The 2024 Atlantic Salmon Ecosystems Forum

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January 9-10, 2024
Orono, Maine USA
University of Maine, Wells Conference Center

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2024 Atlantic Salmon Ecosystems Forum

Program at a Glance

Note that only presenting authors are listed.
Times listed are Eastern Standard Time. Times are subject to change.

Begin	End	January 9, 2024 – morning session
8:30	8:35	*Session 1 - Introduction - Joseph Zydlewski, University of Maine, moderator*
8:35	8:50	**Welcome to the 2024 Atlantic Salmon Ecosystems Forum** *Christopher Gerbi - Associate Dean, College of Earth, Life, and Health Sciences, University of Maine* *Sarah Bland - Deputy Regional Administrator, Greater Atlantic Regional Fisheries Office, NOAA's National Marine Fisheries Service (NOAA Fisheries)*
8:50	9:35	<u>**Keynote**</u> **- Reflections on the 10 year Anniversary of the re-opening of the St.Croix/Schoodic River** - *Chief Hugh Akagi, Leader of the Peskotomuhkati (Passamaquoddy) people in Canada*
9:35	10:05	<u>**Invited talk**</u> **- Climate change impacts on freshwater habitat of wild Atlantic salmon** - *Carole-Anne Gillis, Gespe'gewa'gi Institute of Natural Understanding*
10:05	10:20	**Managing cold-water refuges in a changing world: perspectives and path forward** - *Valerie Ouellet, NOAA Fisheries*
10:20	10:35	**Historical patterns and predictions for environmental streamflows relevant to diadromous fish -** *Glenn Hodgkins, United States Geological Survey (USGS)*
10:35	11:05	***Break***
11:05	11:20	**The Atlantic Salmon Research Joint Venture: utilizing data mobilization in an international scientific partnership to answer Atlantic salmon's big questions -** *Alexis Knight, Fisheries and Oceans Canada*
11:20	11:35	**Thermal refuges in pools and factors behind stratification** - *Simon Joly-Naud, Institut National de la Recherche Scientifique (INRS)*
11:35	11:50	**Managing for Atlantic salmon smolt run timing variability in a changing climate** - *James Hawkes, NOAA Fisheries*
11:50	12:05	***Q&A*** *for all morning talks and housekeeping*
12:05	12:10	**Remembrance** of Erin Peterson and Joan Trial
12:10	13:10	***Lunch*** *– catered lunch is provided with paid registration*

Begin	End	January 9, 2024 – afternoon session
13:10	13:15	*Session 2 – Amanda Cross, U.S. Fish and Wildlife Service, moderator*
13:15	13:45	**Invited talk - Marine-derived nutrients in Atlantic rivers: reconsidering the role of anadromous fishes** - *Kurt Samways, University of New Brunswick*
13:45	14:00	**Using eDNA surveys to describe sea lamprey and American eel distribution following the Penobscot River restoration project** - *Cody Dillingham, University of Maine*
14:00	14:15	**Advancing the multi-species approach towards salmon recovery** *Timothy F. Sheehan, NOAA Fisheries*
14:15	14:30	**Seven dam challenges for migratory fish: insights from the Penobscot River -** *Joseph Zydlewski, USGS*
14:30	14:45	**Identifying cost-optimized road-stream crossings for barrier removal -** *Christian Fox, The Nature Conservancy in Maine*
14:45	15:15	*Break*
15:15	15:30	**Contrasting anadromous and landlocked Alewife interactions with lake food webs -** *Guillermo Figueroa-Muñoz, University of Maine*
15:30	15:45	**Upstream and downstream dam approach and passage of adult alewife on the St. Croix River -** *Emilie Hickox, University of Maine*
15:45	16:00	**Migration Risk: How many Atlantic salmon (*Salmo salar*) smolts could smallmouth bass eat during smolt seaward migration in the Weldon Headpond?** *Rylee Smith, University of Maine*
16:00	16:15	**To catch a predator – Using telemetry and tethering to characterize Atlantic salmon (*Salmo salar*) smolt predation in the Penobscot River-** *Matthew Mensinger, University of Maine*
16:15	16:30	*Q&A for all afternoon talks and housekeeping*
16:30	18:00	*Poster session – refreshments are included with paid registration*

Poster Session Social

4:30pm to 6:00pm - January 9, 2024

BIL, ARPA and IRA walk into a bar and make all your fish passage dreams come true – *Theodore Willis, Maine Department of Marine Resources (MDMR)*

Atlantic salmon (*Salmo salar*) smolt in a marine conservation farm: marine survival and optimal feeding regimes – *Josh LeBlanc, University of New Brunswick*

Conservation and management challenges and opportunities for diadromous fish in licensing of hydropower projects – *Melanie Harris, NOAA Fisheries*

Development of a DNA aptamer to capture free Atlantic salmon cells from environmental samples - *Gerard Zegers, University of Maine at Machias*

Comparing the critical thermal maximum of aquaculture salmon to wild salmon – *Hallie Arno, Memorial University*

Seeing the forests for the streams: framing headwater stream diagnostics for watershed management decision-making in deglaciated landscapes – *Robert King, University of Maine*

Water quality criteria for Maine, why pH criteria are needed for salmon restoration – *Mark Whiting, Hancock County Soil & Water Conservation District*

Maine Climate Science Information Exchange: An office of climate science information coordination based at the University of Maine – *Valerie Watson, University of Maine*

Begin	End	January 10, 2024 – morning session
8:30	8:40	*Session 3 – Dan McCaw, Penobscot Nation, moderator*
8:40	9:10	**Invited talk – "Stage zero" restoration: the evidence, a general overview and some example projects** - *Brian Cluer, NOAA Fisheries*
9:10	9:25	**Narraguagus River process-based restoration project -** *Chris Federico, Project SHARE*
9:25	9:40	**Geomorphic effects and habitat impacts of large wood at restoration sites in New England -** *Audrey Turcotte, Boston College*
9:40	9:55	**Large wood additions on the Narraguagus River (Maine) have little ecological effect at multiple scales -** *Val Watson, University of Maine*
9:55	10:10	**Impacts of clam shell additions to an episodically acidic stream in Eastern Maine -** *Emily Zimmermann, Maine Department of Environmental Protection*
10:10	10:35	*Break*
10:35	10:50	**From RAS to river: the salmon for Maine's rivers program** - *Danielle Frechette, MDMR*
10:50	11:05	**Reinstating Atlantic salmon's natural spawning and life cycle: movement and survival of Atlantic salmon in Maine -** *Carolyn Merriam, University of Maine*
11:05	11:20	**Identifying optimal egg planting scenarios for Atlantic Salmon *(Salmo salar)* in Eastern Maine, USA -** *Ernest Atkinson, MDMR*
11:20	11:35	**Development and genetic monitoring of a thiamine deficiency complex tolerant Atlantic salmon broodstock** - *Kurt Heim, United States Fish and Wildlife Service (USFWS)*
11:35	11:50	**Evaluating stocking strategies for recovery of endangered Atlantic salmon in the Piscataquis River, Maine** - *Justin Stevens, Maine Sea Grant*
11:50	12:10	*Q&A for all morning talks and housekeeping*
12:10	13:10	Lunch

Begin	End	January 10, 2024 – afternoon session
13:10	13:15	*Session 4 – Molly Payne Wynne, The Nature Conservancy in Maine, moderator*
13:15	13:30	**Moving beyond current population dynamic constraints to Atlantic salmon recovery in coastal rivers of Maine to increase climate resilience -** *John Kocik, NOAA Fisheries*
13:30	13:45	**A multi-year assessment of Sandy River population trends in out-migrating Atlantic salmon *(Salmo salar)* smolts -** *Jennifer Noll, MDMR*
13:45	14:00	**Migration and repeat spawning dynamics of Atlantic salmon *(Salmo salar)* kelt** - *Heather Perry, Atlantic Salmon Federation*
14:00	14:15	**Understanding freshwater to marine transitional scale growth in Atlantic salmon *(Salmo salar)*** - *Brandon Ellingson, NOAA Fisheries*
14:15	14:30	**Gill maggots: helpful or headache?** *Christina Murphy, USGS*
14:30	14:45	**Did changing the governance structure of Atlantic salmon in Maine improve collaborative efficacy?** *Melissa Flye, University of Maine*
14:45	15:00	**Chin up, it isn't all bad with Atlantic salmon restoration in the Gulf of Maine distinct population segment** - *Dan Kircheis, NOAA Fisheries*
15:00	15:30	*Break*
15:30	15:45	**Impacts of dams on river herring populations through their native range: what's left?** *Shawn Snyder, University of Maine*
15:45	16:00	**NOAA's River herring conservation and coordination at a coastwide scale -** *Ben German, NOAA Fisheries*
16:00	16:15	**Nearshore Gulf of Maine groundfish diets with a focus on diadromous fish contributions** - *Landon Falke, NOAA Fisheries*
16:15	16:30	*Q&A for all afternoon talks and housekeeping*
16:30	16:45	**Student awards, presentation of partner in the spotlight award, and closing** - *Sarah Bland, NOAA Fisheries*

Invited Talk:

Climate change impacts on freshwater habitat of wild Atlantic salmon

Carole-Anne Gillis, Gespe'gewa'gi Institute of Natural Understanding, Listuguj, QC

The Atlantic Salmon Research Joint Venture recently held a workshop to examine the effects of climate change on the freshwater habitat of wild Atlantic salmon. The workshop focused on the importance of the thermal quality of in-stream habitats for the resilience of Atlantic salmon populations. Climate change and human activities have resulted in significant changes to these habitats, posing challenges for all life stages of freshwater Atlantic salmon. These changes can lead to physiological and behavioral responses that impact the ability of individuals and populations to adapt to a changing climate. It is crucial to understand and monitor the relationship between river temperature dynamics and the physiological needs of Atlantic salmon at different life stages and in different habitat conditions. The workshop concluded with a call to action and a list of recommendations, which will be shared in this presentation.

