DPS rivers

1.2.2F Evaluate the biological effects of low pH and aluminum and its toxicity on Atlantic salmon

1.2.2G Sample resident fish from all DPS rivers and analyze them for tissue residues and bio-chemical factors indicative of exposure to endocrine disrupting chemicals.

1.2.2H Evaluate the chronic and acute effects of agricultural chemicals on Atlantic salmon and how they may impact salmon recovery efforts

1.2.2I Identify and consider appropriate management measures and techniques to mitigate the potential impacts of agricultural chemicals and other contaminants on the DPS

1.2.2J Evaluate the link between pesticides and endocrine disruption

1.2.2K Conduct research on the mechanisms of non-pesticide organochlorines exposure, uptake and effect in rivers where these contaminants are known to occur including, the Dennys below the Superfund site

1.2.2L Continue State program to replace OBDs

1.2.3 Develop and implement a water quality monitoring program for DPS rivers

A comprehensive and integrated long-term water chemistry monitoring program on all DPS rivers should be initiated. The water quality of the main stems of the DPS rivers is well characterized. Historically, water quality data have been collected by several state and federal agencies throughout the range of the DPS. Water temperature measurements have been the most common type of data collected. Extensive pH and alkalinity data have also been collected in some of the DPS river watersheds as part of various research and monitoring programs. These data have been collected using different methodologies and dissimilar quality control and quality assurance procedures. Historical water quality data lack adequate temporal and spatial coverage to document significant trends in water chemistry or biological activity. The Maine DEP has compiled the available historic water quality data for the DPS rivers and is managing the information. These data should be reviewed for consistency and quality, assembled into a comprehensive computer-searchable database and made available to resource managers and researchers.

Since 1999, the DEP has coordinated a water quality monitoring program for each of the eight salmon rivers (MASC 2000). The current program monitors temperature, dissolved oxygen, turbidity, pH, alkalinity, macroinvertebrates, nutrients and a suite of agricultural chemicals. These data provide an important baseline for understanding long-term water quality trends. Recent water quality sampling efforts have focused on monitoring stormwater runoff. Efforts have also focused on measuring water quality of tributaries and headwaters. These data are stored in a central database maintained by the DEP.

The current water monitoring program should be reviewed to ensure that data collection is adequate to document and monitor regional patterns among the DPS river watersheds, intra-basin patterns (e.g., headwater to mouth), tributary-specific water quality (e.g., tributaries with poor or exceptional water quality), long-term trends and episodic events such as spring runoff and storms. DEP sampling locations should be geo-referenced using the interagency “River Kilometer” system. Periodic sampling of a limited set of parameters may be adequate for some water quality monitoring while comprehensive data collection at long-term index sites is required for other water quality monitoring issues. The current water quality monitoring should be continued. Where appropriate, water quality monitoring and data collection programs may be conducted by local conservation groups with technical support to ensure adherence to sampling and reporting protocols.

The Water Resources Center at UM also conducts water quality research on the DPS rivers. The George Mitchell Center at UM is doing high resolution studies of pH, aluminum and other chemical parameters using automated samplers (ISCO samplers). Water quality data from these studies should continue to be integrated into the Maine DEP database.

The potential for water temperature elevation in the vicinity of blueberry processing water discharges has been identified as a water quality issue (see page 1-32). Water temperatures in the vicinity of such discharges should be monitored to assess the potential to adversely affect Atlantic salmon.

Recovery Actions:

1.2.3A Implement a comprehensive and integrated long-term water chemistry monitoring program on all DPS rivers

1.2.3B Monitor water temperatures in the vicinity of blueberry process water discharge sites on the Machias and Narraguagus to assess the potential impact on Atlantic salmon

1.2.4 Prepare and implement plans to reduce pollution

Pollution problems in DPS rivers are generally not attributable to a single point source but are due to cumulative effects of many sources within individual watersheds (Maine TAC 2002). Water quality in the DPS rivers is generally good (see page 1-19). However, several non-point source and point source pollution problems exist.

The Maine DEP has identified numerous non-point sources of pollution as well as unlicenced discharges (e.g., septic systems) within DPS river watersheds. Local groups (i.e., watershed councils, Project SHARE), with the assistance of state and federal biologists, have also completed non-point source assessments on most of the DPS rivers including the Narraguagus, Pleasant, Sheepscot, Dennys, Machias and Ducktrap rivers. The watershed councils' NPS assessments have focused on identifying sources that could have a direct effect on critical salmon spawning or nursery areas. Plans should be developed and implemented to reduce these threats.

For example, the Narraguagus River Watershed Council has developed a comprehensive watershed management plan to address NPS pollution within this watershed. This management plan is based on the results of the NPS survey the watershed council conducted of the Narraguagus River. Several other watershed councils are considering preparing similar plans to address NPS problems within their respective watersheds. State and federal agencies should work with local groups to help develop and implement watershed management plans for DPS rivers. State and federal agencies should provide technical assistance to local groups in the planning, design and implementation of projects to remediate NPS pollution.

As noted (see page 1-62), the EPA delegated authority to the State of Maine to administer the CWA NPDES program, including responsibility for issuing federal national wastewater discharge permits. All future permits for discharges from aquaculture facilities will be issued by the Maine DEP. The Services consulted with EPA on the effect of the delegation of the NPDES program on the DPS. The Services' concerns included the accidental release of farmed Atlantic salmon.

The permit conditions proposed by the State of Maine will require facilities to limit the use of certain chemicals and develop standards that will reduce the nutrient pollutant load; including a reduction of phosphorous discharge by up to 90%. The new permit conditions set forth by the State will be based on the State's water classification standards set by Maine DEP (Maine TAC 2002).

Until recently, EPA has not administered discharge limitations and standards for commercial, state and federal aquaculture operations. Wastewater and effluent discharges from aquaculture facilities can adversely affect freshwater, estuarine and marine environments. EPA is working to develop national discharge standards for commercial and public aquaculture facilities. These standards are intended to reconcile inconsistencies between state regulatory agencies and reduce nutrient loading and adverse water quality impacts due to wastewater and effluent discharge from aquaculture operations. EPA anticipates promulgating new regulations by 2004. These regulations should be fully implemented.

The Maine DEP has provided financial assistance to local groups for projects to reduce NPS pollution through the Section 319 grant program of the Clean Water Act (CWA). Section 319 of the CWA provides states, territories and tribes with grants to implement NPS pollution controls described in approved state NPS pollution management programs. Section 319 grants support a wide variety of activities including technical and financial assistance, training, demonstration projects and monitoring to assess the success of specific NPS pollution mitigation projects.

Hazardous waste sites (i.e., landfills, junkyards, superfund sites) pose a potential threat to water quality within the DPS. The DEP and the watershed councils are planning on sampling surface water near landfills in the Cove Brook, Narraguagus and Machias river watersheds in 2002. The Dennys River Eastern Surplus Superfund (DRESS) site in Meddybemps and nearby Smith junkyard[32] threaten water quality in the Dennys River. PCBs have been found in the Dennys River below the DRESS site in Meddybemps (Mierzykowski and Carr 1998). The Superfund site is in the latter stages of remediation. These remediation efforts should continue to be monitored. Hazardous waste material remains on-site nearby at the Smith junkyard despite significant fines and regulatory efforts to clean up the site. Federal, state and local governments should cooperatively work to permanently close the junkyard, address any groundwater problems and restore this severely degraded site.

Recovery Actions:

1.2.4A Prepare and implement NPS pollution reduction plans for DPS rivers

1.2.4B Prepare and implement point source pollution reduction plans for DPS rivers

1.2.4C Fully implement EPA aquaculture wastewater and effluent discharge regulations

1.2.4D Continue monitoring of the remediation efforts at the Eastern Surplus Superfund site in Meddybemps

1.2.4E Address any groundwater problems at the Smith junkyard on the Dennys River and restore the site

[32] The Smith Junkyard has been proposed for listing as a superfund site by the EPA.

1.3 Ensure timely passage for each life-stage, including connectivity of spawning and nursery habitats, downstream passage for smolts and upstream passage for returning spawners

Historically, man-made dams were a major cause of the decline of Atlantic salmon runs in Maine (Baum 1997). Most man-made obstructions to fish passage on DPS rivers have been removed or breached and no longer restrict salmon migration.

1.3.1 Assess fish passage at dams, fishways and weirs currently in place and repair or improve as needed

The Coopers Mills Dam on the Sheepscot River restricts access to Atlantic salmon spawning and rearing habitat. Improving fish passage at Coopers Mills Dam will reconnect habitats and help assure accessibility to spawning and rearing habitats. IFW, DMR and the Town of Whitefield (which owns the dam) should repair the dam and improve fish passage around the dam or remove the dam.

The Stillwater Dam on the Narraguagus River is equipped with a fishway. Fishways are also present at some natural obstructions within the DPS. At Saco Falls on the Pleasant River, a fishway exists that was constructed to improve existing fish passage above the natural falls. With salmon runs in the Pleasant River being in critical condition, every effort should be made to maximize the opportunity for spawning escapement within the river. ASC should evaluate the need to repair the existing fishway at Saco Falls to improve upstream passage for salmon in order to ensure that salmon have access to upstream habitat. Repairs were slated to begin in Fall 2002 but have not yet been completed.

The efficiency of existing fishways on DPS rivers has not been well documented (Baum *et al.* 1992). The ASC, in cooperation with the state and federal agencies should assess the adequacy of existing fishways to provide up- and downstream passage for Atlantic salmon. Where necessary, fishways should be repaired and maintained.

The potential for weirs to restrict fish passage should be assessed. Little is known about the potential of weirs to delay adult salmon migration. Weirs may potentially deter salmon from continuing upstream or critically delay migration. Weirs may also increase the risk of predation on migrating salmon. Investigations into these issues should be conducted.

Recovery Actions:

1.3.1A Repair or remove the Coopers Mill Dam to improve fish passage around the dam

1.3.1B Evaluate the need to repair the existing fishway at Saco Falls

1.3.2 Identify and improve culverts or other road crossings that impede salmon passage

In addition to dams, poorly designed culverts and bridges can restrict salmon migration. These structures can act as barriers to passage for salmon of varying lifestages by altering natural flow regimes and affecting water depth and velocity.

1.3.3 Identify and manage natural debris jams (including beaver dams) that impede salmon passage

Beaver dams and debris blockages can impede salmon passage and restrict access to spawning and rearing habitat. Currently, biologists and volunteers remove debris jams on DPS rivers and tributaries as time permits. The ASC and FWS should continue to identify areas where beaver dams impede passage to spawning habitat and work with the watershed councils to breach dams in these areas during the spawning migration. Breaching efforts are generally focused on impassable obstructions located downstream of spawning habitat (MASCP 1997). Breaching efforts should be timed to ensure that returning adult salmon are able to access spawning habitat. Current breaching activities appear sufficient to ensure adequate passage for current adult returns. Precautions should be taken to minimize potential negative ecosystem impacts to habitat and juvenile salmon when breaching these obstructions (e.g., sedimentation, increased turbidity).

The Dennys River Watershed Council has developed a plan to control beaver populations to enhance salmon habitat within Venture Brook. Dams will be breached and the recovery of salmon habitat within the stream will be monitored. As part of the project, an ecological assessment of the watershed was conducted including mapping existing habitat and documenting stream flow conditions. The results of this project should be monitored to determine the impact of beaver dam removal and beaver control on the improvement of habitat and Atlantic salmon recovery.

Debris jams can also impede salmon passage. Some debris jams are a result of human disturbances that result in the build up of large woody debris, whereas other debris jams are part of the natural processes that occur in river corridors. The ASC should continue to monitor debris jams and oversee their removal if necessary to provide access to spawning habitat.

1.3.4 Condition permits for activities within the estuaries of DPS rivers so as to minimize potential effects on migration of juveniles and adults

Dredging, construction of drainage systems and construction of culverts and bridges all have the potential to adversely affect Atlantic salmon in estuaries. These activities can result in increased sedimentation, suspension of toxic chemicals or other compounds present in sediments and changes to natural flow regimes (see page 1-28). These changes can disrupt the migration of juvenile and adult Atlantic salmon by creating physical, thermal and sediment migration barriers. Permits for these activities and other activities in estuaries that have the potential to affect the migration of Atlantic salmon should be condition to minimize the impact on migration.

1.4 Secure long term protections for freshwater and estuarine habitats

Long-term protections for freshwater and estuarine habitats includes protecting of the riparian zone as well as ensuring adequate water quality and quantity in the DPS river watersheds. Water quality and quantity are addressed in sections 1.1, 1.2, and 1.3.

1.4.1 Ensure long-term protection of riparian habitat

Vegetated riparian buffer zones should be established and maintained by using the most appropriate tool(s) for each specific situation. Partnerships among private landowners; state, federal, local, and Tribal governments; watershed councils and others will be key to implementing this action. Available tools include, conservation and management agreements, conservation easements, fee acquisitions, state and local land and water use regulations, voluntary BMPs, and other mechanisms to secure long-term protections of riparian and freshwater habitat and ensure that riparian functions are maintained into the future to support recovering salmon populations.

Vegetated riparian buffers provide shade, regulate temperature and stream flow, protect water quality and act as a source of woody debris and organic matter (Kleinschmidt 1999). Vegetated riparian buffers provide a number of functions important for maintaining salmon habitat. Naturally vegetated riparian buffer zones are critical to maintain the health of adjacent aquatic systems. Establishing and maintaining riparian buffers is an critical means of protecting Atlantic salmon habitat. Significant disturbances that alter riparian habitat adjacent to salmon rivers can result in degradation of salmon habitat (Kleinschmidt 1999). Activities that have the potential to degrade instream habitat include timber harvesting, road construction, agriculture and development (Moring and Finlayson 1996).

In 1998, the Maine State Planning Office (MSPO) prepared a methodology to determine minimum buffer widths to protect Atlantic salmon habitat. Otherwise known as the "Kleinschmidt Methodology," the study developed criteria to evaluate a host of physical characteristics of a given riparian zone and calculate a buffer width that is protective of the adjacent instream habitat. Depending upon slopes, soils, surface conditions, vegetative cover and tree canopy, an undisturbed protective buffer can be anywhere from 75 to 300 feet from the mean high water mark. This methodology establishes a scientific basis for determining riparian buffers adequate to protect Atlantic salmon habitat. This methodology is a tool that can be used to establish site-specific protective riparian buffers adjacent to important spawning and rearing habitat in cooperation with willing landowners.

The majority of riparian lands along DPS rivers and streams are in private ownership. Many landowners in DPS river watersheds rely on agricultural, forestry and livestock activities for their livelihood. It is critical that the Services, state and federal agencies, local government and local conservation organizations work with private landowners to provide information about salmon recovery efforts and protect riparian and freshwater habitat.

In Maine, both voluntary guidelines and regulatory measures exist to minimize potential adverse impacts to the aquatic environment and Atlantic salmon from activities within the riparian zone. These include local best management practices, shoreland ordinances, conservation easements, land acquisitions for the purpose of conservation protection and regulatory measures. Efforts to institute long-term protections for riparian and freshwater habitat should be continued.

The State of Maine and the timber industry have implemented regulatory and voluntary measures to minimize the impacts of activities within the riparian zone, including streamside harvesting, stream crossings, haul roads and erosion control techniques.

International Paper (IP) has established voluntary forest management standards that include limitations on timber harvest within riparian buffer zones. The measures establish variable riparian buffers dependent on the stream reach (1st and 2nd order streams - 100 foot buffer; 3rd order streams- 330 foot buffer; 4th and 5th order streams- 660 foot buffers). These measures include no cutting within 25 feet of water and no more than 30% of timber removed over ten years within the riparian zone.

The MFS has developed BMPs to minimize the impact of logging activities in the riparian zone on instream habitat. These BMPs are intended to reduce sediment and pollution inputs into bodies of water. Implementation of BMP recommendations is voluntary. BMPs have been adopted by many landowners and the timber industry. International Paper, for example, has BMPs that are implemented on all their lands in Downeast Maine. The MFS has produced a booklet on all their BMPs and this is used as guidance for all MFS projects and services. The application of sound riparian forest management and BMPs should continue to be encouraged. The MFS should evaluate compliance with voluntary standards and adoption and use of BMPs by landowners. The effectiveness of these practices and programs should be improved where needed. Forestry practices and their impacts should continue to be monitored to determine risk levels, identify threats and remediate impacts to Atlantic salmon and their habitat.

Local organizations and the State of Maine have worked with landowners over the past several years to secure long-term protection of riparian and adjacent instream habitat through conservation easements and direct fee acquisition of riparian habitat along DPS rivers. Conservation easements to protect Atlantic salmon habitat have been secured on most salmon rivers within the DPS. Existing conservation easements contain specific standards designed to preserve canopy, protect cold water inputs and encourage natural stream structure.

Conservation easements typically establish an undisturbed buffer by restricting certain activities from occurring in the riparian zone. Landowners may continue to use their property but agree to certain conditions designed to protect the functions and values provided by riparian buffers. Conservation easements are held by either a qualified state agency or land trust which is responsible for upholding the terms of the easement. If the land is sold, the restrictions run with the deed and continue to benefit the stream and its corridor. Securing appropriate conservation easements should continue to be pursued as a means of providing long-term protection to habitat within the riparian zones of DPS rivers.

Land acquisition is another method available to ensure long-term protection of riparian habitat. To date, ASC and several local conservation organizations including the Quoddy Regional Land Trust, the Downeast Rivers Land Trust, the Sheepscot Valley Conservation Association and the Coastal Mountains Land Trust have acquired riparian property that provides significant protection to instream habitat. Existing land acquisition efforts serve as potential models for protecting the long term viability of habitat on other DPS rivers.

In addition to voluntary BMPs, several laws regulate land use in the riparian zone. The Maine Shoreland Zoning Act regulates land use within 250 feet of rivers with watersheds of at least 25 square miles in drainage area. Where clearing of vegetation and timber harvesting are permitted, selective cutting of not more than 40% of the trees four inches or more in diameter in any ten-year period is allowed provided a well-distributed stand of trees and other natural vegetation remains. This statute also establishes protective standards for significant river segments including parts of the East Machias, Pleasant, Machias and Narraguagus rivers. These standards establish buffer zones around significant river segments that must be applied by each municipality to principle structures, new road construction and new gravel pits. Unorganized territories fall under LURC's jurisdiction. LURC has also established standards for clearing of vegetation and timber harvesting within the shoreland zone of rivers, streams, lakes and ponds.

Current state and local land use regulations should be evaluated to determine the adequacy of existing measures protecting riparian habitat. Where necessary, existing measures regulating activities within the riparian zone should be strengthened including monitoring and enforcement. In addition to regulatory measures, programs to promote better land use practices by local landowners should be continued and expanded.

Recovery Actions:

1.4.1A Provide long-term protection for riparian buffers through fee acquisition, conservation easements, conservation and management agreements, and other appropriate tools

1.4.1B Promote the adoption and use of BMPs by landowners and compliance with these voluntary standards

1.4.1C Evaluate the impacts on Atlantic salmon of activities that may affect riparian buffer zones

1.4.1D Evaluate current state and local land use regulations to determine adequacy of existing measures protecting riparian habitat and revise if appropriate

1.4.1E Enhance protection of riparian areas where necessary through expanded enforcement and modifications to the Natural Resource Protection Act, Forest Practices Act, LURC Zoning standards, and/or Municipal Shoreland Zoning

1.4.2 Protect estuarine habitat used by Atlantic salmon

Activities that have the potential to adversely affect Atlantic salmon should be evaluated and potential adverse impacts minimized. Estuarine habitat is used by both outmigrating Atlantic salmon smolts and returning adult Atlantic salmon. Atlantic salmon smolts are particularly sensitive during their transition to saltwater. Adult salmon are known to hold in estuaries during periods of low-flow in rivers.

Permits for activities in estuaries should be conditioned to minimize any adverse affects on Atlantic salmon and their habitat. Numerous activities can contribute to degradation of estuarine habitat. Activities that have the potential to disturb the estuarine environment include dredging, construction of culverts and bridges, construction of drainage systems and coastal zone development. Activities in estuaries can result in increased sedimentation, suspension of toxic chemicals or other compounds present in sediments, nutrient loading, changes to natural flow regimes and general habitat loss and degradation. Permit conditions can include time of year restrictions, methodology, monitoring and reporting protocols.

Dredging has the potential to adversely affect estuarine habitat in a number of ways (see page 1-29). To minimize the effects on Atlantic salmon, all dredging and/or construction activities in DPS river estuaries should be conducted in such a manner as to minimize the potential to adversely affect Atlantic salmon. Environmental parameters should be monitored throughout projects so that the rate and manner of activity can be adjusted to ensure minimum impacts on the estuarine environment.

Recovery Actions:

1.4.2A Evaluate the potential for activities in estuaries to adversely affect Atlantic salmon

1.4.2B Condition permits for activities within the estuaries of DPS rivers so as to minimize potential effects on Atlantic salmon

1.5 Restore degraded stream and estuarine salmon habitat

Many historical land and water use activities have altered, and in some cases destroyed, the habitat needed by Atlantic salmon for spawning, growth and migration (see page 1-18). There are many habitat restoration needs and opportunities within the DPS. These include stream channel restoration, enhancement of fish passage, riparian habitat restoration, bank stabilization, culvert repair and improved stream crossings. The Services should work with ASC and other organizations to identify, coordinate and implement necessary stream restoration activities. Habitat restoration opportunities in DPS rivers should be identified, catalogued and prioritized.

Restoration projects should be implemented to restore degraded habitat and maximize production of juvenile salmon in Maine rivers.

The ASC and FWS have surveyed Atlantic salmon habitat in all DPS river watersheds within the DPS. These data provide a substantial baseline inventory of current habitat in these watersheds. Further surveys are needed to assess how much habitat was available historically and to assess other elements of habitat suitability such as temperature, pH shading, and additional physical habitat parameters (e.g., substrate embeddedness). The existing physical habitat data should be integrated with habitat suitability data (See Stanley and Trial 1995).

Currently NOAA Fisheries researchers are working on a model that will enable the estimation of Atlantic salmon habitat within rivers for which stream surveys have not been conducted. The model predicts potential habitat/historic habitat within a watershed. The model incorporates stream gradient, valley slope, channel confinement (the ratio of valley width to channel width) and riparian vegetation land cover type within 100 m of the river as inputs.

The model is a landscape predictive model. The model evaluates the shape of the land to determine areas which may provide habitat if other factors are addressed. The landscape predictive model may be able to provide estimates of not only habitat quantity but also estimated quality. Because understanding the quality of existing habitat is an essential component of recovery efforts, efforts should be continued to use this model for this application.

1.5.1 Create regional hydraulic geometry curves and a reference reach database

The FWS, ASC, Maine DOC and USGS are conducting stream assessments in order to establish a regional curve for all Maine rivers. Regional curves relate the dimensions (width, depth, cross sectional area, velocity) of streams at bankfull discharge[33] to drainage area. This information is needed so hydrologists and biologists can evaluate modified stream channels and design appropriate stream channel restoration projects. While general physical characteristics of good juvenile Atlantic salmon habitat are understood, less information is available on the processes that maintain stable channels in Maine rivers. These geomorphologic processes, including sediment transport and deposit, are critical to maintaining stable and productive fish habitat (Hill *et al.* 1991; Leopold *et al.* 1992; McBain and Thrush 1997). A reference reach database will allow the identification of degraded and altered stream channels by determining the characteristics of a naturally stable stream in a particular watershed. Without regional curves, degraded stream channels are less likely to be successfully restored as high quality salmon habitat. Efforts to develop regional curves should be continued and completed.

---

33 The bankfull discharge is the "discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders and generally doing work that results in the average morphologic characteristics of channels" (Dunne and Leopold 1978).

1.5.2 Identify, catalogue and prioritize habitat restoration needs

Throughout the U.S., Canada and Europe, stream channel restoration and habitat enhancement projects have been implemented to restore damaged habitats to more natural conditions and recreate historic geographical and hydrological systems. Available stream restoration techniques include both soft engineering and other techniques that have been used to restore stream flow, bank stabilization and channel reconstruction.

Many restoration opportunities exist within the DPS river watersheds. Efforts to identify these opportunities are underway by state, federal and local organizations. The Services should work with these organizations to identify, catalogue and prioritize habitat restoration needs within DPS river watersheds.

Habitat restoration needs within the DPS river estuaries should be assessed to identify degraded habitat and restoration opportunities. These may include obstruction to fish passage or habitat quality problems that can be addressed to enhance the survival of Atlantic salmon within estuaries. Potential concerns include poorly constructed culverts that restrict fish passage and/or create sedimentation and other water quality issues (see section 1.3).

Local conservation organizations are often uniquely qualified to identify habitat problems and restoration opportunities. These organizations' knowledge of local conditions and communities makes them important partners in identifying and implementing habitat restoration opportunities. Locally initiated actions for watershed protection and management are often more widely accepted and more effective than regulatory intervention. The watershed councils should continue to work in collaboration with landowners, local governments, state and federal agencies, businesses and non-profit organizations to identify and, where appropriate, implement salmon habitat protection and restoration projects.

Recovery Actions:

1.5.2A Identify, catalogue and prioritize habitat restoration needs in DPS rivers

1.5.2B Identify, catalogue and prioritize habitat restoration needs in estuarine habitat of DPS rivers

1.5.3 Conduct high priority restoration projects

Based on the preceding identification and prioritization of habitat restoration needs, the Services in cooperation with state, federal and local organizations, should conduct high priority restoration projects. Many restoration activities are currently being implemented by state, federal and local organizations. For example, local watershed councils have focused their efforts on the restoration of degraded riparian areas. In the Sheepscot, Pleasant and East Machias river watersheds, volunteers have planted trees to stabilize soils and provide shade. Volunteers have also corrected improper road ditching problems and replaced road culverts at road crossings to reduce sedimentation and mitigate chronic erosion problems. On the Narraguagus and Machias rivers, two bridges have been built to provide ATVs an alternative to driving through streams.

1.5.4 Evaluate the potential of stream flow augmentation as a recovery tool to help meet Atlantic salmon flow needs and increase juvenile production and survival

The potential of flow augmentation to increase juvenile salmon survival and production should be evaluated. Augmenting winter flows has been shown to increase parr populations and improve pre-smolt survival (Hvidsten and Ugedal 1991; Hvidsten 1993). Flow augmentation was found to increase parr populations in Barrows Stream in the East Machias River drainage (Havey 1974). Augmenting summer flows increased parr populations in several case studies in Canada (Ruggles 1988) and Maine (Havey 1974). Flows in the Dennys River have been augmented with water released from Meddybemps Lake.

2. Minimize potential for take in freshwater, estuarine, and marine fisheries

2.1 Prevent Directed Take of Atlantic salmon

The intentional capture of Atlantic salmon is a violation of the ESA's Section 9 prohibition against "take" of Gulf of Maine DPS Atlantic salmon (65 FR 69479, 50 CFR 17.21). Under the ESA, the term "take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct.

2.1.1 Maintain and enforce the closure of the directed sport fishery for Atlantic salmon

In December 1999, the State of Maine adopted regulations prohibiting all angling for Atlantic salmon year round in Maine (12 MRSA § 9907). Under these regulations, it is unlawful to angle, take or possess any Atlantic salmon from all Maine waters (including coastal waters). This ban remains in effect. The closure in freshwater is enforced by the Maine Warden Service under the Maine IFW. The Maine Marine Patrol, under the Maine DMR, has jurisdiction over tidal waters, including coastal estuaries. The State should maintain and enforce the closure of the directed sport fishery for Atlantic salmon. It is believed that poaching activity occurs in Maine rivers (see page 1-34). Given the low numbers of returning adult salmon, any poaching is a significant threat. NOAA Fisheries and FWS each have a federal agent in Maine responsible for enforcing the provisions of the ESA. Continued enforcement efforts and adequate penalties are essential to help minimize the threat of poaching.

2.1.2 Maintain current FMP that restricts directed harvest of Atlantic salmon in U.S. estuarine and marine waters

Current regulations in place under the Atlantic salmon FMP that prohibit the direct harvest and possession of Atlantic salmon in the U.S. EEZ should be maintained (see page 1-35). The FMP was intended to safeguard U.S. Atlantic salmon, protect the U.S. investment in the state-federal restoration program and strengthen the U.S. position in international negotiations.

2.1.3 Continue international efforts to reduce threats from commercial fisheries outside of U.S. jurisdiction

Historically, a major source of Atlantic salmon mortality in the marine environment was the directed commercial fishery off the western Greenland and Canadian coasts (see pages 1-37 to1-38)[34]. These commercial fisheries have been greatly reduced but not completely eliminated as a source of mortality to Maine Atlantic salmon. The North American component of this mixed stock fishery[35] likely includes a high proportion of Canadian-origin salmon and a low proportion of U.S. salmon. Maine-origin salmon, including DPS salmon, are likely taken in low numbers in this fishery.

The NASCO is the international organization responsible for the management of Atlantic salmon in the North Atlantic Ocean. The NASCO pursues its goals by controlling the exploitation of Atlantic salmon by member nations. The NASCO consists of a Council and three regional Commissions: the North American (NAC), West Greenland and the Northeast Atlantic Commissions. The U.S. participates in the management activities of both the North American and West Greenland Commissions, as well as in the deliberations of the full Council. The U.S. participates in these international forums to manage the commercial harvest of Atlantic salmon at levels that ensure that adequate numbers of Atlantic salmon are available to meet conservation spawning escapement targets. The goal of these efforts is to ensure adequate escapement of Atlantic salmon to recover U.S. Atlantic salmon populations. The U.S. should continue to advocate for the precautionary, scientifically-based management of Atlantic salmon stocks through the NASCO process.

The NASCO is advised on catch and management options[36] for Atlantic salmon fisheries by the International Council for the Exploration of the Sea (ICES) Advisory Committee on Fishery Management. This management advice is based upon estimates of the pre-fishery abundance (PFA) of non-maturing 1SW salmon available for harvest, accounting for natural mortality and conservation escapement limits. The ICES advice to NASCO for 2002, as it has been in recent years, was that catch should approach or reach zero (ICES 2002).

---

34 Piscine and mammalian predation is another source of mortality on Atlantic salmon during the marine phase of this species life history. Recovery actions necessary to mitigate adverse impacts from predation to the recovery of the DPS are discussed below, pages 4-41 to 4-47.

35 Atlantic salmon are harvested when stocks originating from different countries are intermixed in the marine environment.

36 Catch options are calculated using probability of attaining spawning escapement targets of between 25% and 50%. In 2002, the available catch surplus at the risk neutral (50% probability) was approximately 50,600 fish (ICES 2002). Below the risk averse probability value of 30%, there were no salmon surplus to conservation escapement limits (ICES 2002).

In August 2002, the Greenland Home Rule Government and the Organization of Hunters and Fishermen in Greenland (KNAPK) jointly agreed to suspend all commercial fishing for Atlantic salmon within Greenland territorial waters. This agreement is renewable annually for up to five years and results in suspension of the commercial fishery for Atlantic salmon in Greenland. As noted (see page 1-37), the internal use fishery is not included in the agreement. The agreement was negotiated by the North Atlantic Salmon Fund, the Atlantic Salmon Federation and the National Fish and Wildlife Foundation.

