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

November, 2005

Prepared by

NOAA's National Marine Fisheries Service
(NMFS)
Silver Spring, Maryland

and

Northeastern Region
U.S. Fish and Wildlife Service
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Approved:

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Assistant Administrator for Fisheries
NOAA's National Marine Fisheries Service

Date

12-2-05

Regional Director, U.S. Fish and Wildlife Service

Date

DISCLAIMER

Recovery plans delineate actions that are thought to be necessary to recover and/or protect endangered species. Recovery plans are prepared by NOAA's National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (FWS) and sometimes with the assistance of recovery teams, contractors, state agencies and others. This Recovery Plan for the Gulf of Maine (GOM) Distinct Population Segment (DPS) of Atlantic Salmon (*Salmo salar*) was prepared by the staff of the Northeast Regional Offices of NMFS with the assistance of the 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. 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 NMFS and FWS. They will represent the official positions of NMFS 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.

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Recovery plans can be downloaded via the Internet at:

http://www.nmfs.noaa.gov/pr/
http://endangered.fws.gov.

ACKNOWLEDGMENTS

This recovery plan was prepared by the staff of the National Marine Fisheries Service, Northeast Regional Office, Protected Resource Division with the assistance of the United States Fish and Wildlife Service (FWS) and Maine Atlantic Salmon Commission (ASC). Mark Minton, NMFS' Atlantic Salmon Recovery Plan Coordinator, served as the primary author.

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 authors of the Atlantic salmon recovery plan 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. This recovery plan has undergone extensive internal technical review by NMFS (NEFSC, NWFSC, NERO, F/PR), ASC[1] and FWS staff. This 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. In addition, the Services met with stakeholders throughout the recovery planning process. This included holding public meetings in Maine seeking input on recovery strategies that provide overarching principles intended to guide all recovery activities conducted under the plan. Furthermore, NMFS published a Federal Register notice in September 2001 (66 FR 47452), requesting public input on threats and information that should be considered in the development of the recovery plan.

In June 2004, the Services published a draft recovery plan for public review and comment. During the 90-day public comment period the Services held two formal public hearings as well as numerous meetings and briefings with federal, state, local and private stakeholders to discuss the recovery plan. In addition to public review the recovery plan underwent peer-review. Based on public comments received on the draft plan the Services and the Maine ASC conducted a two-day Threats Assessment Workshop in December 2004. The public and peer review comments received during the public comment period have been fully considered in the preparation of this recovery plan. In addition, the Services have reviewed and considered the recommendations of the recent National Research Council's (NRC) report (see NRC 2004) and this recovery plan has incorporated the recommendations of the NRC Report as appropriate.

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[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.

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 plan.

Lastly the authors would like to extend recognition to all the many individuals who have worked over the years to conserve Atlantic Salmon. This recovery plan builds on the dedication of these individuals and their efforts to preserve this national treasure for the citizens of Maine and the nation.

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.

Historically, the Androscoggin River delineated the range of the DPS to the south. 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 outside 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 2004, total adult returns to the eight rivers still supporting wild Atlantic salmon populations within the DPS were estimated to range from 60 to 113 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, typically spending 2-3 years in freshwater, migrating to the ocean where it also spends 2-3 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.

Threat Assessment: As part of the Recovery Planning process, the Services assembled a team of technical experts from Maine ASC, NMFS and USFWS to conduct a structured threats analysis. This 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:

- Acidified water and associated aluminum toxicity which decrease juvenile survival
- Aquaculture practices, which pose ecological and genetic risks
- Avian predation
- Changing land use patterns (e.g., development, agriculture, forestry)
- Climate change
- Depleted diadromous fish communities
- Incidental capture of adults and parr by recreational fishermen
- Introduced fish species that compete or prey on Atlantic salmon
- Low marine survival
- Poaching of adults in DPS rivers
- Recovery hatchery program (potential for artificial selection/domestication)
- Sedimentation
- Water extraction

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. It is impossible to estimate the cost of recovery for the DPS. The species continues to decline and its status is precarious. Even when we achieve a complete reversal of downward trends and population growth, it is not possible to estimate the cost of recovery of the DPS.

Despite ongoing efforts to arrest and reverse the decline of the DPS adult salmon returns to DPS rivers remain at historic lows (an estimated 60 to 113 adult returns in 2004).

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. The initial goal of recovery efforts is to 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.

Research is ongoing to help identify the causes for the species continued decline and identify appropriate measures to mitigate threats and recover the DPS. Pending the results of the recommended research it is not yet possible to identify recovery actions and strategies to mitigate the threats. Specific research needs, including estimated times and costs, are identified in Part 4 of this plan and prioritized in the implementation schedule. In the face of this continued uncertainty of the overall causes of the species decline it is not possible to identify all recovery actions that may be necessary to recover the DPS and therefore be able to estimate costs for full recovery of the DPS.

As noted, 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. In the absence of final measurable and objective criteria it is not possible at this time to provide a full estimate of the cost of achieving the conditions that will constitute a secure and recovered DPS.

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 $36.6 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 when we achieve 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
FON	Forest operations notification
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 (NMFS)
NFWF	National Fish and Wildlife Foundation
NEFMC	New England Fishery Management Council
NMFS	National Marine Fisheries Service
NPDES	National pollutant discharge elimination system
NWFSC	Northwest Fisheries Science Center (NMFS)
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)

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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 states that recovery plans shall, to the maximum extent practicable, incorporate, objective, measurable 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 (NMFS) 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 (61 FR 47223).

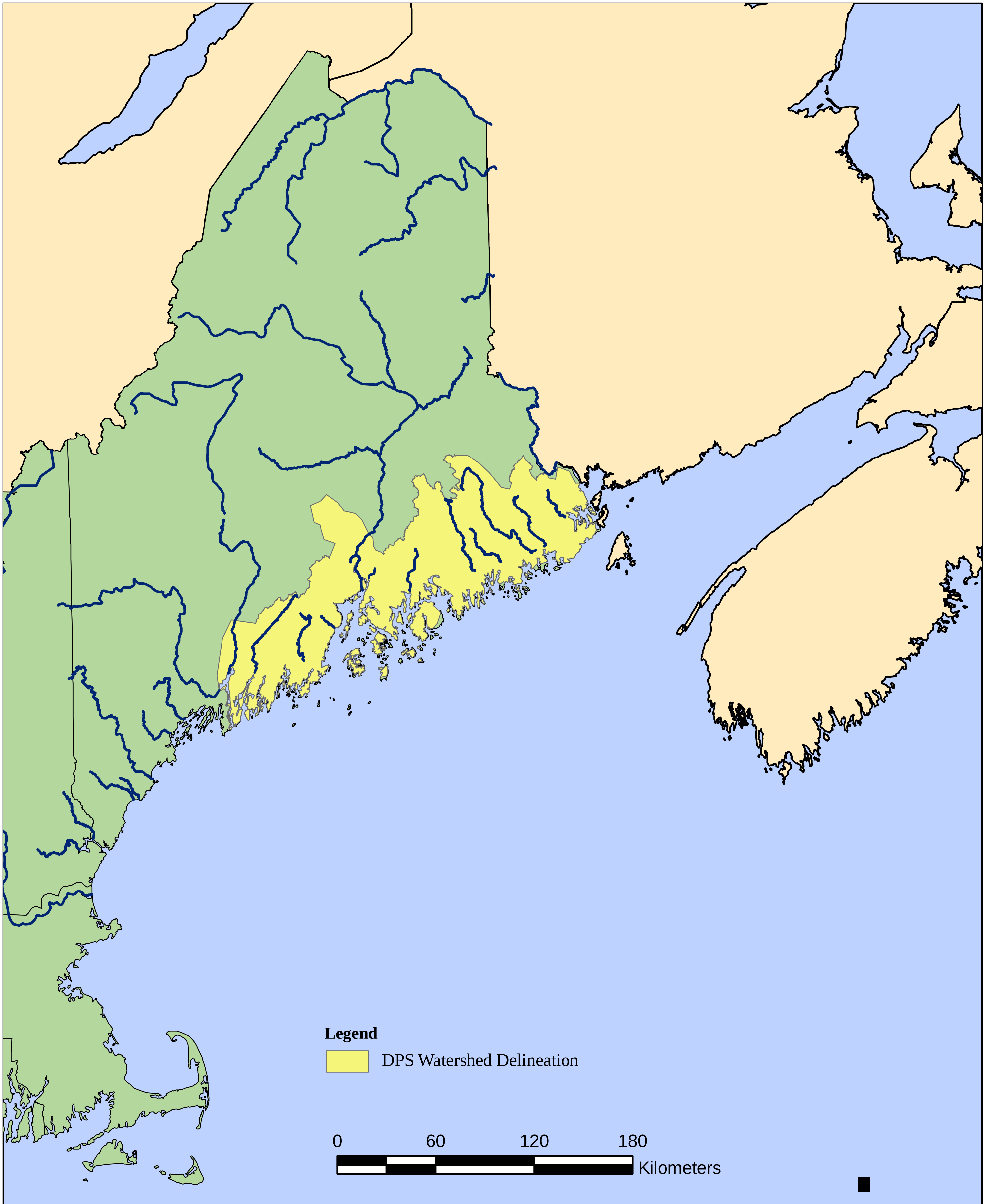
The following Background sections describe the Gulf of Maine DPS of Atlantic salmon and assess its current status, continuing threats to its survival and recovery, and conservation efforts to date. The intent is to provide the context for the recovery strategy, objectives and actions recommended in Parts Two, Three and Four 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)(see figure 1 and 2). 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

Figure 1: Geographic Range of the Gulf of Maine DPS of Atlantic Salmon



Maine Rivers

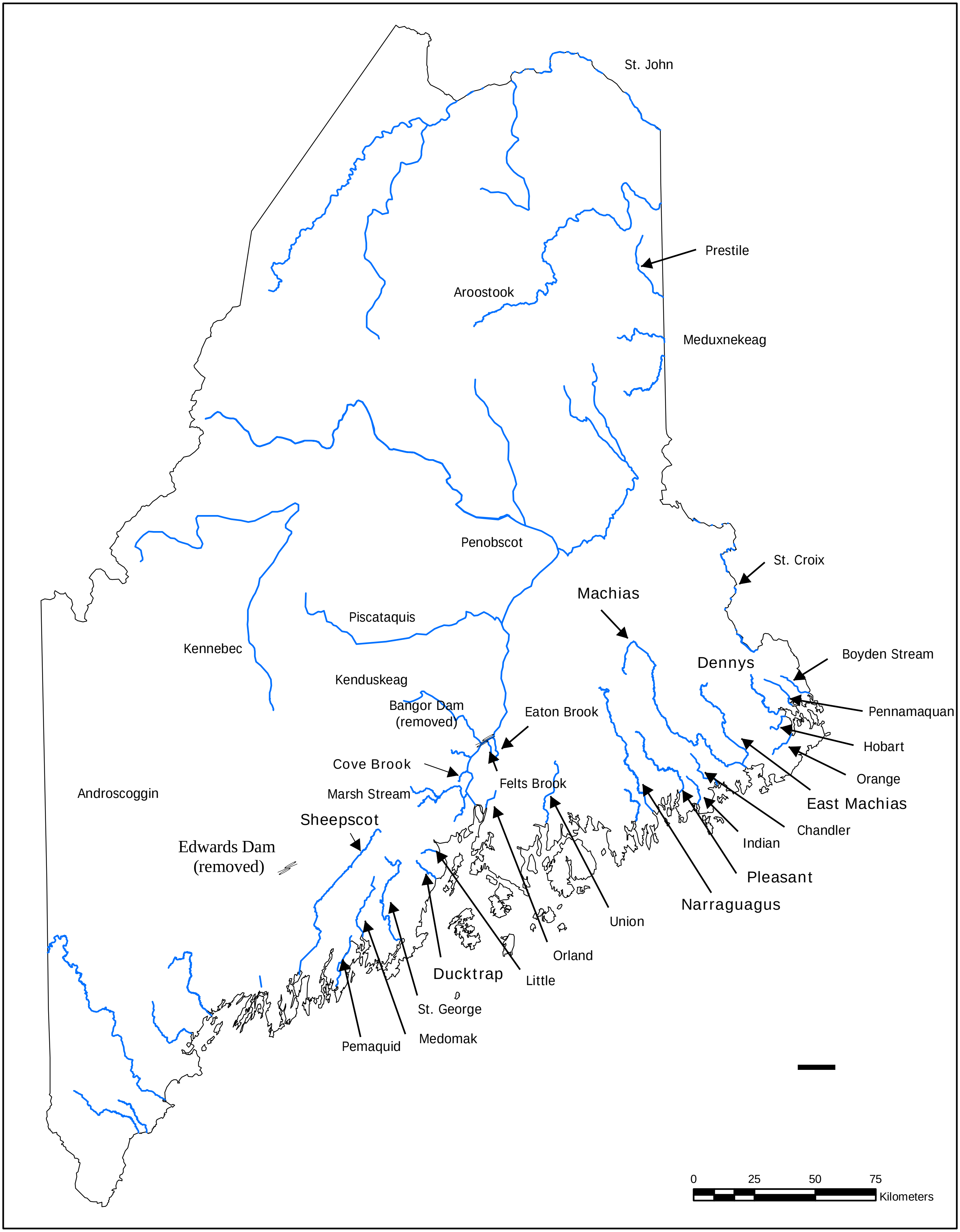


Figure 2

within the geographic range of the Gulf of Maine DPS 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. 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 outside 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). Subsequently, the Species at Risk Act (SARA) was passed in October 2002. The Atlantic Salmon Inner Bay of Fundy populations are protected under SARA.

In the U.S., nearly every major coastal river north of the Hudson River historically supported an Atlantic salmon population (figure 3). 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.

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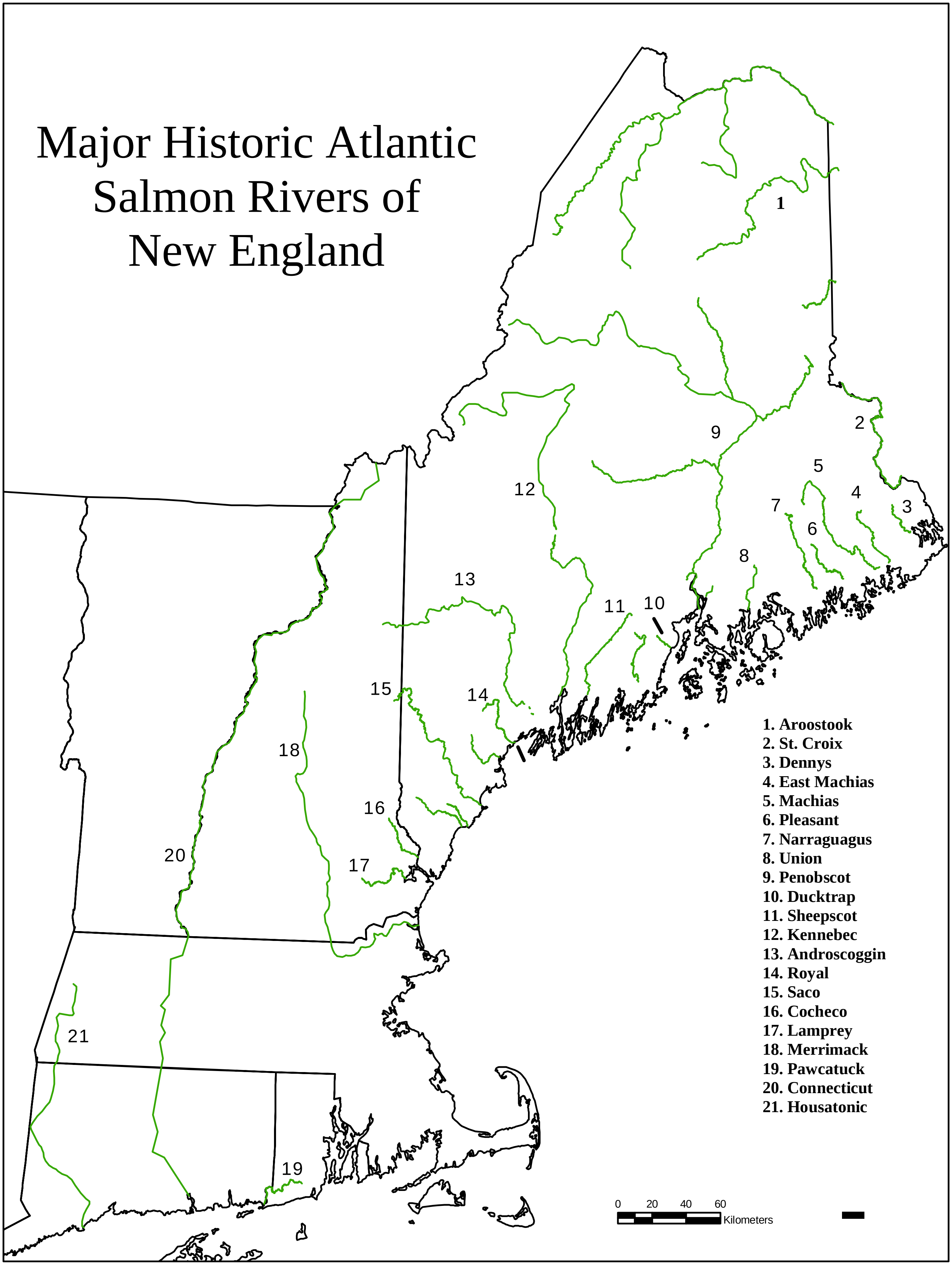
[2] COSEWIC is an independent committee of experts that assesses the status of species suspected of being at risk of extinction. While Canadian federal, provincial and territorial governments recognize COSEWIC as the source of independent advice on the status of species at risk and to work cooperatively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


Major Historic Atlantic Salmon Rivers of New England
1
2
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16
17
18
19
20
21
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
0
20
40
60
Kilometers

Figure 3

Persistent reproducing wild populations of Atlantic salmon occur within the Gulf of Maine DPS but have declined to critically low levels (see page 1-7). Since the listing, adult returns, as well as juvenile abundance estimates and survival have continued to decline. In 2004, the total number of adult returns to the eight rivers still supporting wild Atlantic salmon populations within the DPS was estimated to range from 60 to 113 (USASAC 2005). The best long-term data for adult DPS returns is for the Narraguagus River, which indicates greatly reduced numbers since 1967 (Figure 4). The estimated number of adult returns to other DPS rivers over the past 11 years indicates a similar decline (Figure 5). 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 6). Population assessments on the DPS by USASAC show a current 5-year geometric mean replacement rate of 0.54 (USASAC 2004).

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). 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). In 1999, a Biological Review Team (BRT)[3] completed a status review and 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).

3 Section 4(b)(1)(a) of the ESA provides that the Secretaries of the Interior and of Commerce shall make listing determinations based solely on the basis of the best scientific and commercial data available, after conducting a review of the status of the species and after taking into account those efforts being made by any state or foreign nation to protect such species. Under the ESA, biological review teams can be convened to review the status of species in accordance with section 4(b)(1)(a) of the Act.

Figure 4: Documented Adult returns to the Narraguagus River

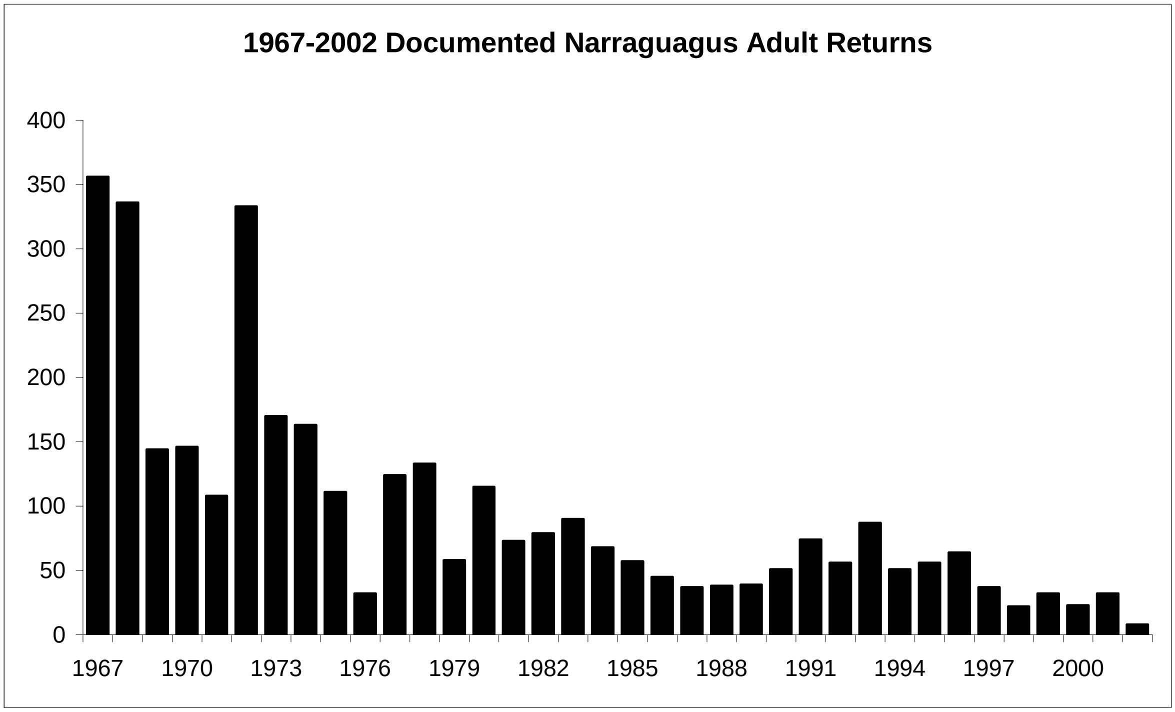


Figure 5: Estimated Adult returns to rivers within the DPS (1991-2002)

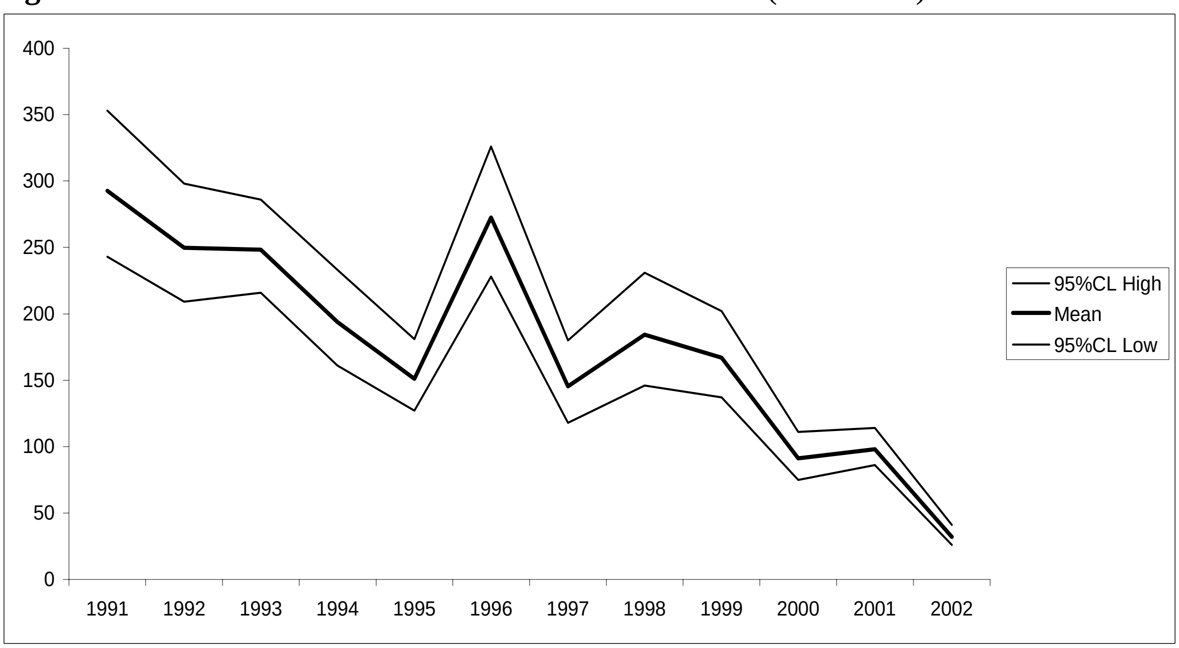
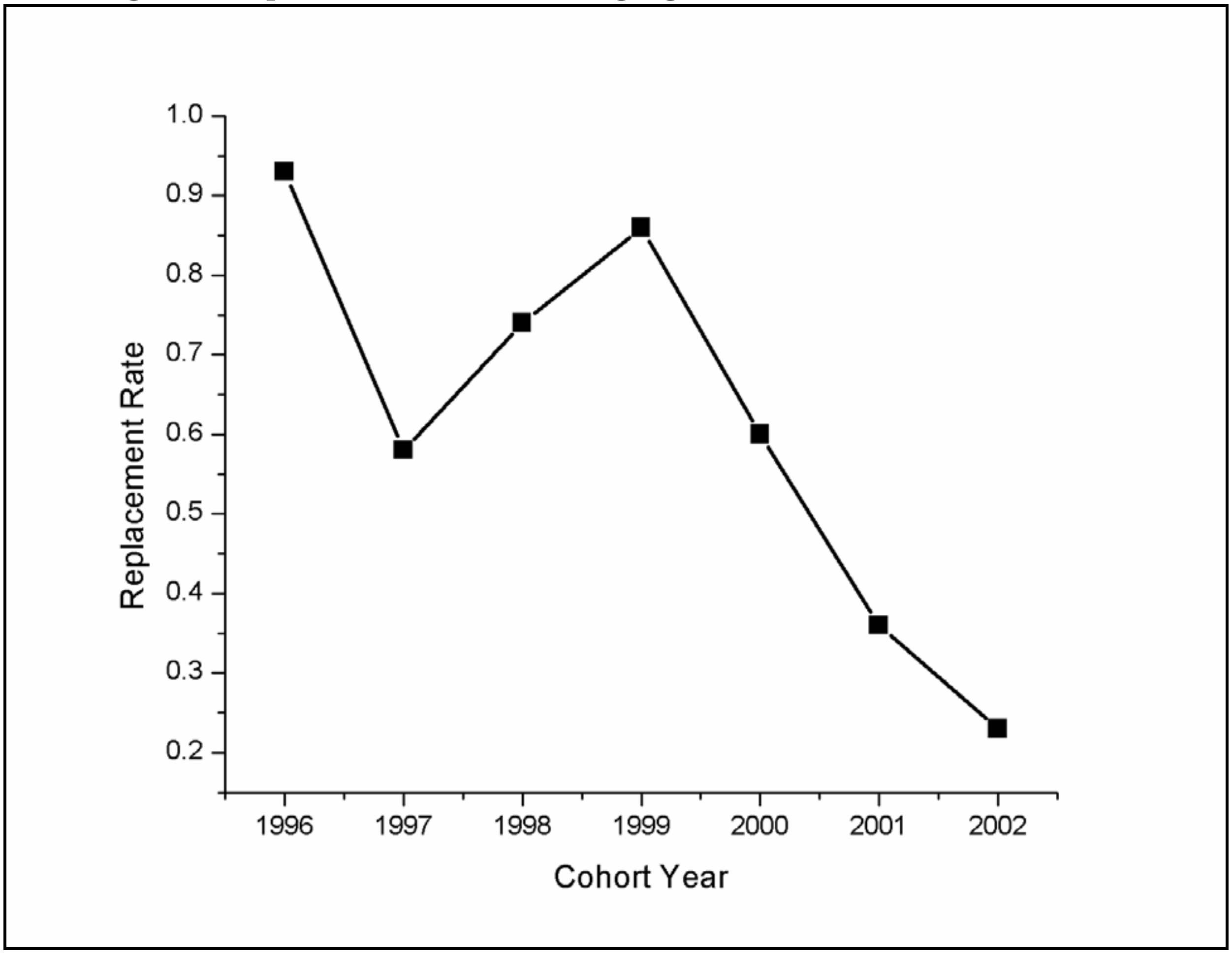


Figure 6: Replacement Rate for Narraguagus River



The occurrence of at least some straying among locally adapted populations allows the development of a metapopulation[4] 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).

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) and Gibson (1993)(figure 7). The typical cycle for Maine salmon is summarized below by life stage.[5]

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 males, 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%) enters 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, 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 Ducktrap River 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,

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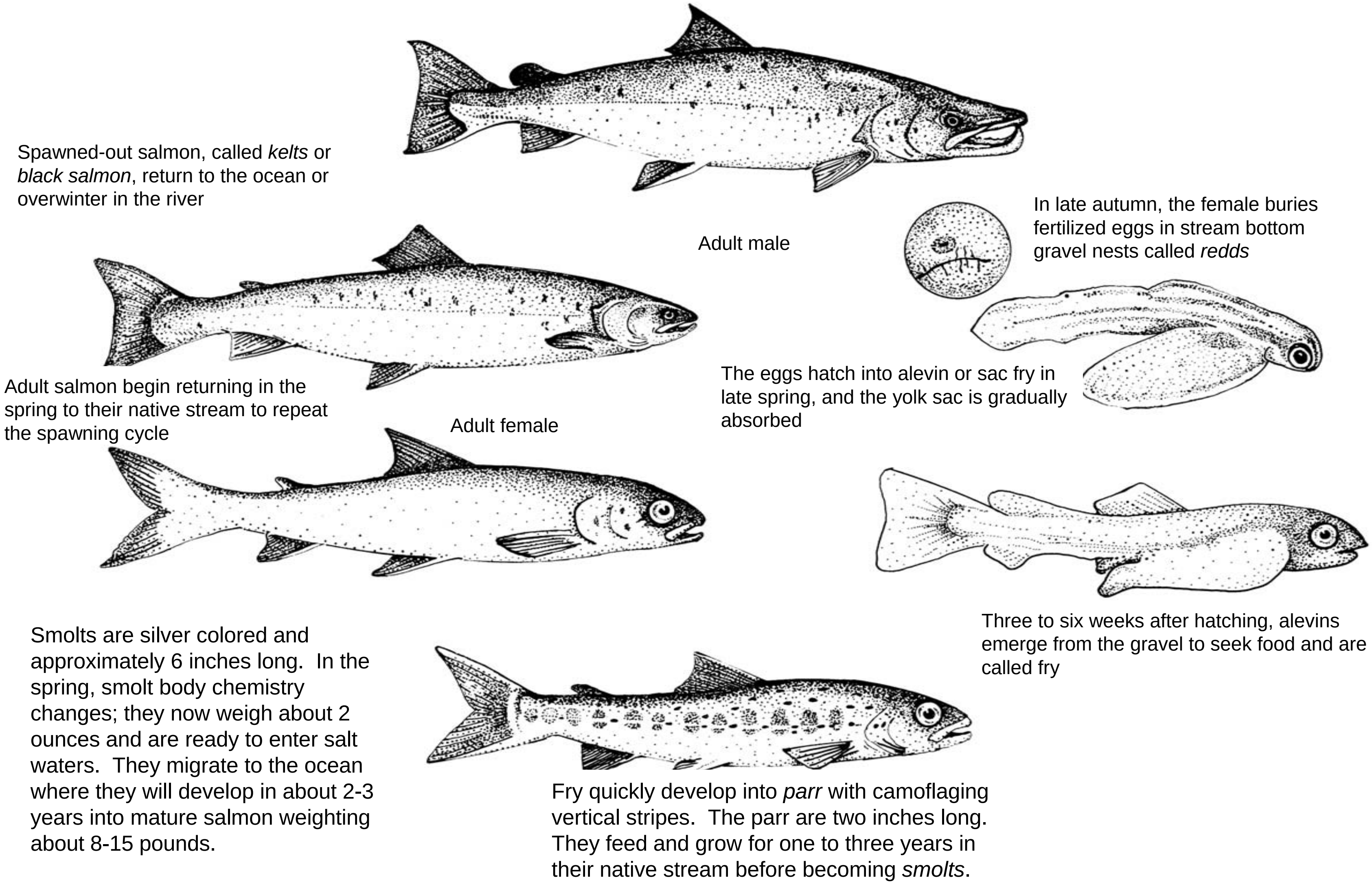
4 A metapopulation is a set of populations (sometimes referred to as subpopulations) connected by straying at low to moderate rates.

5 See appendix 2 for glossary of terms relating to the life history of Atlantic salmon.

Figure 7: Life Cycle of the Atlantic Salmon (*Salmo salar*)



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 22.8ºC 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).

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). The relative survival of kelts, however, has not been calculated for Maine rivers. 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 7-25ºC (Elson 1975; Symons 1979). Temperatures above 28ºC can be harmful to juvenile salmon (Fry 1947). If water temperatures exceed 24ºC for extended time, growth may be affected and may be affected and fish may not reach adequate size to over-winter successfully. 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[6] in their study) was significantly correlated with mean July flow the preceding year and mean August flow two years earlier. Power (1981) found correlation's between low summer flows and the abundance of adult salmon returning to Canadian rivers.

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).

[6] The period from July 1 to December 31 two years after hatching.

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 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 8). 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. ECOLOGICAL RELATIONSHIP OF OTHER NATIVE DIADROMOUS SPECIES

Maine Atlantic salmon rivers historically supported abundant populations of other native diadromous fish species including alewives, blueback herring, American shad, sea lamprey, anadromous rainbow smelt, Atlantic sturgeon, shortnose sturgeon and American eel. Salmon co-evolved over time with these and other aquatic organisms native to Maine rivers. Large populations of clupeids, such as shad, alewife, and blueback herring, used rivers within the DPS as migratory corridors, spawning grounds and juvenile nursery habitat. As these fish completed their life cycles, they likely performed important ecological functions that may have been important to Atlantic salmon in completing their life cycle. Primarily, these functions may be categorized under three

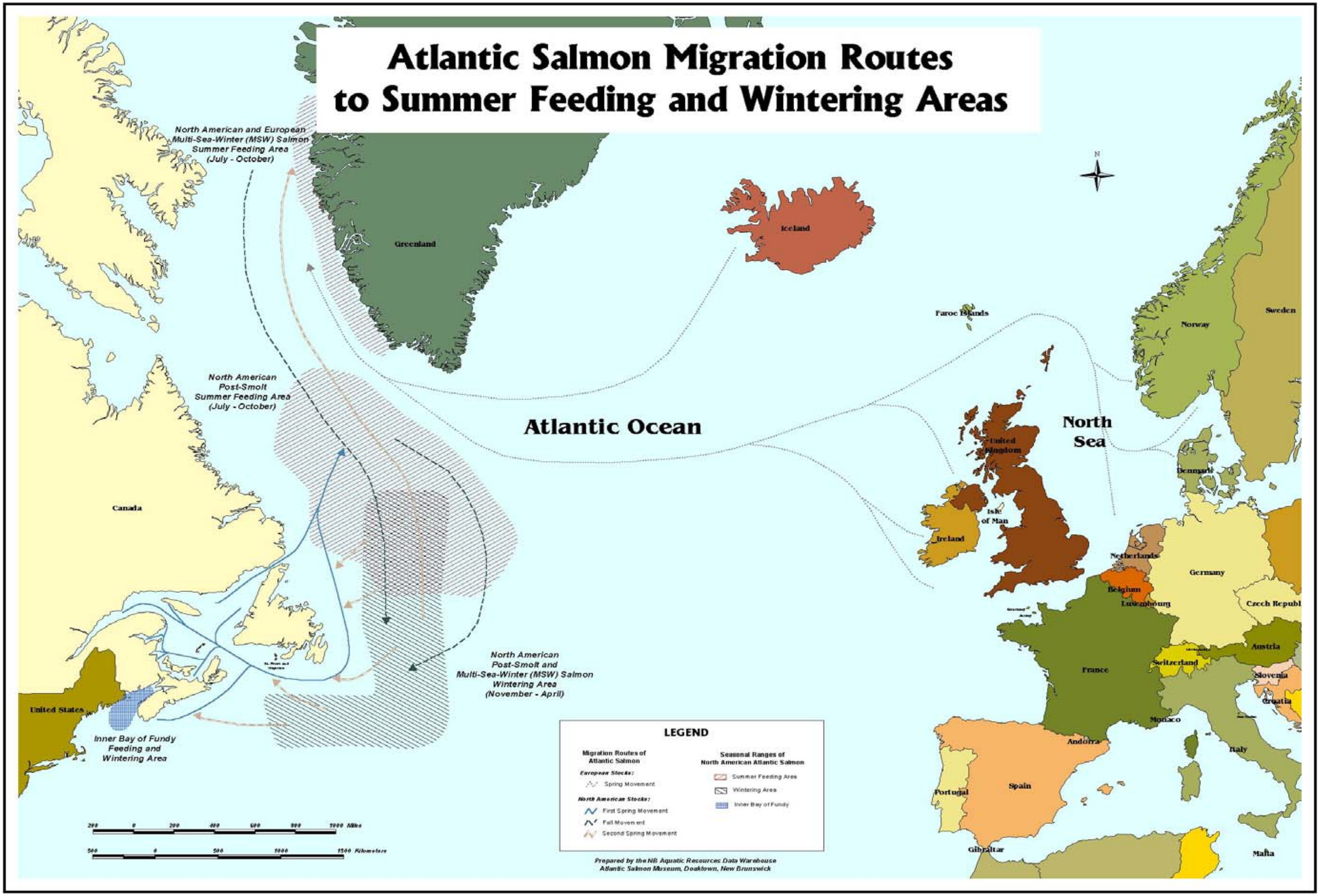

Atlantic Salmon Migration Routes
to Summer Feeding and Wintering Areas
North American and European
Multi-Sea-Winter (MSW) Salmon
Summer Feeding Area
(July - October)
Greenland
Iceland
Faroe Islands
Norway
Sweden
North American
Post-Smolt
Summer Feeding Area
(July - October)
Atlantic Ocean
North
Sea
United
Kingdom
Denmark
Canada
Isle
of Man
Ireland
Netherlands
Germany
Belgium
Luxembourg
Czech Republ
France
Austria
Switzerland
Slovenia
Croatia
Monaco
Italy
Andorra
Spain
Portugal
Gibraltar
Malta
United States
North American
Post-Smolt and
Multi-Sea-Winter (MSW) Salmon
Wintering Area
(November - April)
Inner Bay of Fundy
Feeding and
Wintering Area
LEGEND
Migration Routes of
Atlantic Salmon
European Stocks:
Spring Movement
North American Stocks:
First Spring Movement
Fall Movement
Second Spring Movement
Seasonal Ranges of
North American Atlantic Salmon
Summer Feeding Area
Wintering Area
Inner Bay of Fundy
200 0 200 400 600 800 1000 Miles
500 0 500 1000 1500 Kilometers
Prepared by the NB Aquatic Resources Data Warehouse
Atlantic Salmon Museum, Doaktown, New Brunswick

Figure 8

broad categories: prey buffering, marine derived nutrient cycling and habitat modification and enhancement.