Corresponding Author: Carole-Anne Gillis, cgillis@ginu.co

Managing cold-water refuges in a changing world: perspectives and path forward

Valerie Ouellet, Integrated Statistics contractor for NOAA Fisheries, Northeast Fisheries Science Center, Orono, ME;
Francine Mejia, U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, Seattle, WA

Anthropogenic activities are causing changes in rivers' thermal regimes, which results in increased water temperatures and reduced thermal heterogeneity in many areas. These changes threaten coldwater fish species such as salmonids. Thus, cold-water refuges (CRWs) are increasingly crucial for salmonids' short-term survival. However, there is a lack of cohesive CWR management that considers interlinked physical, biological, and social factors. In the United States, policies exist that target cold-water habitat designation, restrict fishing during warm periods, and implement threshold temperature standards or guidelines, but these policies are rare and uncoordinated across the different states. In this presentation, we provide an overview of the current state of the CWR science and policies to highlight research and policy gaps that may improve management of coldwater species. We provide a path forward to improve CWR management and conservation through an integrative framework that proposes (1) mapping and characterizing CWRs to help prioritize management actions, (2) leveraging existing and new policies, (3) improving coordination across jurisdictions, and (4) using adaptive management practices across different scales. This framework also proposes using common definitions to identify CWRs and for CWRs to be considered distinct operational landscape units that include hydrological and geomorphological processes that allow cold water to persist in time and space. These units facilitate CWR management across scales and can be integrated into watershed management plans.

Corresponding author: Valerie Ouellet, valerie.ouellet@noaa.gov, (302) 212-8026

Historical patterns and predictions for environmental streamflows relevant to diadromous fish

Glenn Hodgkins, U.S. Geological Survey, New England Water Science Center, Augusta, ME;
Mathias Collins, NOAA Fisheries, Office of Habitat Conservation, Gloucester, MA;
Valerie Ouellet, Integrated Statistics contractor for NOAA Fisheries, Northeast Fisheries Science Center, Orono, ME

Environmental streamflows refer to the magnitude, frequency, duration, and seasonal timing of streamflows needed to sustain freshwater and estuarine ecosystems. The U.S. Geological Survey (USGS) and NOAA Fisheries are collaborating to analyze historical trends in selected annual and monthly environmental streamflows at hundreds of USGS gages across the conterminous United States and model these streamflows for thousands of ungaged stream reaches. We are analyzing, together and separately, relatively natural basins and watersheds with substantial human influence on streamflows. We are also investigating relations between environmental streamflows and atmosphere-ocean climate variability patterns. A unique component of the project is analyzing streamflows important for diadromous fish. To identify these flows, we consulted with NOAA scientists, fish passage engineers, and managers in the Northeast, Southeast, Northwest, and Southwest regions as well as other regional diadromous fish experts. All regions identified seasonal metrics of high and low flows as their primary concern, however the seasonal windows are region-specific. In this presentation we will describe the project design, our regional consultation process, each region's identified seasonal flows important for diadromous fish, and any available preliminary results.

Corresponding author: Glenn Hodgkins, gahodgki@usgs.gov, (207) 626-6621

The Atlantic Salmon Research Joint Venture: utilizing data mobilization in an international scientific partnership to answer Atlantic salmon's big questions

Alexis Knight, Fisheries and Oceans Canada, Moncton, NB;
Carole-Anne Gillis, Gespe'gewa'gi Institute of Natural Understanding, Listuguj, QC;
Andre St. Hilaire, Institut National de la Recherche Scientifique, QC;
Edmund Halfyard, Nova Scotia Salmon Association, Bedford, NS;
Julien April, Ministère des Forêts, de la Faune et des Parcs, QC;
Normand Bergeron, Institut National de la Recherche Scientifique, QC;
Ian Bradbury, Fisheries and Oceans Canada, Moncton, NB;
Cindy Breau, Fisheries and Oceans Canada, Moncton, NB;
Jonathan Carr, Atlantic Salmon Federation, Chamcook, NB;
Corey Clarke, Parks Canada, Alma, NB;
Kathryn Collet, New Brunswick Department of Natural Resources, Fredericton, NB;
Guillaume Dauphin, Fisheries and Oceans Canada, Moncton, NB;
Wendy Epworth, Fort Folly First Nations, Dorchester, NB;
David Hardie, Fisheries and Oceans Canada, Moncton, NB;
John Kocik, NOAA Fisheries, Northeast Fisheries Science Center, Orono, ME;
Diane Lavoie, Fisheries and Oceans Canada, Moncton, NB;
Tommi Linnansaari, University of New Brunswick, Fredericton, NB;
Kristin Loughlin, Fisheries and Oceans Canada, Moncton, NB;
Roseanne MacFarlane, Prince Edward Island Department of Fish and Wildlife, Charlottetown, PEI;
Dustin Raab, Fisheries and Oceans Canada, Moncton, NB;
David Reddin, Atlantic Salmon Conservation Foundation, Fredericton, NB;
Martha Robertson, Fisheries and Oceans Canada, Moncton, NB;
Kurt Samways, University of New Brunswick, St. John NB;
Marc Trudel, Fisheries and Oceans Canada, Moncton, NB;
Fred Whoriskey, Dalhousie University, Halifax, NS;
Paul Bentzen, Dalhousie University, Halifax, NS;
Ian Fleming, Memorial University of Newfoundland, St. John's, NL;
Colin Bull, Atlantic Salmon Trust, Battleby House, Redgorton, Perth, UK;
Shelley Denny, Unama'ki Institute of Natural Resources, Eskasoni, NS

With both an international distribution and an anadromous life cycle, producing meaningful and broad-ranging Atlantic salmon (*Salmo salar*) research has historically been a complex undertaking for the scientific community. Despite substantial research and conservation efforts, many salmon populations continue to decline. In order to respond to these issues, the Atlantic Salmon Research Joint Venture was formed in 2016 as a collective of collaborative partnerships between academic, government, non-profit and Indigenous organizations to promote synergistic projects that address priority research themes such as: 1) identifying and comparing trends in abiotic and biotic historical freshwater data to determine influences on smolt condition, outmigration behaviour and marine phase mortality; 2) Investigating whether poor marine survival is the result of a genetic bottleneck selecting for specific traits, and 3) Mobilizing the collection of new information to establish linkages between freshwater conditions and the marine survival of Atlantic salmon. This research relies on combining a backwards-looking approach that collates the abundance of pre-existing high-quality data normally not shared across agencies to address historical data questions, with a forwards-looking approach that identifies understudied sites across the East coast and mobilizes resources to fill the information gaps. By pooling resources, building a sense of trust amongst previously independent stakeholders, and implementing novel initiatives to increase the availability and accessibility of open-access salmon data, the Joint Venture presents an example of an effective strategy for answering salmon's big questions through collaboration.
Corresponding author: Alexis Knight, alexis.knight@dfo-mpo.gc.ca, (416) 995-5664

Thermal refuges in pools and factors behind stratification

Simon Joly-Naud, Institute National de la Recherche Scientifique, Quebec, QC;
Normand Bergeron, Institute National de la Recherche Scientifique, Quebec, QC;
Isabelle Laurion, Institute National de la Recherche Scientifique, Quebec, QC

Atlantic salmon often face high water temperatures during their upstream migration, reaching beyond their optimal thermal limits. To avoid thermal stress, they seek cold water patches, behavior known as thermoregulation. Theses patches are then called thermal refuges. Some can be found at the bottom of pools where many individuals can agglomerate. However, little is known about the dynamics behind the formation of refuges in pools and their temporal evolution. The browning of freshwaters caused by increasing concentrations of colored dissolved organic matter (CDOM) is a widespread phenomenon in the northern hemisphere. Browning is known to strengthen the thermal structures in lakes, but its impact in rivers is not well documented. We investigated 20 pools of various morphologies and hydrometry in 7 rivers along a CDOM gradient in eastern Quebec. We conducted stratigraphic bi-dimensional flow turbulence measurements, short term thermal surveys of the water column with moorings, bathymetric mapping using sonar, and CDOM analysis. These data allow us to test the synergistic impact of pool morphology, currents turbulence, hyporheic and groundwater resurgences, and CDOM content on stratification intensity. We found pools showing diurnal surface stratification reaching between 1.0°C and 3°C of difference between surface and bottom waters, regardless of depth and morphology. We also found pools with stratification of at least 1.5°C lasting over a complete day, regardless of depth and diurnal patterns. The historical floods and rainfalls of summer 2023 in eastern Quebec jeopardized many experiments and data collection in the field. However, they offered unprecedented insights into the dynamics of pools refuges, with drastic changes in groundwater and rivers levels over a short period of time. We observed the formation and destruction of refuges induced by surface warming and resurgences. These unique observations provide new information on a little-known but crucial aspect of thermal refuges in rivers for Atlantic salmon.

