Maine Cooperative Fish and Wildlife Research Unit and Department of Wildlife, Fisheries, and Conservation Biology; University of Maine

2016 Report to Cooperators

UNIT COOPERATORS

University of Maine

Maine Department of Inland Fisheries and Wildlife

United States Geological Survey

United States Fish and Wildlife Service

Wildlife Management Institute

Compiled and Edited by
Cynthia S. Loftin and Rena A. Carey

Special thanks to Mark McCullough for allowing us to use his original pen and ink drawings throughout the report.

To download a digital copy of this report, please visit:
http://www.coopunits.org/Maine/Documents/ *or*
http://umaine.edu/wle/maine-cooperative-fish-and-wildlife-research-unit/

Cover Photo: Leaf-cutting bee on a primrose, photo by Brianne DuClos

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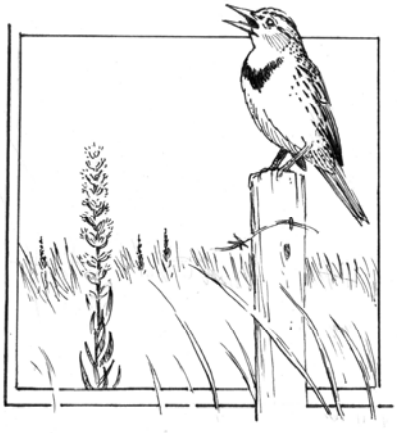
UNIT Mission

The Maine Cooperative Fish and Wildlife Research Unit (CFWRU) is uniquely suited to pursue research relevant to fish and wildlife conservation in northern ecosystems. Maine is the most heavily forested state in the Nation and is covered by numerous ponds, lakes, wetlands, streams, and rivers. Maine has an extensive coast line with a rich variety of habitats adjacent to one of the most productive marine areas of the world, the Gulf of Maine. Tourism and forest product industries are extremely important to Maine's economy and culture. These industries generate management challenges for fish and wildlife that require solutions based on sound science. The Maine CFWRU applies expertise in both terrestrial and aquatic ecology to State and Federal natural resource management priorities.

The primary objectives of the CFWRU are to: (1) facilitate and strengthen professional education and training of fisheries and wildlife scientists; (2) carry out research programs of aquatic, mammalian, and avian organisms and their habitats; and (3) disseminate research results through the appropriate media, especially peer-reviewed scientific articles. The educational and training objective is through advisement of graduate students and their research projects, formal classroom instruction, and supervision of technicians and research associates conducting collaborative research with University staff. In addition, Unit personnel are involved with extension and technical assistance to cooperating agencies and to the general public.

The research program of the Maine CFWRU broadly reflects the needs of the cooperators. Funding in recent years reflects a diversity of studies. Priority research areas are: (1) ecological studies on species of State and Federal interest (e.g., amphibians, Atlantic salmon, brook trout, native pollinators, black bears); (2) management and habitat-related studies with special reference to the effects of land and water-use practices (e.g., forest harvest, dams) on fish and wildlife; and (3) issues related to the effects of land management and forestry on aquatic and wetland systems, and fisheries management in Maine and northern New England.



STATE of the Unit and Department

The Maine Cooperative Fish and Wildlife Research Unit and the University of Maine Department of Wildlife, Fisheries, and Conservation Biology are pleased to summarize the past year's research accomplishments and activities in this annual report. Together, we have collaborated with scientists from State and Federal agencies, universities, and non-governmental organizations on 35 research projects presented in the pages that follow. These collaborative relationships enable us to pose a variety of research questions in interdisciplinary studies to address the resource management information needs of our research sponsors and to advance science in wildlife and fisheries ecology, management, and conservation. We value these opportunities to work together and look forward to continuing these relationships as well as developing new collaborations in the year ahead.

Our research occurs primarily in Maine and New England, however, our science is applicable beyond this geographical area. We broadly group our diverse array of projects into three categories: Fisheries and Aquatic; Wildlife and Habitats; Integrated Ecology. This report includes summaries of research ranging from defining species-habitat relationships, to modeling species responses to habitat change, and to developing tools to integrate public input into natural resource management decisions. Many of these projects have been recent, some are long-term, and some have been completed during the past year. The majority of our research is conducted as part of graduate degree programs; during the past year, Unit and Department faculty mentored 35 graduate students and postdocs, 5 graduate students completed requirements for M.S. or Ph.D. degrees, and 2 graduate students completed requirements for the MWC degree. Our recent graduates are working for universities and non-governmental organizations, as well as pursuing additional graduate degrees.

The year brought several changes to the Unit and its cooperators. The Wildlife, Fisheries, and Conservation Biology Department leadership transitioned to Dr. Malcolm Hunter as interim Department Chair and Dr. Stephen Coghlan as interim Assistant Chair. We welcomed a new Assistant Professor, Dr. Carly Sponarski. Dr. Sponarski's research involves the use of social science theories and methodologies to help understand human-wildlife interactions and to support wildlife management planning so that conflict can be minimized. We look forward to developing collaborative research and teaching opportunities with Dr. Sponarski to address our department's growing needs in instruction, advising, and graduate mentoring. The Maine Department of Inland Fisheries and Wildlife and the U.S. Fish and Wildlife Service-Maine Field Office also welcomed new staff to their programs during the past year. We look forward to continuing to work with them to address their resource management information needs.

The past year has been a productive research year for the Department and Unit, with external research funding continuing to support our growing program. Our graduate program continues to be active and attract great students who ably represent our academic and research programs locally and at professional meetings across the country. Other changes are on the horizon for the department, as we address growing enrollments, while also meeting expanding research opportunities, and faculty transitions.

The Unit and Department look forward to another of continuing and new relationships with our colleagues. You can reach the investigators of the projects summarized in this report via contact information listed on the Unit (www.coopunits.org/Maine/) or Department (www.umaine.edu/wle/) websites. We welcome your comments.

COOPERATING PERSONNEL

UNIVERSITY OF MAINE

Dr. Carol H. Kim, Vice President for Research
Dr. Frederick Servello, Interim Dean, College of Natural Science, Forestry and Agriculture
Dr. Malcolm L. Hunter, Jr., Interim Chair, Department of Wildlife, Fisheries, and Conservation Biology

MAINE DEPARTMENT OF INLAND FISHERIES AND WILDLIFE

Mr. James Connolly, Director, Bureau of Resource Management

U.S. FISH AND WILDLIFE SERVICE

Mr. Peter Lamothe, Supervisor, Maine Field Office

U.S. GEOLOGICAL SURVEY

Dr. John Organ, Chief, Cooperative Research Units Program

WILDLIFE MANAGEMENT INSTITUTE

Mr. Steve Williams, President

UNIT PERSONNEL

SCIENTISTS

Cynthia S. Loftin, Unit Leader, and Associate Professor of Wildlife Ecology
Joseph D. Zydlewski, Assistant Unit Leader for Fisheries, and Professor of Wildlife Ecology

SUPPORT STAFF

Rena Carey, Administrative Support Supervisor
Katherine Goodine, Administrative Specialist

COLLABORATING AGENCIES AND ORGANIZATIONS

American Forest Management
American Recovery and Reinvestment Act (ARRA)
Atlantic Salmon Federation
Audubon Vermont
Baxter State Park
Brookfield Renewable Power
Canadian-American Centre; Downeast Salmon Federation
Central Maine Power
Cornell Lab of Ornithology
Fulbright Student Scholar Program
Gerald Pelletier, Inc.
Indiana University of Pennsylvania
Institute of Marine Biology and Oceanography, University of Sierra Leone
International Joint Commission on the St. Croix Waterway
Katahdin Forest Management
Maine Association of Wetland Scientists
Maine Audubon Society
Maine Department of Inland Fisheries and Wildlife
Maine Department of Marine Resources
Maine Outdoor Heritage Fund
Maine Sea Grant
Michigan Technological University
Muckleshoot Indian Tribe
National Fish and Wildlife Foundation
National Oceanic and Atmospheric Administration
National Park Service
National Science Foundation – Dynamics of Coupled Natural and Human Systems (CNH)
Natural Resources Foundation of Wisconsin
NSF Adaptation to Abrupt Climate Change IGERT
Oazaukee-Washington Land Trust
Orono Land Trust
Passamaquoddy Tribe
Penobscot River Restoration Trust
Penobscot Valley Audubon Chapter
Ruffed Grouse Society
School of Agricultural, Forest, and Environmental Sciences at Clemson University
St. Croix International Waterway Commission
The Nature Conservancy
The World Bank
U.S. Department of Agriculture
U.S. Fish and Wildlife Service
U.S. Fish and Wildlife Service – Craig Brook National Fish Hatchery
U.S. Fish and Wildlife Service – Division of Migratory Birds
U.S. Geological Survey – Biological Resources Discipline
U.S. Geological Survey – Eastern Regional Cooperative Fish and Wildlife Research
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
U.S. Geological Survey – Patuxent Wildlife Research Center
U.S. Geological Survey – Science Support Program
University of Guelph
University of Maine
University of Maine – Department of Wildlife, Fisheries, and Conservation Biology
University of Maine – Maine Agricultural and Forest Experiment Station
University of Maine – Maine Cooperative Forestry Research Unit
University of Maine – School of Biology and Ecology
University of Maine – School of Marine Sciences
University of Maine – Sustainable Solutions Initiative
USDA SARE Grants
Wildlife Management Institute
Wisconsin Audubon Council, Inc. (and eight associated Audubon chapters around Wisconsin)
Wisconsin Department of Natural Resources
Wisconsin SFI Implementation Committee
Wisconsin Young Forest Partnership

UNIVERSITY OF MAINE COLLABORATORS

Department of Wildlife, Fisheries, and Conservation Biology

Malcolm L. Hunter, Jr., *Interim Chair, Professor*
Stephen M. Coghlan, Jr., *Interim Associate Chair, Associate Professor*
Erik J. Blomberg, *Assistant Professor*
Aram J.K. Calhoun, *Professor*
Cory Gardner, *Scientific Research Assistant*
Daniel J. Harrison, *Chair, Professor*
Thomas Hastings, *Scientific Research Specialist*
Jessica J. Jansujwicz, *Research Assistant Professor*
Molly-Jean Langlais-Parker, *Administrative Specialist*
Sabrina Morano, *Research Assistant Professor*
Alessio Mortelliti, *Assistant Professor*
Amber M. Roth, *Assistant Professor*
Frederick A. Servello, *Professor of Wildlife Ecology*
Lindsay C.N. Seward, *Instructor, Wildlife Ecology*
Carly Sponarski, *Assistant Professor*

Department of Anthropology

Samuel P. Hanes, *Assistant Professor*

School of Biology and Ecology

Allison Dibble, *Assistant Research Professor*
Francis A. Drummond, *Professor*
Jacquelyn L. Gill, *Assistant Professor*
Hamish S. Greig, *Assistant Professor*
Rebecca L. Holberton, *Professor*
Michael T. Kinnison, *Professor*
Brian J. McGill, *Associate Professor*
Brian J. Olsen, *Associate Professor*

Department of Civil and Environmental Engineering

Aria Amirbahman, *Professor*

School of Earth and Climate Sciences

Stephen A. Norton, *Emeritus Professor*

School of Economics

Timothy M. Waring, *Assistant Professor*

School of Forest Resources

Shawn Fraver, *Assistant Professor*
Daniel J. Hayes, *Assistant Professor*
Jessica E. Leahy, *Associate Professor*
Robert J. Lilieholm, *Professor*

School of Marine Sciences

Jeffrey A. Runge, *Research Professor*
Gayle B. Zydlewski, *Associate Professor*

EXTERNAL COLLABORATORS

Brad Allen, *Wildlife Biologist, Maine Department of Inland Fisheries and Wildlife*
Kyle Barrett, *Assistant Professor, Clemson University*
Dana M. Bauer, *Assistant Director and Research Scientist, Clark University*
James P. Bogart, *Professor Emeritus, University of Guelph*
John Clare, *former Wildlife Ecology PhD student, University of Maine*
Phillip deMaynadier, *Wildlife Biologist, Maine Department of Inland Fisheries and Wildlife*
John DePue, *Wildlife Biologist, Michigan Department of Natural Resources*
Joseph E. Hightower, *Assistant Unit Leader, NC Cooperative Fish and Wildlife Research Unit*
David Irons, *Alaska Seabird Coordinator, U.S. Fish and Wildlife Service*
Walter Jakubas, *Mammal Group Leader, Maine Department of Inland Fisheries and Wildlife*
Ian Kiraly, *Fisheries Biologist, Gomez and Sullivan Engineers*
Daniel G. McAuley, *Station Leader, USGS Patuxent Wildlife Research Center*
Shawn T. McKinney, *Ecologist, National Center for Landscape Fire Analysis, University of Montana*
Jerry V. Mead, *Assistant Scientist and Section Leader, Drexel University*
Allison Moody, *Post-doctoral Research Associate, University of Wisconsin, Madison*
Priya Nanjappa, *Project Coordinator, Association of Fish and Wildlife Agencies*
Donna L. Parrish, *Research Professor and Unit Leader, VT Cooperative Fish and Wildlife Research Unit*
Jason Jeremy Schaffler, *Senior Quantitative Scientist, Muckleshoot Indian Tribe*
Kelsey Sullivan, *Wildlife Biologist, Maine Department of Inland Fisheries and Wildlife*
William B. Sutton, *Assistant Professor, Tennessee State University*
Joan Trial, *Retired, Maine Department of Marine Resources*
Andrew R. Whiteley, *Assistant Professor, University of Massachusetts Amherst*
Petra B. Wood, *Assistant Unit Leader-Wildlife, WV Cooperative Fish and Wildlife Research Unit*

GRADUATE COMMITTEE LEADERSHIP

Unit scientists served as major advisors or co-advisors for these students during the reporting period.

Loftin	Abdulai Barrie, MS (September 2013 – July 2016) Brianne Du Clos, PhD (September 2012 – Present) Luke Groff, PhD (January 2011 – Present) Jared Homola, PhD (September 2013 – Present) Alyson McKnight, PhD (September 2013 – Present) Brian Rolek, PhD (September 2012 – Present) Nikko Shaidani, MS (September 2012 – Present) Connor Wood, MS (September 2013 – May 2016)
Zydlewski	Betsy Barber, PhD (May 2013 – Present) Abdulai Barrie, MS (September 2013 – July 2016) Megan Begley, MS (May 2014 – Present) Lisa Izzo, MS (September 2013 – August 2016) George Maynard, PhD (May 2013 – Present) Alejandro Molina-Moctezuma, PhD (May 2015 – Present) Andrew O'Malley, MS (May 2012 – May 2016) Daniel Weaver, PhD (May 2013 – Present)

RECENT GRADUATES AND CURRENT PURSUITS

Student, Degree, Curriculum
Current Pursuits

Graduate Date
Advisor(s)

Abdulai Barrie, MS, Wildlife Ecology
Project Manager, Sewa Energy Resources Ltd.

July 2016
Cynthia S. Loftin, Joseph D. Zydlewski

Dana Berendt, Master of Wildlife Conservation
Fish Passage Technician, Brookfield Renewable Energy Partners

January 2016
Malcolm L. Hunter, Jr.

Stephen Dunham, MS, Wildlife Ecology
Scientific Research Assistant, University of Maine

September 2016
Daniel J. Harrison

Lisa Izzo, MS, Wildlife Ecology
PhD Student, University of Vermont

August 2016
Joseph D. Zydlewski

Ryo Ogawa, Master of Wildlife Conservation
Graduate Research Assistant, Mississippi State University

June 2016
Malcolm L. Hunter, Jr.

Andrew O'Malley, MS, Wildlife Ecology
Scientific Research Assistant, University of Maine

May 2016
Joseph D. Zydlewski

Connor Wood, MS, Wildlife Ecology
PhD Student, University of Wisconsin-Madison

May 2016
Cynthia S. Loftin, Shawn T. McKinney

CURRENT STUDENTS & POSTDOCS

Student, Degree, Curriculum	Advisor(s)
Brian Allen, MS, Wildlife Ecology	Erik J. Blomberg
Betsy Barber, PhD, Wildlife Ecology	Joseph D. Zydlewski
Megan Begley, MS, Wildlife Ecology	Stephen M. Coghlan, Jr., Joseph D. Zydlewski
Allison Brehm, MS, Wildlife Ecology	Alessio Mortelliti
Bayu Broto, Master of Wildlife Conservation	Alessio Mortelliti
Anna Buckardt, MS, Wildlife Ecology	Amber M. Roth
Samantha Davis, MS, Wildlife Ecology	Erik J. Blomberg
Brianne Du Clos, PhD, Ecology and Environmental Sciences	Cynthia S. Loftin, Francis A. Drummond
Carly Eakin, PhD, Wildlife Ecology	Aram J.K. Calhoun, Malcolm L. Hunter, Jr.
Luke Groff, PhD, Ecology and Environmental Sciences	Aram J.K. Calhoun, Cynthia S. Loftin
Berlynna Heres, PhD, Wildlife Ecology	Erik J. Blomberg, Joseph D. Zydlewski
Kristine Hoffmann, PhD, Wildlife Ecology	Aram J.K. Calhoun, Malcolm L. Hunter, Jr.
Jared Homola, PhD, Ecology and Environmental Sciences	Cynthia S. Loftin, Michael T. Kinnison
Kevin Job, PhD, Wildlife Ecology	Joseph D. Zydlewski
Lydia Kifner, MS, Ecology and Environmental Sciences	Aram J.K. Calhoun, Aria Amirbahman
Zachary Loman, Postdoctoral Associate	Cynthia S. Loftin, Daniel J. Harrison
Ellie Mangelinckx, MS, Wildlife Ecology	Erik J. Blomberg
George Maynard, PhD, Wildlife Ecology	Joseph D. Zydlewski
Alyson McKnight, PhD, Ecology and Environmental Sciences	Cynthia S. Loftin, Shawn T. McKinney
Alejandro Molina-Moctezuma, PhD, Wildlife Ecology	Joseph D. Zydlewski
Brian Rolek, PhD, Wildlife Ecology	Cynthia S. Loftin, Daniel J. Harrison
Brock Sandrock, Master of Wildlife Conservation	Daniel J. Harrison
Nikko-Ideen Shaidani, MS, Zoology	Cynthia S. Loftin, Michael T. Kinnison
Joel Tebbenkamp, PhD, Wildlife Ecology	Erik J. Blomberg, Daniel J. Harrison
Jonathan Watson, MS, Wildlife Ecology	Stephen M. Coghlan, Jr.
Daniel Weaver, PhD, Wildlife Ecology	Stephen M. Coghlan, Jr., Joseph D. Zydlewski

UNIT SUPPORTED RESEARCH

Name, Affiliation	Unit Advisor(s)
Catherine Johnston, MS, Marine Biology (completed August 2016)	Joseph D. Zydlewski
Catlin Ames, PhD, Marine Biology	Joseph D. Zydlewski

FISHERIES and aquatic

Upstream passage of adult Atlantic salmon in the Penobscot River; assessing critical thresholds for restoration

1. Assess delays that might be incurred through the Great Works and Veazie Dam remnants, the Stillwater Branch, and the new Milford fish lift using radio telemetry and PIT telemetry of Atlantic salmon.
2. Use historic adult Atlantic Salmon scales to investigate changes in ocean growth over six decades in Maine's Downeast rivers.

