The 2022 Atlantic Salmon Ecosystems Forum

January 11 and 12, 2022

In light of ongoing health and safety concerns regarding COVID-19, the 2022 Atlantic Salmon Ecosystems Forum is a fully virtual meeting.

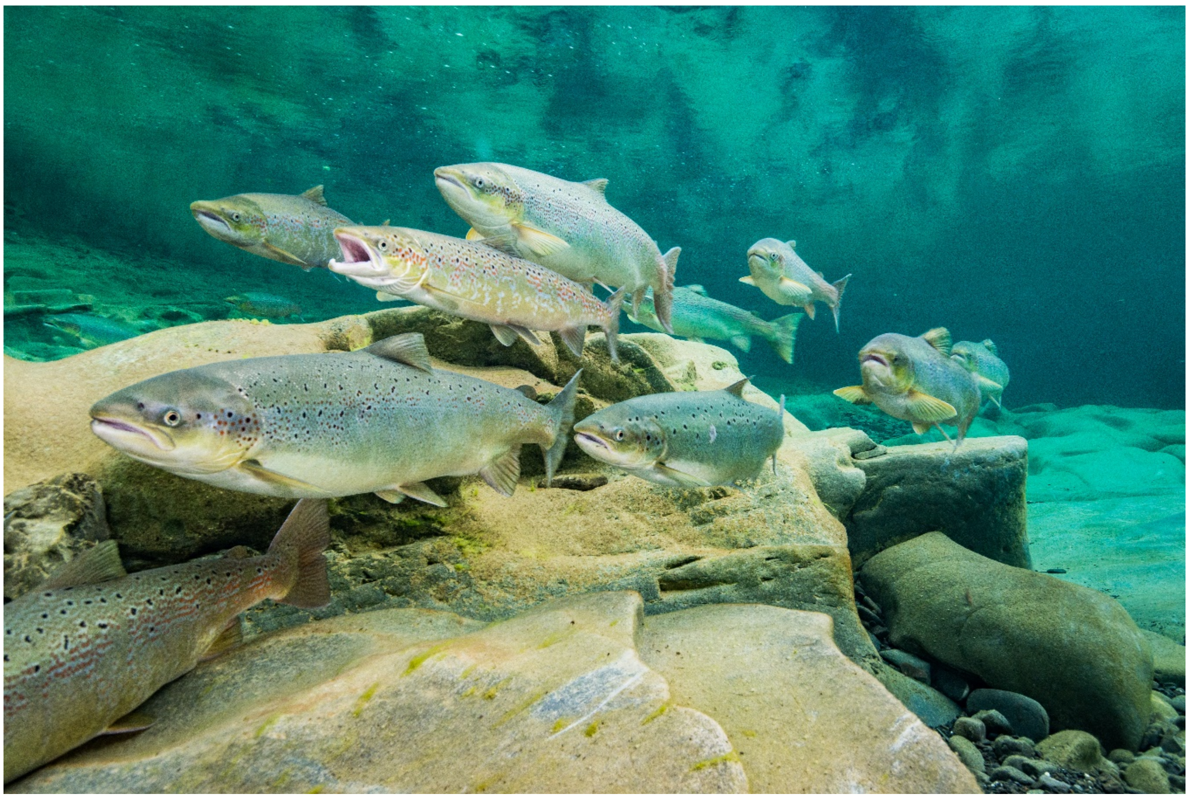

Photo credit: Nick Hawkins

Day 1 (January 11, 2022) Schedule

Note that only first authors are listed below and times are Eastern Standard Time.

Begin	End	January 11, 2022
8:30	9:05	**Housekeeping by the Organizing Committee and Opening Remarks by Patrick Keliher** (Commissioner of the Maine Department of Marine Resources, MDMR)
9:05	9:10	**Session 1 – Introduction** *Meredith Bartron, United States Fish and Wildlife Service (USFWS), moderator*
9:10	9:50	**Keynote - What I learned from Atlantic Salmon – How to survive and thrive as a natural resource manager** - *Mary Colligan, retired*
9:50	10:05	**Imagine a river without diadromous fish** - *Valerie Ouellet, National Marine Fisheries Service (NMFS)*
10:05	10:20	**What have we lost? American Shad's impounded history** - *Joseph Zydlewski, United States Geological Survey (USGS)*
10:20	10:50	**Break**
10:50	11:05	**U.S.-Origin Atlantic Salmon habitat and implications for the future** - *Elisabeth Henderson, Monterey Bay Aquarium Research Institute*
11:05	11:20	**Non-stationary effects of growth on the survival of North American Atlantic salmon (*Salmo salar*)** *– Michael Tillotson, Gulf of Maine Research Institute*
11:20	11:35	**Retrospective analysis of marine growth and relationships to return rates of Penobscot River Atlantic salmon –** *Miguel Barajas, Gulf of Maine Research Institute*
11:35	11:50	**The effect of multiple stressors, including aquaculture production cycle, on Atlantic Salmon post-smolt migration and survival** *– Brent Wilson, Fisheries and Oceans Canada*
11:50	12:00	**Announcements –** *Andy Goode, Atlantic Salmon Federation*
12:00	1:25	**Lunch**
1:25	1:30	**Housekeeping –** *Organizing Committee*
1:30	1:35	**Session 2 – Introduction** *Dan McCaw, Penobscot Nation, moderator*
1:35	2:05	**Invited talk - Looking beneath the surface of public perceptions about fish: Lessons from Maine to Alaska**, *Katrina Liebich, USFWS*
2:05	2:20	**Telling Our Story - Building a partnership for sea-run fish outreach and communications in Maine** - *Molly Payne Wynne, The Nature Conservancy in Maine*
2:20	2:35	**Finding fish: Engaging volunteers to help monitor Maine's sea-run fishes in a changing gulf** - *Danielle Frechette, MDMR*
2:35	2:50	**Collaborative management of the Atlantic Salmon program – an update** - *Julie Crocker, NMFS*
2:50	3:30	**Break**
3:30	3:45	**Regional conservation partnership projects (RCPP) focused on aquatic organism passage in Maine** - *Ben Naumann, Natural Resources Conservation Service*
3:45	4:00	**Collaboration towards recovery across the Sandy River watershed, headwaters of the Kennebec River, Maine** - *Maranda Nemeth*, *Atlantic Salmon Federation*
4:00	4:15	**Conservation aquaculture as a path to recovery: Salmon for Maine's rivers** - *Danielle Frechette, MDMR*
4:15	4:30	**Public perceptions of Atlantic Salmon conservation** - *Melissa Flye, University of Maine*
4:30	4:35	**Housekeeping –** *Organizing Committee*
4:35	5:00	**Break**
5:00	7:15	**Poster Session –** *Hosted by Justin Stevens, Maine Sea Grant*

Poster Session (January 11, 2022) Schedule

The poster session will be different this year – a virtual meeting requires some different thinking and a new approach. Our intent is to create a social and less formal space to support a virtual conversation about each poster. To that end, Justin Stevens (Maine Sea Grant) will lead a session where each presenter highlights their main findings and other participants have a chance to ask questions. Each presenter will have roughly 10 minutes. Like other poster sessions in the past, this one is held after the first day of the meeting and just before dinner. Unfortunately, there is no way to be together sharing refreshments this year. We did, however, keep the timing and less formal approach in hopes of maintaining the social feel of a "normal" poster session.

Note that only first authors are listed below and times are Eastern Standard Time.

Poster Session (5:00PM) **–** *Hosted by Justin Stevens, Maine Sea Grant*

Movement of Alewife around a hydroelectric dam on the Passadumkeag River - *Cody Dillingham, University of Maine*

American Eel personality and body size influence passage success in an experimental fishway – *Matthew Mensinger, University of Maine*

Motive, means and opportunity: Could Smallmouth Bass be a major predator of Atlantic salmon? – *Rylee Smith, University of Maine*

Evaluating sustainability metrics for River Herring populations during restoration – *Margaret Campbell, University of Maine*

Growth of Smallmouth Bass in rivers with a restoring River Herring run – *Maddy Young, University of Southern Maine*

Effects of logging practices on habitat complexity in the Machias River – *Eamonn Powers, The Pennsylvania State University*

Spatial and temporal distribution patterns of Double-Crested Cormorants (*Phalacrocorax auritus*) in the Penobscot Estuary during river restoration - *Hallie Arno, College of the Atlantic*

Demographic and evolutionary impacts of size selection at fishways on Atlantic Salmon - *George Maynard, University of Maine*

Effects of flow on system-wide survival and movement of Atlantic Salmon (*Salmo salar*) in the Penobscot River – *Alejandro Molina Moctezuma, University of Maine*

A grassroots ongoing effort to protect, preserve and restore wild native Atlantic Salmon – *Emily Bastian, Native Fish Coalition*

A collaborative organizational network analysis of the Cooperative Research Units Program – *Sarah Vogel, University of Maine*

Day 2 (January 12, 2022) Schedule

Note that only first authors are listed below and times are Eastern Standard Time.