Corresponding author: Simon Joly-Naud, simon.joly-naud@inrs.ca, (514) 917-7240

Managing for Atlantic salmon smolt run timing variability in a changing climate

Danielle Frechette, Maine Department of Marine Resources, Bureau of Sea-Run Fisheries and Habitat, Augusta, ME;
James Hawkes, NOAA Fisheries, Northeast Fisheries Science Center, Orono, ME;
John Kocik, NOAA Fisheries, Northeast Fisheries Science Center, Orono, ME

The Gulf of Maine Distinct Population Segment of Atlantic salmon (*Salmo salar*) is listed endangered under the U.S. Endangered Species Act. Recovery criteria center on maximizing the number of smolts, particularly those of natural rearing origin, entering the ocean. Because dams represent a substantial source of mortality for smolts, ensuring safe, timely, and efficient passage through dams is critical for recovery. We analyzed data from four long-term trapping sites to characterize smolt emigration dynamics in Maine rivers. From these data, we developed a model to predict the onset of emigration and created a generalized smolt run (or wave) for natural-and hatchery-origin smolts in Maine rivers, which we used to: 1) simulate the movement of smolts in the Kennebec and Penobscot rivers to evaluate management actions, and 2) compare emigration timing between hatchery- and natural-origin smolts. Duration of the natural-origin smolt run was 42 to 58-d across trapping sites. Date of initiation varied by as much as two weeks among years and sites. Emigration dynamics differed between natural-origin and hatchery-origin smolts and our simulations indicated that emigration between the two rearing types was asynchronous. Our approach can be used to adaptively manage timing of protective measures at dams and improve synchrony between natural- and hatchery-origin smolts, thereby increasing in-river and marine survival. Importantly, we found the current 14-d spill windows are too short to consistently protect a large portion of the run or preserve adaptive variation in these populations and should be increased in the absence of other protective measures.

Corresponding author: James Hawkes, james.hawkes@noaa.gov, (207) 866-7109

Invited Talk:

Marine-derived nutrients in Atlantic rivers: reconsidering the role of anadromous fishes

Kurt Samways, University of New Brunswick, St. John, NB

With the dramatic declines in Atlantic anadromous fishes over the past century it is important to identify the roles marine-derived nutrients (MDNs) delivered by these fishes play in influencing freshwater food web dynamics. The role of MDN transport in coastal rivers is a function of net nutrients transferred by all anadromous fish and collectively may result in MDN subsidies equivalent to those delivered by salmon on the Pacific coast. The current scarcity of these fishes may have profound effects on aquatic production, particularly in nutrient-poor systems. To understand the linkages between freshwater and marine ecosystems, observational studies, experimental frameworks, and analytical techniques (e.g., stable isotope and fatty acid analysis) are commonly used to study MDNs effect on i) primary production/productivity; ii) trophic interactions; iii) resource quality; and iv) ecosystem restoration/recovery. The current trend of declining anadromous fish populations in the Atlantic region means fewer nutrient-rich marine subsidies for stimulating trophic production in these river systems. Marine-nutrient subsidies benefit multiple trophic levels of freshwater organisms as well as provide a cross-ecosystem spatial subsidy. The connectivity between freshwater and marine inputs is larger in scope than previously understood. The reduction of MDN may act to constrain freshwater productivity, and therefore, the sustainability of anadromous and resident fish populations. To maintain ecosystem function and productivity, it is critical to include MDNs for effective ecosystem management and river restoration strategies.

Corresponding author: Kurt Samways, kurt.samways@unb.ca, (506) 648-5944

Using eDNA surveys to describe Sea Lamprey and American Eel distribution following the Penobscot River restoration project

Cody Dillingham, Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME;
Lara Katz, Ecology and Environmental Sciences, University of Maine, Orono, ME;
Geneva York, Coordinated Operating Research Entities, University of Maine, Orono, ME;
Michael Kinnison, Maine Center for Genetics in the Environment, University of Maine, Orono, ME;
Joseph Zydlewski, U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit and Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME

Anadromous sea lamprey (*Petromyzon marinus*) and catadromous American eel (*Anguilla rostrata*) are native to Maine's Penobscot River and historically upstream migrants moved through the Penobscot River and its tributaries prior to industrial damming. Recent restoration efforts, including dam removals, have improved connectivity in the lower reaches of the Penobscot River for these and other diadromous fish. Radio telemetry has demonstrated that sea lamprey have been successful in reaching some of the upper tributaries to recolonize their historic habitats. For the American eel, analogous efforts are simply not feasible due to the size of migrant glass eels relative to telemetry tags. For both species, characterizing the extent of their distribution is important to inform restoration efforts and identify dam passage needs. Traditional survey methods like seining and electrofishing require high investments of time and money, precluding extensive use of these approaches. Environmental DNA (eDNA) surveys are an alternative method that is both effective and cost-efficient. In the summer of 2023, we conducted eDNA surveys throughout the Penobscot River watershed to describe the current distribution of sea lamprey and American eel. Water samples were collected from 70 sites representing 39 rivers and streams; species-specific genetic markers within those samples were amplified using qPCR to assess presence or absence. We have shown that American eel are present in the full extent of the area surveyed. The wide distribution may reflect the impressive climbing ability of at least some glass eels to overcome barriers. Sea lamprey are less widely distributed, congruent with the observed patterns of telemetry data. The results suggest that some dams likely continue to exclude upstream migrating adult sea lamprey from spawning habitats, particularly in smaller tributaries.

Corresponding author: Cody Dillingham, cody.dillingham@maine.edu, (207) 399-1194

Advancing the multi-species approach towards salmon recovery

Timothy Sheehan, NOAA Fisheries, Northeast Fisheries Science Center, Woods Hole, MA; Rory Saunders, NOAA Fisheries, Greater Atlantic Regional Fisheries Office, Orono ME; G. Matthew Buhyoff, NOAA Fisheries, Greater Atlantic Regional Fisheries Office, Orono ME

The native suite of sea-run fish convey specific benefits to Atlantic salmon through a series of ecological mechanisms, often referred to as ecosystem services, including the delivery of marine-derived nutrients, the provision of prey items, the conditioning of riverine habitat, and a hypothesized reduction in predation risk via prey buffering. The benefits of these ecosystem services are described in the federal Endangered Species Act listing rule and critical habitat designation for the Gulf of Maine Distinct Population Segment (GOM DPS) of Atlantic salmon. Dams have greatly reduced the abundance and distribution of diadromous fishes within the freshwater range of the GOM DPS, thereby greatly diminishing or eliminating the delivery of these ecosystem services to the detriment of Atlantic salmon productivity. The Atlantic salmon recovery program (encompassing partners in tribal, state, and federal governments; the private sector; and non-governmental organizations) has made progress acknowledging, understanding and restoring these services in a limited manner, but there remains considerable room for improvement towards understanding and addressing how the restoration of these services may influence the recovery potential of the GOM DPS. Defining specific abundance and distribution targets of sea-run fish (i.e., management targets) to ensure the delivery of these ecosystem services would be a key step toward addressing this shortcoming. Once established, these management targets could guide future restoration actions including the development of goals for survival and delay for sea-run fish at hydroelectric dams within the freshwater range of the GOM DPS of Atlantic salmon. The establishment of management targets that deliver “salmon-centric” ecosystem services would also be an incremental step toward implementation of an ecosystem-based fisheries management (EBFM) approach towards the recovery of the GOM DPS of Atlantic salmon and falls in line with NMFS' EBFM policy and “road map" towards implementation. In this presentation, we discuss information gaps that must be filled (e.g., research needs) and steps that must be taken (e.g., management target establishment) in order to make further progress toward advancing the multi-species approach to Atlantic salmon recovery and more complete implementation of EBFM in the future.