U.S. participation in the international sampling program of the West Greenland fishery should be continued. Because the ocean intercept fisheries for Atlantic salmon are mixed-stock, it is important to know what proportion of this catch is U.S. origin fish and if possible, what proportion is DPS fish. One way to get this data is to sample catch from these international fisheries. Efforts by NOAA Fisheries have led to increased sampling of Atlantic salmon captured in the West Greenland fishery in recent years. The goal of this research is to estimate stock specific removal rates of the fishery and to improve our understanding of the impacts of the fishery on U.S. Atlantic salmon populations. Large-scale marking of Penobscot River origin Atlantic salmon (~170,000 marked smolts released annually) provides a method to assess West Greenland fishery impacts on Maine origin, although not listed, Atlantic salmon. While almost half of the Greenland commercial landings were examined for marks in 2001, only one marked Penobscot fish was detected, indicating that interception of Penobscot River origin fish occurs, but likely at low levels.

Efforts should be continued to establish a sampling program to determine the level of take and potential impact this fishery may have on the continued persistence and recovery of the Gulf of Maine DPS. A small commercial Atlantic salmon fishery occurs off St. Pierre et Miquelon and lands approximately 2-3 mt/year. There is great interest by the U.S. and Canada in sampling this catch to gain more information on stock composition. The NOAA Fisheries, working through the U.S. State Department, has sought to establish a sampling program in St. Pierre et Miquelon similar to the one being conducted in West Greenland.

Recovery Actions:

2.1.3A Participate in international salmon management with the goal of ensuring any quotas set are based on the best available scientific data and provide adequate protection of U.S. stocks

2.1.3B Continue U.S. participation in the international sampling program at West Greenland

2.1.3C Continue efforts to implement a biological sampling program at St. Pierre et Miquelon to determine the origin of Atlantic salmon captured in this fishery

2.2 Avoid bycatch of Atlantic salmon

The incidental capture of Atlantic salmon is a violation of the ESA's Section 9 prohibition against "take" of Gulf of Maine DPS Atlantic salmon (65 FR 69479, 50 CFR 17.21). Incidental take is defined as take that is incidental to, and not the purpose of, carrying out an otherwise lawful activity. Juvenile and adult Atlantic salmon may be incidentally taken as bycatch in DPS rivers by state permitted recreational anglers fishing for other freshwater game fish species such as brown trout, brook trout and landlocked salmon (see page 1-35). There are recreational fisheries for marine species of fish (e.g., striped bass and American shad) that also take place in estuaries and in freshwater in DPS rivers. In marine and estuarine waters[37], these fisheries do not require that anglers have a license, they are regulated with size and bag limits. These fisheries generally fall under the jurisdiction of Maine DMR. These fisheries have the potential to incidentally capture DPS Atlantic salmon. There is currently no process in place to assess the number of Atlantic salmon caught as recreational bycatch or to estimate the mortality associated with this take (LWRC 1999).

2.2.1 Monitor, assess and develop methods to avoid bycatch in recreational and commercial freshwater fisheries

The State should assess the level of incidental take of Atlantic salmon in recreational fisheries through appropriate methods such as creel surveys, spot checks and voluntary reporting by anglers. Information should be collected on both the level of effort and amount of take. If necessary, additional measures should be considered to minimize this threat including gear restrictions (i.e., barbless hooks) and time and area closures to minimize the potential for the incidental take of Atlantic salmon.

The State has implemented a number of regulatory measures designed to minimize the potential for the incidental take of Atlantic salmon (see page 1-36). These measures include minimum size limits and seasonal restrictions. The State should review existing regulatory measures to assess their effectiveness in minimizing the incidental capture and injury associated with recreational angling in DPS rivers.

Given the extremely low Atlantic salmon population levels, the harvest (incidental or intentional) of any Atlantic salmon may adversely affect the DPS. Any measurable bycatch mortality could be high enough to cause harm to these populations (Maine TAC 1998). Deliberate targeting of Atlantic salmon by some anglers poses a serious threat to the recovery of Atlantic salmon populations and the DPS as a whole. The Services should work with the Maine IFW to close select cold water adult Atlantic salmon holding areas to all fishing where Atlantic salmon may be taken as bycatch or poached. All fishing should be prohibited in all highly utilized cold water holding areas until such time as wild Atlantic salmon populations have recovered sufficiently to withstand possible adverse impacts associated with incidental take by recreational anglers.

---

[37] There is a license required to take striped bass above the head of tide (i.e., in freshwater).

Under section 10(a)(1)(B) of the ESA, non-federal entities may apply for permits from the Services to take ESA-listed species if such taking is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. The Services should work with the State to develop a Section 10(a)(1)(B) conservation plan for recreational fishing permitted by the State. This plan should institute a reporting and monitoring program to better estimate incidental take of Atlantic salmon in recreational fisheries. This plan should assess the risk of incidental take and its impacts on the recovery of the DPS. This plan should identify specific measures that will be taken to minimize the potential for incidental take of Atlantic salmon by recreational anglers. Under the ESA, the permit shall be issued if: (1) the taking will be incidental; (2) the applicant will, to the maximum extent practicable, minimize and mitigate the impacts of such taking; (3) the applicant will ensure that adequate funding for the conservation plan will be provided; (4) the taking will not appreciably reduce the likelihood of the survival and recovery of the species in the wild; and (5) any other measures that the Services may require as being necessary or appropriate will be met.

The ASC and IFW have developed materials to aid anglers in identifying juvenile Atlantic salmon. These programs should be continued and expanded to minimize the threat of take associated with recreational fisheries.

The State should continue to monitor other commercial freshwater fisheries in order to ensure these fisheries do not incidentally take DPS salmon. Small scale commercial fisheries for species other than salmon are conducted in some DPS rivers. These fisheries may have the potential to incidentally take endangered salmon. Maine DMR staff monitor the elver fishery to assess potential bycatch of other species of fish including Atlantic salmon (see page 1-37). In recent years no incidental bycatch of either juvenile or adult Atlantic salmon has been observed or documented in elver nets. IFW and DMR permit alewife harvest by towns and/or individuals in some of the DPS rivers. The alewife fishery should also be evaluated and monitored.

Recovery Actions:

2.2.1A Assess the level of incidental take of Atlantic salmon by recreational anglers

2.2.1B Prohibit all recreational fishing in select areas utilized by Atlantic salmon as holding areas to all fishing where Atlantic salmon may be taken as bycatch or poached

2.2.1C Develop a Section 10(a)(1)(B) habitat conservation plan for recreational fishing permitted by the State that may incidentally take Atlantic salmon

2.2.1D Continue to monitor commercial freshwater fisheries where the potential for incidental take of Atlantic salmon exists

2.2.2 Monitor, assess and develop methods to avoid bycatch in other estuarine or marine fisheries under U.S. jurisdiction

The potential exists for juvenile and adult Atlantic salmon to be incidentally taken as bycatch in commercial and recreational fisheries targeting other marine and estuarine species (see page 1-36). The NOAA Fisheries should work with the State of Maine and the NEFMC to develop research programs necessary to assess this threat. Based on the results of these assessments, appropriate management strategies and regulatory measures to avoid bycatch of Atlantic salmon in estuarine and marine fisheries should be developed and implemented.

Recovery Actions:

2.2.2A Assess the potential risk for incidental take of Atlantic salmon in marine and estuarine fisheries

2.2.2B Develop appropriate management strategies and regulatory measures to avoid bycatch of Atlantic salmon in estuarine and marine fisheries where significant potential for bycatch is identified

3. Reduce predation and competition on all life-stages of Atlantic salmon

Atlantic salmon are preyed upon by numerous species of mammals, birds and fish (see pages 1-45 to1-55). Predation would not be expected to threaten the continued existence of healthy populations. The threat of predation is significant today because of small salmon populations and the increased populations of some predators.

3.1 Assess impacts of predation on wild and hatchery-reared river-specific salmon populations and develop methods for reducing adverse affects from predation

Predation rates and the impact on the DPS are difficult to estimate and assess because of the wide spatial and temporal distribution of Atlantic salmon and the large number of potential predators. The development and implementation of management measures to minimize potential impacts of predation on the DPS requires a clear understanding of the nature and extent of the threat. Known and potential predators should be ranked relative to their impact on the DPS. This information should be used to direct further research and assessment activities.

3.1.1 Evaluate salmon population management practices, habitat features and water management practices that may exacerbate predation rates

There are a number of factors that can exacerbate predation rates on Atlantic salmon. These include salmon population management practices, natural and man-made concentration sites and land and water management practices that affect the vulnerability of Atlantic salmon to predation. Based on the results of the following recommended research and assessment tasks, appropriate management measures to reduce documented impacts of predation on the DPS should be developed and implemented.

Habitat features

Habitat features that may increase the vulnerability of salmon to predation should be identified and catalogued. These features include natural and man-made obstructions that may restrict passage and/or concentrate salmon (see pages 1-32 to1-34). These obstructions include falls, beaver and debris dams and man-made dams. Information from this assessment should be used to develop management strategies to minimize predation and remediate passage problems where possible. Studies in the Pacific Northwest have shown that pinniped (sea lions and seals) predation, especially at areas of restricted passage, can adversely affect small salmonid populations and impede recovery (NMFS 1999a). Similarly, juvenile salmon are especially vulnerable to cormorant predation when they are concentrated during downstream passage at man-made structures (dams) and natural obstructions.

Salmon management practices

Current salmon population management practices should be reviewed to determine whether modifications are necessary to help minimize the vulnerability of juvenile salmon to predation. There are a number of management practices that may increase the vulnerability of hatchery-reared salmon smolts to predation including method and timing of smolt stocking and tagging methods. Hatchery-reared smolts often show decreased predator avoidance behavior compared to wild smolts. These behavioral differences may contribute to increased predation. Ongoing studies by NOAA Fisheries NWFSC indicate that predator avoidance conditioning can increase the survival of smolts stocked into the wild. Modifications to hatchery practices to condition fish to increase predator avoidance behavior should be evaluated.

The installation and operation of weirs and fish traps are other examples of salmon management practices that might increase the vulnerability of salmon to predation. The potential for these structures to increase predation rates of Atlantic salmon should be assessed. The presence of potential salmon predators within the vicinity of weirs and fish traps should be systematically monitored to determine whether these facilities may concentrate potential salmon predators.

Land and water use management practices

There are a number of land and water management practices that may exacerbate predation rates. Excess sedimentation can lead to loss of habitat and filling of pools. The loss of shelter in interstitial gravel and cobble spaces due to filling by sediment can result in increased predation (Waters 1995)(see page 1-28). Dams and improperly functioning fishways may obstruct fish passage and concentrate juvenile and adult salmon, thus making them more susceptible to predation. Water withdrawals can change basic sediment transport functions and result in stream channel changes. Water withdrawals also have the potential to expose or reduce salmon habitat thereby restricting salmon movement and/or concentrating fish in pools and other holding areas. This could increase their vulnerability to predation.

Recovery Actions:

3.1.1A Identify and catalogue locations that restrict passage and/or concentrate salmon and thereby increase the vulnerability of salmon to predation

3.1.1B Review existing salmon population management practices to determine if they increase the vulnerability of juvenile salmon to cormorant predation

3.1.1C Document and monitor the presence and abundance of potential salmon predators at natural and man-made concentration sites

3.1.1D Assess the potential of land and water use practices to exacerbate predation rates

3.1.2 Implement integrated management of cormorants to reduce predation on Atlantic salmon

Integrated cormorant management[38] should be implemented to reduce predation on Atlantic salmon. Cormorant predation on Atlantic salmon in Maine has been well-studied (see pages 1-47 to1-48). It is known that cormorants prey on hatchery smolts. Cormorant predation is generally higher on hatchery-reared than wild smolts (Blackwell 1996; Anthony 1994; Baum 1997; NMFS 2000). The potential for cormorant predation to adversely affect the recovery of the DPS should be further evaluated. More information is needed on the impacts of predation on hatchery-reared salmon smolts. Studies should identify specific cormorant colonies that may inflict significant levels of depredation on salmon populations within the DPS.

Management measures to reduce cormorant predation on hatchery-reared Atlantic salmon smolts should be evaluated and implemented if appropriate. Potential measures include modifications of man-made structures that slow or impede passage (e.g., fishways, weirs and traps) and selective lethal removal of cormorants at locations where they are observed to be significant salmon predators.

[38] Integrated predator management involves a management approach that emphasizes monitoring and adaptive management. Integrated predator management plans should: identify and prioritize management areas; clearly define goals; identify areas of limited or no predator control for comparison; work with state and local authorities; review plan annually and change/amend as needed; outline specific priorities and tasks.

Lethal control of cormorants is currently subject to depredation permits that may be issued by FWS under the Migratory Bird Treaty Act[39]. The FWS may issue depredation permits authorizing lethal control of cormorants, their eggs, and/or nests, particularly in situations where the need for cormorant control is recognized in a state or federal conservation plan for a sensitive species, including endangered species.

If there are specific reaches or areas on DPS rivers where cormorant predation is adversely affecting the recovery of salmon populations, the birds responsible for the depredation should be targeted for removal. Implementation of specific cormorant management activities should include monitoring to assess their effectiveness and allow for appropriate modification of management protocols.

The restoration of runs of other forage species such as alewife (*Alosa pseudoharengus*), shad (*Alosa sapidissima*) and blueback herring (*Alosa aestivalis*) is one method to mitigate the effects of predation on Atlantic salmon, particularly cormorant predation. Alewife restoration may be particularly beneficial for Atlantic salmon as the time of migration for these two species coincides. The potential for restoration of these runs to help reduce predation on Atlantic salmon should be evaluated. Alewives and shad can serve as buffer species that will dilute the effect of predation on Atlantic salmon.

In addition, recovery efforts that aid fish species such as alewives and shad will be beneficial to Atlantic salmon recovery as well. Restoring the natural runs of these anadromous fish will require removal of barriers to fish passage or the addition of fishways and enhancement of stream and river health (i.e., water of sufficient quantity and quality). Current restoration efforts for these anadromous species occur under the jurisdiction of the Maine DMR Stock Enhancement Program. Efforts include control of fishing effort, construction of fish passage at dams, fish stocking and improvements to water quality and habitat including wetlands, spawning grounds and nursery areas.

Recovery Actions:

3.1.2A Evaluate the potential of cormorant predation to adversely affect the recovery of the DPS

3.1.2B Identify specific cormorant colonies within the DPS that may inflict significant levels of depredation on DPS salmon populations and implement appropriate experimental management measures

3.1.2C Promote the conservation and restoration runs of anadromous forage species to provide a buffer against predation on salmon

[39] In November 2001, FWS released a draft Environmental Impact Statement (EIS) and management plan for the double-crested cormorants. The draft EIS explores additional alternatives for managing cormorants throughout the contiguous United States.

3.1.3 Evaluate the need for integrated management of seals to reduce predation on Atlantic salmon

The extent of seal predation on wild Atlantic salmon in Maine and the impact on the recovery of the DPS has not been adequately assessed and documented. Additional investigation is needed to assess whether seal predation may adversely affect the DPS.

Salmon may be more vulnerable to seal predation in areas where salmon are concentrated. Site-specific investigations of seal predation on DPS Atlantic salmon populations are needed. The presence and abundance of seals at natural and man-made concentration sites (dams, weirs, falls, fishways) should be systematically monitored and documented. These studies should evaluate the spatial and temporal presence of seals in these areas.

Similarly, salmon aquaculture net-pens may play a role in aggregating seals and increasing the potential for predation on both outmigrating post-smolts and returning adults. This potential threat should be investigated in conjunction with research to assess seal attacks on net-pens and implementation of deterrence measures (see page 4-52). Recent changes in aquaculture management that use fallowing may provide opportunities to quantitatively study this impact.

The NOAA Fisheries and ASC should evaluate available predation study techniques to determine their utility to document seal predation on Atlantic salmon. One method to assess seal predation is to examine and quantify the composition of seal diets. The examination of gastrointestinal tracts of seals is one method of quantifying prey consumption rates. This type of approach is difficult due to the wide spatial and temporal distribution of Atlantic salmon at low densities and the fact that seals are opportunistic feeders. Furthermore, this type of study requires the lethal take of seals. The Marine Mammal Protection Act (MMPA) strictly limits the conditions under which marine mammals may by taken[40].

Opportunistic stomach content analysis (e.g., seals taken incidentally in commercial fisheries, seals entrained in power plant coolant water intakes) of seal's food habits provides another potential opportunity to study seal predation on Atlantic salmon. Stomach samples collected from harbor seals incidentally taken in Gulf of Maine sink gillnet fisheries during the period 1991-1997 have been analyzed (Williams 1999). Additional stomachs are archived at the NOAA Fisheries NEFSC Laboratory in Woods Hole. Additional stomach content analysis should be conducted if appropriate.

Alternatives to conventional diet sampling techniques, including scat analysis and fatty acid signature analysis, stable isotope analysis, crittercams should be evaluated. Fatty acid signature analysis can allow researchers to identify individual prey species. Fatty acids are formed when fats are broken down during digestion and are incorporated into the blubber of marine mammals.

---

[40] Under the MMPA take means "to harrass, hunt, capture or attempt to hunt, capture, or kill any marine mammal."

By taking a blubber sample from a predator, researchers may be able to identify specific prey species as certain fatty acids are unique to individual prey species.

Scat analysis has been used to study pinniped food habits. Prey identification is determined by analyses of prey hard parts such as otoliths, fish bones, gill rakers and cartilaginous parts recovered from seal scats. In the Pacific Northwest, researchers found that adult salmon accounted for 6% (percent frequency of occurrence in scats) of harbor seals diets and juvenile salmon accounted for 19% (Browne *et al.* in prep *in* NMFS 2000). Variation in ingestion and digestion of identifiable hard parts makes it difficult to quantify the total contribution of salmon in pinniped diets (NMFS 1999). Scats are difficult to collect on rocky ledges (typical harbor seal and grey seal habitat along the Maine coast). Some samples were collected in Summer 2001 (Jim Gilbert, UM, personal communication).

Predator tags are another promising new research tool to assess predation on juvenile Atlantic salmon. Efforts are ongoing to develop a telemetry tag that will enable researchers to detect predation on stocked smolts. These efforts should be continued.

Scarring and injury (including apparent claw and tooth abrasions) indicative of marine mammal predation have been observed on adult Atlantic salmon during fish trapping operations in Maine (see page 1-46). The ASC should continue efforts to develop a standardized catalogue of these wounds to verify and document seal related injury. These data may enable ASC to assess possible predation trends.

Some individuals and organizations have advocated that lethal seal control programs should be implemented in Maine to control seal populations. This is due to the perception that seal predation is in part responsible for the severely depressed status of wild salmon populations. There is insufficient data on the extent and impact of pinniped predation on the recovery of the DPS to recommend the lethal take of individual seals. Predator culling program may not have direct benefits on specific prey stocks and may not result in increased fish populations (UNEP 1999).

The MMPA prohibits the take of all marine mammals except under strictly defined conditions. Any management measures to mitigate marine mammal predation must conform with the requirements of the MMPA. Section 104(c) of the MMPA grants authority for the issuance of permits to conduct scientific research that includes non-lethal take of marine mammals. Under the MMPA, permits may not be issued for research involving the lethal take of marine mammals unless it can be demonstrated by an applicant that a non-lethal method of conducting the research is not feasible. Additional data are needed before any management measure involving lethal take should be considered or recommended.

Section 120 of the MMPA is the only potential authority for intentional lethal taking[41] of seals. Lethal take is limited under this provision to individually identifiable pinnipeds and includes many related requirements.

Based on the results of the preceding recommended research programs, appropriate management measures should be developed and implemented to mitigate the impact of documented seal predation on wild salmon populations.

Recovery Actions:

3.1.3A Evaluate the effect of seal predation on the recovery of the DPS

3.1.3B Identify sites where seals are concentrated and Atlantic salmon predation may be exacerbated

3.1.3C Conduct research to determine the role of net-pen sites in seal aggregation and salmon predation

3.1.3D Evaluate the potential of alternative research techniques and food habit sampling methodologies to help assess seal predation on Atlantic salmon

3.1.3E Develop and implement appropriate management measures to mitigate the impact of documented seal predation on wild salmon populations

3.1.4 Assess potential effects of other predators

The role of other potential predators of Atlantic salmon to adversely affect the recovery of the species should be evaluated. These other predators include mustelids (e.g. otters and mink), gulls, pelagic birds (e.g., gannets), marine fish (e.g., cod), sharks, estuarine fish (e.g. striped bass) and other marine mammals (dolphins, porpoises, whales). Based on the results of these evaluations, appropriate management measures should be considered and implemented.

---

41 Section 109(h)(1) of the MMPA provides an exception to the takings prohibitions for any federal, state, or local government official or employee, or a person designated under section 112(c), in the course of his or her duties, for taking marine mammals in a humane manner if the taking is for the nonlethal removal of nuisance animals. If the State determined that predation on Atlantic salmon is a "nuisance", then section 109(h) gives them authority to use non-lethal taking without any other permit or authorization requirements. It is important to note that there would probably be some constraints on such an approach - such as confining it to specific areas. NOAA Fisheries and the State of Washington used this authority to remove and hold in temporary captivity sea lions that were adversely affecting steelhead runs at the Ballard Locks in Seattle Washington. Nonlethal deterrent methods, such as hazing and acoustic barriers, were also used.

3.2 Reduce predation and competition between Atlantic salmon and other freshwater fish species

The introduction of non-native fish species into aquatic ecosystems can adversely affect native fish species through competition for food and available habitat, predation, interbreeding and hybridization and the introduction of disease and parasites (see page 1-49).

3.2.1 Review and monitor potential impacts of existing stocking programs for other fish

The Maine IFW stocks brown trout[42], splake, landlocked salmon and brook trout in rivers and lakes within DPS river watersheds in order to enhance recreational fishing opportunities for the public. All existing stocking programs should be evaluated to assess the potential impacts of these introductions on Atlantic salmon populations. Methods to minimize potential adverse affects of these stocking programs should be evaluated.

Stocking of freshwater salmonids in Atlantic salmon river watersheds should be evaluated to fully assess the potential adverse impacts of these programs on the DPS. Program evaluation should include an assessment of the proximity of stocking sites to Atlantic salmon habitat and the potential for direct interactions to occur. Environmental parameters such as temperature and habitat that influence the potential for adverse impacts of the stocking program on the recovery of the DPS should also be assessed. Plans to monitor potential adverse effects of stocking programs should be developed and implemented. Given the severely depressed status of wild salmon populations, and the particular concern for the adverse effects of brown trout, stocking of this species should be suspended in all DPS river watersheds until the potential impacts of these introductions can be fully assessed.

The stocking of non-native and native species into headwater lakes of DPS rivers should also be evaluated immediately to determine the potential impacts of these programs on the DPS. The potential for adverse interspecific competition between other salmonid species (e.g., splake, landlocked salmon and brook trout) stocked in headwater lakes of DPS rivers within the DPS is thought to be low (Ken Beland, ASC, personal communication). Because most of these lakes are glacial oligotrophic or mesotrophic lakes with small outlet streams, there is more spatial segregation of fisheries than might be the case for lakes a river flows through in the case of riverine fish management and stocking programs. In addition, many of the headwater lakes are well separated from areas with documented Atlantic salmon reproduction or juvenile rearing habitat reducing the potential for interactions (Ken Beland, ASC, personal communication).

Landlocked salmon stocked into headwater lakes are found in riverine habitat below these lakes in a number of the DPS rivers. Existing data should be reviewed to determine the extent of

---

42 As noted (page 1-51), brown trout are raised at the Palermo hatchery on the Sheepscot River for stocking purposes. Brown trout escaping from this hatchery contribute to resident populations of brown trout already established in the Sheepscot river.

landlocked salmon distribution within DPS rivers. Based on the results of this review, stocking programs should be modified or suspended if they increase the potential for adverse interactions with wild anadromous Atlantic salmon. The ASC and IFW should continue to monitor the distribution of landlocked salmon in DPS river wtaresheds. This can be accomplished under existing monitoring programs.

In June 2002, the IFW and ASC signed an MOA to guide the management and stocking of fish in Atlantic salmon rivers in order to minimize any potential impacts of stocking on Atlantic salmon. Under the MOA, biologists from ASC and IFW are to meet annually to review existing stocking programs and assess the potential affects of these introductions on Atlantic salmon populations. ASC and IFW staff met in 2001 and 2002 to review stocking plans and resolve concerns about potential interspecific conflicts.

In addition to potential adverse ecological impacts, stocking of game fish into rivers supporting wild salmon may increase the potential for incidental take of Atlantic salmon by anglers targeting these species. The Services should work with the State of Maine to assess the need to develop a Section 10(a)(1)(B) permit for existing stocking programs, and if appropriate, assist in the development of such a permit. On the West Coast, NOAA Fisheries has worked with states to develop habitat conservation plans under Section 10(a)(1)(B) of the ESA for stocking programs that had the potential to adversely affect listed Pacific salmon[43]. Under the ESA, Section 7 consultations provide another means to deleop responsible alternatives to the potential impacts stocking may have on Atlantic salmon. NOAA Fisheries has also conducted Section 7 consultations on the West Coast for federal stocking programs for species such as trout that might interact with listed salmon and result in take.

Recovery Actions:

3.2.1A Review existing stocking programs and assess the potential impacts of these introductions on Atlantic salmon populations and ways to minimize potential adverse affects

3.2.1B Monitor potential adverse interactions of existing stocking programs for freshwater salmonids in Atlantic salmon river drainages and fully assess the potential impacts of these programs on the DPS

3.2.1C Suspend stocking of brown trout immediately in all DPS rivers until the potential impacts of these introductions can be fully assessed

[43] In some cases, NOAA-Fisheries has tried to eliminate or dramatically reduce stocking programs that were thought to cause adverse ecological or genetic impacts. In other cases, mitigation has been required. For example in California, striped bass are stocked into the Sacramento and San Joaquin rivers and delta. Striped bass eat juvenile salmon. The NOAA-Fisheries worked with the State of California to develop an ESA Section 10 permit to address the incidental take of listed salmon caused by this stocking program.

3.2.1D Monitor potential adverse interactions of existing stocking programs for freshwater salmonids (i.e., splake, landlocked salmon, brook trout) in headwater lakes of DPS rivers to determine the potential impacts of these programs on the DPS

3.2.1E Assess the need to develop a Section 10(a)(1)(B) habitat conservation plan for existing stocking programs, and if warranted, develop and implement

3.2.2 Monitor populations of introduced non-salmonid species and implement management controls when appropriate and feasible

The ASC and IFW should continue to monitor populations of introduced species such as smallmouth bass and largemouth bass and implement management controls when appropriate and feasible. The State should continue to enforce laws regulating the introduction of fish species to water bodies within the State. Violations of these laws should be prosecuted and appropriate fines and penalties imposed.

4. Reduce risks from commercial aquaculture operations

Potential interactions between wild Atlantic salmon and salmon aquaculture represent a significant threat to the continued existence of the DPS (65 FR 69459; NMFS and FWS 1999)(see pages 1-57 to1-64). There is substantial documentation that escaped farmed salmon can adversely affect wild salmon populations through ecological, genetic and disease related effects (Fleming *et al.* 2000; DFO 1998; Clifford *et al.*1997; Skaala and Hindar; Carr *et al.* 1997; Crozier 1993; Youngson *et al.* 1993; Lura and Saegrov 1991; Saunders 1991; Windsor and Hutchinson 1990).

The following recovery actions are necessary to minimize the threats posed by the U.S. salmon aquaculture industry to the Gulf of Maine DPS of Atlantic salmon. These actions include measures to minimize the likelihood of incidental take or harm from the accidental release of aquaculture salmon as well as measures needed to minimize the threat of disease and parasites to the DPS.

4.1 Improve containment at existing and future marine sites

As part of the permit requirements from DMR and ACOE for an aquaculture facility, an applicant must conduct a baseline assessment of the site and demonstrate that the equipment proposed for the site is suitable to withstand storm conditions[44]. This evaluation is needed to minimize the risk of catastrophic loss at a site due to net-pen failure during a storm event.

The threats (i.e., disease and/or parasite transfer, ecological interactions) to endangered salmon posed by aquaculture could be reduced by placing marine cages at greater distances from DPS rivers. Establishing a buffer between DPS rivers and marine cages may reduce the potential for diseases and parasites to be transferred to wild salmon migrating past marine cages from the river to the ocean or upon return. In addition, locating marine net-pens further from DPS rivers could reduce the likelihood of farmed fish imprinting on odors from the river and homing to that river in the event of an escape. Unfortunately, the areas suitable for marine cage culture with existing technology largely coincide with areas used by wild fish. While some countries have established "aquaculture free" zones for the protection of wild fish, establishing such zones in Maine would be difficult.

Aquaculture facilities should use a fully functional marine containment system designed, constructed and operated so that no fish from any of the net-pens of the facility escape. All cages should be designed appropriately and mooring systems should be adequately designed, deployed and maintained. Known or suspected escapes should be reported to the appropriate personnel immediately. All aquaculture facilities should maintain permanent records of their containment systems to track cage history, the types of cages on each site, date of manufacture, date of installation, modifications and repairs and inspections. These records should be made available to the Services upon request.

All salmon aquaculture facilities should develop an integrated loss control plan for the facility. Loss Control Plans (LCP) should consist of management and auditing methods to describe or address the following: inventory control procedures, predator control procedures, escape response procedures, unusual event management, severe weather procedures and training. The plan should include a schedule for preventative maintenance and inspection of the facility's containment systems. The LCP should address all the steps involved in the commercial culturing process. The potential for losses at each of these points should be identified and steps taken to minimize the risk of escapement. The LCP should include a facility specific list of critical control points (CCP) where escapes could potentially occur. Each CCP should address the following: specific location, control mechanisms, critical limits, monitoring procedures, appropriate corrective actions, verification procedures that define adequate CCP monitoring and a defined record keeping system. Facilities should be audited annually to evaluate the adequacy of containment measures and compliance with best management measures. Any losses should trigger an evaluation of these measures and any deficiencies should be corrected immediately.

---

[44] The baseline assessment of a proposed facility is also necessary to document potential future impacts to water quality or the benthic environment. Flushing must be adequate to minimize the potential for degradation of the site. The DMR conducts routine benthic monitoring of on-site environmental conditions in proximity to marine net-pen sites under the Finfish Aquaculture Monitoring Program (FAMP). This program is necessary to ensure that aquaculture operations do not degrade the environment.

All salmon aquaculture facilities should develop and maintain an inventory tracking system that allows clear, accurate inventory tracking of all size classes (i.e. average weight and age) of Atlantic salmon, including documentation of mortality events and any escapes. Each facility should have an inventory tracking system as a means to track all fish on site. The inventory tracking system should account for how many fish are stocked at the site originally, how many are harvested for sale, and, if that number differs, where the losses are accounted for. Mortalities should also be recorded and accounted for. Inventory measures should include marking of all fish before they are stocked into marine net-pens. Marks should be permanent and identify the fish to its facility of origin. This information should be provided to ACOE electronically on a monthly and per-pen basis, clearly identifying the total number of fish, number of smolts transferred, fish harvested, mortalities and escapes. This information, along with the containment audit results, will assist in evaluating the effectiveness of the containment management system.

