Maine Cooperative Fish and Wildlife Research Unit and Department of Wildlife Ecology, University of Maine

2011 Report to Cooperators

UNIT COOPERATORS

University of Maine

Maine Department of Inland Fisheries and Wildlife

U.S. Geological Survey

United States Fish and Wildlife Service

Wildlife Management Institute

Compiled and Edited by
Cynthia S. Loftin, Rena A. Carey, and Julie A. Nowell

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

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

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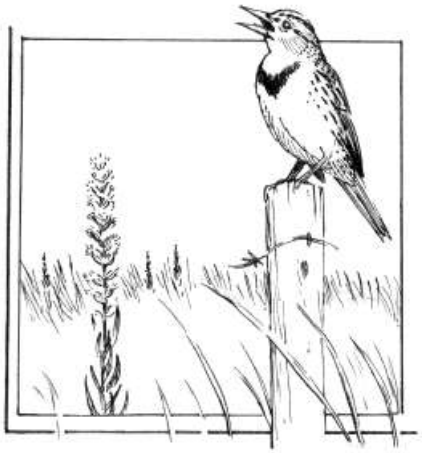
MISSION Statement

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 coordinated 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., four-toed salamanders, freshwater mussels, Atlantic salmon, brook trout, Canada lynx, and marsh birds); (2) management and habitat-related studies with special reference to the effects of land and water-use practices (e.g., logging, 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 Ecology are pleased to summarize the past year's accomplishments and activities in this annual report. Together, we have collaborated with scientists from State and Federal agencies, universities, and non-governmental organizations on 32 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. 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 projects into three categories (Fisheries and Aquatic, Wildlife and Habitats, Integrated Ecology) to capture our program variety. This report includes summaries of research ranging from defining species-habitat relationships to modeling species responses to habitat change or management actions to developing tools to integrate public input into natural resource management decisions. Many of these projects are recently begun, some are long-term studies, and several have been completed during the past year. The majority of our research is conducted as part of graduate degree programs; during the past year, Unit and Department faculty mentored 32 graduate students, and 8 graduate students completed requirements for M.S. or Ph.D. degrees. Our new graduates are working for universities and state and federal agencies, as well as pursuing additional graduate degrees.

The year brought several changes to the Unit and its cooperators. Dr. William Krohn retired after 27 years as Unit Leader and 39.5 years of federal service, and Dr. Cynthia Loftin now serves as the Maine Unit Leader. The vacancy created by Dr. Loftin's reassignment will be filled by a new Assistant Unit Leader-Wildlife in 2012. The Wildlife Ecology Department became the home for the Ecology and Environmental Sciences undergraduate and graduate degree programs, directed by Dr. Aram Calhoun. Dr. Mac Hunter revised the Master of Wildlife Conservation non-thesis program, and the first three graduate students joined the department in the Fall 2011 semester. Other changes are on the horizon for the department, as long time Chair, Dr. Jim Gilbert, prepares for retirement in early 2012. The Maine Department of Inland Fisheries and Wildlife welcomed several new upper level staff to their programs. During the past year we have had opportunities to build relationships with newly hired scientists and administrators in the Maine Department of Inland Fisheries and Wildlife, and we look forward to working with them to address their resource management information needs.

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

COOPERATING AGENCIES

UNIVERSITY OF MAINE

Dr. Michael Eckardt, Vice President for Research

Dr. Jim Gilbert, Chair: Department of Wildlife Ecology

MAINE DEPARTMENT OF INLAND FISHERIES AND WILDLIFE

Mr. John Boland, Director, Bureau of Resource Management

U.S. FISH AND WILDLIFE SERVICE

Ms. Laury Zicari, Supervisor, Maine Field Office

U.S. GEOLOGICAL SURVEY

Dr. B. Ken Williams, 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 Assistant Professor of Wildlife Ecology

William B. Krohn, Retired Professor of Wildlife Ecology, and Cooperating Professor of Zoology

SUPPORT STAFF

Rena Carey, Administrative Assistant

Julie Nowell, Secretary

COLLABORATING AGENCIES AND ORGANIZATIONS

American Philosophical Society
American Recovery and Reinvestment Act (ARRA)
Atlantic Salmon Federation
Biodiversity Research Institute
Biology Department, Acadia University, Nova Scotia, Canada
Biology Department, SUNY Potsdam, NY
Centro de Ecologia Aplicada & CONAMA (National Environment Commission)
Connecticut Department of Energy and Environmental Protection
Cooperative Fish and Wildlife Research Unit, University of Massachusetts,
Eastern Maine Conservation Initiative
Holt Woodlands Research Foundation
Lakes Environmental Association
Maine Aquaculture Innovation Center
Maine Association of Wetland Scientists
Maine Audubon Society
Maine Bureau of Parks and Lands
Maine Congress of Lake Associations
Maine Department of Environmental Protection
Maine Department of Inland Fisheries and Wildlife
Maine Department of Marine Resources
Maine Outdoor Heritage Fund
Maine River Bird Volunteer Network
Maine Sea Grant
Maine Volunteer Lake Monitoring Program
Maine Water Resources Research Institute
Massachusetts Division of Fisheries and Wildlife
National Fish and Wildlife Foundation
National Oceanic and Atmospheric Administration
National Park Service
National Science Foundation
New Hampshire Fish and Game Department
New York State Department of Environmental Conservation
Town of Newry, Maine
Pennsylvania Fish & Boat Commission's Natural Diversity Section
Penobscot Indian Nation
Penobscot River Restoration Trust
Penobscot Valley Audubon Chapter
Project SHARE (Salmon Habitat and River Enhancement)
Saint Joseph's College, Maine
Swampwalkers Wetland Ecosystem Specialists, Parker River Association, MA
The Nature Conservancy
Thompson Lake Association
U.S. Fish and Wildlife Service
U.S. Fish and Wildlife Service – Craig Brook National Fish Hatchery
U.S. Fish and Wildlife Service – Eastern Brook Trout Joint Venture
U.S. Fish and Wildlife Service – Maine Coastal Islands National Wildlife Refuge
U.S. Geological Survey – Biological Resources Discipline
U.S. Geological Survey – Eastern Region Cooperative Fish and Wildlife Research Units
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
University of Georgia – Savannah River Ecological Laboratory
University of Maine
University of Maine – Department of Wildlife Ecology
University of Maine – Maine Agricultural and Forest Experiment Station
University of Maine – Maine Cooperative Forestry Research Unit
University of Maine – School of Biology and Ecology
University of Maine – School of Marine Sciences
University of Maine – Senator George J. Mitchell Center for Environmental and Watershed Research
University of Maine – Sustainable Solutions Initiative
University of Missouri
Wagner Forest, Sunday River Inn, Caribou Springs
White Mountains National Forest

UNIVERSITY OF MAINE COLLABORATORS

Department of Wildlife Ecology

James R. Gilbert, *Chair, Professor of Wildlife Ecology and Cooperating Professor of Marine Sciences*

Aram J.K. Calhoun, *Professor*

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

Daniel J. Harrison, *Professor*

Malcolm L. Hunter, Jr., *Professor*

Linda Ilse, *Research Assistant* Professor

Dawn E. Morgan, *Research Associate*

Judith M. Rhymer, *Associate Professor*

Frederick A. Servello, *Professor*

Lindsay C.N. Seward, *Instructor*

Jack W. Witham, *Assistant Scientist*

School of Biology & Ecology

Francis A. Drummond, *Professor*

William E. Glanz, *Associate Professor of Zoology and Cooperating Professor of Wildlife*

Michael T. Kinnison, *Associate Professor*

Joyce .E. Longcore, *Research Associate Professor*

Brian J. Olsen, *Research Professor and Lecturer*

Jasmine E. Saros, *Associate Professor*

Kevin S. Simon, *Associate Professor*

Seth Tyler, *Professor of Zoology and Cooperating Professor of Marine Sciences*

School of Economics

Kathleen Bell, *Associate Professor*

Mario Teisl, *Professor*

School of Forest Resources

Alan J. Kimball, *Professor*

Robert J. Lilieholm, *E.L. Giddings Associate Professor of Forest Policy*

Steven A. Sader, *Professor*

Robert S. Seymour, *Curtis Hutchins Professor of Forest Resources*

Alan S. White, *Professor*

School of Marine Sciences

James Acheson, *Professor Marine Policy*

Yong Chen, *Professor*

Teresa Johnson, *Assistant Professor Marine Policy*

Linda J. Kling, *Associate Professor*

Gayle Zydlewski, *Assistant Professor*

Department of Communication & Journalism

Laura Lindenfeld, *Associate Professor*

Department of Earth Sciences

Andrew S. Reeve, *Associate Professor*

Department of History

Richard W. Judd, *Adelaide & Alan Bird Professor of History*

Department of Mathematics & Statistics

William Halteman, *Professor and Cooperating Research Professor School of Biology and Ecology*

David Hiebeler, *Associate Professor*

Climate Change Institute

Ann Dieffenbacher-Krall, *Assistant Research Professor*

EXTERNAL COLLABORATORS

Michael M. Bailey, *Fish Biologist, U.S. Fish and Wildlife Service*

Daniel Buckley, *Professor of Natural Sciences, University of Maine at Farmington*

Angela Fuller, *Assistant Professor and Assistant Unit Leader, NY Cooperative Fish and Wildlife Research Unit*

Daniel B. Hayes, *Associate Professor, Michigan State University, Department of Fisheries and Wildlife*

James P. Gibbs, *Professor and Associate Chair, SUNY, Department of Environmental and Forest Biology*

Joseph E. Hightower, *USGS, NC Cooperative Fish and Wildlife Research Unit*

Michael W. Klemens Ph.D., *Michael W. Klemens, LLC.*

John Kocik, *Research Fishery Biologist, NOAA - NMFS Maine Field Station*

Ben Letcher, *Fish Ecologist, S.O. Conte Anadromous Fish Research Center*

Ellen Marsden, *Professor of Fisheries, University of Vermont*

David Owen, *University of Maine School of Law*

John Sowles, *Maine Department of Marine Resources*

Brad Timm, *Department of Environmental Conservation, University of Massachusetts*

Joan G. Trial, *Senior Biologist, Maine Department of Marine Resources*

Jennifer H. Vashon, *Wildlife Biologist, Maine Department of Inland Fish and Wildlife*

Karen Wilson, *Assistant Research Professor, Department of Environmental Science and Aquatic Systems Group, University of Southern Maine*

GRADUATE COMMITTEE PARTICIPATION

Unit scientists served as major advisors or committee members for these students during the reporting period.

Krohn ..... Sheryn Olson, MS (January 1, 2010 – Present)

Loftin ..... Jacolyn E. Bailey, PhD (September 1, 2009 – Present)
Erynn M. Call, PhD (April 7, 2009 – Present)
Sarah Drahovzal, MS (September 1, 2008 – Present)
Luke Groff, PhD (January 1, 2011 – Present)
Margaret Guyette, PhD (January 1, 2008 – Present)
Ian McCullough, MS (September 1, 2010 – Present)
Monika Parsons, MS (January 1, 2008 – May 31, 2011)
Amanda Shearin, PhD (June 1, 2006 - Present)

Zydlewski ..... Wesley Ashe, MS (September 1, 2009 – Present
Erynn M. Call, PhD (April 7, 2009 – Present)
Britt Cline, PhD (January 1, 2010 – Present)
Paul Damkot, MS (May 10, 2010 – Present)
Cory Gardner, MS (September 1, 2007 - January 28, 2011)
Dimitry Gorsky, PhD (January 1, 2006 – May 10, 2011)
Ann Grote, MS (January 1, 2010 – Present)
Margaret Guyette, PhD (January 1, 2008 – Present)
Robert Hogg, MS (October 1, 2009 – Present)
Edward Hughes, MS (October 1, 2009 – Present)
Ian Kiraly, MS (January 1, 2010 – Present)
Dave Kayzak, MS (January 1, 2008 – June 8, 2011)
D. Viorel Popescu, PhD (May 1, 2007 – May 9, 2011)
Silas Ratten, MS (January 1, 2011 – Present)
Kevin Ryan, PhD (January 1, 2008 – Present)
Daniel Stich, PhD (March 14, 2011 – Present)