Corresponding author: Rory Saunders, rory.saunders@noaa.gov, (207) 370-4533

Seven dam challenges for migratory fish: insights from the Penobscot River

Joseph Zydlewski, U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit and Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME;
Stephen Coghlan, Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME;
Cody Dillingham, Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME;
Guillermo Figueroa-Muñoz, Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME;
Carolyn Merriam, Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME;
Sean Smith, School of Earth and Climate Sciences, University of Maine, Orono, ME;
Rylee Smith, Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME;
Daniel Stich, Biology Department, SUNY College, Oneonta, NY;
Sarah Vogel, Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME;
Karen Wilson, Department of Environmental Science and Policy, University of Southern Maine, Gorham, ME;
Gayle Zydlewski, Maine Sea Grant College Program, University of Maine, Orono, ME

More than a century of impoundments in the Penobscot River has contributed to population declines in migratory fish in the system. A decade of change and monitoring has revealed direct and indirect ways that dams have influenced the river habitat, connectivity for migratory fish, and the food web. The removal of two main-stem dams and bolstering of fish passage have been part of coordinated restoration efforts in the watershed. Integral to this undertaking was support for short- and long-term monitoring that included physical habitat, fish passage, and broad scale ecological assessments. Herein we discuss the seven interconnected and complex ways that dams have affected the Penobscot River ecosystem. These include familiar influences ascribed to dams: i) impaired access to habitat, ii) injury and mortality, and (iii) delays of migration. Other ecological influences are less studied and more subtle: iv) facilitation of predation, v) demographic shifts, and vi) community shifts. Lastly, dams result in (vii) a loss of ecosystem services that would otherwise be intact in an unimpounded system. We draw on both direct examples from the Penobscot River and broader information to characterize how impoundments have transformed this ecosystem for more than a century. Recent dam removals and mitigation efforts have reestablished some of these ecological functions.

Corresponding author: Joseph Zydlewski, josephz@maine.edu, (207) 581-2853

Identifying cost-optimized road-stream crossings for barrier removal

Christian Fox, The Nature Conservancy in Maine, Brunswick, ME;
Steve Tatko, Appalachian Mountain Club;
Sean Morrison, Inter-Fluve;
Mike Burke, Inter-Fluve

Headwater stream connectivity throughout Maine is fragmented by thousands of barriers, mostly underperforming road-stream crossings, that prevent access to critical habitat by salmon and other sea-run fish. Replacing these crossings with "Stream Smart" structures is a proven strategy to restore access while at the same time improving transportation infrastructure. However, these projects are increasingly expensive and there is limited engineering and construction capacity available; consequently, implementation must be strategic and coordinated. Our recent Optimization Analysis of the Piscataquis River Watershed builds on the Statewide Barrier Prioritization dataset while adding new replacement cost information to identify sites that offer "the best bang for the buck" in restoration value. The analysis identified populations of projects that together achieve maximum reconnection of high-quality salmon habitat for available budget levels using the OptiPass Migratory Fish Passage Optimization Tool developed by Dr. J.R O'Hanley. Subsequent to the Optimization Study, significant post-processing of the results was required to identify crossings to advance for replacement, five of which are currently in progress. This presentation will cover our study design, process, and results for improved decision-making in project selection.

Corresponding author: Christian Fox, christian.fox@tnc.org, (860) 460-4040

Contrasting anadromous and landlocked Alewife (*Alosa pseudoharengus*) interactions with lake food webs

Guillermo Figueroa-Muñoz, Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME;
Christina Murphy, U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit, Orono, ME;
Joseph Zydlewski, U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit and Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME

Alewife (*Alosa pseudoharengus*) is a socio-ecologically important species native to the East Coast of North America that has discrete, anadromous and landlocked forms. Landlocked alewife have been introduced as a forage fish in many freshwater systems including the Great Lakes. Concurrently, runs of the anadromous form has been severely depleted through its natural range due to fishing, habitat degradation and damming. Recent efforts to recover native anadromous Alewife may return these fish to systems that have been without them for hundreds of years. There are concerns that reintroduction may influence contemporary food webs with high-value non-native cold-water fisheries. Such concerns are often founded on knowledge of landlocked alewife, however anadromous and landlocked forms function differently in lake food webs. Their interactions are shaped by differences in freshwater residence time (year-round v. seasonal) and feeding morphology (gape and raker spacing). Both forms may function as keystone species in lakes, but their ecological relationships are unique. Anadromous Alewife may seasonally: i) constitute a high-quality prey for piscivores, ii) compete for food resources with invertivores, iii) exert top-down control on zooplankton communities, iv) provide a food resource and v) improving primary productivity through transfer of marine derived nutrients. In contrast, landlocked Alewife may, through year-round presence: i) constitute a high-energy prey for piscivores, ii) prey on fish larvae affecting their recruitment, iii) exert top-down control on zooplankton communities, and iv) biosynthesize the enzyme thiaminase, transferring it to piscivores and resulting in early mortality syndrome. This review is intended to provide a synthesis of trophic interactions and highlight knowledge gaps in how anadromous Alewife may influence lake food webs. Such information may guide future study directions and inform restoration actions.

Corresponding author: Guillermo Figueroa-Muñoz, guillermo.figueroa@maine.edu, (207) 563-8115

Upstream and downstream dam approach and passage of adult Alewife on the St. Croix River

Emilie Hickox, Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME;
Danielle Frechette, Maine Department of Marine Resources, Bureau of Sea-Run Fisheries and Habitat, Augusta, ME;
Joseph Zydlewski, U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit and Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME

The St. Croix River is an international waterway dividing New Brunswick (Canada) and Maine (United States). Prior to damming, this system had substantial runs of native Alewife, but fish passage has had a complicated socio-political history. Three major dams: Milltown Dam (at the head tide, removed in 2023), Woodland Pulp and Grand Falls Dams block access to ninety four percent of the spawning habitat. In addition to the Milltown Dam removal, fish passage improvements are anticipated at Woodland Pulp and Grand Falls. We investigated Alewife behavior and dam passage using radio telemetry to inform future passage design decisions. To track upstream migration, adults were electrofished downstream of Woodland Pulp and Grand Falls dams, gastrically tagged, released, and tracked during their ascent in 2022 and 2023 (n=230 and n=250 respectively). To track downstream migrations, an additional 100 fish were tagged in 2023 and transported upstream of both dams. Preliminary results show migrating Alewife exploring on both sides of the river at Woodland Pulp. Overall, the fish tagged at Woodland experienced high fallback rates. Of the fish that approached Woodland, 22% were detected near the current fishway entrance, and 18% were detected near the channel without passage, suggesting that an additional passage path may improve passage success. Of the fish that were tagged downstream of Grand Falls, fish approaching Grand Falls were predominantly observed near the fish entrance (80%), while a few fish (3%) were observed at the channel without passage. This study will improve our understanding of approach and passage of alewife allowing us to contribute to alewife restoration in the St. Croix.

Corresponding author: Emilie Hickox, Emilie.Hickox@maine.edu, (440) 552-6842

Migration Risk: How many Atlantic salmon (*Salmo salar*) smolts could smallmouth bass eat during smolt seaward migration in the Weldon Headpond?

Rylee Smith, Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME;
Christina Murphy, U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit and Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME;
Joseph Zydlewski, U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit and Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME

The Gulf of Maine Distinct Population Segment (DPS) is home to the last population of federally endangered Atlantic salmon in the United States. The Penobscot River, a heavily impounded river, supports the largest run of Atlantic salmon within the DPS. Non-native Smallmouth Bass are widespread throughout Maine waters where endangered Atlantic salmon are found, particularly in the impounded habitat near dams. Smallmouth Bass are known to predate on juvenile salmon during freshwater rearing and during seaward migration. The Weldon Headpond, a 5 km area upstream of Weldon Dam is an area of low survival of migrating smolts. Evidence suggests that lower survival of migrating smolts in the Weldon Headpond is due in part due to predation. The degree to which this influence is ecologically relevant, however, is poorly characterized. To characterize the potential level of predation on migrating smolts, in this reach, we built a heuristic consumption model. The size distribution and population levels of Smallmouth Bass were modeled using values from the literature. In conjunction with water temperature data, we used a bioenergetic model to estimate Smallmouth Bass satiation levels. These data then informed a consumption model to estimate the potential consumption of smolts during their seaward migration by Smallmouth Bass. The results may inform managers as to the theorical predatory potential of Smallmouth Bass on smolts in the Weldon Headpond and the Penobscot River in total.

Corresponding author: Rylee Smith, rylee.smith@maine.edu, (801) 645-7702

To catch a predator – Using telemetry and tethering to characterize Atlantic salmon (*Salmo salar*) smolt predation in the Penobscot River

Matthew Mensinger, Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME;
James Hawkes, NOAA Fisheries, Northeast Fisheries Science Center, Orono, ME;
Graham Goulette, NOAA Fisheries, Northeast Fisheries Science Center, Orono, ME;
Alessio Mortelliti, Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME;
Joseph Zydlewski, U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit and Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME

Atlantic salmon (*Salmo salar*) smolts migrate downstream through Maine rivers, but < 50% survive migration and fewer than 0.1% return as adults. While low marine survival is a significant hurdle to population recovery, the smolt stage is a final opportunity for targeted intervention in fresh water to improve adult return rates. Predation has long been assumed to be a leading source of smolt mortality, but there remains relatively little information on the extent of predation incurred by smolts in the Penobscot River. We used telemetry (acid-sensitive predation transmitters; n=270) and tethering of smolts (n=675) to characterize predation risk throughout the main-stem of the Penobscot River. Over three seasons, we detected more than 250 smolt predation events from a suite of predator species including marine mammals, piscivorous fishes, and diving waterfowl. Predation was the leading source of mortality for migrating smolts. We estimated that at least 55% of smolts stocked upstream of Weldon Dam are predated annually. The greatest risk occurred through hydropower dams and tidal reaches. Predation risk was also associated with warmer water temperatures, proximity to shorelines, and lentic conditions. This research complements decades of smolt telemetry research in the watershed by identifying major smolt predators, quantifying predation-induced mortality, and informing the conditions under which predation risk is increased.