The ACOE should provide an annual report to the Services. The report should include: species authorized and presently cultured; number of fish produced; information on stocking (i.e., number, size, age) and harvesting (i.e., number, size, age); current equipment used; number of aquaculture fish accidentally released and how; presence of ISAV and disease treatments implemented; and the incidence of predator attacks. This report should also include documented mortality and the number of fish unaccounted for.

In addition to containment failures caused by mechanical or human error, seal attacks on net-pen sites may result in damage to nets and allow farmed salmon to escape. The interactions of seals and net-pens should be documented and monitored. The NOAA Fisheries is working with researchers at UM to investigate some of these issues. These researchers are currently focusing on the relationship between pen locations and harbor seal haul-out and pupping ledges. This research should be continued.

In 1996, NOAA Fisheries, under the auspices of Section 120(h) of the MMPA, established a task force to examine the problem of seals interacting with aquaculture resources in the Gulf of Maine and recommend measures to mitigate the interactions (NMFS 1996). The Task Force's report discusses a number of regulatory, technological and financial issues related to the development of measures to minimize these interactions. These included net design, deterrence measures, research and interagency and international cooperation needs. These recommendations should be reviewed and fully implemented as appropriate. Section 101(a)(4) of the MMPA was established for the protection of self, public property and private property. Individuals can take necessary nonlethal steps to protect their property provided the animal is not injured or killed. Killing marine mammals to protect fishing gear or catch, including aquaculture, is prohibited by section 118(a)(5) and 101(a)(4) of the MMPA[45].

[45] Prior to the 1994 amendments, the MMPA authorized fishermen, including aquaculture operators, to use injurious or lethal force to prevent mammals from damaging gear or catch.

Recovery Actions:

4.1A Evaluate new aquaculture lease and permit applications to ensure that net-pens and equipment are adequate for site location and potential storm impact.

4.1B Develop fully functional containment management systems for the containment of farmed salmon at marine sites. Operate marine containment systems so that no farmed salmon escape to open water.

4.1C Develop and implement integrated loss control plans for all salmon aquaculture facilities

4.1D Develop and maintain an inventory tracking system for all aquaculture facilities

4.1E Assess, document and monitor damage caused by seal predation that may lead to the escapement of farmed salmon into the environment

4.2 Minimize the effects of escaped farmed salmon

As noted, escaped farmed salmon may adversely affect wild salmon through ecological, genetic and disease effects (see page 1-58). The Atlantic salmon industry in Maine is concentrated in Cobscook Bay in Washington County (see page 1-57). Five of the DPS rivers (Dennys, East Machias, Machias, Narraguagus and Pleasant rivers) are in close proximity to marine cages. The Dennys River is most likely to be impacted by escapees from marine cages due to the high density of cages in Cobscook Bay and Passamaquoddy Bay (Canada). All DPS river populations are at a heightened risk due to low numbers of wild adult returns. In the Pleasant and East Machias river watersheds, this threat has been exacerbated by the escape of juvenile salmon from commercial freshwater hatcheries in these watersheds (see page 1-59).

4.2.1 Develop and implement contingency measures in case of accidental release of farmed fish

All aquaculture facilities should develop contingency plans in case of an accidental release of farmed salmon. In developing site-specific loss control plans, facilities should identify what methods of recapture of escaped fish are appropriate for their facility and surrounding waters. Recapture of escaped farmed salmon present a number of difficulties including unknown dispersal rates of escaped salmon and possible accidental take (seasonally) of DPS salmon. The potential risk for the accidental capture of wild DPS fish would need to be evaluated for each recapture method and procedure. All necessary equipment and permits should be acquired in advance of an event actually occurring. Contingency measures should include immediate notification of state and federal authorities if loss or escape of farmed salmon occurs.

4.2.2 Maintain existing weirs on DPS rivers and establish additional sites as needed

Information on escaped farmed salmon provides a measure of the success of aquaculture containment systems. Seasonal fish weirs can help reduce opportunities for aquaculture escapees to interact with wild salmon in DPS rivers. Seasonal weirs, while deployed (from late April, early May to mid- to late November), reduce the likelihood that aquaculture escapees will enter DPS rivers, thereby reducing the potential for interbreeding and habitat competition between farmed salmon and wild salmon.

Fish weirs perform several important functions for the recovery of the DPS including exclusion of aquaculture escapees from DPS rivers and assessment of wild populations. Weirs enable biologists to examine migrating adults and deny aquaculture escapees passage upstream to spawning sites. In addition to helping to exclude escaped aquaculture salmon, weirs enable ASC to collect valuable data such as the numbers, source and condition of returning adults. This information is used to monitor the abundance of wild stocks and properly manage the populations (see Section 7).

Accurate screening of fish at weirs is essential. Screening involves observation of phenotype including body-shape and existence of fin deformities along with scale reading used to age fish and determine their origin (i.e., wild or farmed). Two types of errors are possible, aquaculture fish can be allowed upstream and potentially spawn, or DPS fish can be prevented from migrating upstream. Both types of screening errors can be minimized through the use of accurate screening protocols, such as the ones developed by ASC and marking of aquaculture fish. Accurate screening protocols will increase the ability to correctly identify salmon collected at weirs. Screening protocols must balance the necessity of minimizing mortality and handling of fish at the weirs with reducing the potential for screening errors.

The construction, operation and maintenance of weirs on the Dennys, East Machias, Machias, Pleasant and Narraguagus rivers is an integral component of the efforts to conserve and restore wild Atlantic salmon in Maine (MASCP 1997) and should be continued. Seasonal trapping facilities are located on the Narraguagus, Pleasant and Dennys rivers. Plans to construct a weir on the East Machias River have been delayed due to local concerns and denial of a permit by the Town of East Machias to construct the weir. Weirs should be constructed with state-of-the-art technology and operate continuously from ice out to ice in and effectively without hindering the passage of wild Atlantic salmon. The need to construct a weir or fish trap on the Machias River should be evaluated. Bad Little Falls, located at the mouth of the Machias River, may serve as a natural barrier to aquaculture fish. Currently a fishway exists on the east side of the falls.

Recovery Actions:

4.2.2A Maintain existing weirs on DPS rivers to exclude aquaculture escapees, enable data collection and collect broodstock

4.2.2B Construct weirs on DPS rivers, including the East Machias and Machias rivers, where necessary to exclude aquaculture escapees, enable data collection and collect broodstock

4.2.3 Mark all farmed salmon prior to placement into marine net-pens

The marking of aquaculture fish will assist biologists to accurately screen fish captured at weirs. Marking of aquaculture fish will help minimize handling and mortality of wild salmon at the weirs and reduce the potential for screening errors (see above). Quick and positive identification at the weir is critical to allow wild fish to be passed upstream and aquaculture escapees to be denied passage upstream.

Each farmed Atlantic salmon should carry a mark to identify its facility of origin. Fish should be marked before being stocked into a net-pen. Marks should be permanent and, if internal, the tag should be detectable visually or by means of a mechanical or electronic device (e.g., fish should not have to be killed to detect tag). Marks should be detectable with minimum handling of fish. Salmon are often trapped at very high water temperatures (>22°C) which is stressful for the fish. Prior to stocking, the mark should be filed with ACOE and a record of the marks maintained by the aquaculture company. Such a mark will help identify escaped fish at weirs and other sorting sites. This will facilitate the identification and correction of containment failure. The marking of aquaculture fish should be coordinated with Canadian authorities and the Canadian aquaculture industry if possible. Such discussions could occur under the auspices of the North American Committee (NAC) of NASCO to which the U.S. and Canada are members.

In 2001, the National Fish and Wildlife Foundation (NFWF) provided a $500,000 grant to the Maine Aquaculture Association (MMA) designed to help the aquaculture industry address containment concerns and develop a marking program (see below). Under the NFWF grant, an advisory committee and two working groups were established. The working groups include a marking/tagging working group and a containment working group. The containment working group was broken out into two areas, containment at marine sites and containment at freshwater hatcheries. The containment groups have used the Hazard Analysis Critical Control Point (HACCP) approach to identify and begin to implement BMPs at critical control points. The containment working groups have developed a draft HACCP plan intended to serve as the framework for site-specific plans at every facility. The marking working group is evaluating various marking techniques that would allow assessment of containment measures.

4.2.4 Discontinue the culture of non-North American salmon

The use of reproductively viable non-North American Atlantic salmon stocks by the aquaculture industry should be immediately discontinued at all aquaculture facilities. Non-North American stock is defined as any Atlantic salmon (*Salmo salar*) that contains genetic material derived partially (hybrids) or entirely (purebreds) from any Atlantic salmon stocks of non-North American heritage, regardless of the number of generations that have passed since the initial introduction of the non-North American genetic material.

Genetic analysis demonstrates that North American and European Atlantic salmon are genetically distinct (NRC 2002, and references therein). Interbreeding between an escaped Atlantic salmon of European-origin and a DPS fish could lead to the introduction of non-native genetic material that is not adapted to DPS river populations.

4.2.5 Prohibit the placement into marine net-pens of reproductively viable transgenic salmon

The use of reproductively viable transgenic salmonids should be prohibited within the DPS at all aquaculture facilities where an escapement may result in potential interactions with wild Atlantic salmon until a full risk assessment is conducted. Transgenic salmonids are defined as species of the genera *Salmo, Oncorhynchus* and *Salvelinus* of the family Salmonidae that contain within their DNA copies of novel genetic constructs introduced through recombinant DNA technology using genetic material derived from a species different than the recipient. The consequences of potential interbreeding between an escaped transgenic salmonid and a wild Atlantic salmon could be significant.

4.2.6 Continue research into developing strains of aquaculture fish that cannot interbreed with wild fish

One potential means to reduce the genetic threat of interbreeding between wild and domesticated salmon is to develop and raise fish incapable of successfully reproducing. The effectiveness of methods to sterilize Atlantic salmon varies greatly (i.e., sterilization is not always successful). This should be considered when assessing whether the use of sterilized fish will minimize the risk of interbreeding between wild and farmed fish.

Experiments have been conducted in rearing sterile triploid[46] Atlantic salmon for use in commercial culture in order to reduce the potential for genetic interaction with wild stock. While growth and survival in freshwater has been demonstrated to be comparable to diploid strains, mortality during the transition to marine cages has been higher and deformities among triploids remain a major concern (O'Flynn *et al*. 1997). An evaluation of the use of sterile triploid Atlantic salmon was undertaken from 1994-1998 by the Marine Laboratory in Aberdeen, Scotland. Performance trials in Ireland and Norway demonstrated that triploids grew similarly and survived as well as diploids in freshwater. In sea water, triploids grew similarly to diploids but suffered higher losses in half of the trials (The Salmon Research Agency of Ireland Incorporated 1998; Marine Laboratory Aberdeen 1998).

More recent work underway at the Huntsman Marine Science Center (HMSC) in St. Andrews, Canada has produced some promising results. Researchers at the HMSC are working with sterile triploid salmon of the "Cascade" strain, believed to be of Gaspé Peninsula origin. These fish have reportedly performed well in seawater for growth and survival (Fred Whorisky, ASF,

---

[46] Triploid refers to having three copies of each chromosome rather than the normal two copies (i.e., diploid).

personal communication). These fish may be a feasible alternative to reproductively viable strains of domesticated Atlantic salmon now used by the aquaculture industry. Continued research in this field is encouraged. It is also important to note that while triploidy may be effective in preventing interbreeding between escapees and wild fish, sterile escapees may still disrupt the breeding of wild fish and compete for food and habitat.

4.3 Minimize risks of disease and parasite transmission from farmed fish in marine pens to wild fish

Atlantic salmon are susceptible to a number of diseases that can result in direct or indirect mortality (see pages 1-39 to1-44).

4.3.1 Minimize risk of disease transmission

All aquaculture facilities should develop and adhere to stringent pathogen monitoring protocols to minimize the risk of disease transmission from farmed salmon to wild Atlantic salmon including those required by the Maine DMR and USDA APHIS ISAV programs. Monitoring results should be provided to the Services.

All aquaculture facilities should develop remedial action plans in the case of a confirmed case of ISA. Copies of these plans should be provided to the Services. Site-specific remedial action plans should be fully and immediately implemented when necessary.

The USDA APHIS has taken the lead in developing standard operational procedures designed to minimize potential outbreaks of ISA. Proposed management measures to reduce the current biomass loading of Cobscook Bay include reducing stocking densities and alternate year stocking in different management zones. Single generation management can reduce the risk of disease transfer between year classes. These measures were implemented by DMR for Cobscook Bay in 2002.

The discharge of processing wastes and therapeutic compounds not approved by FDA or EPA should be prohibited. All aquaculture facilities should implement strict controls preventing the discharge of blood and other potential infectious material.

Integrated single bay management plans can help reduce the disease risk posed to wild fish from farmed Atlantic salmon. Under such a management plan, all the growers within a bay coordinate stocking densities, disease treatments, fallowing and harvesting of fish. Coordination among growers within a bay has benefits both to the commercial industry and to wild fish. This method can reduce the risk that aquaculture operation will result in a degradation to the environment or other resources within the bay. The development of such plans should be encouraged where commercial sites are already in operation and should be a requirement before any cages are placed in an unoccupied bay.

The U.S. salmon aquaculture industry and regulatory agencies should develop comprehensive bay management plans for all areas used by the Maine salmon farming industry. The plans should include, but not be limited to:

- a concise description of the bay/area in terms of physical characteristics, history, aquaculture operations, future potential/carrying capacity, potential user conflicts and problems
- integration of codes of practice for current aquaculture operations and translation of those codes to the specific circumstances of each bay or coastal region
- a development plan for any future aquaculture activities in the bay
- address other resource use and activities in the bay including culture of species other than salmon.

The development and implementation of bay management plans will need to be coordinated with Canadian authorities and the aquaculture industry[47] if disease risks are to be effectively minimized.

Other protocols and guidelines (e.g., NESFH, NASCO, see page 1-40) also exist to help minimize the risk of disease transmission to wild fish. These should continue to be enforced. Federal import regulations (Title 50) currently apply only to a limited number of pathogens. This regulation should be revised to include the ISA virus and other salmonid pathogens that may be identified in the future. The NESFH guidelines and the NASCO protocols should be maintained and updated to continue to provide protection from diseases that are especially lethal and difficult to control, such as IHN and VHS, both of which are currently limited to salmonids found west of the Rocky Mountains. Appropriately, these pathogens, along with ISA virus, are addressed as exotic diseases of regulatory concern by the Maine Department of Marine Resources Salmonid Fish Health Inspection Regulations.

The FWS established the National Wild Fish Health Survey (Survey) and its associated database in 1997 to determine the national distribution of disease associated fish pathogens. In 1999, due to the realization of this disease's threat to wild salmon, ISA virus (and its established, standardized laboratory procedures for detection) was added to the Survey as a Pathogen of Regional Concern. Through the Survey, cooperating resource agencies have and continue to provide health samples from fish collected from the DPS rivers."

Research is also needed on the migration patterns of early post-smolts in the Maine coastal area to better understand the relationship of migration to net-pen locations and the extent to which wild fish may be vulnerable to exposure to ISA (see section 7).

---

47 As noted (see page 1-59), most aquaculture in Atlantic Canada occurs in the lower Bay of Fundy, where there are an estimated 60 facilities. There are a large number of aquaculture sites on the Canadian side of Cobscook and Passamoquoddy Bays, where they have the potential to affect U.S. aquaculture sites in these bays.

Recovery Actions:

4.3.1A Develop and implement a comprehensive disease management plan that includes siting and standard operational procedures to minimize outbreaks of ISA. This plan should also include procedures for identifying, reporting and controlling outbreaks

4.3.1B Develop and implement comprehensive integrated bay management plans that include coordination of stocking densities, harvesting and fallowing and disease treatment and management

4.3.1C Revise federal import regulations (Title 50) to include the ISA virus

4.3.1D Maintain and update existing fish health guidelines and protocols as necessary, to control the introduction of new pathogens and continue to provide protection from disease

4.3.1E Expand the FWS Wild Fish Health Survey to include DPS rivers

4.3.2 Conduct research on endemic and exotic salmonid pathogens to reduce the potential of disease transfer from farmed fish to wild Atlantic salmon

Research on the ISA virus should be continued. Research is needed on the modes of transmission of ISAV. The role of other fish species (both domesticated and wild) as potential reservoirs and vectors of ISAV should continue to be investigated. The survey of diseases in free ranging marine and anadromous fish is important to understand the role of other species as potential vectors and to evaluate the potential for cross-species transfer of disease. Resident and migratory fish species in aquaculture production bays should be monitored for endemic and exotic salmonid pathogens.

Research is also needed to better understand vertical and horizontal transmission of ISAV and the potential for wild salmon to contract the virus from infected net-pen sites. Research on detection and prevention of salmonid diseases should continue.

In laboratory studies, rainbow trout and brown trout have been shown to be asymptomatic carriers of ISAV that can transmit the virus to salmon by co-habitation (Nylund and Jakobsen 1995; Nylund *et al.* 1995; Nylund *et al.* 1997) (see page 1-42). The expansion of rainbow trout culture should be prohibited until the Maine Fish Health Technical Committee, state and federal biologists have evaluated the disease risk posed by the culture of salmonid species other than Atlantic salmon.

Vaccination technology for Atlantic salmon diseases, including ISAV, should continue to be improved. More effective vaccines and efficient delivery techniques may help reduce the potential for breakouts in net-pens and reduce the potential for this disease to adversely affect the

DPS. The potential to vaccinate Atlantic salmon against other salmonid pathogens should also be investigated and current vaccination programs should be continued.

The presence of SSSV in the DPS was cited as a listing factor for the DPS. The current distribution of this virus within the DPS should be determined. The potential for this disease to affect net-pens and adversely affect the DPS should also be investigated.

Recovery Actions:

4.3.2A Determine the modes of transmission of the ISA virus

4.3.2B Continue to investigate the role of wild fish species as potential reservoirs and vectors of ISA

4.3.2C Initiate screening and long-term monitoring of resident and migratory fish in aquaculture production bays for endemic and exotic salmonid pathogens

4.3.2D Continue active research programs on immunization of farmed fish

4.3.2E Develop an effective diagnostic technique for the SSS virus and determine the distribution of SSS virus within the geographic range of the DPS

4.3.3 Reduce the potential for sea lice outbreaks in farmed and wild salmon populations

The potential of sea lice to adversely affect the DPS and the role of salmon aquaculture sites as a reservoir for this parasite should be investigated. Wild salmon are vulnerable to sea lice infestation originating from aquaculture facilities (see page 1-61). Ongoing sampling of outmigrating salmon smolts in Penobscot Bay and the adjacent nearshore marine environment has not detected significant sea lice burdens on outmigrating Atlantic salmon (see page 1-62). Aquaculture facilities should regularly test and report sea lice burdens at net-pen facilities. Acceptable sea lice burden guidelines should be established based upon the best available information.

The aquaculture industry currently monitors for sea lice infestations and treats infected fish. The Maine aquaculture industry uses emamectin benzoate (brand name SLICE) to treat sea lice as part of an FDA trial to test the effectiveness and safety of this new animal drug. Because farm raised salmon are classified as a food-producing animal, drugs must also be tested for safety to human consumers. The first step in this process is the Investigational New Animal Drug exemption (INAD) (U.S. FDA website). SLICE is used in Maine under an INAD exemption (U Maine website). SLICE is administered to Atlantic salmon orally as an in-feed treatment, eliminating the mass discharge of therapeutant into the ocean as with the previously used sea lice treatment, cypermethrin (brand name Excis)[48]. SLICE treatment prevents recruitment of new lice for ten weeks which can allow the cycle of reproduction to be broken (Stone *et al.* 2000). This treatment could be especially promising if used strategically in a whole bay or system.

A number of preventative measures can be taken to minimize the potential for sea lice originating from salmon aquaculture facilities to adversely affect wild Atlantic salmon. Single bay management has been effective in helping to reduce the frequency and extent of sea lice outbreaks. Among these management techniques are fallowing, single year class stocking, density and siting (see page 4-57).

Recovery Actions:

4.3.3A Investigate the potential of sea lice to adversely affect the DPS and the role of salmon aquaculture sites as a reservoir for this parasite

4.3.3B Regularly test and report sea lice burdens at individual net-pen facilities

4.3.3C Continue treatment for sea lice at aquaculture facilities

4.4 Reduce risk of juvenile escapement from freshwater aquaculture facilities into DPS rivers

Juvenile escapees from freshwater aquaculture hatcheries may pose a larger threat to wild populations than escapees from net-pen sites (see page 1-63). A relationship between the reproductive success of cultured fish and the time the fish has lived in the wild before reaching sexual maturity has been demonstrated (Jonsson 1997).

Until recently, five freshwater hatcheries in the United States provided smolts to the salmon aquaculture industry for stocking into marine net-pens. Two of these commercial hatcheries were operated on two of the DPS rivers (see page 1-57). Juvenile salmon of aquaculture hatchery origin have been documented in DPS rivers in Maine (see page 1-59).

48 Previously, the aquaculture industry in Maine used Excis to treat sea lice. The treatment process includes placing a tarpaulin under the net-pen and drawing the net upwards reducing the volume of water the fish are held in. This reduces the amount of chemical needed to reach the desired concentration for effective treatment. After the appropriate treatment duration the tarpaulin is removed. This treatment methodology results in the release of cypermethrin into the waters surrounding the pens (Milewski 2000). Cypermethrin is no longer used by the aquaculture industry in Maine.

4.4.1 Ensure containment at existing and future freshwater aquaculture facilities accessible to DPS rivers

Freshwater aquaculture facilities should use a fully functional containment management system designed, constructed and operated so that no fish escape from the facility. Known or suspected escapes of any fish should be reported to the appropriate personnel immediately in the event of containment failure.

All salmon aquaculture facilities should develop an integrated loss control plan for the facility. The plan should include a schedule for preventative maintenance and inspection of the facility's containment system. The loss control plan should address contingency escape recovery protocols and facility husbandry practices. Husbandry practices include fish transfer procedures during grading and stocking. This plan should include all the steps involved in the commercial culturing process. An acceptable site-specific plan must include a facility specific list of CCPs where escapes have been determined to potentially occur. The potential for losses at each of these points should be identified and steps taken to minimize the risk of escapement.

Freshwater aquaculture facilities should be audited annually to evaluate the adequacy of containment measures and compliance with best management measures. Any losses should trigger an evaluation of containment measures and any deficiencies should be corrected promptly. All aquaculture facilities should maintain permanent records of their containment systems to track the integrity of barriers, modifications, repairs and inspection of the facilities containment system. Records should be maintained on all containment systems and be made available to regulators upon request.

All salmon aquaculture facilities should develop and maintain an inventory tracking system that allows clear, accurate inventory tracking of all size classes (i.e. average weight and age) of Atlantic salmon, including documentation of any escapes. The information should be provided to the Services on request, clearly identifying the total number of fish reared, number of smolts transferred and probable escapes. This information along with the audit results will assist with evaluating the effectiveness of the containment management systems.

Recovery Actions:

4.4.1A Develop and operate fully functional containment management systems for the containment of farmed salmon at freshwater hatchery sites

4.4.1B Develop integrated loss control plans for all salmon aquaculture hatchery facilities

4.4.1C Develop and maintain an inventory tracking system that facilitates the accurate tracking of total numbers of salmon smolts being produced by the hatchery

4.4.2 Develop contingency plans to reduce adverse impacts if containment measures fail

The potential for failure of containment measures at freshwater facilities needs to be anticipated and appropriate contingency measures developed. A contingency plan should be prepared so that measures can be implemented promptly in the event of catastrophic failure.

5. Supplement wild populations with hatchery-reared DPS salmon

In 1991, based on the recommendation of the Maine TAC, the current river-specific stocking program was initiated (see page 1-16).The river-specific stocking program stocks fish as fry as the primary management strategy to recover the DPS. Fry stocking minimizes the time that fish are held in captivity and reduces the opportunity for hatchery selection.

5.1 Stock cultured fish in natal rivers to supplement contributions of wild-spawned fish

The numbers of fry stocked into a specific river are determined by ASC and approved by the TAC annually based on the available habitat and the amount of habitat not used for spawning the previous fall (i.e., the extent of underused habitat).

The use of smolts (retaining fry in the hatchery until ready to migrate to sea as smolts) for stocking has been initiated on an experimental basis for the Dennys River. The advantage of using smolts is that the numbers of fish stocked is not limited by habitat capacity (as it is with fry) because smolts spend little time in the river before seaward migration. The disadvantages include (a) the need for significantly greater hatchery facility, staff and budgetary resources relative to fry production and distribution; (b) increased potential for hatchery selection to negatively affect genetic diversity; (c) less effective imprinting and resultant higher adult straying rate; and (d) reduced fitness in the wild as a result of conditioning to the hatchery environment (e.g., naivete relative to predator avoidance and foraging). A smolt stocking program in the Pleasant River has also been initiated.

5.1.1 Maintain river-specific hatchery broodstock and continue to stock cultured fish in natal rivers

River-specific broodstock should continue to be maintained at federal fish rearing facilities. Broodstock from six of the eight DPS river populations (Dennys, East Machias, Machias, Pleasant, Narraguagus and Sheepscot rivers) are maintained at the CBNFH. Broodstock are not maintained for the Ducktrap River and Cove Brook because these rivers continue to be managed under a no-stocking policy. The captive broodstock serve multiple purposes. They (a) provide a reservoir of diverse genetic material from the DPS to protect from catastrophic losses in the wild; (b) support river-specific stocking strategy to enhance juvenile population abundance; and (c) increase the effective spawning population size (N_e) of each DPS river population and the overall DPS to minimize loss of genetic diversity (genetic bottlenecks) associated with very small populations.

Captive brood stock populations are maintained by annually collecting juveniles in the wild and rearing them to sexual maturity in the hatchery. Brood stock are genetically characterized prior to reaching sexual maturity to help guide hatchery spawning operations and insure siblings or closely related individuals are not mated, which would result in inbreeding and loss of diversity and fitness. Genetic characterization also allows discrimination of wild from hatchery-origin fish, thus enabling evaluation of stocking success.

Hatchery-reared river-specific Atlantic salmon should continue to be stocked into DPS rivers to aid recovery of wild salmon populations. All federal fish rearing facilities needed for recovery of the DPS should continue to be operated.

Recovery Actions:

5.1.1A Continue operation of federal fish rearing facilities needed for recovery of the DPS, including maintenance of river-specific broodstock

5.1.1B Continue stocking cultured fish to supplement wild salmon populations

5.1.2 Monitor and evaluate the current stocking program

The Services and ASC should continue to monitor and evaluate the current river-specific stocking program. The effectiveness and management advisability of river-specific stocking as a recovery strategy should be continuously reviewed and evaluated. The Services and ASC should also review the need for alternate stocking strategies (see below). The advisability of using smolts should continue to be evaluated as rearing facilities are expanded for possible smolt propagation. The need for a back-up hatchery facility, in addition to CBNFH, should be considered. Such a facility would provide an additional source of broodstock in case of a catastrophic event at CBNFH.

5.1.3 Evaluate and implement, as appropriate, new stocking strategies

New stocking strategies (i.e., alternate life-stage stocking, stream-side hatchery boxes, satellite hatcheries) should be evaluated in an effort to improve the survival of hatchery-reared Atlantic salmon after release. The appropriateness of stocking other life stages (parr, smolts, adults) should continue to be evaluated.

The stocking of different life-stages within DPS rivers provides the opportunity to evaluate the management advisability of this stocking strategy. Since 2001, smolts and parr (byproducts of the smolt stocking program) have been stocked into the Dennys River as part of ongoing salmon research. A smolt stocking program has been initiated for the Pleasant River. As part of this program, parr were stocked into the Pleasant River beginning in Fall 2002. Smolt stocking begin in the Spring 2003. Fry stocking will continue in other DPS rivers providing the opportunity to compare the success of these alternate life-stage stocking programs. The evaluation of these alternate life-stage stocking program is critical for promoting recovery of the DPS and should be continued. These evaluations also provide the opportunity to evaluate the relative survival and return rates of stocking different life-stages.

In 1997, the Services, the State of Maine and representatives of the three largest salmon aquaculture companies (Atlantic Salmon of Maine, Heritage Salmon, Maine Aquafoods) implemented a cooperative program to preserve and rebuild endangered Atlantic salmon populations in Maine. The aquaculture industry raised river-specific Atlantic salmon for select rivers from eggs provided by the CBNFH to mature adults. Adults were stocked into the Dennys, Machias and St. Croix rivers. The objectives of this program were to 1) evaluate the feasibility of using river-specific marine-reared adult salmon to stock rivers and for these adults to successfully reproduce in their natal river, 2) as a gene banking program to protect against the loss of genetic material from these three populations in the event of a cataclysmic event at CBNFH, and 3) involve the industry in the restoration program.

The initial results of the program were mixed. In 2000, a number of redds were constructed but no fry were collected during subsequent sampling of the redds. Based on the 2000 results, stocking logistics were modified for 2001. In 2002, researchers sampled redds on the Dennys and St. Croix rivers to capture emergent fry to evaluate the viability of the progeny. On the Dennys River, only nine fry were captured in fry traps, with an additional 43 being collected in rotary screw traps. On the St. Croix River, twelve redds were sampled at three sites. Researchers collected 8,000 fry at one site, with numbers being lower at the other two locations sampled.

The evaluation of the adult stocking program includes a number of projects to assess its potential to help rebuild and recover Atlantic salmon populations in historic habitat in Maine. Because this is a relatively novel technique, assessment and monitoring of the success of this program in producing Atlantic salmon is important and should be continued.

The use of stream-side incubation facilities is another stocking strategy that may enhance survival as well as add insurance against catastrophic losses due to hatchery accidents. Stream-side hatchery projects offer a unique opportunity to involve the local public in the stocking program. Stream-side incubation facilities would utilize river-specific water sources allowing for the evaluation of this factor. The potential use of stream-side incubation facilities to enhance the effectiveness of juvenile stocking practices should be evaluated.

Recovery Actions:

5.1.3A Evaluate the role of alternate stocking strategies to supplement wild salmon populations

5.1.3B Continue to assess and evaluate the results of the adult stocking program

5.1.3D Evaluate the role of streamside incubation facilities to supplement wild salmon populations

5.1.4 Evaluate the potential role of reintroduction in the recovery of the DPS

The reintroduction of Atlantic salmon to streams and rivers within the DPS's historic range (see page 1-1) from which the species has been extirpated should be evaluated to determine the need to re-establish additional populations to recover the DPS. In addition to the eight DPS rivers known to still support wild salmon populations, there are at least fourteen small coastal rivers within the geographic range of the DPS from which wild salmon populations have been extirpated (Beland 1984; Baum *et al.* 1995). These small coastal river systems have relatively limited juvenile production habitat (see Table 2). The eight DPS rivers known to still support wild populations of Atlantic salmon provide a relatively small potential carrying capacity[49].

The PVA (see page 3-6) can be utilized to help explore relationships between the probability of persistence of existing populations and the role of the extirpated populations in the viability of the DPS. The PVA results will help inform management decisions regarding whether there is a need to re-establish populations into formerly occupied rivers and streams outside those currently known to have persisted. If reintroduction projects are proposed, all necessary environmental reviews will be conducted and the public will be provided an opportunity to review any such proposal at an early stage.