Predation Buffer

Clupeids likely provided an alternative forage base (or prey buffer) for predators of salmon in freshwater and estuarine habitats. Specifically, pre-spawn adult alewives migrate upstream at the same time as salmon smolts would be moving downstream to the estuary through the same river reaches. Conversely, post-spawn adult alewives migrate downstream at the end of the smolt migration period later in the spring. Alewives, similar in size to Atlantic salmon smolts, likely exceeded outmigrating salmon smolts in abundance by several orders of magnitude. Alewives were likely a substantial prey buffer against predation on Atlantic salmon smolts within common migratory corridors by native predators such as cormorants, otters, ospreys and bald eagles, (Schulze 1996, USASAC 2004). Similarly, adult shad migrations that coincided with adult salmon migrations likely served as a prey buffer against seal predation. In addition, the presence of abundant juvenile clupeids (e.g., alewives and shad) would buffer juvenile Atlantic salmon against bird (e.g., cormorant, merganser), and mammal (e.g., mink) predation as these species share similar instream rearing habitat.

Marine Derived Nutrients

In addition to providing a buffer against predation, a diverse and abundant diadromous fish community likely shaped nutrient cycling regimes in the rivers within the DPS. The annual addition of marine derived nutrients (MDNs) was potentially very important for wild Atlantic salmon because rivers in Maine are relatively nutrient poor (Richardson 1993). The upstream migrations of large populations of adult clupeids and sea lampreys, along with adult salmon themselves, may have provided a conduit for the annual import and deposition of marine derived nutrients and biomass into the freshwater environment of these rivers. Mechanisms of direct deposition included discharge of urea, discharge of gametes on the spawning grounds and deposition of post-spawn adult carcasses (Garman and Macko 1998, MacAvoy et al. 2000).

In addition to clupeids sea lampreys were probably much more abundant historically than they are today (Kircheis 2004). Sea lampreys are more habitat selective than clupeids, prefering spawning habitat very similar in location and physical characteristics to that used by Atlantic salmon (e.g., headwater reaches of moderate to large tributaries) (Kircheis 2004). Unlike clupeids, lampreys' experience 100% post-spawning mortality, all of which occurs right on the spawning grounds (Kircheis 2004). This mortality occurs at time that salmon fry are emerging from redds and beginning to occupy adjacent juvenile production habitats. The decomposition of sea lamprey carcasses likely resulted in substantial depositions of MDNs directly into juvenile salmon rearing habitats. These nutrients probably enhance the primary production capability of these habitats for weeks or even months. Moreover these MDNs would gradually be transferred throughout the trophic structure of the ecosystem, including those components most important to juvenile salmon (e.g., macroinvertebrate production). Clupeids also serve as an important vector of MDN, experiencing 20% to 50% post-spawning mortality (Collette and Klein-MacPhee 2002). While clupeid spawning generally occurs in middle to lower river reaches (i.e., below salmon spawning), the resulting MDN influx may still be substantial to a river system as a whole; if not to Atlantic salmon populations specifically. Additional MDNs may not always translate to higher primary productivity levels (Ambrose et al. 2004) but many studies from west coast ecosystems describe the ecological significance of this nutrient cycling function among co-evolved Pacific salmon species (Bilby et al. 1996, Cederholm et al. 1999, Gresh et al. 2000). The scientific basis and biological significance to Atlantic salmon of any parallel nutrient cycling role that co-evolved clupeids, sea lamprey, or Atlantic salmon themselves might represent in east coast salmon rivers is not well studied and therefore not thoroughly understood at this time.

Habitat Modification/Enhancement

Sea lamprey spawning activity can enhance instream substrate structure and thereby benefit other species including Atlantic salmon (Kircheis 2004). Sea lamprey spawning activity loosens and cleans substrate making the site more suited for spawning sites for other salmonids including Atlantic salmon (Kircheis 2004). The disturbance of substrate results in increased permeability and water quality that may enhance salmon egg and fry survival as well as benefiting other important aquatic species such as insects and invertebrates (Kircheis 2004).

VI. 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, 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[7] 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 other 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.

In 1991, based on the recommendation of the Maine Atlantic Salmon Technical Advisory Committee (TAC)[8], the current river-specific stocking program was initiated. The river-

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

8 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

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 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).

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comprised of representatives of the Maine ASC, Maine DMR, Maine IFW, NMFS, FWS and the Penobscot Indian Nation.

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[9]
- 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[10], pose ecological and genetic risks

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

As part of the Recovery Planning process, the Services assembled a team of technical experts from Maine ASC, NMFS and USFWS to conduct a structured threats analysis. This evaluation of the geographic extent and life stage affected by threats, and the

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9 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 1-56). The internal use fishery is not included in the agreement.

10 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.

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:

- Acidified water and associated aluminum toxicity which decrease juvenile survival
- Aquaculture practices, which pose ecological and genetic risks
- Avian Predation
- Changing land use patterns (development, agriculture, forestry etc.)
- Climate Change
- Depleted Diadromous Fish Communities
- Incidental capture of adults and parr by recreational fishermen
- Introduced fish species that compete or prey on Atlantic salmon
- Low Marine Survival
- Poaching of adults in DPS rivers
- Recovery Hatchery Program (potential for artificial selection/domestication)
- Sedimentation
- Water extraction

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, Maine TAC 2002) 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

The following section examines the multiple threats and types of impacts (stressors) that may affect Atlantic salmon habitat. As discussed (see below), many historical land-use activities have likely had a significant impact on the quantity and quality of Atlantic salmon habitat throughout Maine. In addition, numerous current activities (sources) have the potential to affect salmon habitat. The following section examines various threats to habitat and, where appropriate identifies activities that may affect habitat thereby impeding the recovery and conservation of the DPS. In many cases there are multiple potential sources that may contribute to impacts that may affect Atlantic salmon habitat. For example, numerous activities if not conducted properly in accordance with best management practices (BMPs) or in violation of existing regulatory measures may result in sedimentation that has the potential to affect salmon habitat, both quantity and quality.

Historic Impacts

Many historical land and water use activities have altered, and in some cases destroyed, 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 dams, log drives, stream channelization, accelerated sedimentation and road crossings. These factors have altered important habitat features including channel widths and depths, pool-to-pool spacing, modification of floodplain flowage patterns and functionality and substrate composition.

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. Similarly, the NRC (2004) concluded that current forestry practices do not appear to be an important problem for Atlantic salmon in Maine. However, some forest practices (e.g., inappropriate road construction and maintenance, removal of riparian vegetation) have the potential to adversely affect salmon habitat quality and availability and therefore needs to be monitored (NRC 2004).

While many historic land-use practices have largely been eliminated, changes to the physical, chemical and biological structure of rivers and streams may remain for many decades after the activity has been terminated. 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.

Current Habitat Quality

Despite the impacts of past human activities, much of the habitat within the DPS can be generally characterized as being free-flowing, medium gradient, cool in-water temperature and suitable for spawning in gravel substrate areas. While habitat quantity is generally known for rivers within the DPS, the quality of existing salmon habitat has not been fully assessed. The extent to which historic habitat disturbances/alterations continue to impact salmon habitat has not been adequately assessed. Information documenting pre-disturbance conditions is generally lacking making restoration of degraded habitat and ecological processes more difficult. Many physical alterations/factors may be affecting the quality of habitat in rivers and streams within the DPS including; substrate embeddedness, stream channel alteration, diminished habitat complexity and multiple water quality issues.

Substrate Embeddedness and Permeability

The degree by which fine sediments surround coarse substrates on the surface is often referred to as embeddedness (Sylte 2002). Increased embeddedness may block juvenile salmon from seeking shelter beneath substrates during cold temperatures. Recent studies on the Downeast[11] rivers found indications that juvenile densities were inversely related to embeddedness levels (Atkinson et al. 2005). The full extent of embeddedness in rivers within the DPS is not well documented. Additional research into this issue is warranted (see page 4-29).

Many studies have documented the relationship between substrate permeability and salmonid survival during egg incubation and through fry emergence (Wicket 1958, Peterson 1978, McKenzie 1985 and Gustafson-Marjaene 1982). Substrate permeability is reduced when fine sediments are deposited in stream beds. Reduced permeability can lead to lower dissolved oxygen rates and greater concentrations of metabolic wastes around incubating eggs. In Maine, several studies have found similar trends for both natural and artificially created redds. McKenzie (1985) and Gustafson-Marjanen, (1982) found permeability was related to emergence from wild redds in several Downeast rivers. These studies, while somewhat limited in sample size, indicate permeability has a significant affect on survival to emergence of salmon. The Maine Atlantic Salmon Commission has begun studies to estimate permeability in spawning areas on Downeast Rivers in order to try to relate salmon survival to permeability (Sheller 2005).

Stream Channel Alteration

Many reaches of rivers within the DPS display very large channel width to depth ratios. This suggests that in some areas stream channels are overly wide. These shallow channels may be a result of disturbance or a function of bedrock geology. Channels with large width to depth ratios tend to experience more rapid water temperature fluctuations, cooling and heating more quickly than narrow deep channels (Cunjak et al. 1998). Changes in channel geometry could also increase embeddedness as wider channels could decrease bed mobility (e.g., reduce sediment transport).

Alterations of the physical instream habitat have been documented on a number of DPS rivers. For example, an inventory of historic impacts to habitat, prepared for Project SHARE, details a wide variety of instream channel changes on the Machias River (Abbott 2004). Documented stream channel alterations on the Machias River include

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11 Generally, Downeast Maine encompasses coastal Maine, east of the Penobscot River including Washington and Hancock Counties.

widening at the outlet of First Machias Lake, diversions below Holmes Falls and areas of the river bottom covered with slabs of wood.

Diminished Habitat Complexity

Large instream structures such as boulders, large woody debris (LWD) and organic debris can influence sediment sorting and storage, spacing of pool-riffle sequences and overall channel geometry. All of these structures are important for the formation and maintenance of channel morphology including gradient, pool depths and sequencing of features. Structural elements affect channel processes at all scales from distribution of bed materials to valley formation. At a local level, structural controls can create scour conditions that form and maintain pools. At a reach level, LWD can influence pool-riffle sequencing, bank erosion and bar formation. At a valley level, LWD can influence interaction between rivers and their floodplains.

Large instream structure such as boulders, LWD and root wads provide habitat required by Atlantic salmon for survival. In winter, salmon require habitat that provides adequate shelter from adverse physical conditions, particularly high flows as well as protection from predaceous mammals and birds (Cunjak et al. 1998). Availability of winter habitat may influence salmon survival and has been identified as a potential limiting factor for Maine salmon populations (NMFS 2003, unpublished report).

Large Woody Debris (LWD)

Habitat surveys conducted through the 1990's evaluated the presence of large woody debris (LWD) in streams and rivers in Maine including DPS rivers (USFWS 2004). The data indicate that, in channels less than 10 meters wide, 65% of pool, run and riffle habitat features on the Downeast rivers lack LWD.

A 10 meter channel width is used as a threshold as larger channels would be less likely to retain LWD due to higher flows and the absence of trees with channel spanning heights. The significance of the lack of LWD is not known and historic LWD volumes are unavailable for the Downeast rivers. A comprehensive study of LWD, funded by the National Fish and Wildlife Foundation, is currently underway.

Large woody debris (LWD) may be important for Atlantic salmon during several life-history stages. Nislow et al. (1999) found that survival of salmon fry in small streams in Vermont was strongly correlated with the availability of lateral, low-velocity microhabitats[12]. The addition of LWD increased the availability of these habitats (Nislow et al. 1999). LWD may be even more important for older juvenile life-stages. Salmon parr appear to use instream cover extensively, including LWD, particularly during winter (Cunjak et al. 1998). This issue may be particularly relevant to Atlantic salmon in Maine. Data collected from index stream sites indicate that there is a high mortality rate for large (pre-smolt) salmon parr during the winter prior to their

12 Microhabitats habitats away from the main channel (e.g., near banks, lateral channels) that maintain velocities < 0.18 m/sec during the early fry stage.

outmigration as smolts (John Kocik, NMFS, unpublished data). The low over-winter survival rate for large (pre-smolt) salmon parr is having a significant affect on overall smolt production from these systems. This may constitute a bottleneck to population recruitment. If pre-smolt winter survival is linked to the availability of appropriate habitat, increasing the amount of LWD cover may increase overwinter survival and smolt production.

Boulders

While it is clear that juvenile Atlantic salmon use boulders and loose cobble as shelter during winter, few studies have examined habitat preferences for other types of cover. Whalen et al. (1999) found that at night, rock and root wad complexes had higher concentrations of Atlantic salmon parr relative to other locations in the stream, especially during the ice and post-ice periods. These researchers also found parr sheltering in quiet water formed by boulders, woody debris and stream edges (Whalen et al. 1999).

As noted, most of the rivers within the DPS were historically used for log drives. Streams were reportedly channelized and, meanders removed in order to transport logs to sawmills. Similarly large instream structures such as boulders were apparently removed where they might obstruct or hinder the downstream transport of timber. For example, in the Machias River, known habitat alterations include the removal of boulders on the mainstem below Third Machias Lake and above the confluence with the West Branch. In the Narraguagus and Machias rivers, historic alterations also included removal of mid-channel boulders and diking along lower reaches of the Machias River.

As noted above, large instream structure such as LWD and boulders are important for the formation and maintenance of stream channel morphology including gradient, pool depths and sequencing of features. These features provide the habitat complexity that is required by Atlantic salmon. It is known that juvenile Atlantic salmon require a diversity of habitats including unembedded substrate and instream structures such as boulders, root wads and woody debris. For stream restoration efforts to be successful it is necessary to consider the habitat requirements for all lifestages as well as seasonal and temporal needs.

1. Water Use

Water withdrawals for agricultural irrigation was identified as a key threat to Atlantic salmon (65 FR 69459; NMFS and FWS 1999; MASCP 1997). The Services have concluded that water extraction remains a high level threat to the conservation of the DPS. 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 wild 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. Water is needed 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)[13]. The WUMP concludes that withdrawal of surface water during low flows poses the greatest risk to Atlantic salmon 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, wild 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 wild 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

13 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.

(IFIM) studies of Mopang Stream (a major tributary of the Machias River), Narraguagus and Pleasant rivers. The LURC has worked with the Services during review of water withdrawal permit applications to ensure that permits are sufficiently protective of salmon.

In addition, the DEP is in the process of developing in-stream flow standards that will apply to all state waters. These standards are specified in 38 MRSA Section 470E. These standards will recognize existing standards developed for Downeast rivers under the WUMP process. The DEP recognizes that there may be differences between IFIM and low flow analyses to document suitable flow limits and intends to carefully evaluate available information to determine the appropriate stream flow statistic that will protect salmon habitat.

The Maine DEP has the authority to regulate 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 the Maine Environmental 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.

In addition to direct withdrawal for irrigation and other purposes, impoundments used to regulate instream flow affect the hydrologic conditions of DPS rivers. Several DPS rivers have small dams on lakes and ponds within the drainage used to manipulate river flows. For example, the ASC manages low flows in the Dennys River using Meddybemps Dam and there are dams on Cathance Stream that may influence flows. The IFW manages Bog Brook Flowage for waterfowl production, influencing the flow of a tributary to the Narraguagus River. Gardner Lake Dam has partial control of flow in Chase Mill Stream, a tributary to the East Machias River. Pleasant River Lake, source of the Pleasant River, has a dammed outlet. The potential for regulating low flows by impoundments on ponds in the Sheepscot River drainage has not been evaluated. The potential to use stream flow augmentation to meet Atlantic salmon flow needs and increase juvenile production should be investigated (see page 4-38).

The effect that these impoundments have on the hydrologic conditions of individual watersheds and Atlantic salmon habitat has not been assessed. One recent event does underscore the potential for negative impacts on Atlantic salmon. In spring 2002 vandals blocked the fishway at the Meddybemps Lake Dam on the Dennys River, thereby reducing flow in the river, eliminating fish passage into the lake (probably not a major problem for salmon directly, but an ecosystem issue), and increasing the risk of catastrophic dam failure. The water in the lake was high, and blocking the fishway reduced the amount of water flowing out of the lake. If a major storm had occurred, it is conceivable that the dam could have been overflowed. The result of this occurrence was that some salmon habitat in the Meddybemps area had much lower flows than intended.

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 timber harvest activities not conducted in accordance with BMPs, 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 Pleasant River in Deblois (CLOSED) and on Chase Mills Stream (tributary to East Machias River).

In 2001, the Signatories to the Maine Atlantic Salmon Cooperative Agreement (ASC, NMFS, 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.

i. Acidified water and aluminum

The Maine TAC Water Quality Committee concluded that acidification and endocrine disruption are the most significant water quality threats to the DPS. The Services and the NRC (2004) have concluded that water quality problems related to acidification pose a high level threat to the survival and recovery of the DPS.

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. Eggs are susceptible to delayed hatching when exposed to low pH water since spring is a normal time for Maine salmon rivers to experience episodes of low pH. Delayed hatch could put alevin behind with regard to timing of emergence, food availability, and seasonal river temperatures and flow. 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).

Regional trends indicate a move toward Northeast waters becoming more dilute (i.e., fewer dissolved solids) with very little bicarbonate acid neutralizing capacity. However, there is currently no supporting data for the DPS rivers at this time (Steve Kahl, George Mitchell Center, personal communication). 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).

Peat bogs are a common natural landscape feature in much of Maine, especially in the Downeast region. Waters draining peat bogs typically have lower pH due to naturally occurring organic acids produced in low oxygen environments associated with peat bogs. 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 mean pH of rainfall over the last two years in Maine is 4.8). 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 wild 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 potentially 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[14]. 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. Conditions during this critical period of Atlantic salmon's life cycle 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 when exposed to freshwater conditions at pH 5 with 50ug labile aluminum and then subjected to a 24-hour seawater challenge (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

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

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) documented altered behavior of migrating salmon smolts after exposure to constant low pH and elevated aluminum. This may affect smolt survival. Magee et al. (2001) also documented, during the same study that the migratory behavior of salmon smolts in the Narraguagus River was similar to that of hatchery smolts exposed to acidified water in the study. 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 a short (<24 hr) acidic pulse to pH 4.5. In a separate study, there was substantial mortality when smolts, exposed to both a constant low pH and pulsed exposure, were then placed in seawater (Magee 1999; Magee et al. 2003). 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 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 4.8 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 (see page 4-25), 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. Pesticides, other contaminants and endocrine disruption

Pesticides

Pesticides 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 pesticides into DPS rivers and tributary streams. Potential sources of pesticide to Maine rivers and surface waters include low bush blueberry applications, forestry, roadside and powerline applications, municipal sewage, industrial and waste discharges, and possibly atmospheric deposition (Maine TAC 2002).

The effects of pesticide exposure to Atlantic salmon have not been fully investigated. Pesticide effects 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 of pesticides on Atlantic salmon are influenced by factors such as concentration, toxicity, water quality (e.g., 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 (Maine TAC 2002). The effects of mixtures of pesticides upon fish have not been adequately studied (see page 4-25). 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 (Maine TAC 2002).

The effects of chronic or sublethal pesticide exposure to sensitive life stages of Atlantic salmon such as fry emergence and smoltification are not well understood. Sublethal concentrations of pesticides may impair behavior or physiological functions in fish (Trial 1986, Scholz et al. 2000, Waring and Moore 2004). Moore and Waring (1996, 2001) documented the effect of several pesticides on Atlantic salmon olfactory capabilities.

The Maine Board of Pesticides Control (Maine BPC) has conducted most of the recent environmental monitoring of pesticides used on blueberry fields. In 1987, the Maine BPC conducted a drift study during an azinphos-methyl (brand or trade name: Guthion) aerial application. During the sprays, approximately 3% of the spray was estimated to have been deposited off-target (Jennings 1987). Most of the residues were close to the spray area and concentrations decreased with distance from the blueberry fields. Very small amounts of drift were found as far as 400 feet from the spray site (the farthest point were monitoring cards were located).

From 1991 to 1994, the Maine ASC and Maine BPC sampled and analyzed surface water from the Narraguagus, Pleasant, and Machias river drainages for pesticide residues. Samples were screened for all pesticides used in blueberry fields. Only hexazinone (Velpar) was routinely identified in the Narraguagus and Pleasant rivers, where it was found throughout the year (Magee 2001). No other pesticides in the analytical suite were detected. DDT and DDE were found in some samples in the Narraguagus River ranging from 12-314 ppb and 12-39 ppb, respectively (Magee 2001). In recent years, other pesticides have been detected in surface water from Washington County rivers including terbacil (Sinbar; Chizmas 2000), phosmet (Imidan; Chizmas 2001), triforine (Beland et al. 1995), azinphos-methyl (Guthion; Magee 2001), and benomyl (Benlate; Magee 2001).

In 1997, the Maine BPC began a survey of seven of the then official salmon rivers. Of 33 different pesticides tested in surface water samples, only hexazinone was detected in the rivers. Hexazinone was found in 19 of the 64 samples taken, and was only found in the Narraguagus, Pleasant, and Machias Rivers. Concentrations in these three rivers ranged from 0.1-1.7 ppb (Chizmas 1999). In 1999, another study of drift during aerial pesticide applications was conducted by the Maine BPC. Hexazinone (max. concentration 3.8 ppb) was found in 11 of 13 samples taken from the Narraguagus and Pleasant Rivers. Terbacil (Sinbar) was also detected at 0.148 ppb.

In the 2000 field season, the Maine BPC continued their investigation of pesticide drift. Both hexazinone and phosmet were found in off-target areas on drift cards. Water samples were also analyzed in the study. Hexazinone was found in most water samples taken near blueberry barrens. Phosmet was found in three agricultural ponds that are tributaries to the Narraguagus and Pleasant River. The ponds are located immediately adjacent to blueberry fields and are used seasonally as sources of irrigation water. The ponds overflow in the spring, but not in the summer. Phosmet concentrations in pond surface water ranged from 0.08-0.52 ppb (Chizmas 2001).

In 2001, pesticide drift during spray operations was examined by the Maine BPC at three locations on the Narraguagus River and four locations on the Pleasant River (Chizmas 2002). In addition to drift cards, an automated water sampler (Iscos ®) was used to collect a time-series of surface water samples during spray events. Drift during propiconazole and phosmet applications was detected on filter cards, but not in water samples on the Narraguagus River. In the Pleasant River, chlorothalonil (0.103 - 0.79 ppb) and phosmet (0.155 - 3.76 ppb) were detected in water samples and drift cards. Hexazinone was detected in water samples at two Narraguagus River locations (0.084 - 1.22 ppb) and at three Pleasant River locations (0.41 - 2.45 ppb).

The Maine BPC continued its drift studies associated with spray applications in 2003 and placed an automated water sampler and drift cards at eight locations on the Narrraguagus (n=2) and Pleasant Rivers (n=6). Phosmet was found on drift cards at one location on the Narraguagus River, and in water (0.28 - 1.95 ppb) and on drift cards from Montegail Pond, a waterbody that discharges to the Pleasant River. Pesticide drift was detected 1,500 feet from one of the spray sites (Jackson 2003).

As noted, hexazinone has been detected at numerous sites in trace amounts in the Narraguagus, Pleasant and Machias rivers (Beland et al. 1995; Chizmas 1999; Chizmas 2000, Chizmas 2002, Maine TAC 2002). The pervasive presence of hexazinone in surface water sampled at low flow periods suggests that the material is entering the river through groundwater flow rather than storm runoff (Beland et al. 1993). 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).

Monitoring the presence of pesticides in aquatic habitats is complicated by the fact that several compounds (e.g., organophosphate pesticides), are very short-lived in the environment or are not very water-soluble (hexazinone is an exception) and are thus difficult to detect in water or fish tissue. Pesticides can adsorb to soils and be transported to watercourses during storm events. Sediment analyses are one possible means to detect pesticide residues. However, recent analyses of sediments collected above and below areas of blueberry cultivation in the Narraguagus River did not detect any pesticide residues (Spaulding 2005). Pesticide concentrations in sediments of the other DPS rivers have not been determined.

Wild Blueberry Production and Pesticide Use

Wild blueberry production is the primary agricultural land use in the Downeast DPS watersheds. Approximately 60,000 acres of blueberry land is currently in production (only half of which is actually harvested any given year). Approximately 60-70% of this acreage is located in Washington County (Maine TAC 2002). As noted above, there are a number of pesticides used by wild blueberry growers in Maine (brand or trade names in parentheses). Insecticides include azinophos-methyl (Guthion, Sniper 2E), carbaryl (Sevin), diazinon, malathion (Cythion), methoxychlor (Marlate) phosmet (Imidan), and Bacillus thuringiensis (BT)(Javeline, Biobit - BT is a bacterium). 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. DDT (banned since 1972 but its metabolites persist in the environment), phosmet, guthion, propiconazole and chlorothalonil have been detected intermittently at low concentrations. Increased joint monitoring by Maine DEP, Maine BPC, and other agencies is needed to accurately detect levels of pesticides in DPS river watersheds and to determine transport mechanisms, fate and toxicity (see page 4-26).

As noted, hexazinone has been detected at numerous sites in trace amounts in the Narraguagus, Pleasant and Machias rivers (Beland et al. 1995; Chizmas 1999; Chizmas 2000, Chizmas 2002, Maine TAC 2002). Pesticide applications occur from May through June, but hexazinone has been detected in water samples year-round.

Forestry and Pesticide Use

Forest is the dominant cover type and commercial forestry is a major land use bordering most of the Downeast salmon rivers. Along the Pleasant River and Narraguagus River, forested areas are interspersed with tracts of blueberry barrens. Historically, pesticides have been used in commercial forestry to control insect outbreaks such as the spruce budworm. Currently, biological agents (e.g., Bacillus thuringiensis also referred to as Bt) are used to control outbreaks of defoliating insects. These agents are specific to target organisms (e.g., moth larvae). Herbicides are occasionally used to control post-harvest hardwood growth, promote softwood regeneration, and to prepare sites for planting[15].

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[15] Triclopyr (Garlon) and glyphosate (Accord) may be sprayed. Generally, sprays are used on one site for no more than a year or two, no more than one spray a year. Since the harvest frequency is

During herbicide applications, there is the potential for these chemical compounds to enter streams through runoff and drift. Best management practices (BMPs) are recommended to minimize herbicide use (MFS 2004). Statewide, use of forestry herbicides has been declining in recent years as land ownership patterns change and different methods of forest management are applied. While no broad-scale insect control efforts are currently occurring in the managed forests within the DPS watersheds, insect and disease outbreaks in the future could trigger a response with a pesticide component.

Road Maintenance and Pesticide Use

The maintenance of road rights-of-way in Maine includes herbicide spraying for brush control. In the past few years, sprays have not been used in Washington and Hancock Counties (Maine Department of Transportation, Division 2) due to concerns about the health of Atlantic salmon (Maine TAC 2002).

Outside of Maine DOT Division 2, a 50/50 mix of triclopyr (Garlon) and tricamba (Vanquish) are used in most roadside spray applications. No-spray buffers of 100 feet are maintained along the Sheepscot and Ducktrap Rivers and Cove Brook, and within 50 feet of other surface waters. Herbicide sprays are not applied during spring, on standing water or bedrock. All road maintenance crews receive training in Maine DOT's spray protocols. Due to the relatively low toxicity of herbicides and the low application rate, roadside maintenance is not thought to represent a threat to the health of Atlantic salmon (Maine TAC 2002).

Existing Regulatory Measures and Best Management Practices

The application, storage and disposal of pesticides in the state are regulated by the Maine BPC. The Maine BPC has the authority to designate areas where pesticide use is restricted to protect health, welfare and environment. Through the Maine BPC, farmers are encouraged to adopt integrated crop management practices including integrated pest management to minimize pesticide usage. These integrated management practices have reduced the rates and frequency of agricultural chemical applications. The use of hexazinone, for example, in recent years is about one third of historic application rates (Maine TAC 2002). In addition, 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.

The Maine Cooperative Extension Service (2002, 2004) has developed fact sheets outlining best management practices for wild blueberry production and to minimize off-target deposition of pesticide applications. Fact Sheet 251 describes best management practices including proper monitoring, identification of pests, and choice of the least toxic

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about 35-40 years for pulpwood and 80 years for saw logs, the spray frequency is no more than twice in that period.

effective material to control when warranted. Fact Sheet 303 describes methods for reducing pesticide drift during ground and aerial applications and avoidance of sensitive areas including fish-bearing waters. Integrated pest management (IPM) and integrated crop management (ICM) principles are taught to growers and scouts by the Cooperative Extension Service at three ICM field sessions and at spring grower meetings. In addition, planted or natural vegetation buffers, especially buffers comprised of evergreen species, are highly recommended whenever there are sensitive nearby surface waters.

Other Contaminants

Besides the pesticides listed above, Atlantic salmon may be affected by suites of other environmental contaminants including organochlorine compounds (e.g., DDT and its metabolites, polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins, and polychlorinated dibenzofurans), trace elements (e.g., mercury), and other chlorines (e.g., calcium hypochlorite).

Organchlorine compounds

The class of chemical compounds known as organochlorines (or chlorinated organics) is composed of hundreds of chemicals, many of which are structurally complex, and all of which have at least one chlorine atom and one "benzene ring" (C6H6). Many organochlorines of industrial origin have yet to be fully identified or chemically speciated. The most widely recognized and studied contaminant groups within this class are dioxins, furans, and polychlorinated biphenyls (Maine TAC 2002).

A variety of natural processes, such as forest fires, can generate small amounts of a few of these compounds (e.g., dioxins) that can end up in surface waters. Surface waters may also receive dioxins and dioxin-like compounds through atmospheric deposition and trace discharges from municipal sewage treatment plants (Maine TAC 2002). Within Maine DPS rivers, the source of these compounds include landfill and hazardous waste disposal sites (e.g., the Eastern Surplus Superfund site on the Dennys River).

Dioxins, furans, and PCBs can impart sublethal and lethal physiological effects to exposed fish in at least three ways: (1) through direct/acute toxicity to the exposed organism; (2) through chronic bioaccumulation in fatty tissue; (3) through maternal transfer to eggs of exposed gravid females (Maine TAC 2002). Documented effects of exposure by one or more of these routes, in studies using several species of salmonids, include visual/motor function (Carvalho and Tillitt 2004), reduced adult and fry survival (Giesy et al. 2002), total length and cranial length (Carvalho et al. 2004), general physiological and endocrine dysfunction, decreased egg viability, and fry survival (Walker and Peterson 1994; Zabel et al. 1995), abnormal gene expression, genetic fragmentation (genotoxicity), and, in extreme cases, direct mortality (Sijm and Opperhuizen 1996). Notably, few studies have involved anadromous Atlantic salmon.

Results in one relevant study involving Atlantic salmon from two Massachusetts rivers (Rees et al. 2003) indicate that parr with PCB burdens exhibited amplified expression in a widely used biomarker (cytochrome P4501A or CYP1A). This amplified expression was expressed by two orders of magnitude (i.e., 100 fold) or more in gill tissue using a more sensitive technique to detect induction (i.e., quantitative reverse transcription polymerase chain reaction - RT-PCR; Rees et al. 2003). Although this work was not intended to determine the ultimate effects of amplified expression on the affected organism, such investigation would represent the next logical step. NOAA Fisheries initiated a similar study in 2003 using the same biomarker in gill tissue with parr from the Dennys River (a PCB affected river) and Cathance Stream (an unimpacted tributary). The results were less conclusive than the Massachusetts study, in part because of small sample sizes at the two Maine sites.

Individual organochlorine compounds, and even isomers of the same compound, appear to have substantially different toxicities to aquatic life and humans. Generally, the total contaminant burden present in an exposed organism's tissue is calculated and expressed as a weighted sum, termed the "Toxicity Equivalent Quotient" (TEQ). The TEQ value is derived by adding the concentrations of congeners of the compounds adjusted by a toxic equivalency factor relative to the toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin (Van den Berg et al. 1998). This method is only used for dioxin-like compounds (e.g., dioxins, furans, and several PCB congeners).

Organochlorines have a tendency toward high environmental persistence, warranting an examination of historical legacies (e.g. sediment repositories) as well as direct discharges, when assessing potential impacts to aquatic life migrating through contaminated water or inhabiting contaminated habitats or substrates (Maine TAC 2002).

Trace Elements

Trace elements, such as mercury and cadmium, have been detected in sediments and resident fish tissue (e.g., white suckers) in the DPS rivers. These contaminants are taken up by fish through diet or water. Chronic dietary exposure to elevated levels of mercury causes pathological injuries to Atlantic salmon parr including oxidative stress and brain lesions (Berntssen et al. 2003). In other fish species, mercury exposure affected predator avoidance (Webber and Haines 2003).

Chlorines

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)[16] 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

16 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).

Cherryfield. OBDs in rivers other than the Narraguagus should also be assessed to determine the extent and level of threat to the DPS rivers.

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 the Maine 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 (see page 4-24).

Endocrine Disruption

Endocrine disrupting chemicals are substances that disrupt sex hormone systems in animals. The effects can occur in many life stages, and are often delayed in expression. A large number of chemical compounds have been found to have endocrine disrupting activity, including herbicides (2,4-D, atrazine), fungicides (benomyl, zineb), insecticides (DDT, methoxychlor, synthetic pyrethoids), industrial chemicals (dioxin, PCB, nonylphenols, phthalates), and trace metals (cadmium, lead, mercury).

The Maine TAC (2002) concluded that there are not sufficient water quality data to determine the extent of exposure of Atlantic salmon to endocrine disrupting chemicals in the DPS rivers. Moreover, existing data are not sufficient research to ascertain the potential effects of endocrine disruptors on salmon restoration (Maine TAC 2002). The available weight-of-evidence, however, indicates that endocrine disrupting environmental contaminants may be an important factor in Atlantic salmon restoration (Maine TAC 2002).

Endocrine disruptors are believed to affect smoltification in Atlantic salmon by disrupting hormone systems that facilitate the physiological processes necessary for seawater adaptation (Fairchild et al. 1999). In New Brunswick, Fairchild et al. (1999) documented a decline in returning adult Atlantic salmon in areas where the insecticide Matacil 1.8D had been sprayed to control an outbreak of spruce budworm[17] during the time of smolt out-migration. The particular pesticide used was not an endocrine disrupting compound, but the formulation included a known endocrine disruptor (4-nonylphenol) as an emulsifying agent. Exposure to 4-nonylphenol induced vitellogenin (an egg yolk protein) in Atlantic salmon smolts in the same manner as exposure to 17 β-estradiol (Sherry et al. 2001). Moore and Lower (2001) showed that exposure to atrazine (a triazine herbicide) and pentabromodiphenyl ether (a brominated fire retardant) reduced gill Na^+/K^+ ATPase activity, caused osmoregulatory disruption and elevated cortisol

17 Spruce budworm outbreaks are cyclical over 40-80 year periods and are not expected in the next 10-20 years

levels, reduced survival in sea water, and reduced migratory activity. These are the same effects reported by Magee et al. (2001) for Narraguagus River smolts.

The E-SCREEN bioassay (Soto et al. 1995) has been used to demonstrate that several pesticide active ingredients used in blueberry operations exhibited estrogenic activity of 50 to 75% of 17β estradiol, and several commercial formulations had activities of 25% or greater (Van Beneden and Morrill 2002, Haines and Van Beneden 2003). Among these pesticides, 2,4-D, propiconazole, methoyclor, phosmet, and hexazinone exhibited the activity of a xenoestrogen (a foreign substance that may act like estrogen).

In a recent study at the University of Maine, endocrine disruption was not exhibited in Atlantic salmon pre-smolts exposed to several pesticides (Spaulding 2005). Pre-smolts were exposed to mixtures of hexazinone, propiconazole, 2,4-D, terbacil, and phosmet in five weekly, 24-hour tests. The exposures did not affect smoltification, mortality following saltwater challenge tests, body length or weight, hematocrit levels, or plasma steroid concentrations.

Both nonylphenol and diethylhexyl phthalate, demonstrated endocrine disruptors, are on the U.S. Environmental Protection Agency List 1 inert ingredients and are incorporated into a large number of agricultural and industrial chemicals. These substances are commonly found in municipal sewage. Studies to determine the possible presence of these compounds have not been conducted in the DPS rivers.

Endocrine disrupting organochlorine compounds have been detected in Maine Atlantic salmon rivers including dioxin, PCBs, and DDT metabolites (all fish tissue values following expressed in wet weight). In the Pleasant River, DDT metabolites (8.1 - 11.2 ppb) and PCBs (5.3 - 8.6 ppb) have been found in brook trout and white suckers (Maine Department of Environmental Protection 1999). DDE (3 - 5 ppb) has been detected in white suckers from the Narraguagus River, Pleasant River, and Cove Brook (USFWS 2005 unpublished data). PCBs have been found in smallmouth bass (91 - 168 ppb), white suckers (52 - 54 ppb), and sediments from the Dennys River, downstream from the Eastern Surplus Superfund Site (Mierzykowski and Carr 1998, EPA 2005 unpublished data) and in smallmouth bass (23 ppb) and white suckers (12 ppb) from the East Machias River (Mierzykowski and Carr 1998).

iii. Sedimentation

The Services have concluded that sedimentation poses a high level threat to the recovery of the DPS. Sedimentation from a variety of sources may be altering habitat and rendering it incapable of supporting Atlantic salmon (65 FR 69459). Sedimentation may be affecting the quality of habitat in rivers and streams within the DPS including substrate embeddedness, diminished habitat complexity and stream channel alteration.

