Prospectus on Status and Conservation Science for Gulf of Maine Atlantic Salmon

GOM DPS History - US Atlantic salmon once ranged from the Housatonic River, Connecticut to the St. Croix River on the international border with Canada (Fay et al. 2006). Four Distinct Population Segments (DPSs) were identified. Three DPSs, Long Island Sound (LIS), Central New England (CNE), and Gulf of Maine (GOM), lie entirely within US borders. The fourth, the Outer Bay of Fundy Designatable Unit (BOF DU), spans the US and Canada border and is managed under Canadian jurisdiction (Fay et al. 2006). LIS and CNE DPSs are considered extirpated and Federal hatchery restoration efforts ceased in 2013. GOM and BOF contain extant stocks but abundances are much reduced from historical numbers. Conservation Spawning Escapement (CSE), the number of adult salmon needed to fully seed all juvenile rearing habitats, has not been achieved for any US DPS in recent history and averages less than 5%. The GOM DPS was listed as Endangered under the ESA in 2009 with nine remnant stocks identified (USOFR 2009a). One stock, in the Penobscot River tributary Cove Brook, has since been extirpated. Conserving the remaining genetic diversity is essential to the long-term resilience of the species to environmental stochasticity and other threats.

Genetic Baselines - DPS designations were determined on the basis of zoogeographical conditions and genetic analysis that showed a regional cluster of sub-populations (Fay et al. 2006). NRC (2002 and 2004) described the GOM DPS as “Maine salmon,” not just “salmon in Maine.” The high degree of fidelity to natal rivers in Maine has resulted in local adaptation and genetic isolation (Fay et al. 2006). The isolation is evident in the structure of river-specific stocks within the GOM and genetic differences from neighboring stocks in Canada (Spidle et al. 2003). These differences are not only evident in genetic markers but have also been seen in studies documenting local adaptation for somatic and early life history traits (Wilke and Kinnison 2011, Obedzinski and Letcher 2004) and adult morphology (Sheehan et al. 2005). Managing the current low abundance levels requires a balance between maintaining local adaption (Spidle et al. 2003) and increased risk from loss of genetic diversity (Lage and Kornfield 2006).

Recovery Approach - Current restoration efforts are focused on maintaining existing genetic variation in terms of both abundance and spatial distribution. A multi-agency recovery strategy has been developed from the Viable Salmonid Population (VSP) approach (McElhany et al. 2000). Efforts have focused on defining biologically relevant population structure and measuring progress toward goals necessary for population stability: spatial distribution, abundance, population growth, and diversity (genotypic and phenotypic). For the GOM DPS, this approach resulted in the definition of three Salmon Habitat Recovery Units (SHRUs). In each SHRU, recovery benchmarks include abundance levels of 2,000 wild origin Atlantic salmon (50:50 male:female) with 30,000 metric units ($100m^2$) of fully accessible rearing habitat (USOFR 2009b). These criteria are evaluated and monitored annually using adult return metrics, spatial surveys, and systematic habitat assessments. ***Population size*** metrics include total adult returns to the GOM DPS and returns by SHRU. ***Growth rate*** is monitored through replacement rates. ***Spatial structure*** is monitored by tracking habitat accessibility (passage above barriers) and juvenile rearing habitat occupied through wild spawning or stocking. ***Genetic diversity*** is monitored through several metrics (e.g., allelic variation, heterozygosity) based on molecular markers; this assessment occurs during annual collection of broodstock from the wild.

Agencies are currently working toward recovery of the GOM DPS but benchmarks have not yet been met. Current status is that less than 25% of abundance targets and 78% of habitat targets are being met for any SHRU (**TABLE 1, TABLE 2**). The current spatial structure is disproportionate with 8 stocks distributed across the three SHRUs (**FIGURE 1, TABLE 2**). The genetic diversity metric of effective population size is below 100 for 5 of 7 monitored stocks. Because of the current status, sea-run adults are greatly supplemented by an intensive conservation hatchery program to help maintain stocks within the GOM DPS.

Many agencies participate in the monitoring and recovery of GOM Atlantic salmon. National Oceanic and Atmospheric Administration (NOAA) efforts are coordinated under the umbrella of the Northeast Salmon Team (NEST) with staff and contractors from the Northeast Fisheries Science Center (NEFSC), Greater Atlantic Regional Fisheries Office (GARFO), and Habitat Restoration Center (**ASN02**). Domestic Assessments are conducted by the interagency Atlantic Salmon Recovery Assessment Action Team and reviewed and reported through the US

Atlantic Salmon Assessment Committee (**ASN03**). These US assessments are then submitted to the Working Group on North Atlantic Salmon (WGNAS) within the International Council for the Exploration of the Sea (ICES) for further review and use by the North Atlantic Salmon Conservation Organization (NASCO) in international management (**ASN04**).

