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Maine Cooperative Fish and Wildlife Research Unit and Department of Wildlife, Fisheries, and Conservation Biology 2018 Report to Cooperators

Maine Cooperative Fish and Wildlife Research Unit

University of Maine Department of Wildlife, Fisheries, and Conservation Biology

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



2018 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.

This report details the research objectives, procedures, and findings of numerous investigators. Since data contained may be preliminary and inconclusive, permission to reproduce or publish any of the contents of this report in any way is withheld pending specific authorization from the Leader, Maine Cooperative Fish and Wildlife Research Unit; and Chair, Department of Wildlife, Fisheries, and Conservation Biology.

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Cover Photo: Regenerating forests west of Baxter State Park, photo by Dan Harrison



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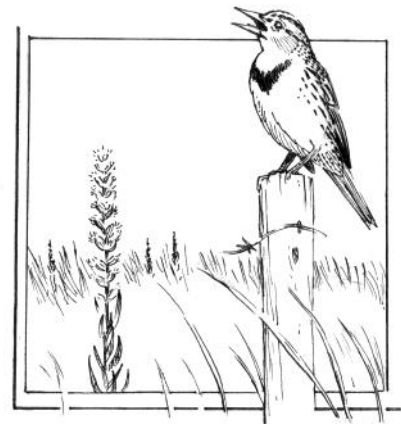
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The Maine Cooperative Fish and Wildlife Research Unit (CFWRU) is uniquely suited to pursue research relevant to fish and wildlife conservation in northern ecosystems. Maine is the most heavily forested state in the Nation and is covered by numerous 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 34 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 and understand the human dimensions affecting conservation actions. The majority of our research is conducted as part of graduate degree programs; during the past year, Unit and Department faculty mentored 33 graduate students and postdoctoral scholars, 4 graduate students completed requirements for M.S. or Ph.D. degrees, and 1 graduate student completed requirements for the Master of Wildlife Conservation degree. Our recent graduates are working for universities, federal and state agencies, and non-governmental organizations, as well as pursuing additional graduate degrees.

This has been a productive year for the Unit and its cooperators. The Department of Wildlife, Fisheries, and Conservation Biology welcomed Dr. Brian Olsen in late summer to serve as Department Chair. We extend our thanks to Dr. Mac Hunter (Chair), Dr. Stephen Coghlan (Assistant Chair), and Ms. Lindsay Seward (Assistant Chair) for their leadership during recent years. The graduate and undergraduate programs continue to grow, presenting us with challenges as well as opportunities. The Maine Department of Inland Fisheries and Wildlife and the U.S. Fish and Wildlife Service-Maine Field Office 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 also 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 outstanding 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 year of continuing our current and developing new collaborations 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.

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COOPERATING PERSONNEL

UNIVERSITY OF MAINE

Dr. Kody Varahramyan, Vice President for
Research and Dean of the Graduate School
Dr. Frederick A. Servello, Dean, College of
Natural Science, Forestry and Agriculture
Dr. Brian J. Olsen, 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

Ms. Anna Harris, 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 Recovery and Reinvestment Act (ARRA)
 Association of Field Ornithologists
 Atlantic Salmon Federation
 Audubon Vermont
 Baxter State Park
 Brookfield Renewable Power
 Canadian-American Centre; Downeast Salmon Federation
 Central Maine Power
 Cornell Lab of Ornithology
 Downeast Lakes Land Trust
 Environment Canada
 Gerald Pelletier, Inc.
 Giraffe Conservation Foundation
 Inland Bird Banding Association
 Indiana University of Pennsylvania
 International Joint Commission on the St. Croix Waterway
 Katahdin Forest Management
 Kruger Energy
 Maine Association of Wetland Scientists
 Maine CFRU Landowner access and assistance
 Maine Department of Inland Fisheries and Wildlife
 Maine Department of Marine Resources
 Michigan Technological University
 Muckleshoot Indian Tribe
 National Fish and Wildlife Foundation
 National Oceanic and Atmospheric Administration
 National Science Foundation – Adaptation to Abrupt Climate Change IGERT
 National Science Foundation – Dynamics of Coupled Natural and Human Systems (CNH)
 National Science Foundation – Experimental Program to Stimulate Competitive Research
 National Wild Turkey Federation
 Natural Resources Foundation of Wisconsin
 New Brunswick Department of Energy and Resource Development (NBERD)
 New Brunswick Quality Deer Management Association (NBQDMA)
 New Brunswick Wildlife Trust Fund
 New Jersey Department of Environmental Protection
 New York Department of Environmental Conservation
 North Carolina Wildlife Resources Commission
 Northern Rangelands Trust
 Ozaukee-Washington Land Trust
 Passamaquoddy Tribe
 Pennsylvania Game Commission
 Penobscot Indian Nation
 Penobscot River Restoration Trust
 Rhode Island Department of Environmental Management
 Saint Croix International Waterway Commission
 San Diego Zoo Global
 South Carolina Department of Natural Resources
 State University of New York – Cobleskill
 The American Woodcock Society
 The Nature Conservancy
 The North Maine Woods
 The Ruffed Grouse Society
 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 – Maine Cooperative Fish and Wildlife Research Unit
 U.S. Geological Survey – Patuxent Wildlife Research Center
 U.S. Geological Survey – Science Support Program
 U.S. Navy
 U.S.D.A. National Cold Water Marine Aquaculture Center
 U.S.D.A. SARE Grants
 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

COLLABORATING AGENCIES AND ORGANIZATIONS

University of Maine – School of Marine Sciences

University of Maine – Sustainable Solutions

Initiative

University of Rhode Island

Virginia Department of Game and Inland

Fisheries

Virginia Game Commission

Weyerhaeuser

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

Brian J. Olsen, *Chair and Associate Professor*

Erik J. Blomberg, *Assistant Professor*

Aram J.K. Calhoun, *Professor*

Stephen M. Coghlan, Jr., *Associate Professor*

Cory Gardner, *Scientific Research Assistant*

Daniel J. Harrison, *Professor*

Malcolm L. Hunter, Jr., *Professor*

Jessica J. Jansujwicz, *Research Assistant Professor*

Molly-Jean Langlais-Parker, *Administrative Specialist*

Zachary Loman, *Scientific Research 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*

Carly C. Sponarski, *Assistant Professor*

Daniel Weaver, *Scientific Research Assistant*

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Samuel P. Hanes, *Assistant Professor*

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Allison Dibble, *Assistant Research Professor*

Francis A. Drummond, *Professor*

Hamish S. Greig, *Assistant Professor*

Rebecca L. Holberton, *Professor*

Michael T. Kinnison, *Professor*

Brian J. McGill, *Associate Professor*

Department of Civil and Environmental Engineering

Aria Amirbahman, *Professor*

Department of Communication and Journalism

Bridie McGreavy, *Assistant Professor*

Laura N. Rickard, *Assistant Professor*

School of Earth and Climate Sciences

Stephen A. Norton, *Emeritus Professor*

School of Economics

Caroline L. Noblet, *Assistant Professor*

Timothy M. Waring, *Associate Professor*

School of Food and Agriculture

Pauline L. Kamath, *Assistant Professor*

School of Forest Resources

Sandra De Urioste-Stone, *Assistant Professor*

Shawn Fraver, *Assistant Professor*

Daniel J. Hayes, *Assistant Professor*

Jessica E. Leahy, *Professor*

Erin Simons-Legaard, *Assistant Research Professor*

School of Marine Sciences

Nishad Jayasundara, *Assistant Professor*

Gayle B. Zydlewski, *Associate Professor*

EXTERNAL COLLABORATORS

Brad Allen, *Wildlife Biologist, Maine Department of Inland
Fisheries and Wildlife*

Dana M. Bauer, *Assistant Director and Research Scientist,
Clark University*

Phillip deMaynadier, *Wildlife Biologist, Maine Department
of Inland Fisheries and Wildlife*

Jenny A. Glikman, *Associate Director of Community
Engagement, San Diego Zoo*

Walter Jakubas, *Mammal Group Leader, Maine Department
of Inland Fisheries and Wildlife*

John Kocik, *Research Fishery Biologist, NOAA - NMFS
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Jerry V. Mead, *Assistant Scientist and Section Leader,
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Trevor Persons, *Herpetologist, Maine Department of Inland
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Jason Jeremy Schaffler, *Senior Quantitative Scientist,
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Michael J.W. Stokesbury, *Canada Research Chair, Acadia
University*

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*

Jerry J. Vaske, *Professor, Colorado State University*

Andrew R. Whiteley, *Assistant Professor, University of
Massachusetts Amherst*

Petra B. Wood, *Assistant Unit Leader-Wildlife, WV
Cooperative Fish and Wildlife Research Unit*

Derek Yorks, *Wildlife Biologist, Maine Department of Inland
Fisheries and Wildlife*



GRADUATE COMMITTEE LEADERSHIP

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

Loftin

Brandon Boxler, MS (September 2017 – Present)
 Brianne Du Clos, PhD (September 2012 – Present)
 Jared Homola, PhD (September 2013 – August 2018)
 Brian Rolek, PhD (September 2012 – Present)

Zydlowski

Ernest Atkinson, MS (September 2018 – Present)
 Betsy Barber, PhD (May 2013 – May 2018)
 Kevin Job, MS (January 2016 – Present)
 George Maynard, PhD (May 2013 – Present)
 Matthew Mensinger, MS (September 2018 – Present)
 Alejandro Molina-Moctezuma, PhD (May 2015 – Present)
 Erin Peterson, PhD (September 2017 – Present)
 Sarah Rubenstein, MS (January 2018 – Present)
 Sarah Vogel, MS (January 2017 – Present)

RECENT GRADUATES AND CURRENT PURSUITS

*Student, Degree, Curriculum
Current Pursuits*

*Graduate Date
Advisor(s)*



Betsy Barber, PhD, Wildlife Ecology
Postdoctoral Associate, University of Maine

May 2018
Joseph D. Zydlewski



Bayu Broto, Master of Wildlife Conservation
Researcher, Forest Research Institute, Indonesia

June 2018
Alessio Mortelliti



Carly Eakin, PhD, Wildlife Ecology
Wildlife Biologist, CNMI Division of
Fish and Wildlife, Saipan

May 2018
Aram J.K. Calhoun, Malcolm L. Hunter, Jr.



Jared Homola, PhD, Ecology and Environmental Sciences
NSF Postdoctoral Research Fellow
Michigan State University

August 2018
Cynthia S. Loftin, Michael T. Kinnison



Lydia Kifner, MS, Civil Engineering
Water Engineer, Weston & Sampson

December 2017
Aram J.K. Calhoun, Aria Amirbahman

CURRENT STUDENTS & POSTDOCS

<i>Student, Degree, Curriculum</i>	<i>Advisor(s)</i>
Ernest Atkinson , MS, Wildlife Ecology	Joseph D. Zydlewski
Betsy Barber , Postdoctoral Associate	Joseph D. Zydlewski
Sara Boone , MS, Wildlife Ecology.....	Alessio Mortelliti
Brandon Boxler , MS, Ecology and Environmental Sciences	Cynthia S. Loftin
Allison Brehm , MS, Wildlife Ecology.....	Alessio Mortelliti
Anna Buckardt , MS, Wildlife Ecology	Amber M. Roth
Elyse DeFranco , MS, Ecology and Environmental Sciences	Carly C. Sponarski
Brianne Du Clos , PhD, Ecology and Environmental Sciences..	Cynthia S. Loftin, Francis A. Drummond
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Kirstin Fagan , PhD, Wildlife Ecology.....	Daniel J. Harrison
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Francesca Gundrum , MS, Wildlife Ecology	Carly C. Sponarski
Christopher Heilakka , MS, Ecology and Environmental Sciences.....	Erik J. Blomberg
Kevin Job , MS, Wildlife Ecology.....	Joseph D. Zydlewski
Scott Lindemann , Master of Wildlife Conservation	Aram J.K. Calhoun, Malcolm L. Hunter, Jr.
George Maynard , PhD, Wildlife Ecology.....	Joseph D. Zydlewski
Matthew Mensinger , MS, Wildlife Ecology.....	Erik J. Blomberg, Joseph D. Zydlewski
Alejandro Molina-Moctezuma , PhD, Wildlife Ecology	Joseph D. Zydlewski
Erin Peterson , PhD, Wildlife Ecology.....	Joseph D. Zydlewski
Nicole Ramberg-Pihl , PhD, Ecology and Environmental Sciences.....	Stephen Coghlan, Hamish Greig
Brian Rolek , PhD, Wildlife Ecology	Cynthia S. Loftin, Daniel J. Harrison
Sarah Rubenstein , MS, Wildlife Ecology.....	Joseph D. Zydlewski
Kirstie Ruppert , PhD, Ecology and Environmental Sciences	Carly C. Sponarski
Joel Tebbenkamp , PhD, Wildlife Ecology.....	Erik J. Blomberg, Daniel J. Harrison
Sarah Vogel , MS, Wildlife Ecology	Jessica J. Jansujwicz, Joseph D. Zydlewski
Kaitlyn Wilson , MS, Wildlife Ecology	Amber M. Roth
Tyler Woollard , MS, Wildlife Ecology.....	Daniel J. Harrison

UNIT SUPPORTED RESEARCH

<i>Name, Affiliation</i>	<i>Unit Advisor(s)</i>
Catlin Ames , PhD, Marine Biology.....	Joseph D. Zydlewski



FISHERIES and aquatic

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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.