Begin	End	January 12, 2022
8:30	8:35	**Housekeeping by the Organizing Committee**
8:35	8:40	**Session 3 – Introduction** *Amanda Cross, USFWS, moderator*
8:40	8:55	**Using dispersal data to optimize egg planting strategies for Atlantic Salmon** - *Ernest Atkinson, MDMR*
8:55	9:10	**Reproductive success of captive-bred and caught-and-released Atlantic Salmon assessed by microsatellite sequencing** - *Raphaël Bouchard, Laval University*
9:10	9:25	**Genetic diversity mapping for restoration of Atlantic Salmon to tribal waters** - *Michael Stover, United States Environmental Protection Agency*
9:25	9:40	**System-wide migratory delays of Atlantic Salmon (*Salmo salar*) in the Penobscot River, Maine** - *Erin Peterson, University of Maine*
9:40	9:55	**Using acoustic predator tags to characterize predation on Atlantic Salmon smolts** - *Matthew Mensinger, University of Maine*
9:55	10:10	**Dams may force semelparity in Atlantic Salmon** - *Sarah Rubenstein, University of Maine*
10:10	10:40	**Break**
10:40	10:55	**Long term biomonitoring of fish assemblages following large scale habitat restoration efforts in the Penobscot River, Maine** - *Kory Whittum, University of Maine*
10:55	11:10	**Measuring food web connectivity in the Penobscot River, Maine following dam removals** - *Matt Brewer, University of Southern Maine*
11:10	11:25	**Sea Lamprey migration and passage at Milford Dam -** *Danielle Frechette, MDMR*
11:25	11:40	**Rewriting the textbooks: Further evidence of life cycle diversity inferred from otolith microchemistry in River Herring** - *Justin Stevens, Maine Sea Grant*
11:40	11:55	**One health assessment of mercury, persistent organic compounds and PFAS for consumption of restored anadromous fish in the Penobscot River** - *Daniel Kusnierz, Penobscot Nation*
11:55	12:00	**Video Presentation** – **Allen Stream restoration projects open 15 miles of Atlantic salmon rearing habitat -** *Eileen Bader Hall, The Nature Conservancy in Maine*
12:00	1:25	**Lunch**
1:25	1:30	**Housekeeping –** *Organizing Committee*
1:30	1:35	**Session 4 – Introduction** *Ben Naumann, Natural Resources Conservation Service, moderator*
1:35	1:50	**Mapping baseflow by reach for streams with endangered Atlantic Salmon in Maine -** *Pamela Lombard, USGS*
1:50	2:05	**The response of benthic habitat and leaf breakdown rates to large wood restoration in the Narraguagus River, Maine: an ecosystem process perspective** - *Valerie Watson, University of Maine*
2:05	2:20	**Geomorphic effects and habitat impacts of large wood at restoration sites in New England** - *Audrey Turcotte, Boston College*
2:20	2:50	**Invited talk - Stream and watershed restoration prioritization** - *George Pess, NMFS*
2:50	3:20	**Break**
3:20	3:35	**Estimating stream flow from images in headwaters -** *Ben Letcher, USGS*
3:35	3:50	**Impact of three years of clam shell additions to an episodically acidic stream in Eastern Maine** - *Emily Zimmermann, Maine Department of Environmental Protection*
3:50	4:05	**Fish passage standards for several species on Maine's largest rivers** - *Casey Clark, MDMR*
4:05	4:30	**Awards and Closing Remarks by Michael Pentony** (Regional Administrator for the Greater Atlantic Regional Fisheries Office, NMFS)

Day 1, Morning

Moderator:

Meredith Bartron, United States Fish and Wildlife Service (USFWS)

Keynote Speaker:

What I learned from Atlantic Salmon – How to survive and thrive as a natural resource manager

Mary Colligan, retired

Just over twenty years ago, in the midst of great controversy and contention, Atlantic salmon were placed on the U.S. list of threatened and endangered species. While a great deal has been accomplished in increasing our understanding of the species and the co-evolved diadromous species complex and to increase connectivity in watersheds, recovery to its former state appears unlikely and perhaps that is not even the appropriate goal. In light of climate change impacts, a better focus may be to envision how Atlantic salmon could exist as part of the ecosystem in the future and how our actions today may facilitate that becoming a reality. Working on species of high conservation concern and strong public interest like Atlantic salmon, North Atlantic right whales, and polar bears provides a unique opportunity to experience the intersection of science and policy. Lessons learned working to address priority conservation challenges point to factors to optimize personal and professional success.

Imagine a river without diadromous fish

Valerie Ouellet, Integrated Statistics contractor for Northeast Fisheries Science Center, Orono, ME;
Mathias Collins, NOAA's Restoration Center, Gloucester, MA;
John Kocik, NOAA's Northeast Fisheries Science Center, Orono, ME
Rory Saunders, NOAA's Greater Atlantic Regional Fisheries Office, Orono, ME
Tim Sheehan, NOAA's Northeast Fisheries Science Center, Woods Hole, MA;
Matthew Ogburn, Smithsonian Environmental Research Center, Edgewater, MD;
Tara Trinko Lake, NOAA's Northeast Fisheries Science Center, Woods Hole, MA

Northeast Atlantic diadromous fish populations once supported extensive subsistence, commercial, and recreational fisheries. These fish also provided a suite of other ecosystem services, such as marine-derived nutrient delivery to freshwater streams. Today, many diadromous populations are near all-time lows due to overfishing, reduced river-ocean connectivity, habitat degradation, and low marine survival. Climate change is an additional stress that modifies terrestrial, freshwater, and marine ecosystems at potentially different rates, which may make adaptation harder for migratory species occupying more than one ecosystem. Diadromous fish are rarely assessed as a community, limiting our understanding of species interactions and their overall importance across the ecosystems they use to complete their life cycle. There is a need to better understand what ecosystem services these fish provide, both individually and as a community across their spatio-temporal range. We review the ecological roles of diadromous fish and describe some of the ways they enhance ecosystem connections. We also identify a series of research gaps and management needs to provide a path toward a more targeted ecosystem-based approach to managing this diverse suite of fishes and the concomitant services they provide. Even at low abundance, diadromous fish are crucial ecosystem architects, and their loss would result in reduced ecosystem functions, highlighting the importance of increasing species productivity in Northeast Shelf watersheds.

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What have we lost? American Shad's impounded history

Joseph Zydlewski, U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit, and University of Maine Dept. of Wildlife, Fisheries, and Conservation
Daniel S, Stich, Biology Department, SUNY College at Oneonta
Sam Roy, Senator George J. Mitchell Center for Sustainability Solutions, University of Maine
Timothy Sheehan, National Marine Fisheries Service, Northeast Fisheries Science Center
Kenneth Sprankle, Connecticut River Fish and Wildlife Conservation Office, U.S. Fish and Wildlife Service
Michael Bailey, U.S. Fish and Wildlife Service, Central New England Fishery Resource Office

American Shad (*Alosa sapidissima*) are native to the east coast of North America from the St. Johns River, Florida, to the St. Lawrence River region in Canada. Since the 1800s, dams have reduced access to spawning habitat. To assess the impact of dams, we estimated the historically accessed spawning habitat in coastal rivers (485,618 river segments with 21,113 current dams) based on (i) width, (ii) distance from seawater, and (iii) slope (to exclude natural barriers to migration) combined with local knowledge. Estimated habitat available prior to dam construction (2,752 km^2) was 41% greater than current fully accessible habitat (1,639 km^2). River-specific population models were developed using habitat estimates and latitudinally appropriate life history parameters (*e.g.,* size at age, maturity, iteroparity). Estimated coast-wide annual production potential was 69.1 million spawners compared with a dammed scenario (41.8 million spawners). Even with optimistic fish passage performance assumed for all dams (even if passage is completely absent), the dam-imposed deficit was alleviated by fewer than 3 million spawners. We estimate that in rivers modeled without dams, 98,000 metric tons of marine sourced biomass and nutrients were annually delivered, 60% of which was retained through carcasses, gametes and metabolic waste. Damming is estimated to have reduced this by more than one third. Based on our results, dams represent a significant and acute constraint to the population and, with other human impacts, reduce the fishery potential and ecological services attributed to the species.

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U.S.-Origin Atlantic Salmon habitat and implications for the future

M. Elisabeth Henderson, Monterey Bay Aquarium Research Institute
Katherine E. Mills, Gulf of Maine Research Institute
Michael A. Alexander, NOAA Physical Sciences Laboratory Miguel Barajas, Gulf of Maine Research Institute
Mathias J. Collins, NOAA Fisheries
Matthew Dzaugis, Gulf of Maine Research Institute
Dan Kircheis, NOAA Fisheries
Timothy F. Sheehan, NOAA Fisheries

The Gulf of Maine hosts the southernmost remaining population of North American Atlantic salmon. Despite extensive hatchery supplementation since the late 1800's, and more recent riverine habitat restoration efforts and fishing restrictions, U.S.-origin Atlantic salmon populations continue to decline and have remained at low abundance over recent decades. Climate change has been identified as a critical threat to the future of U. S. Atlantic salmon. In this study, we synthesized available information on how habitats used by Atlantic salmon across all their life stages will be affected by climate change as well as the suitability of future conditions for salmon's persistence in the region. Maintaining sufficient cool water refugia during increasing summer temperatures in riverine habitats is required for maintaining salmon in the future. Changes in groundwater quantity and temperature, which will depend on future changes in precipitation, will be an important factor for river temperatures as will other land use and land cover factors. While Atlantic salmon's freshwater life stages are heavily documented, the marine phase is relatively less studied. Marine habitat models predict basin-scale changes over the next century but impacts to salmon are difficult to predict. Furthermore, disparate drivers and differential rates of change between freshwater and marine habitats could present an obstacle to transition between phases in the future. We have a general understanding of migration patterns and prey preferences but lack a clear picture of how salmon respond to habitat and ecosystem-level changes associated with climate change progression. More research on Atlantic salmon's spatiotemporal distribution response to marine warming is recommended. The future of U.S.-origin Atlantic salmon is difficult to confidently predict given uncertainties in freshwater climate change and in salmon's marine habitat use.

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Non-stationary effects of growth on the survival of North American Atlantic Salmon (*Salmo salar*)

Michael D. Tillotson, Gulf of Maine Research Institute
Timothy F. Sheehan, NOAA, National Marine Fisheries Service
Brandon Ellingson, NOAA, National Marine Fisheries Service
Ruth E. Haas-Castro, NOAA, National Marine Fisheries Service
Maxime Olmos, Univesity of Washington, School of Aquatic and Fishery Sciences
Katherine E. Mills, Gulf of Maine Research Institute

The productivity of Atlantic Salmon (*Salmo salar*) has declined markedly since the 1980s, in part because of changing ocean conditions, but the mechanisms driving this decline remain unclear. Marine trophic conditions and their influence on growth have been hypothesized to play a critical role in determining marine survival, but prior studies have found divergent relationships between the continental stock groups; post-smolt growth appears to influence the survival of populations in Europe, but not in North America. In order to understand the apparent absence of a growth-survival relationship for these North American populations we used a large, representative archive of multi sea-winter (MSW) salmon scales to reconstruct long-term changes in growth between 1968 and 2018. We then modeled relationships between annual growth indices, estimates of maturation rates, and post-smolt survival, while allowing for the possibility of non-stationary dynamics (i.e. an influence of growth that varies through time). We found that marine growth of MSW salmon has changed significantly over the past 50 years, generally increasing despite declining survival. However, we also found strong evidence of a non-stationary influence of post-smolt growth on survival. Prior to a period of rapid change in the ocean environment during the late-1980s, post-smolt growth was positively related with survival in our North American sample, similar to the pattern observed in European populations. These findings suggest that the mechanisms determining marine survival of North American and European salmon populations may have diverged around 1990. More generally, our results highlight the importance of considering non-stationary dynamics when evaluating linkages between the environment, growth, and survival of Atlantic salmon.