Abstract: Substantial declines of anadromous Atlantic Salmon *Salmo salar* have occurred throughout the range of the species, with many populations at the southern extent of the distribution being extirpated or endangered. While Maine is the last state in the country where adult Atlantic Salmon return to rivers each year to spawn, numbers have decreased dramatically in recent decades, with typically less than 2,000 spawners returning to all Maine's rivers combined. The complex life history of this species, which involves a juvenile freshwater phase followed by a marine phase that can last one to five years before returning to freshwater to spawn has exposed Atlantic Salmon to a series of threats that have contributed to their continued decline. These threats include, among others, dams and changing ocean conditions that can influence marine mortality. This thesis focuses on those two threats by using radio telemetry to assess upstream passage of adult salmon in the lower Penobscot River and scale analysis to interpret ocean growth patterns in relation to ocean conditions.

The Penobscot River Restoration Project (PRRP), completed in 2016, involved an extensive plan of dam removal, increases in hydroelectric capacity, and fish passage modifications to increase habitat access for diadromous species. As part of the PRRP, Great Works (rkm 59) and Veazie (rkm 46) Dams were removed, making Milford Dam (rkm 61) the first impediment to federally endangered Atlantic Salmon and other diadromous species. In 2014 and 2015, a total of 73 adult salmon were radio-tagged to track their upstream movements through the Penobscot River to assess potential delays at 1) the dam remnants, 2) the confluence of the Stillwater Branch and the main stem of the Penobscot River below the impassable Orono Dam, and 3) the Milford Dam fish lift (installed in 2014). Movement rates through the dam remnants and the Stillwater confluence were comparable to open river reaches. Passage efficiency of the fish lift was high in both years (95 and 100%). However, fish experienced long delays at Milford Dam, with approximately 1/3 of fish taking over a week to pass in each year. Telemetry indicates most fish locate the fishway entrance within 5 hours of arrival and were observed at the entrance at all hours of the day. These data indicate that overall transit times through the lower river were comparable before and after changes to the Penobscot River due to the substantial delays seen at Milford Dam fish lift. The results of this study show that while adult Atlantic Salmon locate the new fish lift entrance quickly, passage of these fish was significantly delayed under 2014-2015 operations.

Prior to returning to spawn, Maine's Atlantic Salmon typically spend one or two years at sea feeding. While both one sea winter (1SW) and two sea winter (2SW) spawner numbers for the North American stocks have declined since the 1950s, the decline has been most severe in 2SW spawners. The first months at sea are considered a period of high mortality. However, early ocean mortality alone cannot explain the more pronounced decline of 2SW spawners, suggesting that the second year at sea may be more critical than previously thought. Angler and state agency collected scales from 1946 to 2013 from the five eastern Maine rivers were used to estimate smolt age and ocean age of returning adults. Additionally, seasonal growth rates of maiden 2SW spawners were estimated using intercirculi measurements and linear back-calculation methods. Generalized linear models (Gaussian family, log link function) were used to investigate the influence of average sea surface temperature (SST), accumulated thermal units (ATUs), the Atlantic Multidecadal Oscillation (AMO) and North Atlantic Oscillation (NAO) indices, smolt age, smolt length (FL), and post-smolt growth on growth rate during the oceanic migration of North American Atlantic Salmon. Results suggest that different factors influence salmon growth throughout their oceanic migration, and previous growth can be a strong predictor of future size. Growth was negatively impacted by the phase of

the AMO, which has been linked to salmon abundance trends, in the late winter and early spring following the post-smolt period. This is likely when the 1SW and 2SW stock components separate and these results suggest that this period could play a role in the disproportionate decline in 2SW spawners.

Investigator: Lisa Izzo (MS)

Advisors: Joseph D. Zydlewski (Advisor)
Joseph E. Hightower
Gayle B. Zydlewski

Duration: May 2012—May 2016

Cooperators:

Maine Department of Marine Resources
U.S. Fish and Wildlife Service
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
National Oceanic and Atmospheric Administration
The Nature Conservancy

Shortnose sturgeon movements and habitat use in the Penobscot River, Maine

1. Assess the movements and habitat use of shortnose sturgeon after dam removal in the Penobscot River.
2. Monitor for sturgeon spawning activity in the Penobscot River.

Abstract: Dam removals from the Penobscot River in Maine restored access to freshwater habitat critical for the life cycle of endangered shortnose sturgeon. Prior to the dam removals, shortnose sturgeon spawning activity had not been documented. Instead, evidence suggested that individuals emigrated from the Penobscot River to spawn in the Kennebec complex, 140 km away. A central question of this thesis was whether spawning activity would commence in the first two years following dam removal. Consistent with pre-dam removal movement patterns determined using acoustic telemetry, the majority (78%) of tagged individuals emigrated from the Penobscot River at some point over the study period and, of these, 71% were found on spawning grounds in the Kennebec complex. The high degree of connectivity with other coastal Maine rivers, along with the lack of documented spawning activity, suggests that shortnose sturgeon remain dependent on spawning in the Kennebec complex. For all individuals occupying the Penobscot River, seasonal distributions within the river were consistent among years and similar to those observed pre-dam removal, with upstream/freshwater river use predominating in fall and winter and estuarine/downriver use dominating in spring and summer. In the fall of 2015, individuals were detected in the first 5 km made available by the Veazie Dam removal, offering evidence that shortnose sturgeon could return upstream during future springs to spawn.

Shortnose sturgeon require a suite of habitat characteristics to be present to spawn. Habitat suitability modeling was performed to assess the quality of the newly available habitat in the Penobscot River. Using a two-dimensional hydrodynamic model and ArcGIS, the first 5 km reach made available by the Veazie Dam removal was examined based on velocity, depth, and bottom substrate. Results indicate that at any discharge likely to occur during the spring spawning season, at least 40% of the area is usable for spawning. Velocity is the most limiting habitat characteristic at any simulated discharge. The habitat suitability maps generated could be useful for planning spawning sampling in future years.

Lessons learned from the first two studies were used to suggest future steps for research concerning shortnose sturgeon in the Penobscot River. To more fully describe how this endangered species responds to the recent dam removals, more acoustic tags should be deployed and further examination of habitat suitability should occur. In addition to continued telemetry and habitat assessments, researchers should consider how the emerging threat of climate change could impact shortnose sturgeon recovery. For example, how increased saltwater intrusion affects available habitat for spawning and juvenile rearing. Tracking the behavior and use of newly available habitat will help researchers and managers address threats to the species in the Penobscot River and to the wider population in the Gulf of Maine.

Investigator: Catherine Johnston (PhD)

Advisors: Gayle B. Zydlewski (Advisor)
Michael T. Kinnison
Joseph D. Zydlewski

Duration: January 2012—September 2016

Cooperators:

Maine Department of Marine Resources
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
National Oceanic and Atmospheric Administration
Penobscot River Restoration Trust
University of Maine – School of Marine Sciences
University of Maine – School of Biology and Ecology

Rainbow smelt enhancement as a fisheries management tool

1. Estimate the survival and growth of stocked rainbow smelt fry into Maine lakes.
2. Compare growth between anadromous and landlocked populations of adult smelt.

Abstract: Rainbow Smelt (*Osmerus mordax*) are an important fish distributed throughout northeastern North America with both anadromous and landlocked populations. Abundance, size at age, and maximum size vary widely among populations and life histories. In order to compare anadromous and landlocked populations, we collected spawning adults in 2014 from four anadromous and three landlocked populations. Scales and otoliths from the anadromous fish were examined and compared for estimates of bias and precision in ageing. Analysis of both scales and otoliths provided age estimates that were acceptable, but estimates from scales were more precise and had less bias. Otoliths were used to estimate mean size at age and von Bertalanffy growth parameters for each population. Compared to landlocked populations, anadromous fish exhibited a greater and more variable size at age, and asymptotic size. While anadromous fish generally grew faster than landlocked fish, von Bertalanffy growth parameters were variable across life histories. Age analysis showed that populations of both anadromous and landlocked Rainbow Smelt were comprised of fish age 1 to 4, and were typically dominated by a single age class. These data suggest considerable plasticity associated with tradeoffs between growth and reproduction among different populations and life histories. Commercially reared Rainbow Smelt larvae have recently become available for supplementation for this species that is known to be highly variable in abundance. We stocked smelt larvae into two small ponds in central Maine at a density of approximately 30,000 fish per hectare to assess survival of hatchery reared fish. Fish were double marked with thermal and oxytetracycline marks. We subsequently sampled for stocked larval Rainbow Smelt with ichthyoplankton tows, both day and night for the first four weeks after stocking, capturing more than 1,800 Rainbow smelt in one pond, and two in the other. Capture rate was higher at night than the day, and decreased over the duration of the study. Otoliths were examined from a subset of 339 larval Rainbow Smelt. The median hatch date of all fish was two days after the observed hatch date of our stocked fish. The mean daily growth rate was calculated to vary from a low of 0.3 mm per day at 7 days after hatching, to a high of 0.5 mm per day at 14 days after hatching. There were no distinct marks consistent with oxtretracycline marking found on any of the larval Rainbow Smelt otoliths examined. Potential thermal marks and stocking checks were found on otoliths from 80% and 45% of fish examined respectively. Larval Rainbow Smelt density and distribution was estimated with a linear model and was significantly related to depth, time of day, and sample event. This model was to estimate the population and mortality of Rainbow Smelt. The large difference between the observed and predicted catches of Rainbow Smelt in one of our study waters lends evidence to the poor success of stocking on this water.

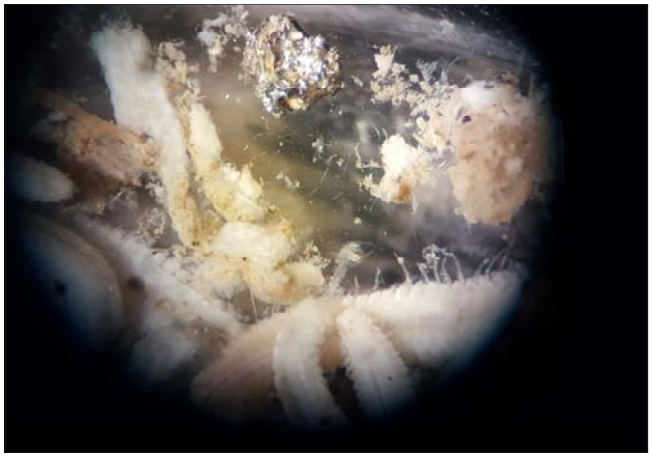
Investigator: Andrew O'Malley (MS)

Advisors: Joseph D. Zydlewski (Advisor)
Stephen M. Coghlan, Jr.
Donna L. Parrish

Duration: May 2012—December 2015

Cooperators:

Maine Department of Inland Fisheries and Wildlife
Maine Outdoor Heritage Fund



Response of sturgeon to the Veazie and Great Works Dam removals

1. Characterize the distributions of adult Shortnose and Atlantic sturgeon in the Penobscot River, particularly in the context of dam removal and habitats upstream to Milford Dam. This will entail determining seasonal sturgeon presence in different river habitats, with a focus on spawning, feeding, and wintering as well as fish condition for those travelling furthest upstream each season.
2. Assess presence of early life stage sturgeon in the Penobscot River, particularly just downstream of the Milford dam site.
3. Model trends in abundance and condition of adults using the Penobscot River during summer, fall, and winter relative to baseline assessments of 2007-2010.

Our research on the Penobscot River aims to document sturgeon use of the river and responses to the recent dam removals. We monitor movement patterns of sturgeon in the Penobscot River using acoustic telemetry. We also sample for early life stage sturgeon, collect data for a robust mark-recapture estimation, and concurrently sample for diet and prey availability. Acoustic telemetry will continue to be used to assess seasonal movements, presence and aggregations. This will include upkeep and data collection from the acoustic receiver array to monitor spatial and temporal distribution of sturgeon from Milford dam to Verona Island from April to November and a smaller receiver array from November to April.

A robust mark-recapture estimate of adult Shortnose Sturgeon using the Penobscot River prior to dam removal exists, and capture efforts will continue for estimates post dam removal for comparison. In conjunction with gill netting, we will use trotlines to ensure capture of all fish size classes. Foraging behavior and habitat will be assessed by capturing sturgeon and observing feeding status (by taking stomach samples) and diet selectivity (by taking prey availability samples of the benthos) to inform presence and distribution of the species as it is related to critical habitat.

Early life stage sampling in 2016 was conducted on 18 nights from May 9 through June 25. Sampling was divided between known sturgeon aggregation sites. No eggs or larvae were collected. Gill netting for adult Shortnose and Atlantic Sturgeon was conducted from July 13-November 30, resulting in the capture of 232 Shortnose Sturgeon and 21 Atlantic Sturgeon. Gastric lavage was performed on 45 Shortnose Sturgeon and 12 Atlantic Sturgeon. PONAR sampling of the river bottom was conducted in tandem with netting to compare available prey with lavaged stomach contents. In addition to PONAR sampling, 38 invertebrate samplers were assembled and deployed on September 30 to better characterize prey availability.

The acoustic receiver array in the Penobscot River that was deployed March 22, and retrieved on December 11. Telemetry data are being downloaded from receivers to be uploaded to a central database. Invertebrate and stomach samples are being processed and categorized.

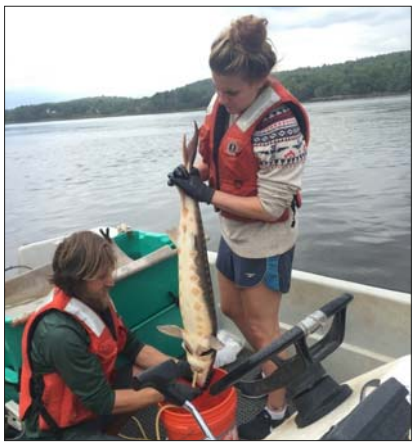
Investigator: Catlin Ames (PhD)

Advisors: Gayle B. Zydlewski (Co-Advisor)
Michael T. Kinnison (Co-Advisor)
Joseph D. Zydlewski

Duration: May 2016—August 2020

Cooperators:

Penobscot River Restoration Trust
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
The Nature Conservancy
University of Maine
University of Maine – School of Biology and Ecology
University of Maine – School of Marine Sciences



Marine-derived nutrient cycling in the St. Croix River, Maine

1. Characterize the food web in the St. Croix prior to alewife return.
2. Characterize the temporal influx of marine nutrients due to alewife migration.
3. Explore how changes in passage efficiency at three main stem dams might change the flow and distribution of nutrients in a complex river system.

The purpose of this study is to determine how the presence of alewife affects the St. Croix watershed, both in terms of nutrient input and food web interactions. This will be done by developing a model of the existing food web using stable isotope data procured through sampling river and lake sites. Isotopes will include carbon and nitrogen, which typically show distinct signatures when moving from marine to freshwater environments. Samples will be collected three times annually at seven sites in the St. Croix concurrent with the alewife run. Nutrient limitation will also be determined at each site. Two sites on the East Machias River will be sampled as a reference.

The data from this study will be incorporated into a model to determine how alewives affect the input and output of nutrients within streams and lakes in the St. Croix watershed. The presence of alewives has the potential to directly affect other species in the system, including species of interest such as small mouth bass. As alewives are reintroduced into the St. Croix watershed in large numbers this study will be able to track their effect on nutrient cycling, as well as determine their role in the food web.

Sampling has been carried out for 2013-2015 at 7 sites in the St. Croix and 2014-2015 at 2 sites in the East Machias. Fish muscle, aquatic invertebrate, and plankton samples were collected at each site in May, June, and July. The majority of these samples have been prepared and sent to a lab for stable isotope analysis, but food web modelling still needs to be performed on the data. All data analyzed so far has revealed expected trophic associations between fish and invertebrate taxa in the region. A marine "signal" was also clear from migrating alewife in the St. Croix system. All sites on the St. Croix are oligotrophic based on nutrient limitation data. Analysis of stable isotope data is nearly complete and nutrient information is being incorporated into an alewife population model to explore nutrient dynamics in the St. Croix River.

Investigator: Betsy Barber (PhD)

Advisors: Joseph D. Zydlewski (Advisor)
Joan Trial
Erik J. Blomberg
Stephen M. Coghlan, Jr.
Hamish S. Greig

Duration: May 2012—October 2017

Cooperators:

Atlantic Salmon Federation
International Joint Commission on the St. Croix Waterway
U.S. Fish and Wildlife Service
University of Maine – Department of Wildlife, Fisheries, and Conservation Biology
Maine Department of Inland Fisheries and Wildlife
Maine Department of Marine Resources
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
Passamaquoddy Tribe
Canadian-American Centre; Downeast Salmon Federation
St. Croix International Waterway Commission

Understanding the impact of commercial harvest on white sucker (*Catostomus commersonii*) in Maine

1. Compare the demographics of spawning suckers from fished and unfished lakes.
2. Use demographic data to assess sensitivity of suckers to fishing pressure.

The State of Maine issues an unlimited number of commercial permits to harvest white sucker in Maine's inland waters. The fishery provides a necessary source of lobster bait to coastal communities at a time when other bait sources are scarce. The impact of the increasing number of permits and subsequent numbers of fishermen on the white sucker population is unknown. The Maine Department on Inland Fisheries and Wildlife (MDIFW) has closed a number of waters due to concerns that overfishing and/or incidental catch of other fish species may occur. The goal of this project is to determine the impacts of commercial fishing on white sucker populations and review the existing management structure to optimize the population size and commercial white sucker harvest in waters that are open. This information will allow the MDIFW to determine which waters that are currently closed can be reopened to harvest.

Before additional waters can reopen, the department needs to determine the effect of the current commercial fishery on existing populations of white sucker. Specific biological data (age, length, sex, fecundity), catch/harvest information, assessment of existing data, needs to occur to determine which areas are overfished from those area that are not overfished. Currently, harvesters are not required to report the amount harvested or bycatch. This information is critical to manage a growing fishery that an increasing number of commercial fishermen are relying on to supply lobster bait and household income.

White suckers were harvested during the spring of 2014 from fished and unfished lakes Biological data was recorded for each individual fish: total length, fork length, total weight, and sex. Ovaries were used to estimate fecundity, and otoliths were sectioned for age estimates. Analysis has revealed that fish from harvested lakes were younger, smaller, and had lower fecundity than fish from reference lakes. Estimated mortality rates for harvested lakes were two fold higher than reference lakes, suggesting that current levels of exploitation are resulting in age truncation.

In addition, we built a deterministic population model of using parameters from literature and our field studies to investigate the theoretical effects of harvest mortality on age-structure and fecundity. When harvesting mortality increased in the model there was an expected truncation in age-classes consistent with field observations.

Finally, we characterized the spatial scale of harvesting effort in Maine using commercial sucker permits issued from 2006 to 2016. A list was also compiled for each biological region for waterbodies to provide managers an idea of where to focus efforts for monitoring in future harvest seasons.

Investigator: Megan Begley (MS)

Advisors: Stephen M. Coghlan, Jr. (Co-Advisor)
Joseph D. Zydlewski (Co-Advisor)

Duration: January 2012—December 2016

Cooperators:

Maine Department of Inland Fisheries and Wildlife

Assessing the influence of imprinting and stocking timing on Atlantic salmon smolt to adult return

1. Assess the influence of imprinting on stocked hatchery Atlantic Salmon smolts to adult return in the Penobscot River.
2. Assess the influence of stocking timing on hatchery Atlantic Salmon smolts to adult return in the Penobscot River.