SHRU Synopsis

Downeast Coastal - The Downeast Coastal SHRU is comprised of small coastal drainages including: the Dennys, East Machias, Machias, Narraguagus, Pleasant, and Union Rivers. These rivers are home to five of the eight remnant stocks of Atlantic salmon in Maine. Dams are a minor issue for Atlantic salmon in the DE SHRU. Only the Narraguagus and Union Rivers presently have dams but both include passage facilities. Several other small fish passage structures are maintained at natural ledges and falls that may be barriers to passage during specific flow regimes. Due to the geology of the SHRU, water quality may be an issue for Atlantic salmon recovery. River-specific hatcheries operated by non-governmental organizations (NGOs) in the East Machias (EM Hatchery) and Pleasant Rivers (Pleasant Hatchery) provide unique capacity and co-management. In addition, local aquaculture net pens may pose a threat to Atlantic salmon through disease and competition from escapees. Poor marine survival/productivity significantly constrains population recovery.

Penobscot Bay - The Penobscot Bay SHRU drains the entire Penobscot River watershed which includes the East and West Branches of the Penobscot, the Piscataquis, and Mattawamkeag. The SHRU also includes Cove Brook (extirpated) and the Ducktrap River (remnant stock) that empties into Penobscot Bay. Dams are a major issue in the Penobscot SHRU with three mainstem dams and numerous smaller dams located within sub-basins and tributaries. The alteration of flow regimes due to the highly managed basin may pose thermal barriers to both emigrating juvenile and returning adult Atlantic salmon. Historic log drives, paper and lumber mills have left relict deposits of sawdust and wood chips in the estuary that may be problematic for Atlantic salmon migration. The Penobscot River stock is maintained primarily by smolt stocking and the Ducktrap River stock does not have any hatchery support. Poor marine survival/productivity significantly constrains population recovery.

Merrymeeting Bay - The Merrymeeting Bay SHRU is composed of two regions – highlands and lowlands. The highlands include the Dead, Sandy, Carrabassett – tributaries of the Kennebec and the upper Androscoggin. The lowlands include the Sheepscot, Damariscotta, Medomak, and St. George. The Sheepscot River is now the southernmost remnant North American stock of Atlantic salmon. Hydroelectric dams and associated fish passage are a major issue on both the Kennebec and Androscoggin Rivers. The Sandy River is being recovered with novel egg planting techniques using Penobscot strain as a donor stock. In the lower portions of the SHRU, agriculture and urbanization pose a threat to water quality for Atlantic salmon river and estuarine habitats. Poor marine survival/productivity significantly constrains population recovery.

Science Approach - To support domestic ESA management needs and international treaty obligations, the NEFSC has taken a three-pronged approach to the science supporting these management enterprises. Two of the primary threats identified by review panels and managers are dam-related mortality and increased mortality at sea (NRC 2004, Fay et al. 2006). The NEFSC approach to these two threats is briefly described below and is more broadly summarized in the Program Highlights document - Partitioning Marine Threats and Quantifying Dam Impacts (**ASN05**). The third approach to salmon conservation science is summarized in the Program Highlights document: Salmon Recovery and Restoring Ocean-River Connectivity: Partnering to Assess Change in Diadromous Ecosystem Structure and Function **(ASN06)**. This ecosystem-based approach to recovery focuses not just on Atlantic salmon but the broader diadromous fish community. The ecosystem-based approach is supported by all three NOAA partners in the NEST but would not be possible without additional partnerships with the State of Maine, conservation groups, NGOs, and universities.