RECENT GRADUATES AND CURRENT PURSUITS

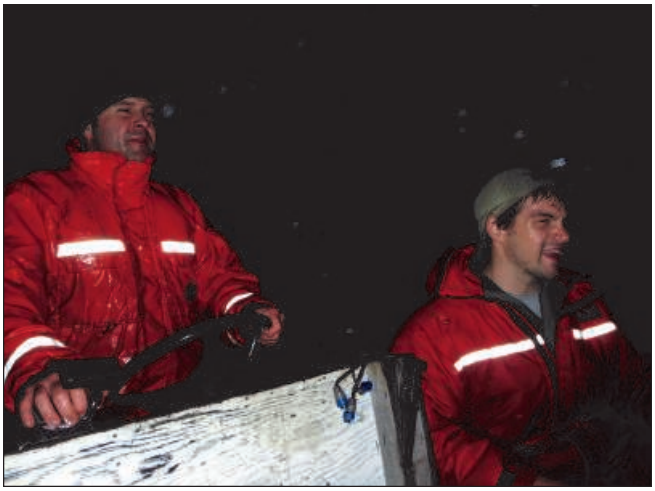
	Student, Degree, Curriculum	*Graduate Date, Advisor(s)*
	Cory T. Gardner MS, Wildlife Ecology GEI Consultants, Denver, CO	January 2011 Stephen M. Coghlan, Jr., Joseph D. Zydlewski
	Dimitry Gorsky, PhD, Wildlife Ecology Fish Biologist, U.S. Fish and Wildlife Service, Amherst, NY	May 2011 Joseph D. Zydlewski
	Jessica S. Jansujwicz, PhD, Ecology and Environmental Sciences Post-Doc, University of Maine, SSI Fellow	August 2011 Aram J.K. Calhoun, R. Lilieholm
	David Kazyak, MS, Wildlife Ecology PhD. Student, University of MD Center for Environmental Science	June 2011 Joseph D. Zydlewski
	Corinne L. Michaud, MS (non-thesis), Ecology and Environmental Sciences Wildlife Biologist, Transcon Environmental, Inc.	January 2011 Judith M. Rhymer
	Pilar A. Palacios, Master of Wildlife Conservation The Nature Conservancy, NC	June 2011 Malcolm L. Hunter, Jr.
	Monika Parsons, MS, Wildlife Ecology Contracting Wildlife Biologist	May 2011 Cynthia S. Loftin, Frederick A. Servello
	D. Viorel Popescu, PhD, Wildlife Ecology Post-doc, University of California-Berkeley	May 2011 Malcolm L. Hunter, Jr.

GRADUATE education

CURRENT STUDENTS

Student, Degree, Curriculum	*Advisor(s)*
Wesley Ashe, MS, Wildlife Ecology	Stephen M. Coghlan Jr.
Jacolyn Bailey, PhD, Ecology and Environmental Sciences	Aram J.K. Calhoun
Erynn Call, PhD, Wildlife Ecology	Malcolm L. Hunter, Jr.
Chen-An Chen, Master of Wildlife Conservation	Malcolm L. Hunter, Jr.
Brittany Cline, PhD, Wildlife Ecology	Malcolm L. Hunter, Jr.
Paul Damkot, MS, Wildlife Ecology	Stephen M. Coghlan Jr.
Adam Derkacz, Master of Wildlife Conservation	Malcolm L. Hunter, Jr.
Sarah Drahovzal, MS, Ecology and Environmental Sciences	Cynthia S. Loftin, Judith M. Rhymer
Shasha Greenspan, MS, Ecology and Environmental Sciences	Aram J.K. Calhoun, Jerry E. Longcore
Luke Groff, PhD, Ecology and Environmental Sciences	Aram J.K. Calhoun, Cynthia S. Loftin
Ann Grote, MS, Wildlife Ecology	Joseph D. Zydlewski
Margaret Guyette, PhD, Wildlife Ecology	Cynthia S. Loftin, Joseph D. Zydlewski
Robert Hogg, MS, Wildlife Ecology	Stephen M. Coghlan Jr., Joseph D. Zydlewski
Edward Hughes, MS (non-thesis), Ecology and Environmental Sciences	Joseph D. Zydlewski
Ian Kiraly, MS, Wildlife Ecology	Stephen M. Coghlan Jr.
Vanessa Levesque, PhD, Ecology and Environmental Sciences	Aram J.K. Calhoun
David Mallett, MS, Wildlife Ecology	Daniel S. Harrison
Ian McCullough, MS, Ecology and Environmental Sciences	Cynthia S. Loftin, Steven A. Sader
Sheryn Olson, MS, Wildlife Ecology	Daniel S. Harrison
Silas Ratten, MS, Wildlife Ecology	Joseph D. Zydlewski
Kevin Ryan, PhD, Wildlife Ecology	Aram J.K. Calhoun
Amanda Shearin, PhD, Ecology and Environmental Sciences	Aram J.K. Calhoun, Cynthia S. Loftin
David Sherwood, Master of Wildlife Conservation	Malcolm L. Hunter, Jr.
Daniel Stich, PhD, Wildlife Ecology	Joseph D. Zydlewski

FISHERIES and aquatics



Investigating the decline of whitefish (*Coregonus clupeaformis*) in Maine

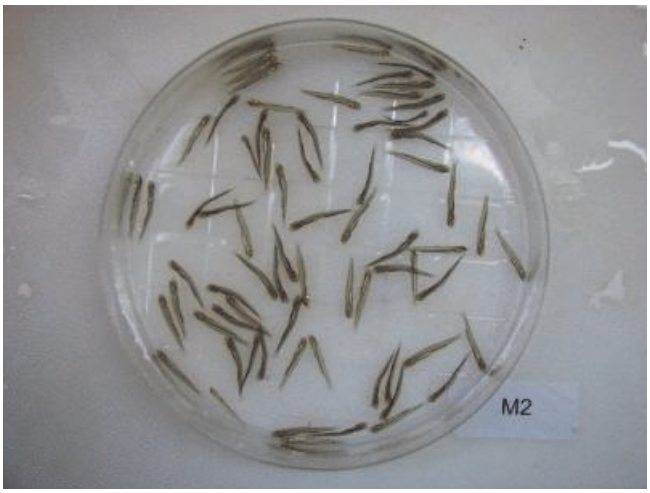
1. Assess adult lake whitefish habitat use through seasons and with respect to temperature.
2. Characterize intra- and interspecific (with rainbow smelt) competitive influence on larval lake whitefish growth.
3. Characterize predation efficiency of adult rainbow smelt on larval lake whitefish through development.
4. Use historic data to create a predictive model of lake whitefish distribution (present or historic).

Abstract of completed dissertation: Seasonal and daily vertical activities of lake whitefish (*Coregonus clupeaformis*) were studied in Clear Lake, Maine using acoustic telemetry from 2004 to 2009. Twenty adult lake whitefish were tagged with acoustic tags that had either a depth sensor or both depth and temperature sensors to assess vertical habitat use of lake whitefish at a seasonal and daily resolution. Vertical habitat selection varied seasonally and was strongly influenced by temperature. Between December and April, when the lake was covered with ice, surface temperature was below 2°C. During this period, tagged whitefish occupied deep areas of the lake (~15 m). Following ice out, whitefish ascended into shallow waters (~5 m) responding to increased water temperature and possibly to increased foraging opportunity. When surface water temperatures exceeded 20° C, fish descended below the developing thermocline (~9 m) where they remained until surface temperatures fell below 20° C. With the lower temperatures, fish ascended into shallower depths presumably for feeding and spawning. Through the winter, fish remained in warmer waters than what was recorded at the surface, and in the summer, selected depths with thermal habitats below 15° C. Though the amplitude varied greatly across seasons, whitefish displayed a strong diurnal pattern of activity, as measured by vertical velocities. Fish were two-fold more active during spring, summer and fall, and less active during winter. The strong linkage between temperature and habitat use may limit the current range of lake whitefish and be directly influenced by climatic change.

Initial feeding of larval fish when they transition from endogenous to exogenous resources is critical to survival. This developmental stage is often the source of the highest juvenile mortality. Understanding factors effecting food availability, such as intraspecific and interspecific competition, on larval lake whitefish growth may thus be vital to understanding population trends in the wild. Lake whitefish were reared in the presence of conspecifics and larval rainbow smelt (*Osmerus mordax*) to determine growth responses to intra- and interspecific competition. For intraspecific competition, whitefish were placed into three different food availability treatments and four different conspecific fish density treatments. Fish were reared for an eight-week period starting at approximately 30 days post hatch. For interspecific competition, whitefish larvae were reared in five different communities with varying rainbow smelt larval densities, ranging from a smelt-dominated to an equal proportion of both species, to a whitefish-dominated assemblage. The growth response of lake whitefish in the intraspecific trials was highly correlated with the estimated number of prey items per individual. During interspecific trials, no negative response was observed in growth of lake whitefish. Rather, lake whitefish growth in interspecific trials mirrored the growth response to their own density observed in intraspecific trials. This research suggests that growth in lake whitefish is more influenced by per capita intraspecific competition, and less by per capita interspecific competition with rainbow smelt during this critical early life history stage.

Because introduced landlocked rainbow smelt are hypothesized to be a major factor in the decline of lake whitefish populations in many lakes. The size of lake whitefish preyed upon by adult smelt and how the efficiency of smelt predation changes with increasing sizes of lake whitefish was assessed. In a laboratory setting, larval lake whitefish of increasing sizes were exposed to groups of seven adult rainbow smelt for a one-hour period and observed predation behaviors and efficiencies. In each trial, the group of smelt consumed at least one larval lake whitefish, consuming whitefish up to 45 millimeters in length (up to 89% of gape width). Predation efficiency, the total number of lake whitefish consumed by smelt during trials, was 100% when whitefish were small and followed a decreasing sigmoidal response to increasing whitefish

lengths. The major predatory window of smelt on lake whitefish appears to be from whitefish size at hatch (~12 millimeters) to approximately 43 millimeters. Smelt generally took multiple attacks to capture a single whitefish. The capture efficiencies of smelt decreased from 30% as whitefish length increased and were highly variable within each whitefish size group. The overall impact smelt predation will have on lake whitefish populations is likely dependent on the growth rate of lake whitefish, environmental conditions that cause the lake whitefish hatching period to coincide with smelt spawning events, and overlap of habitat use between spawning smelt and hatching lake whitefish.



Lake whitefish populations in Maine are poorly understood and may be in decline statewide according to surveys. These surveys are likely non-targeted surveys and may misrepresent lake whitefish distributions and presence. To help identify lakes that are likely to have or have had lake whitefish, predictive models were developed using discriminant analysis (DA) and classification trees based on environmental variables and fish assemblage data. The presence of lake whitefish was predicted using a subset of lakes (649 lakes) within the State of Maine that had sufficient completeness of data (>80%). Lake specific data included physical qualities (size, depth, and location) chemical attributes (turbidity, pH, conductivity) and fish assemblages. Both modeling techniques performed well with regards to correctly predicting lake whitefish absence (specificity ≥ 0.91), but had very different results when it came to correctly predicting lake whitefish presence (sensitivity). The classification trees had a sensitivity of 0.43 while the DA had 0.77. From both models lakes were identified that had characteristics suggesting that they could contain lake whitefish or perhaps had in the past. An interesting outcome of these analyses is the high discriminating power associated with current fish assemblages, namely the presence of burbot (*Lota lota*). Managers can simply use these data in a DA model to identify suitable lakes without sacrificing predictive ability or requiring in-depth data.

Investigator: Dimitry Gorsky (PhD)

Advisors: Joseph D. Zydlewski (Advisor)
Yong Chen
Ellen Marsden
Michael Kinnison
Linda Kling

Duration: January 2006—May 2011

Cooperators:

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

Understanding the ecology of sea-run brook trout in Acadia National Park

1. Characterize the growth variability of brook trout in two coastal systems in Maine using PIT technology.
2. Describe the seasonal movements and habitat use of brook charr using radio telemetry.

Abstract of completed thesis: Brook charr (*Salvelinus fontinalis*) are a popular sport fish and have experienced marked declines in size, abundance, and distribution. The sea-run form of this species has experienced a parallel decline, the causes of which are poorly understood. Growth and movement behaviors are known to interact and influence the survival and fitness of an individual. Furthermore, growth variation in juveniles is linked to life history variation in adults. We used biannual mark-recapture surveys and active telemetry to track the movement and growth of brook charr at Stanley Brook (Seal Harbor, Maine) and Cove Brook (Winterport, Maine) during 2006-2010. Individuals were captured during backpack electrofishing surveys and implanted with a 12.5 mm PIT tag for unique identification. We used a combination of continued electrofishing surveys, PITpacking, radio telemetry, and stationary PIT antenna arrays to follow these fish through space and time. Overall, we marked 7,309 individuals which resulted in 3,619 physical recapture events.

Individual variation in growth rates was best explained by a model containing an interaction between season and an individual's length, mean water temperature, and instream location. Growth rates were fastest in the summer, and smaller individuals grew more rapidly than larger conspecifics. Individuals using habitats closer to the head of tide grew faster than those in upstream locations. We documented considerable stream-to-stream and year-to-year variation in the growth of coastal brook charr. The effects of repeated handling on growth appear subtle relative to other factors, but a slight negative effect was detected.