Table 2 provides estimates of the historic habitat units[50] and habitat currently accessible to Atlantic salmon in Maine rivers. The estimated amount of habitat (historic and accessible) for the eight rivers within the range of the DPS known to still support wild salmon populations is 22,225 habitat units. The estimated amount of historic habitat for the 14 small coastal rivers[51] within the range of the DPS from which wild salmon populations are believed to have been extirpated is 12,642 habitat units. The total estimated historically accessible habitat within the range of the DPS is 34,867[52].

---

[49] The total combined conservation spawning escapement (CSE) targets for these eight populations is 1482 fish.

[50] Historic habitat is the total amount of habitat historically accessible to Atlantic salmon within a given river, one habitat unit = 100 m^2.

[51] These rivers have been grouped into the Central Maine Coastal (CMC) rivers and the Eastern Maine Coastal (EMC) rivers.

[52] As noted, the Services have deferred a decision whether to include the mainstem of the Penobscot River and its tributaries above the former site of the Bangor dam pending further analysis (see page 1-3). The estimated Atlantic salmon habitat in rivers within the DPS still known to support wild Atlantic salmon populations constitutes less than 17% of that in the Penobscot River above the old Bangor Dam.

Table 2: Atlantic salmon habitat		
River	**Currently Accessible Habitat**	**Total Historic Habitat**
Dennys River	2,415	2,415
East Machias River	2,145	2,145
Machias River	6,685	6,685
Pleasant River	1,085	1,085
Eastern Maine Coastal (EMC)	233	1,022
Union River	8,360	8,360
Narraguagus River	6,015	6,015
Ducktrap River	800	800
Cove Brook	235	235
Central Maine Coastal (CMC)	502	3,260
Sheepscot River	2,845	2,845
Penobscot River	102,575	125,000
Kennebec River	1,005	113,700
Androscoggin River	3,175	62,560

EMC Rivers: Indian, Chandler, Orange and Pennamaquan rivers; Tunk, Hobart and Boyden streams

CMC Rivers: Pemaquid, Medomak, St. Georges, Little and Passagassawaukeag rivers

One potential mechanism to facilitate re-introduction of salmon populations is the designation of experimental populations as provided for under Section 10(j) of the ESA. Establishment of experimental populations has the potential to contribute to recovery of the DPS in a number of ways. Examples of potential contributions include:

- Providing opportunities for research on environmental factors that may be limiting survival at various life stages without risk to the remnant populations in the eight rivers (e.g., stocking strategies; impacts of contaminants - acidification of rivers, pesticides, habitat restoration techniques)

- Serving as a hedge against catastrophic events (e.g., disease) that might threaten the river-specific populations of endangered salmon currently maintained at the CBNFH

- Decreasing the vulnerability of the DPS to extinction by increasing overall numbers of fish in the wild, at least in the short-term, while wild populations remain extremely low.

Section 10(j) of the ESA authorizes the establishment of experimental populations to facilitate the recovery of endangered and threatened species. An experimental population is defined as "an introduced and/or designated population (including any off-spring arising solely therefrom) that has been so designated in accordance with the procedures of this subpart but only when and at such times as the population is wholly separate geographically from non-experimental populations of the same species" (49 FR 33894). Essential experimental populations are treated as threatened species under the ESA, which allows the Services to establish special regulations in a 4(d) rule. The Services may use discretion as to the nature of the protective regulations and may exempt experimental populations from protection against any or all prohibited acts outlined in section 9(1)(a).

Experimental populations are classified as either "essential" or "nonessential." An experimental population "whose loss would be likely to appreciably reduce the likelihood of the survival of the species in the wild" is classified as "essential" (49 FR 33894). All other experimental populations are classified as "nonessential" (49 FR 33894). The essential/nonessential classification influences how Section 7 of the ESA is applied to experimental populations. Essential experimental populations are treated as threatened species and subject to protection under both 7(a)(1) and 7(a)(2). Federal agencies are therefore required to engage in consultations with the Services to ensure their actions are not likely to jeopardize the continued existence of the species. Nonessential experimental populations are treated as a species proposed for listing and are only subject to protection under 7(a)(4). Section 7(a)(4) requires federal agencies to conference with the Services when a proposed action is likely to jeopardize the continued existence of a species proposed for listing.

Designation of an experimental population requires consideration of the following issues (50 CFR 17.81(b):

- Possible adverse effects on remnant populations as a result of removal of individuals or eggs
- The likelihood that such an experimental population will become established and survive in the foreseeable future
- The relative effects that the establishment of an experimental population will have on the recovery of the species
- The extent to which the introduced population may be affected by existing or anticipated federal or state actions or private activities within or adjacent to the experimental population area.

A process for periodic review and evaluation of the success or failure of the release and the effect of the release on the conservation and recovery of the species is also required. The Services must consult with appropriate state fish and wildlife agencies, local governmental entities, affected federal agencies and affected private landowners in developing and implementing experimental population rules.

Production of Atlantic salmon in the river-specific hatchery program, in accordance with the broodstock collection, spawning, rearing and stocking protocols, results in unavoidable "surplus" broodstock production. Surplus is defined here as broodstock in excess of the biological carrying capacity of the native watershed of the broodstock. Both the broodstock and their offspring are afforded full protection under the ESA, therefore the Services are responsible for the disposition of "surplus" broodstock pursuant to the Interagency Policy Regarding Controlled Propagation of Species Listed under the ESA (65 FR 56916). Utilizing surplus hatchery products (e.g., surplus broodstock, eggs, fry) to re-establish populations where they are currently extirpated is consistent with the Services' mandate to properly manage propagated species and recover the DPS.

The Services should evaluate whether the use of experimental populations will facilitate the recovery the DPS. As part of this evaluation, the Services should consider criteria to identify candidate rivers for establishing re-introduced populations.

Recovery Actions:

5.1.4A Evaluate the need to re-establish populations of Atlantic salmon in rivers within the DPS's historic range from which river populations have been extirpated

5.1.4B Evaluate whether the use of experimental populations will facilitate the recovery of the GOM DPS of Atlantic salmon

5.2 Maintain Fish Health Practices to Minimize Potential Introduction of Disease to Hatchery Stocks and transmission to Wild Populations

The FWS should continue to rigorously implement fish health practices to minimize potential introduction of disease to hatchery stocks and transmission to wild populations. FWS's fish health practices to minimize disease threats and impacts on both captive and wild populations can be organized into three categories: fish culture management, health surveillance and research.

5.2.1 Continue fish culture management practices at federal hatcheries to minimize the potential for disease

Isolation of broodstock populations from each other at CBNFH is a key element in reducing disease risks. When fish captured from the wild are received at the facility, they are immediately isolated from both other broodstocks and different year classes of the same brood stock for a minimum of one year. This physical isolation includes use of separate equipment, separate water (filtered and disinfected with ultra-violet radiation) and strict sanitary practices, as outlined in the CBNFH Standard Fish Husbandry Procedures for Biosecurity, Best Management Plan for ISA virus and the Best Management Plan for SSS virus.

5.2.2 Continue fish health surveillance efforts and implementation of fish health practices at federal hatcheries

Brood fish collected from the wild are non-lethally screened for bacterial pathogens upon arrival at the facility. All broodstock mortalities are tested for parasites, bacteria and viruses of concern (as well as any presently unknown pathogens or parasites). Fish are also sampled for vertically transmitted (from parent to offspring) pathogens at the time of spawning to reduce the risk of stocking diseased fish. Sampling is done in compliance with FWS Fish Health Policy, the New England Salmonid Health Guidelines and the IFW's Salmonid Fish Health Inspection Regulations. In compliance with these policies, fry are inspected for replicating viral agents prior to release in the wild. All results from recent screenings have been negative.

During a recent typical twelve-month period of fish health surveillance at CBNFH, sampling consisted of 210 mortalities monitored (representing 2.1% to 8.6% of the captive populations they originated from); ovarian fluids from 586 mature females (all of the listed stocks spawned and 148 Penobscot fish); 180 non-lethal bacterial (vent) cultures from recently captured wild young (future broodstock); and 420 lethal samples including fry from all river systems and adult Penobscot fish. During this period, Polymerase Chain Reaction (PCR) screening resulted in one ISA positive Penobscot River sea-run salmon. Follow-up cell culture did not confirm the initial result. During this same period, screening results for all other diseases of concern were negative.

5.2.3 Continue research on fish health issues, detection and prevention

The standard assay of cell culture using the Atlantic salmon head-kidney (SHK-1) cell line continues to be used for broodstock management purposes, but the 28-day time requirement is often too long to allow timely fish health management. The Lamar Fish Health Center (LFHC) has begun investigating the use of PCR for determining incidence of ISA virus.

The laboratory is also participating in a quality assurance and quality control exercise to evaluate detection methodologies for ISAV with NOAA Fisheries, the University of Maine and a private fish health diagnostic lab in Maine. Sample type (e.g., blood versus tissue), laboratory assay (PCR versus cell culture) and tissue transport medium (HBSS versus PBS) are among the parameters being investigated through the use of blind samples consisting of presumed negative fish as well as experimental fish inoculated with ISAV.

The Cornell University College of Veterinary Medicine has continued research on SSSV. It has mapped the entire genome of this retrovirus and has nearly completed an antibody-based (ELISA) assay for detection. The Lamar Fish Health Center has cooperated with the Olympia (Washington) Fish Health Center and USGS-BRD (Biological Resource Division) Seattle Science Center to coordinate testing of Penobscot Atlantic salmon for ISAV susceptibility with

Pacific salmon investigations. The FWS should continue to support work on fish health issues, such as ISA and SSS detection and prevention through its Lamar Fish Health Center.

Research on other potential pathogens is also needed to better understand the threat of disease to the DPS. Efforts to prevent outbreaks of furunculosis in hatcheries should continue as well as research into methods of transmission and prevention of other fungal infection. Ongoing research on bacterial cold-water disease (CWD) caused by the bacterium *Flavobacterium psychrophila*, should be continued. Ongoing studies at the USGS Leetown Science Center have shown that this bacterium is associated with peduncle lesions, skin ulcers, fin erosions, neurological symptoms and skeletal deformities. This bacterium has been shown to be vertically transmitted from carrier adults to offspring via eggs. The bacteria influences egg quality and early life stage survival. The threat from CWD is potentially serious if the bacteria is vertically transmitted from broodstock to eggs and to fry in the hatchery. Research on the use of antibiotics and other methods to prevent outbreaks of this disease should be continued.

Resident fish species within DPS rivers should be monitored for endemic and exotic salmonid pathogens. This monitoring program should annually screen multi-species samples in each DPS river.

Recovery Actions:

5.2.3A Conduct research on ISAV and SSSV detection and prevention

5.2.3B Conduct research on other pathogens to identify potential threats to the DPS

5.2.3C Initiate screening and long-term monitoring of resident fish species in DPS rivers for endemic and exotic salmonid pathogens

5.3 Maintain practices to prevent escapement from federal hatcheries

The CBNFH and the GLNFH are dedicated solely to Atlantic salmon production. The potential exists for juveniles to escape from these facilities into rivers within the geographic range of the DPS (e.g., the lower Penobscot and Union river drainages where the hatcheries are located). Escapees and any resultant adults could be confused with wild salmon and confound surveys and research data related to wild salmon recovery. The risks of hatchery escapes can be minimized by performing annual inspections of each hatchery to identify possible sources of escape, with particular attention paid to discharge and effluent sites. If necessary, remedial actions should be taken to remedy any containment failures. Discharge and effluent management protocols should be implemented to minimize the release of juveniles.

Recovery Actions:

5.3A Develop and implement procedures at federal hatcheries to identify potential escape sources and implement the appropriate modifications

5.3B Implement discharge and effluent management protocols for all federal hatcheries with the goal of controlling and minimizing release of juveniles

6. Conserve the genetic integrity of the DPS

Preservation of the genetic integrity of populations, and the genetic diversity within and among populations, is critical for the long-term fitness and viability of populations (e.g., Schonewald-Cox *et al.* 1983; Reed and Frankham 2003). As such, one of the goals of the Gulf of Maine DPS recovery program is to maintain the genetic integrity of wild and captive populations and prevent irreversible losses of genetic diversity that may result from management actions or lack of actions.

6.1 Ensure that culture and stocking programs conserve the genetic integrity of the DPS

In recognition of the fact that comprehensive genetic data are needed to implement biologically sound management actions, the FWS expanded its Atlantic salmon genetic program in 1999. At the core of this expansion is genetic characterization of all fish intended for broodstock. This offers unprecedented abilities to evaluate many components of the stocking program.

6.1.1 Develop broodstock management plans, including brood fish collection, genetic management and program evaluation protocols

The FWS, in cooperation with other federal and state agencies, should develop broodstock management plans for FWS Maine Hatchery Complex program. An effective broodstock plan must comprehensively cover seven elements: 1) collection of broodstock, 2) broodstock screening (e.g. culling and selection), 3) broodstock composition (e.g., captive, wild collections, backup sources), 4) mating strategies, 5) hatchery logistics (e.g., capacity, physical limitations), 6) production schedules, 7) demographic expectations/projections. While many of these elements are already operationally in place, they should be consolidated and updated in one guiding document.

6.1.2 Continue to genetically characterize and screen all brood fish and to track parentage of all fish produced

As part of ongoing broodstock management, FWS should continue to genetically characterize and screen all broodstock. This will help ensure avoidance of mating closely-related fish (i.e., minimize inbreeding), avoidance of using foreign fish (e.g., aquaculture escapees) as broodstock and maximization of genetic diversity of hatchery-produced fish. The genetic characterization will also allow the production of genetically "marked" offspring that can be distinguished from each other, and from naturally-produced fish.

6.2 Ensure that management plans consider and avoid negative genetic effects of management actions

Many of the management actions associated with recovery of the DPS may present genetic hazards. As management plans are developed and revised, these hazards should be explicitly identified and avoidance measures enacted. The broodstock and stocking program for the DPS is an especially important area of consideration because of the inherent hazards of domestication (i.e., any change in the selection regime of a cultured population relative to that experienced by the natural population) and loss of genetic variability. As the number of returning wild and hatchery-origin adults changes through time, the broodstock stocking program for the DPS must maintain and update the appropriate genetic management plans. Genetic Management Plans (GMPs) will focus on goals to reduce 1) genetic drift; 2) selection; 3) domestication; and 4) inbreeding.

6.3 Explore methods for long-term preservation of gametes and genes for future use

The long-term preservation of gametes is one measure that could help maintain the genetic diversity within the DPS by serving as a gene bank in case of gamete shortages or a catastrophic population loss. At present, techniques for preservation of fish eggs are lacking, but cryopreservation of sperm is a viable technique that is an integral part of propagation programs for other endangered salmon species. Further consideration should be given to the application of this technology to the recovery of the DPS.

6.4 Monitor genetic diversity, including parentage of smolts and returning adults

Genetic monitoring of salmon from the DPS rivers is needed to ensure that genetic diversity is maintained and protected. In addition, monitoring will help assess the effects of management actions and provide information to assist recovery such as which fish stockings were effective, which adults spawned successfully and whether Atlantic salmon stocked in DPS rivers perform, or behave differently compared to naturally-spawned fish.

7. Assess stock status of key life stages

More than a century of restoration efforts for Maine Atlantic salmon and international interest in the conservation of wild Atlantic salmon have produced a rich and valuable body of scientific literature to help guide recovery efforts for the Gulf of Maine DPS. This information is useful for initiating and planning recovery activities. No universal formula for recovery of wild salmonid populations exists. There are significant gaps in our understanding of the factors that continue to depress populations and the actions needed to achieve recovery both across the DPS and in specific DPS rivers. One weakness of U.S. Atlantic salmon recovery efforts to date has been the lack of quantitative information to evaluate management actions. Long time-series of hatchery stocking, adult returns to traps and catch data do exist. The state and federal management agencies responsible for collecting these data are in the process of consolidating information and building electronic databases that will facilitate comprehensive analyses of these data. When historical data are consolidated in databases, historical management practices in Maine should be re-assessed using modern analytical approaches. Recovery efforts for the DPS should use the available comprehensive scientific literature to inform management decisions and actions.

An adaptive management approach is needed that integrates actions to reduce threats to Atlantic salmon and their habitat with ongoing assessment and research activities. All population monitoring and scientific investigations must include an assessment component. An appropriate level of assessment will help inform management decisions and ensure that these decisions are based on the best available and most current scientific information. Ongoing assessment will allow for evaluation of management actions as well as the integration of new ideas and management directions (Smith and Walters 1981; Milliman *et al.* 1987; Walters *et al.* 1993).

Such an approach requires that assessment and research be intensive and that it continually and thoroughly evaluates the results of ongoing actions. This will allow modifications to activities to improve the effectiveness of the overall recovery effort. The Services believe that the scientific investigations described below will provide information for refinement of recovery actions described in other sections of this plan. Likewise, evaluation of the results of these scientific investigations and other recovery actions may suggest the need for additional research tasks or revision of priorities accorded to research tasks specified below.

7.1 Assess abundance and survival of Atlantic salmon at key freshwater and marine life-stages

The relative abundance of Atlantic salmon populations can be monitored by assessment of annual abundance at one life history stage such as adult returns or escapement as indexed by redd counts. However, the conservation of Maine Atlantic salmon populations requires assessments of stage-specific survival for all life stages. This information is needed to understand where and when mortality is occurring and if this mortality is within the expected normal ranges reported for the species. Equally important is the fact that stage-specific data provide information on potential population bottlenecks that might be addressed through adaptive management actions.

Assessing production of Atlantic salmon parr, smolts, returning adults and spawning escapement of adult Atlantic salmon are key elements of evaluating the population dynamics of Atlantic salmon. DPS Atlantic salmon generally live in freshwater for two years and saltwater for two years and use discrete habitats within these ecosystems (tributaries, rivers, estuaries, coastal waters and high seas) (see page 1-6). Focusing assessment work on the transition between these habitats and ecosystems is vital in determining where population growth could be inhibited. In addition, there is some variability in duration of Atlantic salmon's freshwater and marine residency. Therefore, it is important to age Atlantic salmon to facilitate both age-structured as well as stage-specific assessments of mortality rates. This approach will result in data that can be used to continually assess the potential factors impeding or enhancing the recovery of DPS populations. Stage-specific production and mortality rates should be investigated further.

The data collected from assessments outlined below can provide a critical link between freshwater and marine stages across the Gulf of Maine DPS. Collection of these data will provide additional future benefits by enabling researchers to characterize the health of DPS populations compared to historic levels and biological expectations of carrying capacities; to characterize the age distribution of populations, reconstruct the growth histories and compare them to the population growth histories; and identify critical bottlenecks or factors that may be related to survival within the freshwater and marine environment.

Based on stage-specific population assessments (see below), mortality rates can be partitioned to individual life stages. These data, however, do not reveal the underlying causes of mortality. This information should be used to direct research needed to identify factors contributing to mortality at each freshwater and marine life-stage. In order for Atlantic salmon recovery efforts to be successful, sources of stage-specific mortality need to be identified.

While no one particular habitat issue is likely causing the decline in freshwater production, the cumulative impacts of multiple threats may be affecting survival due to habitat degradation and direct mortality. Results of studies on the Narraguagus and Pleasant rivers demonstrate that full freshwater production is not being achieved despite fry stocking efforts. These results suggest that a factor, or factors, within the rivers may be negatively impacting freshwater habitat for Atlantic salmon.

Low survival rates in the marine environment are also hindering Atlantic salmon recovery efforts. As in the freshwater habitat, stage-specific mortality in the marine environment is most likely due to the cumulative effect of a number of factors. Poor adaptation of smolts to the marine environment has been cited as a potential cause of low marine survival. Oceanographic perturbations, including changes in temperature and salinity, may also be contributing factors to low marine survival. Increases in predators and declines in food source, such as capelin, are other potential sources of mortality. Assessment of these factors may allow development of corrective actions and the implementation of appropriate recovery actions.

At current levels of abundance, it is difficult to categorize any threat to the species and its habitat as negligible. Although it is difficult to isolate and evaluate the impact of individual habitat issues, the available information indicates that cumulative impacts from habitat degradation issues (e.g., sedimentation, substrate embeddedness, acidification, endocrine disrupting chemicals) pose a threat to Atlantic salmon stocks. Stream acidification and chronic exposure to chemical residues that act as endocrine disruptors are two threats that may be contributing to mortality of Atlantic salmon in freshwater. In addition, low overwinter survival is also be hindering recovery efforts. This issue needs further investigation. The relationship between these factors and freshwater production and survival of Atlantic salmon needs to be studied in detail so that cause and effect connections can be determined or ruled out. Corrective actions can then be implemented as appropriate to enhance recovery.

7.1.1 Monitor adult returns and spawning escapement

Estimating adult returns and spawning escapement to DPS rivers is essential to assess the status of wild salmon populations within the DPS[53]. These estimates form the basis of population assessments that provide information on the effectiveness of recovery measures and help inform management decisions. Since these assessments document abundance during the least abundant stage of their life history, they provide a vital measurement of stock status and health.

Estimates of adult salmon returns can be made based on fish trap or weir counts. Weirs and traps provide the most accurate assessment tool because they provide actual counts of returns. Weirs enable ASC biologists to collect data on numbers, origin and condition of returning adults. Biological samples such as scales can be collected to determine the age-structure of returning adults. This information is used for annual stock assessment to measure progress in meeting escapement goals. It is also used for management purposes to determine each river's annual stocking requirements and stocking locations.

Weirs are currently in place on the Dennys and Pleasant rivers and there is a fish trapping facility at the Stillwater Dam on the Narraguagus River. Adult Atlantic salmon returns should continue to be monitored at weirs and fishways to obtain accurate counts of returning adult salmon. Weirs and fishways should be constantly monitored to ensure that impacts on the population are minimized while collecting biological data. As new designs and procedures become available, biologists should evaluate these opportunities for their potential to increase counting accuracy, maximize data collected and minimize stress to returning salmon. Weirs should be constructed on the East Machias and Machias rivers to monitor adult returns (see page 4-54).

Estimates of spawners on rivers without weirs or traps are based on redds counts, which can be compared with numbers of returns to weirs/traps using a return-redd model (USASAC 2001). The NOAA Fisheries and ASC developed a model relating redd counts to estimates of adult salmon abundance that has been in use since 2000. The relationship between redd counts and adult abundance is derived from assessments of adult returns and redd counts conducted on the Narraguagus River using data from 1991-2000. Using this model, managers can estimate both the total returns to the river as well as use redd counts directly to evaluate spawning activity within a watershed.

Since these redd counts index escapement directly, they provide information on the natural spawning activity of both naturally-reared and stocked returns. The ASC conducts annual late fall GPS mapping of redds in the eight rivers; this data is then referenced to a GIS river

---

53 Adult returns are defined as the number of pre-spawning Atlantic salmon returning to their natal river. Spawning escapement is the number of adults that actually survive to spawn (late October to early November) after they return to their natal river (May to October).

kilometer network and archived in a digital database to provide estimates of habitat utilization as well as return estimates for the rivers without weirs/traps. This positional data on all redds and redd clusters can be used to minimize interactions between naturally-spawned and fry-stocked juveniles. This level of spatial management provides opportunities that allow fry stocking to enhance the populations while minimizing interactions to improve survival of naturally-spawned fish. Ongoing efforts to refine this model and develop additional reference points on other DPS rivers to improve the model's accuracy should be continued.

Recovery Actions:

7.1.1A Monitor adult returns at existing fishways and weirs

7.1.1B Construct weirs on the East Machias and Machias rivers to monitor adult returns

7.1.1C Conduct intensive redd counts on all DPS rivers to index spawning escapement

7.1.1D Continue development of DPS-level estimates of spawning escapement

7.1.1E Develop accurate extrapolation methods to estimate abundance in areas where traditional redd counts are not feasible or practical

7.1.2 Conduct basinwide assessment of large parr abundance and biological characteristics

Since 1947, ASC and its predecessors have been evaluating large parr (fish > 110 mm total length) production at various index sites in many Maine rivers. Electrofishing surveys of fish in these rivers during August and September can provide information on the abundance and size/age structure of Atlantic salmon juveniles in the rivers. The indices of large parr are particularly useful because most of these fish are nearing the end of utilization of freshwater nursery habitat and will be headed to sea the following spring. Historic data are being compiled by ASC and entered into electronic databases. These index data provide a historic record of the production of juvenile Atlantic salmon in discrete stream reaches over time.

Assessments of large parr are a primary tool for assessment of the freshwater productivity of each river. Since 1991, ASC and NOAA Fisheries have estimated parr production in the Narraguagus River through intensive stream surveys (Beland and Dube 1999). These surveys cover various types of Atlantic salmon habitat from headwaters to lower reaches of the river. With these data, biologists can estimate large parr abundance for the entire river. This type of assessment is time intensive as up to 10% of the watershed may need to be sampled. With these data biologists can evaluate areas that over- or under-produce large parr and determine the variability in basin-wide production on an annual basis. As these data become available, mechanisms that limit the production of salmon can be assessed, identified and mitigated to increase juvenile production.

Assessment of large parr abundance at such an intensive level as conducted in the Narraguagus River may not be needed for all populations in the Gulf of Maine DPS but increased monitoring of large parr abundance would be useful in all rivers. The addition of intensive basinwide estimates of large parr at the extremes of the current distribution of wild salmon populations within the range of the DPS would benefit assessment of inter-river variability in production. The ASC has established a second intensive sampling program on the Dennys River. Large parr assessments in the Narraguagus and Dennys rivers should be continued and the potential for the Sheepscot River to be a third location should be evaluated. It would be useful to establish an additional six to ten representative sites on other rivers to better understand the relative abundance of large parr and provide data to cross reference index-sampled rivers with those being more intensively surveyed. These data would be useful for tracking of management actions such as stocking as well as to assess effects of abiotic factors such as drought, winter severity and floods.

Recovery Actions:

7.1.2A Continue basinwide assessment of large parr abundance and measurement of biological characteristics in the Narraguagus and Dennys river systems

7.1.2B Expand assessments of large parr abundance to a third DPS river

7.1.2C Establish six to ten index sites to assess large parr abundance and biological characteristics in remaining DPS rivers

7.1.3 Conduct quantitative assessments of Atlantic salmon smolt production

In addition to large parr assessments, NOAA Fisheries and ASC monitor the emigration of smolts. This includes the timing of migration and biological sampling. Since 1996, the abundance of smolts in the Narraguagus River has been estimated (Kocik *et al.* 1999). Smolts are captured either with rotary-screw smolt traps (RST) or with experimental weir-based smolt traps (WBST). Smolt assessments provide an opportunity to collect scale samples for aging, tissue samples for genetic studies and gill biopsies for physiological measures. Additionally, smolt trapping in the lower reaches of river systems provides an opportunity for tagging, telemetry and other related projects aimed at improving the understanding of the estuarine and marine ecology of Atlantic salmon.

By comparing smolt population data and large parr population data, biologists can determine overwinter survival from large parr to smolt stage. Data from the Narraguagus River has shown that even in years with a substantial increase in parr production (>125%), smolt production has remained relatively stable (~2% increase). Total freshwater production could potentially be increased if mechanisms for these differences can be identified.

Survival from the parr to the smolt stage in Maine was previously estimated to range from 30% to 70% (Bley and Moring 1988; Baum 1997). Survival estimates in the Narraguagus River for all years studied are substantially lower than the previously reported estimates for Maine (Bley 1987; Bley and Moring 1988; Baum 1997; Kocik *et al.* 1999). Kocik (1999) calculated that parr to smolt survival in the Narraguagus River was less than 30%. Because smolt assessments in the Narraguagus River suggest that production is well below the estimated capacity, it appears that low overwinter survival may be impeding the recovery of this population.

Similar assessments have been initiated on the Pleasant River (1999) and the Sheepscot River (2001) to determine if recent pre-smolt and marine survival estimates on the Narraguagus River are representative of other DPS rivers. The juxtaposition of rearing habitat and smolt trapping sites in both the Pleasant and Sheepscot rivers is such that only an index of smolt emigration can be obtained. These data have shown that the population of naturally-reared smolts is declining in the Pleasant River and is very low in the Sheepscot River. Modeling efforts are underway to improve estimates of smolt abundance in these two index rivers to allow more quantitative assessments of production. Assessment of smolt abundance in an additional river system would be useful for better understanding the total smolt production across the rivers of the DPS and the utility of single or multiple rivers as indices for the entire stock complex.

7.1.4 Monitor estuarine and coastal survival, ecology, and distribution of smolts using telemetry and surface trawling

The emigration of Atlantic salmon smolts from Gulf of Maine rivers occurs from April through June. During this transition, fish experience physiological changes (i.e., smoltification) and encounter new predators upon entering the estuarine and marine environments. Relatively little is known about the behavior of Atlantic salmon during the smolt-post-smolt transition and their migration through coastal waters of the Gulf of Maine. A major obstacle to the study of Atlantic salmon in the marine environment has been the relatively low density of salmon over the extended geographic range in the ocean (Hislop and Shelton 1993). Two relatively new assessment and research tools, ultrasonic telemetry and surface trawling, are now available to monitor fish during this transitional stage in estuarine and marine environments even when fish are relatively scarce.

Ultrasonic telemetry is an effective way to monitor the migration of these fish through this transition and can provide estimates of mortality as fish pass through discrete ecological zones: riverine, estuarine, nearshore and Gulf of Maine. Ultrasonic tracking studies conducted in Maine estuaries, the Gulf of Maine and the Bay of Fundy have provided indications of migration pathways and some information concerning zone-specific mortality.

Ultrasonic tracking studies of Atlantic salmon smolts within the Gulf of Maine have been conducted on both wild and hatchery-reared fish during the period from 1996-1999 and in 2001 for hatchery stocked smolts. The goal of this research is to determine the early migration route through nearshore waters of the Gulf of Maine and to estimate survival rates of both wild and hatchery-reared fish. Pilot studies were conducted on the Narraguagus River in 1996 and from

1997 to 1999. During this time, about 100 wild smolts were monitored to assess their progress migrating to the Gulf of Maine. These studies will be expanded seaward from 2002 through 2005 to determine the initial direction of migration of smolts relative to the Maine Coastal Current.

In 2001, NOAA Fisheries biologists initiated a five-year study to monitor the early marine migration of ultrasonically tagged hatchery-reared Atlantic salmon smolts within the Dennys River and Cobscook Bay. Through a partnership with the Canadian DFO, existing U.S. and Canadian electronic tracking arrays were integrated to track the movement of smolts exiting the Bay of Fundy and entering the Gulf of Maine. Researchers monitored the within-river movements, downstream passage success and early marine migration patterns of these tagged smolts. While these studies are still in progress, preliminary results suggest substantial numbers of smolts die relatively soon after leaving the riverine environment. These findings highlight the need to identify the mechanisms responsible for mortality as smolts enter saltwater.