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Retrospective analysis of marine growth and relationships to return rates of Penobscot River Atlantic salmon

Miguel Barajas, Gulf of Maine Research Institute
Kathy Mills, Gulf of Maine Research Institute
Tim Sheehan, NOAA Fisheries Service
Ruth Haas-Castro, NOAA Fisheries Service
Brandon Ellingson, NOAA Fisheries Service

Beginning in the 1980s, return rates of Atlantic Salmon to the Penobscot River, Maine U.S.A. declined and have persisted at low levels. This downturn coincided with similar declines in North American and European Atlantic salmon stocks and with changes in the Northwest Atlantic ecosystem. Previous studies investigated whether early marine growth explained the declines, but results varied, with decreased growth associated with declines in European stocks but not North American stocks. In this study, we evaluate whether growth over the entire marine stage is related to Atlantic salmon marine survival. We constructed a growth time series from scales of returned Penobscot River Atlantic salmon spanning periods of varying marine survival. We used ANOVA and post-hoc tests to quantify seasonal growth increment differences and principal component analysis to characterize variability among the suite of growth increments. We observed reduced growth during the second winter and second marine year starting in the 1990s, with compensatory seasonal growth relationships. These results indicate that diminished growth during late marine stages is associated with low return rates in this population.

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The effect of multiple stressors, including aquaculture production cycle, on Atlantic Salmon post-smolt migration and survival

Brent Wilson, Fisheries and Oceans Canada
Marc Trudel, Fisheries and Oceans Canada
Matt Black, Fisheries and Oceans Canada
Jon Carr, Atlantic Salmon Federation
Jason Daniels, Atlantic Salmon Federation
David Hardie, Fisheries and Oceans Canada
James Hawkes, National Oceanic and Atmospheric Administration
Chris McKindsey, Fisheries and Oceans Canada
Fred Page, Fisheries and Oceans Canada
Marie-France Lavoie, Fisheries and Oceans Canada
Claire Rycroft, Dalhousie University
Fred Whoriskey, Ocean Tracking Network
Glenn Crossin, Dalhousie University

Atlantic Salmon have been extirpated from several of their native rivers, and often fail to meet conservation requirements, particularly in the Bay of Fundy and Northeast United States. Although multiple factors have likely contributed to these declines, such has habitat destruction, overfishing, and climate change, the cumulative effects of multiple stressors on the survival of Atlantic salmon remains poorly understood. Here, we present the results of an acoustic telemetry project, conducted in both 2019 and 2021, to assess the population response of Atlantic salmon to multiple stressors, including passage of a hydropower system and bycatch mortality associated with in-river fisheries. We also compare migration routes taken during the early marine stage to determine the extent of their interaction with aquaculture, and examine the influence of salmon farm production cycle (empty vs stocked cages). Each year, smolts were tagged with pressure and temperature sensors acoustic tags and released above and below a hydropower dam, before and during a commercial fishery for alewife. Acoustic receivers were placed in the river and estuary of the Magaguadavic River (New Brunswick, Canada), at all the exit areas of Passamaquoddy Bay, as well as at aquaculture sites located in three Bay Management Areas (which cycle between production, harvest, fallow years). It is anticipated that this research will provide information necessary to develop effective mitigation strategies to limit associated threats to Atlantic salmon, to aid in the recovery of wild populations.

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Day 1, Afternoon

Moderator:

Dan McCaw, Penobscot Nation

Invited Talk:

Looking beneath the surface of public perceptions about fish: Lessons from Maine to Alaska

Katrina Liebich, USFWS

To certain segments of society, human connections with fish and associated waterscapes are multifaceted, complex, and saturated with meaning. But fish are still largely invisible to a broad segment of the U.S. population. This presentation explores opportunities to connect people more deeply with native fishes, with two case studies presented. One in Maine, where diadromous fishes historically dominated the freshwater fish community in coastal systems but have declined in concert with sweeping alterations to the region's waterscapes. In this case, so too has their utility, visibility, and relevance to each passing human generation. The other is in Alaska, where culture, food systems, and the economy is inextricably tied to native fishes and intact habitats. Understanding what's relevant to people can help us shape our communications around fish and conservation in deliberate, effective ways.

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Telling Our Story - Building a partnership for sea-run fish outreach and communications in Maine

Molly Payne Wynne, The Nature Conservancy in Maine
Melissa Flye, University of Maine
Danielle Frechette, Department of Marine Resources
Angie Reed, The Penobscot Indian Nation
Justin Stevens, Maine Sea Grant

With the complex nature of the biology and ecology associated with sea-run fish in Maine, combined with the duration of human interaction, there is little surprise at the diversity of players in the research, management and restoration of these twelve native fish species. Despite different approaches and organizational strategies, this "sea-run fish community" shares a primary goal: ensuring that rivers and streams support sustainable fish populations that fuel aquatic ecosystems and the fish are healthy enough for humans to eat. The ability to implement new restoration efforts and management actions depend, in large part, on public endorsement and engagement. While success stories are becoming more common in sea-run fish restoration and conservation, most people in Maine are unaware of the current or historical status of these species; never mind their broader ecological, social, and cultural roles. Recognizing the need for better communication and engagement with humans about sea-run fish, partners from the Penobscot Indian Nation, The Nature Conservancy, Maine Department of Marine Resources, Maine Sea Grant, NOAA Fisheries, and the University of Maine launched a virtual workshop series in 2021 to identify challenges, successes, and shared language to better tell the story of sea-run fish in Maine. This project, Telling Our Sea-run Fish Story, is a participatory process that began with convening leaders from across the sea-run fish community to identify common themes in communications. Results from this meeting informed a training led by communications expert Brooke Tully, where participants from the broader community learned ways to explore storytelling and messaging and prioritized five focused topics for further exploration: river connectivity, dam removal, Tribal sovereignty and sustenance fishing rights, science and research, and celebrating positive, accurate stories. Throughout the summer, participants worked collaboratively in small groups to identify target audiences and message development for each topic to motivate individual action in support of sea-run fish conservation, restoration, and management. The series culminated in a final session where workshop outcomes were shared, needs were articulated, and visioning for the future of this collaborative work. Although networks exist to further collective efforts in other sea-run fish disciplines, to our knowledge this was the first such effort focused specifically on communications. In this presentation, we will share challenges, successes, and lessons learned through this participatory endeavor, and outline our goals for continued collaboration among the sea-run fish community partners in support of healthy, sustainable, sea-run fish populations.

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Finding fish: Engaging volunteers to help monitor Maine's sea-run fishes in a changing gulf

Danielle Frechette, Maine Department of Marine Resources
Sarah Madronal, The Nature Conservancy (presenting author)
Molly Payne Wynne, The Nature Conservancy

Maine's 12 species of native, sea-run (diadromous), fish have significant ecological, economic, and cultural value and resource managers need complete, current coast-wide information to sustainably manage them now and in the future. But with a long coastline and limited resources for conducting in-depth studies, obtaining the up-to-date data needed to inform restoration and management can be challenging. Therefore, to help fill information gaps and re-engage connection to these incredible natural resources, The Nature Conservancy, Gulf of Maine Research Institute (GMRI), Downeast Salmon Federation (DSF), and the Maine Department of Marine Resources (DMR) are collaborating on a project to train interested volunteers to contribute vital information for two of our sea-run fish species – Tomcod (*Microgadus tomcod*) and Rainbow Smelt (*Osmerus mordax*). Launched in 2020, these efforts are part of GMRI's Ecosystem Investigation Network, an online platform that connects and supports a community of partner organizations and volunteer scientists of all ages and backgrounds who are investigating how climate change is impacting the species, communities, and habitats in the Gulf of Maine watershed. The onset of the COVID-19 pandemic led to a virtual approach to survey roll-out, with trainings and contact with volunteers occurring exclusively via e-mail and video conference. The inaugural smelt survey in 2020 involved 10 individuals from among the sea-run fish research and restoration community who conducted surveys in 70 streams spread between Cumberland and Washington counties. In 2021, recruitment of survey participants was expanded to include members of the public: 12 observers logged 141 surveys in 52 streams, representing 31 towns in 8 different coastal counties. The inaugural survey for tomcod involved 30 volunteers who braved the cold to log 91 surveys across eight coastal counties during December 2020 and January 2021. Sightings of tomcod were rare and limited to Damariscotta Mills and three streams in Hancock County. Plans are underway to expand recruitment for the 2021 Tomcod and 2022 smelt surveys with the goal of increasing the spatial coverage of the survey. It is anticipated that results of the presence/absence surveys will help managers identify streams with the best restoration potential and help determine which areas require further research and monitoring to inform management. To participate in either the "Finding Frost Fish" (Tomcod) or "Spawning Smelt" survey, please contact Danielle Frechette (danielle.frechette@maine.gov).

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Collaborative management of the Atlantic Salmon program – an update

Julie Crocker, NMFS

Over the past three years, staff and program leaders from Maine DMR, NOAA, USFWS and the Penobscot Nation have been working very hard to develop and implement an improved governance strategy. This "Collaborative Management Strategy for the Gulf of Maine Atlantic Salmon Recovery Program" promotes communication, collaboration, accountability, transparency and improved decision making for the Atlantic salmon recovery program. The new strategy was initially implemented as a pilot project through calendar year 2020. Implementation of the strategy has continued throughout calendar year 2021 with several key accomplishments including the development of five-year plans for each Recovery Unit, annual reporting on progress toward recovery goals in 2020 and 2021 completed, and enhanced communication in each Recovery Unit. We view the implementation of the strategy as a step in the right direction, building on the many things that the Atlantic Salmon recovery program does well, while taking steps towards improving those areas where we can do better.