We investigated two methods of stocking to increase survival, imprinting and trucking, and night release. For the first method, from 2009-2012 smolts marked with Visual Implant Elastomer (VIE) were transferred from the hatchery and acclimated in upstream "imprinting pools" in the Penobscot River, before being trucked to the estuary. For the second method, from 2014-2016 stocking treatments included a daytime release and a nighttime release downstream of the lowest dam. We will also assess developmental state of release groups. This will be accomplished by non-selectively sampling smolts from each release group 24 h prior to the day of stocking. Sampling will include gill Na^+/K^+-ATPase activity, fish length, and fish condition. Fish will be recovered from this non-lethal sampling and released.

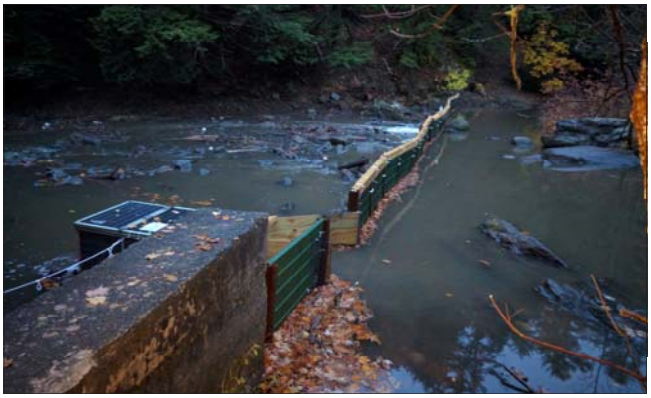
VIE tagging for both stocking methods concluded in 2016. Data suggest that survival of the 2009-2012 smolts that were imprinted and trucked downstream is representative of the upriver releases. Smolt to adult return data for the 2014-2016 stocking treatments is continuing to be collected and analyzed.

Investigators: Cory Gardner, Joseph D. Zydlewski

Duration: March 2009—September 2018

Cooperators:

Maine Department of Marine Resources
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
National Oceanic and Atmospheric Administration
U.S. Fish and Wildlife Service
University of Maine – Department of Wildlife, Fisheries, and Conservation Biology



Life history and migration of American eels in the Penobscot River, Maine

1. Collect migrating American eels and environmental information in order to refine an extant model of the timing of migration.
2. Assess migratory survival of adult American eel through the Milford Dam on the Penobscot River.
3. Use collected data to construct a forecasting model using real time environmental information to characterize probability of migration.

Eels exhibit a complex, catadromous life history, migrating to the Sargasso Sea as large "silver" eels to spawn and die. Their progeny are carried by ocean currents as willow leaf–shaped leptocephalus larvae, metamorphosing into "glass" eels as they enter into river systems whereupon they initiate feeding and become "yellow" eels. Yellow eels take up residence in areas from the estuary to up river sites and grow. This growth phase can last up to 25 years before undergoing a second transformation, including color change, to a downstream-migrating "silver" eel. One well documented source of mortality for these large autumnal migrants is through hydroelectric facilities encountered during downstream migration. Injury and death can often occur.

We will operate a weir on a tributary of the Penobscot River to characterize the timing of migration with respect to environmental variables. Some of these captured fish will be acoustically tagged and tracked in the Penobscot River using a array of more than 100 autonomous, stationary listening devices. These data will be used to assess mortality at main stem dams in the system.

Together, the telemetry and the capture data will be used to inform a predictive Bayesian forecasting modeling framework for both timing of migration and survival at dams. Such a model could serve as a useful tool to managers to inform management and conservation decisions as to hydropower facility operation.

Work in the fall of 2016 included the improved design and installation of a weir and a steal and fiberglass grate trap on a tributary of the Penobscot River. One hundred silver eels were captured, surgically tagged and released into the Penobscot River. Data from the telemetry from these fish is currently being processed.

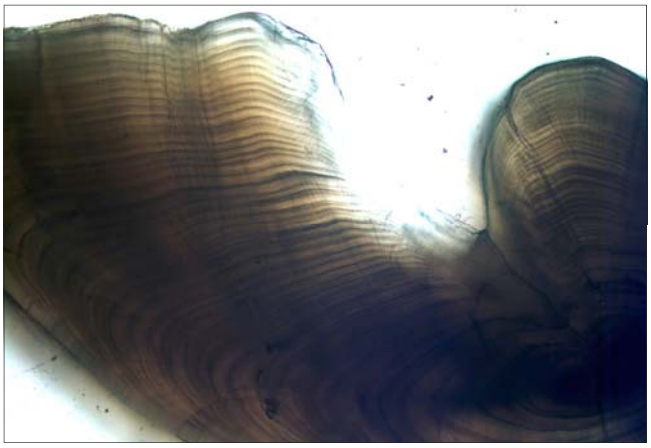
Investigator: Berlynna Heres (PhD)

Advisors: Erik J. Blomberg (Co-Advisor)
Joseph D. Zydlewski (Co-Advisor)
Gayle B. Zydlewski

Duration: September 2015—June 2020

Cooperators:

Maine Department of Marine Resources
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
National Oceanic and Atmospheric Administration
The Nature Conservancy
U.S. Fish and Wildlife Service
National Science Foundation – Experimental Program to Stimulate Competitive Research
Muckleshoot Indian Tribe



Using otolith microchemistry to infer early life histories of American shad and American eel habitat use in the Penobscot river, Maine

1. Using otolith microchemistry, we plan to infer early life histories of American shad and American eel habitat use (spatial and temporal patterns) in the Lower Penobscot River.
2. We plan to utilize microchemical data to provide a baseline for American shad and American eel early life histories in the Penobscot River prior to Veazie dam removal.

Removals of Veazie (2013) and Great Works (2012) Dams were completed in conjunction with three upstream fish passage modification projects on the Penobscot River in Maine as part of the Penobscot River Restoration Project. Prior to these fish passage modifications, upstream passage of American shad was negligible through the historic Veazie Dam and many believed American shad were largely absent from the river. Similarly, upstream passage of juvenile American eels is believed to have been repressed by these Dams. Understanding the degree to which these fish species persisted in the estuary prior to the removal of Veazie and Great Works Dams is important for their management and restoration.

In an attempt to provide a baseline for American shad and American eel early life histories in the Penobscot River prior to dam removal, we plan to analyze otolith (ear bones) microchemical structures (elemental ratios of Barium:Calcium, Strontium:Calcium, etc.), utilizing laser ablation inductively coupled plasma mass spectrometry. Resulting elemental ratios will afford us the opportunity to reconstruct early life histories of American shad and American eels through comparative analysis with surrounding water microchemistries.

We have removed, mounted, and are working to prepair 769 individual otoliths from American shad and American eels. Currently, we have processed American shad otoliths from Penobscot River shad between the years of 2011 and 2016 and Penobscot River eels between the years of 2013 and 2016. Additionally we have processed American eels from the Union River in Maine, and American shad from the Sheepscot river in Maine. Otoliths will be prepaired for microchemical analysis using laser ablation inductively coupled plasma mass spectrometry at the Woods Hole Oceanic Institute in 2017.

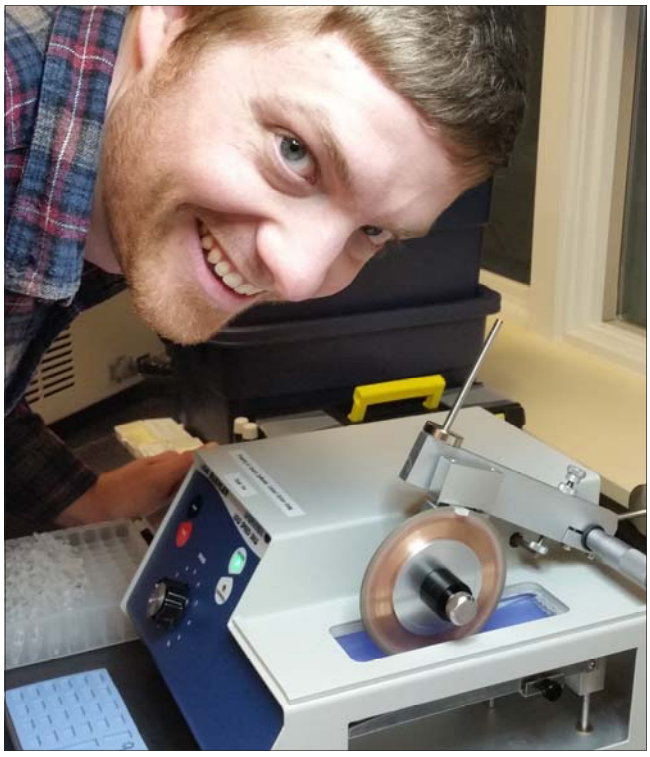
Investigator: Kevin Job (MS)

Advisors: Joseph D. Zydlewski (Advisor)
Jason Jeremy Schaffler

Duration: January 2016—October 2018

Cooperators:

The Nature Conservancy
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
U.S. Fish and Wildlife Service
University of Maine – Department of Wildlife, Fisheries, and Conservation Biology



PIT tag monitoring of migrating anadromous fish in the Penobscot River, Maine

1. Determine the rate, timing and efficiency of upstream passage of Atlantic salmon, American shad and alewife through major dams in Penobscot River.
2. Provide near real time information to cooperating agencies as to the effects of fishway operation on migratory success.
3. Provide a quantitative assessment of the effect of dam removal on the migratory success of migratory fish in the Penobscot River.

The Penobscot River watershed is Maine's largest and hosts a number of anadromous species including the largest remaining run of Atlantic salmon in the USA. For many species, however, the majority of high quality spawning and rearing habitats are located upstream of lower river dams. By the fall of 2013, the two most downstream dams were removed as part of the Penobscot River Restoration Project (PRRP). Ultimately, benefits of dam removal for Atlantic salmon and other species will depend on the degree and fashion by which remaining dams facilitate fish passage success. In order to assess migratory success, we are using passive integrated transponders (PIT tags) to remotely track fish through nine major dams in the lower Penobscot River. Beginning in 2013, PIT tagging of fish occurred at the lower most dam (Milford) requiring an antenna installation at the new fishway in coordination with Maine Department of Marine Resources. This work will incorporate and build on recent research that demonstrated migratory behavior and passage efficiency of Atlantic salmon in the Penobscot River. The long term scope of this project is to monitor the effects of the PRRP with respect to Atlantic salmon in accordance with the State Operational Plan for the Restoration of Anadromous Fishes to the Penobscot River. This study requires coordination with USGS, NOAA, DMR, the Penobscot River Restoration Trust (PRRT), the Penobscot Indian Nation, USFWS, and the various dam operators.

The project was initiated September 2009 and has included an M.S. student, a Ph.D. student and a post-doctoral associate over the years. By spring of 2010, PIT arrays were installed at all targeted lower mainstem dams and preliminary passage data were collected from more than 1,000 tagged fish. By spring of 2011 eight sites were fully functional and were maintained through the 2011 adult salmon season. Coordination with Department of Marine Resources allowed the successful tagging and tracking of 2,429 adult Atlantic salmon in 2011. Efforts were continued in 2012 and priorities will shift to data analysis and "near real time" coordination with management agencies for the optimization of fish passage. A Ph.D. student began this work in spring of 2013 and low Atlantic salmon returns have necessitated a shift in focus to other species. In addition to a limited number of Atlantic salmon in 2014, hundreds of alewife, sea lamprey and American shad have been tagged and tracked.

Additional efforts to radio tag and track adult American shad in 2014-16 have provided an improved picture of habitat use post-dam removal. The presence of iteroparous river herring in the Penobscot River was documented for the first time in recent history as individuals that were PIT tagged in 2014 were tracked upstream in 2015-16. Radio telemetry of Atlantic salmon was made possible in 2016 by a donation of tags from Brookfield Renewable Power.

Investigator: George Maynard (PhD)

Advisors: Joseph D. Zydlewski (Advisor)
Erik J. Blomberg
Michael T. Kinnison
Joan Trial
Gayle B. Zydlewski

Duration: September 2009—October 2017

Cooperators:

American Recovery and Reinvestment Act (ARRA)
Maine Department of Marine Resources
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
National Oceanic and Atmospheric Administration
Penobscot River Restoration Trust
U.S. Fish and Wildlife Service – Craig Brook National Fish Hatchery
Brookfield Renewable Power

Passage of anadromous fish at mainstem dams on the Penobscot River, Maine

1. Model the survival of hatchery-origin Atlantic salmon smolts through the Penobscot River and Estuary.
2. Assess movement and behavioral patterns of migrating Atlantic salmon smolts through the Penobscot River.
3. Characterize passage and survival of Atlantic salmon smolts at Howland Dam in the Piscataquis River.

This project will draw upon a growing body of telemetry data reaching back to work begun in 2005 and continued through to present. Targeted releases of Atlantic salmon smolts implanted with acoustic "pingers" are tracked through the entire Penobscot River system using an extensive deployment of stationary receivers. These acoustic receivers are deployed as part of ongoing cooperative work between NOAA-Fisheries, Maine Cooperative Fish and Wildlife Research Unit and the University of Maine. The observed series of detections of an individual fish are used to construct a model of survival through the River system. Such a model allows the assessment of areas of high mortality, such as dams. We continued tagging hatchery-origin Atlantic salmon smolts from the Penobscot River through 2015. For the upcoming years, this project will focus on survival and passage through Howland Dam in the Piscataquis River. Beginning with the 2016 downstream migration, new downstream fish passage will be present in Howland Dam that has the potential to increase smolt survival. Therefore, it is important to characterize survival in this dam and compare it to survival in previous years.

Acoustic telemetry data have been collected from downstream migrating Atlantic salmon smolts to assess movement and survival through the Penobscot River and Estuary. These data have been used to estimate survival of Atlantic salmon smolts throughout the system and are routinely used by agencies associated with the management of this federally endangered species. This data is currently being analyzed to perform a post-restoration assessment of Atlantic salmon survival in The Penobscot River.

Investigator: Alejandro Molina-Moctezuma (PhD)

Advisors: Joseph D. Zydlewski (Advisor)

Duration: January 2006—January 2020

Cooperators:

American Recovery and Reinvestment Act (ARRA)
Maine Department of Marine Resources
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
National Oceanic and Atmospheric Administration
University of Maine – Department of Wildlife, Fisheries, and Conservation Biology
National Fish and Wildlife Foundation
Penobscot River Restoration Trust

Dam removal and fish passage improvement influence fish assemblages and predator-prey interactions in the Penobscot River, Maine

1. Describe changes to fish assemblages associated with the removal of two main-stem dams on the Penobscot River.
2. Describe species specific shifts associated with dam removal, habitat change, and fish passage modification.
3. Describe smallmouth bass (*Micropterus dolomieu*) growth and diet in sections of the Penobscot River watershed with varying abundances of river herrings.
4. Use bioenergetic modelling to project future changes to smallmouth bass growth associated with the observed population increases of river herrings in this watershed associated with restoration actions.

Dams fundamentally alter the morphology and ecological characteristics of rivers. Notably, populations of diadromous fishes have been drastically impacted by the construction of dams because they severely limit access to habitat that is essential for the completion of their complex life histories. Dam removal has been proposed as a method to restore the integrity of riverine systems and it is becoming an increasingly popular management solution.

The Penobscot River Restoration Project (PRRP) is one of the largest river restoration efforts currently underway in the United States. It aims to increase the ecological integrity of the watershed through both dam removal and enhanced fish passage at remaining barriers. Prior to restoration efforts, we conducted a baseline fish assemblage survey to allow for appraisal of this restoration. We found distinct assemblages associated with the lentic habitat in former impoundments and evidence of low habitat connectivity. We will ultimately describe the initial changes to Penobscot River fish assemblages by comparing pre and post-dam removal surveys.

In addition, we are completing a study examining diet and average growth rates of smallmouth bass in areas of the Penobscot River watershed to determine the extent of their predation of river herrings. We also will perform bioenergetics modelling to describe growth rates under future scenarios of river herring abundance.

We monitored fish assemblages in the Penobscot River using shoreline electrofishing and a stratified random design. We conducted sampling twice a year in both early summer (May-June) and fall (September-October) from the spring of 2010 until the summer of 2012. Sampling was resumed in the spring of 2014 and the initial post removal surveys concluded in the spring of 2016. The dams of interest were removed during the interim (2012-2013) of these sampling periods. Initial results suggest that anadromous fishes are now able to access all areas of the mainstem river and that lacustrine fishes have largely disappeared from former impoundments. In 2015 we collected approximately 750 smallmouth bass at monthly intervals and removed their stomachs and otoliths for diet and growth analyses, which were recently completed. We are currently in the analysis and writing stage for both projects and will finalize both within the next six months.

Investigator: Jonathan Watson (MS)

Advisors: Stephen M. Coghlan, Jr. (Advisor)
Joseph D. Zydlewski
Daniel J. Hayes
Ian Kiraly

Duration: May 2014—April 2017

Cooperators:

American Recovery and Reinvestment Act (ARRA)
Maine Department of Inland Fisheries and Wildlife
Maine Department of Marine Resources
National Oceanic and Atmospheric Administration
Penobscot River Restoration Trust
University of Maine – Department of Wildlife, Fisheries, and Conservation Biology
University of Maine
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
The Nature Conservancy

Anadromous sea lamprey (*Petromyzon marinus*) as vectors of marine-derived nutrients in Atlantic coastal streams

1. Quantify the spatial and temporal effects of marine-derived nutrient subsidies from adult sea lamprey.
2. Compare autotrophic and heterotrophic nutrient response pathways from nutrient subsidies.
3. Characterize the spatial heterogeneity of juveniles (ammocoets) within the Penobscot Watershed.
4. Develop a model that predict nutrient responses in freshwater systems.

Historically, many freshwater systems in Maine were linked to the marine environment by spawning migrations of adult anadromous fishes and subsequent seaward migration of juveniles. These fish were important vectors of marine-derived nutrients that fertilized otherwise oligotrophic freshwater systems until populations declined. Sedgeunkedunk Stream, a 3rd order tributary to the Penobscot River, historically supported several anadromous fish species including sea lamprey and endangered Atlantic salmon. Several small dams constructed in the late 1800s reduced or eliminated spawning runs entirely. As of late 2009, a small population of sea lamprey used the accessible portion of Sedgeunkedunk regularly for spawning. Efforts to restore marine–freshwater connectivity in this system have included the construction of a rock-ramp fishway at 6 in 2008 and the removal of a dam in 2009. The latter has opened up 5 km of lotic habitat and facilitated recolonization and range expansion of sea lamprey, resulting in quadrupling of abundance of spawning adults after 4 years. We hypothesize that sea lamprey will contribute an influx of marine-derived nutrients thereby increasing primary and secondary production in the system.