Also in 2001, NOAA Fisheries initiated a multi-year surface-trawling program to sample U.S. Atlantic salmon post-smolts in Penobscot Bay and nearshore waters of the Gulf of Maine. The goal of the program is to improve current understanding of factors affecting growth and survival and the nearshore migration patterns of Atlantic salmon post-smolts. During this survey, hatchery and wild post-smolts of Penobscot River origin were targeted[54]. This research has the potential to provide important information concerning sources of lethal and sub-lethal mortality. In addition, this research may provide new information concerning early marine survival of Atlantic salmon. This program is part of a multinational effort to improve the understanding of post-smolt ecology through a coordinated NASCO research program.

Results from the 2001 survey indicated that greater than 97% of captured smolts were age 1+ hatchery smolts originating from the Penobscot River. The continuation of this assessment program will improve the understanding of the ecology of post-smolts. This program should be expanded to include more offshore sampling stations, thereby gaining additional information about the migration patterns and survival of post-smolts as they leave freshwater and begin their ocean migration.

Recovery Actions:

7.1.4A Continue telemetry studies of smolt migration from the Dennys (hatchery fish) and Narraguagus (wild fish) rivers

7.1.4B Expand spatial coverage of detection arrays to better assess movements of post-smolts in the Gulf of Maine and the Bay of Fundy

---

54 Two lower Penobscot Bay stocks (Cove Brook and the Ducktrap River) are currently listed under the ESA. Given the estimated smolt production in these systems relative to the Penobscot River, the probability that significant numbers of smolts from these rivers were captured is minimal.

7.1.4C Continue post-smolt surface trawling assessment programs and expand the temporal and spatial extent of coverage

7.1.5 Continue to participate and contribute to international cooperative research and assessment efforts to improve our understanding of salmon at sea

While the marine life history of Atlantic salmon is poorly understood, there has been substantial progress in understanding the marine ecology and population dynamics of Atlantic salmon during the past decade. Progress has been made in our understanding of growth, survival and migration patterns of salmon while in the ocean. Central to this progress has been the work of assessment committees such as the U.S. Atlantic Salmon Assessment Committee (USASAC), the ICES Working and Study Groups (the North American Salmon Study Group (ICES-NASSG) and the North Atlantic Salmon Working Group (ICES-NASWG)(Windsor and Hutchinson 1994). The U.S. should continue to participate in international scientific organizations and forums to identify threats to Atlantic salmon in the marine environment.

International research programs should be pursued as part of efforts to identify threats to marine life stages. NASCO provides a framework for coordinated marine research. NASCO has established an international research fund to promote coordination of research efforts among members. For example, the post-smolt research initiated in 2001 (see above) is part of a multinational effort involving Canadian, Norwegian and Scottish efforts to improve our understanding of post-smolt ecology through a coordinated NASCO research program.

7.1.6 Develop and apply population viability analysis model

Computerized population viability models are valuable tools that can help managers understand the dynamics of species. Such models can be especially useful for species with many life stages that are subject to a large number of highly variable environmental factors, such as Atlantic salmon. Models can help managers evaluate the relative benefits of alternative management actions. While the reliability of such models is dependent on the accuracy of data inputs, population models can help identify which data exert the most influence on model outputs (i.e., sensitivity analysis), thereby assisting prioritization of data collection needs. Sound application of modeling results requires testing of model predictions against empirical data and logical expectations.

In the spring of 2001, biologists from the Services and ASC initiated efforts to develop a population viability analysis (PVA) for the DPS. Like most population viability models, this tool a dynamic model that will change over time as new information becomes available. This model will provide information needed to estimate the relative effects of various threats, environmental factors and potential recovery actions on the DPS and its probability of persistence. For example, population viability modeling may reveal relationships between population size and probability of persistence, including adequacy of target populations to withstand variable cycles in marine survival. The Services and ASC should continue to develop a PVA specific to the DPS and apply the results of this model.

8 Promote salmon recovery through increased public and government awareness

8.1 Develop a comprehensive Education and Outreach Program for the Gulf of Maine DPS of Atlantic salmon

Education and outreach programs are a critical component of successful conservation and recovery plans. Public information and outreach programs help build public support and a strong constituency for Atlantic salmon recovery and conservation in Maine. Efforts to increase and improve public awareness of Atlantic salmon conservation should continue through media, educational material, public forums and workshops, demonstration projects and technical assistance. Virtually all successful conservation programs include education and public outreach programs. Public awareness is important to the success of Atlantic salmon recovery efforts in Maine.

Education and outreach programs inform the general public and interested parties, such as land owners, business and industry, state and local government about the Atlantic salmon recovery process. Education and information campaigns help promote Atlantic salmon as an important national resource and encourage individual and group involvement in the recovery process.

A comprehensive and coordinated Education and Outreach Plan for the Gulf of Maine DPS of Atlantic salmon should be developed. This plan should include a strategy to coordinate the efforts of federal, state and local organizations currently involved in education and outreach programs. The plan should identify target audiences, review existing programs and materials, evaluate the role of public display of Atlantic salmon, identify education and outreach needs, identify responsibilities and costs and develop strategies for dissemination of information and materials.

Numerous education and outreach programs are ongoing and should be reviewed to help identify outreach needs and refine programs as necessary. The plan should consider identified education and outreach needs, some of which are discussed below.

State and federal agencies should provide technical support to landowners for conservation measures that are needed to recover and conserve the DPS. The majority of riparian lands along DPS rivers and streams are in private ownership. Many landowners in DPS river watersheds rely on agricultural, forestry and livestock activities for their livelihood. It is critical that the Services, state and federal agencies, local government and local conservation organizations work with these landowners to provide information about salmon recovery efforts.

Members of the outdoor sporting community, such as recreational anglers and recreational vehicle riders are an important audience to inform on how their activities may affect salmon recovery. The Maine Department of Conservation (DOC) has taken steps to establish ATV clubs and educate recreational riders on responsible practices that minimize the impacts that ATV's have on land and water resources. Efforts by ASC, IFW and ASF to make anglers aware of the difference between trout and young salmon should continue in order to minimize the potential take of juvenile salmon.

There is a need to update and develop new Atlantic salmon education and outreach materials. These materials are needed to reach new target audiences, take advantage of advancing media, and stimulate continuing public interest and awareness. In addition, all materials should be kept current regarding the status of the species and recovery efforts. Efforts to increase and improve public awareness of Atlantic salmon conservation should continue through media, educational material, public forums and workshops, demonstration projects and technical assistance.

Updated educational programs for schools should be developed. These should build upon existing curriculum materials while updating them. The updated classroom materials should also extend beyond elementary schools, where current efforts are focused.

Strong and effective local conservation organizations are important partners in recovery efforts. Local watershed groups need adequate technical support and training to effectively identify and prioritize conservation and restoration projects. Local organizations help promote public awareness, salmon recovery and conservation at the local watershed level. Several of the organizations currently involved in education and outreach efforts are outlined in Appendix 5. While there are numerous local organizations already involved in education and outreach activities, a coordinated network for distribution of information and education materials should be developed. This will allow information sharing between groups as well as a more coordinated effort to distribute relevant information and direct efforts to the appropriate audiences.

Recovery Actions:

8.1A Develop a comprehensive Education and Outreach Plan for the Gulf of Maine DPS of Atlantic salmon

8.1B Continue efforts to educate anglers on the difference between trout and juvenile salmon

8.1C Develop updated educational programs for schools

8.1D Evaluate the role of public display of salmon as an outreach tool

8.2 Maintain, and if necessary increase, coordination/communications between government and local agencies on issues pertaining to Atlantic salmon recovery

Federal and state agencies and local governments should continue to work cooperatively to recover the DPS. Where necessary, interagency communication and coordination should be strengthened. Existing coordination and communication mechanisms between federal and state agencies and local conservation organizations and other constituency groups should be reviewed and strengthened as necessary.

There are many organizations and groups involved in the protection and recovery of Atlantic salmon. Continuing and strengthening existing coordination and communication mechanisms will increase the effectiveness and efficiency of these groups. It is important to ensure that these groups have access to each other and each other's information while maintaining the separate interest and concerns of the individual watersheds. Coordination of local conservation efforts by an umbrella organization could coordinate communications between various local organizations and strengthen the effectiveness of member organizations through the power of combined resources.

Existing communication networks and other mechanisms for exchanging research results and highlighting recovery actions should also be maintained and expanded as appropriate. The Maine Atlantic Salmon Technical Advisory Committee and the Maine Atlantic Salmon Commission are two important state agencies involved in research and management of Atlantic salmon in Maine and should continue. The Services should continue to work with these two groups to coordinate recovery efforts.

9. Assess effectiveness of recovery actions and revise as appropriate

Regular and rigorous monitoring and evaluation are critical to an effective and efficient recovery program for any endangered or threatened species. Monitoring assures that recovery efforts are being implemented in a timely fashion, that effectiveness of those efforts is continually assessed and that appropriate changes are made to maximize conservation of the species. To this end, several types of reviews are necessary.

9.1 Appoint a Recovery Implementation Team to coordinate implementation of recovery plan objectives

A Recovery Implementation Team should be appointed (by the Services) to coordinate implementation of recovery actions, and to assess and integrate ongoing recovery efforts. The Implementation Team should consist of individuals with experience in Atlantic salmon conservation and familiarity with issues affecting the salmon's recovery. Within the overall team structure, a coordinating committee will be appointed who will handle team logistics and organizational matters. The coordinating committee will include a representative of the Maine ASC, NOAA Fisheries and FWS. The Implementation Team will work in concert with other technical and management groups involved in the recovery effort, including the Maine TAC. The coordinating committee and Implementation team will convene periodic meetings to aid in coordination of recovery efforts and implementation of recovery actions. The coordinating committee and Implementation Team will also be responsible for monitoring recovery progress and updating the recovery plan to reflect new scientific findings, current status of the population, improved understanding of factors affecting recovery, and completion of recovery actions and objectives.

9.2 Review implementation of Recovery Plan tasks annually and assess need for revisions, including changes in priorities

The Recovery Implementation Team should meet at least annually to review ongoing recovery efforts and implementation of recovery actions. The Implementation Schedule (see pages 5-1 to 5-11) lists and prioritizes tasks that are necessary to achieve recovery. This schedule should be reviewed annually to assess what efforts have been implemented to date. Not all tasks are of equal priority and it is not expected that every task will be implemented every year. Many tasks will require ongoing implementation, although the type and intensity of activity may change over time. Annual reviews provide important opportunities to identify any gaps in ongoing efforts and improve coordination among all agencies, organizations and other partners.

The ESA mandates that a progress report on the status of efforts to develop and implement recovery plans and the status of the species. This progress report should include actions taken by NOAA Fisheries, FWS, other federal agencies, state and local governments and other organizations that affect the recovery of the species. This information will be compiled into the report sent to the Congress on the status of efforts to develop and implement recovery plans. These reports will also be made available to the public.

Recovery Actions:

9.2A Conduct an annual review of the implementation schedule

9.2B Complete a biennial progress report on completion of recovery actions

9.3 Complete necessary addenda, updates and revisions to the Recovery Plan

Once the recovery plan has final approval, efforts should continue to be made to ensure that all information in the recovery plan is relevant and up to date. As new information on threats, actions, the biology of the species and results of research becomes available, changes to the recovery plan may be necessary. Three types of recovery plan changes are possible: addenda, updates and revisions.

An addendum can be added to a plan after the final plan has been approved. Types of addenda can range from implementation strategies or participation plans to more minor attachments of data. Most addenda will be minor additions and would not require public review or comment.

Recovery plan updates also involve relatively minor changes. An update may identify specific actions that have been initiated or will be initiated since the plan was completed, as well as changes in species status or background information that do not alter the overall direction of the recovery effort. Updates will be completed by the lead biologist for the species or the recovery team. An update represents a minor change to the recovery plan and does not require public review or comment.

A recovery plan revision is a substantial rewrite of at least a portion of a recovery plan and is usually required when there are major changes to be made. A revision may be required when new threats to the species are identified, when research identifies new life history traits that have significant recovery ramifications or when the current plan is not achieving its objectives. Revisions of recovery plans represent a major change to the recovery plan and should include public review and comment.

9.4 Continue to evaluate Atlantic salmon populations in other rivers within the range of the DPS and the appropriateness of their protection under the ESA

Conservation of additional wild stocks and their habitat has the potential to contribute to the recovery of the entire DPS. The final rule listing the DPS under the ESA identified eight rivers within the DPS with wild populations that have persisted through time and therefore possess river-specific characteristics contributing to their productivity and survival. The rule also noted that, "in the future, DPS populations may be identified in additional rivers based on ongoing stream surveys and continuing genetic analyses."

Fish surveys have identified the presence of juvenile Atlantic salmon in other river systems within the historic range of the DPS such as Bond Brook and Togus Stream (tributaries of the Kennebec River), Passagassawaukeag, Eaton Brook, Felts Brook, South Branch Marsh Stream, Kenduskaeg Stream (tributaries of the Penobscot River and estuary) and the Pennamaquan River (Buckley 1999). The status of these populations relative to their demographic history and genetic legacy (DPS, aquaculture strays, Penobscot restoration stock strays) will be addressed by the Services as part of the ongoing status review.

PART FIVE: IMPLEMENTATION SCHEDULE

The following Implementation Schedule outlines actions and estimated time frames for the Atlantic salmon recovery program, with a focus on the next three fiscal years. The schedule is a guide for meeting the recovery objective and criteria discussed in Part Three of this plan. It indicates task priorities, task descriptions and numbers, task duration, agencies and other parties responsible for implementing the tasks and estimated costs. The reader should consult the recovery action table and/or the appropriate section of the recovery plan for the full description of the recommended action proposed for implementation. This implementation schedule will be updated as recovery actions are accomplished or as otherwise dictated.

Key to Task Priority Numbers (Column 1)

PRIORITY	TYPE OF TASK
1	An action that must be taken to prevent extinction or to identify those actions necessary to prevent extinction
2	An action that must be taken to prevent a significant decline in population numbers, habitat quality, or other significant negative impacts short of extinction
3	All other actions necessary to provide for full recovery of the species

Key to Responsible Agencies (column 5)

ACOE	=	Army Corps of Engineers (U.S.)
ASC	=	Atlantic Salmon Commission (Maine)
ASF	=	Atlantic Salmon Foundation
ASMFC	=	Atlantic States Marine Fisheries Commission
BPC	=	Board of Pesticide Control (Maine)
DAFRR	=	Department of Agriculture, Food and Rural Resources (Maine)
DEP	=	Department of Environmental Protection (Maine)
DMR	=	Department of Marine Resources (Maine)
FWS	=	U.S. Fish and Wildlife Service
ICES	=	International Council for the Exploration of the Sea
IFW	=	Inland Fisheries and Wildlife, Department of (Maine)
Industry	=	Forest industry, blueberry and other agricultural industries, aquaculture industry
LURC	=	Land Use Regulatory Commission (Maine)
LWRC	=	Land and Water Resources Council (Maine)
MDEP	=	Maine Department of Environmental Protection
MDOC	=	Maine Department of Conservation

MFS	=	Maine Forest Service
MGS	=	Maine Geological Survey
MSPO	=	Maine State Planning Office
MWBC	=	Maine Wild Blueberry Commission
NASCO	=	North Atlantic Salmon Conservation Organization (international)
NAWG	=	North Atlantic Working Group
NEFHC	=	New England Fish Health Committee
NEFMC	=	New England Fishery Management Council
NFWF	=	National Fish and Wildlife Foundation
NGO	=	Non-governmental organizations (Atlantic Salmon Federation, Downeast Salmon Federation Watershed Councils, Trout Unlimited, Local Land Trusts, Project SHARE, etc)
NOAA	=	National Oceanographic and Atmospheric Administration
NRCS	=	Natural Resource Conservation Service
TAC	=	Technical Advisory Committee (ASC)
UM	=	University of Maine
USDA	=	U.S. Department of Agriculture (APHIS)
U.S. EPA	=	U.S. Environmental Protection Agency
USGS	=	U.S. Geological Survey

				Lead Agency		Estimated Cost			
Priority	**Task**	**Task Description**	**Duration**	**Federal**	**State & Other**	**Year 1**	**Year 2**	**Year 3**	**Comments**
1	1.1.2C	Develop and implement an effective flow monitoring program in addition to gage-sites to monitor stream flow and discharge data at points along rivers.	Long-term	FWS USGS	MGS, DEP, LURC	25K	25K	25K	annual implementation for duration of recovery
1	1.1.3A	Implement the Downeast Salmon Rivers Water Use Management Plan (WUMP) for the Pleasant and Narraguagus rivers and Mopang Stream	5 years	USGS FWS NRCS	ASC, DEP, LURC	1M	1M	1M	Action ongoing, total estimated cost of implementing the WUMP is 5M
1	1.1.3B	Determine the effects of current irrigation withdrawals by all growers in the watersheds on flow and Atlantic salmon	Long-term	USGS FWS	MGS, DEP, LURC	10K	10k	10K	
1	1.1.4A	Ensure that water withdrawal permit requirements protect stream flows required for the recovery and conservation of Atlantic salmon.	Long-term	FWS	ASC, DEP, LURC	10K	10K	10K	
1	1.1.4B	Issue and enforce all appropriate permits for water withdrawals	Long-term	ACOE FWS	DEP, LURC	10K	10K	10K	annual implementation for duration of recovery, action ongoing
1	1.2.2A	Evaluate the impacts of acid rain on juvenile Atlantic salmon survival in DPS rivers	3 years	USGS, NOAA EPA	ASC, DEP, UM, NGOs	75K	75K	75K	
1	1.2.2B	Identify available management measures and techniques to mitigate the potential impacts of acid rain on the DPS. Experimentally evaluate stream acidification mitigation techniques in a natural river system within the range of the DPS	3 years	NOAA FWS USGS	ASC, DEP, NGOs	250K	120K	120K	based on results of pilot study evaulate additional funding needs in out years
1	1.2.2J	Evaluate the link between pesticides and endocrine disruption	3 years	USGS EPA FWS NOAA	DEP, UM, BPC	75K	75K	75K	
1	1.2.2H	Evaluate the chronic and acute effects of agricultural chemicals on Atlantic salmon and how they may impact salmon recovery efforts	3 years	FWS NOAA	BPC, DEP, ASC	75K	75K	75K	
1	1.2.2G	Sample resident fish from all DPS rivers and analyze them for tissue residues and bio-chemical factors indicative of exposure to endocrine disrupting chemicals.	3 years	EPA NOAA FWS	ASC, DEP	45K	45K	45K	
1	1.2.3A	Implement a comprehensive and integrated long-term water chemistry monitoring program on all DPS rivers	1 year	FWS EPA	DEP, UM, ASC, NGOs	25K	25K	25K	Outyear costs TBD
1	1.2.4C	Fully implement EPA aquaculture wastewater and effluent discharge regulations	Duration TBD	EPA FWS	DEP				Costs TBD
1	2.1.1	Maintain and enforce the closure of the directed sport fishery for Atlantic salmon	Long-term	NOAA FWS	IFW, DMR	20K	20K	20K	
1	2.1.2	Maintain current FMP that restricts directed harvest of Atlantic salmon in U.S. estuarine and marine waters	Long-term	NOAA NEFMC					Periodic amendment of FMP as needed. Costs to be determined (TBD)
1	2.2.1B	Prohibit all recreational fishing in select areas utilized by Atlantic salmon as holding areas to all fishing where Atlantic salmon may be taken as bycatch or poached	Long-term		IFW, ASC				
1	2.2.2B	Develop appropriate management strategies and regulatory measures to avoid bycatch of Atlantic salmon in estuarine and marine fisheries where significant potential for bycatch has been identified	Duration TBD	NOAA	DMR, ASC				Costs TBD, action contigent on completion of action 2.2.2A

				Lead Agency		Estimated Cost			
Priority	**Task**	**Task Description**	**Duration**	**Federal**	**State & Other**	**Year 1**	**Year 2**	**Year 3**	**Comments**
1	4.1B	Develop fully functional containment management systems for the containment of farmed salmon at marine sites. Operate marine containment systems so that no farmed salmon escape to open water.	Long-term	ACOE NOAA FWS	Industry, DMR				Action initiated, 500K NFWF Grant used to develop CMS
1	4.1C	Develop and implement integrated loss control plans for all salmon aquaculture facilities	Long-term	ACOE NOAA FWS	DMR Industry				Action initiated, Plans developed for all exisitng sites, Implementation cost estimates not avilable
1	4.2.1	Develop and implement contingency measures in case of accidental release of farmed fish	Long-term	NOAA ACOE FWS	ASC Industry	10K	2K	2K	Outyear costs TBD
1	4.2.2A	Maintain existing weirs on DPS rivers to exclude aquaculture escapees, enable data collection and collect broodstock	Long-term	NOAA FWS	ASC Industry	132K	264K	264K	operation/maintenance costs 66K/weir/year
1	4.2.2B	Construct weirs on DPS rivers, including the East Machias and Machias rivers, where necessary to exclude aquaculture escapees, enable data collection and collect broodstock	Long-term	NOAA FWS	ASC Industry	831K			565K for site/construction Machias weir; 266K for site/construction E.Machias weir
1	4.2.3	Mark all farmed salmon prior to placement into marine net-pens	Long-term		Industry	100K	100K	100K	outyear costs TBD
1	4.3.1A	Develop and implement a comprehensive disease management plan that includes siting and standard operational procedures to minimize outbreaks of ISA.	Long-term	USDA NOAA FWS ACOE	Industry DMR NASCO	200K			MASCP estimates 200K to plan; implementation costs TBD
1	4.3.1B	Develop and implement comprehensive integrated bay management plans that include coordination of stocking densities, harvesting and fallowing and disease treatment and management	3 years	USDA NOAA FWS ACOE	DMR Industry NGOs ASC	50K	50K	50K	costs for development; implementation costs TBD
1	4.3.2A	Determine the modes of transmission of the ISA virus	3 years	USDA NOAA FWS	DMR Industry				Need for additional research to be asessed for out years
1	4.3.2B	Continue to investigate the role of wild fish species as potential reservoirs and vectors of ISA	3 years	NOAA USDA	DMR Industry	120K	120K		Need for additional research to be asessed for out years
1	4.3.2C	Initiate screening and long-term monitoring of resident and migratory fish in aquaculture production bays for endemic and exotic salmonid pathogens.	Long-term	NOAA	Industry DMR	120K	120K	120K	Action initiated
1	4.3.2D	Continue active research programs on immunization of farmed fish	3 years	USDA FWS	Industry DMR				Need for additional research to be assessed in outyears
1	4.3.3C	Continue treatment for sea lice at aquaculture facilities	Long-term	USDA	Industry DMR UM				
1	4.4.1A	Develop and operate fully functional containment management systems for the containment of farmed salmon at freshwater hatchery sites.	Long-term		Industry DEP IFW				Action ongoing
1	4.4.1B	Develop integrated loss control plans for all salmon aquaculture hatchery facilities. Conduct independent audits of freshwater hatcheries once loss control plans are in place	Long-term	ACOE NOAA FWS	Industry DEP DMR				1 year development; ongoing implementation
1	4.4.2	Develop contingency plans to reduce adverse impacts if containment measures fail	2 years		Industry DEP				Plans should be periodically reviewed and revised as appropriate.
1	5.1.1A	Continue operation of federal fish rearing facilities needed for recovery of the DPS, including maintenance of river-specific broodstock	Long-term	FWS		725K	750K	785K	
1	5.1.1B	Continue stocking cultured fish to supplement wild salmon populations	Long-term	FWS NOAA	ASC, TAC	60K	63K	66K	

				Lead Agency		Estimated Cost			
Priority	Task	Task Description	Duration	Federal	State & Other	Year 1	Year 2	Year 3	Comments
1	5.1.2	Monitor and evaluate the current stocking program	Long-term	NOAA FWS	ASC, TAC	150K	150K	150K	Stocking program should be periodically reviewed through out recovery. Outyear costs TBD
1	5.1.3A	Evaluate the role of alternate stocking strategies to supplement wild salmon populations	5 years	NOAA FWS	ASC, TAC, Industry	50K	50K	50K	outyear costs TBD
1	5.1.3B	Continue to assess and evaluate the results of the adult stocking program	2 years	NOAA FWS	ASC, TAC				
1	5.1.3C	Evaluate the role of streamside incubation facilities to supplement wild salmon populations	5 years	NOAA FWS	ASC, TAC	40K	40K	40K	Outyear costs TBD
1	5.1.4A	Evaluate the need to re-establish populations of Atlantic salmon in extripated rivers within the DPS	5 years	NOAA FWS	ASC, TAC				See task 5.1.4B
1	5.2.1	Continue fish culture management practices at federal hatcheries to minimize the potential for disease	Long-term	FWS					See task 5.1.1A for costs
1	5.2.2	Continue fish health surveillance efforts and implementation of fish health practices at federal hatcheries	Long-term	FWS		20K	20K	20K	
1	5.2.3A	Conduct research on ISA and SSS detection and prevention	3 years	NOAA FWS, USGS	ASC	50K	50K	50K	Need for additional research to be asessed for out years
1	5.2.3C	Initiate screening and long-term monitoring of resident fish species in DPS rivers for endemic and exotic salmonid pathogens	Long-term	NOAA FWS	ASC	20K	20K	20K	See task 5.2.3B
1	6.1.1	Update brood stock management plans, including brood fish collection, genetic management, and program evaluation	1 year	FWS	ASC, Maine TAC				Periodic review and revision as appropriate
1	6.1.2	Continue to genetically characterize and screen all brood fish and to track parentage of all fish produced	Long-term	FWS	ASC	60K	60K	60K	
1	6.2	Ensure that management plans consider and avoid negative genetic effects of management actions	Long-term	FWS NOAA	ASC				
1	6.4	Monitor genetic diversity, including parentage of smolts and returning adults	Long-term	FWS	ASC	30K	30K	30K	
1	7.1.1A	Monitor adult returns at existing fishways and weirs	Long-term		ASC	60K	60K	60K	
1	7.1.1B	Construct weirs on the East Machias and Machias rivers to monitor adult returns	2 years	FWS NOAA	ASC				See task 4.4.2B for costs and estimated time
1	7.1.1C	Conduct intensive redd counts on all DPS rivers to index spawning escapement	Long-term	NOAA	ASC	10K	10K	10K	outyear costs TBD
1	7.1.2A	Continue basinwide assessment of large parr abundance and measurement of biological characteristics in the Narraguagus and Dennys river systems	Long-term	NOAA	ASC				
1	7.1.3	Conduct quantitative assessments of Atlantic salmon smolt production	Long-term	NOAA	ASC				Annual assessment and monitoring
1	7.1.4A	Continue telemetry studies of smolt migration from the Dennys and Narraguagus rivers	3 years	NOAA	ASC	100K	100K	100K	outyear costs TBD
1	7.1.4C	Continue post-smolt surface trawling assessment programs and expand the temporal and spatial extent of coverage	3 years	NOAA		283K	283K	283K	
1	7.1.5	Continue to participate and contribute to international cooperative research and assessment efforts to improve our understanding of salmon at sea	Long-term	NOAA FWS	ASC	150K	150K	150K	Out year costs to be determined ES etc.