ABSTRACT: Anadromous species can boost freshwater productivity through nutrient subsidies. Along the Maine coast of the northeast United States, several alewife populations are recovering after freshwater connectivity is restored. Iteroparity in this part of their range may reduce their role as nutrient subsidies. Stable isotope analysis was used to detect marine-derived nutrient input. Spatial and temporal trends were characterized in the St. Croix as a baseline before alewife recovery, and nutrient-diffusing substrates indicated nutrient co-limitation. A reference watershed was used to compare nutrient dynamics when alewives were present versus absent. Results indicated isotope shifts within particular functional feeding groups, but not in the freshwater community as a whole. In addition, potential alleviation of nutrient limitation during the peak of the alewife run was seen.

A deterministic model was developed to explore the theoretical nitrogen and phosphorus dynamics of Alewife migrations under a range of scenarios. At low escapement levels, the number of recruits produced per spawner was high and juvenile nutrient export dominated. At high escapement levels, fewer recruits were produced per spawner, and so adult nutrient import dominated. These trends persisted regardless of scenario, though the magnitude of endpoints changed. When dams were present, the reduction in upstream passage determined adult abundances. Downstream juvenile rates determined recruitment, as well as nutrient export. The effect of poor passage at sequential dams or an in-river fishery depended on their location in relation to spawning habitat. The

St. Croix River, which is located between Maine and New Brunswick, has the majority of spawning habitat upstream. When passage in the lower river was varied, phosphorus difference was insignificant at low passage levels. When varied in the upper river, import dominated at a wide range of upstream passage rates when downstream passage was high. This led to a combined effect of more surviving juveniles per capita spawner, but a narrower range of passage rates that resulted in phosphorus import. Spawner abundance was higher when a fishery was located upstream than at the estuary, highlighting the need to consider dam and fisheries locations in relation to spawning habitat when estimating population recovery and nutrient dynamics.

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

Duration: May 2012—December 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





Painting the big picture: addressing critical research objectives for sturgeon conservation in the Gulf of Maine

1. Determine if Atlantic Sturgeon are forming winter aggregations in Penobscot Bay, describe the physical features coinciding with these areas, and assess abundance of the aggregation.
2. Define critical foraging habitat for both species by determining key prey items, identifying the habitats that contain those prey, and determining environmental predictors of prey occurrence.
3. Develop an age at length relationship for both species to ascertain rates of mortality and growth for better management, and to evaluate use of alternative aging structures.
4. Estimate the population size of both species in the Penobscot River and assess the impact, if any, of management actions in the past decade.

Currently, marine habitat use of Atlantic Sturgeon in the GOM, particularly Penobscot Bay, is limited and does not include habitat features. To expand the range of detection and collect concurrent physical data we will use an autonomous underwater vehicle affixed with a Vemco acoustic receiver. Locations where sturgeon are detected will be surveyed using Side Scan Sonar to determine the presence of sturgeon, approximate abundance, substrate type, and benthic structure. The uncertainty of habitat use of these species in the Kennebec and Penobscot rivers, and need for clarity on critical habitat extent related to foraging, warrants further investigation into the diets and prey availability for sturgeon in the GOM. To accomplish this, we will identify key species of sturgeon diets, habitats that contain those prey, and environmental predictors of prey occurrence. Fisheries management requires variables including age, growth and lengths to determine stock trends. Age, size and weight will be determined from sturgeon captured in the Merrimack, Saco, and Penobscot rivers in Maine. As Atlantic Sturgeon seasonally use Canadian

waters, collections from Minas Passage and New Brunswick will also be provided by collaborators. To estimate the population sizes of Shortnose and Atlantic sturgeon we will combine mark/recapture techniques with telemetry to determine population models for the Penobscot River residents.

A trial mission of a drone mission was carried out in April 2018, and a tracking mission is scheduled for January 2019. The glider was able to navigate complex bathymetry and travelled across Penobscot Bay over two weeks. Diet from both species and prey samples have been obtained from the Kennebec and Penobscot rivers. The rivers differed in prey species, abundance, and in diet suggesting that the interchange between the rivers may be related to specific forage items or competition release. Aging structures have been obtained from both species in the Penobscot River, and data of genetically identified GOM fish from Canada will be incorporated into stock analysis. Size and weight data are and have been collected on both species for 10+ years in the Penobscot. Population sizes of sturgeon from 2007 - 2018 in the Penobscot vary seasonally and annually for both Shortnose (250 - 2924 individuals) and Atlantic sturgeon (500 - 708).

Investigator: Catlin Ames (PhD)

Advisors: Gayle B. Zydlewski (Co-Advisor)
 Michael T. Kinnison (Co-Advisor)
 Joseph D. Zydlewski
 Erik J. Blomberg
 Michael J.W. Stokesbury

Duration: May 2016—August 2020

Cooperators:

Maine Outdoor Heritage Fund
 National Audubon Society
 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





A tool for understanding likely fish passage and harvest management outcomes for alewife on the St. Croix River

1. Develop a user-friendly interface for assessing scenarios associated with the recovery of alewife populations.
2. Engage with stakeholders to develop and address fundamental questions associated with alewife management, resulting in a document with scenario-specific population information.

An interactive web tool that can be used to compare possible management approaches related to passage improvements, commercial fishery placement within the watershed, and stocking, among other potential scenarios. This will involve converting an existing alewife population model from one form to a code format that can be used on a web platform. This will result in a user-friendly online tool that can be made publicly available as a web application. To identify management scenarios that would be of management value, the work will undergo a scientific peer review to ensure that the best available science is used and that all interested parties in both the US and Canada are included in its development. When complete, we will create a video tutorial that describes how to use the web-based modelling application. “Hands on” workshops for the tool will also be held.

We have been primarily focusing on developing the interactive web tool. The existing alewife population model has been converted into a usable form. We are currently constructing the user interface for the project. The beta version of this model will be tested soon and we have created a short survey that will help us streamline the feedback process.

Investigator: Betsy Barber (Postdoc)

Advisors: Joseph D. Zydlewski (Advisor)

Duration: June 2018—December 2019

Cooperators:

International Joint Commission on the St. Croix
Waterway

U.S. Geological Survey – Maine Cooperative Fish and
Wildlife Research Unit



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 prepares more than 800 individual otoliths from

American shad and more than 120 American eels. Currently, we have processed American shad otoliths from Penobscot River shad between the years of 2011 and 2017 and Penobscot River eels between the years of 2013 and 2017. Additionally we have processed American eels from the Union River in Maine, and American shad from the Sheepscot river in Maine.

The microchemistry of these samples has been analyzed using laser ablation inductively coupled plasma mass spectrometry (ICPMS) at the Woods Hole Oceanic Institute. Strontium and barium levels indicate varied time spent in seawater for both species and demonstrate the likely role the lowermost dams have had on disrupting movement patterns.

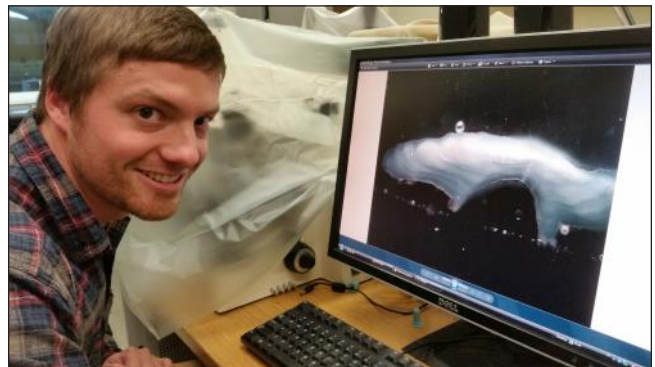
Investigator: Kevin Job (MS)

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

Duration: January 2016—June 2019

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





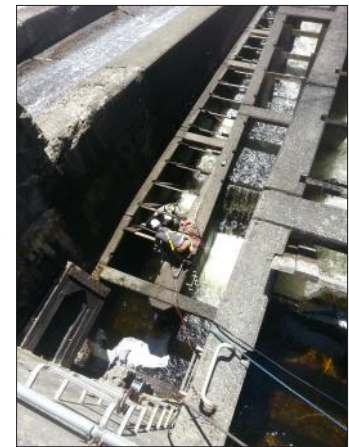
Monitoring of upstream migrating fish in the Penobscot River, Maine

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 2014-17 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. This work will conclude in the spring of 2019.



Investigator: George Maynard (PhD)

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

Duration: September 2009—March 2018

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



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

1. Collect data to inform development of forecasting model to predict downstream migration of American eels based on environmental factors (e.g., weather, lunar phase).
2. Use acoustic tags to track silver eels during emigration from the Penobscot River, and quantify mortality incurred at Milford and West Enfield Dams.

Beginning in 2005, an intensive effort was initiated by the U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit in cooperation with the University of Maine, and NOAA Fisheries to establish an acoustic telemetry infrastructure in the Penobscot River. The developing technology of acoustic telemetry allows us to acoustically tag and identify individual fish at various locations in the Penobscot River during downstream migration through the use of more than 100 autonomous, stationary listening devices.

We have used this array to detect acoustically tagged American eel traveling through the Stillwater Branch and the main-stem of the Penobscot River. Beginning in 2016, we have captured and acoustically tagged 100 adults American eels annually. These fish have been collected at a trap on a tributary of the Penobscot River in the fall and transported upstream to track their migratory progress to the ocean. Using a mark-recapture analysis, we have modelled these data to estimate mortality through the river.

Work in the fall of 2018 included the improved design and installation of a weir and a steel and fiberglass grate trap on a tributary of the Penobscot River. Analysis of the previous years data. In 2016 and 2017, migrating silver eels ($n=200$) from a tributary of the Penobscot River were implanted with acoustic tags and released upstream of Milford and West Enfield dams. In 2018, fifty silver eels were captured, surgically tagged, and released above both Milford and West Enfield Dam (data from 2018 are pending). Nearly all

fish exhibited directed downstream behaviors, but were delayed at the dams. Mortality through both dams was high (13 to 18%). These data suggest that American eels that successfully pass dams as juveniles are limited with respect to estuarine habitat access, likely resulting in slower growth and delayed maturation. As migrating adults, dams cause delay and direct mortality.

Investigator: Matthew Mensinger (MS)

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

Duration: September 2015—June 2021

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





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.

Once Atlantic salmon juveniles (smolts) are tagged and released, the series of detections can be used to estimate the rates of survival through mark-recapture models for the entire river system. Such models help to identify areas of high mortality (e.g., dams). We continued tagging hatchery-origin Atlantic salmon smolts from the Penobscot River through 2018. There has been a focus on survival and passage through Howland Dam in the Piscataquis River because of the recent installation of a new "nature like" downstream fish passage bypass at Howland Dam that has been anticipated to increasing smolt survival. Therefore, it is important to characterize current survival at this dam in comparison to previous years' data.

Acoustic telemetry data have been collected from downstream migrating Atlantic salmon smolts over the last three years to assess movement and survival through the Penobscot River and Estuary. These data

are being 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. In aggregate, these data allow a post-restoration assessment of Atlantic salmon survival in the Penobscot River. A last year of tagging and tracking is planned for 2019.

Investigator: Alejandro Molina-Moctezuma (PhD)

Advisors: Joseph D. Zydlewski (Advisor)
John Kocik
Michael T. Kinnison
Nishad Jayasundara

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





Continued monitoring of Penobscot River migratory fishes to assess the long-term impacts of dam removals

1. Assess the behavior of Atlantic Salmon (*Salmo salar*) delayed below Milford Dam.
2. Assess the demography of the American Shad (*Alosa sapidissima*) since the removal of Veazie Dam, and track their movements upstream of Milford Dam.
3. Evaluate American Shad dietary habits and postspawn activities in the Penobscot River estuary.
4. Determine river herring (*Alosa pseudoharengus* and *A. aestivalis*) run timing and demography for both species throughout the spawning run.
5. Determine if river herring of either species exhibit fidelity to spawning reaches across years.

The above objectives are part of a long-term monitoring project of adult anadromous fishes that has included several previous graduate students. The overarching goal of this project is to assess the impacts on migratory fishes of dam removal and restoration activities undertaken as part of the Penobscot River Restoration Project. Each year, Atlantic Salmon, American Shad, and river herring are tagged and released both above and below Milford Dam, currently the lowest dam on the mainstem Penobscot, and their movements are tracked. Data collected from these efforts is used to determine how regaining access to historical habitat has changed the demography and movements of these fishes, and also to evaluate the effectiveness of the state-of-the-art fish passage facility at Milford Dam.

Fishes are tracked using stationary radio antennas located on shore, weekly mobile radio tracking, acoustic receiver arrays located throughout the river, and PIT antennas installed in the fishways of existing dams.

During 2018, 49 Atlantic Salmon were equipped with radio tags at Milford Dam and transported downstream in order to track their movements up to, and delays below, the dam. We will use this data to create maps of salmon movements that will show where salmon are located while they are delayed.

Seventy American Shad were radio tagged and PIT tagged below Milford, and 30 were acoustically tagged. Additionally, 50 radio-tagged and 10 acoustic-tagged shad were tagged at, and released above, Milford. The tracks of the shad released above Milford represent some of the first data about the movements of this species in the upper river.

We also equipped 3,000 river herring with PIT tags and released them above Milford. Over 100 detections of river herring occurred at upstream dams, a significant increase over previous years. Detections included fish tagged in 2016, which will contribute to future analysis of site fidelity.