Addressing Marine Threats by Identifying Bottlenecks - Gulf of Maine Atlantic Salmon are at the southern edge of the species' North American range, and therefore undertake extensive ocean migrations into the North Atlantic. Increased natural mortality at sea is considered a primary threat that constrains recovery of this endangered species. As such, at-sea conservation takes an international approach (**ASN04**). Domestically, our goal is to partition ocean use in time and space to better investigate and understand limiting factors (**ASN05**). We used multiple methods: smolt trapping, marking, acoustic and satellite telemetry, pelagic trawls, fishery sampling, and modeling. For smolts, estuaries act primarily as corridors (not nurseries) and migration is shifting earlier in response/adaptation to changing climate. Hatchery smolts differ in their early marine diets and despite similar epipelagic migratory patterns have lower ocean survival than naturally-produced fish. Migration continues at a rapid pace with postsmolts exiting US waters in three weeks. Primary marine feeding areas are the Labrador Sea and the coast of West Greenland and although marine diets have remained relatively stable, total energy consumed has decreased. Modeling has identified that climate and ecosystem drivers of Northwest Atlantic conditions directly and indirectly influenced salmon abundance and productivity. While at sea, US Atlantic salmon are exploited in numerous foreign mixed-stock fisheries. NEFSC staff actively participates in the International Council for the Exploration of the Seas Working Group on North Atlantic Salmon (WGNAS). We oversee the monitoring and sampling of the West Greenland fishery and collect and provided critical input data for international stock assessments conducted by WGNAS. We work with international collaborators to develop estimates of US contributions from mixed-stock fisheries where US stocks are exploited. We serve on the US Delegation to NASCO and provide scientific advice to support the development of regulatory measures for these fisheries and the international management of the species. We lead and participate in numerous international collaborative studies, both through and independent of NASCO, to further our knowledge on the marine ecology of Atlantic salmon.

Quantifying and Minimizing Dam Impacts - Dams are a major contributor to the historic decline and current low abundance of diadromous species, including Atlantic salmon, which is listed as endangered in Maine under the Endangered Species Act (**ASN05**). We developed a population viability analysis to quantitatively evaluate the impact of fifteen federally licensed hydroelectric dams on Atlantic salmon dynamics in the Penobscot River, Maine. We used a life stage-specific model to compare the population dynamics of the current state of dam passage success to scenarios with increased dam passage success and increased marine and freshwater survival rates. Adult abundance, distribution of adults throughout the watershed, and number and proportion of smolts killed by dam-induced mortality were used as performance metrics for each scenario. The combination of spatial location and passage success was important to the impact of each dam. This model is being used to support the establishment of performance standards for federally licensed hydroelectric facilities and will help prioritize future passage improvement efforts to minimize the impacts of hydroelectric facilities on the recovery potential of Atlantic salmon in the US.

Diadromous Ecosystems – Processes and Partners - Historically, efforts to restore Atlantic salmon in Maine have focused primarily on supplementing populations though stocking efforts using various life-stages (1800s–1995). Hatchery efforts have resulted in marginal success (living gene banks with static populations) and remain an important fish conservation tool to sustain populations until conditions limiting productivity and recovery can be improved. NOAA recognized a need to go beyond hatchery efforts and focus on key factors limiting production. In freshwater, these efforts are achieved by NOAA partnerships with the academic community and other organizations and agencies. Working collaboratively with fishery and habitat managers, Northeast Center (NEC) staff has served on and led numerous working groups, science steering committees, and graduate committees towards a common goal: restore the overall structure and function of healthy diadromous ecosystems (**ASN06**). This goal has focused NOAA extramural grants and contracts as well as helped partners to leverage funds from other sources. The first layer of this work focuses primarily on understanding connectivity issues and complements NEC dam impact analysis work. The second layer addresses broader ecosystem level processes towards a complete ecosystem approach to the conservation of both endangered Atlantic salmon and the broader diadromous community and associated river, estuary, and coastal ecosystems.

Integrating Science and Management with Stewardship - GOM Atlantic salmon are at critically low abundance despite decades of hatchery management. Threats have been well identified and a broader management approach is being undertaken through a coordinated federal, tribal, and state collaborative. NGO partners are expanding the breadth and capacity of these efforts. The ability for the species to thrive range-wide depends on the success of these recovery efforts. These efforts focus on preserving the remaining genetic diversity while maximizing survival at all life stages. Conservation hatchery practices are being refined to both maintain and enhance genetic diversity. Major threats such as hydropower dams that impede passage to essential headwater nursery habitat and disrupt migratory corridors are being reduced by removal (i.e., Penobscot River Restoration Project, NMFS General Conservation Plan) or implementation of quantitative performance (survival) standards (NMFS 2012). Nursery habitat is being improved through coordinated efforts to reduce pollution and restore altered habitat (i.e., Project SHARE, Machias River Project, Ducktrap River Preserve, Downeast Salmon Federation). Our understanding of marine issues is increasing thanks to technological and modeling advances that are explaining migration and survival dynamics in estuary, coastal, and offshore environments. Exploitation of the GOM DPS in the North Atlantic is being monitored through international efforts to reduce impacts on US stocks.