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Regional conservation partnership projects (RCPP) focused on aquatic organism passage in Maine

Ben Naumann, Natural Resources Conservation Service
Eileen, M, Bader Hall, The Nature Conservancy

The Natural Resources Conservation Service (NRCS) and The Nature Conservancy (TNC), along with many federal, state, tribal and NGO partners have collaborated on the Regional Conservation Partnership Program (RCPP) project "The Maine Connectivity Restoration Project," which started in 2018. The goal of the project was to reconnect at least 50 stream miles of fractured stream habitat centered around the distinct population segment of Atlantic salmon over a five-year period. The presentation will provide an update of the collaborative Aquatic Organism Passage accomplishments for the "The Maine Connectivity Restoration Project," along with the introduction of a new "Watershed-scale Approach to Restoring Stream Systems" (WATRSS) RCPP project. We will also discuss how NRCS RCPP technical and financial assistance has been effective for the completion of road stream crossing projects and an emerging model to large multi-partner dam and fishway projects utilizing RCPP funds.

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Collaboration towards recovery across the Sandy River watershed, headwaters of the Kennebec River, Maine

Maranda Nemeth, Atlantic Salmon Federation (co-presenter)
Jennifer Noll, Maine Department of Marine Resources (co-presenter)
Matt Bernier, NOAA Restoration Center, Orono, ME
Paul Christman, Maine Department of Marine Resources
Kirstin Underwood, U.S. Fish and Wildlife Service Coastal Program

The Sandy River is a major tributary of the Kennebec River within the Merrymeeting Bay Salmon Habitat Recovery Unit (SHRU). The Sandy River is designated as critical habitat for the Gulf of Maine Distinct Population Segment (GOM DPS) of Atlantic Salmon and the watershed contains the largest contiguous amount of high-quality critical habitat within the Merrymeeting Bay SHRU. This habitat is also likely to be the most resilient to climate change due to being located at higher elevations and in largely undeveloped and well-forested mountain areas. The physical characteristics of the Sandy River watershed are well documented and over the past decade, the recovery program in the watershed has shown promising signs of success. Improving safe and timely fish passage for Atlantic Salmon and other co-evolved species to access this this productive spawning habitat will lead to greater species productivity and increases the likelihood of species recovery and persistence over time. Several partners including Atlantic Salmon Federation (ASF), NOAA Restoration Center, Maine Department of Marine Resources, and U.S. Fish and Wildlife Service have established a focus area to plan and implement fish passage projects across the Sandy River Watershed. The presentation will provide an overview of the habitat quality, salmon management and recovery program, restoration efforts, and explore the restoration efforts completed, ongoing and planned within the Sandy River Watershed by ASF and their partners.

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Conservation aquaculture as a path to recovery: Salmon for Maine's rivers

Danielle Frechette, Maine Department of Marine Resources
Sean Ledwin, Maine Department of Marine Resources

Current management of Atlantic Salmon focuses on preventing extinction through the maintenance of genetic diversity using intensive hatchery supplementation, with hatchery offspring stocked into rivers at the egg, fry, parr, and smolt life stages. Hatchery supplementation and habitat restoration projects have prevented extinction and improved aquatic habitat connectivity, but extensive areas of vacant habitat remain. Therefore, the Maine Department of Marine Resources launched an ambitious marine captive rearing program in 2021 alongside project partners - the Penobscot Indian Nation (PIN), US Fish and Wildlife Service, NOAA Fisheries, Cooke Aquaculture USA, and the Downeast Salmon Federation. Under the Salmon for Maine's Rivers Program (SFMR), thousands of smolts are being reared to maturity in salt water for release into high-quality habitat in the Penobscot and Machias rivers, with the goal of increasing natural reproduction. Substantially increasing natural spawning in high quality habitats is expected to increase production of naturally-reared smolts, thereby producing more returning adults with increased fitness, even as marine survival remains low. Returning adults will be considered natural-origin returns and contribute towards demographic federal Endangered Species Act recovery criteria. Challenges imposed by the COVID-19 pandemic resulted in a one-year delay and a revised approach to the start of the SFMR program. In May 2021, salmon smolts of Penobscot and Machias river origins were transferred from Green Lake National Fish Hatchery to the University of Maine Center for Cooperative Aquaculture where they were transitioned to salt water, vaccinated, and reared for subsequent transport to Maine's first salmon conservation aquaculture site in 2022. The first release of mature adults is expected to occur in October 2022. In a parallel effort, we initiated a collaboration with the PIN, Maine Department of Environmental Protection, and the University of Southern Maine in 2020 to collect baseline nutrient, macro-invertebrate, and stable isotope samples in the areas of the East Branch Penobscot and Machias Rivers where adult salmon will released. The objective of this effort is to test the hypothesis that Atlantic salmon, when allowed to spawn in large numbers in Maine rivers, will increase primary and secondary productivity through eggs, excretions, and carcasses. The SFMR effort represents the first time in more than 50 years that these rivers will experience ecologically relevant numbers of spawning adults that approach or exceed conservation spawning escapement, and has the potential to jumpstart recovery of this iconic species, reinvigorate public interest, and rebuild a piece of Maine's heritage.

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Public perceptions of Atlantic Salmon conservation

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Danielle Frechette, Maine Department of Marine Resources

The Gulf of Maine Distinct Population Segment (DPS) of Atlantic Salmon is listed as federally endangered. The current conservation program relies on juvenile stocking to maintain sea-run origin broodstock in the DPS. Despite decades of hatchery supplementation, extirpation remains a threat and natural reproduction is extremely limited. The Maine Department of Marine Resources (partner in the Collaborative Management Strategy [CMS] for salmon management in Maine, along with NOAA, USFWS, and Penobscot Nation) is collaborating with Cooke Aquaculture to apply a novel rearing program aimed at increasing natural spawning. Beginning in 2021, smolts will be transferred to coastal net pens and reared to maturation. These fish will be released into high-quality spawning habitats as adults in an attempt to boost natural reproduction. This effort marks a major shift in management approach and has garnered mixed public reactions. Working with the CMS and other stakeholders, we have developed a sociological questionnaire which has been administered to 900 residents across coastal communities near the proposed net pen site. The questionnaire is meant to capture attitudes, values, beliefs, and knowledge of Maine coastal residents toward sea-run fish, Atlantic salmon, aquaculture, and the use of aquaculture for conservation. Using the Potential for Conflict Index (PCI), this data can highlight contentious aspects of this and other conservation programs. Analysis of this information will allow us to disentangle the many cognitive variables which contribute to public support or opposition of conservation actions.

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Poster Session:

Hosted By:

Justin Stevens, Maine Sea Grant

Movement of Alewife around a hydroelectric dam on the Passadumkeag River

Cody Dillingham, Department of Wildlife, Fisheries, and Conservation Biology, University of Maine
Joseph Zydlewski, Department of Wildlife, Fisheries, and Conservation Biology, University of Maine and U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit

In the Penobscot River of Maine, populations of Alewife (*Alosa pseudoharengus*) have experienced declines due to habitat loss from damming. To access spawning habitat in the upper reaches of the Passadumkeag River, a tributary of the Penobscot, migrating alewife must navigate a 70-meter denile-style fishway at the Lowell Tannery hydroelectric project (FERC No. 4202). Effective fish passage necessitates attraction to the fishway, followed by successful entry and ascent. To assess these components of passage, we captured alewife (n= 80) using a cast net at the base of the dam, tagged (radio and PIT) and released these fish 200m downstream, and monitored re-approach to the dam. Radio tags were tracked using both stationary and mobile telemetry receivers. PIT antennas were installed at the entry and exits of the fishway. Radio telemetry showed that some fish (n=13) that left the study area were later detected on the main stem of the Penobscot River. Fish that approached the dam (n=40) were delayed for as many as 14 days (mean 4 days) before exiting the study area. PIT data revealed that no tagged fish successfully navigated the fishway. We collected positional information via GPS and paired that information with signal strength data from the radio array to discern approximate position of fish approaching the dam. Analysis demonstrated that fish spent more time on the western side of the river (by the tail race) than on the eastern side (where the fishway entrance is located). This suggests that attraction to the fishway may be the primary impediment to timely and successful passage.

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American Eel personality and body size influence passage success in an experimental fishway

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Millions of dams impair watershed connectivity across the globe and have severely affected migratory fish populations. Fishways offer upstream passage opportunities, but artificial selection may be imposed by these structures. Using juvenile American Eel (*Anguilla rostrata*) as a model species, we consider whether individual differences in behavior (*i.e.,* personality) and fish size can predict passage success. We evaluated the expression of bold and exploratory behaviors using open field and emergence assays in the laboratory. Then we assessed the propensity for individuals to volitionally climb through an experimental fishway to understand if personality and fish size could predict climbing success. We demonstrate personality in juvenile eels, and swimming speed in the openfield was negatively associated with climbing propensity. Slower swimmers were up to 60% more likely to use the passage device suggesting that more exploratory eels incurred greater passage success. For successful climbers, climbing time was negatively associated with fish length. Our results suggest fish may segregate at barriers based on personality and size. Preventing a subset of individuals from accessing upstream habitat is likely to have negative consequences for fish populations and aquatic ecosystems. Selection may be alleviated by increasing passage opportunities, maximizing fishway attraction and avoiding inefficient passage solutions.

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Motive, means and opportunity: Could Smallmouth Bass be a major predator of Atlantic salmon?

Rylee Smith, University of Maine
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Smallmouth Bass (*Micropterus dolomieu*) is an introduced nonnative fish widespread throughout Maine waters, and is known to be a predator of juvenile salmon during rearing and migration. The degree to which this influence is ecologically relevant, however, is unknown. During freshwater rearing, spatial overlap between the two species is limited, suggesting competition and/or predatory interactions. We will use GIS analysis of electrofishing data from 1956-2020 to assess the spatial and temporal overlap of Atlantic salmon and smallmouth bass in the river systems of Maine. In addition, changes in smallmouth bass distribution through time may inform projections of spatial overlap under climate change forecasts. As Atlantic Salmon migrate seaward in the spring, high mortality is often observed in dam impoundments and habitat that supports smallmouth bass. We will use mark recapture techniques to assess smallmouth bass density and biomass in a high migratory risk area of the Penobscot River. These data will be used to model the scope of migratory loss of Atlantic salmon that smallmouth bass might be causal to.