Corresponding author: Matthew Mensinger, matthew.mensinger@maine.edu, (207) 581-2853

Invited Talk:

“Stage zero” restoration: the evidence, a general overview, and some example projects

Brian Cluer, NOAA Fisheries, West Coast Regional Office, Santa Rosa, CA;
Paul Powers, United States Department of Agriculture, Forest Service, Washington, D.C.

A main factor impeding salmonid recovery is the significant loss of pre-settlement habitats. The rich fisheries resources and fur trade that were exploited by early European colonists, cannot be supported by the riverscape of the current conditions. This has been understood for some time, leading to the restoration of degraded rivers to improve these lost habitats. Traditional river restoration has focused on enhancing attributes within the contemporary and ubiquitous single-thread channel that is widely viewed as the natural state. However, this view of rivers fails to account for the forgotten legacy of human impacts. Floodplains and wetlands were drained and high capacity river channels were created. An alternative view of the riverscape has recently expanded our understanding of what these rivers were and could be once again. This alternative view recognizes the pre-degradation condition, referred to as Stage Zero, which relies on a set of physical and biological river conditions occurring as a network of small capacity channels in woodland settings, or no channels at all in wetland settings, where the water table and the land surface have extensive temporal and spatial interaction. Stage Zero integrates the river and floodplain across the physical valley plain. There is ample evidence to support the view that these conditions were historically abundant where deposition processes operate in transport-limited reaches of valleys. Stage Zero conditions can occur across a watershed, from course-grained steep alluvial fans to fine-grained flat valley bottoms. Vegetation thrives in these conditions that retain water and sediment, and vegetation has a role in forcing an abundant pallet of habitat features. Restoration projects to achieve Stage Zero conditions typically take one of two approaches; (a) remove old land use infrastructure such as roads, channel berms, and levees, and use that material to infill the incised (or simply oversized) channel, or (b) incrementally aggrade the incised channel with various roughness measures which can work where there is sufficient sediment supply and social commitment to multiple interventions (or help from beaver). Restoration to the Stage Zero condition results in significant increases in the residence time of water/nutrients, increases the availability and connectivity between wetted habitats at all discharge levels and provides the dynamic complexity that can support and hopefully recover salmonids to these areas. Naturally occurring Stage Zero examples and a variety of completed restoration projects will be presented, along with monitoring results, to help explain the appropriate range of settings and the benefits.

Corresponding author: Brian Cluer, brian.cluer@noaa.gov, (707) 575-6061

Narraguagus River process-based restoration project

Christopher Federico, Project SHARE, Cherryfield, ME;
Mark Jordan, Jordan Environmental Engineering and University of Maine, Orono;
William Bennett, U.S. Fish and Wildlife Service, Gulf of Maine Coastal Program, Falmouth, ME;
Colby Bruchs, Maine Department of Marine Resources, Bureau of Sea-Run Fisheries and Habitat, Jonesboro, ME

From the time of early European settlement in Maine, through the early twentieth century, the Narraguagus River watershed experienced intensive timber harvests and river modifications that resulted in a significant loss of Atlantic salmon habitat. The combination of the removal of boulders and large wood from the river, and the use of splash dams that released large torrents of water to facilitate log drives, resulted in river segments that are over-widened and heavily armored. These river segments lack quality habitat due to 1) a lack of depth and flow complexity, 2) elevated water temperatures caused by a combination of a large width to depth ratio, insufficient shading, and reduced connections to hyporheic flow, and 3) increased risk of predation resulting from a lack of plant cover. This talk will outline how Project SHARE, through a multi-disciplinary collaborative effort, undertook a demonstration river restoration project. The presentation will address the determination of location, design, construction and resulting impact of the intervention. The project included three large, engineered logjams, constructed floodplains, numerous combined boulder/log clusters and the re-connection of several floodplain channels to the main channel. This site was selected based upon temperature data indicating cold-water inputs within the area, local disconnected off-channel habitat, and a relatively high river gradient. The design closely follows the principles of process-based river restoration and included several multi-disciplinary workshops. The construction in 2022 was accomplished using all local, natural materials and a local contractor. The project has resulted in improved aquatic habitat and floodplain connectivity.

Corresponding author: Chris Federico, cfederico@salmonhabitat.org, (207) 731-7488

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

Audrey Turcotte, Department of Earth and Environmental Sciences, Boston College, Chestnut Hill, MA; Noah Snyder, Department of Earth and Environmental Sciences, Boston College, Chestnut Hill, MA; Mathias Collins, NOAA Fisheries, Office of Habitat Conservation, Gloucester, MA

Large wood, which refers to trees, logs and other wood within a channel, is beneficial to river ecosystems and is being used more frequently as a component of river restoration projects to achieve various outcomes. One interest of fisheries biologists and restoration practitioners is to use large wood to promote habitat complexity in a channel via the wood itself and wood-induced changes to hydraulics that influence sediment transport locally and thus bed forms. We met with restoration practitioners to identify metrics for evaluating the effectiveness of large wood at promoting ecological and geomorphic complexity within channels. We then evaluated these effectiveness metrics at several sites in New England with naturally recruited or placed large wood (i.e., restoration sites). Large wood structures most often did not cause the geomorphic and hydraulic changes we expected to see. Overall, only 33%, 33%, and 20% of surveyed sites showed significant, expected differences in depth variability, velocity variability, and velocity magnitude, respectively, between test and reference reaches. The availability of mobile sediment in a channel and the stream gradient seem to be important factors in determining whether or not large wood has the ability to impact the geomorphic and hydraulic characteristics of a channel.

Corresponding author: Audrey Turcotte, noah.snyder@bc.edu, (617) 552-0839

Large wood additions on the Narraguagus River (Maine) have little ecological effect at multiple scales

Valerie Watson, Department of Biology and Ecology, University of Maine, Orono, ME;
Hamish Greig, Department of Biology and Ecology, University of Maine, Orono, ME

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 Narraguagus River for restoring habitat components and ecological processes that support juvenile Atlantic salmon (*Salmo salar*) at local and reach scales. We selected ten sites in the mainstem of the Narraguagus River, Maine, to characterize physical habitat, algal and detrital resources, and macroinvertebrate community composition. Then we compared these metrics between restored and reference segments within each site, as well as along a gradient of reach-scale restoration effort. We find few differences between restored and reference site segments across physical and ecological measurements. This is consistent with contemporary geomorphological research completed by Audrey Turcotte of Boston College, which found no consistent geomorphological responses to wood additions in the Narraguagus. There was some evidence that the cumulative number of log structures upstream had positive effects on abundances of detritus-feeding macroinvertebrates. While such results may be discouraging for restoration practitioners, there is good evidence in the literature that macroinvertebrates respond to changes in physical habitat. This suggests restoration in the Narraguagus needs to be done at a larger spatial or temporal scale to create ecological change.

Corresponding author: Val Watson, valerie.k.watson@maine.edu, (207) 581-2445

Impacts of clam shell additions to an episodically acidic stream in Eastern Maine

Emily Zimmermann, Maine Department of Environmental Protection, Augusta, ME

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 was conducted to further investigate this mitigation method, with the goal to increase macroinvertebrate abundance and diversity, and to increase juvenile salmon abundance. Following four years of adding shells to a stream, elevated pH persisted year-round, in addition to elevated baseflow calcium and acid neutralization capacity. Periodically stressful conditions are still occurring coincident with rain events, however, which may cause any positive changes in water quality to be biologically insignificant to the recovery of salmon populations.

Corresponding author: Emily Zimmermann, emily.zimmermann@maine.gov, (207) 446-1003

From RAS to river: the salmon for Maine's rivers program

Danielle Frechette, Maine Department of Marine Resources, Bureau of Sea-Run Fisheries and Habitat, Augusta, ME

Maine rivers support the last remaining wild-spawning Atlantic salmon in the United States but their populations are drastically depleted. Current management of the endangered Gulf of Maine Distinct Population Segment focuses on preventing extinction through intensive hatchery supplementation, with salmon stocked into rivers as eggs, fry, parr, and smolts. Hatchery supplementation and habitat restoration have prevented extinction and improved aquatic habitat connectivity but extensive areas of habitat remain vacant or below carrying capacity because of low spawner abundance. To increase natural spawning, the Maine Department of Marine Resources and project partners have launched a new marine captive rearing program. In May 2021, smolts of Penobscot and Machias river origins were transferred from Green Lake National Fish Hatchery to a recirculating aquaculture system at the University of Maine Center for Cooperative Aquaculture. The first mature adults were released in October 2022, with spring release in June 2023, and final release for the inaugural cohort in October 2023. To further our understanding of how marine captive rearing may contribute to recovery efforts, we are assessing the program at a series of life cycle checkpoints. We are employing acoustic telemetry to study site fidelity to release locations, water quality monitoring to assess changes in primary productivity and macroinvertebrate communities, and electrofishing to document size and age structure of offspring. This effort represents the first time in more than 50 years that these rivers will experience ecologically relevant numbers of spawning adults that approach conservation spawning escapement and has the potential to jumpstart recovery, reinvigorate public interest, and rebuild part of Maine’s heritage.