Interestingly, physical habitat variation was not an important control of individual growth variation within Stanley Brook. Overall, we were able to explain 51.9% of the observed individual growth variation using our model.

Our results suggest that movement is limited during the summer and winter months, but considerable movement occurs during the spring and fall. Using a weight of evidence approach, we conclude that the restricted movement paradigm applies to coastal brook charr populations on a seasonal basis. However, where movements occur, they appear to be ecologically significant, as they allow individuals to transition between important seasonal habitats.

Investigator: David Kazyak (MS)

Advisors: Joseph D. Zydlewski (Co-Advisor)
Ben Letcher (Co-Advisor)
Stephen Coghlan

Duration: January 2006—May 2010

Cooperators:

University of Maine
Maine Department of Inland Fisheries and Wildlife
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
U.S. Geological Survey – Biological Resources Discipline
National Park Service

The growth and survival of stocked juvenile Atlantic salmon (*Salmo solar*) in small tributaries of the Machias river watershed

1. Quantify growth and survival of juvenile ATS in headwater streams, spanning multiple environmental gradients.
2. Determine the relative importance of measured habitat features to juvenile ATS growth and survival.
3. Compare the production potential of headwater streams to the mainstream and other already stocked tributaries.

This study was initiated during the spring of 2010, when approximately 30,000 Atlantic salmon fry were stocked in 20 study reaches. Just prior to stocking, directional traps, spanning the entirety of the stream's wetted width were placed at the up- and downstream ends of a subset of three representative reaches. The traps remained in place for the entirety of the field season and monitored any juvenile salmon that migrated into and out of the study reaches. We measured pH, temperature, velocity, substrate, shelter availability, depth, wetted width, coarse wood, riparian forest structure, invertebrate abundance, and competitor predator abundance in each of the 20 stream reaches during two separate timeframes. The two sampling episodes will account for some of the seasonal variation within the stream. In late August, fish were collected within all sample reaches using standard electro-fishing techniques with backpack units. All collected salmon, as well as other fish species, were measured for length and mass and released alive. These methods were repeated during the same timeframe in 2011 and data analyses are currently underway.

Analyses of project data estimated fry abundance per 100m reach at 40 and 62 individuals (2010 and 2011, respectively) and ranged from 0 to 225 fry. Mean mass of fry at capture was 1.5 g and 1.6 g, and ranged from 0.6 to 2.7 g. Apparent survival among sites ranged between 0 and 50.5%, with yearly means of 13.7 and 13.4%. Mean density was 0.33 and 0.32 fry/m^2 and ranged from 0.00 to 1.21 fry/m^2. Mean biomass was 0.46 and 0.55 g of salmon tissue/m^2 and ranged from 0.00 to 2.15 per reach. Of the habitat variables measured, temperature, brook trout density, interstitial space availability, coarse wood abundance, percent detritus and percent cobble were correlated most strongly with growth and survival. We anticipate results that will validate the importance of headwater streams as critical habitat for juvenile salmon, thus providing the impetus toward culvert removal and the reestablishment of watershed connectivity.

Investigator: Wesley Ashe (MS)

Advisors: Stephen Coghlan (Advisor)
Joseph D. Zydlewski
Joan Trial

Duration: September 2009—August 2012

Cooperators:

University of Maine – Department of Wildlife Ecology
Maine Department of Inland Fisheries and Wildlife
Maine Department of Marine Resources
Maine Water Resources Research Institute
American Recovery and Reinvestment Act (ARRA)
National Oceanic and Atmospheric Administration
Project SHARE (Salmon Habitat and River Enhancement)
U.S. Fish and Wildlife Service – Craig Brook National Fish Hatchery

Ecological implications of the invader *Myriophyllum heterophyllum* on Maine's littoral communities

Investigator:	Jacolyn E. Bailey (PhD)
Advisors:	Aram J.K. Calhoun (Advisor) Ann Dieffenbacher-Krall Cynthia S. Loftin Kevin Simon Dan Buckley
Duration:	May 2008—May 2013

Cooperators:

Maine Department of Environmental Protection
Maine Congress of Lake Associations
Lakes Environmental Association
Saint Joseph's College
Thompson Lake Association
Maine Volunteer Lake Monitoring Program
University of Maine – Department of Wildlife Ecology

1) Document fish and invertebrate communities in native macrophyte beds and managed and unmanged non-native milfoil beds.
2) Measure the relative abundance and presence/absence for fish and invertebrates.
3) Measure plant community composition and structure in native macrophyte beds and managed and unmanaged non-native macrophyte communities.
4) Determine if there are differences in communities in native macrophyte beds and managed and unmanaged invasive macrophyte beds.
5) Determine potential differences in plant and animal community dynamics in these communities.

This project will occur over three years with the option of a fourth year. The first year will be a methodology testing and site location determination year. The years two, three, and if necessary four will include method deployment, data collection and project modification if necessary.

The first year of method testing and site determination has been completed. The year two data collection is also completed and invertebrates collected are being identified and data analyzed over the winter.

Influence of coarse woody debris addition and brook trout relocation on stream communities

1. Quantify the effects of CWD addition on brook trout, aquatic insects, and streamside salamanders in brook trout stream.
2. Quantify the effects of brook trout relocation and/or CWD addition on aquatic insects and salamanders in fishless streams.

We have chosen 20 study sites on headwater streams in the Mahoosuc Range (Oxford and Franklin Counties) to study the interactive effects of CWD addition and trout relocation. Twelve sites contain wild populations of brook trout, six of which will receive CWD addition and six of which will serve as reference sites. The remaining eight sites are currently devoid of fish, although most likely once contained brook trout; two will receive CWD, two will receive brook trout, two will receive both CWD and brook trout, and the remaining two will serve as reference sites. Variables of interest include: 1) abundance, density, biomass, and size-structure of brook trout; 2) abundance and community structure of aquatic insects; 3) abundance of streamside salamanders; and 4) physical habitat characteristics. Sampling occurs seasonally, both prior to treatments and for several years after treatments. Using this before-after / control-impact design, we will be able to quantify the effects of both restoration actions on aquatic fauna. We added CWD to five sites in 2007 and four sites in 2008, and sampling has occurred twice yearly for brook trout, seasonally for aquatic insects, once yearly for salamanders, and once yearly for physical habitat. Brook trout relocation to vacant sites occurred in summer 2010.

Natural abundance of CWD was low (mean ± 2 S.E.: 1.1 ± 0.6 pieces / 200m). Two years after CWD addition, treatment sites contained twice the CWD pieces as reference sites (19 ± 3. 6 pieces vs. 8.5 ± 2.8), but abundance of pools did not differ (12 ± 1.5 vs. 13 ± 1.7 pools /200 m). Brook trout density (range: 0.02 ± 0.001 fish/ m2 to 0.47 ± 0.15) and biomass (range: 0.3 ± 0.15 g/ m2 to 6.1 ± 2.9) was highly variable over time and among sites, and effects of LWD were not clear. In five of six treated sites, trout abundance and density declined sharply after treatment but recovered above pre-treatment levels three years subsequent, but metrics in most reference streams also increased. By the fourth year post-treatment, there were few differences between treated and reference sites. A longer time series is necessary to evaluate the efficacy of LWD addition, but these results suggest little impact on brook trout. Very few brook trout were found in our relocation sites; retention was < 10%.

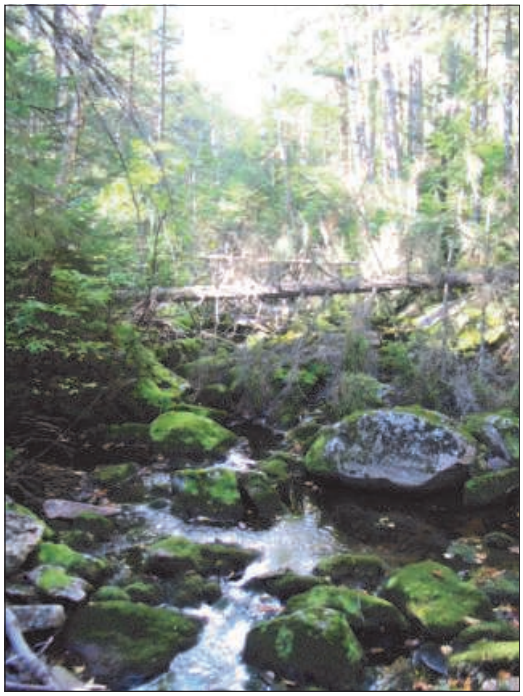
Investigator: Paul Damkot (MS)

Advisors: Stephen Coghlan (Advisor)
Joseph D. Zydlewski
Kevin Simon

Duration: July 2007—January 2012

Cooperators:

University of Maine – Department of Wildlife Ecology
Maine Department of Inland Fisheries and Wildlife
Maine Bureau of Parks and Lands
Maine Department of Environmental Protection
Maine Outdoor Heritage Fund
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
U.S. Fish and Wildlife Service – Eastern Brook Trout Joint Venture
National Fish and Wildlife Foundation
Newry, Town of
Wagner Forest, Sunday River Inn, Caribou Springs



Impacts of riparian characteristics on terrestrial invertebrate input and brook trout bioenergetics

1. Evaluate the influence of riparian characteristics on terrestrial invertebrate input and quantify the resultant energetic input available for brook trout consumption.
2. Quantify the availability of aquatic invertebrates in stream drift and the resultant energy available for brook trout consumption.
3. Assess foraging selectivity in brook trout and quantify the relative amounts of energy provided by aquatic and terrestrial invertebrates.
4. Integrate data with an existing bioenergetics model and simulate the effects of riparian forest structure on brook trout energetics.

Maine contains the largest intact, wild populations of *Salvelinus fontinalis* in the United States. The fate of these fish is linked inextricably to the surrounding watershed, as riparian forests maintain suitable stream temperatures and physical habitat, facilitate aquatic prey production, and provide terrestrial prey subsidies critical for trout survival, growth, and reproduction. Because most brook trout streams in Maine flow through privately-owned land managed for commercial timber harvest, however, disturbances to the structural integrity of the riparian forest are common but their resultant effects on brook trout often are not known or considered. Without adequate knowledge of the effects of forest harvesting and regeneration patterns on brook trout in these streams, resource managers lack a critical piece of the puzzle when projecting outcomes of various management scenarios. We developed a project to investigate the role that riparian forest structure plays in determining growth and production of brook trout in sensitive habitats – that is, headwater streams in the White Mountains region of western Maine surrounded by economically-valuable forests. Specifically, we will quantify the effects of various riparian forest characteristics (e.g., along gradients of coniferous/deciduous dominance, canopy closure, understory cover and ground cover) on stream temperature, aquatic prey abundance, and terrestrial prey input, and ultimately link these factors to brook trout growth and production.

During the summer of 2008, we chose sites on seven headwater streams in western Maine and northeastern New Hampshire along a gradient of deciduous and coniferous riparian stand dominance, presumably reflective of logging history; sites ranged from 99% deciduous and 1% coniferous to 80% coniferous and 20% deciduous. We sampled each stream three times throughout the summers of 2008 and 2009 with 24-hour sampling cycles. During each sampling interval, we collected drifting aquatic invertebrates every six hours with four ½-hour drift net sets and terrestrial invertebrates with six pan traps deployed for the entire 24-hour period. We also collected 10-20 brook trout stomach samples for diet analysis by gastric lavage. In addition, twice each summer we collected terrestrial invertebrates with pan traps set for a period of one week. Invertebrate identification and enumeration of energy availability and consumption was completed during the fall of 2010. Preliminary results indicate that abiotic factors such as wind and rain may be equally as important as stand dominance in determining terrestrial invertebrate availability. The data will be integrated with an existing bioenergetics model to predict how brook trout growth would be affected by riparian forest alterations and climate change.

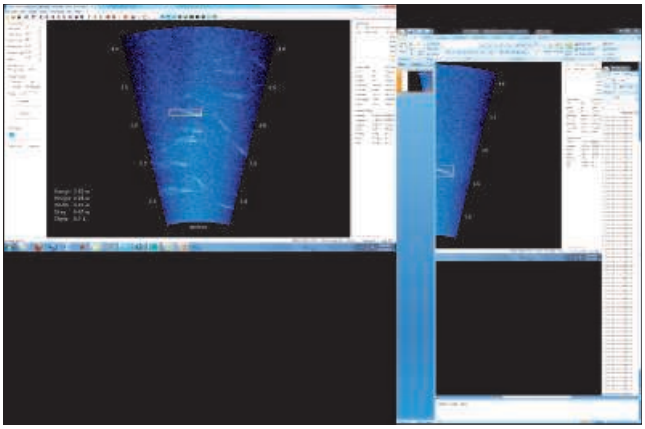
Investigator: Paul Damkot (MS)

Advisors: Stephen Coghlan (Advisor)
Joseph D. Zydlewski
Kevin Simon

Duration: September 2007—May 2012

Cooperators:

University of Maine – Department of Wildlife Ecology
New Hampshire Fish and Game Department
Maine Bureau of Parks and Lands
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
National Fish and Wildlife Foundation
White Mountains National Forest



Establishing baselines for American Shad in the Penobscot River

1. Develop age and length distributions of adult American shad in Penobscot River via electrofishing.
2. Characterize spawning migratory behavior and habitat use with radio and acoustic telemetry.
3. Generate a length frequency distribution of fish approaching Veazie Dam using high definition imaging sonar (DIDSON technology).
4. Generate a population estimate for American shad in the Penobscot River using a novel application of radio telemetry and DIDSON technology.