Investigator: Erin Peterson (PhD)

Advisors: Joseph D. Zydlewski (Advisor)

Duration: September 2017—May 2022

Cooperators:

Maine Department of Marine Resources
 Brookfield Renewable Power
 National Oceanic and Atmospheric Administration
 Penobscot River Restoration Trust
 The Nature Conservancy
 U.S. Geological Survey—Maine Cooperative Fish and Wildlife Research Unit
 University of Maine
 Kruger Energy
 Penobscot Indian Nation





Energetic impacts of passage delays in migrating adult Atlantic salmon

1. Understand and quantify the bioenergetic cost of delays that adult migrating salmon experience at dams
2. Characterize the influence of energy expenditure on female Atlantic Salmon reproductive quality
3. Quantify the bioenergetic effects of thermal experiences on prespawning Atlantic Salmon

The purpose of this study is to understand the energetic impact of dam facilitated delays on migrating adult Atlantic Salmon. Delays below dams expose salmon to increased water temperatures, and this project will explore the connections between thermal experience, energetic expenditure, and reproductive quality. There are three overarching portions of this project. The first is a field-based study to tag and track salmon movement up to and through fish passage at Milford and Lockwood Dams on the Penobscot and Kennebec rivers, respectively, as well as to characterize the energy loss and thermal regimes of those tagged salmon below the dams. From there, a bioenergetic mathematical model will be developed to quantify metabolic loss of delayed salmon. The second part of the study will take place during fall spawning at Craig Brook Fish Hatchery. Female reproductive quality will be investigated through egg count, size distribution, and eye up and hatching dates. The energy reserves of the females (which are Penobscot river run fish) will be connected to the reproductive quality. The final portion of the study will be a collaboration with the National Cold Water Marine Aquaculture Center for a controlled study of bioenergetic effects on prespawning adult salmon experiencing different thermal regimes. Two study groups of fish will be held at different temperatures from spring until fall spawning, allowing the characterization of thermally mediated metabolic acceleration on whole body use and the influence of increased metabolic rate on gametic development and larval metabolism.

Tagging and tracking of 20 Penobscot and 6 Kennebec salmon has occurred for the 2018 summer field season, including the collection of empirical fat data representing energetic costs of migrating salmon delayed below the dams. Preliminary data analysis has shown patterns in fish movement below dams alongside temperature and fat changes. Spawning at Craig Brook will be occurring throughout the month of November, and egg quality will be followed through the winter into spring and hatching. Discussion, project design, and collaboration of the aquaculture portion of the study have begun with the intention of a spring/summer 2019 start.

Investigator: Sarah Rubenstein (PhD)

Advisors: Joseph D. Zydlewski (Advisor)
Nishad Jayasundara

Duration: January 2018—August 2020

Cooperators:

Brookfield Renewable Power
Maine Department of Marine Resources
National Oceanic and Atmospheric Administration
U.S. Fish and Wildlife Service – Craig Brook National Fish Hatchery
University of Maine – Department of Wildlife, Fisheries, and Conservation Biology
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
U.S.D.A. National Cold Water Marine Aquaculture Center





Investigating fish passage decision-making in the FERC regulated hydropower relicensing process

1. Characterize the suite of social and technical factors that influence the implementation of fish passage prescriptions including the regulatory and non-regulatory tools afforded by the existing legal/regulatory framework.
2. Assess basin-wide decision-making and the degree to which regulatory decisions at dams are independent of the characteristics and regulation in other nearby dams.
3. Evaluate the construction and use of ecological information, environmental studies, and the valuation of "best available science" as it pertains to unique stakeholder groups
4. Communicate results to resource agencies to inform future relicensing decisions

Decision-making regarding dams in New England stands at a crossroad. Many dams in Maine, New Hampshire, and Rhode Island will require FERC relicensing in the next decade, many are approaching their design life, and preferences for dams and ecosystem services are changing. However, despite increased momentum for change and renewed calls to consider a broader range of options including removal, dams remain a symbol of cultural identity, economic prosperity, and technological innovation; they represent a source for clean energy and an opportunity for recreation. Placed squarely at the center of the contentious debate are numerous federal and state resource and regulatory agencies charged with the difficult task of balancing ecological, economic, and social tradeoffs related to dam relicensing decisions.

Numerous federal and state agencies assert jurisdiction over dam projects, and a confusing array of laws and policies inform dam relicensing, removal, retrofit, and on-going operations. Through interagency coordination and engagement with stakeholders including private landowners, non-governmental organizations, municipal governments, and industry, agencies have the capacity to mobilize action at the basin-wide scale using a range of regulatory and non-

regulatory tools. The use of science-based information is key to making well-informed decisions and conceptual "blueprints" for basin-scale hydropower development have been introduced.

To date, these decision frameworks have proven difficult to implement in practice. Instead, agency actions tend to be case-specific and reactive to individual projects and events rather than proactive, considering alternative actions and consequences before issues reach a boiling point. This research attempts to characterize agency actions and perspectives including knowledge gaps and challenges faced in the relicensing process.

Work began in 2017 and has focused on content analysis of document sources for 47 projects in the Kennebec and Penobscot River watersheds. A database of fish passage related correspondences, comments, and official documents relating to hydropower energy projects was constructed from the FERC eLibrary. From these sources, technical and social correlates are being quantified in relation to regulatory outcomes. A targeted content analysis of these sources is being used utilizing machine learning techniques to characterize the roles of agencies and tribal entities, entity participation, and agency decision-making behaviors. The use of science in decision-making has been identified as an important component of the relicensing process. Citation analysis is being used to identify major sources of knowledge used in the process, where it originates from, and how it is used. Knowledge of these patterns may inform future relicensing efforts.

Investigator: Sarah Vogel (MS)

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Jessica J. Jansujwicz (Co-Advisor)
Carly C. Sponarski

Duration: June 2017—June 2020

Cooperators:

National Science Foundation – Experimental Program to Stimulate Competitive Research
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit





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

1. Develop a model to forecast the downstream migration timing of American eels based on environmental factors (e.g., weather, lunar phase)

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 more than 25 years before undergoing a second transformation, including color change, to a downstream-migrating silver eel. Historically the American eel was the target species of a lucrative fishery however this fishery has collapsed over the last few decades and eels are in decline worldwide. Such declines are troubling as eels play an integral role in maintaining biotic integrity in fish communities. As such, eel conservation has become a high priority of both fishery managers and conservationists in many freshwater ecosystems.

The proposed work will use field data to inform a predictive forecasting modeling framework as to both timing of migration and behavior and survival of American eel at dams. Such a model could serve as a useful tool to managers to inform management and conservation decisions as to hydropower facility operation. Results from ongoing telemetry work will be used to inform our developing model. If successful, these efforts would allow sensitivity analysis of turbine shut downs to balance conservation and financial objectives for this commercially and ecologically important fish

The project is in the beginning stages of consolidating data and constructing a modeling framework.

Investigator: Daniel Weaver (Postdoc)

Advisors: Joseph D. Zydlewski (Advisor)

Duration: September 2018—December 2020

Cooperators:

The Nature Conservancy

U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit



WILDLIFE and habitats

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Wildlife use of vernal pools in an urbanizing landscape with a focus on vernal pool-breeding amphibian population vitality

1. Characterize wood frog and breeding pools along a gradient of human disturbance via documentation of biotic factors (faunal assemblages, vegetation), abiotic factors (temperature, water chemistry, hydroperiod), and land cover types and configuration at various scales in the surrounding landscape;
2. Examine the effects of breeding pool characteristics on wood frog (*Lithobates sylvaticus*) survival, morphology, and disease susceptibility; and
3. Examine population dynamics (e.g., occupancy, breeding effort and success, and connectivity) relevant to wood frog and mole salamander (*Ambystoma spp.*) population persistence.

ABSTRACT: Vernal pools in the northeastern United States provide essential habitat for pool-breeding amphibians and provide resources for other forest-dwelling wildlife. These pools and pool-breeding amphibians in particular are threatened by land conversion associated with urbanization and urban-associated factors. The responses of these amphibians and of birds and mammals using vernal pools to intermediate levels of urban development are largely unknown. I used field observations and lab experiments to study the amphibians, birds, and mammals associated with vernal pools along an urban development gradient in greater Bangor, Maine.

In Chapter 1, I examined bird and mammal use and assemblage composition at 33 pools, with specific focus on the influence of impervious surface as an indicator of urbanization intensity. I detected 59 bird and mammal species using pools and the adjacent terrestrial areas. Within-pool vegetation and land cover types within 1,000 m of pools likely influenced assemblages with increases in impervious cover linked to shifts towards urban-affiliated species.

Chapters 2 focused on the associations between site characteristics in an urbanizing landscape and wood

frog (*Lithobates sylvaticus*) larval morphology and survival. Differences in morphology were associated with urban land conversion, hydrology, within-pool vegetation, and conspecific density. Urbanization was positively associated with greater tadpole survival, development rate, and size.

In Chapter 3, I examined the carry-over effects of larval morphology and site characteristics, particularly urban-associated land conversion within 1,000 m, on newly emerged and post-breeding male wood frogs in 15 pools. Egg density had a salient influence with negative effects on larval and froglet responses, and the effects of urban-associated cover near pools at larval and adult stages suggest that the carry-over effects of urbanization from larval to froglet stages may not persist to adulthood.

Chapter 4 addresses the effects of urban-associated land conversion and road salt on breeding effort of wood frog, spotted salamander (*Ambystoma maculatum*), and the blue-spotted salamander (including the unisexual complex, *Ambystoma laterale-jeffersonianum*). All three taxa responded negatively to tree cover reduction, but had some positive responses that are indicative of the removal of breeding pools 300-1,000 m from a study pool resulting in displaced adults consolidating breeding in remaining pools.

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—May 2018

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





Water chemistry dynamics in four vernal pools in Maine, USA

1. Measure the aqueous concentrations of the greenhouse gasses CH₄ and CO₂ in four vernal pools in Maine. Estimate diffusive flux from these concentrations and other data collected.
2. Create a carbon mass balance for four vernal pools in Maine, using the evaporative flux and groundwater inflows and outflows. Compare carbon inputs to carbon outputs of vernal pools. Scale up the CH₄ and CO₂ emissions using the vernal pool density in Maine.
3. Identify environmental covariates of CH₄ and CO₂ in four vernal pools in Maine.
4. Characterize temporal water chemistry trends for four vernal pools in Maine. This information can be used to guide future studies of vernal pool biogeochemistry.

ABSTRACT: Vernal pools are small seasonal wetlands that are a common landscape feature that contribute to biodiversity in northeastern North American forests. However, even basic information about their biogeochemical functions, such as carbon cycling, is limited. Dissolved gas concentrations (CH₄, CO₂) and other water chemistry parameters were monitored weekly at the bottom and surface of four vernal pools in central and eastern Maine, USA, from April to August 2016. The vernal pools were supersaturated with respect to CH₄ and CO₂ at all sampling dates and locations. Concentrations of dissolved CH₄ and CO₂ ranged from 0.4 to 2.1·10² μmol L⁻¹ and 72 to 2.3·10³ μmol L⁻¹, respectively. Evaporative fluxes of CH₄ and CO₂ into the atmosphere ranged from 0.2 to 73 mmol m⁻² d⁻¹, and 30 to 5.9·10² mmol m⁻² d⁻¹, respectively. During the study period, the vernal pools emitted between 0.1 to 5.8 kgC m⁻² and 9.6 to 1.2·10² kgC m⁻² of CH₄ and CO₂, respectively. This is a carbon export of up to 2.4·10² kgC, which is less than the estimated carbon leaf litter input. The production rates of CH₄ and CO₂ ranged from -2.4·10⁻² to 6.6·10⁻¹ and 4.0·10⁻¹ to 4.6 gC m⁻² d⁻¹, respectively, and increased significantly

over the season. Concentrations of CH₄ and CO₂ covaried with alkalinity, temperature, and dissolved oxygen. Our study pools were characterized by large concentrations and effluxes of CH₄ and CO₂ with respect to other permanently inundated wetlands, indicating vernal pools may be important contributors to the global carbon budget and are metabolically active sites.

In addition to dissolved gas concentrations, temperature, dissolved oxygen, pH, ortho-P, NO₃⁻, NH₄⁺, Cl⁻, SO₄²⁻, Na⁺, K⁺, Mg²⁺, Ca²⁺, DOC, alkalinity, chlorophyll a, speciated Al, speciated Fe, speciated Mn, and speciated Si were monitored from April to August 2016 to establish general temporal trends in pool biogeochemistry. The pH in the vernal pools generally decreased over the study period. Dissolved oxygen concentrations fluctuated throughout the season but were generally lower in benthic samples than in surface. The nutrients ortho-P and NH₄⁺ increased over the study period. Concentrations of NO₃⁻ were low throughout the study period, indicating denitrification was occurring. Dissolved organic carbon concentrations and alkalinity both increased over the study period. Concentrations of Cl⁻, and Na⁺ decreased over the season. Concentrations of K⁺ increased over the season. Concentrations of the metals Al, Fe, and Mn increased over the study period. The pools in this study are diverse in their biogeochemistry, but do exhibit trends in their aquatic chemistry during the open water season. These data can be used as a jumping off point for future studies on vernal pool biogeochemistry.

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)





Small mammals and seed predation: how their behavior and personality affects forest composition and regeneration

1. To study how individual and population responses interact and affect seed predation. This includes investigating seed preference and choice, and behavior and personality in response to varying ecological factors.
2. To study the response of “individuals” and populations to land-use change processes. The response variables of interest include individual-scale parameters such as health status, personality, and individual survival; and population-scale parameters such as population density, population growth rates, and population structure.