Corresponding author: Danielle Frechette, danielle.frechette@maine.gov, (207) 350-3070

Reinstating Atlantic salmon's natural spawning and life cycle: movement and survival of Atlantic salmon in Maine

Carolyn Merriam, Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME;
Danielle Frechette, Maine Department of Marine Resources, Bureau of Sea-Run Fisheries and Habitat, Augusta, ME;
Joseph Zydlewski, U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit and Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME

The Atlantic salmon (*Salmo salar*) is an ecologically, economically, and culturally important species and is federally listed as Endangered in the Gulf of Maine DPS. The heavily dammed Penobscot River currently supports the largest run of Atlantic salmon in the United States, persisting only with extensive hatchery support. Atlantic salmon are iteroparous and capable of spawning multiple times in their lifetime. However, repeat spawners are rare and post-spawn survival and behavior of downstream migrating salmon are poorly characterized. In this study we use acoustic telemetry to monitor two groups of adult Atlantic salmon: 1) pre-spawn fish from a seawater smolt-to-adult supplementation program (Penobscot and Machias Rivers), and 2) post-spawn sea-run adults used for hatchery broodstock (Penobscot River only). Groups were released into areas of the East Branch of the Penobscot River or the Machias River in 2022 and 2023. Using an array of acoustic receivers, we intend to assess adult Atlantic salmon movement and infer survival during the pre- and post-spawning period, with a particular focus on the overwintering habitat and outmigration survival of salmon in each system. Data and analysis from this research may inform the future management of this species by filling knowledge gaps for the pre- and post-spawn biology of Atlantic salmon in Maine.

Corresponding author: Carolyn Merriam, carolyn.merriam@maine.edu, (508) 808-1974

Identifying optimal egg planting scenarios for Atlantic Salmon *(Salmo salar)* in Eastern Maine, USA

Ernest Atkinson, Maine Department of Marine Resources, Bureau of Sea-Run Fisheries and Habitat, Jonesboro, ME;
Joseph Zydlewski, U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit and Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME

The Gulf of Maine Distinct Population Segment of Atlantic salmon has been reduced through habitat loss and exploitation over the last century. Hatchery supplementation has prevented the extirpation of the species, but stocking methods represent tradeoffs between survival, domestication, and logistics. Identifying optimal stocking locations and densities that maximize survival and recruitment may improve the efficacy of limited hatchery fish, time, and resources while moving Atlantic salmon toward recovery. We developed a model to estimate recruitment to the 0+ parr based on patterns of egg planting, post-emergent fry dispersal patterns, and habitat specific survival. We developed a tool that allows managers to compare a range of stocking numbers and locations in a river network to optimize recruitment and minimize effort. The Machias River was developed as a proof of concept example by running simulations that applied a suite of stocking scenarios to develop a production possibility frontier, and approach frequently used in economics to assess outcomes based on competing objectives. Optimal scenarios may be used to inform the best theoretical combination of locations for a given number of available eggs. This method may be applied to any juvenile life stage by adjusting life stage-specific habitat needs and survival rates.

Corresponding author: Ernest Atkinson, ernie.atkinson@maine.gov, (207) 271-7195

Development and genetic monitoring of a thiamine deficiency complex tolerant Atlantic salmon broodstock

Kurt Conrad Heim, U.S. Fish and Wildlife Service, Lake Champlain Fish and Wildlife Conservation Office, Essex Junction, VT;
Laurie Anne Earley, U.S. Fish and Wildlife Service, Lake Champlain Fish and Wildlife Conservation Office, Essex Junction, VT;
William Rundle Ardren, U.S. Fish and Wildlife Service, Lake Champlain Fish and Wildlife Conservation Office, Essex Junction, VT

Thiamine deficiency complex (TDC) is emerging as a global issue for salmonids of high commercial, recreational, and conservation value. There is mounting evidence for a genetic basis for TDC tolerance, suggesting that artificial selection may be effective in some conservation hatchery scenarios. Here, we describe efforts to develop a TDC tolerant landlocked Atlantic salmon broodstock in Lake Champlain, USA. Salmon rearing in Lake Champlain are severely thiamine deplete because of a diet high in thiaminase-rich introduced Alewives. We collected gametes from wild-reared fish, created single-parent crosses (n = 114 families from 2016 – 2018), and conducted survival experiments on thiamine supplemented (i.e., treated) and untreated eggs from each family. Thiamine treatment improved survival substantially relative to untreated eggs from the same family (2016; mean survival untreated eggs = 27% vs. 77% for treated eggs, 2017= 32% vs. 61%, 2018 = 39% vs. 70%), confirming TDC as a causative factor for high mortality. However, we noted high variation in family-level survival – some families demonstrated excellent survival even without a thiamine supplement. RNA-seq and RAD-seq identified putatively adaptive genetic variation underlying family level survival in the context of TDC. We therefore selected families with high tolerance to TDC, based on survival trials, to use as founders for an experimental 'TDC-tolerant' broodstock (n = 49 founding families). Simultaneously, we developed a control broodstock with higher genetic diversity, that used all families regardless of performance in survival trials (n = 105 founding families). To study performance of these broodstocks in the wild, we implemented lakewide parentage based tagging to release roughly 400,000 fish annually, and implemented a variety of sampling approaches to recapture marked fish at each life stage. We also developed a novel GT-seq panel which includes a highly accurate sex marker, putatively adaptive SNPs, and polymorphic SNPs optimized for parentage analysis. Continued monitoring will address a variety of hypotheses related to the performance of the TDC tolerant broodstock, as well as other applied research questions including variable stocking ages (fry vs. smolt), net pen rearing or direct river stocking, and straying rates. These results will also guide adaptive broodstock management aimed at overcoming contemporary hurdles to recruitment that are currently bottlenecks for restoration efforts.

Corresponding author: Kurt Heim, kurt_heim@fws.gov, (802) 578-1145

Evaluating stocking strategies for recovery of endangered Atlantic salmon in the Piscataquis River, Maine

Justin Stevens, Maine Sea Grant, Orono, ME;
Colby Bruchs, Maine Department of Marine Resources, Bureau of Sea-Run Fisheries and Habitat, Jonesboro, ME;
Peter Rukznis, Maine Department of Marine Resources, Bureau of Sea-Run Fisheries and Habitat, Bangor, ME;
Randy Spencer (retired)

The U.S. Atlantic salmon recovery plan outlines specific metrics for species population recovery including abundance, productivity, and habitat that utilize the principles of resilience (population health), redundancy (distribution), and representation (genetic and niche diversity). Recovery actions are heavily reliant on hatchery products to maintain minimal population levels in the wild and conserving genetic integrity in the hatchery. Hatcheries have produced various life-stages over the course of several decades of restoration varying from eggs to fry, parr, smolts, and pre-spawn adults. Progress toward population recovery has been minimal when evaluated at the course scale of sea-run adult returns. However, U.S. Atlantic salmon population dynamics are confounded by the interplay of marine survival, dam passage, and freshwater habitat quality as well as variation in hatchery practices. To date, no comprehensive evaluation of stocking strategies with these confounding factors integrated has been completed. We used juvenile abundance, smolt estimates, and redd counts from three pre-spawn adult stocking and fry stocking cohorts to derive metrics related to recovery goals including apparent survival, density, and population size. Fry stocking resulted in a median age-0 density of 8.6 per 100m^2 and median age-1+ density of 5.4 per 100m^2. Adult stocking resulted in a median age-0 density of 1.5 per 100m^2 and median age-1+ density of 0.9 per 100m2. Smolt estimates ranged from 5,851to 9,667 (median 7,644) per year for fry and 1,732 to 5,860 (median 3,538) per year from adult stocking. These smolt populations equated to mean production of 2.1 and 0.97 smolts per 100m2 for fry and adult stocking respectively. While both strategies produced relatively high juvenile production, fry stocking resulted in consistently greater juvenile populations. Redd counts demonstrated production from adult stocking was influenced by adult movement out of the study area and spawning downstream of dams. We present these results in context of other recovery metrics such as geographic distribution and genetic diversity to offer novel population parameters for the development of more data-driven management plans in the recovery of Endangered Atlantic salmon.