American shad populations are declining throughout their native range and conservation programs have been implemented in rivers from Maine to North Carolina. The proposed habitat restoration plan to remove the Veazie and Great Works Dams on the Penobscot River (as part of the Penobscot River Restoration Project) is anticipated to reestablish access to spawning and rearing habitat for numerous diadromous fish species, including American shad. Recent modeling efforts indicate that the time to recovery for American Shad in the Penobscot River may be highly sensitive to small changes in starting population size. Additionally, in this model, sensitivity to stocking (the ability of stocking to increase run size) decreases with increasing population size. Because of the timeline of restoration activity and the importance of the current population level, specific demographic information on American shad in the Penobscot River would be invaluable. The work underway is using a combination of radio telemetry and DIDSON hydro acoustic assessment to study American shad to collect baseline data prior to dam removals and implementation of proposed stocking programs. Work will be conducted over three years (2010-2012), and will address two main data gaps: characterization of adult shad migratory behavior and characterizing the existing Penobscot River run.

In 2010 and 2011, a total of ninety three American shad were captured via boat electrofishing. Age and length data were collected for these fish and 85 fish were tagged for telemetry work (70 radio and 15 acoustic). Tagged fish were tracked using fixed radio antenna and acoustic receiver arrays along with active tracking. Directional antennas were mounted at Veazie Dam, to describe dam approach behavior. Additional stationary radio antennas were installed at intervals between Orrington and Veazie Dam. Acoustic receivers were located from at intervals from Penobscot Bay to Veazie Dam.

In 2009 - 2011 a DIDSON hydro acoustic camera was deployed to conduct imaging surveys at the base of the Veazie Dam fishway. Analysis of the 2011 DIDSON data indicate that large numbers of American shad, Atlantic Salmon, and river herring approached the fishway. The DIDSON approach has been an effective tool for making species determinations, measuring the size of fish, and developing size distributions in order to meet the full objectives of this project.

Investigator: Ann Grote (MS)

Advisors: Joseph D. Zydlewski (Co-Advisor)
Michael Bailey (Co-Advisor)
Joe Hightower
Daniel Harrison

Duration: January 2006—August 2012

Cooperators:

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

The role of marine derived nutrients delivered by anadromous fish in restoration of freshwater ecosystems in the Penobscot River watershed, Maine

Objective: Experimentally supplement marine derived nutrients into Atlantic salmon nursery streams to examine effects of increased nutrients on stream productivity (algae, macroinvertebrates) and young Atlantic salmon growth and condition.

The ecological role of prominent migratory fish species is a poorly characterized natural history in the Penobscot River. Manipulation of this river through habitat modification has resulted in a greatly reduced exchange of nutrients between inland and marine waters. Considerable runs of anadromous fish (e.g., American shad, alewife, sea lamprey and Atlantic salmon) occurred in the Penobscot River prior to the construction of main-stem dams in the early 1800s. Fish populations declined precipitously after dams were installed. With the planned removal of two main-stem dams on the Penobscot River, there is great optimism that reestablishment of passage will lead to restoration of the ecosystem. In order to restore, however, it is necessary to understand how historical connectivity affected fish populations. The role of marine derived nutrients (MDN) is of interest as restoration of anadromous fish runs may depend, in part, on a continuous cycle of nutrient import from the ocean. The proposed study will probe the role of MDN in the Penobscot River watershed by studying exchange of nutrients in streams with implanted salmon fry, documenting how increased nutrients affect the productivity and quality of Atlantic salmon, and characterizing historic MDN incorporation in stream ecosystems.

We characterized (stream invertebrates, water chemistry, algal biomass, aquatic macrophytes, fish) four streams that had historic salmon runs in the Penobscot watershed and supplemented selected reaches with marine derived nutrients delivered as anadromous fish analogs in early June and late October 2009 and 2010. We collected pre- and post-treatment stable isotope signatures from all trophic levels at all sites and are tracking responses to nutrient enhancement in the biota and environment. We stocked all streams with Atlantic salmon fry to assess juvenile salmon changes in growth and tissue stable isotope ratios in response to presence and absence of nutrient enhancement. Field work was completed in spring 2011 and laboratory analysis of samples is continuing through 2011. A Ph.D. dissertation is expected to be completed in 2012.

Investigator: Margaret Guyette (PhD)

Advisors: Cynthia S. Loftin (Co-Advisor)
Joseph Zydlewski (Co-Advisor)
Kevin Simon
William Halteman
Jasmine Saros

Duration: September 2007—September 2012

Cooperators:

National Oceanic and Atmospheric Administration
U.S. Geological Survey – Eastern Region Cooperative Fish and Wildlife Research Units
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
University of Maine – Department of Wildlife Ecology
University of Maine – Maine Agricultural and Forest Experiment Station

Barrier removal in Sedgeunkedunk Stream: Sea lamprey recolonization and implications for Atlantic salmon habitat restoration

1. Characterize fish community changes (species, size, abundance, distribution, etc) in response to barrier removals.
2. Evaluate abundance, size-structure, habitat use, and nest fidelity of spawning sea lamprey.
3. Characterize fine scale changes to stream-bed in response to sea lamprey nest construction.
4. Characterize changes to aquatic invertebrate community in response to sea lamprey spawning activities

Sedgeunkedunk Stream, a third-order tributary to the Penobscot River, historically supported several anadromous fish species including sea lamprey and Atlantic salmon. However, two small dams constructed in the 1800s reduced or eliminated spawning runs entirely. In 2009, efforts to restore marine–freshwater connectivity culminated with removal of the lowermost dam returning five-km of lotic habitat accessible to anadromous fish. To evaluate the efficacy of dam removal as a restoration tool, we sought to compare pre- and post-dam removal conditions, as part of an ongoing before-after -control-impact (BACI) study. Electrofishing survey protocols were used to test the hypothesis that dam removal would lead to increased diversity, abundance, and biomass of fish assemblages upstream. Additionally, we tagged and tracked migrating sea lamprey during their annual spring spawning runs to test the hypothesis that dam removal would facilitate recolonization of a sentinel anadromous species. Furthermore, we collected macroinvertebrate drift samples downstream of active lamprey nests to test the hypothesis that spawning activities release benthic invertebrates thereby increasing prey for drift-feeding fishes. Finally, we sampled the stream-bed topography of lamprey nests to test the hypothesis that lamprey "condition" microhabitat to the benefit of Atlantic salmon via alteration of substrate.

Field work was completed in mid-October 2011 and completion of associated lab work is anticipated mid-February 2012. Preliminary analyses revealed that diversity, density, and biomass of the resident fish community increased at all sites upstream of the 2009 dam removal with few changes detected at unimpacted reference sites. The most current surveys revealed a consistent homogeneous distribution of the resident fish along the headwaters-to-mouth gradient with evidence of successful recolonization by anadromous river herring. Additionally, age 0+, 1+, and 2+ Atlantic salmon parr were observed where they were previously absent prior to dam removal. Mark-recapture histories indicated a four-fold increase in the abundance of spawning sea lamprey, and analysis of lamprey nesting sites suggests that spawning activities may have conditioned microhabitats favorably for Atlantic salmon. Additional data analysis and writing are in progress for a Master of Science thesis, expected for completion in August 2012.

Investigator: Robert Hogg (MS)

Advisors: Stephen Coghlan (Co-Advisor)
Joseph D. Zydlewski (Co-Advisor)
Kevin Simon

Duration: January 2010—August 2012

Cooperators:

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

PIT tag monitoring of adult Atlantic salmon in the Penobscot River, Maine

1. Determine the rate, timing and efficiency of upstream passage of Atlantic salmon 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 Atlantic salmon in the Penobscot River.

The Penobscot River watershed is Maine's largest and hosts the largest remaining run of Atlantic salmon in the USA, however the majority of high quality spawning and rearing habitats are located upstream of at least four dams. Plans are currently underway to remove the two most downstream dams as part of the Penobscot River Restoration Project (PRRP). Ultimately, benefits of dam removal for Atlantic salmon restoration will depend in large part on the degree and fashion by which remaining dams facilitate fish passage success. In order to assess migratory success of adult Atlantic salmon, we are using passive integrated transponders (PIT tags) to remotely track fish through nine major dams in the lower Penobscot River. Currently, PIT tagging of fish occurs at the lower most dam (Veazie Dam-which is scheduled for removal in 2012) in coordination with Maine Department of Marine Resources. This work will incorporates and builds 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 will require 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. 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 will be continued in 2012 and priorities will shift to data analysis and "near real time" coordination with management agencies for the optimization of fish passage.

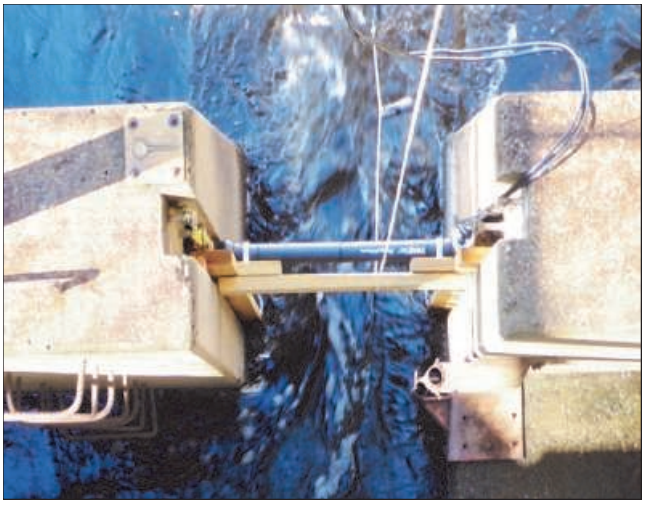
Investigator: Ed Hughes (MS)

Advisors: Joseph D. Zydlewski (Advisor)
Brian Olsen
William Halteman

Duration: January 2006—August 2012

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



Quantifying the effects of dam removal on the structure of fish assemblages in the Penobscot River

1. Establish the level of natural variability within fish assemblages in the Penobscot River before dam removal occurs.
2. Improve the precision of fish assemblage monitoring.
3. Reduce sampling bias within fish assemblage monitoring.
4. Determine the most efficient and/or effective sampling method for quantifying fish assemblages in the Penobscot River.

The Penobscot River once provided spawning and juvenile rearing habitats to migratory fish. The construction of dams blocked migrations of these fish and fragmented resident fish populations, changing the structure of fish assemblages throughout the river. The Penobscot River Restoration Project (PRRP) is anticipated to increase passage of anadromous and resident fishes and improve the connectivity among currently fragmented fish populations. The goal of this study is to quantify and characterize pre-dam-removal fish assemblages in the lower ~70 kilometers of the Penobscot River, along with major tributaries. This project also evaluates the use of two different study designs: Fixed and stratified-random sampling. Study design is extremely important for adequately and accurately assessing the outcomes of any restoration project. Comparing the efficiency and efficacy of these study designs can provide useful information regarding the cost and effort that is required to adequately assess fish assemblages on the Penobscot River, and provide meaningful direction for the future of this project.

Fish assemblages were sampled during the early summer and fall of 2010 and 2011. We used standardized boat electrofishing methods to capture fish while also employing both fixed and stratified-random study designs. The efficiency and efficacy of these sampling designs are currently being analyzed and compared in order recommend future direction for the study design on this project and related projects in large rivers. We are also analyzing the fish assemblages in the Penobscot River and major tributaries, describing current spatial, seasonal, and annual patterns in catch and biomass of a variety of species, along with patterns in alpha and beta diversity. Multiple publication drafts and a Masters thesis are expected by May 2012.

Investigator: Ian Kiraly (MS)

Advisors: Stephen Coghlan (Advisor)
Joseph D. Zydlewski
Daniel Hayes

Duration: January 2010—May 2012

Cooperators:

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

Investigating lake whitefish and Arctic charr reintroductions

1. Characterize lake whitefish movements as they relate to thermal stratification and potential spawning locations.
2. Examine the seasonal movements of reintroduced Arctic charr.
3. Assess lake whitefish growth (annual and seasonal) and spawning within Clear and St. Froid Lakes.
4. Model physical habitat data to identify potential spawning areas for lake whitefish in St. Froid Lake.