Sources of sedimentation within DPS rivers include natural stream bank erosion, poorly maintained roads, improperly constructed culverts, unstable bridge abutments, improper road ditching, road construction and maintenance, poor agricultural practices, stream crossings, recreational all terrain vehicles (ATVs), timber harvest activities not conducted in accordance with BMPs, dredging, and salt and sand from winter road maintenance. Excessive removal of riparian vegetation can accelerate erosion and sedimentation and contribute to thermal loading. Upland and wetland vegetation help prevent NPS pollutants from entering streams.

Sediment can impact salmon habitat in a number of ways. Excessive sedimentation can result in direct mortality to early life stages of Atlantic salmon (i.e., eggs and fry) due to smothering (Shaw and Maga 1943; Shelton 1955; Hall and Lantz 1969; Platts et al. 1979; Bjornn and Reiser 1991). McCrimmon (1954) compared several factors (sediment temperature and food) affecting stocked Atlantic salmon fry. He concluded that sedimentation had the most significant deleterious effect on the survival of fry.

Sediment changes the physical structure of a river's substrate, a critical factor in salmon survival. Excess sedimentation can fill pools, resulting in decreased depths and total area, thus reducing the amount of habitat available for juveniles and adults during the summer and winter months (Cordone and Kelley 1961). Excess sedimentation in pools has been cited as a reason for numerous salmonid populations declines (Saunders and Smith 1965; Peters 1967; Elwood and Waters 1969; Barton 1977).

Sedimentation can adversely affect benthic macroinvertebrate populations (Bjornn et al. 1974, 1977 and McClelland and Brusven 1980). The affected organisms consist mainly of insect orders that are generally the forms most readily available to foraging fish (Waters 1995). Substrate embeddedness and decreased interstitial space can decrease macroinvertebrate production resulting in reduced food supply (Atkinson and Mackey 2005). Reduced food supply may further cause fish to defend larger territories, decreasing the density of fish. Increased substrate embeddedness can result in decreased habitat complexity, reducing visual isolation among individual fish, creating larger territories and lower densities of fish (Atkinson and Mackey 2005).

Sedimentation can result in increased substrate embeddedness (the measure of the extent a rock particle is buried, or embedded in the substrate). Substrate embeddedness can result in a number of changes to habitat that may adversely affect Atlantic salmon. Substrate embeddedness may reduce over-winter sheltering habitat. 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. Increased embeddedness may block juvenile salmon from seeking shelter beneath substrates during cold temperatures and lower overwinter survival rates (Atkinson and Mackey 2005). The loss of shelter in interstitial gravel and cobble spaces can result in increased predation (Cordone and Kelley 1961; Bjornn et al. 1974).

Estimates of embeddedness can be used to assess habitat degradation or identify stream reaches that may benefit from habitat restoration (Atkinson and Mackey 2005). A less embedded streambed has a lower proportion of fine sediments than a more embedded one. Embeddedness can be used to assess the impact of non-point source pollution sources such as erosion at road crossings (Atkinson and Mackey 2005). Estimates of embeddedness are useful in evaluating habitat quality, i.e. available living spaces, for juvenile salmonids, and may provide a measure of habitat quality for salmon rearing and spawning, and for benthic macroinvertebrates.

While there have been a number of NPS surveys conducted on DPS rivers (see below), the full extent of sedimentation and embeddedness is not well documented. In 2004, the ASC surveyed at a number of sites on the Narraguagus River to determine cobble embeddedness levels. The goal of the survey was to assess changes in substrate embeddedness since a previous survey of embeddedness conducted on the Narraguagus in 1993. Preliminary analysis indicates that embeddedness levels may have decreased over the eleven year period (Atkinson and Mackey 2005). The ASC also assessed the interstitial space index (ISI)[18] of substrate at the sites sampled. While the preliminary results suggest an improvement in overall embeddedness levels, ISI seems to be reduced from 1993 to 2004. The reason for this decline is not apparent. Additional analyses will be required to better understand these findings (Atkinson and Mackey 2005).

The ASC also conducted substrate embeddedness surveys on a number of sites on the Dennys River. The surveys were conducted to estimate substrate embeddedness levels in the drainage and examine the relationship between embeddedness and juvenile Atlantic salmon densities (parr) (Atkinson and Mackey 2005). An additional goal was to determine, if possible, a threshold at which high levels of embeddedness significantly affect parr densities (Atkinson and Mackey 2005). Atkinson and Mackey (2005) found indications that young of the year (YOY) salmon densities were inversely related to embeddedness levels (Atkinson and Mackey 2005).

The ASC has begun studies to estimate permeability in spawning areas on Downeast Rivers in order to try to relate salmon survival to permeability (Sheller 2005). As noted above (see also, page 1-23), substrate permeability is reduced when fine sediments are deposited in streambeds. Available studies suggest that substrate permeability has a significant affect on survival to emergence of salmon (McKenzie 1985; Gustafson-Marjanen 1982).

Field evidence suggests that elevated levels of sediment have compromised spawning habitat along certain reaches in several DPS rivers (65 FR 69459). Local organizations have conducted NPS surveys on DPS rivers identifying numerous NPS sites. The majority of the sites are related to erosion resulting in sedimentation problems. These efforts have identified 800 NPS sites on the five Downeast Rivers and over 400 NPS sites on the Sheepscot River (Steve Koenig, Project SHARE, personal communication, see also DRWC NPS inventory, NRWC NPS inventory).

On the Dennys River, NPS surveys, conducted between 1999 and 2003, have documented 69 NPS sites, 84% of which are associated with unpaved roads (logging,

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[18] ISI is an index of the three dimensional interstitial space available for salmonids and other organisms. Atlantic salmon juveniles use the interstitial spaces for shelter from fast moving currents and to find thermal refuge, particularly during winter months.

blueberry-access, town, county, or residential/private)[19]. The problems on these roads include faulty culverts, poor ditching, road runoff and unstable shoulders (DRWC 2005). On the Narraguagus River, a total of seven NPS surveys have been conducted since 1999, approximately 75% of the watershed has been surveyed to date. These surveys documented over 175 NPS sites (NRWC 2003). Approximately 50% of these sites have either been fully repaired or are in the process of completion (NRWC 2003). The NWRC (2003) identifies several potential sources of sedimentation in the Narraguagus River watershed. These include: ATV use, poorly maintained roads (e.g., logging roads, state and municipal roads, private roads, blueberry roads)[20] and timber harvesting practices (NRWC 2003).

On the Sheepscot River, large sections of the 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).

There are no documented NPS sites associated with timber harvesting in either the Dennys or Narraguagus river watersheds (NRWC 2003; DRWC 2005). One recent incident, however, highlights the potential for activities related to timber harvesting to result in NPS pollution when not conducted in accordance with BMPs. In June 2004, an evaluation of a logging operation in Dennysville found a sediment plume covering 50% of the width of the Dennys River (DRWC 2005). The sediment discharge was the result of a skidder[21] crossing an intermittent stream in a very wet area with silt/loam/clay soils. The event appears to have been caused by failure to employ recommended BMPs during the harvest activity (DRWC 2005).

Cooperative efforts among landowners and watershed councils have identified and remedied chronic NPS sites where sedimentation of streams was a concern. Regulatory authority over water quality issues related to forestry currently resides with the Maine Department of Environmental Protection (DEP). In 2006, MFS will assume this authority upon implementation of statewide water quality standards, anticipated in 2006. In the interim, MFS continues to make statewide routine harvest inspections. MFS also continues to work collaboratively with DEP and LURC through existing MOUs that provides MFS authority for early intervention and correction of water quality problems. Significant water quality issues are resolved through DEP and LURC regulatory process with assistance from MFS. In addition, landowners filing a Forest Operations Notification (FONs) within municipal boundaries that contain a DPS salmon watershed receive a notification letter alerting them to potential critical salmon habitat and an offer of assistance from MFS. Recent revisions to this letter now include distribution to stakeholders such as the Atlantic Salmon Commission.

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19 The Narraguagus River Watershed Council (NRWC) and the Dennys River Watershed Council (DRWC), in cooperation with Project SHARE, have developed NPS management plans for the Narraguagus and Dennys rivers.

20 The problems on these roads include faulty culverts, poor ditching, road runoff, sand/salt buildup, and unstable shoulders.

21 Skidders are used to move logs from the woods to the landing

iv. 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 Temperature

The Services have concluded that elevated water temperature poses a medium level threat to the recovery of the DPS. Maine rivers lie near the southern extent of the Atlantic salmon's range in North America, and are vulnerable to elevated water temperature regimes (Maine TAC 2002). Factors that may contribute to elevated water temperatures include improper or unregulated land use practices, impoundment of free-flowing reaches, discharge of industrial processing or cooling water, low flows that increase net insolation (exposure to sun) and broad climatic changes (Maine TAC 2002). Water temperature may be an important factor limiting Atlantic salmon rearing habitat in Maine rivers (Maine TAC 2002). Water temperature may be important alone or in combination with other factors (Maine TAC 2002). The Maine TAC (2002) concluded that there was insufficient information to determine the effect that increased water temperature, from land-use factors, impoundments, industrial cooling water and global climate change may have on Atlantic salmon recovery efforts.

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. Relatively minor increases in water temperature may cause lethal or sub-lethal physiological effects for adult and juvenile salmon (Maine

TAC 2002). 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.

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. Northern 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.

In addition to direct mortality, elevated water temperature may diminish habitat suitability and adversely affect the production potential of a river or stream (Maine TAC 2002). 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). If temperatures exceed 24°C for extended time, growth may be affected and fish may not reach adequate size to over-winter successfully. At over 27°C salmon will seek cooler habitat. With Maine's non-native warm water predators, having to move can result in predation losses. Increased water temperatures can also reduce dissolved oxygen levels in aquatic environments. Dissolved oxygen levels below 6 mg/l are not suitable for salmonids (Maine TAC 2002). On the Sheepscot River, dissolved oxygen (DO) levels often drop below 7 milligrams per liter (mg/l) during summer coinciding with high bacteria counts (Maine TAC 2002). Water temperature above 23°C inhibits spawning migrations (Elson 1969; DeCola 1970; Danie et al. 1984; Hawkins 1989; Shepard 1995).

Recent water temperature data (last 10 years) exist to some extent for most Maine salmon rivers, with the Penobscot and Narraguagus rivers having historical temperature data dating back to the mid 1950's[22]. High water temperatures have been documented on DPS

[22] In January 2002, ASC produced a database with the intent of assimilating available temperature data into one central location. This database will greatly facilitate intra- and inter-river comparisons of water temperatures and long-term trend analysis for Maine salmon rivers.

rivers including the Sheepscot River. High water temperatures have been documented on the main stem of the Sheepscot River at Head Tide. In 2001, 2002 and 2003, days during a period between late June and early August water temperatures exceeded 27°C on at least 7 days and exceeded 30°C on four (ASC 2002). Nighttime temperatures during this same period remained between 20 and 25°C. On at least one occasion, water temperatures reached 31.1°C and was followed by a fish kill upstream in Alna (ASC 2004). ASC data indicates that Long Rips on the Sheepscot also reaches temperatures that may limit production of salmon. In 1994 and 1995, the river reach below the Coopers Mills dam experienced several consecutive days where water temperatures never dropped below 22.5°C (Arter 2004; KRIS 2005).

Elevated water temperatures occur on other DPS rivers. The ASC has recorded continuous water temperatures at several sites on the Narraguagus River (Figure 9). These data show that daily maximum water temperatures often exceed the feeding threshold of 22.5°C in warm years and occasionally in cool years such as 1992 and 1996. At the Deblois station, the feeding threshold (22.5°C) is exceeded on >50 days or approximately one-third of the growing season (May to September) in 5 out of the 8 years of data presented. These data indicate the potential for serious reductions in growth and survival of juvenile salmon due to the cessation of feeding activities. In addition, Figure 9 shows that while daily maximum temperatures exceeded 26°C (threshold for adult mortality) on about ten days during the warmer years, but seldom exceeded this level in cool years. In 2003, the main stem of the Narraguagus exceeded 22.5°C at nine sites and exceeded 27°C at 11 sites. The West Branch at Sprague Falls exceeded 22.5°C on 17 days and exceeded 27°C on six days (ASC 2002).

In 2003, three sites in the Dennys River exceeded 22.5°C. In the Ducktrap River, one site exceeded 22.5°C on nine days and the same site exceeded 27°C on one day. The Machias River had three sites that exceeded 22.5°C, two of which also exceeded 27°C on two days. Old Stream also had a site that exceeded 22.5°C on 7 days and exceeded 27°C on 14 days. The Pleasant River exceeded 22.5°C at four sites and exceeded 27°C at three of those sites on multiple days. Staff reports from the Atlantic Salmon Authority (ASA; predecessor agency to ASC) indicate 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 ((Beland et al. 1995; Horton et al. 1995, ASA 1998).

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.

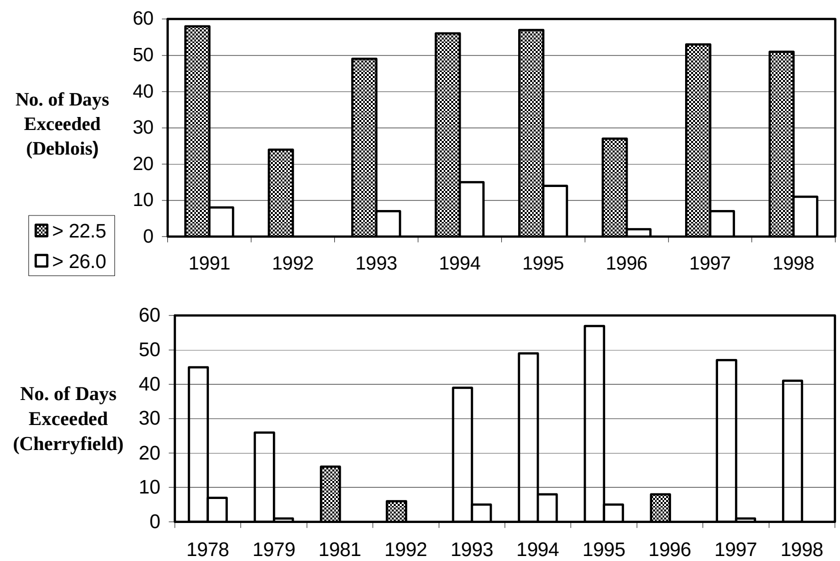

Figure 9 – Number of days when the Narraguagus River daily maximum water temperature exceeded 22.5 or 26 °C at Deblois (upper) and Cherryfield (lower). Data from the Maine ASC.

vi. Environmental Impacts of Changing Landuse Patterns

The Services have concluded that changing landuse and development poses a high level threat to the conservation of the DPS. Changing land-use patterns, particularly development, population growth and land conversion creates a number of issues that may affect the DPS. Population growth and development in Maine has accelerated in recent years, especially in the mid-coast region. The Maine State Planning Office (SPO) projects that the southern, mid-coast and Penobscot regions of Maine will continue to experience changes from current rural land-use to urban/suburban in the next several decades (see Figure 10). Associated with increased population growth, land conversion and development are increased infrastructure needs including road construction and resource demands such as increased water use and water pollution control/treatment.

The Downeast Region of Maine is also experiencing changes in land use patterns particularly land ownership. The Downeast watersheds are sparsely populated and historically have been managed for the growth and harvest of forest products and lowbush blueberries. In the Dennys, East Machias, Machias, Pleasant and Narraguagus watersheds, forestry has historically been the dominant land use. International Paper (IP), until recently the principle land owner Downeast[23], had begun to sell forest lands in

23 In November 2004, International Paper sold its Maine and New Hampshire forestlands, totaling approximately 1.1 million acres, to GMO Renewable Resources, LLC, (GMORR) a private forest

this region. The sale of this property reportedly attracted liquidation timber harvesters and developers, known for intensive logging, followed quickly by subdivision and resale of property. The State of Maine, in response to concerns about the possible impacts of liquidation harvesting, recently enacted legislation intended to control and restrict this practice. It is anticipated that the recent adoption of standards by the Maine Legislature will result in a reduction of this risk by essentially eliminating liquidation harvesting. Nevertheless, the subdivision of what historically have been large tracts of industrial forest into smaller tracts has given rise to concerns about intense localized harvests and conversion to other land uses (e.g., vacation homes, subdivisions).

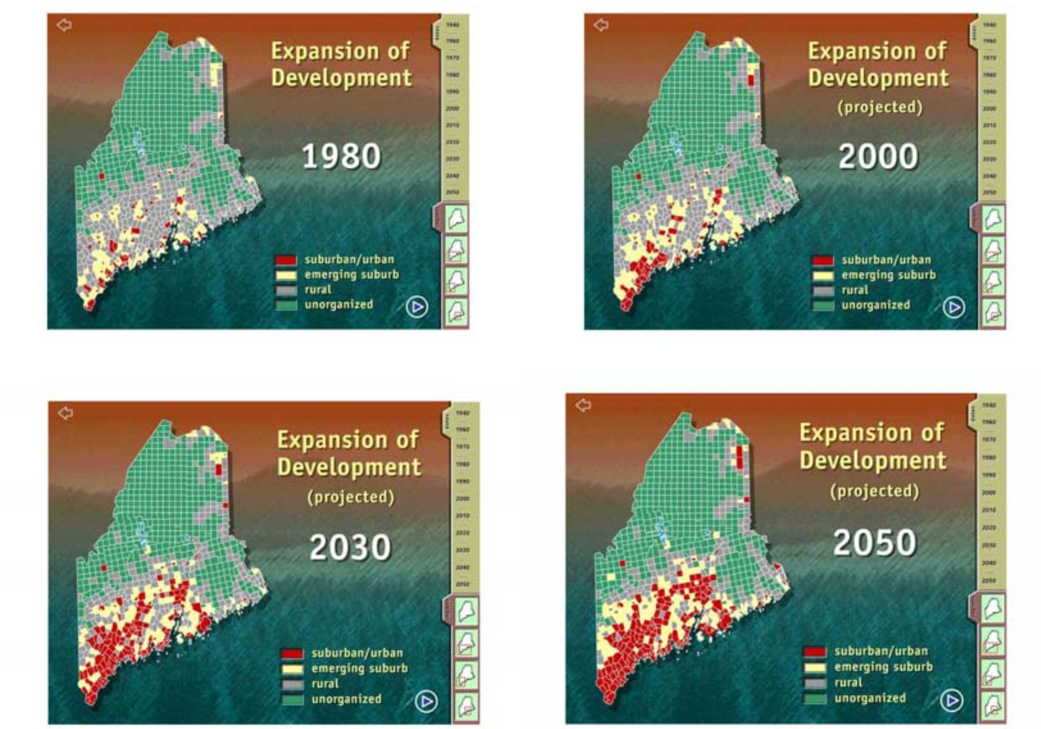

Figure 10. – Projected Expansion of Development 1980-2050 (Maine State Planning Office. http://www.state.me.us/spo/landuse/techassist/expansion/state.php

The changing land use patterns occurring in Maine have the potential to result in a number of ecological impacts that may affect salmon habitat. Increased development and population growth results in land clearing and construction of infrastructure such as roads, road crossing and buildings. These activities can alter and disrupt the hydrological process in the system and result in a decline in water and habitat quality. Changes in land cover and land and water use can result in adverse impacts to freshwater ecosystems. For example, increasing the amount of impervious surface (e.g. roads, parking lots) in a watershed can increase sedimentation/erosion and pollutant loads entering streams and rivers. Land management activities, particularly land clearing for agriculture,

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investment management company. The new landowner plans on keeping the land in the Sustainable Forestry Initiative (SFI) certification program.

development, and timber harvest, have the potential to impact geomorphological and riparian processes (Boyer et al. 2003, NRC 2004). Changing land use patterns and resource demands will need to be managed in order to protect salmon and their habitat.

The construction of new roads facilitates increased access into relatively undisturbed and previously inaccessible areas. Roads are often built in association with logging, agriculture and the development of homes or industrial or commercial projects. All these activities can result in a number of ecological effects. Depending on a large number of factors, the effects of roads on the ecological health of a landscape can be quite severe (Trombulak and Frissell 2000).

Roads can alter many ecological functions and characteristics including the pattern of runoff and surface water flow, sedimentation and increased nutrient loading and chemical contaminants (Trombulak and Frissell 2000). Numerous studies have correlated declines in the ecological health and habitat quality of streams and rivers in relation increasing road density (Trombulak and Frissell 2000). Roads can result in the direct transfer of sediment and other material to streams and other water bodies at road crossings. Roads and bridges can directly alter the development of stream channels. Road crossings commonly act as barriers to the movement of fish. Maintenance and use of roads contribute at least four different general classes of chemicals to the environment: heavy metals, salt, organic molecules, and nutrients (Trombulak and Frissell 2000).

Among the DPS rivers, the Sheepscot River currently has a higher road density and more stream crossings than the other DPS rivers (Maine TAC 2002). The most common roadway impact in Downeast watersheds is related to secondary (paved or unpaved) road crossings of tributary streams. These small streams are relatively fragile and collectively comprise the majority of stream miles and drainage area of each watershed (SHARE 2004).

3. Obstruction to Passage/Habitat Connectivity

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 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. The Services have concluded that manmade obstructions to passage is not a high level threat to the survival and conservation of the DPS. Dams that obstruct passage of salmon do, however, exist on several rivers within the range of the DPS that no longer known to support wild salmon populations (e.g., Orange River, St. George River, Marsh River). Dams exist within the DPS that impede the passage of other diadromous species whose recovery could benefit Atlantic salmon.

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 the dams on DPS rivers 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- ice-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). ASC has been working with the Town of Cherryfield to repair the fishway at the ice control dam (USASAC 2005).

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.

In addition, concerns exist about the potential for barrier weirs to impede passage[24]. Seasonal weirs have been located on the Narraguagus, Pleasant and Dennys rivers. The Recovery Plan recommends (see page 4-58) that barrier weirs be maintained as a means

[24] The construction, operation and maintenance of weirs on DPS rivers has been an integral component of the efforts to conserve and restore wild Atlantic salmon in Maine.

to prohibit passage of aquaculture salmon in DPS rivers and enable data collection. The potential of weirs to impede up and downstream passage of salmon should continue to be assessed (see page 4-30). 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 or other species (see page 4-58).

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), at Saco Falls on the Pleasant River (Dube and Jordan 1982) and at Marion Falls on Cathance Stream (a tributary of the Dennys River). The Bad Little Falls fishway provides passage around the dam that was constructed at the head of the Machias Gorge. In order to facilitate upstream passage, concrete defectors were built to provide eddies and resting areas for salmon moving upstream through the gorge at Bad Little Falls. 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 needs repairs but is 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 may be 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.

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). Currently, biologists and volunteers remove debris jams on DPS rivers and tributaries as time permits.

First-order and smaller second-order streams are those most likely to have chronic beaver dam obstructions, yet these streams are the least likely to be used by a significant portion of salmon run. Typically, spawning salmon use these smaller streams only in years with ample autumn flows and significant salmon runs. In third-order and smaller second-order streams, beaver dams can obstruct access or inundate spawning areas, and occasionally have significant local effects on salmon production. An ongoing study on Venture Brook

(Dennys) conducted by UMaine-Machias seeks to understand the effects of opening up a beaver dam choked small stream

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

1. 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.

A. 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[25] 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.

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

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 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. The Services have concluded that the incidental capture of Atlantic salmon is high level threat to the conservation of the DPS.

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. The Services have also concluded that poaching is a high level threat to the DPS.

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 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 ASC received a request from the Narraguagus and Pleasant River Watershed Councils to pursue this closure. The Maine IFW has permanently closed 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.

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[26] 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). Further, as returning adult salmon rely on fixed energy reserves (e.g., they eat very little once in river) to complete migration and spawning, the exertion expended in a catch and release event may have significant impacts. These possible impacts include comprising its ability to complete the migration to spawn and diversion of energy necessary to complete gamete formation (especially eggs). Given current wild Atlantic salmon population levels, any bycatch mortality would adversely affect the DPS and its recovery.

There are only a few studies on the sub-lethal effects of hook and release of Atlantic salmon. These have focused on post exercise physiology (Wilkey et al. 1996, Wilkey et al. 1997) and post hooking migration (Whoriskey et al. 2000, UK Environmental Agency, 2003, Makinen et al. 2000).

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).

One current fishery operating in near-shore marine waters within proximity of salmon rivers within the DPS is the Atlantic herring fishery. In September 1999, NOAA Fisheries completed a Biological Opinion (BO) under section 7(a)(2) of the ESA for the Atlantic herring fishery. The BO concluded that the continued operation of the fishery was not likely to result in jeopardy to any ESA-listed species under NOAA Fisheries' jurisdiction. In 2004, NOAA reinitiated formal consultation[27] for the herring fishery.

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26 a salmon that has entered its natal stream upon return from the sea.

27 Reinitiation of formal consultation is required should anyone of several triggers be met (e.g., a new species is listed that may be affected by the action, new information becomes available, the level of permitted incidental take is exceeded. On December 17, 2000 the Gulf of Maine Distinct Population Segment (DPS) of Atlantic salmon was listed as endangered under the ESA.

to the recovery of the DPS, the West Greenland internal use fishery is not currently jeopardizing the continued existence of the species.

D. 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. In 2004, a sampling program was initiated through the efforts of the North Atlantic Salmon Conservation Organization (NASCO). The goal of the sampling program is to determine the stock composition of the catch to estimate the level of take and potential threat this fishery may pose to the continued survival and recovery of the DPS.

2. Research and Monitoring

Research and monitoring is needed to help managers monitor the status and trends of wild Atlantic salmon populations in Maine. Research is necessary to reduce uncertainties about the cause of the decline of wild salmon populations in Maine and evaluate current and alternative stocking strategies. Current gaps in the understanding of the reasons for the species continued decline makes it difficult to identify and implement effective management actions needed to reverse the decline of the DPS and recover the species. Further, research and monitoring are key elements in assessing the effectiveness of management actions whereby managers are able to employ an adaptive strategy as part of the overall recovery program.

The NRC Report on Atlantic salmon in Maine (2004) raised concerns about potential mortality associated with research and monitoring. The NRC (2004) concluded that while in most cases the research mortality is so minimal as not to be a serious consideration, in several Maine rivers the populations are so small that any mortality would be of concern. The NRC (2004) concluded that research that increases the risk of death to wild fish should be examined thoroughly. The NRC (2004) specifically identified research that requires fish to be anaesthetized, samples of blood or scales from very small fish, sampling that held fish for long-periods in strong current (e.g., rotary screw traps for smolts during high flows).

The Services and the ASC have conducted a structured analysis of the threats faced by the DPS including the risk associated with research and monitoring (see page 1-93 Threats Assessment). The Services and ASC concluded that, given the high natural mortality and low mortality rates associated with sampling, the low probability of encountering a wild fish, research and monitoring poses a low risk to the species. The Services agree with the NAS that the value of information obtained through research and monitoring activities must be carefully weighed against the possible impact to wild populations that could result from mortality associated with the activity.

The BO again concluded that the herring fishery was not likely to adversely affect the DPS.

While there is potential for Atlantic salmon bycatch to be occurring in pelagic and midwater fisheries due to an overlap in space and time of the fish and gear, there are few observations of it actually happening. Beginning in 2005, observer coverage in the midwater trawl herring fleet was increased and should improve the ability to assess the potential for Atlantic salmon bycatch to occur in the herring fishery. Detection of potential Atlantic salmon smolt bycatch in the midwater trawl herring fishery is complicated by the volume of herring landed and the similarity in size, shape and coloration of the two species.

In addition to outmigrating post-smolts, 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 (see page 4-44).

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.

B. 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.

C. 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 1-20). The internal use fishery is not included in the agreement. From 2002-2004, the internal use fishery landed an estimated 19, 19 and 25 metric tons (mt) annually (reported and unreported catch, ICES 2005)). 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[28]. Based upon tag 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 2005). 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 has dropped to approximately 70% in contemporary times (2000-2004 range of 65-72). This may be due to a shifting of fishing effort southward along the coast of West Greenland relative to 1999, with fishing effort disproportionately distributed in the southern divisions (NAFO subareas 1D & 1F, ICES 2005).

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

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[28] In 2002, based on reported and unreported catch estimates, between 0 and 8 (90% confidence interval) DPS fish may have been caught in the fishery (USASAC 2005).

Section 10(a)(1)(A) of the Endangered Species provides for exemption to the Acts prohibition of "take" for research and other activities designed to further the recovery and survival of the species (insert ESA language). Currently all research and assessment activities conducted by the Services and the ASC are conducted under the authority of Section 10 scientific research permits. As part of the permit application process the impacts of the proposed research activities have been assessed, including the potential mortality of fish and how any potential impacts will be avoided or minimized. Permit conditions require that all mortalities be reported. In response to the NAS report, FWS is reassessing existing procedures for the issuance of Section 10(a)(1)(A) permits to ensure that mortality related to scientific research is minimized.

The Services and ASC have developed sampling protocols designed specifically to minimize the risk of harm to all fish captured and handled as part of ongoing research and assessment activities. The Services continue to investigate ways to minimize any potential adverse effects from research and develop non-invasive ways to acquire the necessary data. For example, the ASC and NOAA have provided support to a University of Maine student to study alternatives to electrofishing as a means to minimize impacts to salmon populations and are assessing the feasibility of hydroacoustics to monitors smolts and returning adults.

In addition to state and federal agencies responsible for Atlantic salmon, the Maine IFW, DEP and DMR, and US EPA, conduct research and assessment activities to monitor other species in waters containing DPS fish. These activities may result in the capture of wild Atlantic salmon. To date, these agencies have not pursued an ESA take permit.

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 (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 non-marine 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 American Fisheries Society/Fish Health Section (AFS/FHS) Suggested Procedures for the Detection and Identification of Certain Finfish and Shellfish Pathogens (2004), the New England Salmonid Health (NESH) Guidelines (2001) 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 psychrophilum*, the bacterium causing cold water disease (CWD). Although this bacterium is considered ubiquitous in the aquatic environment, it is an opportunistic, rather than obligate, pathogen so the impact of horizontal transmission may not be very significant. However, the bacterium has caused acute and chronic mortality in the early life stages of salmon raised in hatchery environments. Experiments strongly suggest that *F. psychrophilum* can be vertically transmitted within salmon eggs and that surviving infected fry may be adversely affected in the natural environment.

1. Infectious Salmon Anemia (ISA)

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.

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 (Nylund et al., 1994). 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 (Jarp and Karlsen, 1997). 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. Outbreaks of ISA in freshwater hatcheries have not been reported from major salmon producing countries that have experienced ISA outbreaks. Still 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 4-69) 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 1-82).

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 Maine occurred in Cobscook Bay at 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 cultured 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 in cooperation with the salmon growing industry. 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 Maine DMR, with assistance of 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 and 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 lain 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 are administered by DMR.

The ISA control program initially divided Cobscook Bay into two management areas, a southern and a northern zone. The southern zone was stocked in even years beginning in Spring 2002. The northern zone was stocked only in odd years, beginning in Spring 2003. Recently, USDA and Maine DMR have determined that the entire Cobscook Bay would be managed as a single area. DMR estimated that by there would be approximately 25% fewer fish in Cobscook Bay compared to previous levels. In addition, several conditions are required for each lot of smolts that are introduced into net-pens from freshwater hatcheries. All aquaculture facilities in Cobscook Bay are only 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 requires that no ISA is 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 requires 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 are subject to routine third-party biosecurity audits. Despite these measures, additional cases of ISAV were detected at aquaculture sites in Cobscook Bay beginning in June 2003 and continuing in 2004.

The DMR's bay management program was 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).

During routine surveillance of all salmon culture sites in Maine, an apparently new strain of ISAV was detected in November 2003 at a site approximately 50 miles from Cobscook Bay. This was the first detection of ISAV at any site in Maine other than Cobscook Bay. The new strain did not cause disease in the cultured salmon and did not grow in the laboratory on various cell lines typically used in ISA isolation. Gene sequencing of this organism indicates it is more closely related to a Norwegian strain than the New Brunswick strain that has caused the mortalities in Cobscook Bay. Subsequently, this new strain has also been found in Cobscook Bay sites. Efforts are underway to sequence archived samples to determine the significance of the virus in the Cobscook Bay system.

One potential mode of disease transmission is through biological sampling conducted by various state and federal agencies in DPS rivers. The development and implementation of disinfection and biosecurity protocols reduces the risk of a pathogen being moved from one location to another (G. Russell Danner, IF&W fish pathologist, personal communication 2004). Disinfection and biosecurity protocols, where not already in place, should be developed and implemented for all research and sampling activities taking place in rivers within the DPS (see page 4-63).

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 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. Ringed seals are seldom observed in the Gulf of Maine (McAlpine et al. 1999; Lucas and McAlpine 2002).

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). Bowen et al. (2003) note that the numbers of gray seal pups on Sable Island, Canada, have been increasing at 12.8% since the early 1960s. 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). Payne and Seltzer (1989) found that in southern New England harbor seal scats collected in winter had a large fraction of sandlance otoliths. 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[29], 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).

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). 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

[29] 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.

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.

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).

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 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

The Services have concluded that avian predation poses a high level threat to the survival and recovery of the DPS. 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. Predation rates on migrating hatchery-reared salmon smolts were found to be as high as 13.4% in the Machias River (Meister and Gramlich 1967). 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. 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 MBTA (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 Services have concluded that predation and competition between Atlantic salmon and other non-native fish species poses a high level threat to the survival and recovery of the DPS. 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). Native species stocked outside their historic range are also a concern. 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). The NRC (2004) concluded that non-native species that prey on salmon and compete with are potentially an important antrhopogenic threat to Atlantic salmon in Maine.

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 was found to contain Atlantic salmon. Maine IFW has removed the bag limit on chain pickerel on the five DPS rivers in Washington County to maximize harvest and reduce pickerel predation on 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). Juvenile smallmouth bass are found consistently in the same habitat as juvenile Atlantic salmon. Interspecific competition between the two species could adversely affect Atlantic salmon.

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). Though little data has been published, smolt predation by smallmouth bass has been observed anecdotally and substantial levels of smolt predation by smallmouth bass have been observed in Pacific salmon populations (Rieman et al. 1991, Tabor et al. 1993). 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. Van den Ende (1993) did not document any consumption of smolts by smallmouth bass in the Penobscot River. Van den Ende concluded that smallmouth bass were probably not a major predator on Atlantic salmon smolts in the Penobscot River. His conclusions were based on a number of factors including: low feeding rates during the beginning of the smolt run[30], 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.

The results of Van den Ende's study, however, are limited because of the small number of smallmouth bass sampled (n=125) and the limited duration of the study (1-year). Furthermore, field sampling was conducted, by angling, in areas known to have relatively high smallmouth bass catch rates. Sampling sites were not selected according to the likelihood of encountering smallmouth bass actively consuming smolts, rather they were chosen based upon accessibility and previous capture success (Van den Ende 1993). Further, prey regurgitation among angled fish is common (West 2001) and likely much higher than with other sampling gear thus the results of dietary analyses on fish sampled by angling should be scrutinized very carefully.

It is 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. 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

30 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.

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)[31]. Stocked brown trout in the Sheepscot River have established a self-sustaining population. The potential exists for brown trout to prey on juvenile Atlantic salmon in the Sheepscot River. The Maine ASC has collected large brown trout (up to about 12") in the vicinity of the head-tide dam and at other lower river sites. This reach of the Sheepscot River has the most continuous and highest quality spawning habitat in the entire river. In addition, the ASC has documented both juvenile and adult brown trout below Branch Pond on the West Branch of the Sheepscot River. The Maine IFW subsequently discontinued stocking of brown trout in Branch Pond in 2004.

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 (Beland et al. 1981, 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. (2001) determined that competition is not limited to the summer months, instead competition for food and resources observed during overwintering indicates potential

31 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.

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.

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 Lake, Second Old Stream, Beddington Lake, Keeley Lake, Burntland Lake, Pleasant River Lake, Sheepscot River and Peaked Mountain Pond. Splake stocking has been successful only where an adequate volume of cool water (12-16ºC) is available. Splake can drop down from lakes and ponds where they are stocked. The Maine IFW has documented numerous splake in the Sheepscot River below the stocking location of Sheepscot Lake.

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. 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. These populations were all introduced. In Maine, only the St. Croix, Union and Penobscot river drainages had native landlocked salmon (LLS) populations. 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. In addition, Sheepscot Lake has a self-sustaining population of landlocked salmon. ASC staff have documented adults and juvenile landlocked salmon below the Lake in the Sheepscot River.

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 (Blackwell and Juanes 1998). Blackwell and Juanes (1998) sampled stomach contents of 212 striped bass on the Merrimack River. This analysis revealed 32 documented and 28 suspected salmon smolts in striped bass sampled. In 1998, 16 of 389 striped bass stomachs analyzed 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). In order to protect DPS fish, 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 are being 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.

In addition to commercial aquaculture hatcheries private and public fish hatcheries exist on DPS rivers. Among these are the Palermo Hatchery on the Sheepscot River operated by the Maine IFW and the Columbia Falls Hatchery on the Pleasant River operated by the Downeast Salmon Federation (DSF). 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. Containment measures should be in place at all private and public hatcheries to prevent escapement from hatcheries into DPS river.

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 potential for interactions between wild Atlantic salmon and aquaculture escapees was key factors in the listing determination. Since the listing, much progress has been made to address the threats posed by salmon aquaculture to wild salmon populations. The Services have concluded, however, that the potential ecological interactions between wild and farmed raised salmon continues to be a high level threat to the conservation of the DPS.