These science and management enterprises can only be successful by bringing together multidisciplinary teams of scientists, outside partners, and the public. Our science team has an active, grassroots outreach program to both the science and management communities and the public (**ASN07**). The capstone of these efforts is the Atlantic Salmon Ecosystems Forum – a biennial meeting with oral and poster presentations, keynote speakers, invited presentations, and panel discussions on diverse topics pertaining to a suite of diadromous and coastal marine species. Despite having only ten staff and contractors, efforts such as the Forum combined with working group and professional society activities have allowed us to partner with well over one hundred other groups (**ASN08**) to further the conservation of Atlantic salmon ecosystems. The team is committed to data access and transparency and has both modernized databases used in interagency collaborative management and expanded data accessibility to cloud-based collaborative efforts such as the Ocean Tracking Network (**ASN09**). Together these efforts will provide the most comprehensive effort ever attempted at recovering Atlantic salmon in the US.

Table 1. Total area of modeled Atlantic salmon habitat (USOFR 2009a) predicted for each management area with source stock (river specific (RS) or SHRU specific) and Conservation Spawning Escapement (CSE) calculated from habitat units. Non-critical habitat represents habitat in the geographic area that is not designated as Critical Habitat.

SHRU	Management Area	Predicted Potential Habitat Units (100 m^2)	Conservation Spawning Escapement (CSE)
Downeast (DE)		**61,395**	**3,559**
	Dennys (RS)	1,717	114
	East Machias (RS)	6,129	409
	Machias (RS)	14,964	998
	Narraguagus (RS)	6,500	433
	Pleasant (RS)	3,025	202
	Union (DE Mixed)	12,125	808
	Unmanaged	8,930	595
	Non-Critical Habitat	8,005	---
Penobscot (PN)		**323,742**	**16,277**
	Piscataquis (PN)	64,610	4,307
	Mattawamkeag (PN)	37,013	2,468
	East Branch (PN)	35,380	2,359
	Mainstem (PN)	70,954	4,730
	Ducktrap (RS)	862	57
	Unmanaged	35,335	2,356
	Non-Critical Habitat	79,588	---
Merrymeeting Bay		**372,640**	**9,855**
	Sheepscot (RS)	7,080	472
	Kennebec – Sandy River (PN)	43,137	2,876
	Androscoggin – Unmanaged	97,598	6,507
	Non-Critical Habitat	224,825	---

Table 2. Current accessible habitat area (Trinko Lake et al. 2011) and five-year mean adult salmon abundance (USASAC In press) with percent of recovery target for each GOM DPS SHRU in parenthesis.

SHRU	Current Accessible Habitat (units) [Percent Recovery Target of 30,000]	Current Wild Spawners Abundance, 5 year mean [Percent Recovery Target of 2000 individuals]
Downeast	23,389 (78%)	140 (7%)
Penobscot	7,703 (26%)	1,150 (58%)
Merrymeeting Bay	8,280 (28%)	50 (3%)