Lake whitefish (*Coregonus clupeaformis*) and Arctic charr (*Salvelinus alpinus*) are native species of substantial historical and recreational importance in Maine. A combination of creel census and annual inventory data collected by Maine Department of Inland Fisheries and Wildlife (MDIFW) indicate lake whitefish and Arctic charr are both experiencing population declines. These findings prompted extensive restoration efforts, including hatchery programs and subsequent reintroductions of these species. This research will provide critical information regarding these lake whitefish and Arctic charr populations.

Acoustic telemetry will be used to characterize lake whitefish and Arctic charr movements. In concert with these efforts, temperature logger arrays will be deployed to provide a better characterize the thermal dynamics of the study lakes. Growth of lake whitefish in St. Froid and Clear Lakes will be assessed through otolith and scales collection. The efficacy of acoustic sonar (DIDSON) to document spawning will be evaluated in Clear Lake. Lastly, an autonomous underwater vehicle (AUV) will be utilized to collect physical habitat data to be incorporated into a habitat model in order to identify potential spawning habitat for lake whitefish in St. Froid Lake.

Lake whitefish otolith and scale samples were collected in 2010 and 2011 for age and growth analysis. Acoustic receivers were deployed in St. Froid Lake(15) and Clear Lake(5) to passively track movements of tagged lake whitefish. Seven lake whitefish have been tracked since 2009 in Clear Lake and additional fish are anticipated to be tagged in 2012. Thirteen lake whitefish were tagged in St. Froid Lake. In the winter of 2012 an additional seven lake whitefish will be tagged in St. Froid Lake. In an analogous manner, acoustic receivers were deployed in Big Reed Pond to passively track the movements of Arctic charr. In the fall of 2011, ten sub-adult Arctic charr were tagged and released. Vertical temperature and light data logger arrays were deployed within each lake system to monitor thermal dynamics and relative light levels (to indicate ice cover).

Investigator: Silas Ratten (MS)

Advisors: Joseph D. Zydlewski (Advisor)
Stephen M. Coghlan, Jr.
Michael T. Kinnison
Gayle Zydlewski

Duration: January 2006—August 2012

Cooperators:

Maine Department of Marine Resources
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
University of Maine — Department of Wildlife Ecology
University of Maine – School of Biology and Ecology
University of Maine – School of Marine Sciences

Passage of Anadromous Fish at Mainstem Dams on the Penobscot River, Maine

1. Model the survival of wild- and hatchery-origin Atlantic salmon smolts through the Penobscot River and Estuary.
2. Assess movement patterns and rates of migration for Atlantic salmon smolts through the Penobscot River.
3. Characterize patch choice and survival of Atlantic salmon smolts at Milford Dam on the Penobscot River.
4. Characterize the development of seawater tolerance and behavioral preference for seawater of Atlantic salmon smolts.

This project will draw upon a growing body of telemetry data reaching back to work begun in 2005 and continued through to present. Targeted releases of Atlantic salmon smolts implanted with acoustic "pingers" are tracked through the entire Penobscot River system using an extensive deployment of stationary receivers. These acoustic receivers are deployed as part of ongoing cooperative work between NOAA-Fisheries, Maine Cooperative Fish and Wildlife Research Unit and the University of Maine. The observed series of detections of an individual fish are used to construct a model of survival through the River system. Such a model allows the assessment of areas of high mortality, such as dams. Beginning in 2010, greater emphasis has been placed on movements near Milford Dam, a known site of high mortality, using radio telemetry. We will continue tagging wild and hatchery-origin Atlantic salmon smolts from the Penobscot River through this periods of study. Beginning 2012, a series of laboratory experiments will be conducted using direct seawater transfer (to assess seawater tolerance) and seawater preference (using a novel selection apparatus). Data from these experiments will be used to inform the interpretation of movement patterns of Atlantic salmon smolt migration through the Penobscot River estuary.

Acoustic telemetry data have been collected since 2005 for hatchery-origin and 2006 for wild origin Atlantic salmon smolts to assess movement and survival through the Penobscot River and Estuary. These data have been used to estimate survival of Atlantic salmon smolts throughout the system and are routinely used by agencies associated with the management of this federally endangered species. The use of radio telemetry was successfully initiated in 2010 and will be continued in 2012 to refine estimates of survival and path choice in smolts. Physiological experiment are being initiated in 2012.

Investigator: Daniel Stich (PhD)

Advisors: Joseph D. Zydlewski (Advisor)
Michael Bailey
Michael Kinnison
John Kocik
Gayle Zydlewski

Duration: January 2006—January 2014

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 Ecology
National Fish and Wildlife Foundation
Penobscot River Restoration Trust
U.S. Fish and Wildlife Service
Penobscot Indian Nation

WILDLIFE and habitats

Monitoring seabird behavior on a coastal Maine island: Developing methods to better understand potential effects of marine finfish aquaculture on seabird breeding colonies

1) Document activity patterns and behavior during nesting and brood-rearing for selected seabird species to inform future studies about aquaculture-seabird interactions in Maine.
2) Develop methods and techniques for monitoring selected seabird species to identify and document effects of aquaculture-related disturbance.

The M.S. thesis was completed in May 2011. We are continuing to develop methods to automate counts of flying gulls captured on digital photographs to improve efficiency of camera-based monitoring.

Abstract of completed thesis: Understanding responses of breeding seabirds to the introduction of new sources of disturbance is important for effectively managing breeding colonies. In Maine, coastal areas where birds nest are subject to a variety of potential disturbances including the establishment of new aquaculture facilities. The response of nearby nesting birds has not been studied in the context of finfish aquaculture in Maine. I examined the effectiveness of methods for remotely monitoring nesting seabird behavior and documenting the behavioral responses of four species of nesting seabirds to disturbance events.

I examined activity of four seabird species nesting on Jordan's Delight Island, Washington County, Maine: common eiders (*Somateria mollissima*), black guillemots (*Cepphus grylle*), great black-backed gulls (*Larus marinus*) and herring gulls (*Larus argentatus*). Given their widespread nesting distribution, these species are likely to be affected by aquaculture operations established near nesting islands along the Maine coast.

This study was conducted during May-August 2008 and 2009. I positioned five time-lapse cameras (Reconyx, Inc.) facing the water to record boat activity and recording one image per minute. Researchers recorded their own activity and spent 180 hours in 2008 and 310 hours in 2009 observing for avian predators. Incubation constancy of common eiders, herring gulls and great black-backed gulls was monitored by recording nest temperature with loggers installed in nests. Colony attendance was measured with time-lapse cameras overlooking four gull nesting areas and two guillemot nesting areas.

Eiders recessed longer in 2008 than 2009 and more often during daylight hours in both years. Multiple incubating eiders simultaneously left their nests in response to researcher activity on the bluffs above the eider nesting area on two of four occasions; however, multiple eiders did not simultaneously leave their nests in response to other monitored disturbances. Recesses in response to researcher activity on the bluffs were longer (61 min) than recesses in the absence of a researcher (34 min).

Herring and great black-backed gulls were indistinguishable from one another in time-lapse photographs, and therefore their photo data were pooled. Gulls exhibited a flight response to eagles and humans but not to ravens and boats. Incubating gulls left their nests for two-three minutes when an eagle flew directly overhead. Colony attendance did not change in response to disturbances other than human activity.

Raven presence was the most frequent and longest duration disturbance to guillemots, preventing them from visiting nesting areas for up to four hours at a time. Guillemots also responded to eagles; however, eagle visits were brief (<five min) and infrequent and did not keep birds off the colony for extended periods. Boats occasionally elicited responses from guillemots;

however, it was not clear why guillemot response to boats was inconsistent.

The methods presented herein are effective for monitoring episodic disturbances similar to the boat, avian predator, and human activity recorded on Jordan's Delight, and, combined with the knowledge of bird behavior in response to these disturbances, will inform studies intended to document behavior of these species before and after aquaculture facility construction.

Investigator: Monika Parsons (MS)

Advisors: Cynthia S. Loftin (Co-Advisor)
Frederick Servello (Co-Advisor)
William Halteman
John Sowles
James Gilbert

Duration: January 2008—May 2011

Cooperators:

Maine Department of Marine Resources
Maine Aquaculture Innovation Center
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
University of Maine – Department of Wildlife Ecology
University of Maine – Maine Agricultural and Forest Experiment Station
U.S. Fish and Wildlife Service – Maine Coastal Islands National Wildlife Refuge

Forest succession and amphibian migrations: Implications for landscape connectivity

1) Evaluate the effects of forest regeneration on a Maine amphibian community up to six year post-harvesting.
2) Quantify the permeability to juvenile amphibian movements of different-aged woodland habitats resulted from clearcutting.
3) Identify orientation mechanisms used by juvenile amphibians during dispersal and migration.
4) Understand the potential effects of microclimate on habitat use by juvenile amphibians.

Abstract of completed dissertation:

Conservation of forest-dependent amphibians is dependent on finding a balance between timber management and species' habitat requirements. Accurate predictions of the response of amphibian communities to disturbance rely on a good understanding of the scales at which ecological processes affect distribution and abundance through space and time. I investigated the response of 14 species to four different forestry treatments (partial harvest, clearcut with coarse woody debris [CWD] removed, clearcut with CWD retained, and uncut control) over a six-year period, using 2.1-ha experimental treatments. Forest amphibians showed a strong negative response to complete canopy removal at a broad spatial scale, but site-specific variation in the use of forestry treatments was the norm at a finer scale. Four forest-dependent species showed substantial declines in abundance beginning at two – three years post-disturbance. Avoidance of clearcuts by forest species and site-specific patterns of habitat use were maintained throughout the study. Incipient vegetative succession and retaining CWD did not mitigate the effects of clearcutting; I found only a modest positive effect of succession on habitat use by emigrating juvenile wood frogs (*Lithobates sylvaticus*). I studied the permeability to juvenile wood frogs movements of four forestry treatments (recent clearcut, mature forest, 11-year-old conifers, and 20-

year-old natural regeneration). I conducted experimental releases in 50 x 3 m terrestrial enclosures built in each treatment. Recent clearcuts and young coniferous stands were significant barriers to movements, and were three times less permeable to movement compared to the mature forest and 20-year-old regeneration. In addition, I found that juvenile wood frogs reared in semi-matural conditions did not show inherited directionality upon emergence, rely on proximate cues for orientation, and avoided forested wetland cues. Vegetative succession in young stands (five-six-year-old) mitigated the effects of clearcutting on microclimate, but juvenile wood frogs strongly avoided these stands. Thus, microclimate cannot be used as a sole parameter to predict potential habitat use by amphibians. Closed-canopy habitat was preferred by all terrestrial life stages of forest amphibians. A viable forest management strategy is to plan for spatially and temporally-structured harvests that retain canopy between high-quality breeding sites, and avoid clearcutting and conversion to conifer plantations.

Investigator: D. Viorel Popescu (PhD)

Advisors: Malcolm L. Hunter, Jr. (Advisor)
Aram J.K. Calhoun
Joseph Zydlewski
James P. Gibbs
Richard Seymour

Duration: January 2006—January 2011

Cooperators:

National Science Foundation
University of Maine – Department of Wildlife Ecology
Maine Association of Wetland Scientists
University of Missouri
University of Georgia — Savannah River Ecological Laboratory

River restoration in the northeast: Implications for avian assemblages

1) Develop a monitoring framework that will assess the response of River Bird Assemblage (RBA) to dam removal.
2) Characterize RBA prior to and potentially during dam removal (pending dam removal timeline).
3) Examine pre-dam removal Osprey distribution, abundance, and productivity as a baseline for measuring response to fish restoration.
4) Investigate the relationship between habitat and RBA.
5) Evaluate the relative importance of marine and freshwater prey to Bald Eagle, Osprey, Belted Kingfisher, and Tree Swallow using analysis of marine derived nutrients.

Understanding the feeding and habitat relationships of various species is a key to unraveling ecosystem function and thus is critically important in discerning responses to human impacts. Most research within river systems identifies fish as the top predators and focuses at this or lower levels in the food web. However, many bird species also rely on the river system and can be linked to the river food web as omnivores, insectivores, and piscivores. Their importance in riverine ecosystems is often overlooked. This study examines community dynamics of riverine birds and their interactions with dams and river habitat variation.

The ultimate goal of the study is to quantify how river associated bird assemblages respond to various habitat conditions that are likely to be impacted by dam removal and the subsequent restoration of spawning diadramous fishes. It is reasonable to assume that dam removal will alter some of these river variables and thus affect bird assemblages in both the short and long -term.