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Evaluating sustainability metrics for River Herring populations during restoration

Margaret Campbell, University of Maine
Justin R. Stevens, Maine Sea Grant

Sustainable River Herring fisheries management in Maine is pursued with a complex process involving local, state, and federal governments. Sustainability is evaluated with metrics of biological characteristics that capture the complexities of the species' life history. We analyzed these metrics for two watersheds in the Penobscot River under active restoration from 2010 to 2020. Blackman Stream is a 688 hectare watershed with unobstructed access to the ocean; the remaining Penobscot River (>10,000 hectares) is controlled by passage at a mainstem dam in Milford. We determined annual species population abundance, sex ratios, age distribution, rates of iteroparity, and stock-recruitment relationships for each species. At Blackman Stream stocking between 4,000 to 7,000 fish in 2010 - 2014 resulted in returns of 400,000 - 600,000 annually from 2014-2020. In the Penobscot River above Milford, stocking of 30,000 - 40,000 River Herring (species undistinguished) annually resulted in returns of two million fish annually. The Blackman stream run was composed entirely of Alewives, whereas the proportions of Blueback Herring at Milford vary from 20-50% per year corresponding to 500-700,000 Blueback Herring per year. Alewives returning to Blackman Stream and Milford and Blueback Herring at Milford had more males in proportion to females in most years. The age distribution at both locations and for both species consisted mainly of age 3 and 4, however, there has been an increase in age 5 and older fish later in the time series. Iteroparity rates for Alewives at Milford has increased from 10% to 40% of the run, and Blueback Herring have increased from 5% to over 25% of the run. At Blackman Stream, iteroparity rates of Alewives have gone from 20% to 45% of the run. At Blackman stream, Alewife returns per recruit were a maximum of 55:1 however, only one complete cohort was available to analyze. At Milford, Alewife returns per recruit have decreased over the time series from 55:1 to 3:1. At Milford, Blueback Herring returns per recruit have ranged from 1:1 to 3:1 and have remained consistent over the time series. These data demonstrate the complexities of management of a species with varied life history and implies the need for consistent, long-term sampling to describe stock demographics. This analysis provides for a baseline for these restoring runs and allow for tracking sustainability which will help protect and understand this and other fisheries in the future.

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Growth of Smallmouth Bass in rivers with a restoring River Herring run

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The purpose of this research is to determine how the growth rates of top predators, such as Smallmouth Bass (*Micropterus dolomieu*), are affected by access to high quality prey like sea-run fish, including Alewife (*Alosa pseudoharengus*), and various environmental conditions. Several studies have documented marine derived nutrients in resident fish predators, but few have investigated how resident fish predator growth is affected by the presence of marine derived nutrients transported into the ecosystem by Atlantic sea-run fish. To determine growth in the presence of sea-run Alewife in the Penobscot River watershed, sagittal otoliths from Smallmouth Bass were aged whole and were then sectioned and aged again in order to determine the accuracy of each aging method. The otolith sections were imaged and the rings were measured in the software ImageJ, using the ObjectJ application. From ObjectJ, inferred annual growth rates were determined as well as a back-calculated length at age. Annual growth rates were compared between sites using comparisons of means tests such as t-tests and ANOVA. Average annual growth rates were analyzed with covariates such as river herring run size, cohort year, seasonal flow rates, and potentially marine derived nutrient (MDN) use at the time of capture. Ages and annual growth rates were paired with stable isotope data from the same fish, allowing for inferred marine derived nutrient use. We expect that the results will show variation in the growth rates of the resident fish between cohort years and between lower mainstem and tributary sites, and that fish from lower mainstem will show more marine derived nutrients in their tissues. Results from this study may help us better understand the role of marine derived nutrients in driving freshwater productivity of resident piscivores.

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Effects of logging practices on habitat complexity in the Machias River

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Historic anecdotes suggest that Atlantic Salmon populations were once much higher than current populations. A possible contributing factor to this is the reduction in habitat complexity in rivers and streams where Atlantic Salmon reproduce and grow. Specifically, historic logging practices have led to a substantial reduction in habitat complexity. This review has investigated historic logging practices on the Machias River, including the use of dynamite as well as the building of dams throughout the Machias River watershed. By reviewing the "Machias River Project" (a collection of interviews from 19 individuals held at the University of Maine's Fogler Library) the location of 20 historic dams were revealed through first-hand accounts of workers on the Machias River. These dams were then mapped out as points. In addition to this, the type of dynamite, and methods used for breaking logjams were revealed through a first-hand interview of a worker on the Machias river. Historical images of the Machias River were collected which showed the extent of logging, as well as general pollution that occurred on the river. We hope that this work will help elucidate the extent and scope of changes to instream habitat in the Machias River as investigators consider the potential effects that these changes may have to productivity of Atlantic Salmon.

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Spatial and temporal distribution patterns of Double-Crested Cormorants (*Phalacrocorax auritus*) in the Penobscot Estuary during river restoration

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Justin R. Stevens, Maine Sea Grant College Program
Rory Saunders, NOAA's Greater Atlantic Regional Fisheries Office, Orono, ME

The Penobscot River has been the focus of substantial restoration efforts over the past twenty years, including dam removals, elimination of point-source pollutants, and restocking of sea-run fish species such as Atlantic Salmon (*Salmo salar*) and River Herring (*Alosa* species). These activities have resulted in increases in riverine and estuary fish biomass, but the interrelated ecological effects of these efforts have not been fully evaluated. For example, piscivorous birds such as the double-crested cormorants (*Phalacrocorax auritus*, referred to henceforth as "cormorants") may benefit from diadromous fish restoration efforts. Cormorants may also negatively affect efforts to rebuild diadromous populations such as Atlantic Salmon. To begin to describe cormorant and fish interactions over space and time, we collected acoustic biomass of fish, counts of seabirds, and environmental parameters including salinity from 2011 to 2019. We consistently found cormorants to be the most abundant bird in the survey throughout the time series. Counts increased over the timeseries, although average counts per survey were consistently higher in April to July than August to October in most years. Spatially, we found that in most (67 of 119 [55%]) surveys cormorants were distributed non-randomly, suggesting clustering in particular locations of the study area. Cormorants were generally more clustered in June, August, September and October and more dispersed in the study area in April, May, and July. Cormorants appeared clustered in areas of higher fish biomass and moderate salinities in June through October but appeared to be associated with lower fish biomass and low salinity in April and May. The localized increases in cormorant counts we observed stand in contrast to declining regional abundance trends of cormorants recently. This may provide some insight into the broader ecological effects of river restoration beyond improvements to fish populations targeted by restoration efforts. Further, evidence of clustered distributions of cormorants in areas having higher fish biomass at specific times of year provide insight into the necessary scale and scope of evaluation of cormorant predation on individual species and life stages (*e.g.,* Atlantic Salmon smolts).

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Demographic and evolutionary impacts of size selection at fishways on Atlantic Salmon

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The migratory routes of Atlantic Salmon have been fragmented throughout their range by damming. Efforts to restore connectivity often include construction of fishways. Empirical studies indicate that these structures create unforeseen obstacles to restoration over time by imposing selective pressures against large-bodied individuals. To determine whether selection at dams can drive evolution of Atlantic salmon, we used an individual-based model under selective pressure previously documented in the Penobscot River to simulate a population of Atlantic salmon in a simplified, relatively small river (~89 rkm) system and followed it over a 100-year period. We varied the number of dams present in the system as well as narrow-sense heritability of length at maturity and age at maturity and tested 150 combinations of these variables 1000 times each. Our results indicate that the probability of extinction increases dramatically when more than one dam is present in the system. Populations never went extinct without dams, but 7.2% went extinct with only a single dam in the system and 63.2 % went extinct with two dams in the system. Additionally, the selective pressure at fishways is strong enough to have observable impacts on the distribution of life history strategies and lengths across a range of heritability values. Coefficient of variation in length decreased over time across all life history strategies with at least one dam present in the system, but did not change in free-flowing systems. Egg production in free-flowing systems was dominated by 2 sea winter fish. The proportion of eggs contributed to the population by multiseawinter (large, slow-growing) fish was highest in two dam systems, which, coupled with low populations in these systems, is indicative of populations under stress. These data indicate that restoration practitioners may wish to pay particular attention to the length-frequency of fish ascending fishways in addition to the number of fish using the structures. Population-level impacts modeled here could complicate efforts to restore populations of migratory salmonids.

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Effects of flow on system-wide survival and movement of Atlantic Salmon (*Salmo salar*) in the Penobscot River

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Joseph D. Zydlewski U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit, University of Maine

We modeled the effects of flow on survival of downstream migrating Atlantic Salmon smolts. Movement, delays, and apparent survival of hatchery smolts (n = 1,536) were evaluated in open river reaches and at dam in the Penobscot River, Maine. Early and late spring releases occurred in 2016 through 2019 at six release sites so that path choices and dams encountered varied among individuals. Flow (as measured using USGS monitoring stations), was used as an explanatory factor in all modeling and calculations. System-wide survival (and movement rates) were high in three high flow years 2017-2019 compared to previous estimates under lower flow conditions in 2005 to 2016 (0.63 versus 0.33) There was an intra-annual effect of flow as well, with survival at dams being higher during period of high flow. Interestingly, survival at one main-stem dam (Weldon Dam) was low in all years independent of flow. Survival for this 4.2 rkm section has been as low as 0.75 (2018). Despite the low survival locally at Weldon Dam, fish released upstream in high flow years still had increased system-wide survival, as losses were offset by high survival in other reaches. High flows not only increased survival directly at most dams, but also increased survival by reducing delays. The results from these high flow years likely represents the most favorable conditions smolts may encounter in this heavily dammed river.