We examined the influence of sea lamprey nutrient subsidies on stream food webs over spatial and temporal scales. We found that carcass decomposition and nitrogen and phosphorus liberation occur within a three week period. We found sea lamprey nutrient subsidies increased algal biomass 57 - 71% over a three week period, alleviating stream nutrient limitations, however we observed no changes in fungal biomass from added nutrients. Using stable isotopes analysis, we found nutrient subsidies were assimilated among stream macroinvertebrates, but found no discernible patterns in assimilation among juvenile sea lamprey (ammocoetes) . Furthermore, our results suggest nutrient subsidies exhibit relatively localized effects, influencing components of food webs adjacent to decomposing carcasses. Additionally, the response pathways by which subsidies are assimilated may depend upon stream and terrestrial covariates (flow and canopy cover). Juvenile sea lamprey are ubiquitous throughout the Penobscot Watershed. Juvenile distributions appear to be functions of historically accessible streams and suitable habitat characterized by slow moving waters with fine substrates. Our work underscores the importance of connectivity in small streams to allow sea lamprey migration and spawning.

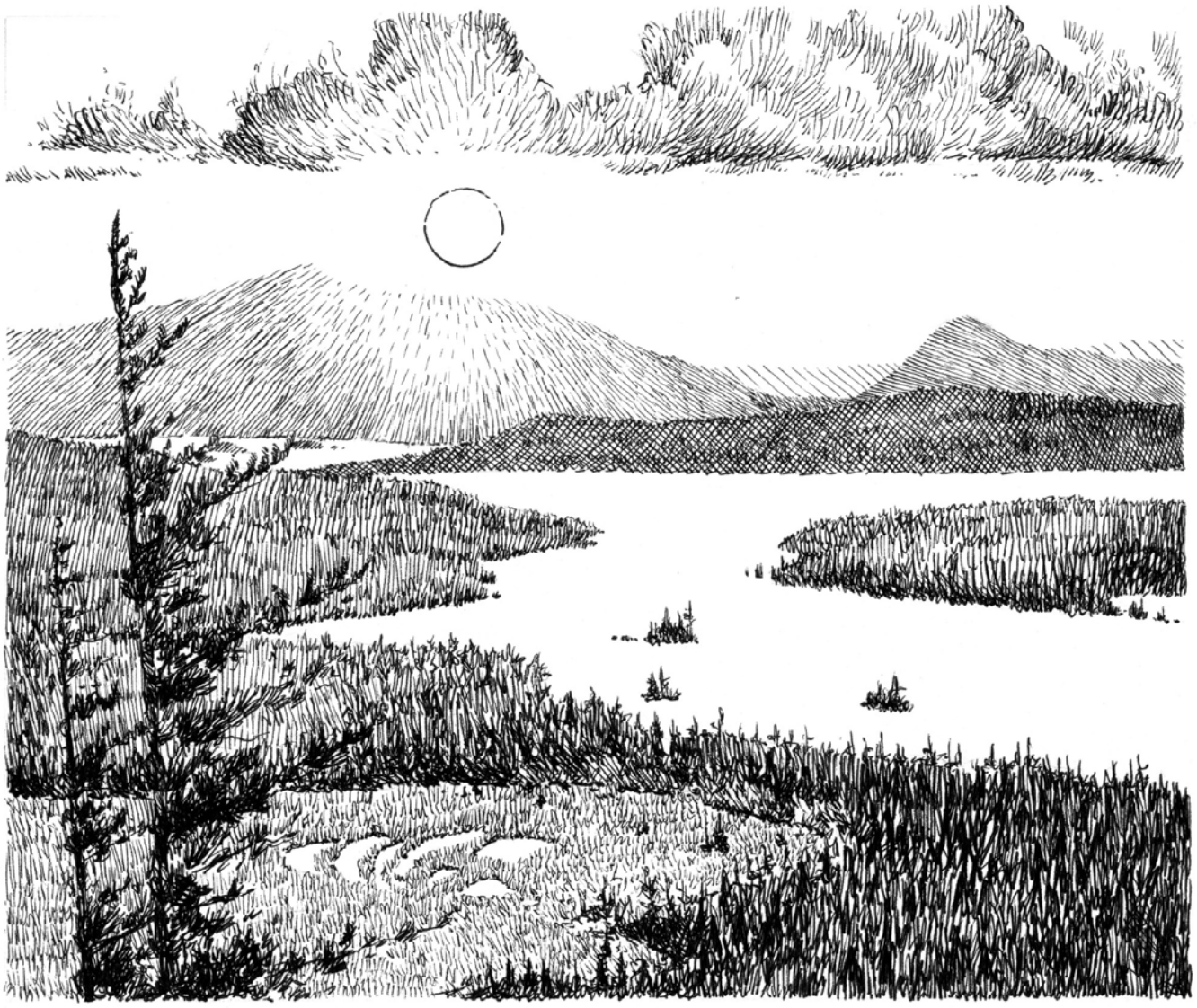
Investigator: Daniel Weaver (PhD)

Advisors: Stephen M. Coghlan, Jr. (Co-Advisor)
Joseph D. Zydlewski (Co-Advisor)
Hamish S. Greig
Michael T. Kinnison
Jerry V. Mead

Duration: May 2013—May 2017

Cooperators:

Maine Sea Grant
Atlantic Salmon Federation
Maine Audubon Society
Maine Department of Inland Fisheries and Wildlife
Maine Department of Marine Resources
University of Maine – Department of Wildlife, Fisheries, and Conservation Biology
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
Penobscot Valley Audubon Chapter
National Oceanic and Atmospheric Administration
The Nature Conservancy



WILDLIFE and habitats

WILDLIFE and habitats continued

Relative densities, patch occupancy, and population performance of spruce grouse in managed and unmanaged forests in northern Maine

1. Quantify patch occupancy of breeding spruce grouse across a variety of harvested and unharvested stands to determine the link between measurements of forest structure and breeding habitat occupancy.
2. Document home range and within-stand habitat selection and composition of brood rearing female spruce grouse with regard to forest vegetation, structure, and harvest history to evaluate effects of forest management on brood rearing habitat.

Abstract: Spruce grouse (*Falcipennis canadensis*) inhabiting the mixed coniferous-deciduous forests of the northeastern United States are at the southern extent of their range. These mixed forests are known collectively as the Acadian forest and represent the transitional zone between the boreal forest to the north and the deciduous northern hardwoods forests to the south. Often assumed to be associated with mature, unharvested forest in this region, few studies have assessed habitat relationships of the species within areas dominated by commercial forest management. We investigated the influence of stand maturity, vertical and horizontal cover, and patchiness on the occupancy and abundance of male spruce grouse during the breeding season (Chapter 1); as well as within stand-scale habitat selection of spruce grouse hens during the brood-rearing season (Chapter 2) in the commercial forests of northcentral Maine. Our study was comprised of six townships that covered 612 km2 within the largest contiguous undeveloped forest in the U.S.

Patterns of occupancy and abundance by male spruce grouse were examined by surveying 30 stands during each breeding season (May-June) in 2012-2014. Areas surveyed represented four forest harvest histories including regenerating clearcut (n = 10), pre-commercially thinned (n = 10), selection harvest (n = 4), and mature unharvested conifer (n = 6) stands. We constructed single season occupancy and abundance models with years and stand types considered as groups, while accounting for nuisance variables that could affect survey outcomes (e.g., weather, density of woody vegetation). Probability of detection given occupancy was 0.61, and the probability of occupancy varied by successional stage from 37.4 to 76.8. Across our study area, individual male grouse had a probability of detection of 0.24 and the abundance of male grouse also varied by successional stage from 0.67 to 2.75. Based upon the covariates included in the models, both occurrence and abundance of breeding male spruce grouse were highest in mid-successional, moderately dense, conifer dominated stands that have experienced intensive forestry practices such as clearcutting, herbicide application, and pre-commercial thinning to promote coniferous regeneration.

We investigated within stand-scale (i.e., 4th-order selection) habitat selection by female spruce grouse during the brood rearing season (June-October) in 2012-2014 by tracking 30 hens captured in 12 stands, which we equipped with VHF transmitters. We used general linear mixed models to construct resource selection functions to compare use to availability for each hen. Female spruce grouse selected for abundant low vegetation structure (<0.5m), lowest tree branches 3-9 m above ground, and for tree densities <1000 /ha. We also developed home range estimates based on 80% fixed kernel utilization distributions to determine appropriate scales for managing brood season habitat. We estimated fixed kernel home ranges for 27 hens, and observed an average home range area of 37.7 ha (SE = 23.9 ha).

Spruce-fir forests in the region have declined in recent years and are predicted to decline further under all future climate scenarios. Thus, forms of harvesting and post-harvest treatments that promote moderately dense conifer-dominated regeneration are recommended to maintain spruce grouse presence in commercially managed forests within the Acadian region. Currently, these conditions selected for by spruce grouse occur predominantly in stands with a past history of clearcutting, followed by post-harvest herbicide application and/or pre-commercial thinning. Changing markets, regulations, and other factors have caused the majority of forest harvests to shift towards partial harvest methods in Maine. Given that the extent and size of residual conifer forest patches has declined substantially over the past three decades, opportunities to manage for spruce grouse and other conifer-dominant species in Maine's commercially managed forests will require future attention and monitoring.

Investigator: Stephen Dunham (MS)

Advisors: Daniel J. Harrison (Advisor)
Brian J. Olsen
Erik J. Blomberg
Daniel G. McAuley (ex-officio)

Duration: July 2011—May 2016

Cooperators:

University of Maine – Maine Cooperative Forestry Research Unit

Small mammal community ecology

1. Determine if elevational gradients in northern New England harbor distinctive small mammal communities.
2. Understand patterns of community assembly and predict response to climate change.
3. Identify foundational species in each community and model their abundance.
4. Model intraspecific functional diversity of common species (Deer Mouse, Red/backed Vole).
4. Survey for high-elevation specialist species (Northern Bog Lemming, Yellow-nosed Vole).

Abstract: Common species are fundamental to the structure and function of their communities, and they may enhance community stability through intraspecific functional diversity. We measured **δ** 15N and **δ** 13C stable isotope signatures of two common small mammal species to determine whether intraspecific functional diversity was evident in their diet and whether this intraspecific functional diversity enhanced population stability. Deer mouse (*Peromyscus maniculatus*) diet reflected the influence of external filters (e.g., climate), which decrease trait variation, and internal filters (e.g., competition), which increase trait variation. In contrast, Southern Red-backed Vole, (*Myodes gapperi*) diet reflected only internal filters. *Peromyscus maniculatus* relative abundance differed significantly between years, as did the overall small mammal community in deciduous forest where they were most abundant. *Myodes gapperi* relative abundance was stable, as was the small mammal community in coniferous forest where they were most abundant. Species responding to internal filters have greater intraspecific functional diversity, contributing to population stability relative to sympatric species responding to external filters. Common species with high intraspecific functional diversity may stabilize their communities. Factors affecting the abundance of common species will disproportionately affect community structure, so understanding the ecological trajectory of those species is important for conservation planning. We evaluated factors driving the abundance of three common small mammal species (Woodland Jumping Mouse, *Napaeozapus insignis;* *M. gapperi;* *P. maniculatus*) sampled at multiple sites along 1,000 m elevational gradients in the northern Appalachian Mountains, USA. We tested five hypotheses of small mammal abundance: climate, food, interspecific interactions, macro-, and micro-habitat structure. Generalized linear models indicated that food and, to a lesser extent, macro-habitat structure, drove the abundance of each species. We tested the average top model of each species' abundance and tested its ability to predict independent data; accuracy varied uniquely by species and habitat, and decreased as observed abundance increased. Species respond individualistically to climate change; unique food and habitat structure needs may represent a common mechanism driving those changes. Community evenness, largely a function of core species abundance, may provide a sensitive measure of ecological change, and understanding the drivers of abundance may help predict species' responses to climate change.

Investigator: Connor Wood (MS)

Advisors: Cynthia S. Loftin (Co-Advisor)
Shawn T. McKinney (Co-Advisor)
Jacquelyn L. Gill
Malcolm L. Hunter, Jr.

Duration: September 2013—May 2016

Cooperators:

Maine Outdoor Heritage Fund
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
University of Maine – Department of Wildlife, Fisheries, and Conservation Biology

American marten in Maine: Understanding spatial population dynamics and evaluating monitoring methods

1. Compare remote cameras and hair-snares as sampling methods for estimating marten occurrence and density.
2. Evaluate the power and precision of different combinations of sampling methods and analyses to detect population trend.
3. Develop optimal sampling design for future monitoring with consideration for cost and effort constraints.
4. Construct spatially-explicit predictive models of marten population parameters in relation to exploitation and habitat composition.
5. Determine the relative sensitivity of marten population size to changes in the underlying mechanistic components (recruitment, adult survival, immigration and emigration).

American marten are valued in Maine for commercial and conservation purposes. Changes in forest management over previous decades have led to reductions in suitable habitat for the species, and climate change poses a major risk to the its long-term viability within the state. Accordingly, Maine's Department of Inland Fisheries and Wildlife (IFW) seeks to enhance current monitoring efforts in order to more accurately gauge population trends. We will weigh different combinations of sampling scheme, methodology, and subsequent metrics in order to identify monitoring designs that are both robust and cost-effective. Focusing our survey efforts in north central Maine, we will also investigate how marten vital rates respond to different environmental and anthropocentric influence, and in turn, how influential specific vital rates are upon population size and stability. This information may be critical for evaluating the potential of varied management actions for manipulating population trend, and understanding how forest condition and configuration influences martens at a population-level scale more aligned with the scale of forest management.

A brief pilot season was conducted in late winter 2014 to both evaluate the ability to identify individual martens based upon photographs, and assess joint camera/hair-snare detection stations. Work in the summer and fall of 2014 focused on optimizing detection station design, and we continued sampling in January 2015 in our north Maine woods study area. Given relocation of the project graduate student and PI, we discontinued the field study at the end of March 2015. We have prepared and submitted two manuscripts summarizing the data collection efforts and are awaiting journal decision.

Investigators: John Clare, Shawn T. McKinney, Walter Jakubas, Cynthia S. Loftin

Duration: September 2013—March 2016

Cooperators:

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

American woodcock migration ecology on the Mid-Atlantic coast

1. To investigate en route second order habitat selection of migratory woodcock during stopover.
2. To evaluate drivers affecting migratory decision making of woodcock during stopover.
3. To determine age- and sex-specific departure rates.
4. To determine if habitat use influences minimum stopover duration: a proxy for habitat quality.

Understanding migration ecology is essential for the conservation of migratory species, and particularly important for effective management of migratory game birds. American woodcock are a migratory game bird undergoing population decline since the 1960's stemming from land-use/land-cover change, specifically forest maturation. Research to date has largely focused on habitat use and demographics on northern breeding areas, and wintering grounds in the southern U. S. This has left a large knowledge gap in woodcock migration ecology. To begin filling this void, an interagency effort between USGS and USFWS was initiated to evaluate habitat selection, timing of migration, and survival during the migration period. The study area was Cape May county, NJ, a well-known concentration point along the Atlantic coast during fall migration. Woodcock were caught on fields used for roosting at night by way of a spotlight and a long-handled net. Approximately 10 birds were banded and fitted with a uniquely tuned very-high frequency (VHF) radio-transmitter per week. Each bird was monitored daily for presence in the study area and homed in on at least twice a week to record a precise location, collect habitat data, and determine live/dead status.

Field work took place from 2010 to 2014 during late October through January. Over the course of this period 497 birds were captured and banded. Of those, 271 were fitted with radio-transmitters. We used 1842 locations from 265 individuals to assess landscape level resource selection across the study area during fall migration stopover. We used GIS to assess landcover types at use locations and random locations, and used logistic regression to evaluate selection of landcover attributes. We developed a cumulative model to produce a map depicting relative probability of use from these results. We are acquiring weather and astrological data evaluate the effects of these variables on stopover duration. Preliminary analyses of these data are currently in progress.

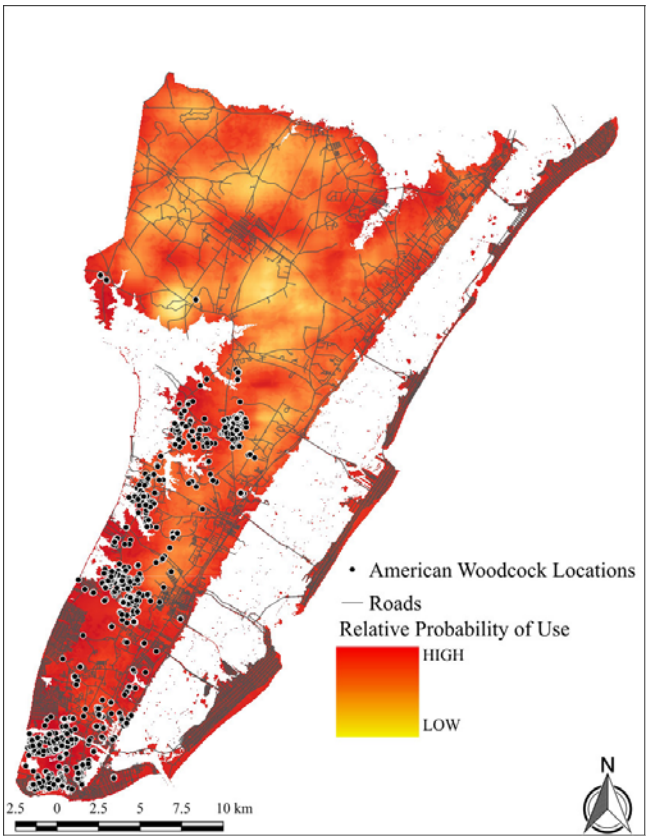
Investigator: Brian B. Allen (MS)

Advisors: Erik J. Blomberg (Advisor)
Daniel G. McAuley
Joseph D. Zydlewski
Brian J. Olsen

Duration: October 2010—May 2017

Cooperators:

U.S. Fish and Wildlife Service – Division of Migratory Birds
U.S. Geological Survey – Patuxent Wildlife Research Center
University of Maine – Department of Wildlife, Fisheries, and Conservation Biology



Investigating the effects of silvicultural practices on individual and population-parameters in small mammals: from personality to seed predation

1. Determine whether or not individuals with different personality types have differential fitness across forest management areas.
2. Explore whether or not personality affects the key processes of seed predation and dispersal.

To investigate the effects of silvicultural practices on both individual and population-level parameters in small mammal communities, we are implementing a large-scale capture-mark recapture study. We will measure individual-level parameters such as body condition, survival, and personality. Population-level parameters that we will measure include density and population growth rates. The data that we collect will allow us to investigate whether or not forest management and forest disturbance give advantage to certain individuals based on personality type by using personality as a predictor of survival in capture-mark recapture models.

Small, scatter-hoarding mammals play a critical role in forest ecosystems through the key processes of seed predation and dispersal. There is extensive evidence that small mammal communities play a significant role in shaping forest composition by selecting the seeds of certain species over others. The decision to predate or disperse a seed is affected by multiple parameters such as vegetation cover, predation risk, seed abundance, and population density. These parameters are likely to be affected by silvicultural practices. Thus far, no previous studies have investigated the role that individual personality may play in the seed decision making process. We will address this key question through a series of seed predation experiments.

During June-November of 2016 we implemented a large-scale capture-mark recapture study in the Penobscot Experimental Forest in Bradley, ME. We have three treatment areas (each with 2 replicates) and two reference areas totaling eight trapping areas. A trapping grid at each area consisted of 150 traps (100 longworth and 50 tomahawk). During this first field season we processed over 2,000 captures and marked over 1,000 different individuals with PIT tags and small mammal ear tags. We measured body condition (weight, body length, tail length, and reproductive status) and personality (using an open-field test) for each individual. We also performed a trial of seed predation experiments but the bulk of this fieldwork will be performed from June-November of 2017.