The Maine Atlantic salmon aquaculture industry is currently composed of seven companies with 41 lease sites, of which 14 are currently active, that cover approximately 750 leased acres of water. There are approximately 200 active net pens covering a surface area of nearly 40 acres. The salmon aquaculture industry has grown rapidly over the last two decades in Maine. Annual Atlantic salmon aquaculture production in Maine increased from an estimated 20 mt in 1984 to a high of more than 16,400 mt. (>36 million pounds) in 2000 (Honey et al. 1993: Baum 2001). From 2000 to 2001, annual production of Atlantic salmon in Maine decreased 28% to 26 million pounds (Sebastian Belle, Maine Aquaculture Association, personal communication). Numerous set backs, including disease and superchill, decreased production to15 million pounds in 2002 and 13.2 million pounds in 2003. The number of farms actively rearing salmon has declined from 31 in 2001 to 14 in 2003. Most farms are concentrated in Cobscook Bay near Eastport, Maine but some are located in Machias Bay and as far south as Blue Hill Bay. The Maine industry is largely composed of international companies operating marine sites and hatcheries in both Canada and the United States.

In Maine, pen-rearing salmon from smolt placement to harvest requires approximately 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 six times the size of the Maine industry, with production in 2003 totaling 73 million pounds.

Until recently, five commercial freshwater hatcheries located in the U.S. largely supported the Maine industry and produced up to four million Atlantic salmon smolts annually. Heritage Salmon operated two hatcheries, Gardner Lake and Deblois, which produced 1.5 million smolts annually until the closure of the Deblois hatchery in the summer of 2002. The Deblois hatchery has been decommissioned and is no longer supporting the Maine Atlantic salmon farming industry. 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 other three hatcheries are located in the towns of Embden, Bingham and Oquossic and are in the Kennebec River drainage. Cooke Aquaculture, Inc. owns the hatcheries in Embden and Oquossic, each of which can annually produce up to 1 million smolts. A fire damaged the Embden hatchery in May 2003, and its future is uncertain at this time. Stolt Sea Farm's Bingham hatchery produces up to 1 million smolts annually, as well as housing adult brood stock. Both Cooke Aquaculture and Heritage Salmon own additional hatchery facilities in Canada, which produce juvenile salmon to support farm sites located in Maine.

In previous years, Atlantic salmon broodstock lines used in aquaculture production included 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 today 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 1-20), 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. Recent MEPDES permit requirements also prohibit Non-North American strain Atlantic salmon from being stocked into Maine waters for aquaculture use after July 31, 2004, with all Non-North American salmon needing to be removed from net pens prior to September 15, 2006.

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). Escaped farmed salmon may adversely affect wild salmon through ecological and genetic effects. Escaped aquaculture salmon may 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[32]. 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). Aquaculture salmon returning to Maine rivers can include mature males and females. 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). Of 45 captive reared fish examined from the St. Croix, Dennys, and Narraguagus rivers (1998-2000) ten females and eight males were mature, nine females and 16 males were immature, and maturity could not be determined for eight females and ten males (ASC unpublished data).

It is currently 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) most aquaculture fish are not currently marked (most aquaculture escapees are currently identified by physical characteristics, such as fin deformities and body shape and size and scale samples[33], although recently some aquaculture fish have been marked with a fin clip) and 3) existing counting facilities do not operate year-round[34]. 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. Although progress has been made since 2003, comprehensive protective solutions to minimize the threat of interactions between wild and aquaculture salmon have not yet been fully implemented.

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 accidentally 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 destroyed a steel cage. When the Services made the final listing decision, the threats posed by aquaculture practices in use at the time and the lack of progress in resolving those concerns were a major consideration.

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).

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32 There were no documented aquaculture salmon detected in 2004.

33 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.

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

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 (ASF), personal communication). NOAA (2004) funded an ASF research project through the Staltonstall-Kennedy grant program to provide additional information on escapes from Maritime Canada. The study is using radio tagged adult aquaculture fish reared at marine sites to track the migration pathways of released fish.

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 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 and recent cooperative efforts with state and federal agencies, Heritage Salmon upgraded the discharge system and developed a Containment Management System plan for the facility. Modifications included adding rotary drum filters to remove solids, a solids collection area and screened outlets from the hatchery. Having an established CMS plan in place and the additional secondary treatment of hatchery effluent should effectively eliminate escapes from the hatchery.

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). While the Gardner Lake hatchery is a likely source for these fish, the ASC captured large age-0+ and age-1+ parr with fin deformities in Chase Mill Stream as early as 1981, several years before that hatchery was constructed. ASC attributed the size of some parr to the abundant food and stable temperatures that occur in this lake outlet. Although rare, ASC staff report that fin deformities among fish with wild scale growth patterns in Chase Mill Stream have been observed. In October 2004 the MEDEP issued a renewed discharge permit for the Gardner Lake hatchery. This permit requires a CMS plan with reporting and auditing requirements and prohibits the use of Non-North American Atlantic salmon strains.

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).

<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 (first detected in 2001) and the close proximity of high density fish farms to DPS rivers raises concerns about transference of this disease to wild salmon. Because 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 one instance in Canada. In this instance 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 of sea lice on North American fish. Penobscot Bay is not in the proximity of aquaculture marine net pens. Post-smolt trawling has not been conducted in Cobscook Bay where the aquaculture industry is currently concentrated. 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 aquaculture industry currently monitors for sea lice infestations and treats infected fish. Maine has coordinated bay wide pest management programs with Canada to more effectively control Sea Lice in Cobscook Bay (ISAV Program Standards 2002). 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 further investigated (see page 4-63). More investigation is needed, especially research regarding *Calligus*, which is another species of Sea Louse that is less host-specific, much more abundant, and has an unknown potential for transmission of disease.

Competition

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). The ASC has documented late-arriving aquaculture salmon in the Dennys River. These fish arrived after the normal wild spawning season.

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).

Until recently, some ACOE permit holders 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 1-77). The Services had long expressed concern that the industry's use of reproductively viable European strains (pure and hybrid) of Atlantic salmon within North America posed 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.

As noted, 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. Newly established MEPDES permit conditions include requirements for genetic testing and data submission to the Services to certify Atlantic salmon stocked in marine cages are of North American origin. In accordance with permit conditions effective July 31, 2004, it is prohibited to stock non-North American Atlantic salmon smolts into Maine waters and prior to September 15, 2006 all non-North American salmon must be removed from net pens.

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

In addition to the threats identified above from current and past 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[35]. 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. Current MEPDES permit conditions prohibits the use of transgenic salmonids.

2. Marine Survival

Marine survival rates continue to be low for U.S. stocks of Atlantic salmon, impeding the recovery of the DPS. The current low marine survival rates remains a high level threat to the conservation 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 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

35 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.

communication). The number of naturally reproducing Atlantic salmon in DPS rivers is at a historic low, placing the DPS in danger of extinction. In 2004, only an estimated 60 to 113 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 theorized 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 1-28). 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 does not explain 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. In Canada, all commercial fisheries are currently closed. In West Greenland, commercial fisheries have been greatly reduced by internationally negotiated quotas that are greatly reduced from past levels of exploitation (see page 1-56). As noted (see page 1-57), 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.

3. Hatcheries

The conservation hatchery program is important in preserving individual and composite stocks until factors currently depressing overall survival rates and production problems can be addressed. As noted (see page 1-17), the first stocking of Atlantic salmon within the range of the Gulf of Maine DPS occurred in the early 1870s. In 1991, the current stocking program (see page 1-18) was initiated to supplement wild Atlantic salmon populations[36]. This is a river-specific program that stocks the progeny of salmon collected from DPS rivers into their river of origin (i.e., river-specific stocking). Broodstock from six of the eight DPS river populations (Dennys, East Machias, Machias, Pleasant, Narraguagus and Sheepscot rivers) are maintained at the CBNFH. In addition to river-specific stocking, these populations could be used to supplement any other rivers in the DPS range as needed by managers to foster the conservation of the DPS. Captive brood stock populations are maintained by annually collecting juveniles in the wild and rearing them to sexual maturity in the hatchery. Current hatchery management goals are intended to minimize risks to the natural genetic integrity of the wild stocks from selective pressures and inbreeding in the captive environment.

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 (Schonewald-Cox et al. 1983; Reed and Frankham 2003). An inherent risk associated with the broodstock and stocking program for the DPS is the risk 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.

The NRC (2004), in its recent review of Atlantic salmon in Maine, reviewed the current hatchery program. The NRC concluded: “The available information is not sufficient to conclude whether hatcheries in Maine can actually help to rehabilitate salmon populations, whether they might even be harming them, or whether other factors are affecting salmon so strongly that they overwhelm any good that hatcheries might do.” In its report, the NRC recommended that current hatchery practices should be evaluated in an adaptive management context to minimize potential genetic and ecological effects and to modify the program as appropriate (NRC 2004). In addition, the NRC report identifies

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36 Wild Atlantic salmon taken for hatchery rearing for broodstock purposes, and any captive progeny of these salmon, are included as part of the DPS. These river-specific hatchery fish are protected under the ESA, they will not be counted towards reclassification and delisting criteria (65 FR 69459).

an urgent need to understand the relative efficiency of stocking different life-stages. The stocking of different life-stages within DPS rivers provides the opportunity to evaluate the management advisability of this stocking strategy. The NRC Report also identifies the need for continued research and scientific guidance on the use of hatcheries in general as a salmon restoration tool. Consistent with the purpose of the recovery process under the ESA, the restoration of self-sustaining populations in the wild, hatchery supplementation will be reduced and ultimately discontinued when populations are recovered to secure levels.

The Services and the ASC have conducted a structured analysis of the threats faced by the DPS including the risks associated with the river-specific hatchery program (see page 1-93 Threats Assessment). The Services and ASC assessed various risks associated with the current hatchery program including (1) artificial selection/domestication (high); (2) conflicting stocking stages (e.g. stocking older life stages over younger life stages; low); (3) low effect population size (medium); (4) maintenance of broodstock at only one Location (medium). The results of the threats assessment concluded that the risk of artificial selection/domestication was high. The risk posed to the DPS from low effective population size and the maintenance of all broodstock at a single location was medium. And that stocking mixtures of different life history stages represented a low-level risk under current management schemes to reduce this risk.

The Services agree with the NRC that there is a high priority need to monitor and evaluate the effectiveness and management advisability of river-specific stocking as a recovery strategy. In 1999, FWS expanded its Atlantic salmon genetic program. At the core of this expansion is genetic characterization of all fish intended for broodstock. The FWS, in cooperation with other federal and state agencies, is currently working to develop broodstock management plans for FWS Maine Hatchery Complex Program. While many of the elements of an effective broodstock plan are operationally in place, they are not well documented and the broodstock management plan will update and consolidate all the elements into one document.

An important component of this plan is a Genetic Management Plan (GMP) that is needed to reduce several risks associated with captive breeding programs. These include 1) genetic drift; 2) selection; 3) domestication; and 4) inbreeding. The GMP will evaluate the success of reducing these risks while maintaining discrete populations through within-river management of spawning, parr collection and other methods. The results of current genetic monitoring indicate that diversity within populations is being maintained. The GMP will assess whether crossing river-specific stocks may be necessary to offset any effects of inbreeding and/or otherwise be advantageous for recovery.

4. Depleted Diadromous Fish Communities

A structured assessment of the threats facing the DPS, found that depleted diadromous fish communities posed a high threat to the recovery of the DPS. As noted (see page 1-14), rivers within the DPS once supported abundant populations of other native diadromous fish species including alewives, blueback herring, American shad, sea lamprey, anadromous rainbow smelt, Atlantic sturgeon, shortnose sturgeon and American eel. Atlantic salmon co-evolved with these and other aquatic organisms native to these rivers. As these fish completed their life cycles, they likely performed some important functions that may have been significant for Atlantic salmon to complete their life cycle. As discussed (see page 1-14) these other native fish species likely provided a number of important ecological functions including serving as an alternative prey base for predators, providing an important source of marine derived nutrients to the freshwater environment and habitat modification and enhancement.

Many of these diadromous species have declined as dramatically as Atlantic salmon in recent years (Collette and Klein-MacPhee 2002). The absence of historical data for these species make it very difficult to assess the functions these fishes may have performed in a properly functioning ecosystem. Nonetheless it is likely that the absence of other populations of diadromous species of fish native to rivers within the DPS may be impeding the recovery of the DPS. Additional investigation of the role and importance of restoring other diadromous fish populations in the recovery of the DPS should be pursued.

5. Climate Change

The Services and ASC have concluded, based on an analysis various threats faced by the DPS, that climate change poses a high level threat to the conservation and recovery of the DPS. The Gulf of Maine DPS is at the southern end of the range. Riverine habitat occupied by the Gulf of Maine population segment of Atlantic salmon is unique in that it is at the southern extent of the North American range of Atlantic salmon (Saunders, 1981; Baum, 1997). To survive at the extreme southern range, U.S. Atlantic salmon populations had to adapt to distinct physical and environmental conditions (Saunders, 1981). In addition to the Gulf of Maine DPS, the Services determined that historic U.S. Atlantic salmon populations were comprised of at least two additional population segments: Long Island Sound (LIS) and Central New England (CNE). The LIS DPS and the CNE DPS were located to the south of the Gulf of Maine DPS. As detailed in the 1999 Status Review, the Long Island Sound and the Central New England population segments have been extirpated.

An examination of the effect of warming climate on fishery resources illustrates the challenges to fish on the southern end of their range. Climate models predict significant warming over the next century as the carbon dioxide content of the atmosphere increases (IPCC 2001). Records show that there have been periods of warming and cooling of the North Atlantic Ocean, but changes have not been uniform over all areas. Global warming can have an effect on sea temperatures, wind currents, fresh water input, and mixing of the ocean’s surface layer.

Fish, being poikilotherms, maintain a body temperature almost identical to their surrounding environment. Thermal changes of just a few degrees Celsius can critically affect biological functions in salmonids. Impacts include such things as protein metabolism (McCarthy and Houlihan 1997; Somero and Hofmann 1997; and Reid et al., 1998), response to aquatic contaminants (Reid et al., 1997), reproductive performance (Van Der Kraak and Pankhurst 1997), smolt development (McCormick et al. 1997), species distribution limits (McCarthy and Houlihan 1997; Keleher and Rahel, 1996; and Welch et al., 1998), and community structure of fish populations. It has been suggested that an overall increase in river water temperatures due to global warming may actually benefit certain fish populations due to greater growth opportunity. Increased opportunities for growth in the spring and summer could increase the percentage of fish that enter the upper size distribution of a population and smolt the following spring (Thorpe 1977; Thorpe et al., 1980; and Thorpe 1994). In addition, warmer rearing temperatures during the late winter and spring have been shown to advance the timing of the parr-smolt transformation in Atlantic salmon (Solbakken et al., 1994). There is, however, an optimal temperature range and a limit for growth after which salmon parr will stop feeding due to thermal stress. During this time, protein degradation and weight loss will increase with rising water temperature (McCarthy and Houlihan 1997).

Research conducted by the U. S. Geological Survey, in cooperation with the Maine Atlantic Salmon Commission, indicate that the timing and magnitude of seasonal river flow, the occurrence and duration of river ice, and the seasonal water-content of coastal snow pack are showing systematic trends over time. Spring runoff has become earlier, water content in snow pack for March and April has decreased, and the duration of river ice has become shorter (Dudley and Hodgkins 2002).

Recent data released by the Climate Monitoring Branch of the National Climatic Data Center show that the 2000-2001 winter was the warmest on record for the United States. The agency also reported that worldwide average temperatures for the last 100 years have increased. In addition, the 10 warmest individual years on record clustered in the 1990's, indicating a global warming trend (IPCC 2001).

Climate change is occurring and will undoubtedly have an effect on Atlantic salmon. As noted above, the Gulf of Maine DPS is at the southern extreme of Atlantic salmon's range in North America. Atlantic salmon are highly sensitive to increased temperature, the Services have concluded that the effects of climate change could be significant. Therefore, climate change has been categorized as a high threat. The NRC (2004) concluded that some degree of climate warming or change in hydrologic regime could be tolerated if other problems affecting Atlantic salmon are reduced. In order to assess the effects of global climate change, very long-term temperature records of very high precision will be required.

VII. THREATS ASSESSMENT

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 anthropogenic factors that may affect its continued existence and recovery. These factors could range from genetic intrusions to catastrophic events. As populations within DPS rivers increase and recovery proceeds, the vulnerability of the

DPS will decrease[37]. 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 precisely threats can be assessed, the more refined and specific the recovery strategy can be, increasing the probability for successful recovery.

A threats assessment should include consideration of both natural and anthropogenic threats that are the result of either intentional or unintentional actions. The current or potential impact of each threat on the DPS is affected by a variety factors including the geographic extent or magnitude of the threat (i.e., how many populations are impacted by the threat) and the specific life stage(s) affected. Generally, the greater the magnitude 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.

In addition to the consideration of the geographic extent and life stage affected, a threats assessment should also evaluate the responsiveness of individual threats 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.

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37 An important distinction exists between vulnerabilities and threats. A vulnerability is a weakness that can influence how various threats affect the resource. 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.

As part of the Recovery Planning process, a two-day threats assessment workshop was held to assess the magnitude and severity of threats affecting the Gulf of Maine distinct population segment (DPS) of Atlantic salmon. The Services assembled a team of technical experts from ASC, NOAA Fisheries and FWS (Threats Assessment Group - TAG) to conduct a structured threats analysis. The TAG members represented many fields of expertise and are all actively engaged in Atlantic salmon management or science (See Appendix 5). The workshop participants reviewed the results of the Threats Assessment conducted as part of the development of the draft recovery plan.

The Threats Assessment exercise was based on a three-step process (see Appendix 5). The first step of the threats assessment process was to assess the magnitude of the threat (i.e. what rivers are affected). The second step of the Threats Assessment exercise required the TAG to rank the severity of the threat at each life stage based on the threats assessment criteria. For simplicity, items were ranked on a scale of 0 to 4 to describe magnitude of threat to each different life stage. A life stage-specific threat severity of "negligible to no threat" was assigned a score of 0. An "unknown (uncertain)" severity received a score of 1, a "low" severity received a score of 2, a "moderate" severity a 3 and a "high" severity a score of 4. In addition, each freshwater life stage (adult spawners, egg, fry, parr and smolt) was assigned a weight of 1 and the marine life stage was assigned a weight of 5. This was not a quantitative assessment but rather a structured categorical one that utilized classifications mutually determined by the TAG and represented by numbers for simplicity. While the full TAG assessed all classifications, when additional fields of expertise were needed (fish health and contaminants) that were not adequately represented on the TAG, additional experts were consulted.

The third step in the threats assessment exercise was the development of the Threats Severity Index (TSI). The participants discussed a number of possible ways to calculate the TSI (e.g., a simple additive index, some type of weighted average). To calculate the TSI score, the life stage weighting was multiplied by its corresponding life stage-specific severity. These are summed across each threat and then multiplied by the numbers of rivers affected by the threat magnitude. The resulting TSI scores were then sorted and assigned a ranking of high, medium or low[38]. To determine the ranking, the sorted TSI scores were divided into thirds and the top third was assigned a ranking of high, the middle third was assigned medium and the lowest third was assigned a ranking of low. The TSI classifications were then carried over into the Implementation Schedule/Recovery Action priority template under the broad Threats/Recovery Actions.

As part of the threats assessment, participants reviewed and discussed a number of broad-based issues related to description of threats and recovery actions raised by public and

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Grouping	**TSI**
low	< 95
medium	95-140
high	>140

peer-review comments received on the draft recovery plan (See Appendix 7). The Workshop participants assessed the magnitude and severity of these threats/issues.

In addition to the threats assessment, the TAG reviewed the Recovery Action priorities identified in the Implementation Schedule of the recovery plan. The goal of this review was twofold: (1) strengthen the linkage between the threats assessment and the Recovery Action prioritization; (2) review current recovery action priorities in light of any new or additional information available since the publication of the draft plan including the views/information provided in public comments received on the draft plan. As part of this analysis, the TAG assessed the implementation feasibility of Recovery Actions[39]. The purpose of this analysis was to highlight actions that would have both a high probability of mitigating specific threats and a high implementation feasibility. The participants identified whether the recovery actions were either research or management related.

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:

- Acidified water and associated aluminum toxicity which decrease juvenile survival
- Aquaculture practices, which pose ecological and genetic risks
- Avian Predation
- Changing land use patterns (e.g., development, agriculture, forestry)
- Climate Change
- Depleted Diadromous Fish Communities
- Incidental capture of adults and parr by recreational fishermen
- Introduced fish species that compete or prey on Atlantic salmon
- Low Marine Survival
- Poaching of adults in DPS rivers
- Recovery Hatchery Program (potential for artificial selection/domestication)
- Sedimentation
- Water extraction

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.

Aquaculture -- Commercial aquaculture of Atlantic salmon poses high risks to all life stages of Atlantic salmon through genetic, disease and ecological interactions. For this

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[39] 1 = Feasible (with adequate resources)
2 = Possible (but with significant logistical, technical and/or legal obstacles)
3 = Unfeasible

reason, actions to minimize the potential interaction between wild and farmed fish should continue to receive a high priority for implementation.

Avian predators have the potential to cause direct mortality to various life stages of Atlantic salmon, including returning adults. 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.

Changing land-use patterns, particularly development, population growth and land conversion create a number of issues that may affect the DPS. For example population growth and development in Maine has accelerated in recent years, especially in the mid-coast region. The Maine State Planning Office projects that the southern, mid-coast and Penobscot regions of Maine will continue to experience changes from current rural land-use to urban/suburban in the next several decades. This type of development will result in a variety of human activities that may affect salmon habitat. In particular construction of buildings, roads and road crossing and land clearing that can alter and disrupt the hydrological process in the system may result in a decline in water and habitat quality if not properly managed.

In the Downeast region, forestry is the current dominant land use in the Dennys, East Machias, Machias, Pleasant and Narraguagus watersheds. In recent years, concerns have grown that large tracts of industrial forest lands are being subdivided and sold off into smaller tracts that will result in more aggressive harvest and development. 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. This trend is projected to continue and will undoubtedly result in increased municipal water use demands. This change in land use patterns and resource demands will need to be managed in order to protect salmon and their habitat.

Climate Change poses a high threat to the conservation and recovery of the DPS. The Gulf of Maine DPS is at the southern end of their range in North America. An examination of the effect of warming climate on fishery resources illustrates the challenges to fish on the southern end of their range. Climate models predict significant warming over the next century as the carbon dioxide content of the atmosphere increases. Records show that there have been periods of warming and cooling of the North Atlantic Ocean, but changes have not been uniform over all areas. Global warming can have an effect on sea temperatures, wind currents, fresh water input, and mixing of the ocean's surface layer. The NRC (2004) concludes that any prolonged or significant warming of Maine's climate would probably make the survival of Atlantic salmon in Maine more difficult due to a number of factors. Some degree of climate warming or change in the hydrologic regime could probably be tolerated if most other problems affecting the DPS were reduced (NRC 2004).

Depleted Diadromous Fish Communities -- Other native diadromous fish populations have declined as dramatically as Atlantic salmon in recent years (Collette and Klein MacPhee 2002). Maine Atlantic salmon rivers historically supported abundant populations of other diadromous fish species including alewives, blueback herring, American shad, sea lamprey, anadromous rainbow smelt, Atlantic sturgeon, shortnose sturgeon, and American eel. Salmon co-evolved over time with these and other aquatic organisms native to these rivers. Large populations of clupeids, such as shad, alewife, and blueback herring, used these river systems as migratory corridors, spawning grounds, and juvenile nursery habitat. As these fish completed their life cycles, they likely performed some important functions that may help Atlantic salmon to complete their life cycle. Primarily, these functions may be classified under two broad categories: prey buffering and marine derived nutrient cycling. Existing records are not adequate to quantitatively assess the ecological functions that these other fishes may have performed in a properly functioning ecosystem and how the loss of these functions may be affecting the survival and recovery of the DPS.

Incidental capture and poaching -- 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.

Introduced fish species -- Stocking of non-native fish species and land-locked salmon should be avoided in rivers within the DPS. Introduced fish species may compete and/or prey on Atlantic salmon. The introduction of non-native fish can endanger or threaten the continued existence of native species of fish. The potential exists for ecological interactions including predation and 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 these ecological interactions are exacerbated by the small size of the Atlantic salmon population.

Low marine survival rates continue to be low for U.S. stocks of Atlantic salmon and is impeding the recovery of the DPS (see page 1-20). The most current estimates indicate that since 1990, return rates to the Penobscot River have been below 0.5% and in the most recent three years, below 0.2% (Russell Brown, NOAA Fisheries, personal communication). 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 factors affecting the survival of salmon during the marine phase of their life history 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. The problem of mortality as smolts transition from freshwater to the ocean as post-smolts needs to be solved. If, as it seems likely, early mortality in estuaries and the ocean is due in part to water chemistry, particularly acidification in freshwater, mitigation of this threat is an urgently needed action (NRC 2004).

Large scale oceanographic processes also likely affect Atlantic salmon survival rates (Dunbar 1993; Friedland 1994). Sea surface temperature (SST) appears to be an important feature of the marine environment that affects Atlantic salmon survival. Correlation 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.

Recovery Hatchery Program -- The conservation hatchery program is important in preserving individual and composite stocks until factors currently depressing overall survival rates and production problems can be addressed. An inherent risk associated with the broodstock and stocking program for the DPS is the risk 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. The results of the threats assessment conducted as part of recovery plan development concluded that the risk of artificial selection/domestication is high. Current hatchery management goals are intended to minimize risks to the natural genetic integrity of the wild stocks from selective pressures and inbreeding in the captive environment.

Sedimentation 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. 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.

Water extraction -- Decreases in instream flows 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 attention 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 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 that 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 and chemical contaminants on all 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 Forest Service, 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.

Governance

In Maine multiple agencies and organizations (e.g., state, federal, local, tribal, private) are involved, either directly or indirectly, in salmon conservation and recovery. The NRC (2004) provides a summary of the many groups involved in programs that influence human activities related to Atlantic salmon conservation. Given the number of agencies and other parties involved in salmon conservation, the potential exists for conflicting goals and mandates, overlapping management responsibility and gaps in authority between existing agencies and organizations.

The NRC (2004) states that it was unable to assess the overall effectiveness and efficiency of efforts to which government agencies were contributing to the conservation and recovery of Atlantic salmon in Maine. The NRC recommended that a systematic assessment of the existing governance framework be conducted to evaluate whether this issue may be constraining the recovery of the DPS.

The effectiveness of efforts to conserve and recover the DPS may have been affected by a failure to learn from policies and other initiatives (NRC 2004). One strategy for addressing this problem is to design policies based on the principles of adaptive management (NRC 2004)[40]. The Recovery Plan states that throughout all phases of recovery plan implementation, recovery actions will be designed as experiments, results will be monitored and future actions modified accordingly, following an adaptive management approach.

[40] Recovery actions and policies need to be designed as experiments so that their impacts can be monitored and results used to inform future recovery strategies and actions.

The Recovery Plan identifies a number of areas where existing governance related issues need to be addressed to ensure consistent and effective protection of Atlantic salmon in Maine. For example, the plan identifies discrepancies in existing permitting of water withdrawals in organized and unorganized townships that fall under the authority of LURC and DEP respectively (see page 1-27). Other areas where the plan identifies the need for greater coordination between existing agencies include, stocking programs, assessment and research, water quality monitoring, information dissemination, inter-agency communication and coordination

The Atlantic Salmon Recovery Team will provide a forum that will serve as a clearing house for information on current activities related to salmon recovery. One of the primary responsibilities of the Atlantic Salmon Recovery Team's Coordinating Committee is to ensure effective communication and coordination between the Recovery Team and other appropriate agencies and groups involved in salmon recovery and conservation (e.g., state and federal agencies, the Maine Technical Advisory Committee (TAC), the USASAC, local conservation organizations, industry). Through the preparation of an annual workplan and progress report, the Recovery Team will help identify areas where overlapping authority and conflicts in mandates may be impeding the efficacy of various recovery actions.

The issue of continued and improved inter-agency coordination has been identified as an important need by a variety of agencies involved in salmon conservation. An example of inter-agency coordination at the state level is the annual meeting between Maine ASC and Maine IFW held to review existing stocking programs and assess the potential affects of these introductions on Atlantic salmon populations. At the federal level, FWS and NOAA Fisheries staff meets with the ACOE once every three weeks to screen permit applications. The purpose of these meetings is to identify projects that warrant Section 7 consultation. At the state level, the Services also meet with Maine Department of Transportation (MDOT) once a month to discuss upcoming projects. MDOT reportedly does a good job identifying salmon concerns before a project gets to the permitting stage. Some MDOT do not undergo Section 7 consultation as there is no federal nexus (no federal highway funds or ACOE permit). In these cases, MDOT typically consults with the Maine ASC.

The Services have developed a workload agreement at the regional level whereby responsibilities related to ESA implementation, particularly with regard to Section 7 and Section 10 are clearly delineated. Under this agreement, FWS is primarily responsible for activities and issues affecting the freshwater environment while NOAA Fisheries has assumed lead responsibility for activities within the estuarine and marine environment. The Services should review the current delineation of ESA responsibilities for the DPS to ensure effective and efficient implementation of activities necessary for the protection and recovery of the DPS. Joint jurisdiction of endangered species by NOAA and FWS creates an additional layer of bureaucracy that may result in delays in the implementation of recovery actions and adherence to other ESA mandates (e.g., permit review, permit issuance, recovery plan development). The Services will continue to review and assess the effectiveness of this workload division to ensure that it achieves the goal of efficient allocation of existing resources and reduces unnecessary delays and duplication of efforts.

Strong and effective local conservation organizations are important partners in recovery efforts. In 2004, the Eight Rivers Roundtable engaged the services of Demont & Associates, Inc., of Portland, Maine to assist in building local watershed capacity. Demont (2005) concluded that coordination of local conservation efforts by an umbrella organization could facilitate coordination between state, federal and various local organizations thereby strengthening the effectiveness of individual local councils. Demont (2005) concluded that in the long run, the existing definition and structure of the existing watershed councils may not be the most viable model for ensuring community-based watershed management. For example, the councils have struggled to maintain active participation and secure funding for restoration activities (Demont 2005). An umbrella organization could provide a number of functions for local watershed organizations including: liaison with state and federal agencies; provide administrative support; provide organizational development and management; provide technical support; fund raising; advocacy for watershed-specific conservation programs and salmon recovery (Demont 2005). The report recommended that such an umbrella organization should be structured as a 501(C)3 organization, with bylaws and an elected board of directors (Demont 2005). It was further recommended that the Eight Rivers Roundtable is positioned to become a more active coordinating body for the watershed councils and a model for the development of other regional watershed bodies throughout the State (Demont 2005).

River-specific Management Planning

Based on an assessment of the threats to the survival and conservation of the species, the Recovery Plan identifies site-specific management actions for all the threats the Services have identified under Section 4(a)(1) of the ESA five-factor analysis. Section 4(f) of the ESA states that recovery plans, to the maximum extent practicable, must incorporate site-specific management actions necessary for the survival and recovery of the species. Some of the threats identified are widespread and therefore the actions identified are applicable throughout the full range of the DPS. Other threats are present in only some of the watersheds and therefore the actions identified only apply in those specific watersheds.

The Recovery Plan (see Implementation Schedule) establishes priorities for all recovery actions identified in the plan. These Recovery Action priorities (1, 2, 3)[41] apply to the DPS as a whole, not a single river. Recovery Action priorities may change on different

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[41] Priority 1 – Actions that must be taken to prevent extinction or to prevent the species from declining irreversibly

Priority 2 – Actions that must be taken to prevent a significant decline in population/habitat quality or in other significant negative impact short of extinction

Priority 3 - All other actions necessary to provide for full recovery of the species spatial or temporal scales. Recovery Actions may be higher priorities for individual rivers and populations then they are for the entire DPS.

An assessment of the magnitude and severity of factors that may be affecting the conservation and recovery of Atlantic salmon reveals discrete issues exist for individual rivers within the DPS (see Threats Assessment). For example, the threat posed by acidity varies in geographic and seasonal patterns. Geographically, the DPS rivers located east of the Penobscot River have a lower pH than those located west of the Penobscot (Haines 1981; Haines et al. 1990). Other examples include different land ownership patterns (i.e., multiple small landowners in Mid-Coast region vs. large landowners Downeast), road density, water use, introduced species and land development pressure.

Implementation of the Recovery Plan may be facilitated by compiling a watershed or river-specific management plan that would include and highlight those threats and accompanying actions applicable within that particular area. River-specific plans could tailor recovery action implementation to specific watersheds to address different environmental conditions and land uses that exist in individual watersheds within the DPS. For example, land acquisition and conservation easements have been pursued on a number of DPS rivers. Within a particular watershed, an evaluation could be conducted to ensure that this type of land protection measures are pursued in areas that are threatened with serious, immediate development pressure, where the relationship between specific land use changes and habitat degradation is firmly established and where high value habitat is at risk. The reader should note that ongoing recovery implementation activities currently are responsive to the specific circumstances within individual watersheds (e.g., NPS surveys, nutrient management plans in the Sheepscot, liming project Downeast).

Management plans for specific issues of concern have been developed, or are envisioned, for many of the rivers and watersheds within the DPS. For example, the Maine ASC has been working to develop river-specific fisheries management plans for individual DPS rivers. The State of Maine, working in cooperation with multiple public and private partners, has developed a water use management plan (WUMP) for the Narraguagus and Pleasant rivers and for Mopang Stream (a tributary to the Machias River) (MSPO 2001)(see page 1-26). The WUMP was developed to address a specific issue (i.e., agricultural water use) that was a concern in these three rivers. In a number of instances, local conservation organizations have begun the process of developing river-specific management plans for specific issues. NPS management plans have been developed for the Narraguagus and Dennys River. These plans were developed by Project SHARE and the Narraguagus and Dennys river Watershed Councils (NRWC, DRWC) with support from a wide range of state, federal and local agencies. Project SHARE has initiated a program whereby river-specific water quality management plans will be developed for each of the eight DPS rivers (Project SHARE 2005). All these initiatives address discrete elements that comprehensive river-specific management plans should encompass.

The NRC (2004) recommended that, over the long-term, some type of comprehensive decision-analysis approach should be utilized. The Services and the ASC continue to review available decision analysis techniques and consider the use of appropriate risk assessment tools in recovery implementation.

The NRC (2004) recommendation related to the use of decision analysis stems in part from its stated view that great uncertainty exists regarding the causes of the decline of salmon populations in Maine and therefore what recovery actions are necessary to reverse the decline of the DPS. While the Services agree that uncertainty exists, the best available information clearly indicates several management approaches that have the potential to improve survival rates for Atlantic salmon at a number of life-stages (e.g., mitigation of low pH, habitat enhancement, predator control). These management strategies are based on the results of recent and ongoing research. As noted, the Services have already conducted a structured threat assessment in conjunction with the development of this Recovery Plan (see page 1-93). As noted, the assessment explicitly addressed the magnitude and severity of threats believed to be affecting the conservation and recovery of the species. When assessing the severity of various threats at individual life-stages uncertainty was explicitly addressed.

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, two 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., acidified water and associated aluminum toxicity, salmon aquaculture, avian predation, changing land use patterns, climate change, depleted diadromous fish communities, incidental capture by recreational fishermen, introduced fish species, low marine survival, poaching, recovery hatchery program, sedimentation and water extraction).

2) Actions that address critical information needs. 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. A population viability analysis (PVA)[42] has been prepared for the eight rivers within the DPS known to still support wild salmon populations, and this, in combination with improved knowledge on threats, will help develop final reclassification and delisting criteria (see Part Three: Recovery Goal, Objectives and Criteria). Actions other than priority 1 recovery actions that can be initiated quickly and have the potential to significantly improve survival and reverse the decline of DPS populations.

Presently a status review is underway to determine 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 not presently within the geographic range of the DPS. Decisions regarding the status of these populations may have significant implications for the recovery strategy.

Full recovery will encompass the full range of the DPS from the Kennebec to the St. Croix River. The initial focus of the recovery program, however, 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.

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42 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.

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 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., Project SHARE, Maine Technical Advisory Committee) 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 and are also included as part of the DPS. However, these hatchery fish will not count toward a delisting until they have spawned naturally in the wild (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 current river-specific hatchery stocking program 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 and maximizing the ability of these stocks to exploit their native habitat. These stocks have evolved over time in response to local conditions. 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. Crossing of river-specific stocks within the GOM DPS would be an acceptable practice if it were deemed necessary and appropriate for recovery of the DPS.

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 predation and competition, and measures must be instituted to limit current and future stocking unless 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 and genetically secure diverse populations within 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 reintroduction, including the potential use of experimental population designations to reintroduce fish to other rivers within the geographic range of the DPS (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.

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[43]. 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 second 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 natural environmental fluctuations. As a target, CSEs do not include consideration of the breadth of the genetic makeup of the species which is critical in order to conserve its adaptive capabilities, do not consider resiliency to ensure that the population can withstand stochastic events, and do not

[43] 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).

consider redundancy in order to provide a margin of safety for the species to withstand catastrophic events.

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[44]. 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. 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 concluded, as a result of the unsuitability of the available approaches, that the development of final demographic recovery criteria would be facilitated by the use 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[45]. 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 reclassification and delisting criteria for the DPS. A PVA is not a replacement for criteria based on threats, but can supplement them. The Services will integrate the existing PVA model with the comprehensive Viable Salmonid Populations (VSP)[46] approach to determine appropriate final reclassification and delisting criteria.

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

45 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, NMFS NEFSC, NWFSC and the SWFSC. In May 2005, the PVA was presented in the peer-reviewed journal, Transactions of American Fisheries Society (see, Legault, C.M. 2005). Population Viability Analysis of Atlantic Salmon in Maine, USA. Transactions of the American Fisheries Society. 134(3):549-562).