Seed predation/dispersal. This experiment's aim is to identify which seeds are preferred by different small mammal species. Our experiment is conducted using techniques such as PIT tags and high-resolution infrared game cameras, which allows us to estimate the predation rate of several different species and the amount dispersed/predated by each individual. It also allows us to assess the behavioral responses by different individual personality types when exposed to various ecological factors such as seed size, hardness, and nutritional value; vegetative cover; predation risk; and other habitat variables. These data are important for providing realistic estimates to be used in regeneration models.

Small mammals and land-use change. We are using a large-scale capture-mark recapture study across two different forest management treatments, as well as unharvested control sites, to allow us to measure individual- and population-level parameters. These data will help us determine if personality and behavior are associated with different silvicultural practices, and what implications forest management will have on the make-up of small mammal communities and their affect on forest composition and regeneration.

We trapped from June through October of 2017 and 2018 in six trapping grids located in the Penobscot

Experimental Forest (PEF) in Bradley, ME. Three grids, each with a replicate (6 total), were set in two different silvicultural treatment sites and one unharvested site. Each grid contained 100 Longworth and 50 Tomakawk traps. Captures were processed twice daily, and individuals were marked with PIT tags and numbered metal ear tags. Weight, sex, reproductive status, and body measurements were recorded. Three field tests were performed to measure personality.

Field seed preference experiments were conducted in two rounds during July and August 2017. Over 3,000 videos recorded six small mammal species selecting seeds from seven available tree species. Ongoing lab experiments will collect videos from individuals of two species, housed in the lab, and released thereafter. Additionally, field experiments were conducted in July, August, and September 2018 to assess how different individual personalities may respond to risk when presented with two seed choices. Over 8,000 videos were collected, and a laboratory version will be conducted over winter 2018.

Investigator: Sara Boone (MS)

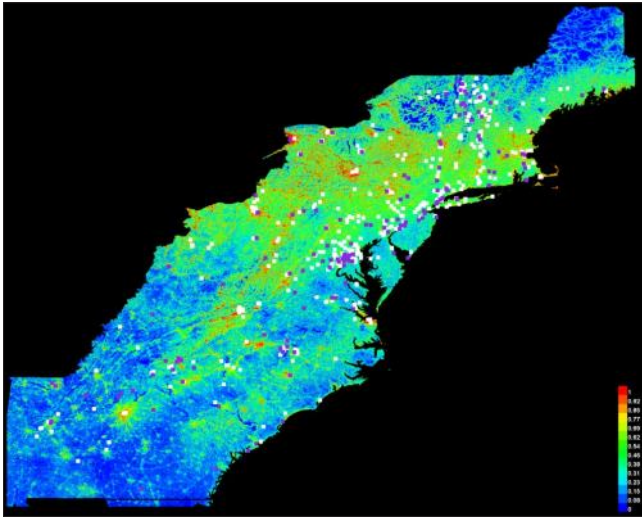
Advisors: Alessio Mortelliti (Advisor)
Malcolm L. Hunter, Jr.
Rebecca L. Holberton

Duration: June 2017—December 2019

Cooperators:

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





Monarch butterfly (*Danaus plexippus*) roosts-site selection and viability east of the Appalachian mountains

1. Characterize the habitat criteria that monarch butterflies in the Atlantic flyway population use in selecting fall stop-over locations.
2. Identify and map sites meeting these habitat criteria, including previously known sites as well as locations where monarchs are not known to occur.
3. Evaluate current and future vulnerability of these sites as defined by adaptive capacity, sensitivity, and exposure.

The monarch butterfly is a flagstone species and pollinator whose populations are declining. The largest population overwinters in Mexico, then disperses north across the United States and Canada to breed in spring and summer. They migrate back south in fall, splitting into two flyways: one in the central U.S., one along the Atlantic coast. They fly during the day, and at night roost in groups. The roost-site criteria that monarchs select for are currently unknown. We are developing an ecological niche model for the Atlantic flyway roost sites using Maximum Entropy and Genetic Algorithm for Ruleset Prediction. We are using citizen scientist reported occurrences and environmental variables that are known to affect monarchs in alternate life stages, including weather, topography, vegetation, and human impacts. We are partnering with land managers to validate model predictions, and developing a phone app to collect data for model validation. The models will be used in a vulnerability analysis of roost habitat with respect to land use and climate change using variables describing exposure, sensitivity, and adaptive capacity. Final products will include models of current monarch roost habitat suitability, and assessment of stopover areas in the Atlantic flyway that are at risk of future change.

All data has been successfully gathered and cleaned. The initial models have been run in both Maximum Entropy and Genetic Algorithm for Ruleset Prediction. Preliminary results show that the primary factors of concern are proximity to roads, temperature, and land cover. The butterflies tend to roost in low temperature grassland areas close to roads. The next steps will involve paring down on included environmental variables to reduce collinearity and comparing the outputs of the different models. The initial smartphone application is completed and will be released to beta testers when concerns over user credentials have been addressed.

Investigator: Brandon Boxler (MS)

Advisors: Cynthia S. Loftin (Co-Advisor)
William B. Sutton (Co-Advisor)
Francis A. Drummond
Joseph D. Zydlewski
Phillip deMaynadier

Duration: August 2017—December 2019

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





Investigating the effects of silvicultural practices on individual and population-level 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.

June-October of 2018 was the third and final field season for this Master's project. We continued our large-scale capture-mark-recapture study in the Penobscot Experimental Forest in Bradley, ME.

We processed over 2,000 captures and marked over 1,000 individuals with PIT tags and small mammal ear tags. We measured body condition (weight, body length, tail length, and reproductive status) and personality (using three different standardized tests) for each individual.

We have completed the analysis from our 2017 seed experiment and results are extremely promising! Specifically, our results show that personality of small mammals influences critical decisions during four major steps of seed dispersal: initial seed preference, dispersal distance, cache location, and seed fate. This study will be the first ever to highlight with empirical data the relationship that personality has with key seed predation and dispersal decisions by small mammals!

Investigator: Allison Brehm (MS)

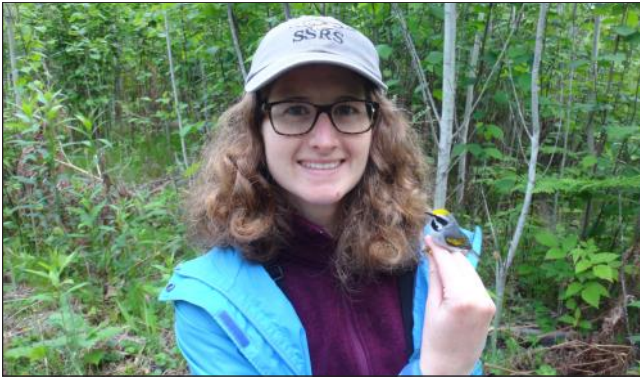
Advisors: Alessio Mortelliti (Advisor)
Erik J. Blomberg
Shawn Fraver

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





Evaluating young forest management as an avian conservation strategy

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. Investigate broad-scale Golden-winged Warbler habitat use and annual movements to determine migration routes and timing and wintering areas.

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. I conducted avian point counts, GWWA playback surveys, and AMWO singing ground surveys to investigate bird use of four forest types in northcentral Wisconsin: mature aspen, mature alder, harvested aspen (<20 years) and sheared alder (<20 years). All harvested and sheared sites were on private family forest lands and mature sites were predominantly on public land. I will use ordination to compare the bird communities using each of the forest types. To understand the potential role of landowners in monitoring young forests on their properties, I conducted interviews asking questions about barriers and preferences for participating in citizen-science-based monitoring. In 2017, a protocol for landowner AMWO monitoring was piloted by landowners and their thoughts on the protocol and monitoring experience were captured through follow-up interviews. Archival light-level geolocators were deployed on male GWWA to gather information on migratory routes, timing, and duration, and stopover and wintering locations.

I completed AMWO singing ground surveys, GWWA playback surveys, avian point counts, and associated

vegetation sampling in spring and summer 2016 and 2017. I am working with collaborators to assess the impacts of young forest habitat management and vegetation characteristics on the abundance of male GWWA and displaying male AMWO. In 2017, 7 of 28 geolocators were recovered from male GWWA. Final analysis of the migratory routes and timing, and the wintering location of these birds and 16 additional GWWA and BWWA from across the breeding range is underway. In collaboration with the Wisconsin Young Forest Partnership, I created a landowner-based monitoring program called Wisconsin's Young Forests. This program was developed based on information from landowner interviews and pilot monitoring in 2016 and 2017 and encourages landowners to interact with the young forest management on their properties while sharing their sightings with managers.

Investigator: Anna Buckardt (MS)

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

Duration: June 2016—May 2019

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
Inland Bird Banding Association
Association of Field Ornithologists
Ozaukee-Washington Land Trust
Michigan Technological University
Inland Bird Banding Association
Association of Field Ornithologists





Examining the interacting roles of social influences and risk perceptions on interactions with wildlife

1. Develop an improved understanding of the individual motivations and cognitions involved with winter deer feeding behavior in New Brunswick.
2. Understand how these may be linked to current deer and forestry management practices.
3. Develop a better understanding of stakeholder attitudes and how this contributes to conflict management

The catalyst for this study stems from a collaborative effort to better understand abiotic and biotic factors impacting the white-tailed deer population across Maine and New Brunswick, known as the Northeast Deer Research Partnership. As part of this effort, researchers from the University of New Brunswick have initiated satellite tracking studies on deer populations; these have demonstrated the significant impact that feeding is having on deer migration patterns. Biologists from the New Brunswick Department of Energy and Resource Development (NBERD) and researchers from Quality Deer Management Association (QDMA) have expressed concern with the broader impacts this winter feeding may be having on both the deer population and on public health and safety. A social science examination of this phenomenon is necessary in order to better understand the complexities of this coupled human-natural system. The project will involve an initial phase of semi-structured interviews, followed by a large-scale survey via mail questionnaire.

Phase one, involving semi-structured interviews with individuals known to participate in winter deer feeding practices, was completed in summer of 2018. Data analysis has started and will be completed by May 2019. Phase two, involving the survey via mail questionnaire, is in a preparation phase. The survey will be mailed out in January 2019.

Investigator: Elyse DeFranco (MS)

Advisors: Carly C. Sponarski (Advisor)
Jerry J. Vaske
Sandra De Urioste-Stone

Duration: September 2017—August 2021

Cooperators:

University of Maine – Maine Agricultural and Forest
Experiment Station
New Brunswick Department of Energy and Resource
Development
New Brunswick Quality Deer Management
Association
New Brunswick Wildlife Trust Fund





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 led 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.

Parameters of the InVEST Crop Pollination model have been updated to reflect on the ground conditions, leading to improvement in model predictions. These predictions were incorporated into BeeMapper, an online decision support system, that displays estimated wild bee abundance throughout Maine's wild blueberry landscape. BeeMapper was launched in July 2017. Surveys of non-crop land cover and assessment of landscape pattern indicate that in Maine, wild bees are more diverse and abundant in urban areas and wild blueberry fields. In the heavily forested Downeast region, wild bees rely heavily on the resources provided by blueberry fields in the early summer and urban areas throughout the summer to survive and provision nests. Analysis of bee communities in power lines will be completed in Spring 2019. Project completion will be in May 2019.

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—May 2019

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





Development of optimal monitoring protocol for mesocarnivores in Maine

1. Assess optimal array (number and transect spacing) for motion-triggered trail cameras used to detect diverse mesocarnivore species in Maine (pilot season completed April 2017).
2. Use trail cameras to survey across distinct landscape types, in both summer and winter, to simultaneously assess occupancy patterns and detection probabilities for marten, fisher, coyote, and other high priority species (year 1 complete, year 2 underway).
3. Provide user-friendly guidelines on optimal monitoring approaches for key species to MDIFW.
4. Investigate interspecies dynamics among native mesocarnivores and the potential impact on detection and occupancy.
5. Assess species response to land use dynamics and the pros and cons of trail camera surveys as the tool relates to large-scale, multi-species management, research and conservation.

This research will assess the efficacy of using arrays of motion-triggered trail cameras, an increasingly popular and robust tool for wildlife research, to collect biologically relevant information on occupancy and detection patterns for mesocarnivores in Maine. Understanding trends in the abundance and distribution of carnivores is important at global, regional and local scales due to their ecological role, their aesthetic and economic value, and the numerous threats to their conservation. American martens (*Martes americana*) and fisher (*Pekania pennanti*) are medium-sized carnivores (*mesocarnivores*) native to North America, and methods to track changes in population independent of harvest reports will be valuable to the Maine Department of Inland Fisheries and Wildlife. These species are also likely to respond to habitat changes that occur as a result of timber extraction, and we are conducting surveys across landscape features to create a natural experiment and

enable comparison between different forest types, harvest histories, and degrees of fragmentation.

We are currently conducting our second year of full scale surveys, out of four years planned for data collection. Over summer 2018 we set 90 locations, expanding both north and south from our year one surveys. During year one (summer 2017-winter 2018) we surveyed 120 sites in distinct categories of timber harvest. For year two (summer 2018-winter 2019), we are re-surveying in a subset of these areas, to collect information on year-to-year changes, as well as expanding into intermediate timber harvest study areas. Earlier completed work includes our pilot season to determine the optimal arrangement and number of cameras deployed at each site, establishing relationships with a spectrum of landowners, and preliminary analyses.