				Lead Agency		Estimated Cost			
Priority	Task	Task Description	Duration	Federal	State & Other	Year 1	Year 2	Year 3	Comments
1	7.1.6	Develop and apply population viability analysis model	1 year	NOAA FWS	ASC	25K			Action initaiated, model being developed by NEFSC
2	1.1.1A	Conduct IFIM studies on additional DPS rivers to determine flow requirements of juveniles	3 years	USGS, FWS, NOAA	ASC, MGS		75K	75K	outyear costs TBD
2	1.1.1B	Determine flow requirements of adult Atlantic salmon in DPS rivers	5 years	USGS, FWS, NOAA	ASC, MGS				costs TBD
2	1.1.2A	Continue analyses of historical flow data for DPS rivers to assess changes over time or hydrologic differences between the rivers that may affect salmon recovery efforts.	1 year	USGS	MGS		20K	Cost TBD	Y3 and outyear costs TBD
2	1.1.2B	Maintain existing USGS stream gages on DPS rivers	Long-term	USGS	MGS ASC	120K	120K	120K	Gages in place,10K/gage/year
2	1.1.2D	Monitor and assess the potential for groundwater withdrawals to impact stream flow and cold water discharges	Long-term	FWS USGS	MGS DEP LURC	100K	100K	100K	Action initiated, outyear costs for monitoring TBD
2	1.1.2E	Continue ongoing multi-year study of low flow characteristics of streams in eastern and northern Maine	3 years	USGS	MGS ASC		56K	56K	Action has been initiated
2	1.1.3D	Develop water use management plans for other DPS rivers	3 years	FWS	LURC DEP MSPO NGOs			250K	initiate action in Y3
2	1.1.3E	Continue periodic assessments of irrigation methods and water demands and their potential effects on hydrology and Atlantic salmon habitat	Long-term	NRCS	DEP LURC		20K		outyear costs TBD
2	1.2.2D	Model the impact on air and water quality issues, especially acid precipitation, on productivity of salmon in DPS rivers	2 years	EPA FWS NOAA	DEP UM ASC		45K	45K	
2	1.2.2E	Evaluate current agricultural practices such as soil acidity management practices to determine whether they may affect pH levels in DPS rivers	3 years	FWS, NRCS	Industry, MDOC MWBC				
2	1.2.2F	Evaluate the biological effects of low pH and aluminum and its toxicity on Atlantic salmon	3 years	USGS EPA FWS NOAA	DEP UM BPC	75K	75K	75K	
2	1.2.2I	Identify and consider appropriate management measures and techniques to mitigate the potential impacts of agricultural chemicals and other contaminants on the DPS	Duration TBD	FWS EPA	DEP BPC MDA MDOC Industry				Costs TBD as appropriate. Action contingent on results of 1.2.2H and 1.2.2I
2	1.2.2K	Conduct research on the mechanisms of non-pesticide organochlorines exposure, uptake and effect in rivers where these contaminants are known to occur including, the Dennys below the Eastern Surplus Superfund site	3 years	EPA USGS FWS	DEP UM		25K	25K	outyear costs TBD as necessary
2	1.2.4A	Prepare and implement NPS pollution reduction plans for DPS rivers	3 years	FWS NOAA EPA	ASC DEP NGOs	32K	32K	32K	Action initiated, Outyears costs TBD
2	1.2.4B	Prepare and implement Point Source pollution reduction plans for DPS rivers	2 year	EPA	DEP		32K	Y3 Costs TBD	Evaluate need for outyear funding for implementation
2	1.2.4D	Continue monitoring of the remediation efforts at the Eastern Surplus Superfund site in Meddybemps	periodic	EPA	DEP		15K	15K	outyear costs TBD
2	1.2.4E	Address any ground water problems at the Smith junkyard on the Dennys River and restore the site	Duration TBD	EPA	DEP				costs TBD
2	1.3.4	Condition permits for activities within the estuaries of DPS rivers so as to minimize potential effects on migration of juveniles and adults	Long-term	ACOE	ASC		45K	45K	ongoing

				Lead Agency		Estimated Cost			
Priority	**Task**	**Task Description**	**Duration**	**Federal**	**State & Other**	**Year 1**	**Year 2**	**Year 3**	**Comments**
2	1.4.1A	Provide long-term protection for riparian buffers through fee acquisition, conservation easements, conservation and management agreements, and other appropriate tools	Long-term	NRCS FWS	LURC MFS Industry ASC NGOs	5 Million	5 Million	5 Million	
2	1.4.2A	Evaluate the potential for activities in estuaries to adversely affect Atlantic salmon	Long-term	NOAA FWS ACOE		Exisitng resources	Exisitng resources	Existing resources	
2	1.4.2B	Condition permits for activities within the estuaries of DPS rivers so as to minimize potential effects on Atlantic salmon	Long-term	NOAA FWS ACOE		Exisitng resources	Exisitng resources	Existing resources	
2	1.5.4	Evaluate the potential of stream flow augmentation as a recovery tool to help meet Atlantic salmon flow needs and increase juvenile production and survival	1 year	FWS	ASC MGS		40K		Based on initial evaluation additional funding needs TBD
2	2.1.3A	Participate in international salmon management with the goal of ensuring any quotas set are based on the best available scientific data and provide adequate protection of US stocks	Long-term	NOAA	ASC	30K	30K	30K	outyear costs TBD
2	2.1.3B	Continue US participation in the international sampling program at West Greenland	Long-term	NOAA		30K	30K	30K	
2	2.1.3C	Continue efforts to implement a biological sampling program at St. Pierre et Miquelon to determine the origin of Atlantic salmon captured in this fishery	Long-term	NOAA USDOS Intnl. Partners		70K			Y1 NOAA costs
2	2.2.1A	Assess the level of incidental take of Atlantic salmon by recreational anglers.	Long-term	FWS	IFW ASC		25K	10K	monitoring costs TBD
2	2.2.1C	Develop a Section 10(a)(1)(B) habitat conservation plan for recreational fishing permitted by the State that may incidentally take Atlantic salmon	2 years	FWS	IFW ASC		50K	50K	costs of development/rulemaking cost of implementation TBD
2	2.2.1D	Continue to monitor commercial freshwater fisheries where the potential for incidental take of Atlantic salmon exists	Long-term		DMR ASC IFW				
2	2.2.2A	Assess the potential risk for incidental take of Atlantic salmon in marine and estuarine fisheries	3 years	NOAA	DMR ASC	45K	45K	45K	Action precursor to action 2.2.2B
2	3.1.1A	Identify and catalogue locations that restrict passage and/or concentrate salmon and thereby increase the vulnerability of salmon to predation	1 year	FWS NOAA	ASC IFW DMR		20K		Action should be conducted in association with 3.1.3A & 3.1.3B
2	3.1.1B	Review existing salmon population management practices to determine if they increase the vulnerability of juvenile salmon to cormorant predation	3 year	FWS	ASC UM	25K	25K	25K	Is this funding adequate?
2	3.1.1C	Document and monitor the presence and abundance of potential salmon predators at natural and man-made concentration sites	3 years	FWS NOAA	ASC UM		25K	25K	
2	3.1.2A	Evaluate the potential of cormorant predation to adversely affect the recovery of the DPS.	3 years	FWS NOAA	ASC IFW		25K	25K	
2	3.1.2B	Identify specific cormorant colonies within the DPS that may inflict significant levels of depredation on DPS salmon populations and implement appropriate experimental management measures	4 years	FWS NOAA	ASC	20K	20K	20K	20K in Y4
2	3.1.3A	Evaluate the effect of seal predation on the recovery of the DPS	Duration TBD	FWS NOAA	ASC				Action should be conducted in association with 3.1.1A & 3.1.3B
2	3.1.3B	Identify sites where seals are concentrated and Atlantic salmon predation is exacerbated.	3 years	NOAA FWS	ASC UM		25K	25K	Action should be conducted in association with 3.1.1A & 3.1.3A

				Lead Agency		Estimated Cost			
Priority	**Task**	**Task Description**	**Duration**	**Federal**	**State & Other**	**Year 1**	**Year 2**	**Year 3**	**Comments**
2	3.1.3C	Conduct research to determine the role of net pen sites in seal aggregation and salmon predation	3 years	NOAA FWS	ASC UM		25K	25K	outyear costs TBD
2	3.1.3E	Develop and implement appropriate management measures to mitigate the impact of documented seal predation on wild salmon populations	Duration TBD	NOAA FWS	ASC				costs TBD, action dependent on the results of 3.1.1A, 3.1.3A, 3.1.3B
2	3.1.4	Assess potential effects of other predators	3 years						costs TBD
2	3.2.1A	Review existing stocking programs and assess the potential impacts of these introductions on Atlantic salmon populations and ways to minimize potential adverse affects	1 year	NOAA FWS	ASC IFW	5K	5K	5K	review annually for duration of recovery period
2	3.2.1B	Monitor potential adverse interactions of existing stocking programs for freshwater salmonids in Atlantic salmon river drainages and fully assess the potential impacts of these programs on the DPS	1 year	NOAA FWS	ASC IFW	20K	20K	20K	Action should be conducted in conjunction with 3.2.1D
2	3.2.1C	Suspend stocking of brown trout immediately in all DPS rivers until the potential impacts of these introductions can be fully assessed			IFW ASC				Action should be implemented immediately
2	3.2.1D	Monitor potential adverse interactions of existing stocking programs for freshwater salmonids (i.e., splake, landlocked salmon, brook trout) in headwater lakes of DPS rivers to determine the potential impacts of these programs on the DPS	1 year	NOAA FWS	IFW ASC	30K	30K	30K	Action should be conducted in conjunction with 3.2.1B
2	3.2.2	Monitor populations of introduced non-salmonid species and implement management controls when appropriate and feasible	Long-term	FWS	ASC IFW	30K	30K	30K	
2	4.1A	Evaluate new aquaculture lease and permit applications to ensure that net pens and equipment are adequate for site location and potential storm impact.	Long-term	ACOE NOAA FWS	DMR ASC		30K	30K	coordination/consultation at estimated cost 30k/year for duration of recovery
2	4.1D	Develop and maintain an inventory tracking system for all marine aquaculture facilities	Long-term	NOAA ACOE FWS	DMR Industry				Action ongoing, Costs estimates unavailable
2	4.1E	Assess, document and monitor damage caused by seal predation that may lead to the escapement of farmed salmon into the environment	3 years	NOAA	Industry, UM, DMR		15K	15K	
2	4.2.4	Discontinue the culture of non-North American salmon	5 years	ACOE NOAA FWS	Industry				Action should be implemented immediately
2	4.2.5	Prohibit the placement into marine net-pens of reproductively viable transgenic salmon		ACOE NOAA FWS	DMR Industry				effective immediately
2	4.3.1C	Revise federal import regulations (Title 50) to include the ISA virus	1 year	FWS			10K		
2	4.3.1D	Maintain and update existing fish health guidelines and protocols as necessary, to control the introduction of new pathogens and continue to provide protection from disease	Long-term	NOAA FWS	ASC DMR				
2	4.3.1E	Expand the FWS Wild Fish Health Survey to include DPS rivers	Long-term	FWS	ASC	20K	20K	20K	
2	4.3.3A	Investigate the potential of sea lice to adversely affect the DPS and the role of salmon aquaculture sites as a reservoir for this parasite	3 year	NOAA ACOE FWS	Industry DMR				Costs TBD
2	4.3.3B	Regularly test and report sea lice burdens at individual net-pen facilities.	Long-term		Industry, DMR				Costs TBD

				Lead Agency		Estimated Cost			
Priority	Task	Task Description	Duration	Federal	State & Other	Year 1	Year 2	Year 3	Comments
2	4.4.1C	Develop and maintain an inventory tracking system that facilitates the accurate tracking of total numbers of salmon smolts being produced by the hatchery	Long-term	ACOE NOAA FWS	Industry DEP DMR		30K	30K	1 year development; ongoing implementation
2	5.1.4B	Establish experimental populations to assist in the recovery of the GOM DPS of Atlantic salmon		NOAA FWS	ASC, TAC		120K	120K	
2	5.2.3B	Conduct research on other pathogens to identify potential threats to the DPS		NOAA FWS	ASC		15K		See Recovery Action 5.2.3C
2	5.3A	Develop and implement procedures at federal hatcheries to identify potential escape sources and implement the appropriate modifications	Long-term	FWS			See Action 5.3A		one year development; ongoing implementation, outyear costs TBD
2	5.3B	Implement discharge and effluent management protocols for all federal hatcheries with the goal of controlling and minimizing release of juveniles	2 year	FWS EPA	DEP		20K	Y3 Costs TBD	Action should be conjunction with 5.3A
2	6.3	Explore methods for long-term preservation of gametes and genes for future use (e.g., cryopreservation)	3 year	FWS, NOAA, USGS	ASC UM		15K	30K	Outyear costs TBD
2	7.1.1D	Continue development of DPS-level estimates of spawning escapement	Long-term	NOAA	ASC, TAC				Annual action, estimates of spawning escapement needed to monitor recovery
2	7.1.1E	Develop accurate extrapolation methods to estimate abundance in areas where traditional redd counts are not feasible or practical	2 year	NOAA	ASC, TAC				Method should be periodically reviewed and revised as appropriate
2	7.1.2B	Expand assessments of large parr abundance to a third DPS river	Long-term	NOAA	ASC, TAC		50K	50K	Annual action, outyear costs TBD
2	7.1.2C	Establish 6-10 index sites to assess large parr abundance and biological characteristics in the remaining DPS rivers	2 years	NOAA	ASC, TAC		50K	50K	Annual action, outyear costs TBD
2	7.1.4B	Expand spatial coverage of detection arrays to better assess movements of post-smolts in the Gulf of Maine and the Bay of Fundy	3 years	NOAA	ASC		283K	283K	
2	8.1A	Develop and implement a comprehensive Education and Outreach Plan for the Gulf of Maine DPS of Atlantic salmon	Long-term	NOAA FWS	ASC		25K	25K	2 years development; implementation costs TBD
2	8.1B	Continue efforts to educate anglers on the difference between trout and juvenile salmon	Long-term	NOAA FWS	ASC IFW DMR		15K	15K	Action ongoing, long-term efforts required
2	8.2	Maintain, and if necessary increase, coordination/communications between government and local agencies on issues pertaining to Atlantic salmon recovery	Long-term	NOAA FWS	ASC				
2	9.4	Continue to evaluate Atlantic salmon populations in other rivers within the range of the DPS and the appropriateness of their protection under the ESA	5 years	NOAA FWS	ASC		25K	25K	outyear costs TBD
3	1.1.3C	Assess and monitor other agricultural water use needs and demands within DPS river watersheds	Long-term	NRCS	LURC DEP		30K	30K	outyear costs TBD
3	1.2.1	Review existing water quality standards for each river within the DPS to determine adequacy to meet needs of Atlantic salmon	1 year	FWS	ASC DEP			3K	3K every 3-5 years to review standards.
3	1.2.2C	Identify point sources of airborne pollutants contributing to acid precipitation that may be adversely affecting the DPS and reduce to levels that will not adversely affect or jeopardize the recovery of the DPS	4 years	EPA FWS NOAA	DEP		25K	25K	outyear costs TBD, funding needs may include modeling needs
3	1.2.2L	Continue State program to replace OBDs	3 years		DEP				currently ongoing, cost estimates unavailable

				Lead Agency		Estimated Cost			
Priority	Task	Task Description	Duration	Federal	State & Other	Year 1	Year 2	Year 3	Comments
3	1.2.3B	Monitor water temperatures in the vicinity of blueberry process water discharge sites on the Machias and Narraguagus to assess the potential impact on Atlantic salmon	Long-term	FWS USGS	DEP NGOs Industry			10K	outyear costs TBD
3	1.3.1A	Repair or remove the Coopers Mill Dam to improve fish passage around the dam	1 year	FWS	ASC IFW DMR Local Gov			65K	
3	1.3.1B	Evaluate the need to repair the existing fishway at Saco Falls	1 year		ASC			50K	
3	1.3.2	Identify and improve culverts or other road crossings that impede salmon passage	Long-term	FWS NRCS NOAA	ASC MFS MDOT NGOs Industry		75K	75K	Action ongoing
3	1.3.3	Identify and manage natural debris jams (including beaver dams) that impede salmon passage	Long-term	FWS	ASC NGOs		5K	5K	Action ongoing
3	1.4.1B	Promote the adoption and use of BMPs by landowners and compliance with these voluntary standards	Long-term		MFS landowners NGOs		25K	25K	Action ongoing
3	1.4.1C	Evaluate the impacts on Atlantic salmon of activities that may affect riparian buffer zones	Long-term		MFS Industry ASC NGOs			25K	Outyear costs TBD
3	1.4.1D	Evaluate current state and local land use regulations to determine adequacy of existing measures protecting riparian habitat and improve if appropriate	2 year	NRCS FWS	ASC LURC MSPO MFS DAFRR		25K	25K	
3	1.4.1E	Enhance protection of riparian areas where necessary through expanded enforcement and modifications to the Natural Resource Protection Act, Forest Practices Act, LURC Zoning standards, and/or Municipal Shoreland Zoning	Long-term		LURC				Costs TBD
3	1.5.1	Create regional hydraulic geometry curves and a reference reach database	3 years	FWS	ASC		75K	75K	Action ongoing, outyear costs TBD. Information is needed to aid in habitat restoration
3	1.5.2A	Identify, catalogue and prioritize habitat restoration needs in DPS rivers	2 years	FWS NOAA	ASC NGOs			32K	periodic needs assesment throughout recovery
3	1.5.2B	Identify, catalogue and prioritize habitat restoration needs in estuarine habitat of DPS rivers	2 years	FWS NOAA	ASC NGOs			32K	
3	1.5.3	Conduct high priority restoration projects	Long-term	NRCS	ASC MFS MDOT NGOs			50K	outyear costs TBD, based on the outcome of 1.5.2A & 1.5.2B
3	3.1.1D	Assess the potential of land and water use practices to exacerbate predation rates	2 years	FWS NOAA	ASC			25K	outyear costs TBD
3	3.1.2C	Evaluate the potential of conserving and restoring runs of anadromous forage species to provide a buffer against predation on salmon	Long-term	FWS NOAA	ASC IFW DMR			100K	outyear costs TBD
3	3.1.3D	Evaluate the potential of alternative research techniques and food habit sampling methodologies to help assess seal predation on Atlantic salmon	3 years	NOAA	ASC UM			35K	outyear costs TBD
3	3.2.1E	Assess the need to develop a Section 10(a)(1)(B) habitat conservation plan for existing stocking programs and if warranted, develop and implement	1 year	FWS	ASC IFW			50K	2 years development; implementation costs TBD
3	4.2.6	Continue research into developing strains of aquaculture fish that cannot interbreed with wild fish	Duration TBD		Industry UM			75K	

				Lead Agency		Estimated Cost			
Priority	**Task**	**Task Description**	**Duration**	**Federal**	**State & Other**	**Year 1**	**Year 2**	**Year 3**	**Comments**
3	4.3.2E	Develop an effective diagnostic technique for the SSS virus and determine the distribution of SSS virus within the geographic range of the DPS	3 years	USWFS NOAA	Cornell U. ASC			25K	
3	8.1C	Develop updated educational programs for schools	Long-term	NOAA FWS	ASC			10K	Materials/programs should be periodically reviewed and updated as appropriate throughout the recovery period
3	9.1	Appoint a Recovery Implementation Team to coordinate implementation of recovery plan objectives		NOAA FWS	ASC				Implementation team can be appointed before recovery plan is finalized
3	9.2A	Conduct an annual review of the implementation schedule	Long-term	NOAA FWS	ASC, TAC		5K	5K	Long-term review and monitoring of recovery plan implementation
3	9.2B	Complete a biennial progress report on completion of recovery tasks	Long-term	NOAA FWS	ASC		5K	5K	Long-term action
3	9.3	Complete necessary addenda, updates and revisions to the Recovery Plan	Long-term	NOAA FWS	ASC				Costs TBD, recovery plan should be revised and updated as necessary throughout the recovery process
3	8.1D	Evaluate the role of public display of salmon as an outreach tool	1 year	NOAA FWS					

LITERATURE CITED

Ainley, D.G. 1984. Comorants Family Phalacrocoracidae. Pages 92-101 *in* D. Haley ed. Seabirds of the eastern North Pacific and Arctic waters. Pacific Search Press, Seattle. 214 p.

Alexander, G. R. 1977. Consumption of small trout by large predatory brown trout in the North Branch of the Au Sable River, Michigan. Michigan Department of Natural Resources, Fisheries Research Report 1855:1-26.

Alexander, G. R. 1979. Predators of fish in coldwater streams. Pages 153-170 in H. Clepper, ed. Predator-prey systems in fisheries management. Sport Fishing Institute, Washington, D.C.

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

ANS (Aquatic Nuisance Species) Task Force. 1994. Intentional introductions policy review, findings, conclusions, and recommendations of the intentional introductions policy review, report to Congress, March 1994.

ASA (Atlantic Salmon Authority). 1998. 1997 Endangered species project report – annual report number 4. ASA, Bangor, Maine.

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

Bailey, J. 1998. Options

Bakshtansky, E.L., I.A.. Barybina, and V.D. Nesterov. 1976. Changes in the intensity of downstream migration of Atlantic salmon smolts according to abiotic conditions. International Council for the Exploration of the Sea. 1-9.

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

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

Barton, BA. 1977. Short-term effects of highway construction on the limnology of a small stream in southern Ontario. Freshwater Biology 7: 99-108.

Baum, E. T. 1997. Maine Atlantic Salmon: A national treasure. Atlantic Salmon Unlimited. 224 pp.

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

Baum, E.T. 2001. US/Ireland cooperative program on salmon aquaculture industry. Final Report. 34 pp.

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

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

Baum, E. T., R. B. Owen, R. Alden, W. Nichols, P. Wass, and J. Dimond. 1995. Maine Atlantic salmon restoration and management plan 1995-2000.

Beall, E., P. Moran, A. Pendas, J. Izquierdo, E. Garcia Vazquez, F. Bergot (coord) and E. Vigneux (coord). 1997. Hybridization in Natural populations of salmonids in south-west Europe and in an experimental channel. LES INTRODUCTIONS D'ESPECES DANS LES MILIEUX AQUATIQUES CONTINENTAUX EN METROPOLE. Pp. 271-285, Bulletin Francais De La Peche Et De La Pisciculture. Paris, No. 344-345.

Beamish, R.J. and D.R. Bouillon. 1993. Pacific salmon production trends in relation to climate. Canadian Journal of Fisheries and Aquatic Sciences 50: 1002-1016.

Beggs, G.L., G.F. Holeton, and E.J. Crossman. 1980. Some physiological consequences of angling stress in Muskellunge, *Esox masquinongy* Mitchell. Journal of Fish Biology. 17: 649-659.

Benke, R.J., and M. Zarn. 1976. Biology and management of threatened and endangered western trouts. Technical Report RM-28, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 45 pp.

Benke, R. 1992. Native trout of western North America. American Fishery Society, Monograph 6. Bethesda, MD, 275 pp.

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

Beland, K. 2001. Memo: Bennington Lake Splake. April 6, 2001.

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

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

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

Beland, K. F. and N. R. Dube. 1999. Atlantic salmon research addressing issues of concern to the NMFS and the Maine Atlantic Salmon Authority; Final Project Report. Bangor, Maine: Maine Atlantic Salmon Authority; Grant NA57FL0149. 60 p.

Beland, K.F., J.F. Kocik, J. VandeSande and T. F. Sheehan. 2001. Striped bass predation upon Atlantic salmon smolts in Maine. Northeastern Naturalist. 8(3): 267-274.

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

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

Birt, V.L., T.P. Birt, D. Goulet, D.K. Cairns, and W.A. Montevichce. 1987. Ashmole's halo: direct evidence for prey depletion by a seabird. Mar. Ecol. Prog. Ser. 40:205-208.

Bjornn, T.C. and seven coauthors. 1974. Sediment in streams and its effects on aquatic life. University of Idaho, Water Resources Research Institute, Research Technical Completion Report Project B-025-IDA, Moscow.

Bjornn, T.C. and six coauthors. 1977. Transport of granitic sediment in streams and its effects on insects and fish. University of Idaho, College of Forestry, Wildlife and Range Sciences, Bulletin 17, Moscow.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 *in* Meehan, W.R., editor. (1991) Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication19.

Blackwell, B. 1996. Ecology of double-crested cormorants using the Penobscot River, Maine, Unpublished Ph.D. Thesis. University of Maine, Dept. of Ecology, Orono, ME.

Blackwell, B.F., W.B. Krohn, N.R. Dube, and A.J. Godin. 1997. Spring prey use by double-crested comorants on the Penobscot River, Maine, USA. Colonial Waterbirds 20(1):77-86.

Blackwell, B.F., W.B. Krohn. 1997. Spring foraging distribution and habitat selection by double-crested cormorants on the Penobscot River, Maine USA. Colonial Waterbirds. 20(1): 66-76.

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

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

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

Bouck, G.R., and R.C. Ball. 1966. Influence of capture methods on blood characteristics and mortality in rainbow trout (*Salmo gairdneri*). Transactions of the American Fisheries Society. 95: 170-176.

Bouchard, D., Brockway, K., Giray, C., Keleher,W., and Merrill, P. L. 2001. First report of Infectious Salmon Anemia in the United States. Bulletin of the European Association of Fish Pathologists 21:86-88.

Boulva, J., and I. A. Mclaren. 1979. Biology of the harbor seal, *Phoca vitulina*, in eastern Canada. Bull. Fish. Res. Board Can. 200, 24 p.

Brobbel, M. A., M. P. Wilkie, K. Davidson, J. D. Kieffer, A. T. Bielak, and B. L. Tufts. 1996. Physiological effects of catch and release angling in Atlantic Salmon (*Salmo Salar*) at different stages of freshwater migration. Canadian Journal of Fisheries and Aquatic Sciences 53(09):2036-2043.

Brown, C. J. D. 1966. Natural hybrids of *Salmo trutta* and *Salvelinus fontinalis*. Copeia 1966(3):600-601.

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

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

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

Chadwick, E.M.P. 1982. Stock-recruitment relationship for Atlantic salmon (*Salmo salar*) in Newfoundland Rivers. Canadian Journal of Fisheries and Aquatic Sciences 39:1496-1501.

Chevassus, B. 1979. Hybridization in salmonids: results and perspectives. Aquaculture 17:113-128.

Chizmas, J. 1999. Study of pesticide levels in seven Maine Atlantic salmon rivers. Maine Board of Pesticides Control, September 1999.

Chizmas, J. 2000. 1999 surface water monitoring summary, Pleasant and Narraguagus rivers, Washington County, Maine. Maine Board of Pesticides Control, May 2000.

Choctawhatchee, Pea and Yellow Rivers Watershed Management Authority. 2000. Recommended practices manual, a guideline for maintenance and service of unpaved roads.

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

Cordone, A.J. and D.W. Kelley. 1961. The influences of inorganic sediment on the aquatic life of streams. California Fish and Game. 47: 189-228.

Crawford, S.S. 2001. Salmonine introductions into the Great Lakes: an historical review and evaluation of ecological effects. Can. Spec. Pub. Fish. Aquat. Sci. 132, 205. p.

Cunjak, R.A. and J. Therrien.1998. Inter-stage survival of wild Atlantic salmon, *Salmo salar* L. Fish. Manag. Ecol. 5(3):209-223.

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

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

Daniels, L. 1999. Diet of American eels (*Anguilla rostrata* Lesueur) in five freshwater lakes, Maine, U. S. A. M.S. Thesis, University of Maine, Orono, Maine. 61 pp.

Dangel, J. R., P. T. Macy, and F. C. Withler, 1973. Annotated bibliography of interspecific hybridization of fishes of the subfamily Salmoninae. U . S. Department of Commerce, NOAA Technical Memorandum WNMFSFC-1. 48 pp.

DeCola, J.N. 1970. Water quality requirements for Atlantic salmon. U.S. Department of the Interior pp, 26-32.

Derby, C.E., and J.R. Lovvorn. 1997. Predation on fish by cormorants and pelicans in a cold-water river: a field and modeling study. Canadian Journal of Fisheries and Aquatic Science 54:1480-1493.

Department of Fisheries and Oceans (DFO). 1998. Atlantic salmon abundance overview for 1997. Stock Status Report D0-02. DFO.

Driscoll *et al.* 2001. Acidic deposition in the northeastern United States: sources and inputs, ecosystem effects, and management strategies. BioScience 51: 180-198

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

Dudley, R.W., and G.A. Hodgkins. 2002. Historical trends in hydrologic and cryospheric variables for coastal river basins in Maine: U.S. Geological Survey Water Resources Investigations Report [in review].

Duffy, D.C. 1995. Why is the Double-crested cormorant a problem? Insights from cormorant ecology and human sociology. Pages 25-32 *in* The Double-crested Cormorant: biology, conservation and management (D.N. Nettleship and D.C. Duffy, eds.) Colonial Waterbirds 18 (Special Publication 1).

Dunbar, M.J. 1993.The salmon at sea - oceanographic oscillations. Pages 163-170 *in* D. Mills, editor. Salmon in the sea and new enhancement strategies. Fishing News Books, Blackwell Scientific, Cambridge, Massachusetts.

Dunbar, M.J., and D.H. Thompson. 1979. West Greenland salmon and climate change. *Medd. Om Grønland*. 202(4) 19 pp.

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

Dunne, T. and Leopold, L.B. (1978) Water in Environmental Planning, W.H. Freeman & Co., New York.

Duston, J., R.L. Saunders, and D.E. Knox. 1991. Effects of increases in freshwater temperature on loss of smolt characteristics in Atlantic salmon. Canadian Journal of Fisheries and Aquatic Sciences 48, 164-169.

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

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

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

Elson, P.F., 1962. Predator-prey relationships between fish-eating birds and Atlantic salmon. Bull. Fish. Res. Bd. Canada 133. 87 pp.

Elson, P.F. 1969. High temperature and river ascent by Atlantic salmon. ICES Anadromous and Catadromous Fish Comm., C.M. 1969/M:12.

Elson, P.F. 1975. Atlantic salmon rivers, smolt production and optimal spawning: an overview of natural production. Int. Atl. Salmon Found. Spec. Pub. No., 6.

Elwood, J.W. and T.F. Waters. 1969. Effects of floods on food consumption and production rates of a stream brook trout population. Transactions of the American Fisheries Society 98: 253-262.

Environmental Protection Agency. EPA. 1996. Nonpoint pointers #6: managing nonpoint source pollution from agriculture, 2 pages, March 1996, (EPA 841-F-96-004F).

Fairchild, W., E. Swansburg, J. Arsenault, and S. Brown. 1999. Does an association between pesticide use and subsequent declines in catch of Atlantic salmon (*Salmo salar*) represent a case of endocrine disruption? Environ. Health Persp. 107: 349-357.

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

Fausch, K.D. 1998. Interspecific competition and juvenile Atlantic salmon (Salmo salar): On testing effects and evaluating the evidence across scales. Canadian Journal of Fisheries and Aquatic Sciences. 20. Vol. 55, suppl. 218-231.

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

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

Ferguson, A., P. McGinnity, C. Stone, J Taggart, D. Cooke, D. Cotter, R. Hynes, and T. Cross 1997. Will interbreeding between wild and cultured fish have negative consequences? *In* Final abstracts: ICES/NASCO Symposium. Interactions between salmon culture and wild stocks of Atlantic salmon: the scientific and management issues. Bath, England, U.K.

Finlay, B. B. and S. Falkow. 1989. Salmonella as an intracellular parasite. Molecular Microbiology 3: 1833-41.

Finstad, B., P.A. Bjorn, A. Grimnes and N.A. Huidsten. 2000. Laboratory and field investigations of salmon lice (*lepeophtheirus salmonis)* infestation on Atlantic salmon (*Salmo salar* L) postsmolts. Aquatic Research 31: 795-803.

Fleming, I.A., K. Hindar, I. Mjølnerød, B. Jonsson. 1997. The simulated escape of farmed salmon in a Norweigian river: breeding success, hybridisation and offspring traits. *In* Final abstracts: ICES/NASCO Symposium. Interactions between salmon culture and wild stocks of Atlantic salmon: the scientific and management issues. Bath, England, U.K.

Fleming, I.A., K. Hindar, I.B. Mj⌀lner⌀d, B.Jonsson, T.Balstad and A.Lamberg. 2000. Lifetime success and interactions of farm salmon invading a native population. Proc. R. Soc. Lond. B 267, 1517-1523.

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

Fletcher, J. S., R. M Jordan, and K. F. Beland. 1982. The Machias River, an Atlantic salmon river management report. Atlantic Sea Run Salmon Commission. Bangor, Maine.

Francis, R.C. and S.R. Hare. 1994. Decadal-scale regime shifts in the large marine ecosystems of the Northeast Pacific: a case for historical science. Fish. Oceanogr. 3: 119-130.

Frenette, M., M. Caron, P. Julien and R.J. Gibson 1984. Interaction entre le debit et les populations de tacons (*Salmo salar*) de la riviere Matamec, Quebec. Canadian Journal of Fisheries and Aquatic Sciences 41:954-963.

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

Friedland, K. D., R.E. Haas, and T.F. Sheehan. 1996. Post-smolt growth, maturation, and survival of two stocks of Atlantic salmon. Fishery Bulletin. 94: 654-663.

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

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

Friedland, K.D. 1998. Ocean climate influences on critical Atlantic salmon (*Salmo salar*) life history events. Canadian Journal of Fisheries and Aquatic Science 55 (Suppl 1): 119-130.

Friedland, K.D. 1994. Marine Survival of Restoration Stocks. Pages 223-239 *in* New England Atlantic salmon management conference. National Marine Fisheries Service, Woods Hole, MA

Fry, F.E.J. 1947. Temperature relations of salmoids. Proc. 10th Meeting Nat. Com. On Fish Culture App. D.F.R.B. Canada

Galloway, J. 2001. Acidification of the world: natural and anthropogenic. Water Air Soil Pollution. 130: 17-24.

Garside, E.T. 1973. Ultimate upper lethal temperature of Atlantic salmon *Salmo salar* L. Canadian Journal of Zoology 51, 898-900.

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

Gephard, S., P. Moran, E. Garcia-Vazquez. 2000. Evidence of successful natural reproduction between brown trout and mature male Atlantic salmon parr. Transactions of the American Fisheries Society. 129(1):301-306.

Gibson, RJ. 1981. Behavioural interactions between Coho salmon (*Oncorhynchus kisutch*), Atlantic salmon (*Salmo salar*), brook trout (*Salvelinus fontinalis*) and steelhead trout (*Salmo gairdneri*) at the juvenile fluviatile stages. CAN. TECH. REP. FISH. AQUAT. SCI., no. 1029, 121 pp.
Gibson, R.J. 1973. Interactions of juvenile Atlantic salmon(*Salmo salar L.*) and brook trout (*Salvelinus fontinalis*)(Mitchell) International Atlantic Salmon Symposium Special Publication 4(1): 181-202.

Gibson, R.J., and R.A. Myers. 1988. Influence of seasonal river discharge on survival of juvenile Atlantic salmon, Salmo salar. Canadian Journal of Fisheries and Aquatic Sciences 45:344-348.

Gilbert, J.R. and N. Guldager. 1998. Status of harbor and gray seal populations in northern New England. Final Report to: National Marine Fisheries Service, Northeast Fisheries Science Center, Woodshole, MA. Under NMFS/NER Cooperative Agreement 14-16-009-1557. 13 pp.