46 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

Development of final objective, measurable reclassification and delisting criteria is not currently practicable for several reasons. The principle reason (as discussed above) is that currently available methods considered do not encompass and integrate the fundamental attributes of viable salmonid populations articulated by the VSP approach. The deficiencies of the available methods underscore the fundamental questions and attributes that the Services must identify (e.g., abundance, spatial distribution, diversity, population growth rate) to establish final recovery criteria. Progress to identify/incorporate these specific attributes has not been accomplished yet as limited resources have been focused on the stabilization criteria and preserving the 8 core populations known to have persisted in the DPS.

Atlantic salmon recovery criteria will focus on achieving population levels consistent with their probability to 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. 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 panels may utilize structured decision making to facilitate the development of these criteria. The Services anticipate that the consideration of VSP attributes and parameters will be an integral element in developing recovery criteria for the DPS. The goal will be to develop a complete set of objective and measurable criteria from which decisions relating to reclassification and delisting may be made. Such criteria must be based on the best available science that can be identified. 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. As illustrated by the steps identified above, a collaborative process will be used to develop the final criteria that will be inclusive of knowledgeable experts and interested and potentially affected stakeholders. The Services are committed to the development of final reclassification and delisting criteria within three years of the finalization of this recovery plan, including technical, peer and formal public review of the criteria.

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.

As stated earlier, it is not practicable to establish a measurable criterion at this time with existing population assessment methodologies. In addition, the resources needed to develop long-term demographic criteria have thus far been directed toward identifying the measures needed to meet the more immediate aim of reversing population declines; upon approval of this plan, these resources will be redirected toward identifying the measures needed for full recovery.

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structure and diversity.

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[47].

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 an objective measure of progress towards recovery, showing that the decline has been halted. 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 its life cycle and return as an adult spawner. Progress towards achieving criterion 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 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.

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47 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/).

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 constitute 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) and threats-based recovery criteria are in the process of development.

While this plan establishes some objective, measurable criteria specific to both population demographics and threat abatement, the Services have concluded that it is not practicable to provide measurable criteria for all demographic and threat based factors at this time. Therefore, qualitative delisting and reclassification criteria are provided as indicated in these instances. The reasons why it is not practicable to provide objective, measurable criteria for all delisting factors are discussed below. The actions necessary to be able to develop final criteria, within three years of this plan being finalized, are identified in this section.

The delisting and reclassification criteria presented below include measurable and objective criteria. They include a component that measures population numbers and trends as well as components addressing threats to the species, including those identified under the five factor analysis conducted when the species was listed under the ESA. It is possible to determine if one has met these criteria or not by examining the population trends, the success of threat abatement and/or the extent of implementation of mitigation measures.

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.

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 outside the geographic range of the DPS. Decisions regarding the relationship and status of these populations may have significant implications for the development of final recovery criteria.

While the following criteria give a road map to the types of criteria that are necessary for recovery they do not, at this time, give the Services the ultimate targets for reclassification or delisting. Therefore, the Services do not believe that Atlantic salmon can be reconsidered for reclassification or delisting based on the available science until additional criteria are developed that address the threats and the population demographics in a more measurable way or there is a change in information that warrants reconsideration of the DPS.

The integration of the VSP approach with PVA results will require scientists and managers to address complex population-level and habitat-related issues. It will also involve the use of expert panels to outline appropriate risk levels and develop alternative scenarios for recovery. The resultant criteria will be reviewed by the scientific community and disseminated for public comment prior to final approval by the Services. Development of measurable demographic criteria should be completed within three years of recovery plan approval.

Preliminary Reclassification Criteria

In order to consider reclassification, the first recovery objective (see above) will have been met, which is to 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. As described above, this recovery objective is meant to address the current situation of critically low numbers of adult Atlantic salmon returns. Once Objective 1 (including criterion 1 and 2) has been met, the following criteria would also need to be met for reclassification.

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, as measured by the replacement rate (5-year geometric mean) of adult salmon within DPS rivers (see Recovery Objective section and footnote for more information on replacement rates).

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 withdrawals, disease, and aqauculture; and low marine survival (65 FR 69479, see page 1-20). Preliminary criteria have also been provided to address several other current or potential threats including acidification of freshwater habitats, depleted diadromous fish communities, direct and indirect marine harvest, incidental capture and poaching, competition with non-indigenous fish, hatchery supplementation, sedimentation, avian predation.

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. *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.

The Gulf of Maine DPS does not have chronically low pH levels, but does experience episodic events resulting in depressed pHs. Research is ongoing to understand the spatial and temporal extent of these events and their effect on the DPS. The Recovery Plan identifies the actions necessary to determine what levels of pH are suitable for the survival and conservation of the DPS. The Services will use the results of ongoing research to determine and establish suitable pH levels necessary for the survial and conservation of the DPS. The levels will serve as objective and measurable criteria.

2. *Aquaculture*:
    a. There is no stocking of reproductively viable non-North American strains of Atlantic salmon in marine cages in Maine.

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.
c. All farmed raised fish in Maine are marked

In November, 2003, NOAA Fisheries issued a Biological Opinion (BO) on the proposed modification of existing ACOE permits authorizing the installation and maintenance of aquaculture fish pens within the State of Maine. The BO establishes reasonable and prudent measures and associated terms and conditions specific to 2a) and 2b) above. These provide the objective and measurable standards by which the attainment of this criterion will be evaluated.

3. *Avian predation*: Active management (e.g., non-lethal and lethal deterrence) results in a statistically significant reduction in predation by double-crested cormorants on migrating Atlantic salmon smolts .

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. The Services have concluded that double-crested cormorant predation has the potential to cause direct mortality to various life stages of Atlantic salmon, including returning adults. An adaptive management program is underway to determine if implementation of avian predator control will assist in the recovery and should be continued and expanded. Smolt outmigration occurs in a relatively narrow time window and along a narrow pathway exposing outmigrating smolts to predation by double-crested cormorants.

4. *Depleted diadromous fish communities*: Diadromous fish species that co-evolved with salmon are restored to the watersheds in order to serve as predator buffers and contribute marine derived nutrients to the ecosystem.

Other native diadromous fish populations have declined as dramatically as Atlantic salmon in recent years. The Services have concluded that the depletion of diadromous fish communities that have co-evolved with Atlantic salmon poses a threat to recovery efforts for Atlantic salmon (see page 1-91). However, the information is not currently available to identify which species, and at what levels, are essential to a fully functioning ecosystem and the recovery of the DPS. The Recovery Plan identifies actions necessary to define the role and function(s) that other diadromous fish species provide essential to the recovery of self-sustaining wild Atlantic salmon populations. These actions will provide the information necessary to establish objective and measurable delisting and reclassification criteria to determine the level of abatement of this threat. With this additional knowledge, the Services will be able to identify those species that are essential to the survival and recovery of the DPS.

5. *Direct and indirect 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.

The International Council for the Exploration of the Sea (ICES) Advisory Committee on Fishery Management annually estimates the pre-fishery abundance (PFA) of non-maturing 1SW salmon available for harvest, accounting for natural mortality. The required conservation escapement limits (CSE) for homewaters are subtracted from the PFA. If there is any surplus, 40% is allocated to West Greenland. This science-based allocation is fully protective of homewater stocks and its continuation is essential to the recovery of the species. The NASCO uses the ICES advice on catch and management options[48] for Atlantic salmon fisheries to make science-based management decisions for this fishery. The ICES advice to NASCO for 2005, as it has been in recent years, was that catch should approach or reach zero.

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).

Rapid detection and response to known and emerging diseases will minimize the risk of exposure and transmission to wild salmon stocks. Disinfection Protocol and/or Biosecurity plans for all field equipment and sampling gear should be established by all agencies (including IF&W and DMR) with personnel working in DPS waters to minimize the inadvertent spread of fish pathogens and other aquatic invasive species.

7. *Incidental capture and poaching*: Regulatory mechanisms are in place and enforced to assure that angling for other species and poaching of salmon will not adversely affect the long-term viability of the DPS.

For reclassification purposes, the level of mortality Atlantic salmon caused by incidental capture or poaching, in combination with other sources of mortality, must be sufficiently low such that the population is stable or increasing as measured by the replacement rate. It is not currently practicable to determine what level of mortality is sufficiently protective of the DPS. The analysis of this risk is dependent on the availability of final demographic criteria.

In the meantime, the effect of incidental take will be analyzed through section 7 and/or section 10 processes. Any take authorized through these processes will not jeopardize the species (in full consideration of all other take occurring).

8. *Introduced fish species including non-indigenous species*:

48 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).

   a. Stocking of non-indigenous fish species is prohibited within the DPS range.

Exemptions to this prohibition could be authorized if a risk analysis demonstrated that the proposed stocking was not likely to adversely affect the long-term viability of the DPS.

   b. All stocking authorized under 6.a) above is accompanied by an ongoing monitoring program to detect and assess any adverse impacts to the DPS.

9. *Recovery hatchery program*: A broodstock and conservation hatchery plan is in place and being implemented for the conservation hatchery program component of the recovery effort. Evaluation of the role and effectiveness of the conservation hatchery program demonstrates its ability to contribute to the recovery of the DPS.

Hatcheries have been used in Maine to attempt to increase the populations of salmon since the 1870s. The NRC recommended that current hatchery practices should be evaluated in an adaptive management context to minimize potential genetic and ecological effects and to modify the program as appropriate (NRC 2004). To minimize the potential genetic and ecological threat posed by the hatchery program, the FWS, in cooperation with other federal and state agencies, is currently working to develop broodstock management plans for the FWS Maine Hatchery Complex Program. While many of the elements of an effective broodstock plan are operational, they are not well documented and the broodstock management plan will update and consolidate all the elements into one document.

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. An important component of this plan is a Genetic Management Plan (GMP) that is needed to reduce several risks associated with captive breeding programs (e.g., genetic drift; selection; domestication; inbreeding).

10. *Sedimentation*: Long-term mechanisms (e.g., regulatory and non-regulatory) are in place to ensure Atlantic salmon habitat is not adversely affected by sedimentation.

Preliminary evidence suggests that substrate embeddedness of between 45-50% results in reductions of production rates for juvenile Atlantic salmon. For activities within Gulf of Maine DPS watersheds, BMPs must be utilized to ensure that sedimentation does not result in embeddedness equal to or greater than 45% in spawning and rearing habitat. This number will be refined and modified as additional information becomes available.

11. *Water withdrawals*: Long-term mechanisms are in place to effectively manage existing and new water withdrawals, to prevent water withdrawals from adversely affecting the long-term viability of the DPS.

The flow requirements of juvenile Atlantic salmon have been assessed in only some of the rivers within the DPS. The Recovery Plan identifies the actions necessary to determine what water and flow levels are necessary to maintain suitable habitat quality and quantity for all life stages of Atlantic salmon throughout the DPS. The levels will serve as objective and measurable criteria.

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, as measured by the replacement rate (5-year geometric mean) of adult salmon within DPS rivers (see Recovery Objective section and footnote for more information on replacement rates).

3. Atlantic salmon populations in the DPS are not dependent on hatchery stocking.

In order to delist the Gulf of Maine DPS of Atlantic salmon the Services must determine that self-sustaining wild Atlantic salmon populations are capable of completing their lifecycle in the absence of hatchery supplementation. The Services may conclude after delisting that hatchery supplementation for other purposes (e.g., recreational fishery) is warranted. However, the contribution of returning wild adult Atlantic salmon spawning in the wild must be sufficient to support a self-sustaining DPS without hatchery supplementation. The contribution of wild salmon versus hatchery reared salmon will be measured and monitored by currently available methods (e.g., genetics, tagging).

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., federal, state or local management mechanisms, treaties) before delisting could occur. It is also important to note that population augmentation through the hatchery program may increase a species' population numbers while a threat continues. That is why for delisting purposes, the criteria include a requirement that the species not be dependent on hatchery stocking.

1. *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.

The Gulf of Maine DPS does not have chronically low pH levels, but does experience episodic events resulting in depressed pHs. Research is ongoing to understand the spatial and temporal extent of these events and their effect on the DPS. The Recovery Plan identifies the actions necessary to determine what levels of pH are suitable for the survival and conservation of the DPS. The Services will use the results of ongoing research to determine and establish suitable pH levels necessary for the survival and conservation of the DPS. The levels will serve as objective and measurable criteria.

2. *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.
    c. All farmed raised fish in Maine are marked

In November 2003, NOAA Fisheries issued a Biological Opinion (BO) on the proposed modification of existing ACOE permits authorizing the installation and maintenance of aquaculture fish pens within the State of Maine. The BO establishes reasonable and prudent measures and associated terms and conditions specific to 2a) and 2b) above. These provide the objective and measurable standards by which the attainment of this criterion will be evaluated.

3. *Avian predation*: Active management (e.g., non-lethal and lethal deterrence) results in a statistically significant reduction in predation by double-crested cormorants on migrating Atlantic salmon smolts that will assist in recovery.

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. The Services have concluded that double-crested cormorant predation has the potential to cause direct mortality to various life stages of Atlantic salmon, including returning adults. An adaptive management program is underway to determine if implementation of avian predator control will assist in the recovery and should be continued and expanded. Smolt outmigration occurs in a relatively narrow time window and along a narrow pathway exposing outmigrating smolts to predation by double-crested cormorants.

4. *Depleted diadromous fish communities*: Diadromous fish species that co-evolved with salmon are restored to the watersheds in order to serve as predator buffers and contribute marine derived nutrients to the ecosystem.

Other native diadromous fish populations have declined as dramatically as Atlantic salmon in recent years. The Services have concluded that the depletion of diadromous fish communities that have co-evolved with Atlantic salmon poses a threat to recovery efforts for Atlantic salmon (see page 1-91). However, the information is not currently available to identify which species, and at what levels, are essential to a fully functioning ecosystem and the recovery of the DPS. The Recovery Plan identifies actions necessary to define the role and function(s) that other diadromous fish species provide essential to the recovery of self-sustaining wild Atlantic salmon populations. These actions will provide the information necessary to establish objective and measurable delisting and reclassification criteria to determine the level of abatement of this threat. With this additional knowledge, the Services will be able to identify those species that are essential to the survival and recovery of the DPS.

5. *Direct and indirect 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.

The International Council for the Exploration of the Sea (ICES) Advisory Committee on Fishery Management, annually estimates the pre-fishery abundance (PFA) of non-maturing 1SW salmon available for harvest, accounting for natural mortality. The required conservation escapement limits (CSE) for homewaters are subtracted from the PFA. If there is any surplus, 40% is allocated to West Greenland. This science-based allocation is fully protective of homewater stocks and its continuation is essential to the recovery of the species. The NASCO uses the ICES advice on catch and management options[49] for Atlantic salmon fisheries to make science-based management decisions for this fishery. The ICES advice to NASCO for 2005, as it has been in recent years, was that catch should approach or reach zero.

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).

Rapid detection and response to known and emerging diseases will minimize the risk of exposure and transmission to wild salmon stocks. Disinfection Protocol and/or Biosecurity plans for all field equipment and sampling gear should be established by all agencies (including IF&W and DMR) with personnel working in DPS waters to minimize the inadvertent spread of fish pathogens and other aquatic invasive species.

7. *Incidental capture and poaching*: Regulatory mechanisms are in place and enforced to assure that angling for other species and poaching of salmon will not adversely affect the long-term viability of the DPS.

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[49] 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).

For delisting to occur, exisitng state regulation and enforcement without the additional protection of the ESA must be determined to be sufficient to allow recovery to continue. It is not currently practicable to determine what level of mortality due to incidental capture and poaching that can be sustained by a recovered DPS. The analysis of this risk is dependent on the availability of final demographic criteria.

8. *Introduced fish species including non-indigenous species*:
    a. Stocking of non-indigenous fish species is prohibited.

Exemptions to this prohibition could be authorized if a risk analysis demonstrated that the proposed stocking was not likely to adversely affect the long-term viability of the DPS.

    b. All stocking authorized under 6.a) above is accompanied by an ongoing monitoring program to detect and assess any adverse impacts to the DPS.

9. *Sedimentation*: Long-term mechanisms (e.g., regulatory and non-regulatory) are in place to ensure Atlantic salmon habitat is not adversely affected by sedimentation.

Preliminary evidence suggests that substrate embeddedness of between 45-50% results in reductions of production rates for juvenile Atlantic salmon. For activities within Gulf of Maine DPS watersheds, BMPs must be utilized to ensure that sedimentation does not result in embeddedness equal to or greater than 45% in spawning and rearing habitat. This number will be refined and modified as additional information becomes available.

10. *Water withdrawals*: Long-term mechanisms are in place to effectively manage existing and new water withdrawals, to prevent water withdrawals from adversely affecting the long-term viability of the DPS.

The flow requirements of juvenile Atlantic salmon have been assessed in only some of the rivers within the DPS. The Recovery Plan identifies the actions necessary to determine what water and flow levels are necessary to maintain suitable habitat quality and quantity for all life stages of Atlantic salmon throughout the DPS. The levels will serve as objective and measurable criteria.

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
  - 1.1.3 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
  - 1.1.5 Evaluate the effect instream water management may have on the hydrologic conditions of individual watersheds and Atlantic salmon habitat

1.1.5A Conduct an inventory and assessment of the ability of dams in DPS watersheds to regulate flow

1.1.5B Review current water management for the dams and develop an assessment of the effect of regulation on a watershed's hydrology and thus Atlantic salmon habitat

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 of 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 Implement a comprehensive and integrated long-term water quality monitoring program on all DPS rivers
1.2.3C 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 Evaluate the impacts of sedimentation on habitat quantity and quality including relationship between substrate embeddedness and habitat productivity in DPS rivers.
1.2.4C Prepare and implement point source (PS) pollution reduction plans for DPS rivers
1.2.4D Fully implement EPA aquaculture wastewater and effluent discharge regulations
1.2.4E Continue monitoring of the remediation efforts at the Eastern Surplus Superfund site in Meddybemps
1.2.4F 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 Identify riparian zone activities (e.g., harvest practices, ATVs, development etc.) and evaluate impacts on Atlantic salmon

1.4.1D Evaluate current state and local land use regulations to determine adequacy of existing measures protecting riparian habitat and instream improve 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
1.5.5 Evaluate the ecological role and importance of restoring other diadromous fish populations

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 where 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

2.2.2C Increase observer coverage in the midwater trawl herring fishery to improve the ability to assess the potential for Atlantic salmon bycatch in the herring fishery.

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 Document and monitor the presence and abundance of seals at natural and man-made concentration sites

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 for 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 Develop a Section 10(a)(1)(B) habitat conservation plan for existing stocking programs if warranted

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.

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 minimize aquaculture escapees spawning, 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

4.3.1F Implement biosecurity and disinfection protocol for all research and assessment activities being conducted in rivers within the DPS

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 and 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 an annual progress report on completion of recovery actions

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

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.

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 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 11 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 that 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 1-20; 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 and 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) initiative and precipitation and rainfall data.

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 - USFWS New England aquatic base flow study 1981). 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.

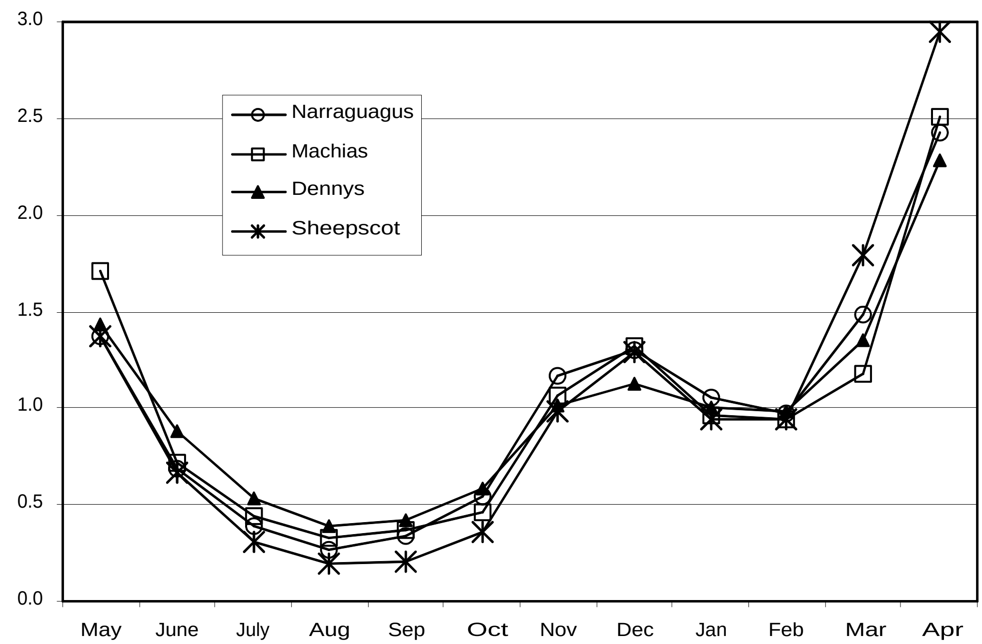

Figure 11: Mean monthly flows for the Narraguagus, Machias, Dennys and Sheepscot rivers, normalized as relative flow. Relative flow is the mean monthly flow expressed as a proportion of the mean annual flow for each river (Q_M/Q_A). Mean monthly flow data are USGS flow statistics from 1949-2000 (Narraguagus), 1949-1977 (Machias), 1955-1998 (Dennys) and 1939-2000 (Sheepscot).

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, Pleasant and Dennys rivers (see page 1-26). 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)[50] 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

50 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.

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, the Maine Geological Survey (MGS; a bureau within the Maine Department of Conservation) and the Aroostook County Water and Soil Management Board, has recently completed two multi-year studies of low-flow characteristics of streams in eastern and northern Maine (Lombard et al. 2003). The purpose of the study was 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 helps 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.

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. Several analyses have been completed (see Nielsen 1999; Dudley and Nielsen 2000; Lombard et al. 2003; Dudley 2004). 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 wild blueberry growers 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

1.1.3 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 by 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)[51] for the Narraguagus and Pleasant rivers and for Mopang Stream (MSPO 2001)(see page 1-26). Current demand for irrigation water by large wild 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 wild 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 wild 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.

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 and trends in those 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.

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51 As noted (page 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.

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[52]. 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 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.

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.

52 Existing water withdrawal permits issued by LURC and the ACOE for wild blueberry growers use the FWS ABF flows.

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

1.1.5 Evaluate the effect instream water management may have on the hydrologic conditions of individual watersheds and Atlantic salmon habitat

As discussed (see page 1-27), impoundments used to regulate instream flow affect the hydrologic conditions of DPS rivers. Several DPS rivers have small dams on lakes and ponds within the drainage used to manipulate river flows. The effect that these impoundments have on the hydrologic conditions of individual watersheds and Atlantic salmon habitat should be evaluated

Recovery Actions:

1.1.5A Conduct an inventory and assessment of the ability of dams in DPS watersheds to regulate flow

1.1.5B Review current water management for the dams and develop an assessment of the effect of regulation on a watershed's hydrology and thus Atlantic salmon habitat.

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 agrochemical

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 1-28). 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 wild 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 1-30). 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 wild 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 1-31). 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 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). Increased joint monitoring by Maine DEP, Maine BPC and other agencies is needed to accurately detect levels of pesticides in DPS river watersheds and to determine transport mechanisms, fate and toxicity.

Research is also needed to understand the chronic and acute effects of pesticides on Atlantic salmon. 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 wild 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 4-28). Further research on the mechanisms of exposure, uptake and effect of non-pesticide organochlorines on Atlantic salmon should be undertaken (Maine TAC 2002)(see page 1-38).

Moore and Waring (1996, 2001) documented the effect of several pesticides on Atlantic salmon olfactory capabilities. 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)[53] 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.

53 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).

Recovery Actions:

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 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 of 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 Downeast Rivers (Narraguagus, Pleasant, Machias, East Machias, Dennys) have an ongoing water temperature monitoring program instituted by the Maine ASC and FWS in the early 1990’s. In addition, the Sheepscot and Ducktrap rivers, along with Cove Brook, have also had recent water temperature monitoring activity (generally late 1990’s to the present), much of which that has been carried out by local watershed councils. Many private conservation groups (e.g. Atlantic Salmon Federation), local watershed councils and Indian tribes (e.g. Penobscot Indian Nation) are carrying out monitoring programs of their own.

The potential for water temperature elevation in the vicinity of blueberry processing water discharges has been identified as a water quality issue (see page 1-46). Water temperatures in the vicinity of such discharges should be monitored to assess the potential to adversely affect Atlantic salmon.

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.

Recovery Actions:

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

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

1.2.3C 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 1-22). 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 unlicensed 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.

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.

As noted (see page 1-40), sediment can impact salmon habitat in a number of ways including substrate embeddedness, diminished habitat complexity and stream channel alteration. Ongoing research conducted by the ASC has begun to investigate the level of NPS related substrate embeddedness and habitat productivity in several DPS rivers. Estimates of embeddedness can be used to assess habitat degradation or identify stream reaches that may benefit from habitat restoration (Atkinson and Mackey 2004). This research should be continued and the results be used to catalogue degraded habitat and prioritize habitat restoration needs.

The EPA has 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. In August 2004, EPA established effluent limitations guidelines for concentrated aquatic animal production facilities including 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 (69 FR 51892). These regulations should be fully implemented.

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 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 Evaluate the impacts of sedimentation on habitat quantity and quality including relationship between substrate embeddedness and habitat productivity in DPS rivers.

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

1.2.4D Fully implement EPA aquaculture wastewater and effluent discharge regulations

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

1.2.4F Address any groundwater 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

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. The Services have concluded that manmade obstructions to passage is not a high level threat to the survival and conservation of the DPS. Dams that obstruct passage of salmon do, however, exist on several rivers within the range of the DPS that no longer support wild salmon populations. The role of vacant habitat within the range of the DPS will be evaluated in the context of the development of final recovery criteria for the DPS (see page 3-13).

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 intermittently 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. The 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

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. The project could be expanded to three areas (one each on an important salmon tributary to the Machias, Pleasant, and Narraguagus rivers). Suitable salmon habitat in Venture Brook is limited -- different tributaries containing substantial amounts of salmon rearing habitat should be selected for study.

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 1-40). 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 conditioned 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 a 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. A watershed-wide risk assessment would be a valuable tool to determine a comprehensive, big picture understanding of the need to protect habitat through the use of riparian buffers.

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) [54] had instituted 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 continue to evaluate and monitor compliance with voluntary standards and adoption and use of BMPs by landowners[55]. 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

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54 As noted, in November 2004, International Paper sold its Maine and New Hampshire forestlands, totaling approximately 1.1 million acres, to GMO Renewable Resources, LLC, (GMORR) a private forest investment management company. The new landowner plans on keeping the land in the Sustainable Forestry Initiative (SFI) certification program.

55 MFS is mandated to evaluate and monitor the use of forestry BMPs in timber harvesting operations to protect water quality (PL 1997 § 648). In 2003, MFS inspected over 3500 timber harvest operations statewide to evaluate the use and effectiveness of BMPs. MFS found 7% of the inspections found insufficient us eof BMPs to protect water quality. In contrast, a similar study in 1995 found only a 47% BMP use.

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 Identify riparian zone activities (e.g., harvest practices, ATVs, development etc.) and evaluate impacts on Atlantic salmon

1.4.1D Evaluate current state and local land use regulations to determine adequacy of existing measures protecting riparian habitat and instream improve 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 should 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 1-40). 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 1-21). 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 (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 in the model.

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[56] to drainage area. This information is

[56] 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).

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.

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 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 watersheds and estuaries should be assessed, catalogued and prioritized 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.

1.5.5 Evaluate the ecological role and importance of restoring other diadromous fish populations

As discussed (see page 1-14), Maine Atlantic salmon rivers historically supported abundant populations of other native diadromous fish species including alewives, blueback herring, American shad, sea lamprey, anadromous rainbow smelt, Atlantic sturgeon, shortnose sturgeon and American eel. As these fish completed their life cycles, they likely performed important ecological functions that may have been important to Atlantic salmon in completing their life cycle. Primarily, these functions may be categorized under three broad categories: prey buffering, marine derived nutrient cycling and habitat modification and enhancement.

Many of these diadromous species have declined as dramatically as Atlantic salmon in recent years (Collette and Klein-MacPhee 2002). The absence of historical data for these species make it very difficult to assess the functions these fishes may have performed in a properly functioning ecosystem. Nonetheless it is likely that the absence of other populations of diadromous species of fish native to rivers within the DPS may be impeding the recovery of the DPS. Additional investigation of the role and importance of restoring other diadromous fish populations in the recovery of the DPS should be pursued.

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 1-35). 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 1-52). 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 1-56 to1-57)[57]. These commercial fisheries have been greatly reduced but not completely eliminated as a

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[57] 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 4-44 – 4-53.

source of mortality to Maine Atlantic salmon. The North American component of this mixed stock fishery[58] 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[59] 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).

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 1-56), 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

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

59 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).

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.

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 NMFS, 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. 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.

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.

The Services have concluded that the potential incidental capture of Atlantic salmon by recreational anglers targeting other fish species poses a high level threat to the DPS. Juvenile and adult Atlantic salmon may be incidentally taken as bycatch by state permitted recreational anglers fishing for other freshwater game fish species such as brown trout, brook trout and landlocked salmon (see page 1-52). 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[60], 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 1-52). 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.

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

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

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 1-55). 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 1-54). The NMFS 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. Based on the potential spatial and temporal overlap of the midwater trawl herring fishery and post-smolt outmigration, observer coverage should be increased in the fleet in order to improve the ability to assess the potential for Atlantic salmon bycatch to occur in the herring fishery.

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

2.2.2C Increase observer coverage in the midwater trawl herring fishery to improve the ability to assess the potential for Atlantic salmon bycatch in the herring fishery.

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 1-65 to1-76). 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 page 1-49). 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 NMFS 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 (Cordone and Kelley 1961; Bjornn et al. 1974, Waters 1995)(see page 1-41). 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[61] should be implemented to reduce predation on Atlantic salmon. Cormorant predation on Atlantic salmon in Maine has been well-studied (see page 1-69). 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 the use of non-lethal deterrence and/or selective lethal removal of cormorants at locations where they are observed to be significant salmon predators.

Lethal control of cormorants is currently subject to depredation permits that may be issued by FWS under the Migratory Bird Treaty Act[62]. The FWS may issue depredation permits authorizing lethal control of cormorants, their eggs, and/or nests, particularly in situations where

[61] 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.

[62] 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.

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

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. Based on the available data, although somewhat minimal, it seems that net-pens do not aggregate seals (Nelson 2004). This potential threat should be investigated in conjunction with research to assess seal attacks on net-pens and implementation of deterrence measures.

The NMFS 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[63].

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 NMFS 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. 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 NMFS 2003). Variation in ingestion and digestion

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

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).

Harbor seal food habit studies that rely on bony parts are likely to underestimate the take of adult salmon. Generally, harbor seals eat small fish (20-30 cm) that can be swallowed whole. Seal predation on adult salmon at aquaculture pen sites and elsewhere however is characterized by bites from the belly of the fish, and no bones large enough to withstand digestion are consumed. Stable isotope analysis (Smith, et al., 1997) is showing more promise for identification of food to species, and genetic analyses of hard parts found in scats may be a precursor to identification of soft tissues from stomachs (Orr, et al., 2004, Purcell, et al., 2004).

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 1-66). 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 (United Nations Environment Program (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[64] 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 Document and monitor the presence and abundance of seals at natural and man-made concentration sites

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.

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64 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. NMFS 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 1-69).

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

The Maine IFW stocks brown trout[65], splake, landlocked salmon and brook trout in rivers and lakes within DPS river watersheds in order to enhance recreational fishing opportunities for the public. The NRC (2004) recommended that the stocking of non-native species, including brown trout, small- and largemouth bass and landlocked salmon, into DPS rivers be avoided. 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

65 As noted (page 51), brown trout are raised at the Palermo hatchery on the Sheepscot River for stocking purposes.

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 have met annually since 2001 to discuss and review stocking and data collection 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, NMFS 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[66]. Under the ESA, Section 7 consultations provide another means to develop responsible alternatives to the potential impacts stocking may have on Atlantic salmon. NMFS 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

66 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 Develop a Section 10(a)(1)(B) habitat conservation plan for existing stocking programs and, if warranted 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. Maine IFW has removed the size and bag limit on smallmouth bass in the Pleasant and Dennys Rivers and is in the process of extending this regulation to Old Stream, New Stream, and Northern Stream. Selected headwater lakes in the Machias and East Machias watersheds are managed for quality sized bass. The IFW has proposed a no minimum length/bag limit on bass and pickerel in the main stem of the Sheepscot from the Route 105 Bridge to the head of tide and on the West Branch from Branch Pond to the confluence with the Main stem.

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 1-78 to1-86). 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

In January 2001, the EPA delegated authority to the State of Maine to administer the CWA, National Pollutant Discharge Elimination System (NPDES) program[67]. An MEPDES general

[67] The EPA retains oversight of this program.

permit for Atlantic salmon aquaculture was finalized in 2003 and includes special conditions for protection of endangered Atlantic salmon. These conditions focused on 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.

As part of these new MEPDES permit requirements, all Atlantic salmon aquaculture facilities are required to use a fully functional marine containment management system (CMS) designed, constructed and operated to effectively achieve zero escapement of fish from the facility. All cages should be designed appropriately and mooring systems should be adequately designed, deployed and maintained. 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 are available to the Services upon request.

Siting and equipment are also very important parts of the permit requirements issued from DMR and the ACOE. For an aquaculture facility, an applicant must conduct a baseline assessment[68] of the site and demonstrate that the leased area is suitable for establishing net pen salmon farming. The applicant must demonstrate the equipment (i.e., moorings, and cages) proposed for use at the site is suitable to withstand environmental conditions typical of the area. This evaluation is needed to minimize the risk of catastrophic loss at a site due to net-pen failure during times such as extreme tides, wind, icing or a storm event.

Presumably, many of 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 and at this point have been determined not to be necessary for recovery of the DPS.

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

[68] 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.

marking working group and a containment working group. The containment working group addressed containment at both marine sites and at freshwater hatcheries. The containment groups used the Hazard Analysis Critical Control Point (HACCP) approach to identify and implement BMPs at critical control points. The containment working groups have developed a generic HACCP plan that now serves as the framework for site-specific plans at every facility (as now required by MEDPES permits). The marking working group is evaluating various marking techniques that would allow assessment of containment measures.

To assist in the development an integrated CMS program for the Maine salmon farming industry, some marine and hatchery facilities participated in a trial audit period to refine the essential components of an effective containment program. Since the inception of the CMS program (2003), all active hatcheries and marine farm sites have been audited through an interagency collaborative process involving DMR, DEP and NMFS personnel.

All salmon aquaculture facilities are required to develop an integrated CMS plan for the facility. The CMS plan 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 CMS should address all the steps involved in the commercial culturing process and the potential for losses at each of these points should be identified through a hazard analysis. The CMS should include a facility specific list of critical control points (CCP) where escapes could potentially occur. Each CCP should address the following to minimize the risk of escapement: specific location, control mechanisms, critical limits, monitoring procedures, appropriate corrective actions, verification procedures that define adequate CCP monitoring and a defined record keeping system. The facility shall report any known or suspected escapes of more than 50 fish with an average weight of 2 Kg each or more within 24 hrs to the appropriate personnel immediately. The CMS will be audited at least once per year and within 30 days of a reportable escape to evaluate the efficacy of containment measures in place and compliance with monitoring critical limits and taking appropriate corrective actions in accordance with best management practices specified in the CMS plan. Any equipment failure or other losses should trigger a corrective action needed to immediately stabilize the situation; upon further evaluation of these measures, any deficiencies noted should be corrected immediately to prevent further loss.

All salmon aquaculture facilities are required to 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 the appropriate permitting agencies (e.g., ACOE and DEP) 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.

Permitting agencies 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 unaccounted fish.

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 NMFS is working with researchers at UM to investigate some of these issues. Nelson (2004) examined the nature and frequency of seal predation at aquaculture facilities and whether the severity of seal predation was related to the proximity of seal haul-out sites at net pens. Neslon found that the further away that a net pen site was located the less likely it was to experience seal predation. Nelson (2004) concluded that aquaculture sites located further than 4.75 – 5 km away from a seal haul out site were at a substantially reduced level of risk for seal predation.

In 1996, NMFS, 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[69].

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.

69 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.

4.1B Develop fully functional containment management systems for the containment of farmed salmon at marine sites.

4.1C Develop and implement Containment Management System 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 1-79). The Atlantic salmon industry in Maine is concentrated in Cobscook Bay in Washington County (see page 1-78). 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 1-81).

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 Containment Management System 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. In addition federal and state biologists should develop contingency plans for the recapture of escaped farmed salmon in estuarine and freshwater habitats.

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 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 has been an important component of the efforts to conserve and restore wild Atlantic salmon in Maine (MASCP 1997). 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. As previously noted (see page 1-51), concrete defectors were built to provide eddies and resting areas for salmon moving upstream through the gorge at Bad Little Falls in order to facilitate upstream fish passage.

Recovery Actions:

4.2.2A Maintain existing weirs on DPS rivers to minimize aquaculture escapees spawning, 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 (>22ºC) which is stressful for the fish. Prior to stocking, the mark should be filed with the appropriate permitting agencies 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.

As noted, 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 an effective marking program. 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 marking working group is currently evaluating various marking techniques that would allow assessment of containment measures.

In accordance with MEPDES permit conditions fish introduced into net pens must be marked to designate their origin so that in the event they escape or are released from a marine facility they may be identified. Timelines are established for achieving several levels of mark specificity, however the specific marking technique or strategy is not specified. All marks, however, must be approved by the MEDEP before use.

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 discontinued immediately at all aquaculture facilities[70]. Non-North American stock is defined as any Atlantic salmon (*Salmo salar*) that contains genetic material derived

70 According to MEDEP permits, no further stocking of NNA salmon will be permitted after July 31, 2004 and all NNA salmon out of pens by Sept. 15, 2006.