Investigator: Bryn E. Evans (PhD)

Advisors: Alessio Mortelliti (Advisor)
Cynthia S. Loftin
Walter Jakubas

Duration: January 2017—December 2021

Cooperators:

Maine Department of Inland Fisheries and Wildlife
Baxter State Park
University of Maine
University of Maine – Maine Cooperative Forestry
Research Unit
Downeast Lakes Land Trust
The North Maine Woods
Maine CFRU Landowner access and assistance





Landscape-scale responses of marten populations to 30 years of habitat change in commercially managed landscapes of northern Maine

1. To replicate previous trapping protocols conducted during 1989–1998 to survey spatial occurrence of martens on commercially managed timberlands bordering the western boundary of Baxter State Park. Radio-collar captured marten and track using VHF triangulation throughout the leaf-on season to estimate boundaries of sex-specific territories.
2. Utilize a time series of satellite imagery, aerial photography, and ground measurements to create a detailed landcover map documenting forest characteristics and harvest histories as they relate to habitat currencies for marten in Maine.
3. Develop landscape-scale models to evaluate how patterns of occurrence, habitat selection, density, and demographics of martens have changed in response to habitat loss and landscape fragmentation.
4. Provide reliable models for predicting forest harvesting effects on martens in contemporary landscapes.

Since the enactment of the Maine Forest Practices Act, it is unclear to what degree forest-dependent wildlife have responded to the resulting patterns of landscape composition and connectivity. Previous research on American marten, an area- and fragmentation-sensitive forest carnivore, demonstrated the utility of martens as an effective umbrella species for 71% of vertebrate species in Maine. Related research documented a widespread loss of marten habitat coincident with decreasing extent and increased fragmentation of suitable habitat patches during 1970–2007. Our goal is to contribute to management planning for viable wildlife populations in the commercial timberlands of Maine by assessing the long-term impacts of habitat loss and fragmentation on marten population density, demographics, and habitat associations. We will

replicate live-trapping and radiotracking protocols established from 1989–1998 to resurvey an industrial forest in northcentral Maine. We will construct models using contemporary and historical data and compare model performance with studies conducted in a neighboring forest reserve and a geographically distinct study area in northwestern Maine. This comparison will enhance understanding of landscape-scale effects of partial harvesting and inform future habitat and harvest management for marten where shifting regulations and land ownership patterns have drastically altered landscape composition and structure

The spring 2018 trapping session (17 May–4 July) consisted of 2954 trap nights and yielded 12 captures and recaptures, including 9 individual marten (7 males, 2 females). Despite consistent trapping effort, our 2018 spring catch rate was on average 81% lower than seven prior field seasons conducted in the same area. Preliminary results suggest a male-skewed sex ratio and greater variance in home range sizes in 2018 compared with prior research. We are currently consolidating historical data and conducting preliminary analyses. We anticipate all field data collection to be completed by October 2019.

Investigator: Kirsten Fagan (PhD)

Advisors: Daniel J. Harrison (Co-Advisor)
Erin Simons-Legaard (Co-Advisor)

Duration: January 2018—December 2021

Cooperators:

University of Maine – Maine Cooperative Forestry
Research Unit

University of Maine – Maine Agricultural and Forest
Experiment Station

Katahdin Forest Management, LLC

Gerald Pelletier, Inc.





American woodcock (*Scolopax minor*) migratory ecology in eastern North America

1. Assess patterns (rate and migratory path) of migration from breeding areas in the fall, and from wintering grounds to breeding areas in the spring.
2. Compare migration ecology for woodcock breeding along a latitudinal gradient to evaluate differences in migration strategies based on breeding latitude.
3. Identify stopover areas and analyze landscape patterns affecting migratory stopover during both spring and fall migration.
4. Evaluate survival of woodcock during migration and relate observed patterns in mortality with processes identified in objectives 1-3.
5. Combine survival data with other existing datasets (band recovery, singing ground survey, parts collection) to develop an integrated, full life cycle population model for American woodcock.

Migratory animals in general face numerous challenges as they traverse seasonally suitable habitats throughout the full annual cycle. Often times, migratory animals must traverse a foreign landscape and face many novel threats to which they are naïve. Migratory bird in particular face numerous challenges in human dominated landscapes facing both direct (e.g., cell towers, wind farms, skyscrapers) and indirect (e.g., changing landscape, light pollution, feral cats) dangers.

The American Woodcock (*Scolopax minor*) is a migratory gamebird that has experienced prolonged declines through eastern North America. Woodcock breed from the south-eastern United State to southern Canada (March-October) and overwinter primarily in the southeastern United States and mid-Atlantic states (November-February). Migratory ecology remains poorly understood, with most information coming from a limited number of inference areas. A significant knowledge gap exists for woodcock range-wide including phenology, survival, and how breeding latitude relates to wintering latitude.

We plan to deploy approximately 200 GPS transmitters on woodcock prior to fall and spring migration throughout eastern North America. We will track woodcock as individuals travel between breeding and wintering sites, documenting migratory routes, stop-over habitat use, phenology, and survival.

As of October 2018, we have deployed 63 GPS transmitters on pre-migratory woodcock; 7 Maine, 9 New York, 2 Ontario, 12 Pennsylvania, 5 Quebec, 15 Rhode Island, and 3 Virginia. We will track all 63 woodcock through fall migration and plan to deploy another 40 GPS transmitters on wintering woodcock (December 2018-February 2019); 10 Maryland, 15 New Jersey, 8 North Carolina 7 South Carolina. We will track winter deployed transmitters throughout spring migration and anticipate a sub-sample of fall deployed transmitters continuing to transmit locations for spring migration.

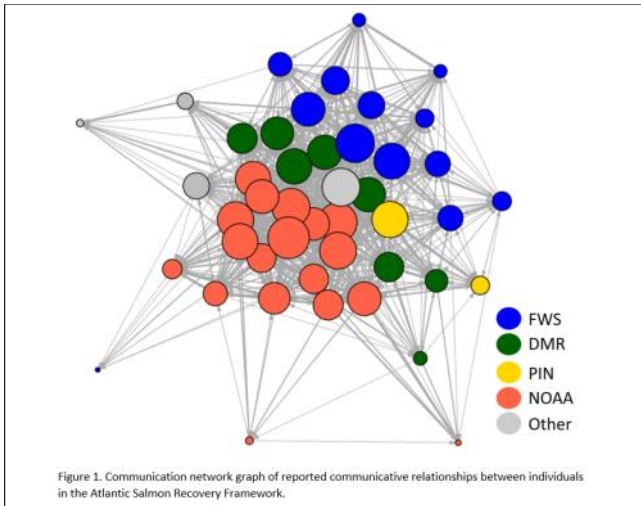
We have commitments to deploy transmitters between the fall and winters of 2019/2020 and 2020/2021, but plan to continue the project as long as interest remains among cooperators. Our project would not be possible without the involvement of state and federal agencies, and non-governmental organizations throughout eastern North America.

Investigator: Alexander Fish (PhD)
Advisors: Erik J. Blomberg (Co-Advisor)
 Amber M. Roth (Co-Advisor)
 Joseph D. Zydlewski
 Erin Simons-Legaard
 Brian J. Olsen

Duration: October 2017—May 2021

Cooperators:

Environment Canada
 Maryland Department of Natural Resources
 New Jersey Department of Environmental Protection
 New York Department of Environmental Conservation
 North Carolina Wildlife Resources Commission
 Pennsylvania Game Commission
 Rhode Island Department of Environmental Management
 South Carolina Department of Natural Resources
 State University of New York -Cobleskill
 The American Woodcock Society
 The Ruffed Grouse Society
 United State Geological Survey – Patuxent Wildlife Research Center
 University of Rhode Island
 Virginia Game Commission



Getting over the dam: Overcoming institutional barriers to the recovery of Atlantic salmon by navigating the social-science/policy interface

1. Investigate how individuals in Atlantic salmon management entities communicate the history of and changes to the management structure over time
2. Evaluate the patterns of communication within and between management entities
3. Investigate member perceptions of management roles and responsibilities
4. Identify opportunities for and barriers to collaboration within and between management entities

Atlantic salmon populations in Maine remain critically low despite hatchery supplementation and habitat improvement efforts over the past four decades. In 2000 the Gulf of Maine Distinct Population Segment was listed as federally endangered with joint listing authority shared by the National Oceanic and Atmospheric Administration and the United States Fish and Wildlife Service. Because, regulators and managers from Federal, State, and Penobscot Nation context operate with independent authorities, recovery decisions depend upon effective communication and coordination. From 1980-2005 management and regulatory bodies, non-profit organizations, and citizens met as a single group, the Maine Technical Advisory Committee (TAC). The dissolution of TAC resulted in reduced coordination across authorities until 2011 when the Atlantic Salmon Recovery Framework (ASRF) was formed. The ASRF is both a management framework and a governance structure which emphasizes coordination and collaboration. We intend to assess the social factors of this governance system using a mixed-methods case study approach involving communication network analysis, semi-

structured interviews, and document analysis. We contend that an evaluation of the interactions among entities may inform the processes by which recovery policies and actions are implemented. Specifically, we intend to characterize institutional barriers and factors that impact Atlantic salmon recovery decision making.

Primary data collection (online network analysis survey, semi-structured interviews) occurred during summer and fall 2018 and is now completed. Quantitative and qualitative data analysis is ongoing.

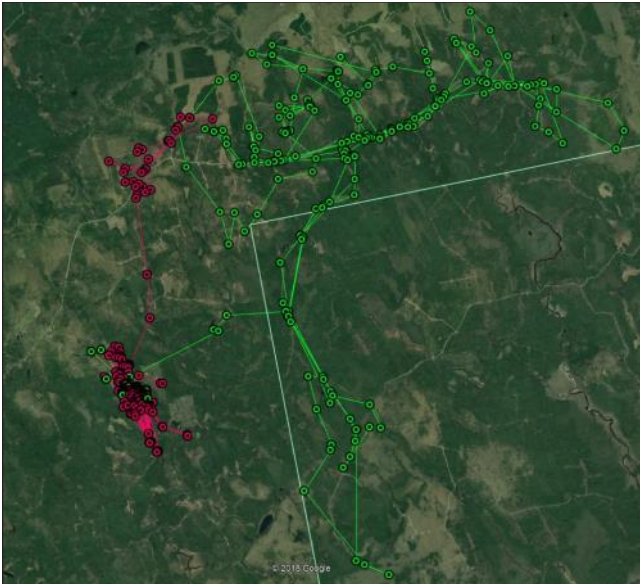
Investigator: Melissa Flye (MS)

Advisors: Carly C. Sponarski (Advisor)
Joseph D. Zydlewski
Bridie McGreavy

Duration: August 2017—December 2019

Cooperators:

University of Maine – Sustainable Solutions Initiative
University of Maine – Maine Agricultural and Forest
Experiment Station
National Oceanic and Atmospheric Administration
U.S. Fish and Wildlife Service
Maine Department of Marine Resources
U.S. Geological Survey – Maine Cooperative Fish and
Wildlife Research Unit



Wild turkey population ecology across land use gradients in Maine

1. Develop a model to estimate wild turkey abundance specific to wildlife management districts in Maine using a band recovery model and harvest information.
2. Develop a multi-scale predictive model for wild turkey nesting habitat based on nest site selection relationships at multiple scales as well as nest success.
3. Use dynamic Brownian Bridge Movement Models to evaluate space use and movement of wild turkeys during different seasons of the year.
4. Create models of nest daily survival rate that accounts for the individual variation that may be caused by differences in hen movement behavior prior to nesting.

This project is focused on trapping and tracking of wild turkeys in Maine to understand the dynamics of their population ecology across a landscape resource gradient. Trapped individuals will be banded for harvest reporting, which will be combined with total harvest information provided by the Maine Department of Inland Fisheries and Wildlife in a Lincoln estimator to estimate population size. We will use VHF and GPS transmitters to monitor hen movements during the prenesting season and to identify nesting behavior. Using this data, we will produce a predictive model of nesting habitat quality that incorporates information on the multiple scales of nest site selection and the probability of nest success. We will use location information from GPS-marked hens in a dynamic Brownian bridge movement model to assess land cover correlates with use a movement behavior during different seasons of the year. This location information will also be used to quantify

different aspects of hen pre-nesting movement behaviors. I will assess whether variation in these movement behaviors affect nest success.

We have currently completed the majority of the pilot year for my dissertation project. In January-March of 2018 we trapped and banded 126 wild turkeys and deployed 54 radio telemetry and GPS transmitters to track individual status and movement of wild turkeys over time. During the 2018 nesting season, we located and monitored 28 nests of our marked hens for daily survival rate. We are currently preparing for the 2019 season in which we will continue to trap and monitor birds across the state. We will be expanding our trapping efforts to include additional regions of Maine for banding and estimation of population size.

Investigator: Matthew Gonnerman (PhD)
Stephanie Shea (PhD)

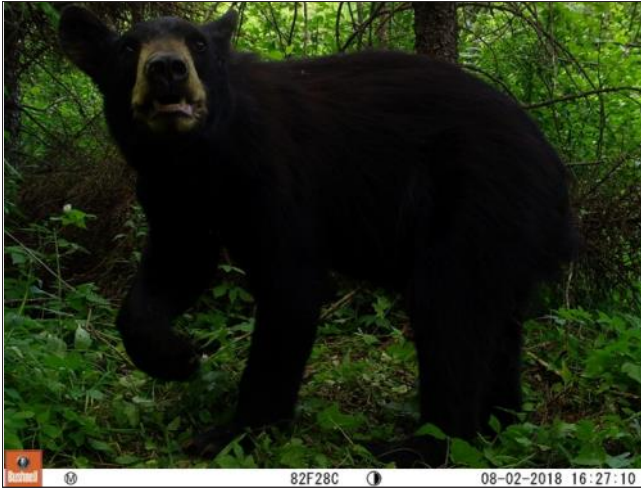
Advisors: Erik J. Blomberg (Advisor)
Kelsey Sullivan
Pauline L. Kamath

Duration: September 2012—January 2017

Cooperators:

Maine Department of Inland Fisheries and Wildlife
National Wild Turkey Federation





Primary data collection (coding media, conducting semi-structured interviews) and quantitative and qualitative data analysis is ongoing. Data analysis will be completed by March, 2019.