Investigator: Allison Brehm (MS)

Advisors: Alessio Mortelliti (Advisor)
Erik J. Blomberg
Shawn Fraver

Duration: June 2016—December 2018

Cooperators:

University of Maine – Maine Agricultural and Forest Experiment Station
University of Maine – Department of Wildlife, Fisheries, and Conservation Biology

Evaluation of young forest management to aid declining bird species

1. To assess the effectiveness of using young forest management on private non-industrial forest lands to create quality habitat for breeding birds.
2. To determine how and in what capacity landowners are willing and able to participate in wildlife monitoring of their young forest management areas.
3. To better understand broad-scale Golden-winged Warbler habitat use and movement throughout their annual life cycle.

American Woodcock (AMWO; *Scolopax minor*) and Golden-winged Warbler (GWWA; Vermivora *chrysoptera*), which require young forest habitat (YFH) for breeding, are experiencing population declines due to YFH loss in the United States. Conservation plans stress the importance of YFH management on public and private lands to increase AMWO and GWWA populations. Best management practices (BMPs) have been created to guide habitat management efforts. Because BMP metrics overlap for these two species, it may be possible to use BMPs for GWWA, which has a narrower range of habitat tolerance, to support AMWO. By surveying management sites on private lands in Wisconsin using a before-after-control-impact design, I will evaluate the success of using GWWA BMPs to increase AMWO abundance and determine how closely post-treatment habitat metrics align with GWWA BMPs. I will explore bird diversity across a management chronosequence by conducting breeding bird point counts, GWWA playback surveys, and AMWO singing-ground surveys at pre- and post-management sites from 0-6 years post-treatment. To understand the potential role of landowners in monitoring young forests on their properties, I will conduct interviews asking questions about barriers and preferences in participating in citizen-science-based monitoring. Using light-level geolocators, I will map annual migration routes and wintering areas.

In March of 2016, pre- and post-management sites were selected in Wisconsin. In early spring, AMWO singing ground surveys were conducted at each site. Breeding bird point counts and GWWA playback surveys were conducted in May and June. During that time, GWWA were located and target netted to deploy 28 light-level geoloctators. In July, a vegetation survey was conducted at all of the survey points in the study sites. Interviews with landowners were conducted throughout the summer. Interview data is currently being transcribed and will be analyzed this spring. A second field season will occur in 2017 where all surveys will be repeated and GWWA will be relocated and their geolocators recovered. Landowners will be encouraged to participate in 2017 AMWO surveys as part of a citizen science monitoring effort.

Investigator: Anna Buckardt (MS)

Advisors: Amber M. Roth (Advisor)
Erik J. Blomberg
Jessica E. Leahy

Duration: June 2016—December 2018

Cooperators:

U.S. Fish and Wildlife Service
University of Maine – Department of Wildlife, Fisheries, and Conservation Biology
Wisconsin Department of Natural Resources
Wisconsin SFI Implementation Committee
Wisconsin Young Forest Partnership
Cornell Lab of Ornithology
Indiana University of Pennsylvania
Audubon Vermont
Wisconsin Audubon Council, Inc. and eight associated Audubon chapters around Wisconsin
Natural Resources Foundation of Wisconsin
Oazaukee-Washington Land Trust
Michigan Technological University

Harvest, seasonal survival, and drumming ecology of ruffed grouse in Maine

1. Evaluate seasonal survival and harvest rates in relation to environmental variables to build and improve future management and harvest practices.
2. Understand relationships among individuals, and groups of individuals such as, age and sex, that contribute to mortality risk throughout the year.
3. Evaluate selected habitat characteristics at display stages of male ruffed grouse during the breeding season by comparing vegetation at used and unused locations.
4. Record drumming rates at each stage to determine if structural differences among drumming stages affect male breeding behavior and performance.

Ruffed grouse are among the most popular game species in Maine, but there is little information on the species' population ecology in the state. For this project we are using a combination of banding and radio-telemetry to monitor demographics (survival and reproductive success) and harvest of ruffed grouse at two studies areas in Maine. Ruffed grouse are captured during late summer using lily-pad interception traps, and are fitted with very high frequency (VHF) radio collars that are equipped with a mortality sensors so that marked birds may be monitored for survival and causes of mortality can be identify as they occur. Additionally, birds are fitted with aluminum leg bands stamped with contact information to allow for hunters to report any harvested grouse. During the breeding season, April through May, males perform a drumming display to attract females using an elevated structure they select within defended territories within a 300 meter radius. To investigate drumming behavior and the associated vegetation structure around drumming stages we recorded drumming rates (display) at each known stage and measured the vegetation structure at those stages.

During August and September we captured and radio-collared ruffed grouse at two study areas. We monitored survival of 105 radio-collared grouse in 2014 following capture season, 96 in 2015 and 53 in 2016. Ruffed grouse hunters reported harvesting 17 grouse in 2014, and 17 in 2015. In addition 28 non-harvested mortalities were recorded in 2014, and 20 non-harvested mortalities in 2015. Winter mortality was higher than expected in 2014 with a total of 16 mortalities recovered during January and February. During spring of 2015 and 2016 we located 94 drumming stages between the two study areas and recorded individual male drumming rates and habitat characteristics at each drumming location. Habitat structure was recorded at the display stages and at 2 paired random points located <200m from the stage. Our field work is ongoing, survival monitoring, and harvest rates will continue to be collected into spring of 2017.

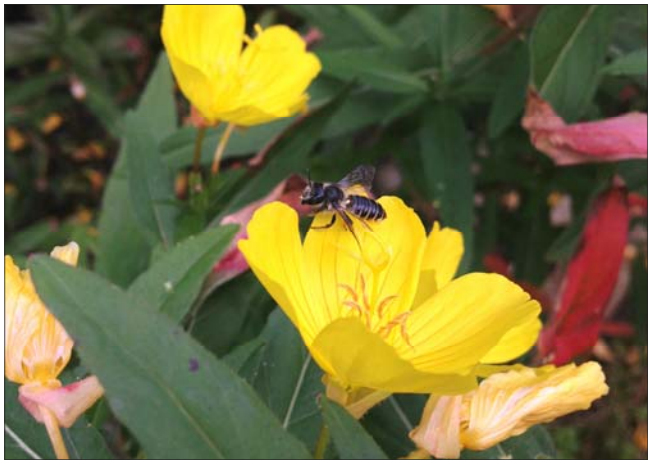
Investigator: Samantha Davis (MS)

Advisors: Erik J. Blomberg (Advisor)
Kelsey Sullivan
Brad Allen
Brian J. Olsen
Alessio Mortelliti

Duration: July 2014—May 2017

Cooperators:

Maine Department of Inland Fisheries and Wildlife
American Forest Management
University of Maine – Maine Agricultural and Forest Experiment Station
University of Maine – Department of Wildlife, Fisheries, and Conservation Biology
The Nature Conservancy



Landscape pattern and native bee communities in the northeastern United States

1. Determine if a relationship exists between pesticide residues in pollen loads and landscape configuration.
2. Examine power line rights-of-way as semi-natural habitat for native bees.
3. Compare the performance of a spatially explicit ecosystem service simulation model in landscapes with different complexities.
4. Develop a tool for blueberry growers to assess native bee habitat in the landscape surrounding their crop fields.

Native bees provide a critical ecosystem service to human and wildlife populations by pollinating fruit-bearing cultivated crops and wildlife forage. Historically, commercially managed bees have been an important pollinator of agricultural crops, however, Colony Collapse Disorder has decreased hive availability, increasing reliance on native bees to provide this service. Enhancing habitat around crop fields to promote native bee populations will benefit fruit production for both agricultural interests and wildlife populations. In Maine, wild blueberry growers invest heavily in honey bees for pollination; concern about pollination deficit due to fewer honey bees and growing costs has lead to increased interest in management to promote native bee pollination. This study is examining factors that potentially affect native bee abundance in wild and cultivated fruits from a spatial ecology perspective. Our spatial assessment includes evaluation of relationships between landscape pattern and composition and exposure of native bees to pesticides applied to crop fields; evaluates habitat quality of power line rights-of-way as semi-natural habitat for native bees; compares performance of a spatially explicit ecosystem service simulation model (InVEST) in landscape with different pattern complexities; and, develops a tool for blueberry growers to use to assess native bee habitat in the landscape surrounding their crop fields.

Native bees have been surveyed in power line rights-of-ways in Downeast Maine during 3 summers, and in mid-coast Maine during 2014 and 2015. Native bees also were surveyed in 8 land cover types in Downeast, Midcoast, and Central Maine during summer 2014-2016. Currently, we are analyzing the bee abundance and diversity dataset developed from this fieldwork, which will be used to improve parameterization of the InVEST model. Modification of this spatial model will begin during early 2017, incorporating data from bee surveys conducted in non-crop land cover types to improve accuracy of the predictive model of bee abundance. A web-based spatial tool for wild blueberry growers and land managers was completed and will be available for use in 2017. Project completion is planned for late summer 2017.

Investigator: Brianne Du Clos (PhD)

Advisors: Cynthia S. Loftin (Co-Advisor)
Francis A. Drummond (Co-Advisor)
Dana M. Bauer
Samuel P. Hanes
Allison Dibble

Duration: January 2012—August 2017

Cooperators:

U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
University of Maine
University of Maine – Sustainable Solutions Initiative
U.S. Department of Agriculture
USDA SARE Grants

Effects of urbanization on pool-breeding amphibians: Implications of condition for persistence of wood frog (*Lithobates sylvaticus*) and spotted salamander (*Ambystoma maculatum*)

1. Characterize wood frog and/or spotted salamander breeding pools along a gradient of human disturbance via documentation of biotic factors (faunal assemblages, vegetation characteristics), abiotic factors (temperature, water quality, hydroperiod), and land cover types and configuration at various scales in the surrounding landscape.
2. Examine the effects of breeding pool characteristics on amphibian health (i.e., development, morphology, disease susceptibility, and physiology).
3. Examine population dynamics (e.g., occupancy, breeding effort and success, and connectivity) relevant to population persistence.

Pool-breeding amphibians in Maine, similar to most groups of amphibians worldwide, are threatened by human land use disturbance and the resultant habitat loss, fragmentation, and degradation. These amphibians require both aquatic and terrestrial habitats to complete their life cycles and are, thus, sensitive to disturbances in both environments. Animal response to changes in landscape conditions may not immediately affect population demographics; i.e., there may be a time lag between impaired condition and reductions in fecundity and survival. Amphibian populations that are chronically exposed to adverse factors may have reduced likelihood of survival. It is currently unknown how amphibian health and survival are affected by various intensities of development. Understanding how pool-breeding amphibians respond to development will provide crucial information for land managers and policy makers to make decisions about development that best conserves pool-breeding amphibian species. Our project addresses how land use disturbance affects pool-breeding amphibian health and survival. In 2017 we will analyze data and write manuscripts addressing, specifically: (1) Assemblages of camera-trapped wildlife at vernal pools along an urbanization gradient; (2) Vernal pool-breeding amphibian larval morphology, development, and survival along an urbanization gradient; (3) Relationships between vernal pool breeding amphibian reproductive effort and larval survival and morphology along an urbanization gradient; (4) Examination of the seasonality of Ranavirus (*Rv*) infection in wood frog larvae. Community dynamics among indicator vernal pool-breeding amphibians and their key amphibian predators along an urbanization gradient; (5) Influences of road salt on wood frog larvae growth, development, survival, and gene expression from high and low conductivity source pools.

We have completed three field seasons focusing on characterizing vernal pools and the health and survival of larval wood frog (*Lithobates sylvaticus*) and mole salamander (*Ambystoma spp.*) populations along a development gradient. We conducted egg mass, clutch size, and prometamorphic larvae counts to estimate reproductive effort and the percent of eggs that survived to leave pools. Throughout the season we conducted weekly tadpole growth, development, and disease surveillance surveys and quantified changes in within-pool vegetation and water characteristics which likely affect larval amphibian health and survival. We conducted trail camera and visual detection surveys to describe vertebrate predator pressures on pool-breeding amphibians. We also trapped adult unisexual Ambystoma for experimental testing of their susceptibility to a fungal pathogen, Bsal (*Batrachochytrium salamandrivorans*). In the lab we conducted experiments to better understand the influence of road salt, food availability, ranavirus infection, and insect predators on wood frog tadpole growth, development, and survival.

Investigator: Carly Eakin (PhD)

Advisors: Malcolm L. Hunter, Jr. (Co-Advisor)
Aram J.K. Calhoun (Co-Advisor)
Hamish S. Greig
Rebecca L. Holberton
Michael T. Kinnison

Duration: August 2013—December 2017

Cooperators:

National Science Foundation – Experimental Program to Stimulate Competitive Research
University of Maine – Department of Wildlife, Fisheries, and Conservation Biology
University of Maine – Maine Agricultural and Forest Experiment Station

The habitat ecology of pool-breeding amphibians during all annual life history periods in the Mountains of the Dawn

1. Identify the habitat features selected by wood frogs (*Lithobates sylvaticus*) during spring migration and the post-breeding period, and determine if these periods are ecologically distinct. Describe the spatial and temporal arrangement of habitats used during the breeding, spring and fall migration, post-breeding, and hibernal periods.
2. Identify the habitat features selected by wood frogs prior to hibernation and investigate the thermal ecology of overwintering frogs.
3. Evaluate the influence of local and landscape scale variables on wood frog and spotted salamander (*Ambystoma maculatum*) breeding site occupancy in Maine's Upper Montane/Alpine Zone ecoregion.

Maine is ecologically diverse with varied landscapes. Although pool-breeding amphibians generally are distributed across the state, the vernal pools they typically use for breeding are more limited geographically. Current legislation to protect vernal pools is based on research conducted in southern, central, and downeast Maine where vernal pools are relatively abundant; it is not clear how these species use alternative breeding habitats where vernal pools are scarce. For example, Maine's montane region is rugged and relatively wetland-limited, with one of the coldest climates in New England. Very little is known about pool-breeding amphibian dispersal, migration, hibernation, and habitat selection in wetland-limited landscapes. Hibernaculum selection may be critical to individual fitness, as six-months of hibernation is immediately followed by a short, explosive breeding period. Our research examines habitats used by pool-breeding amphibians throughout the species' annual life history cycle in Maine's western and interior mountains.

We have completed four field seasons; two investigated wood frog post-breeding and overwintering habitat selection, and two investigated wood frog and spotted salamander breeding site occupancy. We used radio telemetry to track the post-breeding movements of 71 wood frogs at Turtle Ridge in Maine's Nahmakanta Public Reserved Land during 2011-2013. We continued to track a reduced number of frogs throughout fall and early winter in 2011 and 2012 until they were poised for hibernation. We then erected enclosures around each hibernating frog, which served to contain them until we arrived on-site to attach new radio transmitters; doing so allowed us to track individuals across all annual life history periods. We conducted amphibian breeding surveys at 135 wetlands in six study areas during late spring and summer in 2013 and 2014. We have published four manuscripts, another currently is in-revision, and another will be submitted in 2017. Luke Groff has defended and will graduate in December 2016.

Investigator: Luke Groff (PhD)

Advisors: Cynthia S. Loftin (Co-Advisor)
Aram J.K. Calhoun (Co-Advisor)
Daniel J. Harrison
Brian J. McGill
Francis A. Drummond

Duration: January 2010—December 2016

Cooperators:

Maine Department of Inland Fisheries and Wildlife
U.S. Geological Survey – Eastern Regional Cooperative Fish and Wildlife Research
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
University of Maine – Department of Wildlife, Fisheries, and Conservation Biology
University of Maine – Sustainable Solutions Initiative
School of Agricultural, Forest, and Environmental Sciences at Clemson University

Land-use effects on movement between and around breeding sites by wood frogs

1. Study the post breeding movements of adult wood frogs in a suburban landscape, including migration movements among distinct environments.
2. Study adult wood frog post-breeding habitat selection in a suburban landscape.
3. Evaluate hibernacula habitat selection in a suburban environment. Study the microclimate of each hibernaculum selected.
4. Determine habitat use during migration movements towards and away from vernal pools located in suburban landscapes.

Continue the wood frog radiotelemetry project associated with Mitchell Jones' PhD. project. Mr. Jones left his project and Thomas Hastings is continuing the tracking of up to 20 frogs during their post-breeding phase into hibernation at the Mt. Hope area study site in Bangor.

Adult wood frogs were tracked in a forested wetland patch surrounded by suburban terrain such as neighborhoods, buildings, and roads. Frogs were tracked using radiotelemetry. Transmitters were fitted to frogs using stretch bead cord belts that slip over the back legs. Frogs were captured and refitted with new belts about every two months when transmitter batteries were expected to expire. We tracked frogs to within centimeter accuracy four to seven times a week. Distance and direction were recorded for each movement. Habitat data (at two scales) was collected for each new frog location. Tracking continued until it was determined that each frog selected a winter hibernaculum. Enclosures were built around each hibernating frog to study hibernacula microclimate, winter survival, and migration patterns to vernal pools in a suburban area. We placed thermochron iButtons at each hibernaculum to record temperatures and evaluate microclimate. In the spring of 2017, adult wood frogs will be tracked using radio telemetry to evaluate habitat use during migration movements. Tracking will begin upon emergence from hibernacula.

All field work has been completed for objectives one and two. Starting in April, up to 17 adult wood frogs were tracked as they moved out of two vernal pools in suburban Bangor environments. Nine adult wood frogs were tracked at the Mt Hope Avenue site until they selected hibernacula in a forested wetland area. This forest patch is separated from the vernal pool by about 150 meters of neighborhood area. Objective three is in progress. Winter enclosures were built around each hibernating frog and temperature loggers were positioned to collect microclimate information. Temperature loggers are currently collecting information. Maps of all frog movements to date (18 January 2017) have been created. Objective four will be addressed in the spring of 2017

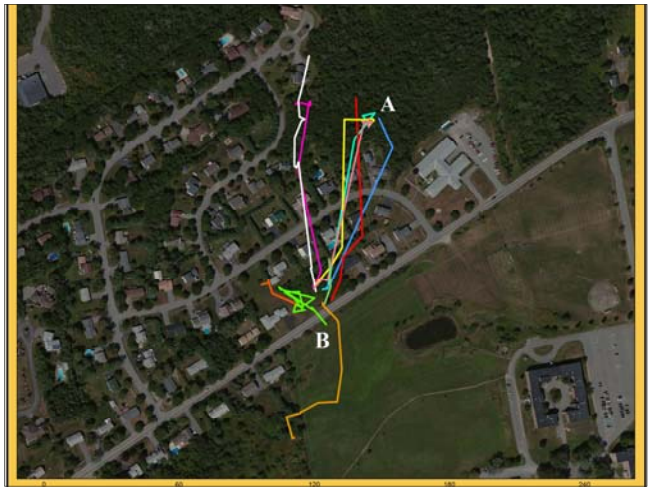
Investigator: Thomas Hastings

Supervisors: Malcolm L. Hunter, Jr.
Aram J.K. Calhoun

Duration: September 2015—February 2018

Cooperators:

National Science Foundation – Dynamics of Coupled Natural and Human Systems (CNH)



Breeding ecology and habitat selection of the blue-spotted salamander (*Ambystoma laterale*) and its unisexual kleptogen

1. Compare the breeding site selection of blue-spotted salamanders to that of unisexual salamanders.
2. Explore terrestrial habitat use by unisexual salamanders.
3. Examine the breeding success, abundance, sex ratio, and orientation of each lineage at 4 vernal pools.
4. Investigate statistical methods used to assess directionality at amphibian drift fence arrays using both field data and simulations.