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. The MEPDES permits prohibit the use of transgenic salmon.

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[71] 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).

71 Triploid refers to having three copies of each chromosome rather than the normal two copies (i.e., diploid).

The United States Department of Agriculture (USDA) has initiated a breeding program to assist in the development of suitable North American strains of Atlantic salmon for use in aquaculture. Recent work on different genetic strains underway at the Huntsman Marine Science Center (HMSC) in St. Andrews, Canada has produced some promising results. Researchers at the HMSC and USDA facility 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, 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 1-58 to1-65).

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, at the invitation of the Maine DMR, 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[72] if disease risks are to be effectively minimized.

Other protocols and guidelines (e.g., AFS/FHS, 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 which is currently limited to salmonids found west of the Rocky Mountains, and non-marine VHS which occurs in European and other countries. 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.

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[72] 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.

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.

As discussed (see page 1-64), another potential mode of disease transmission is through biological sampling conducted by various state and federal agencies in DPS rivers. The development and implementation of disinfection and biosecurity protocols reduces the risk of a pathogen being moved from one location to another (G. Russell Danner, IF&W fish pathologist, personal communication 2004). Disinfection and biosecurity protocols, where not already in place, should be developed and implemented for all research and sampling activities taking place in rivers within the DPS.

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

4.3.1F Implement biosecurity and disinfection protocol for all research and assessment activities being conducted in rivers within the DPS

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, including the role of other fish species (both domesticated and wild) and sea lice as potential reservoirs and vectors of ISAV. 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 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 1-61). The expansion of marine 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 sea lice and 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 1-84). 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 1-83).[73] 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) (United States Food and Drug Administration (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)[74]. 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. Since sea lice have been implicated in the transmission of ISAV, control of lice is important to the industry and recovery efforts.

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 4-61).

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

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73 As noted (see page 1-83), Penobscot Bay is not in the proximity of aquaculture marine net pens. Post-smolt trawling has not been conducted in Cobscook Bay where the aquaculture industry is currently concentrated. 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).

74 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 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 1-85). 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 1-78). Juvenile salmon of aquaculture hatchery origin have been documented in DPS rivers in Maine (see page 1-81).

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

The DEP is currently in the process of renewing the discharge permits for all freshwater hatcheries in Maine, including those used by the aquaculture industry. In October 2004, DEP issued a new permit to the Gardner Lake hatchery, requiring a fully functional CMS plan with escape reporting requirements. Furthermore, because it directly discharges to a DPS river (Chase Mills Stream, a tributary of the East Machias River) this hatchery is prohibited from possessing any non-North American salmon.

All salmon aquaculture hatcheries 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 are required to have annual audits 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 hatcheries 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. The Containment Management System plans developed for each facility should include emergency response procedures designed to minimize escapes from the facility in the event the final containment barrier is compromised.

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 1-18). 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. A broodstock program was not developed for the Ducktrap River and Cove Brook. 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 (Ne) 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 NRC (2004) concluded that there has not been an adequate assessment of whether returning stocked salmon contribute offspring to the next generation. 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 NRC (2004) concluded that there is an urgent need to understand the relative efficiency of the stocking of different life-stages of salmon in terms of adult returns and their reproductive success.

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, at the time, 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 streamside incubation facilities is another stocking strategy that may enhance survival as well as add insurance against catastrophic losses due to hatchery accidents. Streamside hatchery projects offer a unique opportunity to involve the local public in the stocking program. Streamside incubation facilities would utilize river-specific water sources allowing for the evaluation of this factor. The potential use of streamside 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 geographic 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. The PVA (see page 3-12) 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

The eight DPS rivers known to still support wild populations of Atlantic salmon provide a relatively small potential carrying capacity when compared to the Penobscot and Kennebec rivers[75]. Table 2 provides estimates of habitat units[76] present in river within the geographic range of the DPS. (see Table 2). In addition to the eight DPS rivers known to still support wild

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75 The total combined conservation spawning escapement (CSE) targets for these eight populations is 1482 fish.

76 One habitat unit = 100 m^2.

salmon populations, there are a number of 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 support additional unoccupied juvenile production habitat

The estimated amount of habitat for the eight rivers within the range of the DPS known too still support wild salmon populations is 22,425 habitat units. The estimated amount of habitat found in small coastal rivers within the geographic range of the DPS from which wild salmon populations are believed to have been extirpated is approximately 24,688 habitat units[77].

One potential mechanism to facilitate reintroduction 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 Aan 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).

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.

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77 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).

Table 2: Atlantic salmon habitat within the range of the Gulf of Maine DPS and other Maine Rivers[78]	
Drainage	Total Habitat Units
Pennamaquan River	52
Dennys River	2,152
Grand Manan Channel Coastal[79]	3,674
East Machias River	3,006
Machias River	6,156
Chandler River	167
Roque Bluffs Coastal[80]	1,641
Pleasant River	1,220
Narraguagus River	6,014
Tunk Stream	625
Mt Desert Coastal	1805
Union River	2594
Kennduskeag	559
Cove Brook	235
Marsh Stream	3,490
Passagassawaukeag River	331
Ducktrap River	845
Western Penobscot Bay Coastal	1,613
Sheepscot River	2,797
Central Maine Coastal (CMC)[81]	7,412
Cobbosseecontee Stream	170
Togus Stream	380
Bond Brook	175
Penobscot River	114,453
Kennebec River	77,209
Androscoggin River	46,472

78 Estimates of habitat abundance are derived from stream survey data and a watershed area to habitat regression methodology developed by the NEFSC.
79 Grand Manan Channel Coastal includes Orange River and Hobart and Boyden streams
80 Roques Bluff Coastal includes Indian River
81 CMC Rivers: St. Georges, Medomak and Pemaquid rivers

Essential experimental populations are treated as threatened species and subject to protection under both 7(a)(1) and 7(a)(2) of the ESA. 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. Because 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).

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. The Craig Brook NFH produces fry in excess of current stocking density demands for the DPS rivers. 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 of the DPS. As part of this evaluation, the Services should consider criteria to identify candidate rivers for establishing re-introduced populations. In 2002, at the direction of the Signatories (ASC, NMFS, FWS), the TAC evaluated appropriate use and potential expansion beyond the rivers of origin for the Signatories. This document provides a rigorous examination of the technical merits of utilizing existing hatchery products that exceed current stocking density targets. This evaluation identified and prioritized potential rivers that could be candidates for utilization of these bonus fish.

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 other broodstocks and from 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 and ISAV 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, Reverse Transcription Polymerase Chain Reaction (RT-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 ISAV 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. In addition, the Lamar Fish Health Center (LFHC) is using RT-PCR for detection of ISAV and has begun using the Atlantic salmon kidney (ASK) cell line for ISAV assay, along with the OIE approved SHK-1 cell line. The ASK cells respond well and show effects of infection sooner than the SHK-1 cells.

The laboratory has participated in quality assurance and quality control exercises to evaluate detection methodologies for ISAV with NMFS, the University of Maine, USDA-APHIS, DFO-Canada 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 parameters 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 developed a PCR assay and 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 influence egg quality and early life stage survival. The threat from CWD is potentially serious if the bacteria are 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 management of 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 detrimental 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 and trait 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. In 2002, in collaboration with the University of Maine, FWS began trait monitoring of captive river-specific broodstock. This combination of genetic screening and trait monitoring offers unprecedented abilities to evaluate many components of broodstock management and population health.

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.

In addition to monitoring of neutral genetic variation, monitoring of heritable trait variation is important because trait variation relates more directly to features that influence the performance of fish in the wild. Long-term monitoring of trait variation is needed to effectively evaluate deleterious or positive trends in trait means and diversity.

6.2 Ensure that management plans consider and avoid negative genetic effects of management actions and promote preservation of adaptive variation

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 adaptive 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) unintentional 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 important trait variation and parentage of smolts and returning adults

Genetic monitoring of salmon from the DPS rivers is needed to ensure that adaptive 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.

As noted (see page 1-57), concerns exist about potential mortality associated with research and monitoring activities. The Services will continue assess the benefits and risks of research and avoid and minimize any potential adverse effects of research and monitoring activities through stringent sampling and handling protocols. The Services will consider the impacts, both direct and cumulative, of ongoing and proposed research permitted under Section 10(a)(1)(A) permits and will seek to avoid and minimize any potential adverse effect. The Services will ensure that all research and monitoring conducted in habitat containing DPS fish is done so in accordance with the requirements of the ESA. The Services will continue to work to develop and implement non-invasive means of conducting research and data collection necessary to monitor and assess the status and trends of the DPS.

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). 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 may 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[82]. 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 currently 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. 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. The need for weirs on the East Machias and Machias rivers should be evaluated (see page 4-58).

82 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).

Using weirs to assess adult returns has risks (blocking passage, delaying migration, possible adult mortality). Before weirs are installed in additional rivers, risks should be fully assessed in comparison to the risk of aquaculture escapes to the river system. Weirs and fishways should be constantly monitored to ensure that impacts on the population are minimized while collecting biological data.

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 NMFS 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 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 NMFS 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, NMFS 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, NMFS 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, NMFS 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[83]. This research has the potential to provide important information concerning sources of lethal and sub-lethal mortality. In addition,

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83 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.

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

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 is 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. Ensuring inter-organizational coordination and communication mechanisms are in place will increase the effectiveness and efficiency of these groups. 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 (See Demont 2005).

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 entities involved in research and management of Atlantic salmon in Maine. The Services should continue to work closely with the ASC and the Maine TAC 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 Atlantic salmon 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, NMFS and FWS. The Recovery Team will work in concert with other technical and management groups involved in the recovery effort, including the Maine TAC. The coordinating committee and Recovery Team proper will convene periodic meetings to aid in coordination of recovery efforts and implementation of recovery actions. The coordinating committee and Recovery 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 NMFS, 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 an annual 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.

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[84]. 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 site specific management actions planned 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	Actions that must be taken to prevent extinction or to prevent the species from declining irreversibly
2	Actions that must be taken to prevent a significant decline in population/habitat quality or other significant negative impact short of extinction
3	All other actions necessary to provide for full recovery of the species

Total Estimated Cost of Recovery: The total cost of recovery is undeterminable at this time. It is impossible to estimate the cost of recovery for the DPS. The species continues to decline and its status is precarious. Even when we achieve a complete reversal of downward trends and population growth, it is not possible to estimate the cost of recovery of the DPS.

Despite ongoing efforts to arrest and reverse the decline of the DPS adult salmon returns to DPS rivers remain at historic lows (an estimated 60 to 113 adult returns in 2004).

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. The initial goal of recovery efforts is to 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.

Research is ongoing to help identify the causes for the species continued decline and identify appropriate measures to mitigate threats and recover the DPS. Pending the results of the recommended research it is not yet possible to identify recovery actions and strategies to mitigate the threats. Specific research needs, including estimated times and costs, are identified in Part 4 of this plan and prioritized in the implementation schedule. In the face of this continued uncertainty of the overall causes of the species decline it is

84 Consistent with NMFS Recovery Planning Guidance the implementation schedule provides cost estimates for three years.

not possible to identify all recovery actions that may be necessary to recover the DPS and therefore be able to estimate costs for full recovery of the DPS.

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. In the absence of final measurable and objective criteria it is not possible at this time to provide a full estimate of the cost of achieving the conditions that will constitute a secure and recovered DPS.

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 $36.6 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 when we achieve a complete reversal of downward trends and population growth, it is not possible to estimate the date of recovery of the DPS.

Key to Responsible Agencies (column 5)

ACOE	Army Corps of Engineers (U.S.)
ASC	Atlantic Salmon Commission (Maine)
ASF	Atlantic Salmon Federation
ASMFC	Atlantic States Marine Fisheries Commission
BPC	Board of Pesticide Control (Maine)
BPL	Bureau of Parks and Lands (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
MDOT	Maine Department of Transportation
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)
NEFHC	New England Fish Health Committee
NEFMC	New England Fishery Management Council
NFWF	National Fish and Wildlife Foundation
NGO	Non-governmental organizations (e.g., ASF, DSF Watershed Councils, TU, Local Land Trusts, Project SHARE)
NOAA	National Oceanographic and Atmospheric Administration
NRCS	Natural Resource Conservation Service
TAC	Technical Advisory Committee
UM	University of Maine
USDA	U.S. Department of Agriculture (APHIS)
U.S. EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WCSWD	Washington County Soil and Water Conservation District
WGNAS	Working Group on North Atlantic Salmon

IMPLEMENTATION SCHEDULE
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Priority	Task	Task Description	Duration	Lead Agency: Federal	Lead Agency: State & Other	Estimated Cost: Year 1	Estimated Cost: 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	92K	92K	92K	annual implementation for duration of recovery
1	1.1.2D	Monitor and assess the potential for groundwater withdrawals to impact stream flow and cold water discharges	Long-term	FWS USGS	DAFRR MGS DEP LURC Industry	100K	100K	100K	Action initiated, outyear costs for monitoring TBD
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	DAFRR MGS, DEP, LURC Industry	100K	100k	100K	
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 DAFRR Industry	45K	45K	45K	
1	1.1.4B	Issue and enforce all appropriate permits for water withdrawals	Long-term	ACOE FWS	DEP, LURC DAFRR Industry	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, NMFS 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	NMFS FWS USGS	ASC, DEP, NGOs	250K	120K	120K	based on results of pilot study evaulate additional funding needs in out years
1	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 NMFS	DEP		25K	25K	outyear costs TBD, funding needs may include modeling needs
1	1.2.2F	Evaluate the biological effects of low pH and aluminum and its toxicity on Atlantic salmon	3 years	USGS EPA FWS NMFS	DEP UM	75K	75K	75K	
1	1.2.2J	Evaluate the link between pesticides and endocrine disruption	3 years	USGS EPA FWS NMFS	DEP, UM, BPC	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 NMFS 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	100K	100K	100K	Outyear costs TBD
1	1.2.4B	Evaluate the impacts of sedimentation on habitat quantity and quality including relationship between substrate embeddedness and habitat productivity in DPS rivers.		NMFS, FWS, USGS	ASC NGOs				Costs TBD
1	1.4.1C	Identify riparian zone activities (e.g., harvest practices, ATVs, development etc.) and evaluate impacts on Atlantic salmon	Long-term		MFS Industry ASC NGOs			25K	Outyear costs TBD
1	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
1	1.5.3	Conduct high priority restoration projects	Long-term	NRCS	ASC MFS MDOT NGOs			300K	outyear costs TBD, based on the outcome of 1.5.2A & 1.5.2B
1	1.5.5	Evaluate the ecological role and importance of restoring other diadromous fish populations							Costs TBD

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				Lead Agency		Estimated Cost			
Priority	**Task**	**Task Description**	**Duration**	**Federal**	**State & Other**	**Year 1**	**Year 2**	**Year 3**	**Comments**
1	2.1.1	Maintain and enforce the closure of the directed sport fishery for Atlantic salmon	Long-term	NMFS 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	NMFS NEFMC					Periodic amendment of FMP as needed. Costs to be determined (TBD)
1	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	NMFS	ASC	30K	30K	30K	outyear costs 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				Monitoring and Enforcement costs TBD
1	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
1	3.1.2C	Evaluate the potential of conserving and restoring runs of anadromous forage species to provide a buffer against predation on salmon and other ecological benefits	Long-term	FWS NMFS	ASC IFW DMR			100K	outyear costs TBD
1	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	NMFS FWS	ASC IFW	5K	5K	5K	review annually for duration of recovery period
1	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	NMFS FWS	ASC IFW	20K	20K	20K	Action should be conducted in conjunction with 3.2.1D
1	3.2.1E	Develop a Section 10(a)(1)(B) habitat conservation plan for existing stocking programs and, if warranted and implement	1 year	FWS	ASC IFW			50K	2 years development; implementation costs TBD
1	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	Outyear costs TBD
1	4.1B	Develop fully functional containment management systems for the containment of farmed salmon at marine sites.	Long-term	ACOE NMFS 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 NMFS FWS	DMR Industry				Action initiated, Plans developed for all exisitng sites, Implementation cost estimates not avilable
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 NMFS FWS ACOE	Industry DMR NASCO	200K			MASCP estimates 200K to plan; implementation costs TBD
1	4.3.2A	Determine the modes of transmission of the ISA virus	3 years	USDA NMFS 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	NMFS USDA	DMR Industry	120K	120K		Need for additional research to be asessed for out years
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 NMFS FWS	Industry DEP DMR				1 year development; ongoing implementation
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	

Priority	Task	Task Description	Duration	Lead Agency: Federal	Lead Agency: State & Other	Estimated Cost: Year 1	Estimated Cost: Year 2	Estimated Cost: Year 3	Comments
1	5.1.1B	Continue stocking cultured fish to supplement wild salmon populations	Long-term	FWS	ASC, TAC	60K	63K	66K	
1	5.1.2	Monitor and evaluate the current stocking program	Long-term	NMFS 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	NMFS FWS	ASC, TAC, Industry	50K	50K	50K	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	NMFS FWS	ASC, TAC				See task 5.1.4B
1	5.1.4B	Establish experimental populations to assist in the recovery of the GOM DPS of Atlantic salmon		NMFS FWS	ASC, TAC		120K	120K	
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	NMFS FWS, USGS	ASC	50K	50K	50K	Need for additional research to be asessed for out years
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 NMFS	ASC				Costs TBD
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 NMFS	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		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	NMFS	ASC	100K	100K	100K	Out year costs TBD
1	7.1.3	Conduct quantitative assessments of Atlantic salmon smolt production	Long-term	NMFS	ASC	250K	250K	250K	Annual assessment and monitoring
1	7.1.4A	Continue telemetry studies of smolt migration from the Dennys and Narraguagus rivers	3 years	NMFS	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	NMFS		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	NMFS FWS	ASC	150K	150K	150K	Out year costs to be determined ES etc.
1	8.2	Maintain, and if necessary increase, coordination/communications between government and local agencies on issues pertaining to Atlantic salmon recovery	Long-term	NMFS FWS	ASC				Costs TBD

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				Lead Agency		Estimated Cost			
Priority	**Task**	**Task Description**	**Duration**	**Federal**	**State & Other**	**Year 1**	**Year 2**	**Year 3**	**Comments**
2	1.1.1A	Conduct IFIM studies on additional DPS rivers to determine flow requirements of juveniles	3 years	USGS, FWS, NMFS	ASC		75K	75K	outyear costs TBD
2	1.1.1B	Determine flow requirements of adult Atlantic salmon in DPS rivers	5 years	USGS, FWS, NMFS	ASC				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	1.1.3A	Implement the Downeast Salmon Rivers Water Use Management Plan (WUMP) for the Pleasant and Narraguagus rivers and Mopang Stream	5 years	USGS FWS NRCS	DAFRR, Industry ASC, DEP, LURC	1M	1M	1M	Action ongoing, total estimated cost of implementing the WUMP is 5M
2	1.1.3D	Develop water use management plans for other DPS rivers	3 years	FWS	DAFRR, Industry 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	DAFRR DEP LURC Industry		20K		outyear costs TBD
2	1.1.5B	Review current water management for the dams and develop an assessment of the effect of regulation on a watershed's hydrology and thus Atlantic salmon habitat							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 NMFS	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				Costs TBD
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	1.2.2H	Evaluate the chronic and acute effects of agricultural chemicals on Atlantic salmon and how they may impact salmon recovery efforts	3 years	FWS NMFS	BPC, DEP, ASC	75K	75K	75K	
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	1.2.2L	Continue State program to replace OBDs	3 years		DEP				currently ongoing, cost estimates povided by State states "several projects on DPS rivers could easily be in the several million dollars."
2	1.2.3B	Implement a comprehensive and integrated long-term water quality monitoring program on all DPS rivers							Costs TBD
2	1.2.4A	Prepare and implement NPS pollution reduction plans for DPS rivers	3 years	FWS NMFS EPA	ASC DEP MFS SWCD NGOs	100K	100K	100K	Action initiated, Outyears costs TBD

IMPLEMENTATION SCHEDULE
ATLANTIC SALMON RECOVERY PLAN

Priority	Task	Task Description	Duration	Lead Agency: Federal	Lead Agency: State & Other	Estimated Cost: Year 1	Estimated Cost: Year 2	Estimated Cost: Year 3	Comments
2	1.2.4C	Prepare and implement Point Source pollution reduction plans for DPS rivers	2 year	EPA	DEP		32K	Y3 Costs TBD	currently ongoing, cost estimates povided by State states "several projects on DPS rivers could easily be in the several million dollars."
2	1.2.4E	Continue monitoring of the remediation efforts at the Eastern Surplus Superfund site in Meddybemps	periodic	EPA	DEP		15K	15K	outyear costs TBD
2	1.2.4F	Address any ground water problems at the Smith junkyard on the Dennys River and restore the site	Duration TBD	EPA	DEP				costs TBD
2	1.3.1A	Repair or remove the Coopers Mill Dam to improve fish passage around the dam	1 year	FWS	ASC IFW DMR Local Gov			65K	
2	1.3.2	Identify and improve culverts or other road crossings that impede salmon passage	Long-term	FWS NRCS NMFS	ASC MFS MDOT NGOs Industry		75K	75K	Action ongoing
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
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	1.4.1B	Promote the adoption and use of BMPs by landowners and compliance with these voluntary standards	Long-term		MFS landowners NGOs		25K	25K	Action ongoing
2	1.4.1D	Evaluate current state and local land use regulations to determine adequacy of existing measures protecting riparian habitat and instream improve if appropriate	2 year	NRCS FWS	ASC LURC MSPO MFS DAFRR		25K	25K	
2	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
2	1.4.2A	Evaluate the potential for activities in estuaries to adversely affect Atlantic salmon	Long-term	NMFS 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	NMFS 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		60K	60K	Based on initial evaluation additional funding needs TBD
2	2.1.3B	Continue US participation in the international sampling program at West Greenland	Long-term	NMFS		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	NMFS USDOS Intnl. Partners		70K			Y1 NMFS 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	2.2.1D	Continue to monitor commercial freshwater fisheries where the potential for incidental take of Atlantic salmon exists	Long-term		DMR ASC IFW				Costs TBD
2	2.2.2A	Assess the potential risk for incidental take of Atlantic salmon in marine and estuarine fisheries	3 years	NMFS	DMR ASC	45K	45K	45K	Action precursor to action 2.2.2B

IMPLEMENTATION SCHEDULE
ATLANTIC SALMON RECOVERY PLAN

				Lead Agency		Estimated Cost			
Priority	**Task**	**Task Description**	**Duration**	**Federal**	**State & Other**	**Year 1**	**Year 2**	**Year 3**	**Comments**
2	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	NMFS	DMR, ASC				Costs TBD, action contigent on completion of action 2.2.2A
2	2.2.2C	Increase observer coverage in the midwater trawl herring fishery to improve the ability to assess the potential for Atlantic salmon bycatch in the herring fishery.		NMFS NEFMC	DMR				Costs TBD
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 NMFS	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 NMFS	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 NMFS	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 NMFS	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 NMFS	ASC				Action should be conducted in association with 3.1.1A & 3.1.3B
2	3.1.3B	Document and monitor the presence and abundance of seals at natural and man-made concentration sites	3 years	NMFS FWS	ASC UM		25K	25K	Action should be conducted in association with 3.1.1A & 3.1.3A
2	3.1.3C	Conduct research to determine the role of net pen sites in seal aggregation and salmon predation	3 years	NMFS FWS	ASC UM		25K	25K	outyear costs TBD
2	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	NMFS	ASC UM			35K	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	NMFS 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	NMFS FWS	ASC, UM				costs TBD
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	NMFS FWS	IFW ASC	30K	30K	30K	Action should be conducted in conjunction with 3.2.1B
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 NMFS FWS	DMR ASC		30K	30K	coordination/consultation at estimated cost 30k/year for duration of recovery

IMPLEMENTATION SCHEDULE
ATLANTIC SALMON RECOVERY PLAN

Priority	Task	Task Description	Duration	Lead Agency: Federal	Lead Agency: State & Other	Estimated Cost: Year 1	Year 2	Year 3	Comments
2	4.1D	Develop and maintain an inventory tracking system for all marine aquaculture facilities	Long-term	NMFS 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	NMFS	Industry, UM, DMR		15K	15K	
2	4.2.1	Develop and implement contingency measures in case of accidental release of farmed fish	Long-term	NMFS ACOE FWS	ASC Industry	10K	2K	2K	Outyear costs TBD
2	4.2.2A	Maintain existing weirs on DPS rivers to minimize aquaculture escapees spawning, enable data collection and collect broodstock	Long-term	NMFS FWS	ASC Industry	132K	264K	264K	operation/maintenance costs 66K/weir/year
2	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	NMFS FWS	ASC Industry	831K			565K for site/construction Machias weir; 266K for site/construction E.Machias weir
2	4.2.3	Mark all farmed salmon prior to placement into marine net-pens	Long-term		Industry	100K	100K	100K	outyear costs TBD
2	4.2.4	Discontinue the culture of non-North American salmon	5 years	ACOE NMFS FWS	Industry				Action should be implemented immediately
2	4.2.5	Prohibit the placement into marine net-pens of reproductively viable transgenic salmon		ACOE NMFS FWS	DMR Industry				effective immediately
2	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 NMFS FWS ACOE	DMR Industry NGOs ASC	50K	50K	50K	costs for development; implementation costs TBD
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	NMFS FWS	ASC DMR				costs TBD
2	4.3.1E	Expand the FWS Wild Fish Health Survey to include DPS rivers	Long-term	FWS	ASC	20K	20K	20K	outyear costs TBD
2	4.3.1F	Implement biosecurity and disinfection protocol for all research and assessment activities being conducted in rivers within the DPS		NMFS FWS EPA USGS	ASC DMR IFW				Costs TBD
2	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	NMFS	Industry DMR	120K	120K	120K	Action initiated
2	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
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	NMFS 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
2	4.3.3C	Continue treatment for sea lice at aquaculture facilities	Long-term	USDA	Industry DMR UM				Action ongoing
2	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

Priority	Task	Task Description	Duration	Lead Agency: Federal	Lead Agency: State & Other	Estimated Cost: Year 1	Estimated Cost: Year 2	Estimated Cost: 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 NMFS FWS	Industry DEP DMR		30K	30K	1 year development; ongoing implementation
2	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.
2	5.1.3B	Continue to assess and evaluate the results of the adult stocking program	2 years	NMFS	ASC, TAC				
2	5.1.3C	Evaluate the role of streamside incubation facilities to supplement wild salmon populations	5 years	NMFS FWS	ASC, TAC	40K	40K	40K	Outyear costs TBD
2	5.2.3B	Conduct research on other pathogens to identify potential threats to the DPS		NMFS FWS	ASC		15K		See Recovery Action 5.2.3C
2	5.2.3C	Initiate screening and long-term monitoring of resident fish species in DPS rivers for endemic and exotic salmonid pathogens	Long-term	NMFS FWS	ASC	20K	20K	20K	See task 5.2.3B
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, NMFS, USGS	ASC UM		15K	30K	Outyear costs TBD
2	7.1.1D	Continue development of DPS-level estimates of spawning escapement	Long-term	NMFS	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	NMFS	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	NMFS	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	NMFS	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	NMFS	ASC		283K	283K	
2	7.1.6	Develop and apply population viability analysis model	1 year	NMFS FWS	ASC	25K			Action initaiated, model being developed by NEFSC
2	8.1A	Develop and implement a comprehensive Education and Outreach Plan for the Gulf of Maine DPS of Atlantic salmon	Long-term	NMFS FWS	ASC		75K	75K	2 years development; implementation costs TBD
2	8.1B	Continue efforts to educate anglers on the difference between trout and juvenile salmon	Long-term	NMFS FWS	ASC IFW DMR		15K	15K	Action ongoing, long-term efforts required
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	NMFS 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

IMPLEMENTATION SCHEDULE
ATLANTIC SALMON RECOVERY PLAN

Priority	Task	Task Description	Duration	Lead Agency: Federal	Lead Agency: State & Other	Estimated Cost: Year 1	Year 2	Year 3	Comments
3	1.1.5A	Review current water management for the dams and develop an assessment of the effect of regulation on a watershed's hydrology and thus Atlantic salmon habitat.							Costs TBD
3	1.2.1	Review existing water quality standards for each river within the DPS to determine adequacy to meet the needs of Atlantic salmon	1 year	FWS	ASC DEP			3K	3K every 3-5 years to review standards.
3	1.2.3C	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	Long-term	FWS USGS	DEP NGOs Industry			10K	outyear costs TBD
3	1.2.4D	Fully implement EPA aquaculture wastewater and effluent discharge regulations	Duration TBD	EPA FWS	DEP				Costs TBD
3	1.3.1B	Evaluate the need to repair the existing fishway at Saco Falls	1 year		ASC			50K	Has been Repaired
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	1.5.2A	Identify, catalogue and prioritize habitat restoration needs in DPS rivers	2 years	FWS NMFS	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 NMFS	ASC NGOs			32K	
3	3.1.1D	Assess the potential of land and water use practices to exacerbate predation rates	2 years	FWS NMFS	ASC			25K	outyear costs TBD
3	4.2.6	Continue research into developing strains of aquaculture fish that cannot interbreed with wild Atlantic salmon	Duration TBD		Industry UM			75K	
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 NMFS	Cornell U. ASC			25K	Completed?
3	8.1C	Develop updated educational programs for schools	Long-term	NMFS FWS	ASC			10K	Materials/programs should be periodically reviewed and updated as appropriate throughout the recovery period
3	8.1D	Evaluate the role of public display of salmon as an outreach tool	1 year	NMFS FWS					
3	9.1	Appoint a Recovery Implementation Team to coordinate implementation of recovery plan objectives		NMFS 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	NMFS 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	NMFS FWS	ASC		5K	5K	Long-term action
3	9.3	Complete necessary addenda, updates and revisions to the Recovery Plan	Long-term	NMFS FWS	ASC				Costs TBD, recovery plan should be revised and updated as necessary throughout the recovery process

LITERATURE CITED

Abbott, Alex. 2004. Maine Atlantic Salmon Habitat Downeast Oral History Atlas. Prepared for Project SHARE and Maine Atlantic Salmon Commission. Bangor, ME.

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.

Allin, L.C. and R.W. Judd. 1995. Creating Maine's resource economy. Pages 262-288 in Judd, R.W., E.A. Churchill and J.W. Eastman editors. Maine: The Pine Tree State from Prehistory to Present. Orono ME: University of Maine Press.

Ambrose, H.E., M.A. Wilzbach, and K.W. Cummins. 2004. Periphyton response to increased light and salmon carcass introduction in northern California streams. Journal of the North American Benthological Society 23(4): 701-712.

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.

Aquatic Nuisance Species (ANS) Task Force. 1994. Intentional introductions policy review, findings, conclusions, and recommendations of the intentional introductions policy review, report to Congress, March 1994.

Arter, B.S. 2004. Sheepscot River Water Quality Strategic Plan: A Guide for Coordinated Water Quality Monitoring Efforts on an Atlantic Salmon Watershed in Maine. Eastport ME: Project SHARE.

ASA (Atlantic Salmon Authority). 1998. 1997 Endangered species project report B annual report number 4. ASA, Bangor, Maine.

ASC. 2004. Atlantic salmon freshwater Assessments and Research: Semi-annual project report. NOAA Grant NA17FL1157. Bangor ME: Maine Atlantic Salmon Commission.

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.

Atkinson, E.J., G. Mackey, and J. Trial. 2004. Substrate embeddedness and juvenile Atlantic salmon (*Salmo salar*) habitat in the Narraguagus River. Unpublished report.

Atkinson, E. J. and Mackey, G. 2005. Survey of Substrate Embeddedness. Maine Atlantic Salmon Commission: Atlantic Salmon Freshwater Assessments and Research Semi-Annual Project Report. Prepared for NOAA-Fisheries. Gloucester, MA.

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.

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., F. L. Roberts, and R. L. Saunders. 1981. Evidence of *Salmo salar* X Salmo trutta Hybridization in a North American River. Canadian Journal of Fisheries and Aquatic Sciences. 38: 552-554.

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. Van deSande and T. F. Sheehan. 2001. Striped bass predation upon Atlantic salmon smolts in Maine. Northeastern Naturalist. 8(3): 267-274.

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.

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.

Berntssen M.H.G., A. Aatland and R.D. Handy. 2003. Chronic dietary mercury exposure causes oxidative stress, brain lesions, and altered behavior in Atlantic salmon (*Salmo salar*) parr. Aquatic Tox. 65:55-72.

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.

Bilby, R.E., B.R. Fransen, and P.A. Bisson. 1996. Incorporation of nitrogen and carbon from spawning coho salmon into the trophic system of small streams: evidence from stable isotopes. Canadian Journal of Fisheries and Aquatic Sciences 53: 164-173.

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.

Bowen, W. D., J. McMillan and R. Mohn. 2003. Sustained exponential population growth of grey seals at Sable Island, Nova Scotia. I C E S Journal of Marine Science 60:1265-1274.

Boyer, K.L., D.R. Berg and S.V. Gregory. 2003. Riparian management for wood in rivers. Pages 407-420 in D. R. Montgomery, S. Bolton, D. B. Booth and L. Wall editors. Restoration of Puget Sound Rivers. University of Washington Press, Seattle, WA.

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.

Brocksen, R. W., M. D Marcus and H. Olem. 1992. Practical guide to managing acidic surface waters and their fisheries. Lewis Publishers, Inc. Chelsea, Michigan, USA.

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.

Burton, T. A. and G. W. Harvey. 1990. Estimating inter gravel salmonids living space using the cobble embeddedness sampling procedure. Idaho Water Quality Bureau, Water Quality Monitoring Protocols – Report No. 2.

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.

Carvalho P.S.M. and D.E. Tillitt. 2004. 2,3,7,8-TCDD effects on visual structure and function in swim-up rainbow trout. Environ. Sci. Tech. 38:6300-6306.

Carvalho P.S.M., D.B. Noltie and D.E. Tillitt. 2004. Intra-strain dioxin sensitivity and morphometric effects in swim-up rainbow trout (*Oncorhynchus mykiss*). Comp. Biochem. Physio. 137:133-142.

Cederholm, C.J., M.D. Kunze, T. Murota, and A. Sabatini. 1999. Pacific salmon carcasses: essential contributions of nutrients and energy for aquatic and terrestrial ecosystems. Fisheries 24(10): 6-15.

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.

Chizmas, J. 2001. 2000 drift study of the Pleasant and Narraguagus rivers (Draft). Maine Board of Pesticides Control, February 2001.

Chizmas J.S. 2002. 2001 drift study of the Pleasant and Narraguagus Rivers. Maine Board of Pesticide Control. Augusta, Maine

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.

Collette, B. B. and G. Klein-MacPhee. 2002. Fishes of the Gulf of Maine, Third Edition. Smithsonian Institution Press. Washington. D.C.

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.

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.

Cunjak, R. A. 1988. Behaviour and microhabitat of young Atlantic salmon (*Salmo salar*) during winter. Can. J. Fish. Aquat. Sci. 45: 2156-2160.

Cunjak, R.A., Prowse, T.D., and D.L. Parrish. 1998. Atlantic salmon in winter: ‘the season of parr discontent’ Canadian Journal of Fisheries and Aquatic Sciences 55: 161-180.

Cunjak, R.A. and J. Therrien.1998. Inter-stage survival of wild Atlantic salmon, *Salmo salar* L. Fish. Manag. Ecol. 5(3):209-223.

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.

Demont and Associates. 2005. Capacity-Building Project for the Eight Rivers Roundtable. Capacity-Building Project Conducted and Published by Demont & Associates, Inc. for the Eight Rivers Roundtable, in conjunction with the Atlantic Salmon Federation Brunswick, Maine. 196. pp.

Department of Fisheries and Oceans (DFO). 1998. Atlantic salmon abundance overview for 1997. Stock Status Report D0-02. DFO.

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.

Donald, A. P. and A. S.Gee. 1992. Acid waters in upland Wales - causes, effects and remedies. Environmental Pollution 78: 141-148.

Driscoll, C T., G. B., Lawrence, A.J. Bulger, J. Thomas, C. Cronan, C. Eagar, K.F. Lambert, G.E. Likens, J.L. Stoddard, K.C. Weathers. 2001. Acidic Deposition in the Northeastern United States: Sources and Inputs, Ecosystem Effects, and Management Strategies. BioScience. 51(3): 180-198

DRWC. 2005. Dennys River Watershed Nonpoint Source Pollution, Management Plan. Dennys River Water Shed Council 113 pp.

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. 2004. Estimating monthly, annual and low 7-day, 10-year streamflows for ungaged rivers in Maine, SIR2004-5026, 22 p.

Dudley, R.W., and J.P. Nielsen 2000. Streamflow statistics for the Narraguagus River at Cherryfield, Maine, OFR 00-95, 18 p.

Dudley, R.W., and G.A. Hodgkins. 2002. Trends in streamflow, river ice, and snowpack for coastal river basins in Maine during the 20th Century. WRIR02-4245, 26 p.

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. 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.

Fleming, I.A., K. Hindar, I.B. Mjølnerød, 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.

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. 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.

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., 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.

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.

Garman, G.C. and S.A. Macko. 1998. Contribution of marine-derived organic matter to an Atlantic coast, freshwater, tidal stream by anadromous clupeid fishes. Journal of the North American Benthological Society: 17: 277-285.

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, 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. 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. 1993. The Atlantic salmon in freshwater: spawning, rearing, and production. Reviews in Freshwater Biology and Fisheries. 3 39-73.

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.

Giesy J.P., P.D. Jones, K. Kannan, J.L. Newsted, D.E. Tillitt and L.L. Williams. 2002. Effects of chronic dietary exposure to environmentally relevant concentrations of 2,3,7,8-tetrachlorodibenzo-p-dioxin on survival, growth, reproduction and biochemical responses of female rainbow trout (*Oncorhynchus mykiss*). Aquat. Tox. 59:35-53.