Battle over black bears: Investigating perceptions of the black bear hunting referendums in Maine

1. Characterize the role news media played in the 2004 and 2014 black bear hunting referendums.
2. Understand if one “position” towards the bear hunting referendum was portrayed more or less than the other in news media.
3. Investigate varying attitudes, beliefs, and norms shared by those on either side of the debate.
4. Explore black bear hunting as a phenomenon to help characterize its contentious nature in Maine.
5. Characterize institutional barriers and factors that will impact future black bear hunting policy in Maine.

Over the last twenty years, black bear (*Ursus americanus*) management has become one of the most contentious and public political issues in Maine. Approximately 93% of bears are hunted in the state either by baiting, hounding, or trapping; Maine is the only state that still allows all three methods. In 2004 and 2014, referendum questions asked residents whether they support a ban on the baiting, hounding, and trapping of bears in the state—both were narrowly not supported. It is clear that print media played an integral role in informing the public of this issue. We are investigating these records of conflict and debate given its powerful impacts on voting decisions and identifying themes in public discourse. The goal of this assessment is to shed light on the types of information communicated to the public, what were the key issues from both sides of the debate, who were the key stakeholders, and what were the cognitive and emotional components of the persuasive targeting used by stakeholders. Additionally, we will be conducting 10-15 semi-structured interviews to further characterize bear hunting as a phenomenon in Maine.

Investigator: Francesca Gundrum (MS)
Advisors: Carly C. Sponarski (Advisor)
Laura N. Rickard
Sandra De Urioste-Stone

Duration: September 2017—June 2019

Cooperators:

University of Maine – Maine Agricultural and Forest
Experiment Station
Maine Department of Inland Fisheries and Wildlife



Maine amphibian and reptile atlas project update

1. Investigate knowledge gaps in species ranges in the Maine Amphibian and Reptile Atlas Project with field work in the summer of 2018, in coordination with the Maine Department of Inland Fisheries and Wildlife
2. Create material for a Maine Amphibian and Reptile Atlas Project website, in coordination with the Maine Department of Inland Fisheries and Wildlife
3. Publish or otherwise share results of field work during summer 2018 field season.
4. Potentially, assist in the publication of a new edition of the book *Maine Amphibians and Reptiles*.

Reptiles and amphibians are a valued aspect of Maine's natural heritage and an essential component of its ecosystems. Much of the information that we have on Maine reptiles and amphibians comes from database records of the Maine Amphibian and Reptile Atlas Project (MARAP), a citizen science project that was initiated in 1986 by the Maine Audubon Society, the University of Maine, and three other organizations.

Despite this success, there is still much that we do not understand about these species' ranges. Understanding the current ranges of these species is critical to their conservation because we cannot effectively conserve without understanding species' distribution across the state.

The MARAP project update team identified four species of interest—one turtle, one snake, and two frogs—and investigated those species in targeted field work during the summer of 2018. Mr. Lindemann and volunteer citizen scientists undertook field surveys in northern and eastern Maine, documenting all encountered herpetofauna and recording ecological and morphological data.

In addition, Mr. Lindemann is creating material for a MARAP website, in coordination with the Maine Department of Inland Fisheries and Wildlife, and may be helping with the publication of a third edition of the book *Maine Amphibians and Reptiles*.

In progress. Field work has been completed, and results are being prepared for publication. Work on the project website is ongoing; much of the content has been completed and is pending publication on the website.

Investigator: Scott Lindemann (MWC)

Advisors: Aram J.K. Calhoun (Co-Advisor)
Malcolm L. Hunter, Jr. (Co-Advisor)
Phillip deMaynadier
Derek Yorks
Trevor Persons

Duration: August 2018—May 2019

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





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 1-2 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.

From the projects' initiation in September 2015, we have completed soliciting and compiling the necessary data to perform the validation and have completed an assessment and achieved the project objectives.

Investigator: Zachary Loman (Postdoc)

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

Duration: September 2015—September 2018

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



Laying the groundwork for science-based management of colonial waterbirds

1. Evaluate contents of USGS-managed CWBD database and update with data for the eastern US since the database became inactive (~2013), including archived data made available by partners.
2. Provide guidance on coordinated surveys in the eastern US in 2018 for selected species and regions based on consultation with stakeholders and preliminary assessment.
3. Evaluate and revise CWBD user access, data security and quality, meta-data content and quality, and data entry and viewing formats, and facilitate data export for stakeholder use, and work with partners to compile information to inform development of a geospatial user interface for viewing, summarizing, manipulating, and analyzing CWBD contents.
4. Update revised CWBD with completed 2018 survey data provided by partners.
5. Provide guidance for future surveys by standardizing methodologies.
6. Display species trends for select focal species (e.g., Black Skimmer, Laughing Gull) graphically within the CWBD user interface, and evaluate trends and conservation goals.

The CWB database is incomplete, and quality and format of previously contributed data varied. Therefore, we will evaluate current CWBD data protocols and data condition, and work with the Atlantic Marine Bird Cooperative's SCAW-WG, associated subgroups, and state and federal biologists charged with conducting waterbird surveys to facilitate standardizing survey data to enhance accuracy and efficiency for inclusion in the revised CWBD.

We will work with USGS-Patuxent CWBD developers to improve format and accessibility of the database. The web portal will provide a species data summary

and retrieval, and trend analysis. Additionally, we will summarize interviews regarding spatial data display needs to inform development of a geospatial user interface for CWBD contents. We will incorporate 2018 data provided by partners into the CWBD, evaluate and summarize 2018 data, and develop a comprehensive trend analysis of the complete record for each species with adequate data.

We will evaluate data quality and develop summaries of archived data for a subset of CWBD species. We will display trends and compare data among years to provide guidance for improving reliability of trend assessments with additional data. We will assess threats to breeding success and management currently employed to address those threats within the region.

We have updated the CWBD website, and are in the midst of working with partners to collect and collate 2018 MANEM survey data. We have conducted surveys of past efforts and missing existing data from 2013 MANEM surveys. We have collected missing data from several states and incorporated it into a revised and updated CWBD. We have provided states with an updated data entry protocol to provide data for easy entry into the CWBD. We are in the middle of development of a web-based application to provide geographical output of waterbird data, an interface for downloading that data, and a graphical interface for displaying colony and trend data through time and across states and provinces in the Atlantic Flyway.

Investigator: Zachary Loman

Advisors: Cynthia S. Loftin (Advisor)

Duration: July 2018—May 2020

Cooperators:

U.S. Geological Survey – Patuxent Wildlife Research Center

Virginia Department of Game and Inland Fisheries

U.S. Fish and Wildlife Service – Division of Migratory Birds

U.S. Geological Survey – Science Support Program



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; UMaine Department of Wildlife, Fisheries, and Conservation Biology; 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 2018.

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—December 2018

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





Human dimensions of giraffe conservation in northern Kenya

1. Establish baseline measurements of community knowledge, attitudes, and beliefs around human-giraffe interactions.
2. Quantify local levels and identify areas of giraffe part and product usage in and two conservancies.
3. Investigate how estimates of poaching behavior differ between three questioning techniques.
4. Integrate human dimensions data with giraffe movement patterns to inform conservancy management.

Giraffe are icons of Africa, but given their high profile, knowledge about giraffe is surprisingly limited. Population estimates across the continent suggest that giraffe numbers have fallen by about 40% in the last few decades, prompting a reassessment in 2016 by the IUCN that moved their status from “Least Concern” to “Vulnerable.” This rapid decline is mainly thought to be due to habitat loss and fragmentation, land degradation, and poaching. There is yet to be any published literature on the social aspects of giraffe conservation and associated threats, which points to the urgent need for human dimensions (HD) research to inform the many growing conservation efforts.

Despite the prevalence of poaching and connection to decreasing giraffe populations, the factors that influence hunting activity are not well understood. This research will estimate levels of giraffe part and product usage among two pastoralist communities in northern Kenya and assess the relationships between key cognitions, like attitudes, norms, and beliefs, with poaching-related behaviors.

My PhD research is part of a larger conservation program, based at the research arm of the San Diego Zoo. The giraffe research program began in May 2016, and I have been leading the training and

coordination of our field team. Preliminary data has been collected and now we are analyzing data for reports and my thesis.

Investigators: Kirstie Ruppert (PhD)

Advisors: Carly C. Sponarski (Co-Advisor)
Jenny A. Glikman (Co-Advisor)
Sandra De Urioste-Stone
Laura N. Rickard
Caroline L. Noblet

Duration: January 2017—December 2019

Cooperators:

The Nature Conservancy
Northern Rangelands Trust
San Diego Zoo Global
Giraffe Conservation Foundation





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

1. Estimate demographic rates of spruce grouse, including adult survival, 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 select resources and how these choices affect demographic rates during important life history phases such as nesting, brood rearing, and dispersal.
3. Relate objectives one and two 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 are using radio telemetry and mark-recapture methods to collect data on survival and reproductive success of marked individuals. Survival is being evaluated year-round, as well as during distinct biological seasons (e.g. breeding vs. overwinter). Reproductive success is being monitored during the spring and summer breeding season (May - August). We are monitoring birds in

areas of varying forest composition and silvicultural activities, and have sampled vegetation characteristics at the micro-site scale as well as to characterize habitat at a larger scale that would likely be used on a daily or seasonal basis. 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.

Field work was completed during fall 2018. We monitored 150 radio-marked spruce grouse during our 6-year study, and located and monitored 26 nests, 60 broods, 43 juvenile and 116 adult spruce grouse. We collected >1,000 spruce grouse locations that contributed to our understanding of spruce grouse use of commercial forest stands. Analyses are ongoing and reports to funding organizations are being prepared. The primary graduate student has taken a temporary leave of absence and comprehensive examinations and completion of the dissertation will be primary future activities in 2019 and 2020.

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—September 2020

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
 Baxter State Park
 Katahdin Forest Management
 Gerald Pelletier, Inc.



Bicknell's Thrush distribution and habitat relationships on commercial forestlands in Maine

1. Identify forest structure characteristics associated with breeding habitat selection by Bicknell's Thrush on commercial forestlands in Maine at multiple scales, both above and below the traditional elevation threshold for the species.
2. Identify novel, LiDAR-derived forest structure estimates that explain Bicknell's Thrush habitat selection.
3. Evaluate the influence of forest characteristics on Bicknell's Thrush nest survival.
4. Obtain or recreate forest management records to describe the management history that has resulted in the occupied breeding habitat.

Bicknell's Thrush (*Catharus bicknelli*; BITH) is a rare, range-restricted habitat specialist occurring in balsam fir-dominated montane forests that have been recently disturbed and are undergoing successional growth. The species traditionally occurs at elevations above 800 meters in the U.S., but if suitable habitat is available BITH can occur at elevations below this threshold. The potential for suitable habitat at lower elevations exists in Maine because of the state's unique distribution of tree communities, and due to changes in forest structure and composition brought about by forestry practices. The extent to which BITH use regenerating fir stands at lower elevations in Maine, however, remains unknown. Further, while best management practices (BMPs) have been developed for Canada and the U.S., they have not been applied and evaluated in Maine. By means of telemetry, resource selection functions and LiDAR, this research aims to understand the use and availability of breeding habitat for BITH in commercial forestlands in Maine. The research will produce a detailed description of BITH use of commercially managed fir-spruce forests in Maine. Furthermore, the research will contribute to the eventual development of Maine-specific forest

BMPs to provide high quality breeding habitat for BITH while meeting commercial forest landowner objectives

During the 2018 breeding season, we captured 22 Bicknell's Thrush and fitted 20 of these individuals with a VHF-radio transmitter. Of the 20 tagged birds, 13 were tagged in a harvested landscape at Kibby Mountain and seven were tagged in an unharvested landscape at Mt. Redington. We successfully tracked 11 birds throughout the breeding season (six at Kibby Mountain, and five at Mt. Redington) and obtained at least 40 relocations per individual. In addition to tracking efforts, preliminary forest measurements were collected for use in ground-truthing LiDAR models. We also located three nests during tracking efforts, one of which fledged successfully while the other two were predated. Currently, home-range analysis is underway, as well as efforts to validate LiDAR models for use at our study areas. We are also currently investigating the use of archival GPS tags for the 2019 breeding season.

Investigator: Kaitlyn Wilson (MS)

Advisors: Amber M. Roth (Advisor)
Erik J. Blomberg
Daniel J. Hayes
Adrienne J. Leppold

Duration: August 2017—May 2020

Cooperators:

University of Maine – Maine Agricultural and Forest
Experiment Station
University of Maine
University of Maine – Maine Cooperative Forestry
Research Unit
The Nature Conservancy
U.S. Navy
Weyerhaeuser





Effects of 30 years of extensive forest change on American marten stand-scale selection

1. Quantify the current stand-scale (within home range) habitat selection of American marten and assess longitudinal responses in selection by marten to changes in forest type availability by modeling marten habitat selection as a function of year and habitat availability using data from three studies conducted in the same study area (1989-1990, 1994-1997, 2018-2019) with differing habitat configuration and composition.
2. Assess stand-scale marten habitat selection response to forest edges across all study years by identifying and classifying edges within home ranges and analyzing differences between observed and expected distance from forest edges within used habitat patches.