The blue-spotted salamander complex in Maine consists of the blue-spotted salamander (*Ambystoma laterale*) and a unisexual lineage containing both the DNA of the blue-spotted and Jefferson salamander (*A. jeffersonianum*). The unisexuals are almost entirely polyploid females, and parasitize sperm from the blue-spotted salamanders to reproduce (kelptogens). We are examining the breeding site selection, reproductive variation, and upland habitat use of this complex.

Breeding site selection: We trapped salamanders, collected tissue samples, and recorded environmental data at wetlands in the Greater Bangor Area. We modeled factors that influenced the breeding site selection of each lineage, and are currently preparing our manuscript for submission.

Habitat use: We implanted breeding salamanders with radio transmitters and followed them as they emigrate from the pool to summer activity areas. We are currently modeling their terrestrial habitat use.

Breeding success: Using drift fences at four vernal pools, we captured adult and juvenile salamanders. We explored their population dynamics (including sex, genetic ratios, size) and are preparing our manuscript.

Directional statistics: We are revising this manuscript for resubmission.

We have completed all field work and are analyzing our last data set. Most chapters have completed drafts, and two are near submission.

Investigator: Kristine Hoffmann (PhD)

Advisors: Aram J.K. Calhoun (Co-Advisor)
Malcolm L. Hunter, Jr. (Co-Advisor)
Daniel J. Harrison
Michael T. Kinnison
James P. Bogart

Duration: January 2012—January 2017

Cooperators:

National Science Foundation – Experimental Program to Stimulate Competitive Research
University of Guelph
Orono Land Trust
University of Maine – Department of Wildlife, Fisheries, and Conservation Biology
University of Maine – Sustainable Solutions Initiative

Characterizing vernal pool biogeochemistry across a land use gradient in Maine, USA

1. Explore pool chemistry, carbon turnover, and cycling of phosphorous, nitrogen, and carbon in the water column and at the sediment water interface at four Maine vernal pools (two with low modification and two with higher modification).
2. Determine if these systems are closed with respect to nutrients, and investigate the driving environmental factors behind the chemical reactions in the pools.
3. Create a mass balance for all chemical species in the pools. The masses that are produced and consumed can be converted to fluxes from the bottom sediments.
4. Create a mass balance for greenhouse gasses (CO_2, CH_4, and N_2O). Perform diffusive flux and ebullition calculations. Calculate the global warming potential of the gasses released from the pools. Determine if the four vernal pools are sources or sinks of greenhouse gasses.
5. Explore controls on alkalinity of the vernal pool systems. Determine the contribution to alkalinity from organics, metals, and carbonate. Compare alkalinity controls over the season.

Vernal pools are small ephemeral wetlands that are crucial for maintaining biodiversity in northeastern forests. These seasonally inundated wetlands are an excellent example of small natural features in a landscape that can have a broad impact on the much larger ecosystem around them. Water quality and nutrient cycling are important aspects of vernal pool functions, however, there is little information known about their biogeochemistry. Understanding the dynamics among water, sediments, and biota is crucially important for the conservation and management of vernal pools and the ecosystems and animals that depend on them. We will explore carbon dynamics, nutrient cycling, fluxes of metals, ions, and alkalinity. We will examine the environmental controls on the chemical processes occurring in four vernal pools in Maine. The results of this study will be used to inform ecologists, developers such as civil engineers, and public agencies who work with vernal pools on the implications of biogeochemical processes with respect to nutrient cycling and transport. This research has future implications in the study of small natural features and their broader impacts, as these seasonally inundated wetlands have wide-reaching impacts over larger ecosystems.

We have completed one field season focused on vernal pool water chemistry and biogeochemical cycles within the pool. We collected weekly samples from benthic and surface locations at 4 pools. We analyzed the water samples for pH, dissolved oxygen, strong acid anions, strong base cations, gasses (CO_2, CH_4, and N_2O), P, N, Fe, Mn, Al, Si, DOC, and chlorophyll a between April and August 2016. We also tracked water level changes in the vernal pools to quantify masses and fluxes of chemicals in the water column. Data sets are near completion. Data analyses have begun.

Investigator: Lydia Kifner

Advisors: Aram J.K. Calhoun (Co-Advisor)
Aria Amirbahman (Co-Advisor)
Stephen A. Norton

Duration: August 2015—December 2017

Cooperators:

National Science Foundation – Dynamics of Coupled Natural and Human Systems (CNH)

Evaluation of representative bird species' Landscape Capability models developed by the Designing Sustainable Landscapes project in the 13-state, northeastern region of the United States

1. Evaluate relationships between abundance of selected representative species and DSL Landscape Capability products with breeding bird points count survey data collected within the northern region of the Connecticut River watershed and then across the NA-LCC region.
2. Evaluate Landscape Capability models under development for additional species (e.g., Cerulean Warbler) for which we have point count data and after upon completion of the models by the DSL project (scheduled for completion by 2015).
3. Evaluate relationships between predictions of representative species Landscape Capability models evaluated in Objectives 1-3 and the species they represent within ME, NH, PA, VA, and WV to evaluate the models from watershed to regional extents.
4. Provide information to managers regarding relationships of priority, forest-associated avian species populations and forest structure and landscape conditions to inform conservation and land management planning.

The University of Massachusetts Designing Sustainable Landscapes (DSL) project has developed Landscape Capability models (LC) for representative species, integrating climate niche, habitat capability, and prevalence models to assess sustainability of the representative species in the 13 northeastern states under future landscape conditions. Several representative species for which Landscape Capability models have been completed are USFWS priority species of high conservation concern in coniferous, hardwood-dominated or mixed coniferous-deciduous forest in the northeastern region, and models for some representative species are expected to serve as surrogate models for other species with USFWS Northeast Region conservation priority designation. Although the LC models for most bird species have been evaluated with recent eBird data, they have not been evaluated with data collected in independent, systematic, repeated surveys, nor has the transferability of the representative species models been evaluated for the species they are assumed to represent. Additionally, the application of DSL models to meet regional population objectives remains uncertain, because these models have not been tested for associations between abundance while accounting for detectability. Our analysis will incorporate detectability in evaluating the utility and predictive ability of DSL LC models and will facilitate transferability of these models into concrete conservation objectives and actions.

Activity on the project began in early September 2015 with appointment of the Post-Doctoral Research Associate, Dr. Zachary Loman, to the project. We have compiled available point count data collected by colleagues across the project area and have begun analyses of the point count data as density estimates to validate the abundance or occupancy predictions of the DSL LC models. We have evaluated DSL LC models for Ruffed Grouse and American Woodcock with point- and management unit-scale monitoring data to verify and validate these models for predictions of relative abundance and occupancy at these scales. A manuscript detailing this analysis is in review. We are currently evaluating representative species models and represented species are summarizing these analyses in manuscripts to be submitted for journal review in early 2017.

Investigator: Zachary Loman (Postdoc)

Advisors: Cynthia S. Loftin (Co-Advisor)
Daniel J. Harrison (Co-Advisor)
Petra B. Wood (Co-Advisor)

Duration: September 2015—December 2017

Cooperators:

U.S. Geological Survey – Biological Resources Discipline
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
U.S. Fish and Wildlife Service
U.S. Geological Survey – Science Support Program

Ruffed grouse nest-site selection, nest success, and summer habitat use in central Maine

1. Identify vegetative and microclimatic variables that are associated with successful ruffed grouse nests, calculate a cumulative nest success rate for ruffed grouse nests in Maine, and compare this rate to that observed in other portions of the ruffed grouse range.
2. Identify vegetative variables that are selected by non-reproductive and brood rearing ruffed grouse at the home range and study area scales, which could guide future management for high-quality ruffed grouse habitat in Maine.
3. Contribute to the broader understanding of forest management effects on wildlife populations by examining variation in ruffed grouse demographic rates as a function of forest structure, composition, landscape characteristics, and forest management practices.

Ruffed grouse are a native Maine bird, and are arguably the most popular small game animal in the state. We are using a combination of banding and radio-telemetry to monitor demographics (survival and reproductive success) of ruffed grouse at two studies areas in Maine. Ruffed grouse are captured during the late summer using cloverleaf interception traps, and birds are fitted with very high frequency (VHF) radio collars that include mortality sensors so that marked birds may be monitored remotely for survival. During the breeding season we quantify characteristics of reproduction, such as clutch size, nest success, and brood productivity, and will evaluate the effects of habitat characteristics (e.g. stem density, understory coverage, species composition, microclimatic conditions) on reproductive output. In addition, we monitor males throughout the breeding season to study how habitat characteristics affect selection by ruffed grouse. This work seeks to inform ruffed grouse management and improve our ability to conserve the species in Maine.

During August and September 2014-2016, we captured and radio-collared ruffed grouse at two study areas in central Maine. We will continue to monitor the survival of our radio-collared grouse year-round, while attempting to identify the causes of their mortality. In 2015 and 2016, we monitored a combined total of 33 ruffed grouse nests between the two study areas until each nest either succeeded or failed. Brood productivity was monitored via weekly flush counts until chicks reached 6 weeks of age. Additionally, we obtained 2 locations per radio-collared bird per week June through July of 2015 and 2016, and measured habitat characteristics at 365 locations used by non-reproductive and brooding ruffed grouse to compare to 1) random locations <200m from birds' locations and 2) randomly generated locations within the study areas.

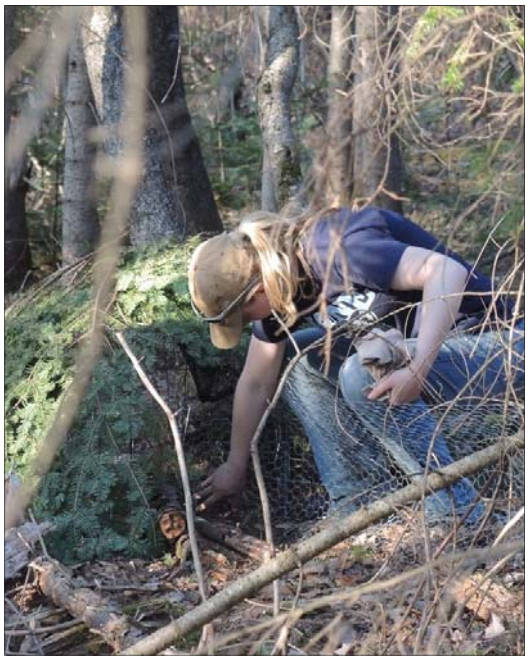
Investigator: Joelle "Ellie" Mangelinckx (MS)

Advisors: Erik J. Blomberg (Advisor)
Kelsey Sullivan
Brad Allen

Duration: August 2014—August 2017

Cooperators:

Maine Department of Inland Fisheries and Wildlife
University of Maine – Maine Agricultural and Forest Experiment Station
University of Maine – Department of Wildlife, Fisheries, and Conservation Biology
Ruffed Grouse Society



Individual, colony, and metapopulation-level drivers of seabird colony dynamics

1. Investigate long-term costs of reproduction in a long-lived seabird.
2. Investigate differences in life-history strategy between two allopatric seabird populations with differing survival rates.
3. Investigate factors driving seabird productivity.
4. Investigate seabirds' ability to buffer productivity against fluctuations in food availability.
5. Investigate factors driving seabird colony initiation and extinction.
6. Investigate factors affecting seabird nesting patch selection.
7. Use results from 1-6 to develop an agent-based model of seabird dynamics to allow population-level prediction in novel situations.

The purpose of this research is to investigate seabird dynamics on multiple scales and to use the resulting information to assess the resilience of seabirds to ecosystem perturbation. First, I will use a long-term mark-recapture dataset to revisit a reproductive cost experiment on Black-legged Kittiwakes (*Rissa tridactyla*) in Alaska to examine how cumulative reproductive costs may play out over an individual's lifespan. I then will use the same dataset to explore differences in life history strategy between this Pacific population vs. published accounts of an Atlantic population with differing survival rates. Next, I will use a 30-year monitoring dataset from the same region to examine how multiple stressors interact to affect kittiwake productivity on a colony scale and to identify which productivity components are used to buffer productivity. I then will investigate factors driving colony initiation and extinction. A s a part of this last component, I will test several hypotheses regarding recruit attraction to nesting patches. Finally, I will synthesize this work in developing a general agent-based model to predict seabird responses to changes in the marine ecosystem.

All data are collected, most cleaning and proofing is complete, and analyses are underway. Project completion is anticipated in 2017.

Investigator: Alyson McKnight (PhD)

Advisors: Shawn T. McKinney (Co-Advisor)
Cynthia S. Loftin (Co-Advisor)
Erik J. Blomberg
Brian J. Olsen
Jeffrey A. Runge
David Irons

Duration: September 2013—May 2017

Cooperators:

U.S. Fish and Wildlife Service

Effects of forest management practices in the Acadian northern forest region on forest bird communities, with emphasis on species of regional conservation priority and concern

1. Quantify and define the composition and forest associations of coniferous bird communities in several silvicultural treatments including: regenerating, mature, overstory removal, precommercially thinned, selection, and shelterwood harvest.
2. Model the influences of silvicultural practices and vegetative attributes on coniferous forest bird communities.
3. Model factors influencing the abundance, occupancy, and distribution of focal species. This analysis will take a multi-scale approach and use both USGS Breeding Bird Surveys along with surveys that will be conducted 2013-2015.

To test for effects from forestry on bird densities, we conducted multi-species point count surveys in 2013 through 2015 during the breeding season of most passerine species (June through August) in the silvicultural treatments listed above. Our surveys recorded the number of birds present for each species along with variables that may influence their probabilities of detection. We measured vegetation at each survey location in 2014. Stand attributes will be used to assess habitat selection on focal species and communities. Additionally, we surveyed Bay-breasted Warbler reproductive success and spruce budworm adult moths (prey) in 2015. These data will be supplemented with USGS Breeding Bird Survey data to address large-scale questions, temporal trends, and the influence of budworm outbreaks. We will model habitat selection by birds to make inference about their responses to silvicultural management. We thank the U.S.F.W.S. Migratory Bird Division, U.S.F.W.S. National Wildlife Refuge System, UMaine Cooperative Forestry Research Unit, and UMaine Department of Wildlife Ecology, Maine Cooperative Fish and Wildlife Research Unit, and Baxter State Park for access to sites, project support, and funding.

We established sampling protocols for birds and vegetation and collected multi-species bird data at five areas throughout the Acadian forest region: Nulhegan NWR (VT), Umbagog NWR (NH), North Maine Woods (ME), Baxter State Park (ME), Aroostook NWR (ME), and Moosehorn NWR (ME) using standardized point count surveys. A total of 6,163 bird surveys were conducted during the summer of 2013, 2014, and 2015, and 65,760 detections of birds were collected during surveys at 657 point count locations within 117 forest stands. Vegetation surveys were completed at all sites during 2014. Reproductive success and eastern spruce budworm data were collected in 2015. All field data collection was completed in 2015. Statistical analysis and reporting of results are underway, with project completion anticipated in late 2017.

Investigator: Brian Rolek (PhD)

Advisors: Daniel J. Harrison (Co-Advisor)
Cynthia S. Loftin (Co-Advisor)
Petra B. Wood
Brian J. McGill
Brian J. Olsen

Duration: August 2012—August 2017

Cooperators:

University of Maine – Department of Wildlife, Fisheries, and Conservation Biology
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
U.S. Fish and Wildlife Service
University of Maine – Maine Cooperative Forestry Research Unit
Baxter State Park

Biogeography and conservation of Maine's island amphibians, with focus on redback salamanders (*Plethodon cinereus*)

1. Survey Maine islands and near coastal areas for redback salamanders (*Plethodon cinereus*).
2. Conduct microsatellite DNA and trait-based assessments of genetic diversity, local adaptations, and colonization history of island redback salamanders and relate these data to spatial analyses of island features and historic sea levels.
3. Share information on islands likely to support genetically unique populations with stakeholders, and collaborate on outreach concerning the importance of islands for the natural history and conservation of Maine's amphibians.

Amphibians face some of the greatest rates of local and global extinctions among vertebrates. A significant challenge for conservation of amphibians is simply a lack of sufficient data on their historic and current distribution and where important genetic resources exist to target for conservation. Much of what we know about amphibian distributions is from accessible mainland habitats, and information about amphibian distributions on coastal islands is largely lacking. Amphibians are physiologically intolerant of seawater, and thus, island populations may have been isolated for thousands of years. Such populations can serve as important reserves of unique genetic diversity. Indeed, island populations of other taxa often possess unique morphological, behavioral and physiological adaptations relative to mainland populations. The proposed project seeks to conduct surveys of amphibians on coastal islands along the entire Maine seaboard to enhance current knowledge of their distributions. It also seeks to characterize genetic diversity and the ancient history of island colonization in one species, the redback salamander (*Plethodon cinereus*), that we anticipate is widely distributed on Maine's islands. By combining our surveys and genetic data with spatial analyses (GIS) we will identify islands most likely to support amphibian populations and communities that warrant conservation priority. We also will collaborate with project partners on outreach surrounding the role of islands in the natural history and conservation of Maine's amphibians.

We conducted surveys for redbacked salamanders on 16 coastal islands and 9 mainland locations, and have collected over 600 genetic samples. Data analysis is complete. The thesis will be completed in early 2017.

Investigator: Nikko-Ideen Shaidani (MS)

Advisors: Cynthia S. Loftin (Co-Advisor)
Michael T. Kinnison (Co-Advisor)
Rebecca L. Holberton

Duration: September 2012—January 2017

Cooperators:

Maine Outdoor Heritage Fund
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
U.S. Fish and Wildlife Service
University of Maine
National Park Service

Population dynamics of spruce grouse in the managed forest landscapes of northern Maine

1. Estimate demographic rates of spruce grouse, such as adult survival for males and females, nest success, chick survival, and recruitment using radio -telemetry and capture-mark-recapture methods.
2. Evaluate habitat characteristics at multiple spatial scales to determine how spruce grouse choose resources and how these choices affect demographic rates during important life history phases such as nesting, brood rearing, and dispersal.
3. Relate objectives 1 and 2 to population performance using predictive stage-structured population models. Then, use these results to evaluate the overall trajectory of spruce grouse populations, and classify populations as stable, increasing, or declining.
4. Provide guidance in the form of a status evaluation and recommendations for future conservation of spruce grouse populations. Specifically, with regards to how forest management activities may promote habitat structure and composition that is consistent with healthy spruce grouse populations.

Spruce grouse are native forest birds that inhabit conifer forests throughout the northern U.S. and Canada. The mixed Acadian forests of the northeastern U.S. represents the southeastern periphery of the spruce grouse's range. In other northeastern states spruce grouse are state-listed as threatened or endangered, but the current status of spruce grouse in Maine is unclear. We will use radio telemetry and mark-recapture methods to collect data on survival and reproductive success of marked individuals. Survival will be evaluated year-round, as well as during distinct biological season's (e.g. breeding vs. overwinter). Reproductive success will be monitored during the spring and summer breeding season (May - August). We will monitor birds in areas of varying forest composition and silvicultural activities, and will sample vegetation characteristics at the micro-site scale as well as characterize habitat at a larger scale that would likely be used on a daily basis or within an individual's home range. Using these data we will evaluate the current status of spruce grouse populations to determine the populations trajectory based on observed demographic rates. Ultimately, we will link population characteristics to components of spruce grouse habitat for the purpose of informing forest management and state-level management decisions.