The river bird monitoring framework was established in the fall of 2008 and became fully operational the following spring with a network of 45 volunteers set up along the Penobscot and other Maine rivers. The

first four years of monitoring encompass the time prior and potentially during dam removal (pending 2012 dam removal) and provide context for the next four years of river bird monitoring, post-dam removal. Funding was awarded by the Maine Outdoor Heritage Fund (MOHF) to examine Osprey distribution, abundance, and productivity measures were acquired during the 2011 breeding season. Habitat variables at each survey site are being collected at low, normal (bankfull), and high water levels (or low and high tide as applicable) over the course of the project and additional bankfull measurements were collected in 2011. MOHF also facilitated the collection and processing of bird and prey samples as part of Objective five.

Investigator: Erynn M. Call (PhD)

Advisors: Malcolm L. Hunter, Jr. (Advisor)
Cynthia Loftin
Brian Olsen
Karen Wilson
Joseph Zydlewski

Duration: April 2009—May 2013

Cooperators:

Eastern Maine Conservation Initiative
Maine Department of Inland Fisheries and Wildlife
Biodiversity Research Institute
Maine Audubon Society
Maine River Bird Volunteer Network
The Nature Conservancy
Penobscot River Restoration Trust
University of Maine – Sustainable Solutions Initiative
University of Maine – Department of Wildlife Ecology

Amphibian movement in complex landscapes: Effects of forestry and urbanization on juvenile dispersal of vernal pool-breeding amphibians

1. Quantify differences in habitat permeability of open-canopy habitats (forest clear-cuts, lawns, hayfields, row crops) to juvenile wood frogs during post-metamorphic dispersal period.
2. Develop a miniaturized harmonic direction finding (HDF) system for direct tracking of individual amphibians, with applications for other small-bodied organisms or commercialization of the technology.
3. Assess effects of heavy partial harvest systems on dispersing and overwintering juveniles.
4. Assess effects of landscape composition on dispersing and overwintering juveniles – using a combination of direct-tracking and field/laboratory trials to quantify movement, microhabitat selection and terrestrial settling patterns (aspects of amphibian terrestrial ecology heretofore limited by transmitter lifespan).
5. Quantify individual amphibian movement parameters for building and validating an individual-based behavioral model of dispersal (*Lithobates sylvaticus*; *Ambystoma maculatum)*

For many amphibian species, the juvenile life stage represents the primary driver of gene flow and population connectivity. However, there is a paucity of data on juvenile movement/emigration because direct tracking is hampered by: (a) the small size of metamorphs; (b) the biphasic (terrestrial-aquatic) life history and cryptic behavior associated with this life stage; and (c) prior limitations in longevity/size of tracking technologies. Thus, our research focuses on juveniles, with a principal intent to describe breeding dispersal – or the process of emigration from natal pool to eventual breeding pool. Development of a miniaturized technology (harmonic radar transponder tags) will allow us to follow the fate and behavior of

individually-marked amphibians across multiple life stages. Our ultimate objective is to assess the effects of different land-use and forestry practices on amphibian dispersal, to understand how these movement processes affect population persistence.

This project is part of the Land-use Effects on Amphibian Populations (LEAP) project. We also pursue interdisciplinary research in coupled social-ecological systems (SESs) through the Sustainability Solutions Initiative (SSI), as part of the subproject "Protecting Natural Resources at the Community Scale: Using Population Persistence of Vernal Pool Fauna as a Model System to Study Urbanization, Climate Change and Forest Management."

Our research in 2011 focused on the influence of forest edges and the permeability of different forested and non-forested habitats to juveniles. Specifically, we quantified the differences in habitat permeability of (1) open-canopy habitats; and (2) heavy partial harvests to juvenile wood frogs (*Lithobates sylvaticus*) during the post-metamorphic period.

For our first objective, we constructed terrestrial runways and conducted experimental releases of metamorphs in: (1) hayfield, (2) row crop (feed corn), (3) lawn (varying % canopy cover classes), and (4) clear-cuts (two-three yrs post-harvest). Our second objective is part of a larger suite of experimental and descriptive studies (2011-12) to examine the implications of current harvest practices on amphibians in the Acadian forest. In 2011, we assessed the dispersal orientation of juveniles along silvicultural edges in heavy partial harvests via experimental-release trials (10-m diameter arenas); our study yielded simple data to describe the dichotomous choice between contiguous forest and harvests.

Investigator: Britt B. Cline (PhD)

Advisors: Malcolm L. Hunter, Jr. (Advisor)
Aram J.K. Calhoun
David Hiebeler
Robert Seymour
Joseph D. Zydlewski

Duration: January 2010—January 2014

Cooperators:

National Science Foundation
University of Maine – Department of Wildlife Ecology
University of Maine – Sustainable Solutions Initiative
Maine Association of Wetland Scientists (MAWS)

Environmental assessment of circumneutral fens with shrubby cinquefoil (*Dasiphora fruticosa*): Host plant of the endangered Clayton's copper butterfly (*Lycaena dorcas claytoni*)

1) Characterize the physical environment of wetlands supporting shrubby cinquefoil in Maine, including wetlands with and without Clayton's copper butterflies.
2) Compare age structure, phenology, and stand characteristics among shrubby cinquefoil populations with and without nectaring populations of Clayton's copper.
3) Compare shrub morphology and quality of flowers and leaves of shrubby cinquefoil plants in wetlands inhabited and uninhabited by Clayton's copper butterfly.

Clayton's copper butterfly (*Lycaena dorcas claytoni*) is a Maine state endangered species that relies exclusively on shrubby cinquefoil (*Dasiphora fruticosa*) as its host plant. This shrub typically is found on the edges of wetlands rich in calcium carbonate or limestone. Currently only 21 sites in Maine are known to support large stands of *D. fruticosa*, and *L. d. claytoni* populations have been observed at only nine of these. Conservation of *L. d. claytoni* depends in part on the ecological integrity of its habitat. It is unknown what factors of the host plant contribute to the suitability of a site for Clayton's copper. We are examining the quality of the habitat and plants selected by *L. d. claytoni* for nectaring and egg-laying to randomly selected plants, to address the following questions: Is there an association between butterfly occurrence and the hydrological environment, pore water chemistry, peat chemistry and morphology, and plant assemblages of a wetland site? Is there an association between butterfly occurrences and the age structure, phenology, and size of the shrubby cinquefoil stands within a wetland site? Is there an association between butterfly occurrence and cinquefoil morphology or "robustness," quality and quantity of flowers, quality and quantity of leaves, and location of individual shrubby cinquefoil plants in the wetland?

We installed continuous water level recorders at all sites inhabited by Clayton's copper butterfly and three uninhabited sites to determine vertical flow and water table fluctuations in each wetland. We collected pore water and peat samples within the root zone of *D. fruticosa* to examine nutrients, chemical conditions, and peat morphology between occupied and unoccupied sites. We are comparing chemical composition, water content, and physical characteristics of leaves collected at occupied and unoccupied sites. Nectar samples were collected at several locations to evaluate collection and analysis techniques. We have sectioned, measured and counted growth rings in collected shrubs to characterize population age structure.

Finally, we characterized the shrub and tree communities on transects placed within shrubby cinquefoil patches where other chemical, physical, and cinquefoil sample collections occurred, and where Clayton's copper population surveys were completed in previous studies. Data analysis currently is underway, and the M.S. thesis will be completed by August 2012.

Investigator: Sarah A. Drahovzal (MS)

Advisors: Cynthia S. Loftin (Co-Advisor)
Judith M. Rhymer (Co-Advisor)
Frank A. Drummond
Andrew S. Reeve

Duration: September 2008—May 2012

Cooperators:

American Philosophical Society
Maine Department of Inland Fisheries and Wildlife
The Nature Conservancy
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
University of Maine – Maine Agricultural and Forest Experiment Station

Harbor Seal Abundance Survey

1) Develop a statistically robust harbor seal aerial abundance survey design based on bay units that were delineated in a 2001 survey.
2) Conduct harbor seal live capture and tagging (VHF, satellite, sonic) in Chatham Harbor, Cape Cod Bay, and western Penobscot Bay.
3) Conduct aerial photographic surveys and VHF radio tracking along the Maine coast during peak pupping period.
4) Write a report suitable for publication in a peer review journal.

Up to 60 harbor seals will be captured in March and April and fitted with VHF radio tags. An aerial survey will be conducted in late May to count the numbers of harbor seals in sample areas of the coast. A second aircraft will be deployed to determine the fraction of radio-tagged harbor seals that are on ledges and available to be counted.

The sample counts and fractions of tags available will be combined to estimate harbor seal abundance during the pupping season. The design-based estimator is a Hanson - Horwitz Estimator with-replacement sampling with sample area probability of selection proportional to the expected numbers of harbor seals.

Project extended one year.

Investigator: James R. Gilbert

Duration: May 2011—September 2012

Cooperators:

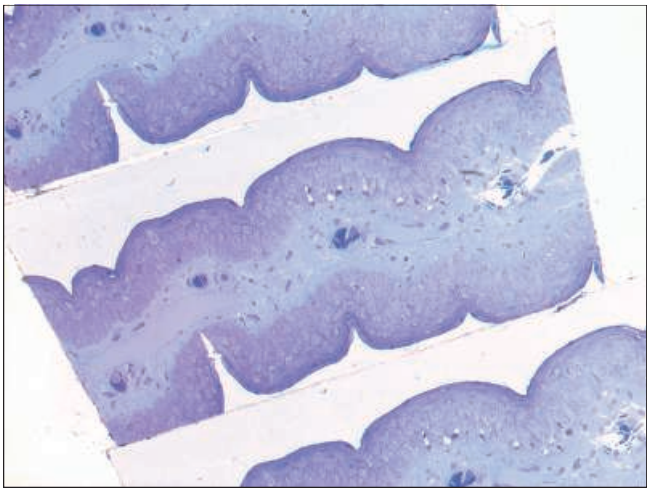
National Oceanic and Atmospheric Administration
University of Maine – Maine Agricultural and Forest Experiment Station

Establishment of *Batrachochytrium dendrobatidis* in anuran epidermis and experimental transmission from bullfrogs to wood frogs

1) To determine how the amphibian skin pathogen *Batrachochytrium dendrobatidis* (Bd) invades host cells
2) To determine if skin structure differs in Bd-resistant bullfrogs and Bd-susceptible wood frogs
3) To determine if the bullfrog acts as a vector of Bd

Chytridiomycosis, a skin disease caused by the fungus Batrachochytrium dendrobatidis (Bd), threatens anuran populations worldwide. Mild infections in the bullfrog are well-documented. In contrast, wood frogs can die from chytridiomycosis. We tested whether skin structure and host invasion by Bd differed in bullfrogs and wood frogs. Bullfrog skin was thicker than wood frog skin. Bd invades host cells with germination tubes; the invasion process did not differ in the model hosts. We encourage further research on skin structure as a potential determinant of susceptibility to Bd. We also conducted an ex-situ experiment to determine whether Bd-infected bullfrogs can act as disease vectors. Bullfrogs transmitted Bd to wood frog tadpoles, causing mortality in wood frogs after metamorphosis. We highlight bullfrog disease screening as a management challenge because their low infection loads can be difficult to detect.

All experiments complete. Project is in writing stage.



Investigator: Sasha E. Greenspan (MS)

Advisors: Aram J.K. Calhoun (Co-Advisor)
Joyce E. Longcore (Co-Advisor)
Seth Tyler

Duration: September 2009—December 2011

Cooperators:

University of Maine – Department of Wildlife Ecology
University of Maine – School of Biology and Ecology

Amphibian use of naturally fishless lakes, stocked historically fishless lakes, and montane wetlands in western Maine

1) Determine if fish presence has an influence on amphibian community composition and reproductive effort.
2) Develop a habitat selection model for wood frog (*Lithobates sylvaticus*) in western Maine compare findings for northern and western mountain region's to eastern lowlands.

Amphibian populations face a multitude of complex threats, including habitat loss or modification. Fish introduction to previously fishless alpine lakes in the western United States has led to declines in endangered frogs and salamanders found in those systems, however, effects of fish introductions on the amphibian communities breeding in western Maine's lakes are not well-documented. Our research documents amphibian communities and reproductive effort in 14 mid-elevation lakes in western and northern Maine and wetlands within a 1km buffer surrounding the lakes. The study lakes are of three types: naturally fishless since deglaciation, historically fishless but stocked with brook trout during the past century, and historically stocked and now fishless.

We are documenting amphibian presence and abundance with visual encounter surveys, passive auditory surveys (i.e., remote audio recorders), and trapping. Our study focusses on vernal pool breeding species' (*Ambystoma maculatum, Ambystoma laterale, Rana sylvatica*) use of these aquatic habitats and linkage with wetlands and the surrounding terrestrial environment, to understand potential effects of modifying the non-breeding habitat on persistence of these species in this wetland-limited landscape.