We will replicate resident marten trapping protocols conducted by studies in 1989-1990 and 1994-1997 during 2018 and 2019. Captured marten will be chemically immobilized, ear-tagged, fitted with VHF collars, and their sex, reproductive status, morphometric measurements, and age from tooth extraction and subsequent cementum analysis will be determined. Marten will be located approximately 50 times during the leaf-on season. Current (2018-2019) and historical (1989-1990, 1994-1997) forest type maps based on harvest history, species composition, canopy cover and tree height will be used to quantify stand-scale habitat availability, use and selection across this 30-year period. We will model selection as a function of sex, study-year, and availability of suitable habitat to evaluate longitudinal responses in selection by marten to cumulative changes in forest composition, age, and configuration in extensively managed area.

To investigate the potential effect of forest edges on stand-scale habitat selection we will evaluate differences in the observed and expected distance from forest edges of marten locations using edge type and

forest type as covariates. We anticipate that our findings will help inform future marten conservation and provide an evaluation of stand-scale responses of an area-sensitive, forest obligate umbrella species to cumulative changes in habitat composition and configuration.

We conducted our first season of field work between May and October, 2018, during which time we captured seven male and two female marten; we were able to consistently track five individuals. We collected an average of 45 radio locations for each animal and have generated home ranges for each tracked marten. We are in the process of developing a current forest type classification map consistent with the classification schemes used in previous studies. We will replicate our trapping and tracking protocols in the summer of 2019, during which time we will also ground-truth our forest type map. All data collection will be completed by October 2019 and we anticipate project and thesis completion by August, 2020.

Investigator: Tyler Woollard (MS)

Advisors: Daniel J. Harrison (Advisor)

Duration: May 2018—August 2020

Cooperators:

University of Maine – Maine Agricultural and Forest Experiment Station

University of Maine – Maine Cooperative Forestry Research Unit





Eco-evolutionary implications of environmental change
across developing landscape 51

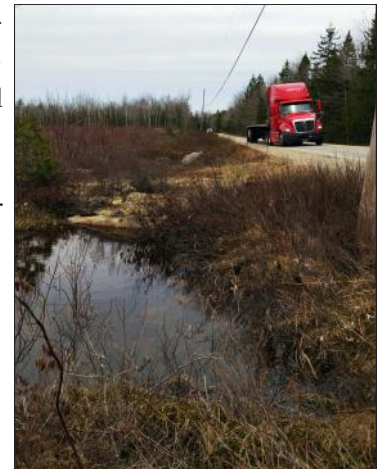


Eco-evolutionary implications of environmental change across developing landscape

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

ABSTRACT: Species use a variety of mechanisms to adapt to environmental change. These range from spatially tracking optimal environments, to phenotypically plastic responses and evolutionary adaptation. Due to increases in anthropogenic influence on environments, characteristics of change such as their duration and magnitude are undergoing fundamental shifts away from the natural disturbance regimes that shaped species' evolution. This dissertation uses empirical data and simulation models to examine the ecological and evolutionary consequences of environmental change across real, heterogeneous landscapes for multiple species, with an emphasis on anthropogenic changes. I used landscape genetics to evaluate the effects of urbanization on two native amphibian species, spotted salamanders (*Ambystoma maculatum*) and wood frogs (*Lithobates sylvaticus*). Population isolation was positively associated with local urbanization and lessened genetic diversity for both species. Resistance surface modelling revealed connectivity was diminished by developed land cover, light roads, interstates, and topography for both species, plus secondary roads and rivers for wood frogs, highlighting the influence of anthropogenic landscape features relative to natural features. Further study of a subset of wood frog populations revealed adaptive evolution associated

with urban environments. I identified a set of 37 loci with the capacity to correctly reassign individuals into rural or urban populations with 87.5 and 93.8% accuracy, respectively. I developed an agent-based model to examine how gene flow, rates of change, and strength of landscape spatial and temporal autocorrelation influence abundance outcomes for species experiencing an environmental shift. Analysis of 36 environmental scenarios suggests that environmental variation, which is an emergent property of landscape autocorrelation, is negatively associated with the magnitude and duration of abundance declines following environmental change. Higher levels of gene flow lessened this effect, particularly in abrupt change scenarios, although gradual changes also resulted in demographic costs. Lastly, I used an investigation of an emerging disease in American lobsters (*Homarus americanus*) to study within-generation responses to environmental pressures. Using whole transcriptome shotgun sequencing I identified eight differentially expressed unigenes associated with the disease and seven related to environmental differences. Collectively, my dissertation provides numerous examples of how anthropogenically induced environmental change can direct ecological and evolutionary processes.



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—August 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)





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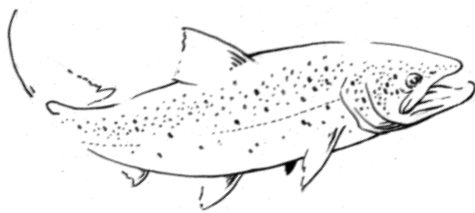
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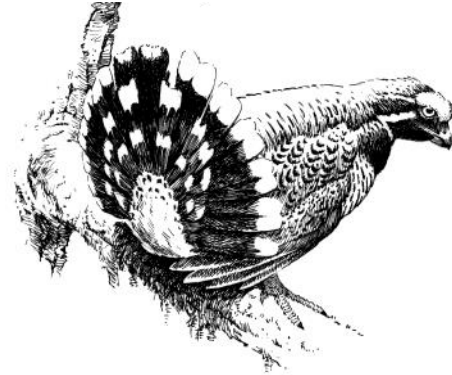
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Ames, C., Neary, M., Pettigrew, N., Kinnison, M., Zydlewski, J., and Zydlewski, G. (2018) "Population characteristics of sub-adult Atlantic Sturgeon in the Penobscot River, Maine". Maine Cooperative Fish and Wildlife Research Unit Cooperator's Meeting, March 22, Orono, ME.

Ames, C., Neary, M., Pettigrew, N., Kinnison, M., Zydlewski, J., Zydlewski, G. (2018) "Use of a slocum glider for active tracking and winter habitat description of Atlantic Sturgeon (*Acipenser oxyrinchus*) in mid-coast Maine". 148th Annual Meeting of the American Fisheries Society, August 20, Atlantic City, NJ.

Ames, C., Zydlewski, G., Kinnison, M., and Zydlewski, J. (2018) "Population-level responses of sturgeon to dam removals in Maine". 74th Annual Northeast Fish & Wildlife Conference, April 15, Burlington, VT.

- Ames, C., Zydlewski, G., Kinnison, M., and Zydlewski, J. (2018) "Population characteristics of sub-adult Atlantic Sturgeon (*Acipenser oxyrinchus*) in the Penobscot River, Maine". 2018 Atlantic salmon ecosystems forum, January 17, University of Maine, Orono, ME.
- Barber, B., Gibson, J., Molina Moctezuma, A., and Zydlewski, J. (2018) "A tool for understanding likely fish passage and harvest management outcomes for alewife on the St. Croix River, Maine". 148th Annual Meeting of the American Fisheries Society, August 20, Atlantic City, NJ. Poster.
- Barber, B., Gibson, J., O'Malley, A., and Zydlewski, J. (2018) "Exploring how a range of management objectives could affect alewife population recovery". 148th Annual Meeting of the American Fisheries Society, August 20, Atlantic City, NJ.
- Barber, B., Gibson, J., O'Malley, A., and Zydlewski, J. (2018) "Marine-derived nutrient cycling in the St. Croix River, Maine". Maine Cooperative Fish and Wildlife Research Unit Cooperator's Meeting, March 22, University of Maine, Orono, ME.
- Blomberg, E. 2017. "Two birds, one stone; bringing basic perspectives to applied research on eastern gamebirds". University of New Hampshire Environmental Sciences Series, November 3, Durham, NH.
- Blomberg, E. 2017. "Where to stay and when to go: American woodcock migration ecology at an important stopover: Cape May, New Jersey". American Woodcock Symposium, October 24-27, Roscommon, MI.
- Blomberg, E. 2018. "Twenty five years of change in spruce grouse occupancy on Mount Desert Island, Maine". American Ornithological Society Conference, April 9-14, Tucson, AZ.
- Calhoun, A. 2017. "Conserving small natural features: A Maine case study with vernal pools". San Diego Zoo, 29 November, San Diego, CA.
- Calhoun, A. 2018. "Citizen Science data collection for vernal pools using middle school students". Gulf of Maine Research Institute, May 8, Webinar.
- Calhoun, A. 2018. "Conserving wetlands at a landscape scale: training for EPA Region 1". Environmental Protection Agency, Region 1, 17 August, Webinar.
- Calhoun, A. 2018. "The Maine vernal pool special area management plan and field trip". Bangor Land Trust, 16 May, Bangor, ME.
- Calhoun, A. 2018. "The Maine vernal pool special area management plan and field trip". Friends of Sears Island, 9 May, Searsport, ME.
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- Calhoun, A. 2018. "The Maine vernal pool special area management program". Darling Marine Center, 2 May, Walpole, ME.
- Calhoun, A. 2018. "The Maine vernal pool special area management program". Gulf of Maine Research Institute, 8 May, Webinar.
- Calhoun, A. 2018. "The Maine vernal pool special area management program". Kennebec Land Trust Lyceum, 29 April, Wayne, ME.
- Calhoun, A. 2018. "The Maine vernal pool special area management program". Wells Estuarine Reserve, 24 April, Wells, ME.

Coghlan Jr., S.M. 2018. “Fish Ecology and Dam Removal”. Guest lecture / expert opinion given at Town of Danforth / Baskahegan Lake Stakeholder’s Meeting, April 12, Danforth, ME.

Coghlan Jr., S.M. and J.V. Mead. 2018. “Energy Return on Investment of “living off the land”: natural production, human labor, and petroleum subsidies required to support a rural Maine homestead”. Presented at the 9th Annual Conference of the International Society of Biophysical Economics, June 15, Wells College, Aurora, NY.

Coghlan, S. 2018. “Energy, economics, and climate change: connecting the dots”. Panel presentation / discussion, Honors Program Climate Change Symposium, April 26, University of Maine, Orono, ME.

Coghlan, S. 2018. “Energy, economics, and climate change: connecting the dots”. School of Social Work’s Symposium on Human Impacts of Climate Change, May 5, University of Maine, Orono, ME.

Coghlan, S. 2018. “Energy, economics, and climate change: connecting the dots”. Keynote Address to Alliance for the Common Good’s annual assembly at Hall of Flags, Maine Statehouse, January 18, Augusta, ME.

Du Clos, B., C.S. Loftin, F. Drummond, and P. deMaynadier. 2018. “Rights-of-way management for native insect pollinators in the northeastern USA: literature meta-analysis and preliminary summary of Maine’s bumblebee and butterfly roadside surveys”. Presentation at the Northeastern Transportation and Wildlife Conference, 9-12 September, Amherst, MA.



DuClos, B. C.S. Loftin, and F. Drummond. 2017. “Improving parameterization of a predictive bee abundance model in a complex landscape”. Annual meeting of the Entomological Society of America, 5-8 November, Denver, CO.

Fagan, K.E., E.V. Willcox, L.T. Tran, R.F. Bernard, and W.H. Stiver. 2017. “Roost selection by bats in buildings of Great Smoky Mountains National Park”. Paper presented at 47th Annual Symposium of the North American Society for Bat Research, 18-21 October, Knoxville, TN.

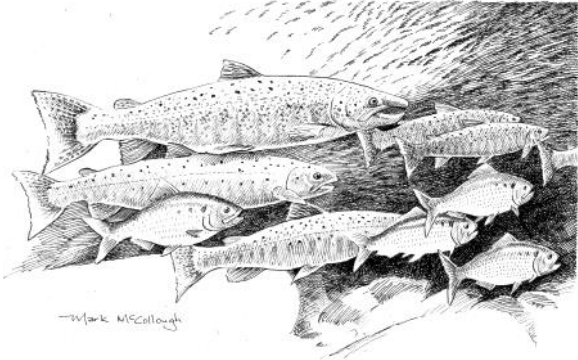
Flye, M., Sponarski, C., Zydlewski, J., McGreavy, B., and Strong, A. (2018) “Getting over the dam: Overcoming the barriers to Atlantic salmon recovery by navigating the social science/policy interface”. Maine Cooperative Fish and Wildlife Research Unit Cooperator’s Meeting, March 22, University of Maine, Orono, ME.

Flye, M.E., Sponarski, C.C., McGreavy, B., Strong, A.L. and Zydlewski, J. (2018) “Getting over the dam: Overcoming institutional barriers to the recovery of Atlantic salmon by navigating the social-science/policy interface”. 2018 Atlantic Salmon Ecosystems Forum, January 17, University of Maine, Orono, ME. Poster.

Hawkes, J., Kocik, J., Zydlewski, J., Stich, D., Sheehan, T., Goulette, G., and Renkawitz, M. (2018) “Atlantic salmon: Assessments through the estuary and beyond”. 74th Annual Northeast Fish & Wildlife Conference, April 15, Burlington, VT.

Hawkes, J., Kocik, J., Zydlewski, J., Stich, D., Sheehan, T., Goulette, G., and Renkawitz, M. (2018) “Atlantic salmon: Assessments through the estuary and beyond”. Salmon Ocean Ecology Meeting, February 27, Newport, OR.