During the 2016 field season we monitored 54 radio-marked spruce grouse, including 15 that were previously radio-marked and 39 captured during the 2016 field season. We located and monitored 7 nests, and obtained weekly location and survival data for 14 females and 8 males between mid-June and 1 August. We conducted vegetation sampling at nest sites and 3 dependent random locations near nests. We also measured vegetation at weekly locations of males and females and at 1 dependent random location for each. All radio-marked birds, including those captured during fall, were located twice per week from 1 August through 31 October. All radio-marked grouse will continue to be monitored once a month for survival over the winter. Starting May 2017 we will resume monitoring spruce grouse on a weekly basis, locate and monitored new nests, and continue our capture efforts to supplement our sample sizes for survival and habitat analyses.

Investigator: Joel Tebbenkamp (PhD)

Advisors: Erik J. Blomberg (Co-Advisor)
Daniel J. Harrison (Co-Advisor)
Rebecca L. Holberton
Alessio Mortelliti
Shawn Fraver
Brad Allen
Kelsey Sullivan

Duration: September 2014—May 2018

Cooperators:

Maine Department of Inland Fisheries and Wildlife
Maine Outdoor Heritage Fund
University of Maine – Maine Cooperative Forestry Research Unit
University of Maine – Maine Agricultural and Forest Experiment Station
Katahdin Forest Management
Gerald Pelletier, Inc.

INTEGRATED ecology

Changes in fish communities and chimpanzee distributions in the Bumbuna hydroelectric project area following impoundment by the dam

1. Characterize patterns in fish assemblages from estuary to the upper reaches of the Seli River prior to impoundment and compare the changes in fish assemblages in the upper reaches of the Seli River pre and post impoundment.
2. Describe the distribution of chimpanzees in the pre- and post-impoundment area.

Abstract: The Bumbuna Hydroelectric Dam was completed in 2009 and is located upstream of the Bumbuna Falls on the Seli River in Sierra Leone. Fish species diversity and composition in the river were assessed pre-impoundment (2006) from the estuary to the upper reaches of the river. Post-impoundment (2012) surveys focused on sites near the new dam. In 2006, we observed 81 species and 29 families over the longitudinal section of the river, with the greatest diversity observed in the open river reaches upstream of the estuary. There were clear discontinuities in species distributions and reduction in diversity upstream of Bumbuna Falls, a natural falls. Post-impoundment, we captured fewer species and families at the three sites nearest to the dam. Species richness and Shannon-Wiener and Jaccard's diversity indices declined post-impoundment for the reservoir and sites immediately downstream of the dam. Whereas Cyprinidae was the dominant family pre-impoundment, Cichlidae dominated the reservoir after impoundment (e.g., *Tilapia joka* and *T. louka*). Construction of the dam near Bambuma Falls may have mitigated overall effects of impoundment. While downstream species diversity remained unchanged, species composition shifted to cichlids. Effects of this and other dams are complex and are not fully characterized by diversity metrics.

The Bumbuna Hydroelectric Project Area is a mosaic of forest patches, savanna, riparian forest and agricultural lands with high prevalence of palm trees (*Elaeis guinensis*). Chimpanzee surveys and population estimates were conducted in 2006 using nest clusters and reconnaissance (recces) surveys to identify group size and follow chimpanzees. In 2013, we used nest observations with a traditional line transect method and distance sampling to estimate and compare the 2006 recce and estimates to the 2013 distance estimates. We calculated the density of chimpanzees to be 0.10 individuals/km2 (CV=63%; 95% CI=0.031-0.33), with a population of 6 individuals (CV=57%; 95% CI=2-17). The pre- (9; range 9-14) and post-impoundment (2; 2-17) BCA community estimates are similar for the different approaches. The majority of nest clusters were individual nests, and the largest nest cluster was 16. Most nests were in clusters of two and six nests. The majority of nests occurred on fruiting tree species. Chimpanzees consumed the pith and fruits of *Elaies guineensis* and *Ficus spp.* throughout the study period.

Investigator: Abdulai Barrie (MS)

Advisors: Cynthia S. Loftin (Co-Advisor)
Joseph D. Zydlewski (Co-Advisor)
Erik J. Blomberg
Robert J. Lilieholm

Duration: September 2013—May 2016

Cooperators:

Fulbright Student Scholar Program
The World Bank
Institute of Marine Biology and Oceanography, University of Sierra Leone
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit

Eco-evolutionary implications of environmental change across developing landscape

1. Empirically evaluate the eco-evolutionary consequences of ongoing urbanization on the structure and connectivity of Maine's wood frogs and spotted salamanders.
2. Develop eco-evolutionary agent-based models to examine consequences of varying rates and forms of environmental perturbation across a complex landscape.
3. Quantify the gene expression profiles of ESD infected and uninfected lobsters to evaluate correlations between environmental stress and disease presence.

The influence of natural and anthropogenic barriers to gene flow among wood frog and spotted salamander populations will be assessed using a landscape genetics approach, whereby observable inter-population genetic structure is evaluated for correlations with various landscape features. The patterns documented using landscape genetic analyses will be incorporated into agent-based simulation models (ABMs), which will be used to assess the ecological and evolutionary responses of species to environmental perturbation. Because ABMs allow simulated individuals with unique characteristics to interact with each other in a simulated environment, they provide an excellent tool for capturing emergent phenomena in naturally complex eco-evolutionary systems. Model parameterization and validation will be informed using empirical data on vernal pool amphibians originating from landscape genetic analyses and the literature. Finally, as part of an interdisciplinary research effort designed to improve understanding of the causes of epizootic shell disease (ESD), I will be quantifying differences in gene expression profiles of infected and uninfected lobster from presumably high stress and low stress environments. These analyses will be competed using the RNA-Seq technique, which has recently been developed to utilize advances in next generation sequencing technologies to quantify gene expression profiles in non-model organisms.

Sampling for wood frog and spotted salamander larvae for use in landscape genetic analyses began in the spring of 2014 and continued during spring-early summer 2016. We have sampled 65 sites from throughout central and southern Maine, and final collection from 10 pools is planned for spring 2017. Collection of microsatellite data is continuing, with 12 loci being genotyped for wood frogs and 10 for spotted salamanders. Analyses will be completed during 2017. The agent-based model simulation framework is continuing. I have continued to work with experts in epizootic shell disease, lobster biology and ecology, and disease ecology to finalize methods for sampling and analyzing lobster from the Gulf of Maine for my IGERT research project. This work will be completed in early 2107.

Investigator: Jared J. Homola (PhD)

Advisors: Cynthia S. Loftin (Co-Advisor)
Michael T. Kinnison(Co-Advisor)
Malcolm L. Hunter, Jr.
Timothy M. Waring
Andrew R. Whiteley

Duration: September 2013—May 2018

Cooperators:

Maine Department of Inland Fisheries and Wildlife
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
Maine Association of Wetland Scientists
NSF Adaptation to Abrupt Climate Change IGERT
Central Maine Power
National Science Foundation – Dynamics of Coupled Natural and Human Systems (CNH)

Assessing Priority Amphibian and Reptile Conservation Areas (PARCAs) and vulnerability to climate change in the North Atlantic Landscape Conservation Cooperative

1. Compile reptile and amphibian species record data from states in the NE-LCC region into a data base.
2. Develop species distribution models of priority amphibians and reptiles in the NA-LCC region. Combine these models with richness data to identify conservation areas for priority reptile and amphibian species (PARCAs).
3. Combine modeled PARCAs with climate vulnerability models to identify areas within the NA-LCC where losses of vulnerable species are anticipated, where potential climatic refugia for priority species occur, and identify species for which gaps in current known distributional data prohibit these projections.
4. Identify conservation lands that fall within the priority amphibian and reptile areas identified in Objective 2, and identify areas with highest priority for supporting reptiles and amphibians in the Northeast that are not currently protected.
5. Incorporate climate vulnerability projections into final PARCA analysis, including a ranking of high priority current and future conservation areas.
6. Communicate results to key state, federal, and NGO partners via publications and regional workshops.

Amphibians and reptiles are experiencing severe habitat loss throughout North America; however, this threat to biodiversity may be mitigated by identifying and conserving areas that serve a disproportionate role in sustaining herpetofauna. Identification of such areas must take into consideration the dynamic nature of habitat suitability. Areas currently deemed climate-suitable may no longer be so in the future. We are collaborating with scientists from Clemson University, Tennessee State University, Maine Department of Inland Fisheries and Wildlife, and the Association of Fish and Wildlife Agencies to generate spatially-explicit models to (1) identify Priority Amphibian and Reptile Conservation Areas (PARCAs) – those discrete areas most vital to maintaining reptile and amphibian diversity, (2) project regions of current and future climatic suitability for a number of priority reptiles and amphibians in the North Atlantic Landscape Conservation Cooperative, and (3) identify gaps in distributional data for these species that may prevent or inhibit the identification of species-level climatic suitability.

We received species occurrence data from 13 NA-LCC states and Washington, DC and converted datasets into a spatial format. We combined occurrence data with expert-selected environmental variables to develop species distribution models with the Maximum Entropy modeling approach, combined these models with species richness information, and spatially applied guidelines (Sutherland and deMaynadier 2012) for identifying priority reptile and amphibian habitat to model draft PARCAs. We evaluated draft models developed with richness data from state and web-available sources, scaled to state and ecoregions within state, and with alternative estimates of landscape viability, incorporating feedback from state reptile and amphibian experts into the revised PARCA maps. The final phase of the project will combine the proposed PARCAs with species climate niche models to evaluate predicted distributions of climate suitable habitat with climate change. Final project products will include a modeled PARCA map database with species distribution models, PARCAs resulting from modeling approaches and state-provided feedback, and guidelines for spatially implementing the criteria (Sutherland and deMaynadier 2012) in other regions.

Investigators: Cynthia S. Loftin, Phillip deMaynadier, Kyle Barrett, William B. Sutton, Priya Nanjappa, Allison Moody

Duration: August 2012—December 2016

Cooperators:

U.S. Fish and Wildlife Service
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
University of Maine
Maine Department of Inland Fisheries and Wildlife
Wildlife Management Institute

PUBLICATIONS and presentations

SCIENTIFIC PUBLICATIONS

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Mortelliti, A., Crane M., Okada S., Lindenmayer D.B. 2015. Marsupial response to matrix conversion: results of a large-scale long-term 'natural experiment' in Australia. *Biological Conservation* 191:60-66.

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Rohrbaugh, R.W., D.A. Buehler, S. Barker Swarthout, D.I. King, J.L. Larkin, K.V. Rosenberg A.M. Roth, R. Vallender, and T. Will. 2016. Conservation perspectives: Using new science to improve strategic Golden-winged warbler conservation. Landscape-scale habitat and climate correlates of breeding Golden-winged and Blue-winged warblers. *Studies in Avian Biology* 49: 207-216.

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Sigourney, D., Zydlewski, J., Hughes, E., Cox, O. 2015. Transport, passage and size selection of adult Atlantic salmon in the Penobscot River, Maine. *North American Journal of Fisheries Management* 35:6, 1164-1176, DOI: 10.1080/02755947.2015.1099578.

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Sozio, G., Iannarilli F., Melcore I., Boschetti M., Fipaldini D., Luciani M., Roviani D., Schiavano D., Mortelliti A. 2016. Forest management affects individual and population parameters of the hazel dormouse (*Muscardinus avellanarius*). *Mammalian Biology* 81:96–103.

Sozio, G., Mortelliti A. 2015. Empirical evaluation of the strength of interspecific competition in shaping small mammal communities in fragmented landscapes. *Landscape Ecology* 31:775–789.

Stich, D.S., Zydlewski, G.B., and Zydlewski, J. 2015. Effects of physiological preparedness and saltwater tolerance on behavioural preferences and thresholds. Migration. *Journal of Fish Biology* 88 (2):595-617. DOI:10.1111/jfb.12853.

Stirnemann, I., Mortelliti A., Gibbons P., Lindenmayer D.B. 2015. Fine-scale habitat heterogeneity influences occupancy in terrestrial mammals in a temperate region of Australia. *Plos One* 10(9). doi:10.1371/journal.pone.0138681.

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Tuckett, Q.M., K.S. Simon, J.E. Saros, S.M. Coghlan Jr., and M.T. Kinnison. 2015. Biomass versus biodiversity: the relative contribution of population attributes to consumer nutrient loading in aquatic systems. *Evolutionary Ecology Research* 16:705-723.

THESES AND DISSERTATIONS

Barrie, A. 2016. Changes in fish communities and chimpanzee ecology in the Bumbuna hydroelectric project area following dam impoundment. M.S. Thesis, Wildlife Ecology, University of Maine, Orono: 90 pp.

Dunham, S. 2016. Spruce grouse habitat ecology in Maine's commercially managed Acadian forest. M.S. Thesis, Wildlife Ecology, University of Maine, Orono: 87 pp.

Izzo, L.K. 2016. Exploring the threats of dams and ocean conditions: In-river movements and ocean growth of Atlantic salmon (*Salmo salar*) from Maine's rivers. M.S. Thesis, Wildlife Ecology, University of Maine, Orono: 101 pp.

O'Malley, A. 2016. Assessment of a hatchery based rainbow smelt supplementation effort. M.S. Thesis, Wildlife Ecology, University of Maine, Orono: 71 pp.

Wood, C. 2016. Community ecology of small mammals: predicting change and its consequences. M.S. Thesis, Wildlife Ecology, University of Maine, Orono: 48 pp.

PROFESSIONAL TALKS PRESENTED

Allen, B.B., D.G. McAuley, E.J. Blomberg, R. Brown, and C. Dwyer. 2016. "Evaluating habitat selection and stopover duration of American Woodcock on the Cape May, NJ, Peninsula". Poster. Maine Cooperative Fish and Wildlife Research Unit Annual Meeting. March 23. Orono, ME.

Anderson, E., E.J. Blomberg, and S. Fraver. 2016. "Environmental features influencing Myotis bat presence in the Penobscot Experimental Forest, Central Maine". Poster. International Bat Research Symposium. April 26. Winter Harbor, ME.

Barber, B. and Zydlewski, J. 2016. "Marine-derived nutrient cycling in the St. Croix River, Maine". International St. Croix River Watershed Board Meeting. June 14. Calais, ME.

Barber, B., and Zydlewski, J. 2016. "Alewife (*Alosa pseudoharengus*) as marine-derived nutrient subsidies in two northeast Maine rivers". 2016 Atlantic Salmon Ecosystems Forum. January 6-7. University of Maine, Orono, ME.

Barber, B., and Zydlewski, J. 2016. "Alewife (*Alosa pseudoharengus*) as marine-derived nutrient subsidies in two northeast Maine rivers". Annual meeting of the Maine Cooperative Fish and Wildlife Research Unit, University of Maine. March 23. Orono ME.

Barrie, A., C. Loftin, and J. Zydlewski. 2016. "Changes in fish assemblages after completion of the Bumbuna hydroelectric dam, northern Sierra Leone, West Africa". Annual meeting of the Maine Cooperative Fish and Wildlife Research Unit. March 23. University of Maine, Orono, ME.

Barrie, A., C. Loftin, and J. Zydlewski. 2016. "Changes in fish assemblages and chimpanzee communities after completion of the Bumbuna hydroelectric dam, northern Sierra Leone, West Africa". Annual meeting of the Maine Cooperative Fish and Wildlife Research Unit. March 23. University of Maine, Orono, ME.

Blomberg, E.J., S. Morano, and C. Mosby. 2016. "Monitoring bat populations in Maine: new strategies for citizen science data collection". Paper. Northeast Bat Working Group Symposium. January. Baltimore, MD.

Bothwell, K., M. Crandall, and A. Roth. 2016. "An economic evaluation of alternative silvicultural systems for managing deer wintering areas in northern Maine." Annual meeting of the Maine Cooperative Fish and Wildlife Research Unit. March 23. University of Maine, Orono, ME.

Boyd, K., Barber, B., and Zydlewski, J. 2016. "Relative abundance and size of zooplankton within the St. Croix watershed prior to alewife recolonization". 72nd Annual Northeast Fish & Wildlife Conference. April 3. Annapolis, MD.

Davis, S., E.J. Blomberg, J. Mangelinckx, R.B. Allen, and K. Sullivan. 2016. "Harvest, seasonal survival, and drumming ecology of ruffed grouse in Maine, USA". Poster. Maine Cooperative Fish and Wildlife Research Unit Annual Meeting. March 23. Orono, ME.

Dever, M., Kocik, J., Zydlewski, J., Hebert, D., and Stich, D. 2016. "Linkage between coastal conditions and migratory patterns and behavior of Atlantic salmon smolts along the Halifax line". 2016 Ocean Sciences Meeting. February 21-26. New Orleans, LA.

Du Clos, B., C.S. Loftin, and F. Drummond. 2016. "Landscape pattern and native bee communities in the northeastern U.S." Poster Presentation at the Annual Meeting of the Maine Cooperative Fish and Wildlife Research Unit's Coordinating Committee Meeting. March 23. Orono, ME.

Du Clos, B., C.S. Loftin, and F. Drummond. 2016. "Landscape pattern and native bee communities in the northeastern U.S." Presentation at the Annual Meeting of the Maine Cooperative Fish and Wildlife Research Unit's Coordinating Committee Meeting. March 23. Orono, ME.

Du Clos, B., C.S. Loftin, and F. Drummond. 2016. "Where the wild bees are: how wild bees use Maine's landscape". UMaine Student Research Symposium. April 27. Bangor, ME.

Du Clos, B., S.P. Hanes, S.C. Groff, C.S. Loftin, and F.A. Drummond. 2016. "A tool for grower assessment of wild bee abundance in the Maine wild blueberry landscape". Colby Conference on Community, Culture, and Conservation. 7-9 April. Waterville, ME.

Du Clos, B., S.P. Hanes, S.C. Groff, C.S. Loftin, and F.A. Drummond. 2015. "BeeMapper: A tool for grower assessment of wild bee abundance". Wild Blueberry Research and Extension Workers 2015 Annual Conference. 13 October. Bar Harbor, ME.

Du Clos, B., S.P. Hanes, S.C. Groff, C.S. Loftin, and F.A. Drummond. 2015. "A tool for grower assessment of wild bee abundance in the Maine wild blueberry landscape". Student Conference on Conservation Science. 7-9 October. New York, NY.

Dunham, S.W., and D.J. Harrison. 2016. "Female spruce grouse habitat selection during the brood-rearing season in managed conifer forests". Poster. Sixth North American Ornithological Conference. August 17. Washington, DC.

Dunham, S.W., D.J. Harrison, and E.J. Blomberg. 2016. "Relationships among forest management and Spruce Grouse (*Falcipennis canadensis*) patch occupancy and abundance in commercially-managed forests". Poster. Maine Cooperative Fish and Wildlife Research Unit Annual Meeting. March 23. Orono, ME.