We are tracking post-breeding wood frogs with radio transmitters to determine their hibernacula selection and wetlands used for breeding habitat. The habitat use information gained from our telemetry studies will be combined with wetland and lake amphibian presence and reproductive effort surveys to improve our understanding of how this landscape is used throughout the year. This information will provide guidance for conservation of these western Maine lakes and surrounding uplands to ensure longterm persistence of these species in this region

We have completed one field season, focusing on surveying the lakes and the area within 1 km of the lakes for breeding habitat use and availability and wetlands and uplands used during the non-breeding season. Audio surveys for breeding anurans were conducted during spring-summer 2011. We used radio telemetry to track post-breeding movements of wood frogs in the landscapes surrounding two study lakes, and we will continue these surveys post-hibernation

Investigator: Luke Groff (PhD)

Advisors: Cynthia S. Loftin (Co-Advisor)
Aram J.K. Calhoun (Co-Advisor)
Committee TBD

Duration: January 2010—December 2014

Cooperators:

Maine Department of Inland Fisheries and Wildlife
U.S. Geological Survey – Eastern Region Cooperative Fish and Wildlife Research Units
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
University of Maine – Department of Wildlife Ecology
University of Maine – Sustainable Solutions Initiative

Spatial responses of Canada lynx to changing hare densities

1. To evaluate if landscape-and stand-scale habitat choices by lynx are different during periods of low vs. high hare densities.
2. To evaluate how changing hare densities affect spatial requirements and extent of spatial overlap among adjacent lynx.
3. To understand the effects of vegetation type, topography, and season on accuracy and success of GPS fixes of radio-collared lynx.

Canada lynx (*Lynx canadensis*) have been listed as federally threatened under the Endangered Species Act since 2000. Lynx are a specialist predator of snowshoe hares and their populations closely lag the snowshoe hare population cycle. During periods of lower hare abundance, lynx may be forced to alter aspects of their spatial ecology to survive. For example, habitat selection, home range area, recruitment, and territorial overlap may change as lynx adjust to declining numbers of prey. Some of these relationships have been studied in the northern portion of their range, but the existence of hare cycles, and the expected responses of lynx to changing hare densities are unknown within the Acadian Forest region where the dominant factor influencing the quality and supply of high quality lynx and hare habitat is commercial-scale forest harvesting.

The largest population of lynx in the contiguous U.S. occurs in Maine where large clearcuts were a common form of timber harvest prior to the enactment of the Maine Forest Practices Act in 1989. Since 1992, partial harvests have become the dominant form of timber harvest, thus reducing the extent, of regenerating conifer-dominated clearcut stands. Those changes densities of regenerating conifer stems, which are positively associated with hare density and patterns of lynx occupancy. Additionally, broad-scale factors that might contribute to regional changes in hare populations could exacerbate effects of anthropogenic processes on future habitat quality for hares and lynx.

This project looks at the relationships among temporally changing hare densities, spatial ecology of lynx, and multi-scalar patterns of habitat selection by lynx within northern Maine. Additionally, we are evaluating effects of vegetation, topography and season on our success and accuracy at locating lynx using GPS collars to account for methodological biases that might occur using GPS technology.

We continue to monitor hare density by conducting biannual fecal pellets counts in 29 stands representing two types of timber harvests, including regenerating conifer clearcuts (since 2001) and in partially harvested stands (since 2005), as well as in two types of mature softwood-dominated and mature-mixed forest habitat (since 2008). Previous work identified 2 periods of high and low hare density and we have collected home range, inra- and inter-sexual spatial overlap, stand-scale and landscape-scale habitat selection information for 13 male and 11 female Canada lynx during the high hare density period and for 10 male and 6 female lynx during the low hare density period. Our telemetry data has been collected using both VHS and GPS collars as part of a collaborative field study administered by the Maine Department of Inland Fisheries and Wildlife. To account for these different technologies, we conducted a companion study to assess location error and fix success across 2 seasons, 66 test sites, and 7 habitat types. Analyses of all aspects of the project have been completed and an M.S. thesis summarizing findings is scheduled for completion by May 2012.

Investigator: David Mallett (MS)

Advisors: Daniel J. Harrison (Co-Advisor)
Angela K. Fuller (Co-Advisor)
Richard S. Seymour
Jennifer H. Vashon (ex-officio)

Duration: January 2006—May 2012

Cooperators:

University of Maine – Department of Wildlife Ecology
University of Maine – Maine Agricultural and Forest Experiment Station
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
U.S. Fish and Wildlife Service
Maine Department of Inland Fisheries and Wildlife
University of Maine – Maine Cooperative Forestry Research Unit

Seasonal variation of snowshoe hare density and implications for Canada lynx in managed forests of northern Maine

1. To document the influence of different forest stand types and seasonality on stand-level snowshoe hares densities.
2. To determine the relationship between seasonal changes in vegetation structure among different forest stand types and seasonal snowshoe hare densities.
3. To evaluate how relative snowshoe hare densities, which differ seasonally among forest stand types, affect lynx reproductive success.
4. To document seasonal food habits of Canada Lynx in northern Maine.

The federally threatened Canada lynx (*Lynx canadensis*) are specialist predators of snowshoe hare (*Lepus americanus*) which comprise up to 97% of lynx diet. Lynx movement, survival, and recruitment are closely associated with snowshoe hare availability. Harvest activities alter the composition and structure of forests, affecting the quality and availability of snowshoe hare and lynx habitat. Refugia from predators provided by vegetative cover changes seasonally and by forest stand type, which may affect snowshoe hare reproductive success.

This project will quantify vegetation characteristics that change dramatically with seasons, such as canopy closure, among four forest stand types in leaf-on, then leaf-off seasons to determine the stands' relative influence on temporal and spatial densities of hares.

Relative seasonal hare abundance among different habitats may influence hunting success and consequently reproductive performance of female lynx. This work will determine the relation between lynx reproductive parameters and snowshoe hare availability by season and forest stand type.

Lynx can shift to alternative prey at their southern extents of their distribution, during low hare density periods and during snow-free periods. This project will document seasonal lynx dietary habits to determine if there is a dietary shift from snowshoe hares when other prey is seasonally available.

Hare fecal pellet counts were conducted biannually in 29 stands composed of four types in 2010 and 2011. These data continue a time series collected since 2001. Data have been compiled and analysis is scheduled to begin in April, 2011.

To assess lynx diet, winter samples collected by MDIFW and previously by personnel in our lab have been compiled. Additionally, summer scats were collected using a scat detection dog team in July, 2011. Scat samples were sent to the University of Washington for genetic analysis to confirm species before diet analyses, which will be performed during spring 2012.

In August-September 2011, vegetation data were collected from 20 plots in each of 28 stands. Metrics used were lateral cover, canopy cover, and vegetation composition at four levels of a 10 m squared plot. From January-March 2011, the stands will be re-measured for the same lateral and canopy cover variables, as well as snow depth.

Investigator:	Sheryn J. Olson (MS)
Advisors:	Daniel J. Harrison (Advisor) William B. Krohn Richard S. Seymour J. H. Vashon (ex-officio) Mark McCullough (ex-officio)
Duration:	January 2010—December 2012

Cooperators:

University of Maine – Department of Wildlife Ecology
University of Maine – Maine Agricultural and Forest Experiment Station
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
U.S. Fish and Wildlife Service
Maine Department of Inland Fisheries and Wildlife
University of Maine – Maine Cooperative Forestry Research Unit

Genetic analysis of Blanding's turtle populations

1. Assess the population genetic structure of Blanding's turtle populations in the Northeast and incorporate findings into conservation planning and priority area management in Maine, Massachusetts, New Hampshire, New York, and Pennsylvania.
2. Examine isolated/outlier Blanding's turtle populations in Pennsylvania and New York to determine origin (naturally occurring or introduced).
3. Compare the genetic structure of Blanding's turtle populations within the Northeast region to those in the Midwest region and Canada to provide a spatially explicit assessment of the discrete population groups across the species' range.

The geographic range of Blanding's turtle (*Emydoidea blandingii*) occurs in the mid-continent of North America, with the majority of populations occurring in the Great Lakes region and southern Ontario. In the Northeast United States, there is a small contiguous population in Massachusetts, New Hampshire and Maine, two disjunct populations in eastern New York, and one population in Pennsylvania of unknown status. Blanding's turtle populations are declining throughout their range, and are state-listed as threatened in New York and Massachusetts, as endangered in Maine and New Hampshire, and as a Species in Greatest Need of Conservation (SGCN) in all Northeast states where it occurs. In Canada, the Great Lakes/St. Lawrence population in Ontario and Quebec is listed as threatened and the disjunct population in Nova Scotia is listed as endangered (Committee on the Status of Endangered Wildlife in Canada, COSEWIC). A status assessment has been completed for the species in the Northeast and the next high priority action to implement is the development of a regional conservation plan including an assessment of genetic variation throughout the region, and development and implementation of a monitoring protocol. Although some research has been done on the genetic structure of Blanding's turtle populations among regions across their range, adequate information is not available to determine the degree and boundaries of discreteness of northeastern populations. This research will compare the genetic structure of populations in the Northeast with those across the species range in the United States and Canada using DNA sequencing and genotyping. Results will be used to determine the distinctiveness of the Northeast populations compared to the Midwest/Great Plains region, which could affect the approach to managing the species in the Northeast. These data are essential for informed management and conservation planning for Blanding's turtles in the Northeast.

Investigator: Judith M. Rhymer

Duration: June 2011—May 2014

Cooperators:

Maine Department of Inland Fisheries and Wildlife
University of Maine – Department of Wildlife Ecology
University of Maine – Maine Agricultural and Forest Experiment Station
U.S. Fish and Wildlife Service
Cooperative Fish and Wildlife Research Unit, University of Massachusetts,
Massachusetts Division of Fisheries and Wildlife
New York State Department of Environmental Conservation
Biology Department, Acadia University, Nova Scotia, Canada
Swampwalkers Wetland Ecosystem Specialists, Parker River Association, MA
Biology Department, SUNY Potsdam, NY
New Hampshire Fish and Game Department
Pennsylvania Fish & Boat Commission's Natural Diversity Section

Genetic structure of Clayton's copper butterfly (*Lycaena dorcas claytoni*) metapopulation

Analyze genetic structure of Clayton's copper butterfly metapopulation in Maine with nuclear DNA loci [microsatellites and Amplified Fragment Length Polymorphisms (AFLPs)].

The focus of this research is to analyze the genetic structure of Clayton's copper butterfly populations in the state of Maine. Clayton's copper is a state endangered species and is currently found at only nine sites in Maine, however nothing is known about the metapopulation structure of this subspecies. This research will estimate levels of gene flow among sites, which will help us to understand the metapopulation dynamics of Clayton's copper butterfly by estimating levels of dispersal and isolation that contribute to population stability.

Preliminary results indicate that there are three distinct clusters of subpopulations in Maine: northern Maine near Caribou, northwestern Maine in the Allagash region and central Maine near Lincoln. Genetic structure of subpopulations within regions will be analyzed with AFLP data. Results will contribute to efforts to estimate the diversity and size of the Clayton's copper population in the state, and will aid in developing a management strategy for the species in Maine.

Investigator: Judith M. Rhymer

Duration: September 2008—December 2012

Cooperators:

University of Maine – Department of Wildlife Ecology
University of Maine – Maine Agricultural and Forest Experiment Station
U.S. Fish and Wildlife Service
Maine Department of Inland Fisheries and Wildlife
Maine Outdoor Heritage Fund
The Nature Conservancy
American Philosophical Society

Breeding and terrestrial habitat requirements of the eastern spadefoot (*Scaphiopus holbrookii*) and pure-diploid blue-spotted salamander (*Ambystoma laterale*) in eastern Connecticut

The objectives of the study are to collect information on:

1) breeding population size
2) breeding philopatry
3) movement patterns of adults/juveniles to and from breeding wetlands (immigration and emigration orientation)
4) juvenile recruitment
5) juvenile and adult dispersal rates
6) non-breeding habitat use and home range size
7) burrowing ecology (eastern spadefoot)
8) larval interactions (blue-spotted salamander and spotted salamanders [A. maculatum])

The research provides valuable information on two Massachusetts, New York and Connecticut State-listed species, the eastern spadefoot (*Scaphiopus holbrookii*) and the pure-diploid blue-spotted salamander (*Ambystoma laterale*). Both species merit scientific investigation as information on the terrestrial ecology of both animals is sparse. Our results will help to determine best management practices for mitigation of developments affecting habitat for these and other pool-breeding species that depend on adjacent terrestrial habitats for the majority of their lives.

Information is collected on study animals through the use of: (1) pitfall trapping (mark-recapture), (2) radio-telemetry, (3) PIT tag scanning: a technique entailing systematically scanning for animals with implanted PIT tags using a PITpack (an electronic tag reading device reminiscent of a metal detector), and (4) toad-totes (a stationary tag-reading device used to monitor eastern spadefoot toad burrow emergence). The larval experiment was conducted using a series of mescosms.