Corresponding author: Justin Stevens, justin.stevens@maine.edu, (207) 581-1434

Moving beyond current population dynamic constraints to Atlantic salmon recovery in coastal rivers of Maine to increase climate resilience

John Kocik, NOAA Fisheries, Northeast Fisheries Science Center, Orono, ME;
Ernest Atkinson, Maine Department of Marine Resources, Bureau of Sea-Run Fisheries and Habitat, Jonesboro, ME;
Colby Bruchs, Maine Department of Marine Resources, Bureau of Sea-Run Fisheries and Habitat, Jonesboro, ME;
James Hawkes, NOAA Fisheries, Northeast Fisheries Science Center, Orono, ME

The Narraguagus River was a focal point for Atlantic salmon monitoring and hatchery supplementation since the 1960s. With intensified monitoring since 1997, we documented low freshwater production with a median smolt production averaging 1,649 (+/- 369) and natural adult returns ranging from a low of five to a high of 87 (median 25). In nine of 23 years, smolt production was supplemented with the stocking of between 53,000 to 100,000 hatchery-reared smolts that yielded an average of 31 (+/-20) additional adults. Wild populations remain at precariously low abundance, population rebuilding is not occurring, and smolt supplementation was unexpectedly ineffective. We conclude that current recovery programs are maintaining a population primarily within conservation hatcheries and functioning as a wild-exposed living gene bank. This is an important stopgap against extinction. Our literature assessment found much greater diversity in Atlantic salmon life history, habitat, and population genetic diversity was present in the past. To move to the next phase of recovery, rebuilding, urgent emphasis on new actions to enhance freshwater productivity and genetic diversity are essential. Scientists and managers need to modify approaches using best available science to focus on actions that have the potential to increase marine returns. We believe priority actions should include: 1) responding to limited habitat restoration responses by implementing new strategies and fully integrating rapid assessment techniques to assess habitat impacts and 2) evaluating, planning, and experimentally implementing genetic rescue and proven techniques such as pedigree lines used on other highly endangered salmon populations.

Corresponding author: John Kocik, john.kocik@noaa.gov, (207) 866-7341

A multi-year assessment of Sandy River population trends in out-migrating Atlantic salmon *(Salmo salar)* smolts

Jennifer Noll, Maine Department of Marine Resources, Bureau of Sea-Run Fisheries and Habitat, Augusta, ME;
Ruth Haas-Castro, NOAA Fisheries, Northeast Fisheries Science Center, Woods Hole, MA;
Paul Christman, Maine Department of Marine Resources, Bureau of Sea-Run Fisheries and Habitat, Augusta, ME

The Sandy River is a large tributary to the Kennebec River that encompasses cold, clear, high gradient, and alluvial attributes. This watershed is a major portion of the critical habitat listed in the Merrymeeting Bay Salmon Habitat Recovery Unit (MMB SHRU) of the Gulf of Maine Distinct Population Segment (GOM DPS). At the beginning of the recovery program in the Sandy River, minimal salmon releases occurred until an increased emphasis on restoration focused on egg planting in 2010. Managers highlighted a need to characterize the out-migrating smolt run by run timing, age, size distribution, and population estimates for each year. The Maine Department of Marine Resources (MDMR), in cooperation with the National Oceanic and Atmospheric Administration (NOAA) Northeast Fisheries Science Center, ran rotary screw traps in the lower Sandy River, in New Sharon, ME in 2021, 2022 and for a limited period in 2023. Since this river system is considered a closed system due to impassible hydro-projects being present downstream, precise egg to smolt and egg to adult calculations were able to be calculated, which in turn provides insights on how productive the habitat is for Atlantic salmon. Results of this work will be used to inform management practices.

Corresponding author: Jennifer Noll, jennifer.b.noll@maine.gov, (207) 592-2402

Migration and repeat spawning dynamics of Atlantic salmon *(Salmo salar)* kelt

Heather Perry, Atlantic Salmon Federation, St. Andrews, NB;
Jonathan Carr, Atlantic Salmon Federation, St. Andrews, NB;
Jason Daniels, Atlantic Salmon Federation, St. Andrews, NB;
Graham Chafe, Atlantic Salmon Federation, St. Andrews, NB

Elevated marine mortality has prevailed as the leading cause of Atlantic salmon (*Salmo salar*) declines across their range since the 1990s, though complexities of their life history and marine distribution constrain efforts to identify and manage specific marine threats. Repeat spawners can make vital contributions to their population's productivity and genetic diversity, particularly in depleted stocks. These fish may return to rivers in consecutive or alternate years, though the frequency of either strategy varies temporarily within and among populations. Current estimates of marine returns, a foundational metric in determining causes of marine mortality, often fail to consider repeat spawning dynamics and the nuances of life-stage specific migrations. From 2008 to 2019, we acoustically tracked 530 post spawned Atlantic salmon (kelt) from the Miramichi, Restigouche and Cascapedia rivers tagged along their spring migration path into the Gulf of St. Lawrence (GoSL) and Labrador Sea. We investigated the overall repeat spawning rate, as well as the relative use of consecutive and alternate spawning strategies and their respective distribution throughout the study area. Alternate and consecutive return rates exhibited similarly high variability between years and rivers, and appeared to be unrelated, suggesting they are regulated by different processes. Consecutive returns outnumbered alternate returns on the Miramichi, while the opposite was true on the Restigouche and Cascapedia, possibly reflecting different resource exploitation or genetic pre-dispositions. Residency time in the gulf was influenced by date of entry to the gulf, bay of origin and point of exit (Labrador Sea vs river return). Consecutive spawners remained in the GoSL the longest and none were detected exiting through the Strait of Belle Isle (SoBI) or Cabot Strait receiver arrays. All alternate spawners exited the gulf via SoBI. The Cabot Strait was the preferred point of re-entry into the gulf, though at least two kelt were detected returning through SoBI. Return rates and migration dynamics of each strategy could reveal regions and timeframes that pose elevated risk to kelt.

Corresponding author: Heather Perry, hperry@asf.ca, (506) 754-1921

Understanding freshwater to marine transitional scale growth in Atlantic salmon *(Salmo salar)*

Brandon Ellingson, Integrated Statistics contractor for NOAA Fisheries, Northeast Fisheries Science Center, Woods Hole, MA;
Ruth Haas-Castro, NOAA Fisheries, Northeast Fisheries Science Center, Woods Hole, MA;
Douglas Sigourney, NOAA Fisheries, Northeast Fisheries Science Center, Woods Hole, MA;
John Kocik, NOAA Fisheries, Northeast Fisheries Science Center, Orono, ME;
Timothy Sheehan, NOAA Fisheries, Northeast Fisheries Science Center, Woods Hole, MA

Scale measurements support retrospective growth analyses, and the accuracy of these analyses is influenced by the interpretation of scale features by scale readers. The first marine circulus is the scale feature associated with marine entry and has been used to support research evaluating the impact of size at marine entry on marine survival. Ambiguity in growth rates and circuli deposition during the transition from freshwater to the marine environment leads to difficulty in correct identification of the first marine circulus, resulting in the classification of early marine growth as freshwater growth and vice versa. This transitional growth occurs shortly before, during, and after the migration to the marine environment and is a scale feature termed run-out when observed on adult scales. When this transitional growth is observed on emigrating smolt scales the scale feature is termed plus-growth and only contains the freshwater portion of run-out. We examined transitional growth in smolts migrating out of the Narraguagus River and found that plus-growth was present in over 95% smolts leaving the river and represented on average 12.2% of total freshwater growth. The high occurrence and large contribution of plus-growth to overall freshwater growth suggests plus-growth may present a significant source of error in growth analyses. Examination of the drivers of plus-growth using linear mixed effect models suggests that later migrating smolts have more plus-growth likely due to an increased opportunity for freshwater growth. Evaluation of plus-growth drivers informs annual variability in plus-growth metrics and the potential implications for survival upon marine entry. Assessing the frequency of occurrence and magnitude of plus-growth on emigrating smolt scales improves the understanding of the characteristics of this scale feature supporting accurate identification of marine entry for future Atlantic salmon marine growth studies.

Corresponding author: Brandon Ellingson, brandon.ellingson@noaa.gov, (860) 573-7825

Gill maggots: helpful or headache?

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

The Recovery Plan for the Gulf of Maine DPS of Atlantic salmon (*Salmo salar*) highlights potential threats and impediments to recovery of the species. Efforts to "manage for resilience" are highlighted, including the characterization of interactions with parasites (section M2.3). While parasitic exposure is often considered in the context of aquaculture activities, natural exposure to parasitic organisms occurs in ecologically intact systems and may inform patterns of salmon recovery. The salmon parasite known as the "gill maggot" (*Salmincola salmoneus*) infects Atlantic salmon in freshwaters throughout its range. Because attachment occurs in fresh water, *Salmincola* can provide indications of repeat spawning in adults. However, based on recent studies of related species, *Salmincola* may impact fish performance, outmigration success of smolts, and could facilitate the spread of secondary pathogens. We will discuss the state of the science for *Salmincola* as salmon parasites and consider the potential for these parasitic copepods to be important in Maine and elsewhere. Greater vigilance could benefit management as habitat alterations, changing supplementation strategies, and climate change may all influence parasitic exposure and risk, thereby influencing the recovery potential of Atlantic salmon.

Corresponding author: Christina Murphy, christina.murphy@maine.edu, (207) 581-3010

Did changing the governance structure of Atlantic salmon in Maine improve collaborative efficacy?