Heres, B., Zydlewski, J., and Blomberg, E. (2018) “Survival and delay of American eel (*Anguilla rostrata*) through two hydroelectric dams on the Penobscot River, Maine”. 2018 Atlantic Salmon

- Ecosystems Forum, January 17, University of Maine, Orono, ME.
- Hoffmann, K., T. Hastings, M. Jones, A. Calhoun, and M. Hunter. 2018. "Wood frog movement and habitat selection in urban settings". Presented at the Northeast Natural History Conference, April 13, Burlington, VT.
- Homola, J.J., K.M. Cammen, C.S. Loftin, C.C. Helbing, I. Birol, T.F. Schultz, and M.T. Kinnison. 2018. "Replicated landscape genomic study design identifies evidence of local adaptation to urbanization in a pool-breeding amphibian species". Presentation at the 103rd Annual Meeting of the Ecological Society of America, 5-10 August, New Orleans, LA.
- Homola, J.J., M.T. Kinnison, and C.S. Loftin. 2018. "Landscape genetics reveals differing effects of urbanization for two sympatric pool-breeding amphibian species". Presentation at the Annual Meeting of the Society of Freshwater Science, 20-24 May, Detroit, MI.
- Hunter, M.L. and A. JK Calhoun. 2017. "Conserving small natural features with large ecological roles". San Diego Zoo, 29 November, San Diego CA.
- Hunter, M.L. and A. JK Calhoun. 2017. "Conserving small natural features with large ecological roles". Northern Prairies Research Center, 11 June, Jamestown, ND.
- Hunter. 2017. "History and overview of the Holt Research Forest". Holt Research Forest Workshop, 5 October, Bath, ME.
- Hunter. 2017. "History and overview of the Holt Research Forest". Holt Research Forest Workshop, 13 December, Orono, ME.
- Izzo, L.K., D.L. Parrish, G.B. Zydlewski, and C. MacKenzie. 2018. "Estimating abundance of spawning lake sturgeon in the Winooski River, VT using dual-frequency identification sonar (DIDSON)". 74th annual Northeast Fish and Wildlife Conference, 15-17 April, Burlington, VT.
- Job, K., Schaffler, J., and Zydlewski, J. (2018) "Estuarine habitat use and spawning demographics of American Shad in the Penobscot River before dam removal". 148th Annual Meeting of the American Fisheries Society, August 20, Atlantic City, NJ.
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- Job, K., Schaffler, J., and Zydlewski, J. (2018) "Using otolith microchemistry to infer habitat use of American shad, Atlantic tomcod, and American eel prior to and following dam removals in the Penobscot River, Maine". Maine Cooperative Fish and Wildlife Research Unit Cooperator's Meeting, March 22, University of Maine, Orono, ME.
- Job, K., Zydlewski, J., and Schaffler, J. (2018) "Using otolith microchemistry to infer habitat use of American shad prior to dam removal in the Penobscot River, Maine". 2018 Atlantic Salmon Ecosystems Forum, January 17, University of Maine, Orono, ME. Poster.
- Kocik, J.F., Cieri, M., Goulette, G., Manning, J., Renkawitz, M., Sheehan, T., Tierney, D., Welch, L., and Zydlewski, J. (2018) "Partitioning the big blue box: A synthesis of marine and estuary action team science". 2018 Atlantic Salmon Ecosystems Forum, January 17, University of Maine, Orono, ME.
- Loman, Z., D. Harrison, B. Rolek, W. Deluca, C. Loftin, and P. Wood. 2018. "Latent indicators and bayesian model selection in identifying forest bird habitat modeling error". Paper presented at American Ornithological Society Meeting, April 12, Tucson, AZ.

Loman, Z., W. Deluca, D. Harrison, C. Loftin, B. Rolek, and P.B. Wood. 2018. "Identifying error in forest landscape capability models". 136th American Ornithological Society Meeting, 9-14 April, Tucson, AZ.

Molina Moctezuma, A., and Zydlewski, J. (2018) "Assessing Atlantic salmon downstream migration in a changing system (Penobscot River, Maine)". Maine Cooperative Fish and Wildlife Research Unit Cooperator's Meeting, March 22, Orono, ME.

Molina Moctezuma, A., and Zydlewski, J. (2018) "System-wide survival of downstream-migrating Atlantic salmon smolts in the Penobscot River, Maine in 2017". 148th Annual Meeting of the American Fisheries Society, August 20, Atlantic City, NJ.

Molina-Moctezuma, A., and Zydlewski, J. (2018) "A decision-making tool for evaluating biological and statistical thresholds for survival analysis". 74th Annual Northeast Fish & Wildlife Conference, April 15, Burlington, VT.

Molina-Moctezuma, A., and Zydlewski, J. (2018) "System-wide survival of downstream-migrating Atlantic salmon smolts in the Penobscot River, Maine". 2018 Atlantic Salmon Ecosystems Forum, January 17, University of Maine, Orono, ME.

Peterson, E., Maynard, G. and Zydlewski, J. (2018) "Penobscot River Restoration Project, Upstream migrations on the Penobscot River, Maine". Maine Cooperative Fish and Wildlife Research Unit Cooperator's Meeting, March 22, University of Maine, Orono, ME.

Peterson, E., Sheehan, T. and Zydlewski, J. (2018) "Verification of circulus deposition rates in Atlantic salmon, *Salmo salar*, smolts from three Maine rivers". 148th Annual Meeting of the American Fisheries Society, August 20, Atlantic City, NJ.

Peterson, E., Sheehan, T.F., and Zydlewski, J. (2018) "Verification of circulus deposition rates in Atlantic salmon *Salmo salar* smolts

from three Maine rivers". 2018 Atlantic Salmon Ecosystems Forum, January 17, University of Maine, Orono, ME.

Rolek, B.W., D. Harrison, C.S. Loftin, P.B. Wood. 2018. "Softwood forest birds and forestry in New England". Presentation to Cooperating Committee Meeting for Maine Cooperative Fish and Wildlife Research Unit, March 22, Orono, ME.



Roy, S., Uchida, E., Wilson, K., Neptune, S., Gold, A., Gardner, K., Klein, S., Fox, E., Smith, S., Zydlewski, J., and Hart, D. (2018) "How interdisciplinary approaches to big data analytics can strengthen the role of science in dam decisions". Society for Freshwater Science, May 20, Detroit, MI.

Rubenstein, S., Jayasundara, N., and Zydlewski, J. (2018) "Energetic impacts of passage delays in migrating adult Atlantic salmon". Maine Cooperative Fish and Wildlife Research Unit Cooperator's Meeting, March 22, University of Maine, Orono, ME.

Rubenstein, S., Jayasundara, N., and Zydlewski, J. (2018) "Energetic impacts of passage delays in migrating adult Atlantic salmon". 148th Annual Meeting of the American Fisheries Society, August 20, Atlantic City, NJ. Poster.

Song, C., Mo, W., Zydlewski, J., and O'Malley, A. (2018) "System dynamics modeling of energy and fish tradeoffs under various dam decision scenarios". International Symposium for Sustainable Systems and Technology, June 25, Buffalo, NY.

Sponarski, C. 2018. "Battle over black bears (*Ursus americanus*): A media analysis of the 2014 black bear referendum". Maine Cooperative Fish and Wildlife Research Unit 2018 Coordinating Committee Meeting, March 22, University of Maine, Orono, ME.

Sponarski, C. 2018. "Evaluating perceptions of deer feeding in New Brunswick". Maine Cooperative Fish and Wildlife Research Unit 2018 Coordinating Committee Meeting, March 22, University of Maine, Orono, ME.



Sponarski, C. 2018. "Getting over the dam: Overcoming barriers by navigating the social science/policy interface". 2018 Atlantic Salmon Ecosystems Forum, January 17, University of Maine, Orono, ME.

Sponarski, C. 2018. "Getting over the dam: Overcoming barriers by navigating the social science/policy interface". Maine Cooperative Fish and Wildlife Research Unit 2018 Coordinating Committee Meeting, March 22, University of Maine, Orono, ME.

Sponarski, C. 2018. "How social trust can influence ecosystem management in coastal New Brunswick, Canada". Pathways to Success Africa, January 8, Fort Collins, CO.

Sponarski, C. 2018. "Living with giraffe: Conserving Africa's towers". Pathways to Success Africa, January 8, Fort Collins, CO.

Sponarski, C. 2018. "Long term effects of experiential learning on attitudes".

Pathways to Success Africa, January 8, Fort Collins, CO.

Sponarski, C. 2018. "Taking towers: Poaching as a threat to giraffe in northern Kenya". Maine Cooperative Fish and Wildlife Research Unit 2018 Coordinating Committee Meeting, March 22, University of Maine, Orono, ME.

Vogel, S., Jansujwicz, J., and Zydlewski, J. (2018) "Fish passage at hydropower dams on the Penobscot and Kennebec Rivers: A content analysis of the FERC eLibrary database". 2018 Atlantic Salmon Ecosystems Forum, January 17, University of Maine, Orono, ME.

Vogel, S., Jansujwicz, J., and Zydlewski, J. (2018) "The role of science in hydropower licensing: Lessons from the Kennebec and Penobscot Rivers, Maine". 148th Annual Meeting of the American Fisheries Society, August 20, Atlantic City, NJ.

Vogel, S., Jansujwicz, J., and Zydlewski, J. (2018) "Unraveling the FERC eLibrary: fish passage and hydro relicensing". Maine Cooperative Fish and Wildlife Research Unit Cooperator's Meeting, March 22, University of Maine, Orono, ME.

Weaver, D., Brown, M., and Zydlewski, J. (2018) "Behavior of American shad approaching the Brunswick dam fishway on the Androscoggin River, Maine". 148th Annual Meeting of the American Fisheries Society, August 20, Atlantic City, NJ.

Weaver, D.M., Coghlan Jr., S.M, and Zydlewski, J. (2018) "Closing the Loop': Anadromous sea lamprey carcasses influence larval conspecifics". New York Chapter of the American Fisheries Society Annual Meeting, February 7, Cooperstown, NY.

Weaver, D.M., Coghlan Jr., S.M, and Zydlewski, J. (2018) "Closing the Loop': Anadromous sea lamprey carcasses influence larval conspecifics". 2018 Atlantic Salmon

Ecosystems Forum, January 17, University of Maine, Orono, ME.

Zydlewski, J., Blomberg, E., and Job, K. (2018) "Dam influences on habitat use and migratory survival of American Eel in the Penobscot River, Maine". 148th Annual Meeting of the American Fisheries Society, August 20, Atlantic City, NJ.

Zydlewski, J., Maynard, G., Molina-Moctezuma, A., Stich, D., and Zydlewski, G. (2018) "Understanding fish passage in a changing system- lessons from restoration efforts in the Penobscot River". 74th Annual Northeast Fish & Wildlife Conference, April 15, Burlington, VT.

Zydlewski, J., Molina-Moctezuma (2018) "Understanding fish passage in a changing system- lessons from restoration efforts in the Penobscot River". 2018 Maine Sustainability & Water Conference, March 29, Augusta Civic Center, Augusta, ME.

WORKSHOPS, NEWSPAPER, RADIO, TELEVISION INTERVIEWS/ARTICLES

Loftin, C. 2018. Freshwater mussels research featured on State of Maine's myloonplate.com web page (describes collaborative research with J. Rhymer on Maine's freshwater mussels).



Loftin, C. 2018. Interview with Big Sky productions; documentary about pollinator conservation, September 1.

Vogel, S. 2018. "How do dam decisions get Made?" Senator George J. Mitchell Center for Sustainability Solutions, February 13, University of Maine, Orono, ME.

Sponarski, C. 2018. "Industrial-scale' feeding of deer is making them less wild: biologist." Telegraph-Journal, March 29, New Brunswick, Canada.

Sponarski, C. 2018. "UMaine researchers get \$1.17M to help protect forest workers from tick-borne illnesses." Mainebiz, July 19, Portland, ME.

AWARDS

Brehm, A. 2018. Chase Distinguished Research Assistantship. University of Maine, Orono, ME.

Brehm, A. 2018. Edith Patch Award. Friends of Dr. Edith Marion Patch, Orono, ME.

Brehm, A. 2018. Outstanding Graduate Student Award. Department of Wildlife, Fisheries, and Conservation Biology; University of Maine; Orono, ME.

Brehm, A. 2018. Outstanding Master's Degree Student Award. College of Natural Sciences, Forestry, and Agriculture; University of Maine; Orono, ME.

Buckardt, A. 2018. Edith Patch Award. Friends of Dr. Edith Marion Patch, Orono, ME.

Buckardt, A. 2018. Howard L. Mendall Memorial Scholarship. Department of Wildlife, Fisheries, and Conservation Biology; University of Maine; Orono, ME.

DeFranco, E. 2018. Foreign Language and Areas Studies Award. Canadian-American Center, University of Maine, Orono, ME.

Gundrum, F. 2018. Graduate Trustee Tuition Scholarship. The Graduate School, University of Maine, Orono, ME.

Job, K. 2018. Penobscot County Conservation association – Horace Bond Memorial Scholarship. Department of Wildlife, Fisheries, and Conservation Biology; University of Maine; Orono, ME.

- Loftin, C. 2018. Selected by the USGS for Cohort 13, National Conservation Leadership Institute.
- Loftin, C. and J. Zydlewski. 2018. CRU Unit Science Award, USGS-CRU.
- Ramberg-Pihl, N. 2018. Penobscot County Conservation association – Horace Bond Memorial Scholarship. Department of Wildlife, Fisheries, and Conservation Biology; University of Maine; Orono, ME.
- Rolek, B. 2018. Summer Dissertation Writing Fellowship, June through August 2018. University of Maine Graduate School, University of Maine, Orono, ME.

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