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A grassroots ongoing effort to protect, preserve and restore wild native Atlantic Salmon

Emily Bastian, Native Fish Coalition

Since 2017, the Maine Chapter of NFC has engaged with local communities in an effort to save Atlantic salmon from extinction. NFC and our partners' efforts to protect, preserve and restore wild native Atlantic salmon include: NFC volunteers designed, printed and posted informational signage specific to Atlantic salmon in critical habitat in Downeast Maine and the Penobscot River watershed, in partnership with Downeast Salmon Federation (DSF), Atlantic Salmon Federation (ASF), and Maine Department of Marine Resources (DMR); NFC designed, printed and distributed informational cards highlighting the plight of Atlantic Salmon to members of the public throughout Maine and New England, encouraging conversation, increased awareness, public support for preservation, and action at the state and national levels; NFC initiated a campaign to list Atlantic Salmon as endangered at the state level in Maine through letters to Maine Department of Inland Fisheries and Wildlife (IFW) and DMR, culminating in a formal legislative proposal to list Atlantic salmon as endangered; NFC submitted an official letter to National Oceanic and Atmospheric Association Fisheries (NOAA) requesting the federal agency work with Maine IFW and DMR to facilitate a state-level listing for Maine's federal-listed and critically endangered Atlantic Salmon to ensure that the state and federal agencies are all on the same page; NFC worked directly with DMR to establish a 25" maximum length limit on Brown Trout to help protect adult Atlantic Salmon from accidental harvest due to species misidentification; NFC has authored multiple articles in local and national media publications regarding the plight of Atlantic Salmon and efforts to save the species.

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A collaborative organizational network analysis of the Cooperative Research Units Program

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Joseph Zydlewski, U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit and University of Maine, Department of Wildlife, Fisheries, and Conservation Biology

The U.S. Geological Survey's Cooperative Fish and Wildlife Research Units Program (CRU) establishes a relationship among the U.S. Geological Survey (USGS), U.S. Fish and Wildlife Service (USFWS), Wildlife Management Institute (WMI), a host university, and state resource agencies. The program's mission is to provide education and technical assistance through graduate research in order to address the information needs of its members. Originating in 1935, it currently consists of 40 units in 38 states. Staff within the CRU have conducted decades worth of research while mentoring graduate students and providing technical assistance to cooperators on wildlife management issues. While the program's mission has remained largely unchanged, the issues challenging fish and wildlife conservation have changed. Landscapes are increasingly fragmented, individuals are generally less attracted to outdoor activities, and wildlife use has shifted towards non-consumptive uses. This raises questions about the CRU's support and sustainability into the future. The Maine CRU is one such Unit that has spent decades on wildlife and fisheries research, including research on Atlantic salmon. Our study examines the CRU model that integrates graduate education in research and technical assistance to address Cooperator information needs, to explore the relevance of the model in the current context of natural resource conservation. We are evaluating the program's structure and socio-technical connectivity to identify motivations, relationships, and layered networks among members and their relationships to outcomes through an Organizational Network Analysis and Dynamic Network Analysis. Our investigation will include simulations informed by statistical analysis of the social networks and their evolutions and adaptations, to predict conditions under which outcomes may change. The goal is to elucidate how organizational factors may contribute to each cooperator network, how the networks have evolved, and how factors may influence future conditions of individual units and the CRU Program in general.

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Day 2, Morning

Moderator:

Amanda Cross, USFWS

Using dispersal data to optimize egg planting strategies for Atlantic Salmon

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The Gulf of Maine Distinct Population Segment of Atlantic Salmon has suffered from habitat loss and exploitation over the last century. Hatchery supplementation has unquestionably prevented the extirpation of the species, but stocking methods represent tradeoffs between survival, domestication and logistics. Egg planting maximizes wild rearing opportunities which may be important for adaptation. This method, however, is logistically demanding and requires significant labor over a large spatial scale. This is incongruent with the short time window for planting dictated by the ontogenic development of the fish. We sought to develop an optimization tool that would allow managers to best select the number of eyed egg batches and their planting locations within a drainage targeted for supplementation. We defined available habitat using existing GIS layers for Atlantic salmon habitat and configured a spatially explicit recruitment model. After choosing a series of randomly assigned stocking events and locations (followed by density dependent loss [Ricker] and dispersal [empirically derived]) a projection of young of the year the following fall was calculated as our measure of performance. By running the model though repeated simulations, we developed production possibility frontiers based on number of embryos dedicated to supplementation, delineating the number of embryos per site and locations for optimal performance. Results of this work will be used to inform decisions related to stocking in Maine.

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Reproductive success of captive-bred and caught-and-released Atlantic Salmon assessed by microsatellite sequencing

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Louis Bernatchez, Laval University
Julien April, Ministère des Forêts, de la Faune et des Parcs

Stocking and catch-and-release (C&R) are among the most commonly used recreational fisheries management practices, particularly for Atlantic salmon. However, few studies have documented the impact of those management tools on reproductive success of this emblematic species. Using high-throughput microsatellite sequencing of 50 microsatellites, we accurately assigned 2500 offspring to their respective parents from a salmon population in Québec. This analysis gave us insight on the reproductive pattern of stocked salmon; stocked salmon had fewer partners than wild salmon which lead to a significant reduction of reproductive success compared to their wild counterpart. Moreover, we demonstrate for the first time that caught-and-released female salmon have a significantly reduced reproductive success, averaging 73% of the reproductive success of non-caught salmon. These new results will help refine our ability to analyze the risks and benefits associated with stocking and C&R, and thus, optimize conservation and management practices used for the preservation of Atlantic Salmon.

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Genetic diversity mapping for restoration of Atlantic Salmon to tribal waters

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Jack Parr and Cassandra Schwartz, EPA Office of Research and Development
Sharri Venno and Sam St. John, Houlton Band of Maliseet Indians
Aruna Jayawardane, Maliseet Nation Conservation Council
Kaleb Zelman, Sheresse McWilliam, Louise de Mestral, Nathalie Brodeur, and Brendan Winge, Department of Fisheries and Oceans Canada (DFO)
Scott Pavey, Univ of New Brunswick (UNB) Saint John Campus
Erik Pilgrim, EPA Office of Research and Development

Maliseet Nation members in northern Maine and New Brunswick, Canada have traditionally engaged in sustenance fishing of Atlantic salmon and other fish species in the Wolastoq (St. John River) as a key part of their diet. However, in recent years, industrial development, decreasing water quality, loss of fish habitat, and obstacles to fish migration pathways have resulted in the elimination of Atlantic salmon in the upper waters of the Meduxnekeag River, a tributary to the Wolastoq, upon which the Houlton Band of Maliseet Indians (HMBI) relies for sustenance. This presentation will explore how EPA, HMBI, Maliseet Nation Coservation Council and US/Canadian federal partners are collaborating to develop a cloud-based population diversity database of Wolastoq salmon DNA. The proposed database will be used to establish genetic markers and provide key information on natural diversity, including the identification of the Meduxnekeag-specific genetic strain of Atlantic Ssalmon. This genetic information will serve to inform future efforts for future live gene banking, captive rearing, and salmon stocking efforts by HBMI and others.

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System-wide migratory delays of Atlantic Salmon (Salmo salar) in the Penobscot River, Maine

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Delays caused by dams adversely affect adult Atlantic Salmon (Salmo Salar) as they move from the ocean to their spawning grounds. We used a seven-year dataset of 309 radio-tagged adult Atlantic Salmon from the Penobscot River, Maine, to investigate delays and passage efficiency at six main-stem dams. While most salmon (92%) did successfully pass the first dam, Milford Dam, most (88.9%) incurred delays greater than 48 hours. In 2019 and 2020, fish (n=90) spent an average of 14-18 days (median delays of 9.5 and 7 days, respectively) below Milford Dam before either passing the dam or abandoning migration. We developed an index to describe the fish's location below Milford Dam to assess if it was attracted to the fishway (east side of the river), or if it was searching on the west side of the dam, where there is no upstream passage and fish may become stranded. In aggregate, fish spent more than 50% of their time in between approach and either passage or migratory abandonment in the western side of the river. Atlantic Salmon also experienced low passage efficiencies at upstream dams and displayed extensive searching behavior when approaching the confluence of the Piscataquis River and the main-stem Penobscot River. Most spawning adults in the Penobscot River are hatchery smolt -origin fish stocked below Milford Dam. While this stocking practice may reduce out-migration mortality at dams, it may also influence the process of imprinting, thereby impairing upstream migration in pre-spawn adults. The observed patterns suggest that the observed searching, fall backs, and reversals of these returning adults may delay them in reaching upriver holding habitat prior to spawning.

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Using acoustic predator tags to characterize predation on Atlantic Salmon smolts

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The Gulf of Maine Atlantic Salmon Distinct Population Segment is federally endangered with fewer than 2,000 adults returning to spawn annually. Juvenile salmon (smolts) migrate seaward after 2–3 years of rearing in freshwater. Mortality during this 4–6 week emigration period is naturally high, yet is exacerbated by dam passage. Understandably, reducing mortality during migration is a high priority for conservation efforts. More than 5,000 smolts have been released in the Penobscot River and tracked using acoustic transmitters to better understand behavior and to characterize survival during this vulnerable migration stage. This research has shown that dam headponds and the Penobscot River estuary are areas of high smolt mortality, where more than 30% of migrating smolts are lost annually. Conspicuous losses and movement patterns in these environments (relative to free-flowing, freshwater reaches) suggest that predation may be a significant cause of mortality. In 2021, we tagged 72 smolts with acoustic "predator" tags which enabled us to recognize predation events and identify body temperatures of the predator species. Fish were released in Medway, Maine and tracked over 175km through the Penobscot River estuary. Predation rates in free-flowing, headpond, and estuarine sections of river were modeled using a multistate mark-recapture framework where individuals entered an alternative state once predated. We identified 22 smolts (~31%) as predated before exiting the system. Fish were the dominant predator species (n=16), while six events were attributed to avian (n=3) and mammalian (n=3) taxa. Predation was estimated to be the leading cause of mortality for smolts, and predation rates were highest in dam headponds. Collectively, our results suggest that predation pressure on Atlantic Salmon smolts may be greater than anticipated.