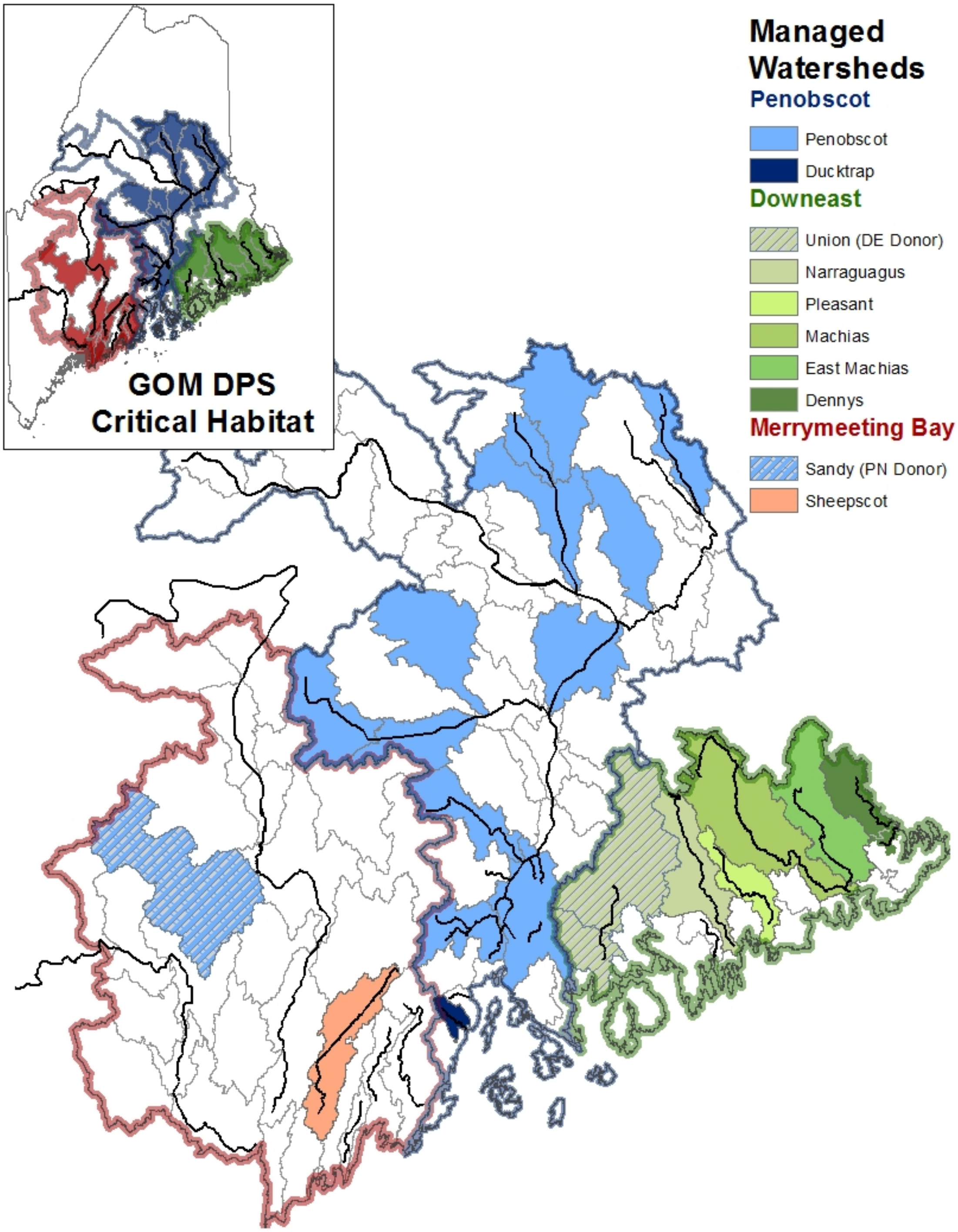

Figure 1. GOM DPS SHRUs – 2014. Inset map shows Downeast Coastal (green), Penobscot (blue), and Merrymeeting Bay (red) SHRUs – outline represents historic boundary; shaded areas are designated critical habitat. Primary map illustrates diversity distribution at the HUC-10 watershed; each shade represents a different stock, hash-marks represent donor stocks, and unshaded segments represent areas not currently managed (through stocking or spawning inventory).

Briefs Supporting this Prospectus

ASN02- Introduction to the Northeast Salmon Team

ASN03- Program Highlights: Assessment of Gulf of Maine Atlantic Salmon, Data Collection, ESA Assessment to US Atlantic Salmon Assessment Committee

ASN04- Program Highlights: Atlantic Salmon International Science and Management

ASN05- Program Highlights: Partitioning Marine Threats and Quantifying Dam Impacts

ASN06- Program Highlights: Salmon Recovery and Restoring Ocean-River Connectivity: Partnering to Assess Change in Diadromous Ecosystem Structure and Function

ASN07- Atlantic Salmon Science Outreach: Peers, Partners, and Public

ASN08- Atlantic Salmon Science: International and Domestic Partnerships

ASN09- Atlantic Salmon Data Access

ASN10- Science Products of the Atlantic Salmon Research and Conservation Task and Selected Northeast Fisheries Science Center Diadromous Fish Materials

Source Materials

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USOFR (U.S. Office of the Federal Register). 2009a. Endangered and threatened species; determination of endangered status for the Gulf of Maine distinct population segment of Atlantic salmon; final rule. Federal Register 74:117(19 June 2009):29344–29387. link

USOFR (U.S. Office of the Federal Register). 2009b. Endangered and threatened species; designation of critical habitat for Atlantic salmon (*Salmo salar*) Gulf of Maine distinct population segment; final rule. Federal Register 74:117(19 June 2009):29300–29341. link

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