Greig, H. S., Ramberg-Pihl, N., Coghlan, Jr., S. and Zydlewski, J. 2016. "Improving assessment of critical habitat for Atlantic salmon in a rapidly-changing climate". Maine Sea Grant Research Symposium. April 15. University of Maine, Orono, ME.

Groff, L.A., A.J.K. Calhoun, and C.S. Loftin. 2015. "Habitat features mediate wood frog hibernaculum microclimate". 9th Northeast Alpine Stewardship Gathering, Baxter State Park. 6-8 November. Millinocket, ME.

Groff, L.A., C.S. Loftin, and A.J.K. Calhoun. 2015. "Predictors of breeding site occupancy by pool-breeding amphibians in Maine's wetland-limited, montane landscapes". 9th Northeast Alpine Stewardship Gathering, Baxter State Park. 6-8 November. Millinocket, ME.

Guettler, J., J. Leahy, A. Roth, E. Silver Huff, and M. Crandall. 2016 . "Investigating the impact of

forest certification on forest bird habitat conservation in western Maine." 22nd International Symposium on Society and Resource Management. 23 June. Houghton, MI.

Guettler, J., J. Leahy, M. Crandall, E. Silver Huff, and A. Roth. 2016. "Understanding socio-ecological linkages between family forest certification and songbird habitat." Maine Sustainability and Water Conference. 29 March. Augusta, ME.

Hanes, S.P., B. Du Clos, S.C. Groff, C.S. Loftin, and F.A. Drummond. 2016. "When farming is like fishing: Lessons from the BeeMapper". Senator George J. Mitchell Center for Sustainability Solutions Seminar. 15 February. Orono, ME.

Harrison, D. and S. Dunham. 2016. "Final project report: Relative densities, patch occupancy, and population performance of spruce grouse in managed and unmanaged forests in northern Maine." Presentation at Maine Cooperative Forestry Research Unit Spring 2016 Advisory Committee Meeting, Bangor, Maine, April 20.

Harrison, D.J. 2015. "Updates on wildlife projects funded by the Maine Cooperative Forestry Research Unit (CFRU)". Presentation at CFRU Advisory Committee Meeting. October 28. Houlton, ME.

Homola, J.J., M.T. Kinnison, and C.S. Loftin. 2016. "Comparative population structure of vernal pool amphibians across a changing landscape". Oral presentation at the University of Maine Graduate and Undergraduate Research Symposium. 27 April. Bangor, ME.

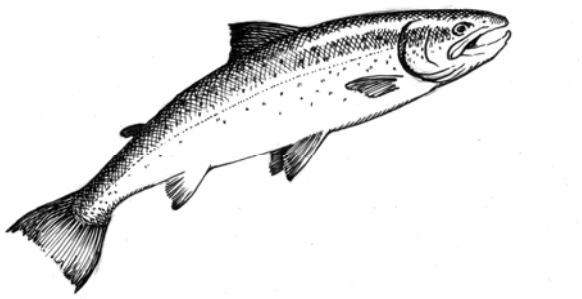
Homola, J.J., M.T. Kinnison, and C.S. Loftin. 2016. "Comparative population structure of vernal pool amphibians across a changing landscape". Oral presentation at the Northeast Natural History Conference. 22 April. Springfield, MA.

Homola, J.J., M.T. Kinnison, and C.S. Loftin. 2016. "Comparative population structure of vernal pool amphibians across a changing landscape". Presentation at the Maine Cooperative Fish and Wildlife Research Unit's Annual Coordinating Committee Meeting, Orono, ME. 23 March.

Homola, J.J., M.T. Kinnison, and C.S. Loftin. 2016. "Comparative population structure of vernal pool amphibians across a changing landscape". Poster. Maine Cooperative Fish and Wildlife Research Unit's Annual Coordinating Committee Meeting, Orono, ME. 23 March.

Izzo, L., Maynard, G. and Zydlewski, J. 2016. "Behavior and upstream passage of Atlantic Salmon at the new Milford fish lift on the Penobscot River, ME". 2016 Atlantic Salmon Ecosystems Forum. January 6-7. University of Maine, Orono, ME.

Izzo, L., Maynard, G. and Zydlewski, J. 2016. "Behavior and upstream passage of Atlantic salmon at the new Milford fish lift on the Penobscot River, ME". Annual meeting of the Maine Cooperative Fish and Wildlife Research Unit, University of Maine, Orono, ME. March 23.



Job, K. and Zydlewski, J. 2016. "Using otolith microchemistry to infer life history and habitat use of American shad in the Penobscot River, Maine". Annual meeting of the Maine Cooperative Fish and Wildlife Research Unit, University of Maine, Orono, ME. March 23.

Johnston, C., Zydlewski, G., Zydlewski, J., Kinnison, M., and Smith, S. 2016. "Shortnose sturgeon spawning potential in the Penobscot River after dam removals". 2016 Atlantic Salmon Ecosystems Forum. January 6-7. University of Maine, Orono, ME.

Johnston, C., Zydlewski, G., Zydlewski, J., Kinnison, M., and Smith, S. 2016. "Shortnose sturgeon spawning potential in the Penobscot River after dam removals". Annual meeting of the Maine Cooperative Fish and Wildlife Research Unit, University of Maine, Orono, ME. March 23.

Loftin, C., W. Sutton, P .deMaynadier, K. Barrett, P. Nanjappa, and A. Moody. 2016. "Modeling Priority Amphibian and Reptile Conservation Areas (PARCAs) in the Northeastern United States". 2016 North American Congress for Conservation Biology, Madison, WI. 17-20 July.

Loftin, C., W. Sutton, P. deMaynadier, K. Barrett, P. Nanjappa, and A. Moody. 2016. "Identifying Priority Amphibian and Reptile Conservation Areas (PARCAs) in the Northeastern United States". 72nd Annual Northeast Fish and Wildlife Conference, Annapolis, MD. 3-5 April.

Loman, Z.G., D. Harrison, C.S. Loftin, and P.B. Wood. 2016. "Validating predictions of upland game bird space use in multiple management contexts". Presentation at the 72nd Annual Meeting of Northeast Fish and Wildlife Agencies, Annapolis, MD. 4 April.

Loman, Z.G., W.V. Deluca, D. Harrison, C.S. Loftin, B.W. Rolek, P.B. Wood. 2016. "Evaluation of a fine-grained landscape conservation planning tool for songbird conservation in the Northeastern United States." Poster at North American Ornithological Conference, Joint meeting of American Ornithological Union, Cooper Ornithological Society, Wilson Ornithological Society, Association of Field Ornithologists, and Society of Canadian Ornithologists. Washington, D.C. 16-20 August.

Mangelinckx, J., E.J. Blomberg, S. Davis, R.B. Allen, and K. Sullivan. 2016. "Nest-site selection and nest success of ruffed grouse in Maine". Poster. Maine Cooperative Fish and Wildlife Research Unit Annual Meeting. Orono, ME. March 23.

Maynard, G., Dill, R., Kinnison, M., Halteman, W., and Zydlewski, J. 2016. "Size matters: Fishways can exert size selection in Atlantic salmon migrating in the Penobscot River". 2016 Atlantic Salmon Ecosystems Forum. January 6-7. University of Maine, Orono, ME.

Maynard, G., Kinnison, M., and Zydlewski, J. 2016. "Size matters: Fishways can exert size selection in Atlantic salmon migrating in the Penobscot River". Annual meeting of the Maine Cooperative Fish and Wildlife Research Unit, University of Maine, Orono, ME. March 23.

McKnight, A., C.S. Loftin, and S. McKinney. 2016. "Does reproduction incur long-term costs in a colonial seabird*?*" Maine Cooperative Fish and Wildlife Research Unit Annual Coordinating Committee Meeting, Orono, ME. 23 March.

McKnight, A., C.S. Loftin, and S. McKinney. 2016. "Does reproduction incur long-term costs in a colonial seabird*?*" Presentation at the Gulf of Maine Seabird Working Group Annual Winter Meeting, Bangor, ME. 7 March.

McKnight, A., C.S. Loftin, and S.T. McKinney. 2016. "Individual, colony, and metapopulation level drivers of seabird colony dynamics." Poster. Maine Cooperative Fish and Wildlife Research Unit Annual Coordinating Committee Meeting, Orono, ME. 23 March.

Molina-Moctezuma, A., Stich, D., and Zydlewski, J. 2016. "Post-restoration assessment of Atlantic salmon (*Salmo salar*) survival during their downstream migration in the Penobscot River, Maine". 2016 Atlantic Salmon Ecosystems Forum. January 6-7. University of Maine, Orono, ME.

Molina-Moctezuma, A., Stich, D., and Zydlewski, J. 2016. "Post-restoration assessment of Atlantic salmon (*Salmo salar*) survival during their downstream migration in the Penobscot River, Maine". Annual meeting of the Maine Cooperative Fish and Wildlife Research Unit, University of Maine, Orono, ME. March 23.

Morano, S., E.J. Blomberg, and C. Mosby. 2016. "Monitoring bat populations in Maine: New strategies for citizen science data collection". Poster. International Bat Research Symposium, Winter Harbor, ME. April 26.

O'Malley, A., Zydlewski, J., and Enterline, C. 2016. "Size, age, and longevity of seven populations of landlocked and anadromous rainbow smelt (*Osmerus mordax*)". 2016 Atlantic Salmon Ecosystems Forum. January 6-7. University of Maine, Orono, ME.

O'Malley, A., Zydlewski, J., and Enterline, C. 2016. "Size, age, and longevity of seven populations of landlocked and anadromous rainbow smelt (*Osmerus mordax*)". Annual meeting of the Maine Cooperative Fish and Wildlife Research Unit, University of Maine, Orono, ME. March 23.

Olson, S.J., D.J. Harrison, A.K. Fuller, J.H. Vashon. 2015. "Canada lynx food habits responses to seasons, and to low vs. high hare density periods: Always a specialist*?*" Poster presentation at The Wildlife Society Annual Conference, Winnipeg, Manitoba, Canada, October 21-22.

Rolek, B.W., C. Loftin, D. Harrison, and P. Wood. 2016. "Softwood forest birds and silviculture in northern New England". Annual Meeting of the Maine Cooperative Fish and Wildlife Research Unit's Coordinating Committee Meeting, Orono, ME. 23 March.

Rolek, B.W., D. Harrison, C.S. Loftin, P.B. Wood. 2016. "Opportunities to enhance habitat for spruce-fir passerines using commercial forest management." Paper at North American Congress for Conservation Biology, Society for Conservation Biology, Madison, Wisconsin, USA. July 17-20.

Rolek, B.W., D. Harrison, C.S. Loftin, P.B. Wood. 2016. "Softwood forest birds and forestry in New England." Poster. Maine Cooperative Fish and Wildlife Research Unit Annual Coordinating Committee, Orono, Maine, USA. March 23.

Rolek, B.W., D.J. Harrison, D.W. Linden, C.S. Loftin, and P.B. Wood. 2016. "Long-term effects of forest harvesting on spruce-fir avian communities". The 2016 North America Congress for Conservation Biology, Madison, WI. 17-20 July.

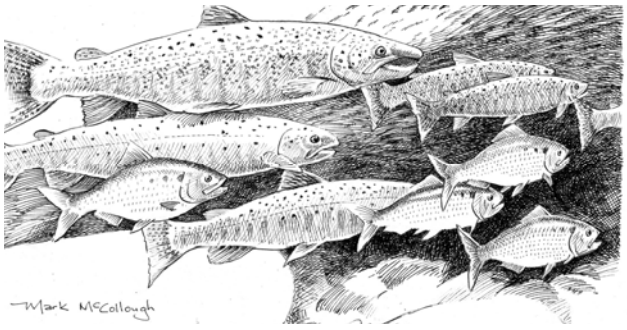
Roth, A. 2016. "Midwest landbird migration monitoring network: Strategic plan implementation and inter-regional collaboration." Annual meeting of the Northeast Regional Migration Monitoring Network. Acadia National Park, ME. April 28.

Roth, A., W. Mueller, B. Lenz, and K. Koch. 2016 . "Midwest landbird migration monitoring network – process and progress 2011-2016." Annual meeting of the Inland Bird Banding Association. Connersville, IN. November 11-13.

Roth, A., W. Mueller, B. Lenz, and K. Koch. 2016. "Midwest landbird migration monitoring network – process and progress 2011-2016." State of Stopover Symposium. Milwaukee, WI. October 5-7.

Roth, A.M. and L.M. Gordillo. 2016. "Conservation art: art-science collaboration with conservation solutions." 76th Annual Meeting of the Midwest Fish and Wildlife Conference. Grand Rapids, MI. January 27.

Sigourney, D. and Zydlewski, J. 2016. "Modeling migration of silver eels to forecast critical intervals of risk". 2016 Atlantic Salmon Ecosystems Forum. January 6-7. University of Maine, Orono, ME.



Stich, D., Sheehan, T., and Zydlewski, J. 2016. "Projected tradeoffs in population abundance of American shad (*Alosa sapidissima*) in relation to upstream and downstream passage at dams". 2016 Atlantic Salmon Ecosystems Forum. January 6-7. University of Maine, Orono, ME.

Sutton, W.B., K. Barrett, C. Loftin, P. deMaynadier, P. Nanjappa, and A. Moody. 2016. "Determining Vulnerability of Priority Amphibian and Reptile Conservation Areas to Climate Change in the Northeastern United States". Presentation at the North American Congress for Conservation Biology, Madison, WI. 17-20 July.

Sutton, W.B., K. Barrett, C. Loftin, P. deMaynadier, P. Nanjappa, and A. Moody. 2016. "Determining Vulnerability of Priority Amphibian and Reptile Conservation Areas to Climate Change in the Northeastern United States". Presentation at the annual meeting of The Wildlife Society, Raleigh, NC. 15-21 October.

Tebbenkamp, J., E.J. Blomberg, D. Harrison, R.B. Allen, and K. Sullivan. 2016. "Spruce grouse demography and population status in commercially-harvested forests of Northern Maine". Poster. Maine Cooperative Fish and Wildlife Research Unit Annual Meeting. Orono, ME. March 23.

Thornton, E.J., E. Blomberg, and J. Zydlewski. 2016. "American eel survival through Milford Dam on the Penobscot River, Maine". Atlantic Salmon Ecosystem Forum. Orono, ME. January 6-7.

Watson, J., Coghlan, Jr., S., Zydlewski, J., Hayes, D. and Kiraly, I. 2016. "Dam removal and fish passage improvement influence fish assemblages in the Penobscot River, Maine". 2016 Atlantic Salmon Ecosystems Forum. January 6-7. University of Maine, Orono, ME.

Watson, J., Coghlan, Jr., S., Zydlewski, J., Hayes, D., and Kiraly, I. 2016. "Dam removal and fish passage improvement influence fish assemblages in the Penobscot River, Maine". Annual meeting of the Maine Cooperative Fish and Wildlife Research Unit, University of Maine, Orono, ME. March 23.

Watson, J., Coghlan, Jr., S., Zydlewski, J., Hayes, D., and Kiraly, I. 2016. "Dam removal and fish passage improvement influence fish assemblages in the Penobscot River, Maine". Penobscot Watershed Conference, Northport, ME. April 8.

Weaver, D., Coghlan Jr., S., and Zydlewski, J. 2016. "Sea lamprey carcasses influence food webs in an Atlantic coastal stream". 2016 Atlantic Salmon Ecosystems Forum. January 6-7. University of Maine, Orono, ME.

Weaver, D., Coghlan Jr., S., and Zydlewski, J. 2016. "Sea lamprey carcasses influence food webs in an Atlantic coastal stream". Annual meeting of the Maine Cooperative Fish and Wildlife Research Unit, University of Maine, Orono, ME. March 23.

Whitaker, D., Hawkes, J., Zydlewski, J., and Sheehan, T. 2016. "Do we hit to the target? Evaluation of thermal exposure of river- and hatchery-reared juvenile Atlantic salmon prior to migration on the Narraguagus River, Maine U.S.A". 2016 Atlantic Salmon Ecosystems Forum. January 6-7. University of Maine, Orono, ME.

Wood, C., S. McKinney, and C.S. Loftin. 2015. "Dynamics of alpine small mammal communities". 9th Northeast Alpine Stewardship Gathering, Baxter State Park, Millinocket, ME. 6-8 November.

Wood, C., S. McKinney, and C.S. Loftin. 2015. "Dynamics of small mammal communities". 9th Northeast Alpine Stewardship Gathering, Baxter State Park, Millinocket, ME. 6-8 November.

Wood, C., S. McKinney, and C.S. Loftin. 2015. "Intraspecific functional diversity of common species enhances community stability". 6th annual SCCS-NY meeting of the American Museum of Natural History's Center for Biodiversity and Conservation, New York, NY. 7-9 October.

Zydlewski, J. and Barber, B. 2016. "Connectivity, aquatic communities and climate change". International St. Croix River Watershed Board Meeting, Public Meeting. Calais, ME. June 14.

PUBLIC TALKS PRESENTED

Du Clos, B., S.P. Hanes, C.S. Loftin, and F.A. Drummond. 2015. "Honey bees and the landscape: Choosing an optimal apiary site". Maine State Beekeepers Association, Hampden, ME. 14 November.

Loftin, C.S. 2015. "Responsible conduct in research: Animal welfare". Presentation to SFR 521 Research Methods, University of Maine, Orono, ME. November 4.

Loftin, C.S. 2015. "Interpolation and surface creation with Geostatistical Analyst". Presentation to INT527 Integration and remote sensing in natural resources applications, University of Maine, Orono, ME. November 16.

Zydlewski, J. 2016. "Restoration of migratory fish to the Penobscot River". Maine Chapter of the Appalachian Mountain Club Seminar Series, Fields Pond Audubon Center, Orrington, ME. April 14.

WORKSHOPS, NEWSPAPER, RADIO, TELEVISION INTERVIEWS/ARTICLES, AND OUTREACH

Blomberg, E. 2015. "Blomberg seeks to increase awareness, monitoring of declining bat populations in Maine". UMaine Today Magazine, November 5.

Blomberg, E. 2016. "Why are spruce grouse declining in the Northeast? Study aims to find out." Bangor Daily News. July 14.

Calhoun, A. 2015. "Pooling Resources: Ecologist Aram Calhoun forges creative alliances in her quest to protect ephemeral vernal pools". Pages 26-28 *In* Science 350:62.56

Roth, A. 2016. Written by B. Roth. "Undergraduate Education." Chestnut 30(3):22-25. (Fall Issue from The American Chestnut Foundation)

AWARDS

Du Clos, B. 2015. Graduate Student Research Award, Maine's Sustainability Solutions Initiative.

Du Clos, B. 2016. Chase Distinguished Research Assistantship Award, University of Maine.

DuClos, B. 2016. Graduate Student Research Presentation Award, International Congress of Entomology, Orlando, FL.

Homola, J. 2016. Janet Waldron Doctoral Research Fellowship Award, University of Maine.

McKnight, A. 2016. Howard Mendall Memorial Scholarship Award, University of Maine.

Wood, C. 2015. First Place Poster Award, 6th annual SCCS-NY meeting of the American Museum of Natural History's Center for Biodiversity and Conservation.

Wood, C. 2016. Graduate Research Excellence Award for M.S. student; University of Maine, College of Natural Sciences, Forestry, and Agriculture.

Wood, C. 2016. Outstanding Graduate Student Award; University of Maine, Department of Wildlife, Fisheries, and Conservation Biology.