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 Fisheries 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).

Gresh, T., J. Lichatowich, and P. Schoonmaker. 2000. An estimation of historic and current levels of salmon productivity in the northeast Pacific ecosystem: evidence of a nutrient deficit in the freshwater systems of the Pacific Northwest. Fisheries 25(1): 15-21.

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.

Grow, Mary M. 1975. China, Maine: Bicentennial History. Weeks Mills ME: Marion T. Van Strien.

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.

Gustafson-Marjanen, K.A. 1982. Atlantic salmon (Salmo salar L.) fry emergence: success, timing, distribution. M.S. Thesis. University of Maine at Urono. 72 pp.

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.

Haines T.A. and R. Van Beneden. 2003. Endocrine disruption in Atlantic salmon exposed to pesticides - Annual progress report 2001 - 2002. USGS/BRD and University of Maine. Orono, Maine. 21 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).

Halsted, M. 2002. The Sheepscot River, Atlantic Salmon and Dams: A Historical Reflection. Alna ME: Sheepscot Valley Conservation Association.

Halsted, M. 2004. Proceedings of the Sheepscot River Symposium. Augusta ME: Kennebec County Soil and Water Conservation District.

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.

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.

Hansen, L. P., N. Jonsson, B. Jonsson. 1993. Oceanic migration in homing Atlantic salmon. Anim. Behav. 45, 927–941.Freshwater Biol. 24: 63-67.

Hansen, L.P., and Quinn, T.P. 1998. The marine phase of Atlantic salmon (Salmo salar) life cycle, with comparisons to Pacific salmon. Can. J. Fish. Aquat. Sci. 55(Suppl. 1): 104–118.

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. 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.

Havey, K. A., and J. S. Fletcher. 1956. The Pleasant River: fish management and restoration. Maine Department of Inland Fisheries and Game, Augusta, Maine.

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.

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.

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.

Henrikson, L. and Y. W. Brodin. 1995. Liming of acidified surface waters: a Swedish synthesis. Springer. Berlin; New York.

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.

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.

Hesthagen, T. and B. M. Larsen. 2003. Recovery and re-establishment of Atlantic salmon, *Salmo salar,* in limed Norwegian rivers. Fisheries Management and Ecology 10: 87-95.

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.

Hindar, A., B. L. Skjelkvale and N.R. Scelthum. 2001. Recommended Liming Strategies for Salmon Rivers in Nova Scotia, Canada. Norway, Norwegian Institute for Water Research.

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. 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.

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.

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.

ICES. 2002 Report of the North Atlantic Salmon Working Group. Copenhagen, Denmark, 3-13 April 2002. ICES, Doc. CM 2002/ACFM:14. 305 pp.

ICES. 2003 Report of the North Atlantic Salmon Working Group. Copenhagen, Denmark, 31 March - 10 April 2003. ICES, Doc. CM 2003/ACFM:19. 310 pp.

ICES. 2004 Report of the North Atlantic Salmon Working Group. Halifax, Canada, 29 March - 8 April 2004. ICES, Doc. CM 2004/ACFM:20. 292 pp.

ICES. (2005 Report of the North Atlantic Salmon Working Group. Nuuk, Greenland, 5-15 April 2005. ICES, Doc. CM 2005/ACFM:17. 297 pp.

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.

IPCC (Intergovernmental Panel on climate Change). 2001: Climate Change 2001: The Scientific Basis, Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel of Climate Change. J.T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P.J. vander Linden, X.Dai, K. Maskell, and C.A. Johnson (Eds.), Cambridge University Press, 881 pp.

ISAV Program Standards. 2002. Appendix D V6.2 March 18, 2002.

ISAB (Independent Scientific Advisory Board). 2002. Hatchery surpluses in the Pacific Northwest. Fisheries 27:16-27.

Jackson H.P. 2003. 2003 Drift study of two aerially applied blueberry pesticides. Maine Board of Pesticides Control. Augusta, Maine. 20 pp.

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.

Jarp, J. and E. Karlsen. 1997. Infectious salmon anaemia (ISA) risk factors in sea-cultured Atlantic salmon *Salmo salar*. Diseases of Aquatic Organisms 28: 70-86.

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., 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.

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. 1997. A review of ecological and behavioral interactions between cultured and wild Atlantic salmon. ICES J. Mar. Sci. 54, 1031-1039.

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.

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.

Kahl, J.S., S.A. Norton, T.A. Haines, E.A. Rochette, R.H. Heath, and S.C. Nodvin. 1992. Mechanisms of episodic acidification in low-order streams in Maine, USA, Environ. Pollut. 78: 37-44.

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, S.K, 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.

Keleher, C.J. and F. J. Rahel 1996 Thermal Limits to Salmonid Distributions in the Rocky Mountain Region and Potential Habitat Loss Due to Global Warming: A Geographic Information System (GIS) Approach *Transactions of the American Fisheries Society*;125:1–13.

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 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.

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.

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.

Kircheis, F.W. 2004. Sea lamprey: *Petromyzon marinus* Linnaeus 1758. F.W. Kircheis L.L.C. Carmel, Maine. 23pp.

Klemetsen, et. al. 2003. Atlantic salmon, *Salm*o salar (L.), brown trout Salmo truta (L.), and Arctic charr, Salvelinus alpinus (L): a review of aspects of their life histories. Ecology of Freshwater Fish. 12:1-59.

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.

KRIS. Hypothesis #2. Elevated water temperature is limiting Atlantic salmon production in many reaches and tributaries of the Sheepscot River. http://www.krisweb.com/krissheepscot/ (February 25, 2005).

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.

Kroglund, F., H.C. Teien, B.O.Rosseland, B. Salbu. 2001. Time and pH dependant detoxification of aluminium in mixing zones between acid and nonacid rivers. Water, Air, and Soil Pollution 130, 905-910.

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.

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.

Legault, C.M. 2005. Population Viability Analysis of Atlantic Salmon in Maine, USA. Transactions of the American Fisheries Society. 134(3):549-562.

Leopold, L.B., M.G. Wolman and J.P. Miller. 1992. Fluvial processes in geomorphology. Dover Publications. New York.

Lombard, P.J., and G.D. Tasker, M.G. Nielsen. 2003. August median streamflow in ungaged streams in Eastern Aroostook County, Maine, Water-Resources Investigations Report 03-4225, 19 p.

Lucas, Z. N., and D. F. McAlpine. 2002. Extralimital occurrences of ringed seals, Phoca hispida, on Sable Island, Nova Scotia. Canadian Field-Naturalist 116 607-10 pp.

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.

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.

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.

MacAvoy, S.E., S.A. Macko, S.P. McIninch, and G.C. Garman. 2000. Marine nutrient contributions to freshwater apex predators. Oecologia 122: 568-573.

Magee, J. 2001. Agrichemical monitoring and potential effects on Atlantic salmon in eastern Maine rivers. National Marine Fisheries Service Report.

Magee, J. 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.

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.A., M. Obedzinski, S.D. McCormick, and J.F. Kocik 2003 Effects of episodic acidification on Atlantic salmon (Salmo salar) smolts Can. J. Fish. Aquat. Sci./J. can. sci. halieut. aquat. 60(2): 214-221 (2003).

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. 2000. Atlantic Salmon Conservation Plan For Seven Maine Rivers. 2000 Annual Progress Report. 109 pp.

Maine Atlantic Salmon Commission. 2001. Beddington Lake Splake Memo.

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 Atlantic Salmon Conservation Plan (MASCP). 1997. Maine Atlantic Salmon Task Force. Atlantic Salmon Conservation Plan for Seven Maine Rivers.

Maine Cooperative Extension Service. 2002. Minimizing off-target deposition of pesticide applications. Fact Sheet No. 303. Orono, Maine. 5 pp.

Maine Cooperative Extension Service. 2004. Best management practices for wild blueberry production in Maine. Fact Sheet No. 251. Orono, Maine. 3 pp.

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 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 Forest Service (MFS). 2004. Best management practices for forestry: protecting Maine's water quality. Augusta, Maine. 93 pp.

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.

McAlpine, D. F., P. T. Stevick and L. D. Murison. 1999. Increase in extralimital occurrences of ice-breeding seals in the northern Gulf of Maine region: More seals or fewer fish? Marine Mammal Science 15 906-11 pp.

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.

McCarthy, I.D. and D.F.H. Houlihan, 1997: The effect of temperature on protein metabolism in fish: the possible consequences for wild Atlantic salmon (Salmo salar) stocks in Europe as a result of global warming. In: *Global Warming: Implications for Freshwater and Marine Fish* [Wood, C.M. and D.G. McDonald (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 51–77.

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., L.P., Hansen, T.P., Quinn, and R.L.Saunders. 1998. Movement, migration, and smolting of Atlantic salmon (Salmo salar). Can. J. Fish. Aquat. Sci. 55(Suppl. 1): 72–92.

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.

Mierzykowski, S., and K. Carr. 2002. Organochlorine compounds and mercury in bald eagle eggs, Penobscot River, Maine. U.S. Fish and Wildlife Service. Maine Field Office. Special Project Report FY-02-MEFO-1-EC. Old Town, ME

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 C.P. Waring. 1996. Sublethal effects of the pesticide Diazinon on olfactory function in mature male Atlantic salmon parr. J. Fish. Biol. 48: 758-775.

Moore A., and C.P. Waring. 2001. The impact of two pesticides on olfactory-mediated endocrine function in mature male Atlantic salmon (*Salmo salar* L.) Parr. Comp Biochem Physiol B Biochem Mol Biol 129(2-3): 269.

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, p 30.

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.

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.

National Research Council (NRC). 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.

National Research Council (NRC). 2004. Atlantic salmon in Maine, Report from the Committee on Atlantic Salmon in Maine. Washington. DC: National Academy Press., 275 pp.

Newcomb, C., and J. Jensen. 1996. Channel suspended sediments and fisheries: A synthesis for quantitative assessment of risk and impact. N. Am. J Fish. Manage. 16: 693-727.

Nielsen, J.P. 1999, Water resources data Maine, water year 1998: U.S. Geological Survey Water Data Report ME-98-1, 178 p.

Nilsson, N.A. 1965. Food segregation between salmonid species in North Sweden. Rep. Inst. Freshw. Res. Drottningholm, 46: 58–78.

Nislow, K.H., C.L, Folt and D.L. Parrish. 1999. Favorable foraging locations for age-0 Atlantic salmon: application to the restoration of populations and habitats. Ecological Applications.9: 1085-1099.

NMFS (National Marine Fisheries Service) 1999. Report to Congress. Impacts of California sea lions and Pacific harbor seals on salmonid and west coast ecosystems. Prepared by U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

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.

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

Norton et al. 1999. The Bear Brook watershed, Maine (BBWM), USA. Environmental Monitor. Assess. 55: 7-51.

NRWC 2003. Narraguagus River Watershed Nonpoint Source Pollution Management Plan. Narraguagus River Watershed Council 86 pp.

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, T. Hovland, K. Hodneland, F. Nilsen, and P. Lovik. 1994. Mechanisms of transmission of infectious salmon anaemia (ISA). Diseases of Aquatic Organisms 19: 95-100.

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.

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.

OIE (Office of International Epizootics). 2000. Infectious salmon anaemia in the Faroe Islands. OIE Disease Information, Vol. 13 (14):53.

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.

Olem, H. 1991. Liming Acid Surface Waters. Lewis Publishers, Inc, Michigan, USA.

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.

Oregon Department of Fish and Wildlife (ODFW) and National Marine Fisheries Service (NMFS). 1999. Management implications of co-occurring native and introduced species. Proceedings of the Workshop, October 27-28, Portland, Oregon. 224 pp.

Orr, A. J., A. S. Banks, S. Mellman, H. R. Huber, R. L. DeLong and R. F. Brown. 2004. Examination of the foraging habits of Pacific harbor seal (Phoca vitulina richardsi) to describe their use of the Umpqua River, Oregon, and their predation on salmonids. Fishery Bulletin 102: 108-17 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. 1978. Physical characteristics of Atlantic salmon spawning gravel in some New Brunswick, Canada, streams. Can. Fish. Mar. Serv. Tech. Rep. No. 785:1-28.

Peterson, R. H., 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.

Project SHARE 2005. Sheepscot River Water Quality Monitoring Strategic Plan, A Guide for Coordinated Water Quality Monitoring Efforts in an Atlantic Salmon Watershed in Maine. Project SHARE, Research and Management Committee In Cooperation with the Sheepscot Valley Conservation Association. 91 pp.

Purcell, M., G. Mackey, E. LaHood, H. Huber and L. Park. 2004. Molecular methods for the genetic identification of salmonid prey from Pacific harbor seal (Phoca vitulina richardsi) scat. Fishery Bulletin 102 213-20 pp.

Purcell, M., G. Mackey, E. LaHood, H. Huber and L. Park. 2004. Molecular methods for the genetic identification of salmonid prey from Pacific harbor seal (Phoca vitulina richardsi) scat. Fishery Bulletin 102 213-20 pp.

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., A. G. Murray and A. Gregory. 2001. Infectious salmon anemia virus in wild fish in Scotland. Diseases of Aquatic Organisms 46:93-100.

Reddin, D.G. 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.

Rees C.B., S.D. McCormick, J.P. Vanden Heuvel and W. Li. 2003. Quantitative PCR analysis of CYP1A induction in Atlantic salmon (*Salmo salar*). Aquatic Tox. 62:67-78.

Reiman, B.E., R.C. Beamesderfer, S. Vigg, T.P. Poe, 1991. Estimated loss of juvenile salmonids to predation by northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. Trans. Am. Fish. Soc. 120: 448–458.

Richardson, J.S. 1993. Limits to productivity in streams: Evidence from studies of macroinvertebrates. p. 9-15. In R.J. Gibson and R.E. Cutting (ed.) Productionof juvenile Atlantic salmon, *Salmo salar*, in natural waters. Canadian Special Publications of Fisheries and Aquatic Sciences 118.

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 COMPLETE?. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. National Marine Fisheries Service. Seattle, WA.

Rosseland, B. O., Skogheim, O. K., Abrahamsen, H., and Matzow, D. 1986. Limestone slurry reduces physiological stress and increases survival of Atlantic salmon (*Salmo salar*) in an acidic Norwegian river. Canadian Journal of Fisheries and Aquatic Sciences 43: 1888-1893.

Rosseland, B.O., Kroglund, F., Staurnes, M., Hindar, K., Kvellestad, A., 2001. Tolerance to acid water among strains and life stages of Atlantic salmon (Salmo salar L.). Water, Air, and Soil Pollution 130(1-4), 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. 1981. Atlantic salmon (*Salmo salar*) stocks and management implications in the Atlantic Provinces and New England, USA. Can. J. Fish. Aquat. Sci. 38: 1612-1625.

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

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

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

Saunders, R.L., 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.

Scholz N.L., N.K. Truelove, B.L. French, B.A. Berejikian, T.P. Quinn, E. Casillas and T.K. Collier. 2000. Diazinon disrupts antipredator and homing behaviors in Chinook salmon (*Oncorhyncus tshawytscha*). Can. J. Fish. Aquat. Sci. 57:1911-1918.

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.

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

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.

Sheller, Z. 2005. Estimation of Spawning Gravel Permeability in Downeast Salmon Rivers. Maine Atlantic Salmon Commission: Atlantic Salmon

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.

Sherry, J., C. Tinson, K. Haya, L. Burridge, W. Fairchild, and S. Brown. 2001. An ELISA for Atlantic salmon (*Salmo salar*) Vg and its use in measuring the response of salmon smolts to 17 β-estradiol and 4-nonylphelol treatments. In: J. McKernan, B. Wilkes, K. Mathers, and A. Niimi (editors), Proceedings of the 28th Annual Aquatic Toxicity Workshop: September 30-October 3, 2001, Winnipeg, Manitoba. Canadian Technical Report of Fisheries and Aquatic Sciences 2379.

Sijm D. and A. Opperhuizen. 1996. Dioxins: and environmental risk for fish? Pages 209 – 228 in Beyer W.N., G.H. Heinz and A.W. Redmon-Norwood (eds.) Environmental contaminants in wildlife – interpreting tissue concentrations. CRC Press. Boca Raton, FL. 494 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.

Smith, S. J., S. J. Iverson and W. D. Bowen. 1997. Fatty Acid Signatures and Classification Trees: New Tools for Investigating the Foraging Ecology of Seals. Canadian Journal of Fisheries and Aquatic Sciences 54:1377-1386.

Solbakken, V.A., Hansen, T., Stefansson, S.O., 1994. Effects of photoperiod and temperature on growth and parr– smolt transformation in Atlantic salmon (*Salmo salar* L.) and subsequent performance in seawater. Aquaculture 121, 13– 27.

Somero, G.N., and G.E. Hofmann. 1997. Global warming: implications for freshwater and marine fish. Society of Experimental Biology Seminar Series [SOC. EXP. BIOL. SEM. SER.]. no. 61. pp. 1-24.

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.

Soto A.M, C. Sonnenshein, K.L. Chung, M.F. Fernandez, N. Olea and F.O. Serrano. 1995. The E-SCREEN assay as a tool to identify estrogens: and update on estrogenic environmental pollutants. Environ. Health Perspect. 103:113-122.

Spaulding B.W. 2005. Endocrine disruption in Atlantic salmon (*Salmo salar*) exposed to pesticides. M.S. Thesis. University of Maine. Orono, Maine. 66 pp.

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.

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.

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.

Svenson, T., Dickson, W., Hellberg, J., Moberg, G., and Munthe, N. 1995. The Swedish liming programme. Water Air and Soil Pollution 85: 1003-100

Sylte, T.L. and Fischenich J.C. 2002. Techniques for measuring substrate embeddedness. EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-36), U.S. Army Engineering Research and Development Center, Vicksburg, MS.

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.

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.

Tabor, R.A., R.S. Shively, T.P. Poe, 1993. Predation on juvenile salmonids by smallmouth bass and northern squawfish in the Columbia River near Richland, Washington. N. Am. J. Fish. Manage. 13: 831–838.

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.

Thorpe, J.E. 1977. Bimodal distribution of lengths of juvenile Atlantic salmon (*Salmo salar* L.) under artificial rearing conditions. J.Fish Biol. 11: 175–184.

Thorpe, J.E. 1994. Reproductive strategies in Atlantic salmon, *Salmo salar* L. Aquacult. Fish. Manage. 25: 77-87.

Thorpe, J.E., R.I.G., Morgan, E.M., Ottaway, and M.S.Miles. 1980. Time of divergence of growth groups between potential 1+ and 2+ smolts among sibling Atlantic salmon. J. Fish Biol. 17: 13–21.

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.

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

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.

United Nations Environment Program (UNEP). 1999. Report of the Scientific Advisory Committee of the Marine Mammals Action Plan. United Nations Environment Programme. 26 pp.

United States Atlantic Salmon Assessment Committee (USASAC). 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.

USASAC (US Atlantic Salmon Assessment Committee). 2004. Annual Report of the US Atlantic Salmon Assessment Committee . 2004/16. USASAC, Woodshole, Massachusetts.

USASAC (US Atlantic Salmon Assessment Committee). 2005. Annual Report of the US Atlantic Salmon Assessment Committee . 2005/17. USASAC, Woodshole, Massachusetts.

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.

USFWS – Gulf of Maine Coastal Program. 2004. Atlantic Salmon Habitat Survey Level 3. Augusta, ME. Maine Office of GIS.

United States Food and Drug Administration (FDA) Website. Office of New Animal Drug Evaluation. www.fda.gov/cvm/aboutcvm/aboutona.htm

United States Geological Survey (USGS). 2002. Ground-water studies in Maine. http://me.water.usgs.gov/groundwater.html

University of Maine Website. Sea lice bullets. Animal, Veterinary and Aquaculture Extension Office. www.umaine.edu/livestock/Publications/sea_lice_bullets.htm.

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 Beneden, R. and W. Morrill. 2002. Investigation of the estrogenic potential of agrochemicals and their effect on the Atlantic salmon (*Salmo salar*). Progress Report - Project #2000625. University of Maine. Orono, Maine. 13 pp.

Van den Berg, M., L. Birnbaum, A.T.C Bosveld, B. Brunstrom, P. Cook, M. Feeley, J.P. Giesy, A. Hanberg, R. Hasegawa, S.W. Kennedy, T. Kubiak, J.C. Larsen, F.X.R. van Leeuwen, A.K.D. Liem, C. Nolt, R.E. Peterson, L. Poellinger, S. Safe, D. Schrenk, D. Tillitt, M. Tysklind, M. Younes, F. Waern and T. Zacharewski. 1998. Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. Environ. Health Persp. 106(12):775-792.

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.

Van Der Kraak, G. and N.W. Pankhurst 1997. Temperature effects on the reproductive performance of fish. In: Global warming-implications for freshwater and marine fish. Eds. D.G. McDonald and C.M. Wood. Society for Experimental Biology Seminar Series, 61; Cambridge University Press, Cambridge UK. pp. 159-176.

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.

Walker, M.K. and R.E. Peterson. 1994. Toxicity of 2,3,7,8-tetrachlordibenzo-p-dioxin to brook trout (Salvelinus fontinalis) during early development. Environ. Toxicol. Chem. 13(5):817-820.

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.

Waring, C.P. and A. Moore. 2004. The effect of atrazine on Atlantic salmon (*Salmo salar*) smolts in fresh water and after sea water transfer. Aquat. Tox. 66:93-104.

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.

Warner, K. 1972. Further studies of fish predation on salmon stocked in Maine lakes. The Progressive Fish-Culturist 34(4): 217-221.

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.

Webber, H.M. and T.A. Haines. 2003. Mercury effects on predator avoidance behavior of a forage fish, golden shiner (*Notemigonus crysoleucas*). Environ. Tox. Chem. 22(7):1556-1561.

Wehnes, R.E. 1992. Streams for the future: integrating public involvement in stream improvement program in Missouri. American Fisheries Society Symposium. 13:229-236.

Welch, D.W., Y. Ishida, and K. Nagasawa 1998. Thermal limits and ocean migrations of sockeye salmon (*Oncorhynchus nerka*): long-term consequences of global warming. Can. J. Fish. Aquat. Sci. 55(4): 937-948

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.

Whoriskey, F.G., S. Prusov, et al. 2000. Evaluation of the effects of catch and release angling on Atlantic salmon of the Ponoi River, Kola Peninsula, Russian Federation. Ecology of Freshwater Fish. 9:1-2.

Wilcove D.S., Bean M.J. 1994. The big kill: declining biodiversity in America's lakes and rivers. Washington, DC: Environmental Defense Fund.

Wilkie, M. P., M. A. Brobbel, et al. (1997). Influences of temperature upon the postexercise physiology of Atlantic salmon (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Sciences. Ottawa 54(03): 503-511.

Wilkie, M. P., K. Davidson, et al. (1996). Physiology and Survival of Wild Atlantic Salmon Following Angling in Warm Summer Waters. Trans. Am. Fish. Soc. 125: 572-580.

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., and P. Hutchinson. 1990. The potential interactions between salmon aquaculture and the wild stocks- a review. Fisheries Research 10: 163-176.

Windsor, M.L., and P. Hutchinson. 1994. International management of Atlantic salmon, *Salmo salar* L., by the North Atlantic Salmon Conservation Organization, 1984-1994. Fisheries Management and Ecology. 1(1): 31-44.

Wolk, K. 1988. Atlantic salmon swim bladder sarcoma virus. Pages 349-351 in K. Wolf, editor. Fish viruses and fish viral diseases . Cornell University; Ithaca, New York.

Wood, C. C. 1987. Predation of juvenile Pacific salmon by the common merganser (Mergus merganser) on eastern Vancouver Island II: Predation of stream-resident juvenile salmon by merganser broods. Canadian Journal of Fisheries and Aquatic Sciences 44(5): 950-959.

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.

Zabel, E.W., P.M. Cooke and R.E. Peterson. 1995. Potency of 3,3',4,4',5-pentachlorobiphenyl (PCB 126), alone and in combination with 2,3,7,8-tetrachlrodibenzo-p-dioxin (TCDD), to produce lake trout early life-stage mortality. Environ. Toxicol. Chem. 14(12):2175-2179.

Zurbuch, P. E. 1984. Neutralization of acidified streams in West Virginia. Fisheries 9: 42-47.

APPENDIX 1: LISTING FACTORS (THREATS) AND RECOVERY TASKS

LISTING FACTORS/RECOVERY ACTIONS

Listing Factor*	Threat	Recovery Actions
A	Water Use	1.1.1A; 1.1.1B; 1.1.2A; 1.1.2B; 1.1.2C; 1.1.2D; 1.1.3A; 1.1.3B; 1.1.3C; 1.1.3D; 1.1.3E; 1.1.4A; 1.1.4B; 1.1.5A; 1.1.5B
A	Water Quality	1.2.1; 1.2.2L; 1.2.3A; 1.2.4C; 1.2.4D; 1.2.4E
A	Acidified Water and Aluminum	1.2.2A; 1.2.2B; 1.2.2C; 1.2.2D; 1.2.2E; 1.2.2F; 1.2.3A
A	Pesticides, other contaminants and endocrine disruption	1.2.2G; 1.2.2H; 1.2.2I; 1.2.2J; 1.2.2K; 1.2.3A; 1.2.4F
A	Sedimentation	1.2.4A; 1.2.4B; 1.3.4
A	Excess Nutrients	1.2.3A; 1.2.4A; 1.2.4C
A	Elevated Water Temperatures	1.2.3A; 1.2.3B; 1.2.3C
A	Obstruction to Passage	1.3.1; 1.3.1A; 1.3.1B; 1.3.2; 1.3.3; 1.3.4; 1.1.5A; 1.1.5B
A	Manmade Barriers	1.3.1; 1.3.1A; 1.3.1B; 1.3.2
A	Natural Barriers	1.3.3; 1.3.4
A	Habitat Protection	1.4.1A; 1.4.1B; 1.4.1C; 1.4.1D; 1.4.1E; 1.4.2A; 1.4.2B
A	Ecosystem Function and Habitat Restoration	1.5.1; 1.5.2A; 1.5.2B; 1.5.3; 1.5.4; 1.5.5
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; 2.2.2C
B	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; 2.2.2C

Listing Factor*	Threat	Recovery Actions
B	Canadian Fisheries	2.1.3; 2.1.3A
B	West Greenland Fishery	2.1.3A; 2.1.3B
B	St. Pierre et Miquelon	2.1.3C
C	Disease	4.3.1A; 4.3.1B; 4.3.1C; 4.3.1D; 4.3.1E; 4.3.1F; 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	Infectious Salmon Anemia (ISA)	4.3.1A; 4.3.1B; 4.3.1C; 4.3.1D; 4.3.1E; 4.3.1F; 4.3.2A; 4.3.2B; 4.3.2C; 4.3.2D; 4.3.3A; 4.3.3B; 4.3.3C; 5.2.1; 5.2.3A; 5.2.3
C	Salmon Swimbladder Sarcoma (SSS)	4.3.1D; 4.3.1E; 4.3.1F; 4.3.2C; 4.3.2E; 5.2.1; 5.2.3A; 5.2.3
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	Marine Mammals	3.3.1A; 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	Avian Predators	3.1.1A; 3.1.1B; 3.1.1C; 3.1.1D; 3.1.2A; 3.1.2B; 3.1.2C
D	Double-crested Cormorants	3.1.1B; 3.1.1C; 3.1.1D; 3.1.2A; 3.1.2B; 3.1.2C
D	Mergansers	3.1.2C; 3.1.4
D	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	Freshwater	3.1.2C; 3.2.1A; 3.2.1B; 3.2.1C; 3.2.1D; 3.2.1E; 3.2.2
D	Estuarine and Marine	3.1.2C; 3.1.4
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
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

Listing Factor*	Threat	Recovery Actions
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; 4.3.1F; 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	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; 4.3.1F; 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	Marine Survival	2.1.3A; 2.1.3B; 2.1.3C; 2.2.1A; 2.2.1C; 2.2.2A; 2.2.2B; 2.2.2C; 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
F	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
F	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; 9.2B; 9.3

*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

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[85] on the seven rivers known to support wild salmon populations. The charge of the

[85] Current watershed councils include, Dennys River Watershed Council, East Machias River Watershed Council, Machias River Watershed Council, Pleasant River Watershed Council, Narraguagus River

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 handbooks. The identification pamphlets provide information on characteristics that distinguish juvenile salmon from other salmonids, such as brook trout and brown trout.

National Marine Fisheries Service

NMFS 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. The NMFS has also

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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.

provided funding for the operation of the Wild Salmon Resource Center in Columbia Falls. The NMFS 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, NMFS 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.

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.

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'ssince becoming a smolt.

3SW: a salmon that has passed three December 31st' 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 (EEZ): 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 aquatic environments (e.g., rivers, lakes, wetlands)

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.

APPENDIX 5: GULF OF MAINE DPS OF ATLANTIC SALMON THREATS ASSESSMENT

Threats Assessment Workshop
December 3 & 4, 2004, Portland Maine

Workshop Participants

Melissa Halsted (ASC)
Pat Keliher (ASC)
Joan Trial (ASC)

Meredith Bartron (FWS)
Carl Burger (FWS)
Wende Mahaney (FWS)
Steve Mierzykowski (FWS)
Jed Wright (FWS)

Jessica Anthony (NOAA)
John Kocik (NOAA)
Mark Minton (NOAA)
Rory Saunders (NOAA)
Tim Sheehan (NOAA)

Severity Index

0 = negligible to no threat
1 = Unknown (Uncertain)
2 = low
3 = moderate
4 = high

Threats Assessment
Worksheet

				Current Severity at Each Lifestage							
Threat	**Source**	**MAGNITUDE**	**# of Rivers**	**Lifestage**						**TSI score**	**TSI grouping**
		weighting		**1**	**1**	**1**	**1**	**1**	**5**		
				Adult Spawners	egg	fry	Parr	Smolt	Marine		
A. PRESENT (includes historic**) OR THREATENED DESTRUCTION, MODIFICATION OR CURTAILMENT OF HABITAT OR RANGE**											
	Water Use										
	Instream Management	4,5,6,7,8	5	4	4	4	4	3	0	**95**	**medium**
	Extraction	1,2,3,4,5,6,7,8	8	4	4	4	4	2	0	**144**	**high**
	Water Quality										
	Acidified water and aluminum	4,5,6,7,8	5	3	4	4	4	4	4	**195**	**high**
	Chemical Contaminants	1,2,3,4,5,6,7,8	8	3	3	3	3	3	0	**120**	**medium**
	Physical Habitat Alteration										
	Sedimentation	1,2,3,4,5,6,7,8	8	3	4	3	4	2	2	**208**	**high**
	Excess Anthropogenic Nutrients	1,3	2	3	2	2	3	2	0	**24**	**low**
	Elevated Water Temperatures	1,2,3,4,5,6,7,8	8	4	2	3	3	0	0	**96**	**medium**

Threats Assessment
Worksheet

Threat	Source	MAGNITUDE	# of Rivers	Lifestage						TSI score	TSI grouping
		weighting		**1**	**1**	**1**	**1**	**1**	**5**		
				Adult Spawners	egg	fry	Parr	Smolt	Marine		
	Obstruction to Passage										
	Manmade Barriers	1,2,3,4,5,6,7,8	8	4	0	2	3	3	0	**96**	**medium**
	Natural Barriers	1,2,3,4,5,6,7,8	8	3	0	2	2	2	0	**72**	**low**
B. OVERUTILIZATION FOR COMMERCIAL, RECREATIONAL, SCIENTIFIC OR EDUCATIONAL PURPOSES											
	U.S. Commercial Fisheries	1,2,3,4,5,6,7,8	8	2	0	0	0	0	1	**56**	**low**
	U.S. Recreational Fisheries	1,2,3,4,5,6,7,8	8	3	0	0	2	2	3	**176**	**high**
	Canadian Fisheries (All)	1,2,3,4,5,6,7,8	8	0	0	0	0	0	2	**80**	**low**
	West Greenland Fishery	1,2,3,4,5,6,7,8	8	0	0	0	0	0	3	**120**	**medium**
	St. Pierre et Miquelon Fishery	1,2,3,4,5,6,7,8	8	0	0	0	0	0	1	**40**	**low**

Threats Assessment
Worksheet

Threat	Source	MAGNITUDE	# of Rivers	Lifestage						TSI score	TSI grouping
		weighting		**1**	**1**	**1**	**1**	**1**	**5**		
				Adult Spawners	egg	fry	Parr	Smolt	Marine		
	Scientific Research	1,2,3,4,5,6,7,8	8	4	0	0	2	2	0	**64**	**low**
C. Predation, Disease, and Competition	Cold Water Disease	1,4,6,7,8	5	0	3	4	1	1	0	**45**	**low**
	Infectious Salmon Anemia (ISA)	1,2,3,4,5,6,7,8 (4,5,6,7 to lesser extent)	8	2	0	0	0	2	2	**112**	**medium**
	Salmon Swimbladder Sarcoma (SSS)	1,4,5,6,7	5	2	1	1	1	1	2	**80**	**low**
	Marine Mammals	1,2,3,4,5,6,7,8	8	0	0	0	0	0	3	**120**	**medium**
	Avian Predators	1,2,3,4,5,6,7,8	8	2	0	0	3	3	2	**144**	**high**
	Piscine Predators and Competitors										
	Introduced	1,2,3,4,5,6,7,8	8	4	3	4	4	4	0	**152**	**high**
	Native	1,2,3,4,5,6,7,8	8	0	0	2	2	0	0	**32**	**low**
	Marine	1,2,3,4,5,6,7,8	8	0	0	0	0	2	2	**96**	**medium**
D. INADEQUACY OF EXISTING REGULATORY MECHANISMS (Water Withdrawal, Aquaculture, other)											

Threats Assessment
Worksheet

Threat	Source	MAGNITUDE	# of Rivers	Lifestage						TSI score	TSI grouping
		weighting		**1**	**1**	**1**	**1**	**1**	**5**		
				Adult Spawners	egg	fry	Parr	Smolt	Marine		
E. OTHER NATURAL AND ANTHROPOGENIC FACTORS AFFECTING THE SPECIES' CONTINUED EXISTENCE											
	Salmon Aquaculture										
	Genetic Introgression w/ aquaculture escapees	1,2,3,4,5,6,7,8	8	3	1	1	3	1	1	**112**	**medium**
	Ecological/ Disease	1,2,3,4,5,6,7,8	8	4	4	3	3	3	2	**216**	**high**
	Hatchery Program										
	Genetic Introgression	1,4,5,6,7,8	6	4	2	2	2	2	2	**132**	**medium**
	Overrepresentation from excess broodstock	1,4,5,6,7,8	6	4	4	0	0	0	0	**48**	**low**

Threats Assessment
Worksheet

Threat	**Source**	**MAGNITUDE**	**# of Rivers**	**Lifestage**						**TSI score**	**TSI grouping**
		weighting		**1**	**1**	**1**	**1**	**1**	**5**		
				Adult Spawners	egg	fry	Parr	Smolt	Marine		
	Artificial Selection/ Domestication	1,4,5,6,7,8	6	4	4	4	4	4	4	**240**	**high**
	Conflicting Stocking Stages	1,4,5,6,7,8	6	0	0	3	3	3	0	**54**	**low**
	Low Effect Population Size	1,4,5,6,7,8	6	4	2	2	2	2	2	**132**	**medium**
	Restriction of Broodstock to One Location	1,4,5,6,7,8	6	4	4	4	4	4	0	**120**	**medium**
Other Hatchery Programs (Palermo)		1	1	4	3	4	4	4	0	**19**	**low**
Poaching		1,2,3,4,5,6,7,8	8	4	0	0	2	2	2	**144**	**high**
Depleted Diadromous Fish Communities		1,2,3,4,5,6,7,8	8	2	2	3	3	3	3	**224**	**high**
Marine Survival		1,2,3,4,5,6,7,8	8	0	0	0	0	0	4	**160**	**high**
Land Use (development, agri, forestry etc.)		1,2,3,4,5,6,7,8	8	4	4	4	4	4	0	**160**	**high**
Climate Change		1,2,3,4,5,6,7,8	8	4	4	4	4	4	4	**320**	**high**

APPENDIX 6: RESPONSE TO PUBLIC AND PEER-REVIEW COMMENTS

Recovery Plan for the Gulf of Maine
Distinct Population Segment of Atlantic Salmon

Response to Public and Peer-Review Comments

In June 2004, the Services distributed a draft recovery plan for the Gulf of Maine distinct population segment (DPS) of Atlantic salmon for public review and comment. During the 90-day public comment period the Services held two formal public hearings as well as numerous meetings and briefings with federal, state, local and private stakeholders to discuss the recovery plan.

The Services received comments from a wide range of stakeholders and interested parties including state, federal and local government agencies, local stakeholder groups, NGOs, industry and private citizens. The comments received ranged from endorsements of the plan to disagreement with specific as well as general elements contained in the plan. Many of the comments received provided technical corrections and additional information for the Service's consideration in the preparation of a final plan.

The Maine ASC coordinated the review of the draft plan by state agencies. The State agencies involved in the Plan review were the ASC, DMR, IFW, DEP, DAFRR, BPC, DOC, BPL, MFS, MGS, DOT and SPO.

In addition to public review, the recovery plan underwent peer-review. The Services and the state identified and contacted 27 peer reviewers with specific technical and other relevant expertise, requesting review and comments on the draft recovery plan. These individuals were asked to review relevant sections of the plan for technical accuracy and completeness. The peer-reviewers were also asked to identify any specific issues or information that the Services should consider in the preparation of a final draft plan. The Services received 8 responses from the individuals contacted.

In conjunction with efforts to prepare a final recovery plan, the Services and the Maine ASC conducted a two-day Threats Assessment Workshop in December 2004. The public and peer review comments received during the public comment period were explicitly considered by workshop participants. In addition, the Services reviewed and considered the recommendations of the recent National Research Council's (NRC) report (see NRC 2004). The results of this workshop were incorporated into the final recovery plan.