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

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

Graham, M.S., C.M. Wood, and J.D. Turner. 1982. The physiological responses of the rainbow trout to strenuous exercise: interactions of water hardness and environmental acidity. Canadian Journal of Zoology. 60: 3153-3164.

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

Greenstreet, S.P.R. and J.R.G. Hislop. 1991. Predators of Atlantic salmon, *Salmo salar*. SOAFD Fiseheries Research Services Report, 16/91.

Greenstreet, S.P.R., R.I.G. Morgan, S. Barnett and P. Redhead. 1993. Variation in the number of Shags (*Phalacrocorax aristotelis*) and Common seals (*Phoca vitulina*) near the mouth of an Atlantic salmon (*Salmo salar*) river at the time of the smolt run. Journal of Animal Ecology 62(3).

Gross, M. R., 1998. One species with two biologies: Atlantic Salmon (Salmo Salar) in the wild and in aquaculture. Canadian Journal of Fisheries and Aquatic Science 55 (supp 1):131-144.

Gulf of Maine Council on the Marine Environment. 2001. “The dreaded spread of sprawl, while coastal southern Maine struggles to control development, Midcoast residents worry as the trend moves north.” Gulf of Maine Times, Gulf of Maine Council on the Marine Environment. Winter, 2001. 5(4).

Gunnes, K. 1979. Survival and development of Atlantic Salmon eggs and fry at three different temperatures. Aquaculture 16, 211-218.

Haines, T.A. 1981. Effects of acid rain on Atlantic salmon rivers and restoration efforts in the United States. Atlantic Salmon Found. Spec. Pub No. 10. pages 57-64.

Haines, T.A. 2001. The potential role of acidity from acid rain in the decline of Atlantic salmon in Maine. Presentation to the National Academy of Sciences, Bangor Maine. June 2001.

Haines, T.A., S.A. Norton, J.S. Kahl, C.W. Fay, S.J. Pauwels and C.H. Jagoe. 1990. Final Report: Intensive studies of stream fish populations in Maine. US Environmental Protection Agency, Corvallis, Oregon. Report No. EPA/600/3-90/043. 339 pp.

Hall, J.D. and R.L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. Pages 355-375 in Northcote (1969).

Hammill, M.O. and G.B. Stenson. 2000. Estimated prey consumption by harp seals (Phoca groenlandica), hooded seals (*Cystophora cristata*), grey seals (*Halichoerus grypus*) and harbour seals (*Phoca vitulina*) in Atlantic Canada. Journal of Northwest Atlantic Fisheries Science 26:1-23.

Hammill, M. O., G. B. Stenson, R. A. Myers, and W. T. Stobo. 1998. Pup production and population trends of the grey seal (*Halichoerus grypus*) in the Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 55: 423-430.)

Harrison, P. 1983. Seabirds: an Identification Guide. Houghton Mifflin Company. Boston. 448.

Harwood, A. J., N.B. Metcalfe, J.D. Armstrong and S.W. Griffiths. 2001 Spatial and temporal effects of interspecific competition between Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) in winter. Canadian Journal of Fisheries & Aquatic Sciences. 2001; 58(6):1133-1140.

Havey, K. A., and J. S. Fletcher. 1956. The Pleasant River: fish management and restoration. Maine Department of Inland Fisheries and Game, Augusta, Maine.

Havey, K.A. 1974. Effects of Regulated flows on standing crops of juvenile salmon and other fishes at Barrows Stream, Maine. Trans. Am. Fish. Soc. 103:1-9.

Hawkins, A.D. 1989. Factors affecting the timing of entry and upstream movement of Atlantic salmon in the Aberdeenshire Dee. Salmonid Migration and Distribution Symp. p.101-105.

Haya, K., B.A. Waiwood, and L Van Eeckhaute. 1985. Disruption of energy metabolism and smoltification during exposure of juvenile Atlantic salmon (*Salmo salar*) to low pH. Comp. Biochem. Physiol. 82C:323-329.

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

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

Heggberget, T.G., B.O. Johnsen, K. Hindar, B. Jonsson, L.P., Hansen, N. Hvidsten, A.J. Jensen. 1993. Interactions between wild and cultured Atlantic salmon: a review of the Norweigian experience. Fisheries Research 18:13-146.

Hesthagen, T. Movements of brown trout, *Salmo trutta*, and juvenile Atlantic salmon, *Salmo salar*, in a coastal stream in northern Norway. Journal of Fish Biology. 1988; 32(5):639-653.

Herbinger, C. and Newkirk, G. 1987. Atlantic salmon (*Salmo salar*) maturation timing: Relations between age at maturity and other life history traits: Implications for selective breeding. Selection, Hybridization and Genetic Engineering in Aquaculture. Vol.1.; Bundesforschungsanst. Fisch., Hamb 1: 341-343.

Hill, M.T., W.S. Platts and R.I. Baschta. 1991. Ecological and geomorphologic concepts for instream and out-of-channel flow requirements. Rivers 2:198-210.

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

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

Horsley and Witten. 2000. Draft hydrologic aspects of the water use management plan for the Pleasant River, downeast Maine. 97 pp. 2 Appendices.

Horsley and Witten. 2001. Hydrologic aspects of the water use management plan for the Pleasant River, Downeast Maine. 50 pp. 2 Appendices.

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

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

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

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

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

Hvidsten, N.A. and O. Ugedal. 1991. Increased densities of Atlantic salmon smolts in the River Orkla, Norway, after regulation for hydroelectric production. American Fisheries Society Symposium No. 10, 219-225.

Hvidsten, N.A. 1993. High winter discharge after regulation increases production of Atlantic salmon (*Salmo salar*) smolts in the River Orkla, Norway. Can. Spec. Publ. Fish. Aquat. Sci. No. 118:175-177.

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

ICES-NASWG (International Council for the Exploration of the Sea-North Atlantic Salmon Working Group). 2000. Report of the North Atlantic Salmon Working Group, Reykjavik, 3-13 April 2000. Doc. C.M. 2000/Assess: ACFM:13, Copenhagen.

Institute of Marine Fisheries. 2001. Large quantities of sea lice on emigrating post smolt in the Sognefjord. Press Release, July 7, 2001. Norwegian Ministry of Fisheries.

ISAB (Independent Scientific Advisory Board). 2002. Hatchery surpluses in the Pacific Northwest. Fisheries 27:16-27.

Jacobs, S. and J.M. Terhune. 2000. Harbor Seal (*Phoca vitulina*) numbers along the New Brunswick coast of the Bay of Fundy in autumn in relation to aquaculture. Northeastern naturalist 7(3): 289-296.

Jaoge, C.H., and T. A. Haines. 1990. Morphometric effects of low pH and limed water on the Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. 47:2451-2460.

Jensen, A.J., B.O. Johnsen 1999. The functional relationship between peak spring floods and survival and growth of juvenile Atlantic Salmon (*Salmo salar*) and Brown Trout (*Salmo trutta*) Functional Ecology. 6: 778-785.

Jensen, A.J., B.O. Johnsen, and T.G. Heggberget. 1991. Initial feeding time of Atlantic salmon, *Salmo salar*, alevins compared to river flow and water temperature in Norwegian streams. Environmental Biology of Fishes 30:379-385.

Jensen, A.J. and B.O. Johnsen. 1999. The functional relationship between peak spring floods and survival and growth of juvenile Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*). Func. Ecol. 13:778-785

Johnson, S.C. and L.J. Albright. 1991. The developmental stages of *Lepeophtheirus salmonis* (Krøyer, 1937) (Copepoda: Caligidae). Can. J. Zool. 69: 929-950.

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

Jones, M.L., and L.W. Stanfield. 1993. Effects of exotic juvenile salmonines on growth and survival of juvenile Atlantic salmon (*Salmo salar*) in a Lake Ontario tributary p. 71-79. *In* Gibson, R.J., and R.E. Cutting (eds.) 1993. Production of juvenile Atlantic salmon (*Salmo salar*) in natural waters. Can. Spec. Pub. Fish. Aquat. Sci. 118.

Jonsson, B. and J. Ruud-Hansen. 1985. Water temperature as the primary influence on timing of seaward migration of Atlantic salmon (*Salmo salar*) smolts. Can, J. of Fish. Aquat. Sci. 42:593-595.

Jonsson, B. and J. Ruud-Hansen. 1985. Water temperature as the primary influence on timing of seaward migrations of Atlantic salmon (*Salmo salar*) smolts. Canadian Journal of Fisheries and Aquatic Sciences 42:593-595.

Jonsson, N., B. Jonsson, and L.P. Hansen. 1990. Partial segregation in the timing of migration of Atlantic salmon of different ages. Anim. Behav. 40:313-321.

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

Jonsson, B. 1997. A review of ecological and behavioral interactions between cultured and wild Atlantic salmon. ICES J. Mar. Sci. 54, 1031-1039.

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

Jordan, W.C., and E. Verspoor. 1993. Incidence of natural hybrids between Atlantic salmon, *Salmo salar L*. and brown trout, *Salmo trutta L*., in Britain. Aquacult. Fish Manage. 24:371-374.

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

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

Kapuscinski, A.R. and E.M. Hallerman. 1990. Transgenic fishes. American Fisheries Society position statement. Fisheries 15(4):2-5.

Katona, SK, V.R. Rough, and D. Richardson. 1993. A Field Guide to the Whales and Seals from Cape Cod to Newfoundland. 4th Edition, revised. Smithsonian Institution Press, Washington, DC. 316 pp.

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

Kennedy, G.J., and J.E. Greer. 1988. Predation by cormorants, *Phalacrocorax carbo* (L.) On the salmonid populations of an Irish river, Northern Ireland, UK. Aquacult. Fish. Manage. 19:159-170.

Kennedy, G.J.A. and C.D. Strange. 1986a. The effects of intra- and inter-specific competition on the distribution of stocked juvenile Atlantic salmon, *Salmo salar L.*, in relation to depth and gradient in an upland trout, *Salmo trutta L.*, stream. J. Fish Biol. 29:199-214.

Kennedy, G.J.A. and C.D. Strange. 1986b. The effects of intra- and inter-specific competition on the survival and growth of stocked juvenile Atlantic salmon, *Salmo salar L.*, in an upland trout, *Salmo trutta L.*, stream. J. Fish Biol. 28:479-489.

Kibenge, F. S. B., Garate, O.N., Johnson, G. Arriagada, R., Kibenge, M. J. T., and Wadowska, D. 2001. Isolation and identification of infectious salmon anemia virus (ISAV) from Coho salmon in Chile. Diseases of Aquatic Organisms 45:9-18.

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

King, T.L, A.P. Spidle, M.S. Eackles, A.B. Lubinski, and W.B. Schill. 2000. Mitochondrial DNA diversity in North American and European Atlantic salmon with emphasis on the Downeast rivers of Maine. Journal of Fish Biology. 57(3):614-630.

King, T.L., S.T Kalinowski, W.B. Schill, A.P. Spidle, and B.A. Lubinski. 2001. Population structure of Atlantic salmon (*Salmo salar* L.): A range wide perspective from microsatellite DNA variation. Molecular Ecology 10(4):807-821.

Kleinschmidt Associates. 1999. Method to determine optimal riparian buffer width for Atlantic salmon habitat protection. Report to the Maine State Planning Office, Augusta, Maine, by Kleinschmidt Associates, Pittsfield, Maine.

Kocik, J.F., K.F. Beland and T.F. Sheehan. 1999. Atlantic salmon overwinter survival and smolt production in the Narraguagus River. O-99-NEC-1. Woods Hole, Massachusetts.

Kohler, C.C. and W.R. Courtenay, Jr. 1986. American Fisheries Society position on introductions of aquatic species. Fisheries 11(2):34-38.

Krohn, W.B., R.B. Allen, J.R. Moring and A.E. Hutchison. 1994. Double-crested cormorants in New England: population and management histories. Colonial Waterbirds (18) (Special Publications).

Krohn, W.B., R.B. Allen, J.R. Moring and A.E. Hutchison. 1995. Double-crested Cormorants in New England: population and management histories. Colonial Waterbirds 18 (Special Publications 1):99-109

Kroglund *et al.* 2001. Water quality dependent recovery from aluminum stress in Atlantic salmon smolt. Water Air Soil Pollution. 130: 911-916.

Krueger, C.C., and B. May. 1991. Ecological and genetic effects of salmonid introductions in North America. Can. J. Fish. Aquatic Sci. 48 (Suppl. 1):66-77.

LaBar, G.W., J.D. McCleave and S.M. Fried. 1978. Seaward migration of hatchery-reared Atlantic salmon (*Salmo salar*) smolts in the Penobscot River estuary, Maine: open-water movements. J. Cons. Int. Explor. Mer. 38(2):257-269.

LWRC (Land & Water Resources Council). 1999. Land & Water Resources Council 1998 Annual progress report Atlantic salmon conservation plan for seven Maine rivers; Annual Progress Report.

Lacroix, G.L., J. Korman. 1996. Timing of episodic acidification in Atlantic salmon rivers influences evaluation of mitigative measures and recovery forecasts. Canadian Journal of Fisheries and Aquatic Sciences. 53(3): 589-599.

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

Lassuy, D. 1999. Introduced species as a factor in the extinction and endangerment of native fish species *In* ODFW and NMFS (Oregon Department of Fish and Wildlife and National Marine Fisheries Service). 1999. Management implications of co-occurring native and introduced species. Proceedings of the Workshop, October 27-28, Portland, Oregon. 224 pp.

Leary, R.F., F.W. Allendorf and G.K. Sage. 1995. Hybridization and introgression between introduced and native fish. Amer. Fish. Symp. 15:91-101.

Leopold, L.B., M.G. Wolman and J.P. Miller. 1992. Fluvial processes in geomorphology. Dover Publications. New York.

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

MacLean, S. A., Bouchard, D. A. and Ellis, S. K. 2003. Survey of nonsalmonid marine fishes for detection of infectious salmon anemia virus and other salmonid pathogens. In: Miller, O. and Cipriano, R., tech. coords. 2003. Infectious salmon anemia: control and management. Tech. Bull. Washington, DC: U.S. Department of Agriculture, Animal and Plant Health Inspection Service.

Magee, J., T. Haines, J. Kocik, K. Beland, and S. McCormick. 2001. Effects of acidity and aluminum on the physiology and migratory behavior of Atlantic salmon smolts in Maine, USA. Water Air Soil Pollution. 130: 881-886.

Magee, J. 2001. Agrichemical monitoring and potential effects on Atlantic salmon in eastern Maine rivers. National Marine Fisheries Service Report.

Magee, J.A. 2002. Acid Rain: Still a problem for Maine's Atlantic salmon? Presentation at the Maine TAC Atlantic Salmon Research Forum, Orono, Maine. January 16, 2002.

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

Maine Atlantic Salmon Commission. 2001. Beddington Lake Splake Memo.

Maine Atlantic Salmon Commission. 2000. Atlantic Salmon Conservation Plan For Seven Maine Rivers. 2000 Annual Progress Report. 109 pp.

Maine Atlantic Salmon Conservation Plan (MASCP). 1997. Maine Atlantic Salmon Task Force. Atlantic Salmon Conservation Plan for Seven Maine Rivers.

Maine Department of Environmental Protection. 1999. Surface water ambient toxic Monitoring program 1996 data report. DEPLW1999-3, Maine Department of Environmental Protection, Augusta, Maine.

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

Maine Department of Inland Fisheries and Wildlife (IFW). 2001. Home page. December 14, 2001. http://www.state.me.us/ifw/fish/f-bntrout.htm.

Maine Department of Inland Fisheries and Wildlife. 2003. Migratory Game Bird Hunting Schedule.

Maine State Planning Office. 2001. Downeast salmon rivers water use management plan: Pleasant and Narraguagus Rivers, Mopang Stream.

Maine Technical Advisory Committee. 1998. Recommendations regarding the appropriateness of catch and release angling for Atlantic salmon in the seven Downeast rivers in 1998. February 1998.

Maine Technical Advisory Committee. 2000. Draft management plan for the Pleasant River. U.S. Fish and Wildlife Service, East Orland, Maine.

Maine Technical Advisory Committee, Ad Hoc Committee on Water Quality. 2002. Water quality issues as potential limiting factors affecting juvenile Atlantic salmon life stages in Maine rivers. 31 pp.

Mansfield, A.W. The grey seal. Ottawa: DFO Underwater world fact sheet nr. 26. 12 pp.

Marine Laboratory Aberdeen. 1998. Minimizing the interaction of cultured and wild fish: a comprehensive evaluation of the use of sterile, triploid, Atlantic salmon. AIR3-CT94-2216. Final Report 1994-1998.

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

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

McBain, S. and B. Trush. 1997. Thresholds for managing regulated river ecosystems. *In* Sommarstom, S. ed. Proceedings of the sixth biennial watershed management conference. Water Resources Center Report #92. University of California, Davis.

McClelland,W.T., M.A. Brusven. 1980. Effects of sedimentation on the behavior and distribution of riffle insects in a laboratory stream. Aquatic Insects, 2(3), 161-169.

McCormick, S.D., R.W. Brown, J.F.Kocik, J.A. Magee, and C. Tinus. 2002. Physiological changes in wild and hatchery Atlantic salmon smolts in Maine: Implications for survival. Presentation at the Maine TAC Atlantic Salmon Research Forum, Orono, Maine. January 16, 2002.

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

McElhany, P., M.H. Ruckleshaus, M. J. Ford, T.C. Wainwright and E. P Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. NOAA Technical Memorandum NMFS-NWFSC-42. 156 p.

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

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

McLaughlin, E.A. and A.E. Knight. 1987. Habitat criteria for Atlantic salmon. FWS Special Report, 18 pages.

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

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

Mierzykowski, S.E., and K.C. Carr. 1998. Environmental contaminants in fish and mussels from Meddybemps Lake, the Dennys River, and East Machias River. Eastern Surplus Superfund Site, Meddybemps, Maine. US Fish and Wildlife Service, New England Field Office Special Project Report FY98-MEFO-1-EC.

Milewski, Inka. 2000. Impacts of Salmon aquaculture on the coastal environment: a review. Conservation Council of New Brunswick.

Milliman, S.R., A. P. Grima, and C.J. Walters. 1987. Policy making within an adaptive management framework, with an application to lake trout (*Salvelinus namaycush*) management. Canadian Journal of Fisheries and Aquatic Sciences. 44(Suppl. 2)(2):425-430.

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

Mohn, R. and W. D. Bowen. 1996. Grey seal predation on the eastern Scotian Shelf: modeling the impact on Atlantic cod. Can. J. Fish. Aquat. Sci. 53: 2722-2738

Moore, A and N Lower. 2001. The effects of aquatic contaminants on Atlantic salmon (*Salmo salar* L.) smolts. Sixth International Workshop on Salmonid Smoltification, Westport, Ireland, 3-7 September 2001.

Moring, J.R. and K. Finlayson. 1996. Relationship between land use activities and Atlantic salmon (*Salmo salar*) habitat: a literature review, report to the National Council of the Paper Industry for Air and Stream Improvement, Inc., January 1996.

Morris, D.S., 1996. Seal predation at salmon farms in Maine, an overview of the problem and potential solutions. Marine Technical Society Journal. 30(2): 39-43.

Moyle, P. B., 1976. Fish introductions in California: history and impact on native fishes. Biol. Conserv. 9:101-118.

Mullins, J. E., Groman, D., and Wadowska, D. 1998. Infectious salmon anemia in salt water Atlantic salmon (*Salmo salar* L.) in New Brunswick, Canada. Bulletin of the European Association of Fish Pathologists 18:110-114.

Naevdal, G. 1983. Genetic factors in connection with age at maturation. Aquaculture. 33(1-4):97-106.

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

National Marine Fisheries Service. 1996. Report of the Gulf of Maine Aquaculture-Pinniped Interaction Task Force. 70 Pages.

National Maine Fisheries Service and US Fish and Wildlife Service (NMFS and FWS), Anadromous Atlantic Salmon Biological Review Team. 1999. Review of the status of anadromous Atlantic salmon (*Salmo salar*) under the US Endangered Species Act.

National Marine Fisheries Service. 2000. Predation on Salmonids relative to the federal Columbia River power system. White paper, Northwest Fisheries Science Center, 64 pp.

NRC (National Research Council). 2002. Genetic status of Atlantic salmon in Maine, Interim Report from the Committee on Atlantic Salmon in Maine. Washington. DC: National Academy Press., 62 pp.

Nolan, D.T. P. Reilly, and SE Wendelaar Bonga. 1999. Infection with low numbers of the sea louse *Lepeoptheirus salmonis* induces stress-related effects in post-smolt Atlantic salmon (*Salmo salar*). Canadian Journal of Fish and Aquatic Science 56: 947-959.

Norton *et al.* 1999. The Bear Brook watershed, Maine (BBWM), USA. Environmental Monitor. Assess. 55: 7-51.

Nylund, A., C. Wallace and T. Hovland. 1993. The possible role of *Lepeophteirus salmonis* (Krøyer) in the transmission of infectious salmon anemia. In: *Pathogens of Wild and Farmed Fish: Sea Lice (ed. By G. Boxshall and D. Defaye)*, pp 367-373. Ellis Horward Ltd. Chichester.

Nylund, A. and Jakobsen, P. 1995. Sea trout as a carrier of infectious salmon anemia virus. Journal of Fish Biology 45:174-176.

Nylund, A., Alexandersen, S., Rolland, J. B., and Jakobsen, P. 1995. Infectious salmon anemia virus (ISAV) in brown trout. Journal of Aquatic Animal Health 7:236-240.

Nylund, A., A.M. Kvenseth, B. Krossey and K.Hodneland. 1997. Replication of the infectious salmon anaemia virus (ISAV) in rainbow trout, *Oncorhynchus mykiss* (Walbaum). Journal of Fish Diseases 20, 275-279.

OIE (Office of International Epizootics). 2000. Infectious salmon anaemia in the Faroe Islands. OIE Disease Information, Vol. 13 (14):53.

O'Flynn, F.M., S.A. McGeachy, G.W. Friars, T.J. Benfey, and J.K. Bailey. 1997. Comparisons of cultured triploid and diploid Atlantic salmon (*Salmo salar* L.). ICES Journal of Marine Science, 54: 1160-1165.

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

Olivier, G. 2002. Disease interactions between wild and cultured fish - Perspectives from the American Northeast (Atlantic Provinces). Bulletin of the European Association of Fish Pathologists: 22:103-109.

ODFW and NMFS (Oregon Department of Fish and Wildlife and National Marine Fisheries Service). 1999. Management implications of co-occurring native and introduced species. Proceedings of the Workshop, October 27-28, Portland, Oregon. 224 pp.

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

Palm, S. and Ryman, N. 1999. Genetic basis of phenotypic differences between transplanted stocks of brown trout. Ecology of Freshwater Fish. 8:169-180.

Pauwels, S. 1990. Some effects of exposure to acid and aluminum on several life stages of the Atlantic Salmon (*Salmo salar*). Ph.D. dissertation, thesis, University of Maine, Orono, Maine, USA.

Peake, S. and R.S. McKinley. 1998. A re-evaluation of swimming performance of juvenile salmonids relative to downstream migration. Canadian Journal of Fisheries and Aquatic Sciences 55:682-687.

Peters, J.C. 1967. Effects on a trout stream of sediment from agricultural practices. Journal of Wildlife Management 31: 805-812.

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

Platts, W.S., M.A. Shirazi, and D.H. Lewis. 1979. Sediment particle sizes used by salmon for spawning, with methods for evalutation. US EPA, EPA Report 600/3-79-043, Washington DC.

Power, G. 1981. Stock characteristics and catches of Atlantic salmon (*Salmo salar*) in Quebec and Newfoundland and Labrador in relation to environmental variables. Canadian Journal of Fisheries and Aquatic Sciences 38:1601-1611.

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

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

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

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

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

Raynard, R. S., Murray, A. G., and Gregory, A. 2001. Infectious salmon anemia virus in wild fish in Scotland. Diseases of Aquatic Organisms 46:93-100.

Reddin, D. 1988. Ocean life of Atlantic salmon (*Salmo salar* L.) in the Northwest Atlantic. Pages 483-511 In: D. Mills and D. Piggins [eds.] Atlantic Salmon: planning for the future. The proceedings of the third international Atlantic salmon symposium, Held in Biarritz, France, 21-23 October, 1986. Timber Press, Portland, Oregon.

Reddin, D.G. and J.E. Carscadden. 1982. Salmon-capelin interactions. International Council for the Exploration of the Sea C.M. 1982/M:17.

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

Reddin, D.G., K.D. Friedland, P.J. Rago, D.A. Dunkley, L. Karlsson and D.M. Meerburg. 1993. Forecasting the abundance of North American two-sea winter salmon stocks and the provisions of catch advice for the west Greenland salmon fishery. International Conference for the Exploration of the Sea C.M. 1993/M:43.

Reed, D. H., and R. Frankham. 2003. Correlation between fitness and genetic diversity. Conservation Biology 17:230-237.

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

Rodger, H.D., Turnbull, T., Muir, F., Millar, S., and Richards, R. H. 1998. Infectious salmon anaemia (ISA) in the United Kingdom. Bulletin of the European Association of Fish Pathologists 18:115-116.

Roni, P., T. J. Beechie, R. E. Bilby, F. E. Leonetti, M. M. Pollock, and G. R. Pess. *In press*. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. National Marine Fisheries Service. Seattle, WA.

Rosseland *et al.* 2001. Tolerance to acid water among strains and life stages of Atlantic salmon. Water Air Soil Pollution. 130: 899-904.

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

Ruggles, C.P. 1980. A review of the downstream migration of Atlantic salmon. Canadian Technical Report of Fisheries and Aquatic Sciences No. 952:39 pages.

Ruggles, C.P. 1988. Juvenile Atlantic salmon (*Salmo salar*) abundance and angling success before and after river diversion. Biological Conservation 43:279-294.

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

Sandøy, S., and R. Langåker. 2001. Atlantic salmon and acidification in southern Norway: A disaster in the 20th century, but hope for the future? Water Air Soil Pollution. 130: 1343-1348.

Saunders, J.W. and M.W. Smith. 1965. Changes in a stream population of trout associated with increased silt. Journal of the Fisheries Research Board of Canada 22: 395-404.

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

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

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

Saunders, R.L., E.B. Henderson, P.R. Harmon, C.E. Johnston, and J.G. Eales.. 1983. Effects of low environmental pH on smolting of Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. 40:1203-1211.

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

Scarnecchia, D.L., A. Isaksson and S.E. White. 1989. Effects of oceanic variations and the West Greenland fishery on age at maturity of Icelandic west coast stocks of Atlantic salmon (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Sciences 46: 16-27.

Schofield, C.L. 1981. Aquatic effects of acid rain. Int. Atlantic Salmon Found. Spec. Pub No. 10. pages 17-20.

Schonewald-Cox, C. M., S. M. Chambers, B. MacBryde, and W. Thomas (eds.). 1983. Genetics and conservation: a reference for managing wild animal and plant populations. Benjamin/Cumminngs, Menlo Park, CA.

Schwartz, F. J., 1972. World literature to fish hybrids with an analysis by family, species, and hybrid. Publication no. 3, Gulf Coast Research Laboratory and Museum, Ocean Springs, MS. 328 pp.

Schwartz, F. J., 1981. World literature to fish hybrids with an analysis by family species, and hybrid. Supplement 1. NOAA Technical Report no. 750, NMFS, Special Scientific Report-Fisheries. 507 pp.

Scott, M. 2002. Occurrence of smallmouth bass (*Micropterus dolomieu*) in the Pleasant River watershed. Presentation at the Maine TAC Atlantic Salmon Research Forum, Orono, Maine. January 16, 2002.

Sharpe, F. P. 1962. Some observations of the feeding habits of brown trout. Prog. Fish-Cult. 24(2):60-61.

Shaw, P.A. and J.A. Maga. 1943. The effect of mining silt on yield of fry from salmon spawning beds. California Fish and Game 29:29-41.

Shelton, J.M. 1955. The hatching of chinook salmon eggs under simulated stream conditions. Progressive Fish Culturist. 17:20-35.

Shepard, S.L. 1991. Report on radio telemetry investigations of Atlantic salmon smolt migration in the Penobscot River. Bangor Hydro-Electric Company. Bangor, Maine. 35 pp with appendices.

Shepard, S.L. 1995. Atlantic salmon spawning migrations in the Penobscot River, Maine – Fishways, flows and high temperatures. MS Thesis, University of Maine, Orono, Maine. 111 pp.

Sinha, V. R. P. and J. W. Jones. 1967. On the food of the freshwater eels and their feeding relationship with the salmonids. J. Zool., London. 153: 119-137.

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

Smith, A. D. M. and Carl J. Walters. 1981 Adaptive management of stock-recruitment systems. Can. J. Fish. Aquat. Sci. 38(6):690-703.

Solomon, D.J., H.T. Sambrook and K.J. Broad. 1999. Salmon migration and river flow. Environment Agency and Southwest Water Research and Development Publication No. 4. 110 pages

Spidle, A.P., S.T. Kalinowski, B.A. Lubinski, D.L. Perkins, K.F. Beland, J.F. Kocik, and T.L. King. 2003. Population structure of Atlantic salmon in Maine with reference to populations from Atlantic Canada. Transactions of the American Fisheries Society 132:196-209.

Spidle, A. P., W.B. Schill, B.A. Lubinski, T.L. King. 2001. Fine-scale population structure in the Atlantic salmon from Maine's Penobscot River drainage. Conservation Genetics 2:11-24.

Stanley, J. G. and J. Trial. 1995. Habitat suitability index models for non migratory freshwater life stages of Atlantic salmon. National Biological Service. Biological Science Report 3. Washington, D.C.

Staurnes, M., P. Blix, and O.B. Reite. 1993. Effects of acid water and aluminum on parr-smolt transformation and seawater tolerance in Atlantic salmon, *Salmo salar*. Can. J. Fish. Aquat. Sci. 50:1816-1827.

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

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

Stenson, G. B., M. O. Hammill, and J. W. Lawson. 1997. Predation by harp seals in Atlantic Canada: Preliminary consumption estimates for Arctic cod, capelin and Atlantic cod. J. Northw. Atl. Fish. Sci., Vol. 22 137-154.

Stoddard *et al.* 1999. Regional trends in aquatic recovery from acidification in North America and Europe. Nature 401: 575-578.

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

Stone, J., I.H. Sutherland, C. Richards, RG Endris. 2000. The duration of efficacy following oral treatment with emamectin benzoate against infestations of sea lice, *Lepeoptheirus slamonis* (Kroyer), in Atlantic salmon *Salmo salar*. Journal of Fish Diseases 23, 185-192.

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

Symons, P.E.K. 1979. Estimated escapement of Atlantic salmon (*Salmo salar*) for maximum smolt production in rivers of different productivity. J. Fish. Res. Bd. Can. 35:132-140.

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

Taylor, V.R. (1985) The early Atlantic salmon fishery in Newfoundland and Labrador. Can. Spec. Publ. Fish Aquat. Sci, 76.

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

Thompson, P.M. and F. Mackay (1999). Pattern and prevalence of predator damage on adult salmon returning to a Scottish river system. Fisheries Management and Ecology, 6: 335-343.