Melissa Flye, Ecology and Environmental Science, University of Maine, Orono, ME;
Carly Sponarski, Canadian Forest Service, Northern Forestry Centre, Edmonton, AB;
Annabel Zlatich, School of Marine Sciences, University of Maine, Orono, ME;
Joseph Zydlewski, U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit and Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME

The Gulf of Maine Distinct Population Segment (DPS) of Atlantic salmon (*Salmo salar*) has been listed as federally endangered since 2000. The DPS has been jointly managed by Federal, State, and Tribal entities under several different governance structures. In 2017, we conducted a communication network analysis of the Atlantic Salmon Recovery Framework (ASRF). The results contributed to the formation of a new collaborative governance structure in 2019, the Collaborative Management Strategy (CMS). After three years as a pilot program, we have partnered with managers to proactively conduct an evaluation of the CMS as part of an adaptive management strategy. While the previous governance structure limited membership to managing entities, the CMS has created regional teams which are open to the public. In 2022 we distributed an online sociometric questionnaire to members of the CMS (n=155; 60%). The resulting communication network analysis was used to examine communication efficacy among CMS members and to investigate whether members feel the CMS has successfully addressed the collaborative challenges identified in the ASRF, (a) confusion surrounding leadership, (b) slow and ineffective decision making, and (c) low adaptive capacity. Influential capacity (as measured by eigenvector centrality) is more evenly dispersed among managing entities within the CMS suggesting more equitable representation. While leadership in the CMS is better aligned with the formal governance structure, confusion surrounding membership and roles increased, possibly reflecting the transition process. The data suggest that three distinct communities (aligned with USFWS, NOAA and Maine DMR/Penobscot Nation) remained constant across both governance structures. Members feel the CMS has improved communication and increased adaptive capacity regarding social and biological change but feel it has been less effective in managing conflict and defining roles. These findings may inform leadership in the CMS of areas for potential improvements in communication.

Corresponding author: Melissa Flye, melissa.flye@maine.edu, (207) 922-8260

Chin up, it isn't all bad with Atlantic salmon restoration in the Gulf of Maine Distinct Population Segment: A perspective from a couple of Grumpy Old Farts

Ernie Atkinson, Maine Department of Marine Resources, Bureau of Sea-Run Fisheries;
Daniel Kircheis, NOAA's Greater Atlantic Regional Fisheries Office, Orono ME

Atlantic salmon in Maine represent the last remaining populations in the United States. With populations at critically low levels, Atlantic salmon were listed as endangered under the U.S. Endangered Species Act in 2000. As allies of this magnificent fish, which once attracted anglers and sportspersons or anyone who enjoys wild places and quiet rivers, it is easy for us to be discouraged by the low numbers of adult returns that are less than 6% of the current recovery goal. Our efforts to increase abundance and survival through restoration actions is enormously challenging, and often times very frustrating, because of competing environmental laws and concerns, limitations of our regulatory authorities, competing human interests and needs, and associated costs both monetarily and socially. However, the agencies, tribes, NGOs, and academia working on salmon should be proud of all they have accomplished, as much progress has been made to improve the Atlantic salmon's welfare. The collective work of this team, whether through direct project management, funding, administrative and policy support, research, and assessment has resulted in huge conservation successes that deserves a round of applause. Although Atlantic salmon have been slow to respond (as expected given their complex life history), there are many indicators, particularly alosines, that have shown us that our conservation efforts are paying off. And, despite continued low adult returns the news for salmon is not all bad either. In our presentation, we will reflect on the tremendous progress that we have collectively made over the years and, for a change, we will talk about some of the good news for salmon. We will then look forward at ways we could adapt our program in the midst of climate change to give salmon the best hope that they will be here for future generations to enjoy.

Corresponding author: Ernie Atkinson, ernie.atkinson@maine.gov, (207) 255-2095

Impacts of dams on river herring populations through their native range: what's left?

Shawn Snyder, Ecology and Environmental Science, University of Maine, Orono, ME;
Daniel Stich, Biology Department, SUNY College, Oneonta, NY;
Joseph Zydlewski, U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit and Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME

Due to overfishing, and habitat loss through degradation and damming, river herring (alewife, *Alosa psuedoharengus*, and blueback herring, *Alosa aestivalis*) populations are at historic lows across their native range. In the last 200 years, dams and other impoundments have reduced access to spawning habitat for these and other anadromous fish. River herring are native along the East Coast of North America and provide ecosystem services to freshwater habitats. To assess coast-wide spawning potential for river herring, we identified historically accessible spawning habitat (pre-dam) in coastal freshwater rivers based on physical river characteristics (stream width, depth, and gradient). To assess the impact of dams on spawning habitat, we used a dams database to segment river reaches to characterize spawning habitat upstream and downstream of dams. River-specific population models were then used to estimate the number of potential spawners for each species based on habitat estimates and life history parameters. Because of differences in spawning habitat (alewife using impounded area and blueback herring using fee flowing reaches) impoundments have species specific influences. We investigated three scenarios: no dams, favorable dam passage, and no dam passage. We use these simulations to compare the theoretical spawning potential for river herring prior to and after dam construction coastwide.

Corresponding author: Shawn Snyder, shawn.snyder@maine.edu, (717) 683-4226

NOAA's River herring conservation and coordination at a coastwide scale

Ben German, NOAA Fisheries, Greater Atlantic Regional Fisheries Office, Gloucester, MA;
Jonathan Watson, NOAA Fisheries, Greater Atlantic Regional Fisheries Office, Annapolis, MD;
Chris Boelke, NOAA Fisheries, Greater Atlantic Regional Fisheries Office, Gloucester, MA

NOAA Fisheries works to promote the conservation and restoration of river herring (Alewife *Alosa pseudoharengus* and Blueback Herring *A. aestivalis*, collectively) populations from a coastwide perspective. Their wide geographic distribution, complex life histories, and deep social-ecological connections require that conservation efforts employ a wide variety of approaches in a similarly diverse suite of settings. Recently, NOAA Fisheries has worked to promote regional restoration and conservation efforts through two initiatives — the River Herring Habitat Conservation Plan (published 2023) and the Atlantic Coast River Herring Collaborative Forum, which has been meeting since 2016. The former catalogs life history studies and fisheries management, examines known and emerging threats to conservation, highlights the species' role in our coastal social-ecological systems, and culminates with a suite of broadly-applicable goals and recommendations intended to support protection and restoration efforts at the watershed level. The latter is intended to serve as an information exchange among the academic community, fisheries managers, and the public to foster collaboration and understanding across a range of stakeholders. Substantial effort is needed to restore populations of these valuable fishes to some semblance of their historical abundance at a coastwide scale. Through these initiatives, NOAA Fisheries is working to support these efforts in collaboration with a broad range of stakeholders.

Corresponding author: Ben German, benjamin.german@noaa.gov, (978) 281-9353

Nearshore Gulf of Maine groundfish diets with a focus on diadromous fish contributions

Landon Falke, Integrated Statistics contractor for NOAA Fisheries, Northeast Fisheries Science Center, Woods Hole, MA;
Brian Smith, NOAA Fisheries, Northeast Fisheries Science Center, Woods Hole, MA;
Stacy Rowe, NOAA Fisheries, Northeast Fisheries Science Center, Woods Hole, MA;
Rebecca Peters, Maine Department of Marine Resources, West Boothbay Harbor, ME;
Timothy Sheehan, NOAA Fisheries, Northeast Fisheries Science Center, Woods Hole, MA

In nearshore areas of the Gulf of Maine (GoM), consumption by marine predators could represent a key ecosystem service (and source of mortality) of diadromous fishes as they migrate to and from freshwater. However, information on the contributions of diadromous fishes to diets of piscivorous marine predators is lacking. We combined prey composition from >3,000 stomachs of six marine groundfish predators (monkfish, spiny dogfish, Atlantic cod, red hake, white hake, and silver hake) with prey availability from nearshore trawls conducted bi-annually (spring and autumn) between 2012 to 2022 in GoM waters near the mouths of the Kennebec and Penobscot Rivers. Diet composition was generally dominated by non-diadromous fishes (especially silver hake and Atlantic herring) and crustaceans (especially shrimp and krill), but substantial differences among predator species, between seasons, and by depth were detected. Alosines (alewife, blueback herring, and American shad) were the only diadromous fishes confirmed in stomachs, contributing largely to spiny dogfish diets (overall, nearly 50% contribution by mass), to a small degree (~2-5%) in monkfish and silver hake diets, and minimally (<1%) in diets of the other three predator species. Generally, piscivory reflected interspecific differences in foraging behavior (e.g., high amounts of schooling fish prey in dogfish, but predominantly crustaceans in hake and cod). Piscivory also reflected relative prey availability and a potential dilution of diadromous prey, with silver hake and Atlantic herring being over 5-fold more abundant on average in catches than all diadromous fishes combined. Additionally, decreasing abundance and size of the groundfish predators with decreasing depth indicates that a depth-related spatial mismatch of habitat use might limit predator-prey interactions involving alosines, which were more abundant in shallower areas. Regionally, alosines showed greater abundance, a more balanced size structure, and a slightly higher occurrence in groundfish stomachs near the mouth of the Kennebec River, reflecting a potential influence of differing levels of river restoration in the study area. However, insignificant increases in catch abundance and diet contributions of diadromous fishes across years suggest that production in freshwater systems is still a potentially limiting factor. Our findings provide new information on the trophic ecology of commercially important species in nearshore areas of the Gulf of Maine and the potential of recovering diadromous fish populations to contribute to the diets of nearshore marine predators.

Corresponding author: Landon Falke, Landon.Falke@noaa.gov, (512) 365-0061