The public and peer review comments received during the public comment period have been fully considered in the preparation of this recovery plan. In response to comments received the Services have made revisions to the draft plan as appropriate. In addition, the Services have reviewed and considered the recommendations of the recent NRC (2004) report on Atlantic

Salmon in Maine and incorporated the recommendations as appropriate.

Comment 1: Threats Assessment
A number of comments were submitted questioning the relationship between the threats assessment and the text related to those identified threats and/or their priorities in the implementation table. It was suggested that better documentation of the risk assessment method used to identify the top threats would be instructive for the reader. Others commented that some of the threats were more applicable to some watersheds and not to others. Finally, some questioned the estimates of costs in the Implementation Schedule and the State of Maine suggested that they could assist the federal Services, with the assistance of the Recovery Team, to refine these estimates.

Response: A workshop was held with state and federal agency experts to conduct a threats assessment. The purpose of this workshop was to address the concerns submitted by the public with the goal of expanding the section of the recovery plan to include an explanation of the process utilized and factors considered in conducting the threats assessment. Another goal was to attempt to link the threats assessment to the implementation schedule and to ensure consistency in addressing threats throughout the body of the recovery plan. The final plan includes a revised threat assessment that was the product of the workshop mentioned above.

Comment 2: Water Use
Some comments recommended that the plan take a broader approach to addressing water use related to hydrologic manipulation of river flow. Others stated that the terms "excessive or unregulated withdrawals" were not accurate or instructive and stated that the Plan did not adequately acknowledge the existing state regulatory programs that are in place to guard against threats to habitat due to water withdrawal. It was suggested that too much emphasis was placed on water withdrawal in the plan and that the plan should focus on a solution based approach as agreed to by private and public, State and Federal partners in the Downeast Rivers Water Use Management Plan (WUMP) developed under the State Atlantic Salmon Conservation Plan instead of focusing on water-use permitting.

The Downeast Salmon Federation (DSF) states that the draft plan should specifically state that the Water Use Management Plan (WUMP) is not comprehensive enough to truly deserve the name. DSF states that a reader of the recovery plan unfamiliar with the WUMP might conclude that these "plans" address cumulative as well as individual withdrawals. DSF comments that the WUMP actually addresses only those withdrawals made by the larger industry users and does not do a thorough or precautionary job of planning or managing water use in these watersheds. Lastly, DSF states that the documents referred to as the WUMP provide a basis from which to move forward, but are sorely lacking in addressing the impact of the full range of irrigators within these watersheds.

Response: The Recovery Plan endorses the implementation of the WUMP as an important recovery action for the DPS. The Services agree with the comment that the practical threat of water use is much less today than it was in 1995 when the State Conservation Plan was being developed. As explained in the Plan, the WUMP is a significant accomplishment and provides an excellent foundation as a planning document. In order for it to be effective as a tool for the protection and recovery of Atlantic salmon, however, the WUMP needs to be endorsed by the state regulatory agencies and consistently applied in the State of Maine in both organized and unorganized territories. While voluntary compliance with the WUMP by growers may be reducing the practical threat of water withdrawals to salmon and their habitat today, it does not provide security into the future that this threat will remain reduced.

Comment 3: **Forestry**
Some comments were submitted concurring with the conclusion in the draft plan that current timber harvesting activities do not represent a significant threat under current management measures and harvest practices. Other commenters questioned the basis for this conclusion. They cited the following potential impacts from forest practices: sedimentation, thermal loading, altering water chemistry, altering hydrology and limiting large woody debris. Other commenters raised concern that changes in land ownership could lead to increased harvesting and impacts to Atlantic salmon and their habitat. One comment requested that the Services review the state laws that govern forest management and timber harvesting and another comment specifically stated that the State of Maine's Forest Practices Act provides little protection to smaller order streams. In addition, some stated that there was little to no enforcement of existing forest laws and regulations. Some commenters contend that the draft plan does not adequately describe the forestry issue. DSF states that forestry practices impact watershed productivity particularly when first order streams do not receive adequate protection from cutting activities. These commenters state that these streams receive the least protection under current law and the least emphasis under current conservation easement strategies and as a result these water bodies are experiencing the most abuse and neglect.

Response: In the recovery plan we acknowledge that forestry practices can negatively impact Atlantic salmon habitat. Due to state laws and best management practices (BMPs), widespread problems with forestry practices have not been documented. These impacts can occur, however, and in some cases the protective measures currently in place are best management practices that are not regulatory in nature. In general, landowners are required to protect water quality and to utilize best management practices to ensure that water quality is not negatively impacted by harvesting. The BMPs are not prescriptive in nature, however, and instead require what is necessary to achieve the outcome of preventing negative impacts to water quality. Foresters are provided with a range of BMPs and training in those techniques, but the ultimate decision of what specific techniques to apply is left to their discretion in light of the site specific circumstances. We acknowledge that land ownership is changing in Downeast Maine and we cannot take for granted the excellent relationship we have had with landowners in the past who have voluntarily adopted protective measures for Atlantic salmon. Efforts to work with new landowners are ongoing and Project SHARE has been very instrumental in this effort. It will be important during implementation of the recovery plan for the Services to continue to work with landowners and the Maine Forest Service to ensure that salmon habitat is not negatively impacted by forestry practices.

Comment 4: Land Acquisition & Riparian Buffers
Some suggested land acquisition and conservation easements should be pursued in areas that are threatened with serious, immediate, development pressure, where the relationship between specific land use changes and habitat degradation is firmly established and where high value habitat is at risk. Others argued that the case for riparian buffer protection is based on the presumed impacts of sedimentation, removal of shade and associated increases in stream temperature, alteration of natural processes that create large woody debris, low DO from nutrient enrichment, runoff of chemical contaminants from agricultural and silvicultural lands. These individuals state that there is little documentation of existing problems.

Response: The available scientific literature provides a strong basis for the need for a riparian buffer zone to prevent adverse impacts to water quality. The major focus in recovery planning and implementation is to ensure that buffers are adequate to prevent impacts to water quality. If receiving waters are not impacted by sediment, nutrients, chemicals, and sufficient vegetation remains to prevent increases in water temperature then Atlantic salmon habitat should be protected. Purchasing all of the land in the riparian habitat in the Gulf of Maine DPS of Atlantic salmon is not possible and is not necessary for salmon protection and recovery. Our focus is, therefore, on ensuring that regulations and best management practices to protect water quality are fully implemented and evaluated. Where opportunities present themselves, the purchase of land and conservation easements has been and likely will continue to be an important tool in the effort to protect important riparian areas adjacent to salmon habitat.

Comment 5: Aquaculture
Comments were provided stating that some of the section in the draft plan on aquaculture was outdated and requesting that the final recovery plan acknowledge progress made to address the threat of aquaculture. Other comments identified areas where actions to address the threat from aquaculture needed to be strengthened and specifically cited disease management, the establishment of aquaculture free-zones and bay management planning.

Response: We have updated the section in the recovery plan related to aquaculture. As noted in the comments, the Services have been working with the aquaculture industry and the State of Maine for a number of years to implement measures to minimize the potential for aquaculture practices to negatively impact Atlantic salmon and their habitat. As correctly noted in the comments, significant progress has been made recently to incorporate a number of these protective measures in permit conditions. Aquaculture free-zones have been considered, but not implemented due to the lack of adequate sites sufficiently removed from the Gulf of Maine DPS. Bay management planning is an excellent tool for ensuring that aquaculture practices are well coordinated and that cumulative impacts are identified and assessed. We have included a discussion on bay management in the final recovery plan.

Comment 6: Habitat Quality and Restoration
Comments were submitted stating that the recovery plan needed to identify habitat as a limiting factor to Atlantic salmon throughout Maine and placing habitat restoration as a top priority. One comment stated that poor large parr survival indicated that habitat in the rivers may be marginal

and that greater emphasis should be placed on investigating this further. Comments suggested that a greater emphasis needed to be placed on restoring the structure and function of these rivers. Another comment recommended that the size and scale of riparian buffer zones needs to be carefully assessed to determine if they are adequate to meet the needs of Atlantic salmon and the rest of the ecosystem.

Response: The plan does identify habitat quality as a significant threat to the recovery of Atlantic salmon. As explained in the plan, assessment activities have documented significant mortality occurring during the last winter large parr are in the river and also as smolts are migrating out of the river. These research findings indicate that there are problems with habitat quality. Research and management efforts are now concentrated on specifically identifying limiting factors in the freshwater, estuarine and marine environments. Examples include assessment of embeddedness and substrate permeability and its relationship to productivity and consideration of a pilot liming study to evaluate the benefits of buffering the river as smolts migrate into saltwater. In addition, the final recovery plan discusses the need to investigate the potential role of diminished habitat complexity in the conservation of the DPS.

Comment 7: Ecosystem Restoration

Comments recommended that the plan needed to go further in incorporating an ecosystem approach to recovering the DPS and should consider rivers as entire systems. One comment stated that non-native species should not be stocked into rivers within the DPS and another recommended pursing the restoration of alewives. Other comments stated that to restore salmon we need to restore the other species with which it co-evolved over the years.

Response: The goal of the Endangered Species Act is to conserve the ecosystems upon which endangered and threatened species depend. The plan acknowledges that recovery of endangered Atlantic salmon depends on recovery of the rivers, estuaries and marine environment. Recovery includes restoration of other diadromous species which provide important benefits to Atlantic salmon including serving as predator buffers and contributing marine derived nutrients to the ecosystem.

Comment 8: Changing land-use patterns

A comment recommended that changing land use patterns (i.e., development and sprawl) needs to be addressed more thoroughly in the plan. It was also suggested that habitat protection needs to be guided by an ecosystem management approach that looks at what is happening across the landscape. One comment stated that if the long term effects of historical land use and impacts from current land use are not addressed rapidly and aggressively we will not see the restoration of self-sustaining Atlantic salmon populations in Maine.

Response: The recovery plan focuses on threats to Atlantic salmon habitat so the impacts of changing land use patterns are addressed in a variety of sections. As noted in the comment, development can impact Atlantic salmon habitat by contributing sediments, chemicals and nutrients and increasing water temperature. Land use changes will continue to be monitored during implementation of the recovery plan with a focus on how those changes increase impacts to salmon habitat.

Comment 9: Stakeholder and community involvement
Comments stated that the plan does not identify many areas where non-agency organizations and stakeholders are involved and recommended that the plan identify more ways to include stakeholders and the local knowledge that these individuals and groups possess. Another comment stated that the Watershed Councils are essential for salmon recovery and must have the backing of state and federal agencies involved in salmon restoration. It further suggested that the "Implementation Schedule" should include funding to support the full time staff needed to keep the Watershed Councils functioning as an effective component of salmon restoration efforts.

Response: The recovery plan acknowledges the critical role that local citizens and organizations have and will continue to play in recovery of Atlantic salmon. These individuals serve as the eyes and ears in these watersheds and are frequently the first to identify specific habitat problems that need to be addressed and opportunities for habitat enhancement. The implementation schedule identifies the actions at the local level and the funding estimated to be necessary to carry out those activities. Included in these estimates would be the personnel resources needed to carry out these tasks.

Comment 10: Hatcheries
A number of comments were submitted on the existing hatchery program. One comment suggested that the plan identify the need to assess whether hatchery-reared fish, which are essentially land-locked, are capable of transitioning to saltwater water. Another comment suggested that there should not be a "broodstock retirement" program as currently exists and that instead these brood fish should be producing progeny for other rivers to establish experimental populations. It was suggested that stocking of additional streams might provide a surprising result in terms of a few returning adults and perhaps a catch and release fishery at some point in the future which could go a long way toward rebuilding popular support for the recovery program as a whole.

Response: The recovery plan supports the recommendation from the NRC report that the hatchery program should be reviewed. The issues identified above, including the source of the fish taken into the hatchery, the use of spent broodstock, life stage to be stocked, and evaluation of hatchery products should all be included in a review as recommended in the final recovery plan. The recovery plan also includes a recommendation to evaluate additional stocking in other rivers within the DPS.

Comment 11: West Greenland Fishery
A comment suggested that the management and establishment of commercial quotas should not be left solely up to NASCO and stated that NASCO failed to follow ICES advice to adopt the zero quota for the WGF in 2001 and 2002. It suggested that the plan recommend a continued suspension of a commercial fishery for Atlantic salmon until such time as rivers within the United States have self-sustaining populations. It further recommended that the recovery plan explicitly support the existing 5-year Greenland Conservation agreement and call for the

continued elimination of the West Greenland Fishery as a priority recovery action.

Response: NASCO is the international organization created with the purpose of international coordination and cooperation for Atlantic salmon conservation and management. It is the forum for the Untied States to engage Denmark, on behalf of Greenland, in discussions on management of Atlantic salmon fisheries. The recovery plan identifies the commercial catch of Atlantic salmon off the coast of Greenland as a threat to the recovery of the Gulf of Maine DPS. The model utilized by ICES to provide management advice to NASCO estimates pre-fishery abundance off Greenland and subtracts the spawning escapement needs for all the rivers represented in that mixed stock and then allocates a portion of the remainder to the Greenland fishery. While this, in theory, offers adequate protection to all stocks contributing to the mixed stock off Greenland, some stocks may be disproportionately affected by the fishery. For instance, if Canadian and Northern European stocks recovery more quickly than U.S. and Southern European stocks then the pre-fishery abundance may increase enough to allow for a commercial harvest off Greenland yet the stocks in the southern portion of the range may still be significantly lower than spawning escapement goals. Continued involvement in the international management forum and involvement of conservation organizations is necessary to ensure adequate protection of U.S. stocks.

Comment 12: Penobscot and Other Large Rivers
Several commenters stated that the Recovery Plan does not adequately address the relationship and importance of the Penobscot to the listed rivers. These comments stated that this is a serious omission in the draft recovery plan. The recovery plan's failure to adequately recognize the importance of the Penobscot to the listed rivers is a serious omission and needs to be rectified in the final plan. Likewise, the plan needs to look at the role of Maine's other large salmon rivers, particularly those within the geographic range of the DPS, i.e., the Kennebec, Androscoggin and St. Croix rivers, as well as the Saco River.

Response: The recovery plan is for the listed entity – the Gulf of Maine DPS of Atlantic salmon that was listed in 2000. At the time of the listing, the mainstem Penobscot River was excluded from the Gulf of Maine DPS due to outstanding data and analysis. The plan properly focuses on the threats to Atlantic salmon and their habitat as listed and identifies actions necessary to avoid or minimize those threats in the future.

Comment 13: Acid Rain
A comment offered support for efforts to mitigate the effects of acid rain on the DPS, but stated that the draft plan does not place adequate emphasis on mitigating the underlying causes of acid rain. The comment recommended that the Services place a high priority on consulting with the EPA on identifying point sources of air pollution contributing to acid rain.

Response: The available information on acid deposition in Maine indicates that, as a result of air pollution regulations, acid deposition is decreasing. The current problems appear to be caused by the removal of buffering capacity in these rivers over time which now allows acid pulses to cause effects to Atlantic salmon. The mitigation effort appears to be necessary to provide buffering capacity until such time as the habitat recovers from the years of significant acid rain deposition and leaching of buffering capacity from the watersheds.

Comment 14: Elevated Water Temperature
A comment stated that the draft recovery plan does not adequately discuss the threat of elevated water temperature.

Response: There is no question in the literature as to the negative effects of high temperature. The best available data seems to show a significant number of days when the temperature goes above the thresholds for feeding and survival. The draft recovery plan identifies elevated water temperature as a threat to Atlantic salmon. As noted in the comment, temperatures have been recorded at levels higher than that preferred and sometimes even tolerable for salmon. The recovery plan also identifies activities that can cause increased water temperature including removal of vegetation in the riparian zone and water withdrawals.

Comment 15: Education
A comment stated that education is an essential component to species or population restoration and will require substantial investment and commitment on the part of all of the players in this recovery. The commenter stated that the recovery plan's implementation schedule lacks funding and commitment for education.

Response: The Recovery Plan states that education and outreach programs are a critical component of successful conservation and recovery plans. The Recovery Plan states that public information and outreach programs help build public support and a strong constituency for Atlantic salmon recovery and conservation in Maine. The Recovery Plan recommends that 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. The Recovery Plan notes that 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.

The Recovery Plan states that 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. The Recovery Plan recommends that 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.

Comment 16: Governance
A comment suggested that the plan should include a discussion on governance and referenced the NRC report which also suggested that this issue should be investigated. The comment suggested that the Services should pull language from the NRC report and the comments received to help create this new section. The DSF suggests a review of the literature on the topic of natural resource “co–management” and referenced lobster fisheries co-management in Maine as one example of an alternative and reasonably successful structure that should be reviewed.

Response: The Recovery Plan recommends that 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. The Plan acknowledges that there are many organizations and groups involved in the protection and recovery of Atlantic salmon. Ensuring inter-organizational coordination and communication mechanisms are in place will increase the effectiveness and efficiency of these groups. The implementation schedule in the recovery plan identifies responsible entities for each of the recovery plan actions. There are a number of organizations, agencies, individuals and industries involved in Atlantic salmon protection and recovery as noted in the NRC report. By assigning responsibility appropriately for carrying out activities, the plan describes roles for each of these groups in recovery implementation. The recovery plan implementation team will also coordinate actions and help reduce the potential for overlap. The Recovery Plan has been revised to include an expanded discussion of the issue of governance as it relates to the recovery of the DPS. The Services agree that the complexity of the multiple state, federal, local and private groups involved in salmon recovery or related activities presents specific challenges that must be addressed if recovery is to be successful.

Comment 17: River-specific recovery planning
Several comments stated that the recovery plan did not address recovery action at a river-specific scale. These individual state that the plan does not make any attempt to address individual rivers, identify unique threats to salmon in each and describe actions necessary to address each threat. In addition, the comments state that the threats identified in the plan are not the most important in all watersheds.

Response: The Recovery Plan considers threats to the DPS at a river-specific scale and discusses regional differences that exist between various watersheds and regions in Maine. The Recovery Plan identifies site-specific management actions for all the threats the Services have identified under Section 4(a)(1) of the ESA five-factor analysis. The Services acknowledge that the Recovery Plan does not present comprehensive river specific recovery strategies for each of the rivers still known to support wild salmon populations. The Services agree that recovery implementation may be further facilitated by the development of watershed or river-specific management plans that would include and highlight those threats and accompanying actions applicable within that particular area. The Recovery Plan acknowledges ongoing recovery implementation activities that are currently responsive to the specific circumstances within individual watersheds (e.g., NPS surveys, nutrient management plans in the Sheepscot, liming project Downeast). Management plans for specific issues of concern have been developed, or are envisioned, for many of the rivers and watersheds within the DPS. For example, the Maine ASC has been working to develop river-specific fisheries management plans for individual DPS rivers. The State of Maine, working in cooperation with multiple public and private partners, has developed a water use management plan (WUMP) for the Narraguagus and Pleasant rivers and for Mopang Stream (a tributary to the Machias River) The WUMP was developed to address a specific issue (i.e., agricultural water use) that was a concern in these three rivers. In a number of instances, local conservation organizations have begun the process of developing river-specific management plans for specific issues.

Comment 18: Pesticides
The Services received a number of comments related to pesticides. Comments provided by the State of Maine questioned the factual basis of statements in the draft plan that drift of hexazinone from aerial applications has been documented. The State stated that it had no documentation of hexazinone drift in its records. The DSF commented that the plan did not adequately present the extent of pesticide use and the threat to the DPS posed by DPS by this activity. The Services received comments that the threat from pesticides warrants consultation between the Services and the EPA on the effects of pesticide registration on the DPS. This commenter stated that pesticides should not be used until this consultation has taken place. Further, these comments stated the view that the recovery plan does not place a high enough priority on measures to control pesticide use. Lastly, the comments stated that no pesticides can be discharged into DPS waters without a CWA, NPDES permit.

Response: The Services have revised the recovery plan based on public comments received. An assessment of the magnitude and severity of the threat posed to the survival and recovery of the DPS by chemical contaminants resulted in the conclusion that pesticides currently are not a high-level threat to the DPS recovery. The recovery plan identifies a number of recovery actions related to continued monitoring of any threat to the DPS related to pesticides. Should water quality or other data indicate that pesticides applied in accordance with approved labeling instructions may be adversely affecting the DPS, the Services will consult with the U.S. Environmental Protection Agency (EPA) to address any potential impact to the DPS.

APPENDIX 7: PUBLIC AND PEER REVIEW COMMENTS

The Services received comments from a wide range of stakeholders and interested parties including state, federal and local government agencies, local stakeholder groups, NGOs, industry and private citizens. The comments received ranged from endorsements of the plan to disagreement with specific as well as general elements contained in the plan. Many of the comments received provided technical corrections and additional information for the Service's consideration in the preparation of a final plan. The Maine ASC coordinated the review of the draft plan by state agencies. The State agencies involved in the Plan review were the ASC, DMR, IFW, DEP, DAFRR, BPC, DOC, BPL, MFS, MGS, DOT and SPO.

In addition to public review, the recovery plan underwent peer-review. The Services and the state identified and contacted 27 peer reviewers with specific technical and other relevant expertise, requesting review and comments on the draft recovery plan. These individuals were asked to review relevant sections of the plan for technical accuracy and completeness. The peer-reviewers were also asked to identify any specific issues or information that the Services should consider in the preparation of a final draft plan. The Services received 8 responses from the individuals contacted.

Complete copies of the public and peer-review comments received by the Services are available on request from:

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APPENDIX 8
RECOVERY ACTIONS

Priority	Task	Task Description	Duration	Lead Agency: Federal	Lead Agency: State & Other	Estimated Cost: Year 1	Estimated Cost: Year 2	Estimated Cost: Year 3	Comments
2	1.1.1A	Conduct IFIM studies on additional DPS rivers to determine flow requirements of juveniles	3 years	USGS, FWS, NMFS	ASC		75K	75K	outyear costs TBD
2	1.1.1B	Determine flow requirements of adult Atlantic salmon in DPS rivers	5 years	USGS, FWS, NMFS	ASC				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
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	92K	92K	92K	annual implementation for duration of recovery
1	1.1.2D	Monitor and assess the potential for groundwater withdrawals to impact stream flow and cold water discharges	Long-term	FWS USGS	DAFRR MGS DEP LURC Industry	100K	100K	100K	Action initiated, outyear costs for monitoring TBD
2	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	DAFRR, Industry 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	DAFRR MGS, DEP, LURC Industry	100K	100k	100K	
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
2	1.1.3D	Develop water use management plans for other DPS rivers	3 years	FWS	DAFRR, Industry 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	DAFRR DEP LURC Industry		20K		outyear costs TBD
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 DAFRR Industry	45K	45K	45K	
1	1.1.4B	Issue and enforce all appropriate permits for water withdrawals	Long-term	ACOE FWS	DEP, LURC DAFRR Industry	10K	10K	10K	annual implementation for duration of recovery, action ongoing
2	1.1.5B	Review current water management for the dams and develop an assessment of the effect of regulation on a watershed's hydrology and thus Atlantic salmon habitat							costs TBD
3	1.1.5A	Review current water management for the dams and develop an assessment of the effect of regulation on a watershed's hydrology and thus Atlantic salmon habitat.							Costs TBD
3	1.2.1	Review existing water quality standards for each river within the DPS to determine adequacy to meet the needs of Atlantic salmon	1 year	FWS	ASC DEP			3K	3K every 3-5 years to review standards.
1	1.2.2A	Evaluate the impacts of acid rain on juvenile Atlantic salmon survival in DPS rivers	3 years	USGS, NMFS EPA	ASC, DEP, UM, NGOs	75K	75K	75K	

APPENDIX 8
RECOVERY ACTIONS

				Lead Agency		Estimated Cost			
Priority	**Task**	**Task Description**	**Duration**	**Federal**	**State & Other**	**Year 1**	**Year 2**	**Year 3**	**Comments**
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	NMFS FWS USGS	ASC, DEP, NGOs	250K	120K	120K	based on results of pilot study evaulate additional funding needs in out years
1	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 NMFS	DEP		25K	25K	outyear costs TBD, funding needs may include modeling needs
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 NMFS	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				Costs TBD
1	1.2.2F	Evaluate the biological effects of low pH and aluminum and its toxicity on Atlantic salmon	3 years	USGS EPA FWS NMFS	DEP UM	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
1	1.2.2J	Evaluate the link between pesticides and endocrine disruption	3 years	USGS EPA FWS NMFS	DEP, UM, BPC	75K	75K	75K	
2	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 NMFS	BPC, DEP, ASC	75K	75K	75K	
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
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 NMFS FWS	ASC, DEP	45K	45K	45K	
2	1.2.2L	Continue State program to replace OBDs	3 years		DEP				currently ongoing, cost estimates povided by State states "several projects on DPS rivers could easily be in the several million dollars."
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	100K	100K	100K	Outyear costs TBD
2	1.2.3B	Implement a comprehensive and integrated long-term water quality monitoring program on all DPS rivers							Costs TBD
3	1.2.3C	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	Long-term	FWS USGS	DEP NGOs Industry			10K	outyear costs TBD
1	1.2.4B	Evaluate the impacts of sedimentation on habitat quantity and quality including relationship between substrate embeddedness and habitat productivity in DPS rivers.		NMFS, FWS, USGS	ASC NGOs				Costs TBD

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2	1.2.4A	Prepare and implement NPS pollution reduction plans for DPS rivers	3 years	FWS NMFS EPA	ASC DEP MFS SWCD NGOs	100K	100K	100K	Action initiated, Outyears costs TBD
2	1.2.4C	Prepare and implement Point Source pollution reduction plans for DPS rivers	2 year	EPA	DEP		32K	Y3 Costs TBD	currently ongoing, cost estimates povided by State states "several projects on DPS rivers could easily be in the several million dollars."
3	1.2.4D	Fully implement EPA aquaculture wastewater and effluent discharge regulations	Duration TBD	EPA FWS	DEP				Costs TBD
2	1.2.4E	Continue monitoring of the remediation efforts at the Eastern Surplus Superfund site in Meddybemps	periodic	EPA	DEP		15K	15K	outyear costs TBD
2	1.2.4F	Address any ground water problems at the Smith junkyard on the Dennys River and restore the site	Duration TBD	EPA	DEP				costs TBD
2	1.3.1A	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	Has been Repaired
2	1.3.2	Identify and improve culverts or other road crossings that impede salmon passage	Long-term	FWS NRCS NMFS	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
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
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	1.4.1B	Promote the adoption and use of BMPs by landowners and compliance with these voluntary standards	Long-term		MFS landowners NGOs		25K	25K	Action ongoing
1	1.4.1C	Identify riparian zone activities (e.g., harvest practices, ATVs, development etc.) and evaluate impacts on Atlantic salmon	Long-term		MFS Industry ASC NGOs			25K	Outyear costs TBD
2	1.4.1D	Evaluate current state and local land use regulations to determine adequacy of existing measures protecting riparian habitat and instream improve if appropriate	2 year	NRCS FWS	ASC LURC MSPO MFS DAFRR		25K	25K	
2	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
2	1.4.2A	Evaluate the potential for activities in estuaries to adversely affect Atlantic salmon	Long-term	NMFS FWS ACOE		45K	45K	45K	
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	NMFS FWS ACOE		45K	45K	45K	
1	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 NMFS	ASC NGOs			32K	periodic needs assesment throughout recovery

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3	1.5.2B	Identify, catalogue and prioritize habitat restoration needs in estuarine habitat of DPS rivers	2 years	FWS NMFS	ASC NGOs			32K	
1	1.5.3	Conduct high priority restoration projects	Long-term	NRCS	ASC MFS MDOT NGOs			300K	outyear costs TBD, based on the outcome of 1.5.2A & 1.5.2B
1	1.5.5	Evaluate the ecological role and importance of restoring other diadromous fish populations							Costs TBD
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		60K	60K	Based on initial evaluation additional funding needs TBD
1	2.1.1	Maintain and enforce the closure of the directed sport fishery for Atlantic salmon	Long-term	NMFS 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	NMFS NEFMC					Periodic amendment of FMP as needed. Costs to be determined (TBD)
1	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	NMFS	ASC	30K	30K	30K	outyear costs TBD
2	2.1.3B	Continue US participation in the international sampling program at West Greenland	Long-term	NMFS		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	NMFS USDOS Intnl. Partners		70K			Y1 NMFS 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
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				Monitoring and Enforcement costs TBD
1	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				Costs TBD
2	2.2.2A	Assess the potential risk for incidental take of Atlantic salmon in marine and estuarine fisheries	3 years	NMFS	DMR ASC	45K	45K	45K	Action precursor to action 2.2.2B
2	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	NMFS	DMR, ASC				Costs TBD, action contigent on completion of action 2.2.2A
2	2.2.2C	Increase observer coverage in the midwater trawl herring fishery to improve the ability to assess the potential for Atlantic salmon bycatch in the herring fishery.		NMFS NEFMC	DMR				Costs TBD
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 NMFS	ASC IFW DMR		20K		Action should be conducted in association with 3.1.3A & 3.1.3B

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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 NMFS	ASC UM		25K	25K	
3	3.1.1D	Assess the potential of land and water use practices to exacerbate predation rates	2 years	FWS NMFS	ASC			25K	outyear costs TBD
2	3.1.2A	Evaluate the potential of cormorant predation to adversely affect the recovery of the DPS	3 years	FWS NMFS	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 NMFS	ASC	20K	20K	20K	20K in Y4
1	3.1.2C	Evaluate the potential of conserving and restoring runs of anadromous forage species to provide a buffer against predation on salmon and other ecological benefits	Long-term	FWS NMFS	ASC IFW DMR			100K	outyear costs TBD
2	3.1.3A	Evaluate the effect of seal predation on the recovery of the DPS	Duration TBD	FWS NMFS	ASC				Action should be conducted in association with 3.1.1A & 3.1.3B
2	3.1.3B	Document and monitor the presence and abundance of seals at natural and man-made concentration sites	3 years	NMFS FWS	ASC UM		25K	25K	Action should be conducted in association with 3.1.1A & 3.1.3A
2	3.1.3C	Conduct research to determine the role of net pen sites in seal aggregation and salmon predation	3 years	NMFS FWS	ASC UM		25K	25K	outyear costs TBD
2	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	NMFS	ASC UM			35K	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	NMFS 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	NMFS FWS	ASC, UM				costs TBD
1	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	NMFS FWS	ASC IFW	5K	5K	5K	review annually for duration of recovery period
1	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	NMFS 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	NMFS FWS	IFW ASC	30K	30K	30K	Action should be conducted in conjunction with 3.2.1B
1	3.2.1E	Develop a Section 10(a)(1)(B) habitat conservation plan for existing stocking programs and, if warranted and implement	1 year	FWS	ASC IFW			50K	2 years development; implementation costs TBD

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				Federal	State & Other	Year 1	Year 2	Year 3	
1	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	Outyear costs TBD
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 NMFS FWS	DMR ASC		30K	30K	coordination/consultation at estimated cost 30k/year for duration of recovery
1	4.1B	Develop fully functional containment management systems for the containment of farmed salmon at marine sites.	Long-term	ACOE NMFS 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 NMFS FWS	DMR Industry				Action initiated, Plans developed for all exisitng sites, Implementation cost estimates not avilable
2	4.1D	Develop and maintain an inventory tracking system for all marine aquaculture facilities	Long-term	NMFS 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	NMFS	Industry, UM, DMR		15K	15K	
2	4.2.1	Develop and implement contingency measures in case of accidental release of farmed fish	Long-term	NMFS ACOE FWS	ASC Industry	10K	2K	2K	Outyear costs TBD
2	4.2.2A	Maintain existing weirs on DPS rivers to minimize aquaculture escapees spawning, enable data collection and collect broodstock	Long-term	NMFS FWS	ASC Industry	132K	264K	264K	operation/maintenance costs 66K/weir/year
2	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	NMFS FWS	ASC Industry	831K			565K for site/construction Machias weir; 266K for site/construction E.Machias weir
2	4.2.3	Mark all farmed salmon prior to placement into marine net-pens	Long-term		Industry	100K	100K	100K	outyear costs TBD
2	4.2.4	Discontinue the culture of non-North American salmon	5 years	ACOE NMFS FWS	Industry				Action should be implemented immediately
2	4.2.5	Prohibit the placement into marine net-pens of reproductively viable transgenic salmon		ACOE NMFS FWS	DMR Industry				effective immediately
3	4.2.6	Continue research into developing strains of aquaculture fish that cannot interbreed with wild Atlantic salmon	Duration TBD		Industry UM			75K	
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 NMFS FWS ACOE	Industry DMR NASCO	200K			MASCP estimates 200K to plan; implementation costs TBD
2	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 NMFS FWS ACOE	DMR Industry NGOs ASC	50K	50K	50K	costs for development; implementation costs TBD
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	NMFS FWS	ASC DMR				costs TBD
2	4.3.1E	Expand the FWS Wild Fish Health Survey to include DPS rivers	Long-term	FWS	ASC	20K	20K	20K	outyear costs TBD
2	4.3.1F	Implement biosecurity and disinfection protocol for all research and assessment activities being conducted in rivers within the DPS		NMFS FWS EPA USGS	ASC DMR IFW				Costs TBD

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1	4.3.2A	Determine the modes of transmission of the ISA virus	3 years	USDA NMFS FWS	DMR Industry				Need for additional research to be asesed 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	NMFS USDA	DMR Industry	120K	120K		Need for additional research to be asesed for out years
2	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	NMFS	Industry DMR	120K	120K	120K	Action initiated
2	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
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 NMFS	Cornell U. ASC			25K	Completed?
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	NMFS 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
2	4.3.3C	Continue treatment for sea lice at aquaculture facilities	Long-term	USDA	Industry DMR UM				Action ongoing
2	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 NMFS FWS	Industry DEP DMR				1 year development; ongoing implementation
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 NMFS FWS	Industry DEP DMR		30K	30K	1 year development; ongoing implementation
2	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	ASC, TAC	60K	63K	66K	
1	5.1.2	Monitor and evaluate the current stocking program	Long-term	NMFS 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	NMFS FWS	ASC, TAC, Industry	50K	50K	50K	outyear costs TBD
2	5.1.3B	Continue to assess and evaluate the results of the adult stocking program	2 years	NMFS	ASC, TAC				
2	5.1.3C	Evaluate the role of streamside incubation facilities to supplement wild salmon populations	5 years	NMFS 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	NMFS FWS	ASC, TAC				See task 5.1.4B

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1	5.1.4B	Establish experimental populations to assist in the recovery of the GOM DPS of Atlantic salmon		NMFS FWS	ASC, TAC		120K	120K	
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	NMFS FWS, USGS	ASC	50K	50K	50K	Need for additional research to be asesed for out years
2	5.2.3B	Conduct research on other pathogens to identify potential threats to the DPS		NMFS FWS	ASC		15K		See Recovery Action 5.2.3C
2	5.2.3C	Initiate screening and long-term monitoring of resident fish species in DPS rivers for endemic and exotic salmonid pathogens	Long-term	NMFS FWS	ASC	20K	20K	20K	See task 5.2.3B
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
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 NMFS	ASC				Costs TBD
2	6.3	Explore methods for long-term preservation of gametes and genes for future use (e.g., cryopreservation)	3 year	FWS, NMFS, USGS	ASC UM		15K	30K	Outyear costs TBD
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 NMFS	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		ASC	10K	10K	10K	outyear costs TBD
2	7.1.1D	Continue development of DPS-level estimates of spawning escapement	Long-term	NMFS	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	NMFS	ASC, TAC				Method should be periodically reviewed and revised as appropriate
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	NMFS	ASC	100K	100K	100K	Out year costs TBD
2	7.1.2B	Expand assessments of large parr abundance to a third DPS river	Long-term	NMFS	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	NMFS	ASC, TAC		50K	50K	Annual action, outyear costs TBD

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1	7.1.3	Conduct quantitative assessments of Atlantic salmon smolt production	Long-term	NMFS	ASC	250K	250K	250K	Annual assessment and monitoring
1	7.1.4A	Continue telemetry studies of smolt migration from the Dennys and Narraguagus rivers	3 years	NMFS	ASC	100K	100K	100K	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	NMFS	ASC		283K	283K	
1	7.1.4C	Continue post-smolt surface trawling assessment programs and expand the temporal and spatial extent of coverage	3 years	NMFS		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	NMFS FWS	ASC	150K	150K	150K	Out year costs to be determined ES etc.
2	7.1.6	Develop and apply population viability analysis model	1 year	NMFS FWS	ASC	25K			Action initaiated, model being developed by NEFSC
2	8.1A	Develop and implement a comprehensive Education and Outreach Plan for the Gulf of Maine DPS of Atlantic salmon	Long-term	NMFS FWS	ASC		75K	75K	2 years development; implementation costs TBD
2	8.1B	Continue efforts to educate anglers on the difference between trout and juvenile salmon	Long-term	NMFS FWS	ASC IFW DMR		15K	15K	Action ongoing, long-term efforts required
3	8.1C	Develop updated educational programs for schools	Long-term	NMFS FWS	ASC			10K	Materials/programs should be periodically reviewed and updated as appropriate throughout the recovery period
3	8.1D	Evaluate the role of public display of salmon as an outreach tool	1 year	NMFS FWS					
1	8.2	Maintain, and if necessary increase, coordination/communications between government and local agencies on issues pertaining to Atlantic salmon recovery	Long-term	NMFS FWS	ASC				Costs TBD
3	9.1	Appoint a Recovery Implementation Team to coordinate implementation of recovery plan objectives		NMFS 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	NMFS 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	NMFS FWS	ASC		5K	5K	Long-term action
3	9.3	Complete necessary addenda, updates and revisions to the Recovery Plan	Long-term	NMFS FWS	ASC				Costs TBD, recovery plan should be revised and updated as necessary throughout the recovery process
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	NMFS FWS	ASC		25K	25K	outyear costs TBD