Thorud, K. and Djupvik, H.O. 1988. Infectious anemia in Atlantic salmon (*Salmo salar* L.). Bulletin of the European Association of Fish Pathologists 8: 109-111.

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

Trial, J.G. 1986. Environmental monitoring of spruce budworm suppression programs in the Eastern United States and Canada: an annotated bibliography. Maine Agricultural Experiment Station Misc. Report. 321. 36 pp.

Tufts, B.L., Y. Tang, K. Tufts, and R.G. Boutilier. 1991. Exhaustive exercise in "wild" Atlantic salmon (*Salmo salar*): acid-base regulation and gas transport. Canadian Journal of Fisheries and Aquatic Sciences. 48: 868-874.

UNEP (United Nations Environment Program). 1999. Report of the Scientific Advisory Committee of the Marine Mammals Action Plan. United Nations Environment Programme. 26 pp.

United States Environmental Protection Agency. 2000. Water quality conditions in the United States: A Profile from the 1998 National Water Quality Inventory Report to Congress. EPA-841-F-00-006. 413 pp.

United States Geological Survey (USGS). 2002. Ground-water studies in Maine. http://me.water.usgs.gov/groundwater.html

U Maine Website. Sea lice bullets. Animal, Veterinary and Aquaculture Extension Office. www.umaine.edu/livestock/Publications/sea_lice_bullets.htm.

US FDA Website. Office of New Animal Drug Evaluation. www.fda.gov/cvm/aboutcvm/aboutona.htm

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

USASAC (US Atlantic Salmon Assessment Committee). 1997. Annual report of the US Atlantic Salmon Assessment Committee: Report No. 9 - 1996 Activities. Annual Report 1997/9. Hadley, Massachusetts.

USASAC (US Atlantic Salmon Assessment Committee). 1999. Annual Report of the US Atlantic Salmon Assessment Committee . 1999/11. USASAC, Gloucester, Massachusetts.

USASAC (US Atlantic Salmon Assessment Committee). 2000. Annual Report of the US Atlantic Salmon Assessment Committee . 2000/12. USASAC, Gloucester, Massachusetts.

USASAC (US Atlantic Salmon Assessment Committee). 2001. Annual Report of the US Atlantic Salmon Assessment Committee . 2001/13. USASAC, Gloucester, Massachusetts.

USASAC (US Atlantic Salmon Assessment Committee). 2003. Annual Report of the US Atlantic Salmon Assessment Committee . 2003/15. USASAC, East Orland, Maine.

Utter, F., K. Hindar, and N. Ryman. 1993. Genetic effects of aquaculture on natural salmonid populations. Pages 144-165 *in* K. Heen, R. L. Monahan, and F. Utter, editors. Salmon Aquaculture. Fishing News Books, Oxford.

Utter, F. M., J. E. Seeb, and L. W. Seeb. 1993. Complementary uses of ecological and biochemical genetic data in identifying and conserving salmon populations. Fisheries Research 18: 59-76.

Van den Ende, O. 1993. Predation on Atlantic salmon smolts (*Salmo salar*) by smallmouth bass (*Micropterus dolomeiu*) and chain pickerel (*Esox niger*) in the Penobscot River, Maine. Master's thesis. University of Maine, Orono.

Verspoor, E., 1997. Genetic diversity among Atlantic salmon (Salmo salar L.) populations. ICES Journal of Marine Science 54:965-973.

Volpe, JP; Anholt, BR; Glickman, BW. 2001. Competition among juvenile Atlantic salmon (*Salmo salar*) and steelhead (*Oncorhynchus mykiss*): relevance to invasion potential in British Columbia. Can. J. Fish. Aquat. Sci. 58(1):197-207.

Walters, C., R.D. Goruk and D. Radford. 1993. Rivers inlet sockeye salmon: an experiment in adaptive management. North American Journal of Fisheries Management.; 13(2):253-262.

Warner, K. 1972. Further studies of fish predation on salmon stocked in Maine lakes. The Progressive Fish-Culturist 34(4): 217-221.

Waring, G. T., J. M. Quintal, and S. L. Swartz, eds., 2000. US Atlantic and Gulf of Mexico marine mammal stock assessments – 2000. US Dep. Commer., NOAA Tech. Memo. NMFS-NE-162, 303 pp.

Waring, G. T., J. M. Quintal, and S. L. Swartz, eds., 2001. US Atlantic and Gulf of Mexico marine mammal stock assessments – 2001. US Dep. Commer., NOAA Tech. Memo. NMFS-NE-168, 310 pp.

Waters, T.F. 1995. Sediment in Streams: sources, biological effects, and control. American Fisheries Society. 251 pp.

Watt, W.D. 1981. Present and potential effects of acid precipitation on the Atlantic salmon of eastern Canada. Int. Atlantic Salmon Found. Spec. Pub No. 10. pages 39-46.

Watt, W., C. Scott, and W. White. 1983. Evidence of acidification of some Nova Scotian rivers and its impact on Atlantic salmon, *Salmo salar*. Can. J. Fish. Aquat. Sci. 40:462-473.

Watt, W., C. Scott, P. Zamora, and W. White. 2000. Acid toxicity levels in Nova Scotia rivers have not declined in synchrony with the decline in sulfate levels. Water Air Soil Pollution. 118: 203-229.

Webb, J. H., D. W. Hay, P. D. Cunningham, and A. F. Youngson. 1991. The spawning behavior of escaped farmed and wild adult Atlantic salmon (*Salmo salar* L.) in a northern Scottish river. Aquaculture 98: 97-110.

Webb, J.H., A.F. Youngson, C.E. Thompson, D.W. Hay, M.J. Donagy and I.S. McLaren. 1993. Spawning of escaped farmed Atlantic salmon, *Salmo salar* L., in western and northern Scottish rivers: egg deposition by females. Aquat. Fish Managent. 24(5):663-670.

Wehnes, R.E. 1992. Streams for the future: integrating public involvement in stream improvement program in Missouri. American Fisheries Society Symposium. 13:229-236.

Whalen, K.G. and D.L. Parrish. 1999. Nocturnal habitat use of Atlantic salmon parr in winter. Can. J. Fish. Aquat. Sci. 56, 1543-1550.

Wheeler, A., and D. Gardner. 1974. Survey of the literature of marine predators on Atlantic salmon in the North-east Atlantic. Fisheries Management 5.

White, H. C. 1936. The food of kingfishers and mergansers on the Margaree River, Nova Scotia. Journal of the Biological Board of Canada 2(3): 209-309.

White, H. C. 1939. Bird control to increase the Margaree River salmon. Bulletin No. 58. Fisheries Research Board of Canada, Atlantic Biological Station, Ottawa.

White, H. C. 1939. Factors influencing descent of Atlantic salmon smolts. Journal of the Fisheries Research Board of Canada 4(5): 323-326.

White, H. C. 1939. The food of *Mergus serrator* on the Margaree River, N. S. Journal of the Fisheries Research Board of Canada 4(5): 309-311.

White, H.C. 1957. Food and natural history of Mergansers on salmon waters in the maritime provinces of Canada. Bulletin of the Fisheries Resources Board of Canada.

White, R.J. 1995. Hatchery versus wild salmon. Calabri S., A. Stout (eds). A hard look at some tough issues. New England Atlantic Salmon Management Conference. Newburyport, MA: New England Salmon Association: 90-115.

Wilcove D.S., Bean M.J. 1994. The big kill: declining biodiversity in America's lakes and rivers. Washington, DC: Environmental Defense Fund.

Williams, A. S., 1999. Prey selection by harbor seals in relation to fish taken by the Gulf of Maine sink gillnet fishery. Thesis, Master of Science in Wildlife Ecology, University of Maine.

Windsor, M.L., P. Hutchinson. 1994. International management of Atlantic salmon, *Salmo salar* L., by the North Atlantic Salmon Conservation Organization, 1984-1994. Fisheries Management and Ecology. 1(1): 31-44.

Windsor, M. L., and P. Hutchinson. 1990. The potential interactions between salmon aquaculture and the wild stocks- a review. Fisheries Research 10: 163-176.

Wolk, K. 1988. Atlantic salmon swim bladder sarcoma virus. Pages 349-351 *in* K. Wolf, editor. Fish viruses and fish viral diseases . Cornell University; Ithaca, New York.

Wood, C. C. 1987. Predation of juvenile Pacific salmon by the common merganser (*Mergus merganser*) on eastern Vancouver Island II: Predation of stream-resident juvenile salmon by merganser broods. Canadian Journal of Fisheries and Aquatic Sciences 44(5): 950-959.

Wood, C.M., J.D. Turner, and M.S. Graham. 1983. Why do fish die after severe exercise? Journal of Fishery Biology. 22: 189-201.

Wooten, R., J.W. Smith, and E.A. Needham. 1982. Aspects of the biology of the parasitic copepods *Lepeophtheirus salmonis* and *Caligus elongatus* on farmed salmonids, and their treatment. Proceedings of the Royal Society of Edinborough. 81B:185-197.

Wydoski, R.S. , G.A. Wedemeyer, and N.C. Nelson. 1976. Physiological response to hooking stress in hatchery and wild rainbow trout (*Salmo gairdneri*). Transaction American Fisheries Society. 105: 601-606.

Youngson, A.F., J.H. Webb, C.E. Thompson and D. Knox. 1993. Spawning of escaped farmed Atlantic salmon (*Salmo salar*): Hybridization of females with brown trout. Can. J. Fish. Aquat. Sci. 50(9):1986-1990.

Youngson, A. F., and E. Verspoor, 1998. Interactions between wild and introduced Atlantic salmon (*Salmo Salar*). Canadian Journal of Fisheries and Aquatic Sciences 55(supp 1):153-160.

APPENDIX 1: LISTING FACTORS (THREATS) AND RECOVERY TASKS

LISTING FACTORS/RECOVERY ACTIONS

Listing Factor*	Threat		Recovery Actions
A	(A)(1)	Water Use	1.1.1A; 1.1.1B; 1.1.2A; 1.1.2B; 1.1.2C; 1.1.2D; 1.1.2E; 1.1.3A; 1.1.3B; 1.1.3C; 1.1.3D; 1.1.3E; 1.1.4A; 1.1.4B
A	(A)(2)	Water Quality	1.2.1; 1.2.2L; 1.2.3A; 1.2.4D; 1.2.4E
A	(A)(2)(i)	Acidified Water and Aluminum	1.2.2A; 1.2.2B; 1.2.2C; 1.2.2D; 1.2.2E; 1.2.2F
A	(A)(2)(ii)	Agricultural Pesticides	1.2.2G; 1.2.2H; 1.2.2I; 1.2.2J; 1.2.2K
A	(A)(2)(iii)	Sedimentation	1.2.4A; 1.3.4
A	(A)(2)(iv)	Excess Nutrients	1.2.4A; 1.2.4B; 1.2.4C
A	(A)(2)(v)	Elevated Water Temperatures	1.2.3B
A	(A)(3)	Obstruction to Passage	1.3.1A; 1.3.1B; 1.3.2; 1.3.3; 1.3.4
A	(A)(3)(i)	Manmade Barriers	1.3.1A; 1.3.1B; 1.3.2
A	(A)(3) ii	Natural Barriers	1.3.3; 1.3.4
B	(B)	Commercial and Recreational Fisheries	2.1.1; 2.1.2; 2.1.3A; 2.1.3B; 2.1.3C; 2.2.1A; 2.2.1B; 2.2.1C; 2.2.1D; 2.2.2A; 2.2.2B
B	(B)(1)	US Fisheries	2.1.1; 2.1.2; 2.1.3A; 2.1.3B; 2.1.3C; 2.2.1A; 2.2.1B; 2.2.1C; 2.2.1D; 2.2.2A; 2.2.2B
B	(B)(2)	Canadian Fisheries	2.1.3A

Listing Factor*	Threat		Recovery Actions
B	(B)(3)	West Greenland Fishery	2.1.3A; 2.1.3B
B	(B)(4)	St. Pierre et Miquelon	2.1.3C
C	(C)	Disease	4.3.1A; 4.3.1B; 4.3.1C; 4.3.1D; 4.3.1E; 4.3.2A; 4.3.2B; 4.3.2C; 4.3.2D; 4.3.1E; 4.3.3A; 4.3.3B; 4.3.3C; 5.2.1; 5.2.2; 5.2.3A; 5.2.3B; 5.2.3C
C	(C)(1)	Infectious Salmon Anemia (ISA)	4.3.1A; 4.3.1B; 4.3.1C; 4.3.1D; 4.3.1E;4.3.2A; 4.3.2B; 4.3.2C; 4.3.2D; 4.3.3A; 4.3.3B; 4.3.3C
C	(C)(2)	Salmon Swimbladder Sarcoma (SSS)	4.3.1D; 4.3.1E; 4.3.2C; 4.3.2E
D	(D)	Predation	3.1.1A; 3.1.1B; 3.1.1C; 3.1.1D; 3.1.2A; 3.1.2B; 3.1.2C; 3.1.3A; 3.1.3B; 3.1.3C; 3.1.3D; 3.1.3E; 3.1.4; 3.2.1A; 3.2.1B; 3.2.1C; 3.2.1D; 3.2.1E; 3.2.2
D	(D)(1)	Marine Mammals	3.1.1C; 3.1.1D; 3.1.2C; 3.1.3A; 3.1.3B; 3.1.3C; 3.1.3D; 3.1.3E
D	(D)(2)	Avian Predators	3.1.1B; 3.1.1C; 3.1.1D; 3.1.2A; 3.1.2B; 3.1.2C
D	(D)(2)(i)	Double-crested Cormorants	3.1.1B; 3.1.1C; 3.1.1D; 3.1.2A; 3.1.2B; 3.1.2C
D	(D)(2)(ii)	Mergansers	3.1.2C; 3.1.4
D	(D)(3)	Piscine Predators and Competitors	3.1.2C; 3.1.4; 3.2.1A; 3.2.1B; 3.2.1C; 3.2.1D; 3.2.1E; 3.2.2
D	(D)(3)(i)	Freshwater	3.1.2C; 3.2.1A; 3.2.1B; 3.2.1C; 3.2.1D; 3.2.1E; 3.2.2
D	(D)(3)(ii)	Estuarine and Marine	3.1.2C; 3.1.4
E	E	Water withdrawals	1.1.1A; 1.1.1B; 1.1.2A; 1.1.2B; 1.12C; 1.1.2D; 1.1.2E; 1.1.3A; 1.1.3B; 1.1.3C; 1.1.3D; 1.1.3E; 1.1.4A; 1.1.4B

Listing Factor*	Threat		Recovery Actions
E	E	Disease	4.3.1A; 4.3.1B; 4.3.1C; 4.3.1D; 4.3.1E;4.3.2A; 4.3.2B; 4.3.2C; 4.3.2D; 4.3.1E; 4.3.3A; 4.3.3B; 4.3.3C
E	E	Aquaculture	4.1A; 4.1B; 4.1C; 4.1D; 4.1E; 4.2.1; 4.2.2A; 4.2.2B; 4.2.3 ;4.2.4; 4.2.5; 4.2.6; 4.3.1A; 4.3.1B; 4.3.1C; 4.3.1D; 4.3.1E; 4.3.2A; 4.3.2B; 4.3.2C; 4.3.2D; 4.3.2E; 4.3.3A; 4.3.3B; 4.3.3C; 4.4.1A; 4.4.1B; 4.4.1C; 4.4.2
F	(F)(1)	Salmon Aquaculture	4.1A; 4.1B; 4.1C; 4.1D; 4.1E; 4.2.1; 4.2.2A; 4.2.2B; 4.2.3; 4.2.4; 4.2.5; 4.2.6; 4.3.1A; 4.3.1B; 4.3.1C; 4.3.1D; 4.3.1E; 4.3.2A; 4.3.2B; 4.3.2C; 4.3.2D; 4.3.2E; 4.3.3A; 4.3.3B; 4.3.3C; 4.4.1A; 4.4.1B; 4.4.1C; 4.4.2
F	(F)(2)	Marine Survival	2.1.3A; 2.1.3B; 2.1.3C; 2.2.1A; 2.2.1C; 2.2.2A; 2.2.2B; 3.1.3A; 3.1.3B; 3.1.3C; 3.1.3D; 3.1.3E; 3.1.4; 4.3.3A; 4.3.3B; 4.3.3C; 7.1.4A; 7.1.4B; 7.1.4C; 7.1.5

***Listing Factors**:
A. Causes of Present or Threatened Destruction, Modification or Curtailment of Habitat or Range
B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes
C. Disease
D. Predation and Competition
E. Inadequacy of Existing Regulatory Mechanisms
F. Other Natural and Manmade Factors Affecting the Species Continued Existence

OTHER FACTORS/RECOVERY ACTIONS

Factor	Recovery Actions
Habitat Protection	1.4.1A; 1.4.1B; 1.4.1C; 1.4.1D; 1.4.1E; 1.4.2A; 1.4.2B
Habitat Restoration	1.5.1; 1.5.2A; 1.5.2B; 1.5.3; 1.5.4
Low abundance and survival	5.1.1A; 5.1.1B; 5.1.2; 5.1.3A; 5.1.3B; 5.1.3C; 5.1.4A; 5.1.4B; 5.1.4C; 5.3A; 5.3B
Conserve genetic integrity	6.1.1; 6.1.2; 6.2; 6.3; 6.4
Population assessments	7.1.1A; 7.1.1B; 7.1.1C; 7.1.1D; 7.1.1E; 7.1.2A; 7.1.2B; 7.1.2C; 7.1.3; 7.1.4A; 7.1.4B; 7.1.4C; 7.1.5; 7.1.6
Education and Outreach	8.1A; 8.1B; 8.1C; 8.2
Assess recovery program	9.1; 9.2A; 9.3; 9.4

APPENDIX 2: REGULATORY PROTECTIONS

Maine Laws and Regulations

Department of Conservation
- Land Use Regulation Law, 12 MRSA §§ 681-689
- Forest Practices Act, 12 MRSA §§ 8867-8869
- Forest Products Refuse Act, 38 MRSA § 417
- Tree Growth Tax Law, 36 MRSA § 578

Department of Marine Resources
- Fishways Laws, 12 MRSA §§ 6121-6125
- Commercial and Sport Fishing Limits, 12 MRSA § 6553
- Importation, Leases, Research 12 MRSA §§ 6071(4), 6072, 6078
- Fish Health, 12 MRSA § 7202

Maine Department of Inland Fisheries and Wildlife
- Fish Hatcheries Laws, 12 MRSA §§ 7611-7674
- Fishways and Dams Laws, 12 MRSA §§ 7701-A to 7702
- Atlantic Salmon Laws, 12 MRSA §§ 9901-9907

Maine Department of Environmental Protection
- Maine Rivers Laws, 12 MRSA §§ 401-407
- Water Quality Laws, 38 MRSA §§ 361-372, 401-424, 451-452, 464-470, 571
- Mandatory Shoreland Zoning Act, 38 MRSA §§ 435-449, 436-A, 437, 438-A, 439-A - 441, 443-A -449
- Natural Resources Protection Act, 38 MRSA §§ 480-A to 480-U
- Site Location of Development Law, 38 MRSA §§ 481 to 490-J
- Maine Waterway Development and Conservation Act, 38 MRSA §§ 630-637, 640
- Maine Dam Registration, Abandonment, and Water Level Act, 38 MRSA §§ 815-818, 830-843
- Oil and Hazardous Materials, 38 MRSA §§ 543-550
- Nutrient Management Act, 7 MRSA §§ 4201-4214
- Wastewater Discharge Law, 38 MRSA § 413

Atlantic Salmon Authority
- Enabling Legislation, 12 MRSA §§ 9901-9906
- Atlantic Salmon Angling Prohibition, 12 MRSA § 9907

Maine Department of Agriculture Food and Rural Resources
- The Right to Farm Law, 17 MRSA §§ 2805
- Board of Pesticide Control Laws, 7 MRSA §§ 601-625 and 22 MRSA § 1471 A-X
- Manure Handling and Spreading Laws, 38 MRSA §§ 2701-B, 417-A

Federal Laws and Regulations

Endangered Species Act of 1973, 16 USC 1531 et seq.
Fishery Conservation and Management Act of 1976, 16 USC 1801 et seq.
Fish and Wildlife Coordination Act, 16 USC 661
Federal Power Act, 16 USC 791a
Federal Water Pollution Control Act, 33 USC 1251
Fish and Wildlife Act of 1956, 16 USC 742a
Federal Aid in Fish Restoration Act, 16 USC 777
Anadromous Fish Conservation Act, 16 USC 757
National Environmental Policy Act, 42 USC 4321
Rivers and Harbor Act of 1899 (33 USC sec. 403).

APPENDIX 3: ESTABLISHED EDUCATION AND OUTREACH PROGRAMS AND GROUPS IN MAINE

Project SHARE

In 1994, project SHARE (Salmon Habitat and River Enhancement), was established to provide a forum to protect and enhance Atlantic salmon habitat in the five Downeast Maine salmon rivers (Narraguagus, Pleasant, Machias, East Machias and Dennys rivers). Project SHARE provides educational and outreach services through bi-monthly forums on salmon related issues; coordinating public meetings and educational sessions; and assisting local watershed groups in fund raising and capacity building.

Atlantic Salmon Federation and the Maine Council

In 1992, the Atlantic Salmon Federation and their affiliate, the Maine Council of the Atlantic Salmon Federation, began sponsoring the “Fish Friends”program. Fish Friends provided Atlantic Salmon egg incubators to many schools in Maine and other New England states, as well as in New Brunswick and Nova Scotia. In 1995, Craig Brook National Fish Hatchery (CBNFH) joined in partnership with the Maine Council and extended the program into high schools in several central and eastern Maine communities where wild Atlantic salmon populations still exist. The CBNFH has supplied Atlantic salmon eggs for Maine schools and one business site in the Bangor region each year. The “Fish Friends” and “Salmon-in-Schools” programs educate thousand of students each year about Atlantic salmon, their habitat and the general ecology of watershed ecosystem ecosystems. The ASF has also developed educational materials designed to promote catch and release, fish identification (trout vs. young salmon for example) and raise public awareness.

The Ducktrap Coalition

In 1995, the Ducktrap Coalition, the watershed council for the Ducktrap River, was established. The Coalition established an education committee that has conducted a number of outreach programs. Programs include a newsletter sent to all residents of the watershed; press releases about the projects conducted by the Coalition; development of a watershed curriculum for elementary school students; placement of the Fish Friends salmon nursery aquaria in schools and forest management workshops. The Coalition also holds public events called "Ducktrap Celebrations" to invite the public to meet the Coalition members and learn about conservation efforts in the Ducktrap River watershed.

The Eight Watershed Councils

In 1997, the State of Maine published the MASCP. The Plan called for establishing watershed councils[55] on the seven rivers known to support wild salmon populations. The charge of the watershed councils was to help guide salmon conservation activities specific to each individual watershed. Watershed councils are involved in numerous public information and educational activities including organizing and facilitating public forums and workshops and establishing and maintaining informational kiosks. In 2000, a watershed council was established on Cove Brook independent of the State Conservation Plan, though carrying out similar activities.

The Wild Salmon Resource Center

In 1991, the Wild Salmon Resource Center was established as an educational and outreach center to help increase public awareness and knowledge about wild Atlantic salmon in Maine. The Center has organized public field trips and helped develop a K-12 ecology/watershed curriculum utilizing Atlantic salmon biology and conservation issues.

Soil and Water Conservation Districts:

The Soil and Water Conservation Districts (SWCD) play an important role in Atlantic salmon outreach and education efforts. The SWCD provide professional resources to local volunteer groups, businesses and, local, state and federal governments.

The SWCD outreach efforts include hosting workshops on land and water conservation measures to minimize the impacts from irrigation and pesticide use, identifying and remediating nonpoint source pollution problems and educating land owners on forest and agriculture BMPs. The SWCD also provide technical expertise in conducting watershed assessments and surveys, assist state agencies with water quality planning and monitoring and coordinate community based restoration and river cleanup efforts.

State Fisheries Agencies

The ASC and IFW have developed catch and release brochures and identification pamphlets that are distributed as wallet inserts to recreational anglers and are included in fishing regulations

---

55 Current watershed councils include, Dennys River Watershed Council, East Machias River Watershed Council, Machias River Watershed Council, Pleasant River Watershed Council, Narraguagus River Watershed Council, the Ducktrap River Watershed Coalition, Cove Brook Watershed Council and the Sheepscot River Watershed Council. In addition, the Ducktrap Coalition is coordinated with the Coastal Mountains Land Trust, an active land trust whose mission is to establish a system of conservation lands in the Western Penobscot Bay region. The Downeast Salmon Federation is another local organization involved Atlantic salmon recovery efforts in Downeast Maine. This organization coordinates the Downeast Rivers Coalition, which in turn provides supports the five Downeast watershed councils.

handbooks. The identification pamphlets provide information on characteristics that distinguish juvenile salmon from other salmonids, such as brook trout and brown trout.

The US Fish and Wildlife Service

The newly reconstructed Craig Brook National Fish Hatchery in East Orland, Maine contains an outreach and education center. This facility includes the Atlantic Salmon Museum and a nature trail. The education and outreach center is open to school groups and the public. The center helps raise public awareness of Atlantic salmon conservation and recovery efforts. In addition, the new Craig Brook facility provides meeting facilities for federal, state, tribal, non-governmental agencies and organizations, groups and individuals engaged in Atlantic salmon issues and projects.

National Marine Fisheries Service

NOAA Fisheries has provided funding to the watershed councils and the Downeast Salmon Federation to develop education programs and establish KIOSKs that provide information to the public on Atlantic salmon life history and ongoing salmon protection efforts. NOAA Fisheries has also provided funding for the operation of the Wild Salmon Resource Center in Columbia Falls. NOAA Fisheries maintains a website (http://www.nero.nmfs.gov/atsalmon/) that provides information on the issues related to the recovery and conservation of Maine's wild Atlantic salmon populations.

In 2002, NOAA Fisheries hired an education and outreach coordinator to focus on Atlantic salmon issues. The coordinator will focus on promoting and educating the public about efforts to enhance Atlantic salmon populations. The coordinator will also assist watershed councils and promote cooperative efforts implemented to protect, enhance or restore Atlantic salmon populations.

Other Ongoing Outreach and Education Efforts

Members of the outdoor sporting community, such as recreational anglers and recreational vehicle riders are an important audience to inform on how their activities may affect salmon recovery. The Maine Department of Conservation (DOC) has taken steps to establish ATV clubs and educate recreational riders on responsible practices that minimize the impacts that ATV's have on land and water resources. There has also been considerable efforts by ASC, IFW and ASF to make anglers aware of the difference between trout and young salmon to minimize the potential take of juvenile salmon.

APPENDIX 4: GLOSSARY OF TERMS

0+ parr*:* Parr that are less than one year old.

1SW: a salmon that has passed one December 31st since becoming a smolt.

2SW: a salmon that has passed two December 31st's since becoming a smolt.

3SW: a salmon that has passed three December 31st's since becoming a smolt.

Adaptive management: Adaptive management is a systematic process for continually improving management policies and practices by learning from the outcomes of management actions. Adaptive management requires the rigorous combination of management, research and monitoring to gain critical knowledge currently lacking.

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

Allele: One member of a pair or series of genes that occupy a specific position on a specific chromosome.

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

Benthic: Relating to or occurring near the bottom of the ocean.

Black salmon: an adult salmon that has already spawned and is still found in the freshwater reaches of the river between November of the year of spawning until the salmon returns to sea the following year. Also known as kelt.

Bright salmon: a salmon that has entered its natal stream upon return from the sea.

Broodstock: Mature fish held in a hatchery for breeding purposes

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

Distinct Population Segment (DPS): Defined by the ESA as a population segment that is "discrete," that is, it is to some extent separated from the remainder of the species, and is "significant," biologically and ecologically.

Effective population size: the number of individuals in a population contributing directly to the gene pool

Endocrine: the system of chemical communications within an organism, including hormones and other regulatory mechanisms.

Epizootic: a disease affecting a large number of animals within a geographic area at the same time.

Escaped Salmon: spent part or all of their life cycle undergoing artificial propagation and originate from accidental or unplanned releases into the wild.

Exclusive economic zone: area extending up to 200 nautical miles from the US coastline.
Eyed egg: the stage from the appearance of faint eyes until hatching.

Fry: the stage between alevin and parr; fish are actively feeding and living in their natal stream.

Genetic bottle necking: a significant reduction in genetic diversity due to a sudden decrease in population size

Grilse: a 1SW salmon that has matured after one winter at sea. This term applies to salmon that have returned to their natal river.

Heterozygosity having different alleles at one or more corresponding chromosomal loci.

Homozygosity: having the same alleles at a particular gene locus on homologous chromosomes.

Kelt: this term is synonymous with black salmon.

Landlocked salmon: non-anadromous Atlantic salmon; i.e., these fish do not migrate away from the rivers upon maturity.

MSW salmon: multi-sea winter salmon have matured after two or more winters at sea.

Native Salmon: wild salmon that are members of a population with no known effects from intentional or accidental releases

Naturalized Salmon: salmon that have spent their entire life cycle in the wild and originate from parents, one or both of which were not wild or native salmon

Nonpoint source pollution: NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away pollutants, finally depositing them into rivers, wetlands, etc.

Osmoregulation: the process by which the balance of water and salt is regulated.

Parr: juvenile salmon before smoltification; parr are characterized by 8-11 vertical, dark-pigmented bars (known as “parr marks”) on silvery sides.

Pathogen: a disease causing agent, such as a bacteria or virus.

Pelagic Relating to or occurring in the open ocean

Point source pollution: pollutants that come from a concentrated originating point, such as a sewer line or a factory.

Post-smolt: the life stage during the first year of life at sea, from July 1 to December 31 of the year the salmon left the river as a smolt.

Precocious parr: an Atlantic salmon that becomes sexually mature in freshwater without ever going to sea.

Pre-smolt: parr that have began the smoltification process.

Redd: nest where female salmon lay their eggs. Typically covered with gravel.

Repeat spawners: adult salmon found in freshwater on its second (or more) spawning migration.

Riparian: relating to or located on the banks of a river or stream

Sac-fry: also known as alevin.

Salmon: any adult salmon after the post-smolt stage.

Salmonid: fish belonging to the family Salmonidae including salmon and trout.

Smolt: juvenile salmon that have completed the smoltification process. Smolts are silvery-colored and can survive the transition from fresh to salt water. This stage describes juvenile salmon during its active migration to sea in the spring.

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

Spawning escapement: number of mature salmon that successfully return to their rivers of origin to spawn.

Splake: hybrid of a female lake trout and a male brook trout

Stock: a species or unit of a species that is a race, a population or a subpopulation generally defined for management purposes.

Straying: describes fish that spawn in a stream other than the one they were hatched in.

Stocked Salmon: salmon that have had artificial spawning or rearing techniques applied at some point in their life cycle and/or originate from intentional releases to the wild.

Transgenic fish: a genetically modified fish into which additional genes have been inserted

Triploid: having three copies of each chromosome, rather than the normal two copies.

Weir: a structure across a river channel which obstructs the free passage of fish and is used for the purpose of taking or facilitating the taking of fish.

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