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Dams may force semelparity in Atlantic Salmon

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Adult Atlantic Salmon endure a long upstream migration without feeding, entering freshwater in May-July to reproduce. If energy stores allow, these fish may return the ocean to repeat the process. The remaining wild populations of U.S. Atlantic salmon are predominantly found in Maine rivers within highly dammed watersheds. We used radio telemetry in the Penobscot and Kennebec Rivers and demonstrated incomplete passage and substantial delays for fish captured at each dam and displaced downstream. By using a Distell Fatmeter on first capture and recapture, we demonstrated that these delayed fish lose 11-19% of their fat reserves. The rate of loss was strongly correlated with thermal experience, as measured by accumulated thermal units (ATUs). Upstream waters are cool compared with temperatures encountered below dams (often surpassing thermal tolerances of >26oC). We modelled the bioenergetics costs incurred by delay fish under temperature regimes that would be encountered under a "no dam" (no delay) scenario versus one, two, three, or four dams. These projections were based on assumptions of: i) river entry date from the Penobscot River, ii) delay distribution based on radio telemetry data, and iii) length distribution of returning adults from the Penobscot River. Our model shows that representative estimates of delay at four sequential dams results in a 6-fold increase in the number of fish that would run out of energy before spawning (presumably to die or abandon migration). This effectively means one out of three returning adults would be eliminated from spawning because of delays. The model also indicates a 65% decrease in the number of fish that would have enough reserves to spawn successfully and recondition (potential repeat spawners). It is notable that the majority of suitable habitat in both the Kennebec and Penobscot Rivers is upstream of four (or more) dams, and that repeat spawning is nearly absent in the Gulf of Maine.

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Long term biomonitoring of fish assemblages following large scale habitat restoration efforts in the Penobscot River, Maine

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The Penobscot River Restoration Project is one of the largest ever completed river rehabilitation projects, culminating in the removal of the two lowermost dams on river and improvements to fish passage on several remaining dams. To quantify spatial and temporal changes associated with river rehabilitation efforts, fish assemblages were surveyed for 3 years prior to dam removal, 3 years after, and now 8 years post dam removal. Assemblages showed a significant reduction in lacustrine species in formerly impounded sections, shifting towards more lotic and diadromous species shortly after dam removal. Longer-term fish assemblage responses demonstrated the greatest shifts in fish assemblage structure occurred immediately following dam removal with minimal changes occurring during the long term sampling period. Long term sampling revealed that the lower tributaries and tidally influenced area experienced the greatest changes as a result of both adult and young of the year river herring (*Alosa* spp.) occurring in greater abundances. Two new species, Northern Pike (*Esox lucius*) and White Catfish (*Ameiurus catus*) were detected during the extended sampling suggesting an increase in their relative abundance since dam removals. Although fish passage upgrades were implemented, impounded habitats by dams remain dominated by lacustrine species and minnow species.

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Measuring food web connectivity in the Penobscot River, Maine following dam removals

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Diadromous fish provide ecological subsidies of materials and energy to both freshwater and marine food webs through excretion, eggs, and direct consumption. A main goal of the Penobscot River Restoration Project (PRRP) was to increase connectivity between marine and freshwater systems by removing two mainstem dams, improving fish passage, and reintroducing River Herring through stocking. Diadromous fish are now able to reach historic spawning habitat that was not accessible for centuries. River Herring runs in the Penobscot River have increased from 2,336 fish in 2009 to over 2 million fish by 2018. To assess food web connectivity in the Penobscot watershed, we conducted Stable Isotope Analysis (SIA) of the food webs from before (2009-2010) and after (2020-2021) dam removals. We sampled species ranging in trophic level from piscivorous fish to baseline primary consumers (mussels and snails). Fish and invertebrates were sampled from three mainstem (around dam removal sites) and three major upstream tributary sites as well as multiple areas of Penobscot Bay. We focused specifically on top fish predators that can directly consume River Herring. Top fish predators included Smallmouth Bass and Chain Pickerel in freshwater and Atlantic Cod in Penobscot Bay. Pre-restoration data indicate little connectivity between food webs in the Penobscot River and Bay, with the exception of Smallmouth Bass below Veazie Dam. Preliminary fall data from the Penobscot in 2020 shows some shifts in mean isotope values of freshwater species indicative of incorporating marine derived isotopes. These shifts in mean values from the fall data occur primarily in the mainstem sites below Milford Dam. We are waiting on data from the Spring of 2021 which was collected during the River Herring spawning run and may show a stronger marine signal in freshwater fish predators. Food web connectivity and increasing trophic diversity is an important metric for restoration, and is anticipated to lead to a more resilient system that is more capable of withstanding disturbances.

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Sea Lamprey migration and passage at Milford Dam

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Native, anadromous Sea Lamprey play important roles in Maine's rivers as ecosystem engineers and source of nutrient subsides but access to upstream habitat is impeded by dams throughout much of the state. Restoring sea lamprey and the ecosystem services they provide, therefore, relies on effective fish passage at existing dams. Milford Dam (river km 62) is the first upstream impediment to high quality upstream habitat in the Penobscot River and has recently been equipped with fish lift on the eastern side of the river. In 2020 we assessed the ability of lamprey to find and use the fish lift by tagging fish (n=50) and releasing them 1 km downstream on the east shore. All of the tagged lampreys were detected in the fish way following release, with forty-eight (96%) of lamprey arriving within 24 h. Forty-one tagged lamprey (82%) successfully passed Milford Dam, with 27 doing so in 48 h after approaching the fish way. In 2021 we tested the hypothesis that release on the east side was advantageous in quickly finding the fish lift; one group (n=50) of fish was released on the east shore (as in 2020) with a second group (n=50) was released on the western shore. Passage success was comparable between these groups (73 v. 70% for west and east releases, respectively). The majority of these fish passed at night in both years. Mobile tracking revealed extensive searching movements of these fish in the tail race of the dam, consistent with high migratory motivation. Successfully passed fish were observed to make extensive (>50 km) movements upstream. These data suggest a high capacity for the restoration of these fish in response to effective passage.

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Rewriting the textbooks: Further evidence of life cycle diversity inferred from otolith microchemistry in River Herring

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Life cycle diversity has been described for a number of marine and diadromous fish species as a characteristic for populations to exploit a variety of habitats and resources to increase productivity. Alosines have had relatively little focus on life cycle diversity patterns, despite managers identifying these critical data gaps. Emerging technology such as laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) has provided fisheries scientists the ability to examine life history patterns by utilizing microchemical signatures on structures such as otoliths. We investigated freshwater - estuary - marine habitat migration patterns by characterizing strontium and barium concentration patterns from natal origin through adult regions of Alewife and Blueback Herring otoliths. Fish were captured as adults in the Penobscot River, Maine as they made their upstream migration for spawning. Previous studies have indicated that age-1 juveniles in this system commonly inhabit estuary habitat but the prevalence of this pattern in adults was unknown. We found that few fish (12% of Alewives and 0% of Blueback Herring) exhibited what would be considered “textbook” migration patterns of a freshwater residence followed by a rapid emigration to marine habitat for the remainder of their lives. However, 68% of Alewives and 66% of Blueback Herring demonstrated a pattern where initially “textbook” migration occurred, but was followed by emigration back to lower salinity habitat. Most Blueback Herring and Alewives demonstrated migrations where individuals experienced multiple freshwater and marine habitat transitions. Whereby, we observed 11 (18%) Blueback Herring and 67 (24%) Alewives with 2 transitions, 19 (31%) Blueback Herring and 33 (12%) Alewives with 3 transitions, and 26 (42%) Blueback Herring and 31 (11%) Alewives with 4 or more transitions. We also observed fish with no apparent initial freshwater rearing in 9 (15%) of Blueback Herring and 63 (22%) of Alewives. In contrast, we found prolonged estuary or freshwater residence with no evidence of full marine transition in 10 (16%) of Blueback Herring and 27 (10%) of Alewives. These results, combined with previous work along the East Coast, suggest that management allows unobstructed passage from the freshwater to and from marine environments for juvenile and adult life stages. Aligning management measures to biological requirements is essential to allow the full diversity of life histories for these species to persist and proliferate.

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One health assessment of mercury, persistent organic compounds and PFAS for consumption of restored anadromous fish in the Penobscot River

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Penobscot Indian Nation (PIN) tribal members fish for sustenance in the Penobscot River and its tributaries in Maine. Recent removal of dams has resulted in the return of anadromous fish species, including Alewife, American Shad, Blueback Herring, Rainbow Smelt, Striped Bass, and Sea Lamprey, into the Tribe's waters. USEPA, ATSDR and PIN collaborated on a project to assess the safety of human and wildlife consumption of these returning fish. Attendees will learn about results of this study that included analysis of fish tissue for levels of PCBs, PBDEs, dioxins/furans, and PFAS; and a risk assessment for Penobscot tribal members when engaging in sustenance fishing and their traditional cultural practices. The results will be used by PIN to provide appropriate consumption guidelines and educational outreach materials.

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Video Presentation: Allen Stream restoration projects open 15 miles of Atlantic salmon rearing habitat

Eileen Bader Hall, The Nature Conservancy in Maine

Using survey data and a decision tool developed by The Nature Conservancy (TNC), TNC staff determined that removing two stream barriers would open 15 miles of ideal cold-water spawning habitat in Allen Stream within the greater Kenduskeag and Penobscot River watersheds. Prior to removal in 2020, the two barriers were located on a potato farm in Exeter, Maine. Atlantic salmon spawning has been documented downstream of the former stream barriers. Utilizing technical and financial assistance from the Maine Aquatic Connectivity Restoration Project – made possible by a $6 million award to TNC through the Regional Conservation Partnership Program (RCPP), a program of the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS), the five-year project augments private landowner funding and provides expertise in stream restoration efforts like this one. While the program, in addition to the landowner, covered the costs of the stream restoration, TNC also helped offset the expense of a new irrigation system by connecting existing rain retention ponds to the fields watered by the current system. This funding agreement ensured that surface water from Allen Stream was no longer needed – and Allen Stream will no longer be affected by irrigation use. The video produced by The Nature Conservancy and featuring NRCS, the landowner, and partners, highlights the success of the Allen Stream projects and demonstrates how innovative technology, key financial resources, and partnerships can restore critical Atlantic Salmon habitat.

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Day 2, Afternoon

Moderator:

Ben Naumann, Natural Resources Conservation Service

Mapping baseflow by reach for streams with endangered Atlantic Salmon in Maine

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Mathias J. Collins, NOAA's National Marine Fisheries Service
Rory Saunders, NOAA's Greater Atlantic Regional Fisheries Office, Orono, ME
Ernie Atkinson, Maine Department of Marine Resources

The freshwater range of the Gulf of Maine Distinct Population Segment of the endangered Atlantic Salmon includes watersheds from the Androscoggin River northward along the Maine coast to the Dennys River. Diminished habitat quality and accessibility are among the leading threats identified in the endangered listing rule and addressed in the recovery plan of 2019. As with other salmonids, Atlantic salmon must have access to cold water throughout the warmest parts of the summer, particularly in the southern portions of their range, which includes Maine. Temperature is a critical component of water quality, and thus restoring and maintaining access to high-quality freshwater and estuarine habitats in Maine are the primary focus of efforts to aid in the recovery of Atlantic salmon. Baseflow is the flow that exists in the stream without the contribution of direct runoff from rainfall and is often associated with cooler stream temperatures. We published a regression model for estimating mean August baseflow per unit of drainage area to help resource managers assess relative amounts of baseflow in Maine streams with Atlantic salmon habitat. We used this model to develop a map of the Narraguagus River watershed with reaches color coded by relative amounts of baseflow per unit of drainage area predicted by the model. The map can be used to identify river reaches with relatively higher amounts of baseflow during summer low-flow conditions that may be high-quality habitat for Atlantic Salmon and other coldwater fish. We are currently expanding this map to include the entire range of Atlantic salmon in Maine, which will help natural-resource managers prioritize reach-based conservation and restoration efforts both within individual watersheds and across watersheds.

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The response of benthic habitat and leaf breakdown rates to large wood restoration in the Narraguagus River, Maine: an ecosystem process perspective

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Process-based restoration, or restoration of ecosystems with the goal of reestablishing the natural processes that underlie ecosystem function, is an increasingly popular tool in river and salmonid restoration. To properly evaluate the success and sustainability of such projects, it is essential to estimate the response of ecosystem processes to restoration efforts. We assessed the effectiveness of large wood additions to the stream channel for restoring Atlantic Salmon (*Salmo salar*) habitat and ecosystem processes in eastern Maine's Narraguagus River. We selected ten sites in the mainstem of the Narraguagus River, Maine, each with a restored test section (either griphoist-felled trees or post assisted log structures) and a reference section upstream. In each section of all sites, we measured habitat variables including depth, velocity, aquatic macrophyte cover, and percent cover of substrate classes. We also measured leaf breakdown rates by deploying red maple (Acer rubrum) leaf packs at all sites for five weeks each in June and August, 2021. Then we compared habitat variables, leaf pack dry masses, and leaf pack ash-free dry masses between restored and reference samples within each paired site. We find that restored stream segments have higher heterogeneity in benthic habitat conditions, particularly velocity, as well as higher heterogeneity in rates of leaf breakdown. This implies that large wood restoration in the Narraguagus River is increasing heterogeneity at multiple levels of the ecosystem. These results are part of an ongoing project which will also look at basal resources and macroinvertebrate communities in restored and reference stream segments.

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Geomorphic effects and habitat impacts of large wood at restoration sites in New England

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Mathias J. Collins, NOAA Restoration Center, Boston College

Large wood (LW) within rivers affects flow patterns and sediment storage, creating channel and floodplain complexity and providing diverse habitats for aquatic and riparian species. For Atlantic salmon, LW also provides protection from predators as well as temperature and nutrient benefits. With LW increasingly being used for river restoration, metrics to evaluate how effective LW is at achieving project goals need to be identified. We collaborated with fisheries biologists and restoration practitioners to understand restoration goals and establish appropriate effectiveness measures. The consensus, priority measures identified were scour, sediment variability, velocity, cover, and logjam dimensions versus channel geometry. We evaluated the geomorphic and habitat impacts of LW using these measures at river systems throughout New England with intentionally placed wood and wood that is passively-derived. Passively-derived LW is LW recruited to the channel through natural processes such as bank erosion, even if the recruitment occurs after human intervention (e.g., dam removal). At the Narraguagus River, Maine, we quantified these measures at ten sites with intentionally placed LW via cross-section surveys, drone-based aerial photographs, direct LW measurements, and visual sediment texture characterizations. All sites included a reference reach (no active restoration) and a test reach (LW additions present). We are collaborating with a team investigating macroinvertebrate response at the same Maine sites to obtain complementary data to further understand biophysical linkages. Ecogeomorphic metrics were also evaluated at five other sites throughout New England, two of which included intentionally placed LW, and three containing passively-recruited LW. We statistically compared test and reference reaches, and different sites, hypothesizing that velocities, sediment grain sizes, and water depths would be more variable in river reaches containing LW. Preliminary results indicate that for the majority of Narraguagus sites, velocity and depth standard deviations were larger and smaller, respectively, for test reaches when compared to reference reaches. By evaluating our ecogeomorphic metrics at sites where LW was passively recruited, and at engineered sites where wood has been intentionally placed, we aim to assess whether or not active restoration using LW is providing the geomorphic, hydraulic, and ecological effects desired by restoration practitioners.

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Invited Talk:

Stream and watershed restoration prioritization

George Pess, NOAA's Northwest Fisheries Science Center
Tim Beechie, NOAA's Northwest Fisheries Science Center
Phil Roni, Watershed Sciences Lab, Cramer Fish Sciences

The prioritization of stream and watershed restoration actions to aid in the recovery of salmonids is a critical and necessary step to the salmon recovery success. The process of determining what actions come first and where is typically a function of the overall restoration goal and multiple objectives, as well as limited funding. There are different types of restoration prioritization strategies that can be utilized, depending upon the level of information and understanding of the groups implementing restoration. Regardless of the method there are common steps that clarify the objectives and scale, determine the team, select the approach and criteria, compare and contrast the data and models used, examine the ranking of actions, and redo the adaptive management loop once the prioritization process occurs. We will go over the strengths and weaknesses of seven methods used for restoration prioritization and conclude with some key points, regardless of the prioritization method used.

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Estimating stream flow from images in headwaters

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Stream flow is a critical environmental variable, but very few headwater streams are currently gaged by USGS. Gaging headwater streams is particularly challenging because it is difficult to use standard gage technology in smaller streams and because of the very high number (and cost) of streams that could be gaged. Recent advances in Artificial Intelligence make it possible to think about developing a low-cost headwater gaging system based on images from time-lapse game cameras. The key challenge with AI-based stream flow estimation is the large number of images required for model training. Here we describe a database in the EcoSheds application environment for collecting imagery and flow data (when available). Users can easily upload images and flow data and explore the images over time or ranked by flow. The image and flow data will be seamlessly linked with AI deep learning models that relate flow to the images providing predictions of flow for each image. This headwater stream flow modeling system will increase the potential for more widespread flow estimates across headwaters and could serve as a complement to existing USGS gages in larger rivers.

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Impact of three years of clam shell additions to an episodically acidic stream in Eastern Maine

Emily Zimmermann, Maine Department of Environmental Protection

Despite restored access, Atlantic Salmon (*Salmo salar*) populations in eastern Maine remain low and are federally listed as endangered. Loss of fish populations due to acidification in the North Atlantic region has been well documented. Most waters in eastern Maine periodically experience acidic conditions ($pH<6.5$), resulting in detrimental impacts to salmon, especially during snow melt and spring/fall runoff. Liming acidic waters (using agricultural lime) has increased salmon abundance in Scandinavia and Nova Scotia, and has been recommended as a restoration action for Maine. A 2009 Project SHARE (Salmon Habitat and River Enhancement) pilot study investigating the efficacy of using clam shells to lime streams suggested a positive trend. In collaboration with the Downeast Salmon Federation, a multi-year effort in the East Machias River watershed is continuing to investigate the efficacy of this mitigation method, with the goal to increase macroinvertebrate abundance and diversity, and to increase juvenile salmon abundance. Following three years of adding shells to a stream, preliminary data analysis suggests that elevated pH persists only during baseflow conditions, however minimum calcium levels may have increased (1.4 versus 0.9 mg/L at the upstream control). Periodic stressful conditions are still occurring coincident with rain events. Monitoring, including biological sampling, will continue for two more years, five years from the first shell placement, to determine the efficacy of using clam shells to mitigate acidity.

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Fish passage standards for several species on Maine's largest rivers

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Of the 13 native diadromous species in Maine, six species migrate great distances upstream of head of tide to reach spawning or rearing habitat. They are Atlantic Salmon (*Salmo salar*), American Shad (*Alosa sapidissima*), Alewife (*Alosa pseudoharengus*), Blueback Herring (*Alosa aestivalis*), American Eel (*Anguilla rostrata*), and Sea Lamprey (*Petromyzon marinus*). Significant portions of spawning and rearing habitat for these species are upstream of one or more dams in all the large rivers in Maine (Androscoggin, Kennebec, and Penobscot). For populations that must pass several dams, the impacts of those dams are additive leaving a smaller and smaller proportion of the population that successfully completes their migration and could prevent or significantly delay restoration of species to historic abundances if the sum of impacts is too great. Therefore, it is critically important to know the scope of impact of each dam on each lifestage of each species. While relatively thorough testing, in the form of passage survival and efficiency studies, has been carried out for Atlantic salmon on the Penobscot River, testing on other rivers and other species has been inconsistently applied. Typically, these studies are requested by natural resource agencies during the Federal Energy Regulatory Commission (FERC) relicensing process. In recent years, FERC has not supported these requests because no standard upon which the results of the requested studies would be measured has been set by FERC, the licensee, or the resource agencies for the relevant species. To further restoration of these species, Maine Department of Marine Resource (MDMR) utilized best available science and collaborated with seasoned experts to develop passage standards for several species. This presentation will focus on: 1) the need for passage standards; 2) where passage standards have been implemented in the NE and what they are based on, and 3) a brief, non-technical overview of the passage standards developed by MDMR.

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