The spring, summer, and fall of 2011 represented the fourth and final field season of data collection. The highlight of the final field season was the discovery of an eastern spadefoot breeding pool; this represents the

first discovery of a breeding pool for the eastern Connecticut spadefoot population. Formal data analysis is to begin immediately.

Investigator: Kevin J. Ryan (PhD)

Advisors: Aram J.K. Calhoun (Advisor)
Michael W. Klemens
Joseph D. Zydlewski
Brad Timm
Malcolm L. Hunter, Jr

Duration: January 2008—August 2013

Cooperators:

University of Maine – Department of Wildlife Ecology
University of Maine – Sustainable Solutions Initiative
Connecticut Department of Energy and Environmental Protection
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit

Amphibian communities in vernal pools, fishless lakes, and fish-containing lakes in Downeast Maine, and effects of predation of spotted salamanders (*Ambystoma maculatum)*

1) Characterize amphibian communities of fishless and fish-containing lakes in Maine.
2) Determine if egg mass morphology and oviposition affect *Ambystoma maculatum* resistance to predation.
3) Determine morphological plasticity of larvae and fitness of adult *Ambystoma maculatum* breeding in vernal pools, fishless lakes, and fish-containing lakes.

Lakes in Maine with natural and stocked fish populations support invertebrate communities that differ from those naturally without fish. The introduction of fish to historically fishless lakes also may affect the amphibian species that reside, breed, or feed in these water bodies. Introduced fish potentially eat amphibians and aquatic insects that prey on or are food for amphibians. Amphibian species that are palatable to fish may avoid predation by using alternative breeding sites or post-breeding habitat. Lakes stocked with fish may become biological sinks for amphibian populations that continue to use the water bodies for egg-laying in spite of fish predation. Habitat characteristics such as structural complexity of egg laying sites as well as characteristics of eggs masses may affect breeding success in these permanent water bodies. It is not clear if amphibian behavioral or morphological plasticity allows their persistence in these modified environments. We will determine if amphibian community composition differs among fishless and fish-containing lakes and identify habitat conditions and characteristics of *Ambystoma maculatum* (spotted salamander) egg masses occurring in fishless and fish-containing lakes and adjacent vernal pools.

Fishless and fish-containing lake pairs in Downeast Maine were surveyed for amphibian occurrence with audio, visual, and trapping surveys in 2007 and 2008. Associated vernal pools were surveyed in 2008 and

2009. Adult *A. maculatum* fitness characteristics were measured in spring 2009. Field and lab experiments examining the effects of fish and invertebrate predators on *A. maculatum* egg masses and larvae were completed in summer 2009. Vegetation and substrate surveys for all lakes and vernal pools were completed in summer 2009. Data analysis and synthesis are currently underway with the dissertation expected to be completed in May 2012.

Investigator: Amanda Shearin (PhD)

Advisors: Cynthia S. Loftin (Co-Advisor)
Aram J.K. Calhoun (Co-Advisor)
Kevin Simon
William Halteman
William Glanz

Duration: January 2006—December 2011

Cooperators:

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

A long-term forest ecosystem study

1. Describe the structure of the plant and animal communities in an oak-pine forest ecosystem.
2. Investigate the effect of woodlot management on populations and community structure.
3. Document phenological, inter annual, and long-term changes in population and community structure.

This continuing study is being conducted on a 120 ha, red oak-white pine woodlot in Arrowsic, Maine, called the Holt Forest. A 40 ha study area is gridded into forty 1-ha blocks with 20 ha serving as a control area and 20 ha as an experimental area.

Over the years we have collected data sets that include a 100% inventory of trees (>10cm DBH), intensive inventories of tree saplings and seedlings, tree mapping on 20ha, a complete record of the vascular plant vegetation using the relevé technique, an inventory of all breeding bird territories, annual small mammal trapping, salamander cover object counts, estimates of seed and fruit production, frass counts of canopy insect defoliators, and vascular plant densities in 1m2 plots.

A 1987/-1988 timber harvest with three objectives: (1) increase wood production; (2) increase wildlife diversity and abundance; and (3) maintain the forest's aesthetic value has provided a basis of comparison to better understand the impacts of harvesting. By continuing to monitor populations and processes, we have better insights into plant and wildlife populations. Over the course of nearly 30 years, we have begun to better understand seasonal and annual changes in populations and the ecosystem structure.

In 2011, our 29th field season, all yearly monitoring projects were completed, a remeasurement of 1m2 relevé plots was the major initiative for the field season. In 2012, our goal is to evaluate the vascular plant vegetation over a large portion of the study area. This will give us insights into impact of deer on the herbaceous vegetation community and the changes in relation to the successional stage of the forest. All

yearly monitoring will be conducted except for fruit counts which were discontinued due to the much reduced fruit production in recent years.

High acorn mast in 2010 and good conditions in the spring of 2011 resulted in the highest density of oak seedlings ever recorded at HRF. Where they were prolific, oak seedlings were the dominant vegetation of the forest floor. Extra effort will be made to tract this cohort of oak seedlings in 2012 and future years.

Investigators: Malcolm L. Hunter, Jr.
Alan J. Kimball
Alan S. White
Jack W. Witham

Duration: January ongoing—January 2013

Cooperators:

Holt Woodlands Research Foundation
University of Maine – Sustainable Solutions Initiative

Mark McCollough

INTEGRATED ecology

Managing natural resources on private lands: Theory and practice of collaborative approaches using vernal pool conservation planning in Maine

1. Discuss the theoretical underpinnings of collaboration, addressing the hypothetical benefits, expected outcomes, and critical concerns.
2. Consider the limitations of past and current approaches used to evaluate collaboration in practice.
3. Develop an integrated performance evaluation framework to measure success and failure of collaborative initiatives.
4. Offer a practical example to examine the social and environmental outcomes of collaborative vernal pool conservation planning in Maine.
5. Evaluate the role of collaboration in shaping the character of local-level planning efforts.
6. Provide insight on the barriers and opportunities for using collaboration as a management tool for protecting natural resources on private lands.

Abstract of completed dissertation: Vernal pools are small, seasonal wetlands that provide critical breeding habitat for a unique assemblage of amphibians and invertebrates and important habitat for rare and endangered species. The overarching goal of my research was to better understand the challenges and opportunities for conserving vernal pools on private land using regulatory and voluntary approaches. In pursuing this goal, I examined the process and outcomes of collaborative planning at the state and local level using a mixed-methods approach of observations, interviews, focus groups, and a mail survey. I interviewed members and stakeholders of the state-driven Vernal Pool Working Group (VPWG) to link the process and outputs of multi-stakeholder collaboration with social and environmental outcomes. Using interviews, focus groups, and a mail survey, I explored private landowner response to vernal pools, vernal pool regulations, and the Vernal Pool Mapping and Assessment Program (VPMAP), a community-based citizen science education and outreach program. I also used interviews, focus groups, and observations to investigate how VPMAP structured interactions between experts and stakeholders in community-based conservation planning. Intangible outcomes such as building relationships, establishing trust, and sharing information among participants were the most beneficial aspects of VPWG deliberations. Consensus among stakeholders on new state vernal pool regulations and "spin-off" partnerships such as VPMAP emerged from the social, political, and intellectual capital developed during the 10-year deliberative process. Data from participant observation, interviews, and focus groups revealed a diversity of frames that landowners used to describe vernal pools, vernal pool regulations, and VPMAP. Quantitative analysis of the mail questionnaire identifed three distinct clusters of landowners based on similar views of property rights, conservation, development, and economic factors. While VPMAP mobilized support for community-based management, enhanced awareness and understanding of vernal pools at the local level, and improved participatory local planning through a process of collaborative learning, communication was a significant barrier for the effective functioning of VPMAP as a participatory strategy to engage a wider network of stakeholders in proactive conservation planning. I conclude that initiating and supporting voluntary community-based processes within top-down regulatory structures is a challenging task requiring a continuous exchange of social and ecological information.

Investigator: Jessica S. Jansujwicz (PhD)

Advisors: Aram J.K. Calhoun (Co-Advisor)
Robert J. Lilieholm (Co-Advisor)
James Acheson
Richard W. Judd
Laura Lindenfeld

Duration: January 2006—January 2009

Cooperators:

University of Maine – Senator George J. Mitchell Center for Environmental and Watershed Research
University of Maine – Department of Wildlife Ecology
University of Maine – Sustainable Solutions Initiative

Priority sites for Chilean wetlands conservation

1) Assess the vulnerability, condition and irreplaceability of Chilean wetlands remotely based on biological and physical information, and human demography.
2) Combine information about condition and vulnerability to identify those wetlands that should be targeted for conservation in three political regions that are representative of the major geographical areas of the country.
3) Compare the above results, by political region, to the more subjective process conducted by CONAMA.

Abstract of completed report: The goal of this project is to identify areas where wetlands are most threatened in the Valparaiso region of Chile, located in a biodiversity hotspot, and in one of the most populated areas of the country, by undertaking a systematic analysis. Prior to this project, priority areas for wetland conservation in Chile and the Valparaiso region had been selected based solely on expert opinion. For the identification of vulnerable wetland sites, Geographical Information Systems software was used to combine digital information about populated areas, roads, water extraction, and wetland distribution. We created four different vulnerability scenarios where each human impact had different weight. We found one wetland, a Myrceugenia exsucca swamp forest located in the city of Quintero, which was classified as highly vulnerable in all four scenarios studied. Overall, 18 wetlands were identified as highly vulnerable when combining all the studied scenarios.

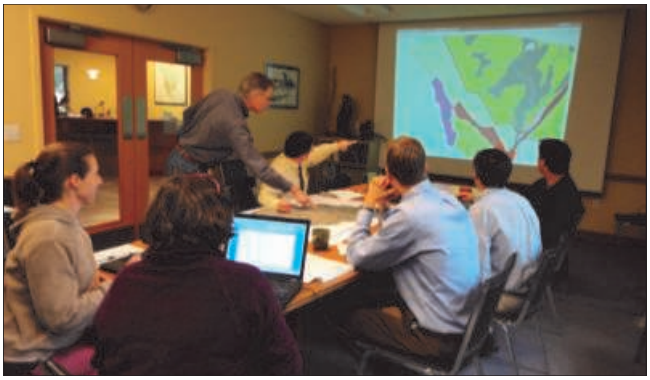
Investigator: Pilar A. Palacios (MWC)

Advisors: Malcolm L. Hunter, Jr. (Co-Advisor)
Aram J.K. Calhoun (Co-Advisor)
J. Swenson

Duration: January 2006—January 2011

Cooperators:

Centro de Ecologia Aplicada & CONAMA (National Environment Comission)



An examination of the drivers, institutions and economics of sustainability planning in Maine

1. Characterize sustainability policies in Maine municipalities and identify the drivers that lead to the adoption of such policies.
2. Study efforts of two Maine towns that are developing vernal pool regulatory policy, as an example of a sustainable policy.
3. Conduct economic policy analysis to inform local vernal pool policy development.

1) Develop specific measures of sustainability patterns in Maine towns and examine patterns of adoption using spatial analysis and statistical classification (January through December 2012). 2) Participant observation of all relevant stakeholder meetings (throughout 2012). Draft semi-structured interview protocol (Summer 2012). Conduct interviews (Fall 2012). Collect documents (throughout 2012).
3) Conduct economic analysis for towns (January - April 2012). Continue developing research plan (Spring-Summer 2012).

Project proposal and proposal seminar completed. Attended approximately 20 stakeholder meetings in 2011. Presented project update to AAAS review of SSI in May 2011.

Investigator: Vanessa Levesque (PhD)

Advisors: Aram J.K. Calhoun (Co-Advisor)
Kathleen Bell (Co-Advisor)
Mario Teisl
Teresa Johnson
David Owen

Duration: January 2010—May 2013

Cooperators:

Maine Department of Environmental Protection
Maine Department of Inland Fisheries and Wildlife
University of Maine – Sustainable Solutions Initiative

Remote monitoring of water clarity of Maine lakes using Landsat Thematic Mapper

1) Determine if Landsat data can reliably duplicate late water clarity assessment with Secchi Depth and chlorophyll a data collected at selected lakes.
2) Determine temporal frequency (when, how often) and spatial limitations (resolution, location) of image collection for lake water clarity monitoring to complement field data collection programs.
3) Retrospective analysis of Maine's lake water clarity based on archived remote sensing data.

Maintaining quality of Maine's abundant lakes is a priority of the state natural resource management agencies as well as of interest to the public using the lakes. Monitoring lake water quality can be accomplished with an in situ sampling program, however, few of the state's lakes are monitored annually owing in part to their remoteness. In addition, temporal and spatial variations in lake condition can affect how representative a collected sample is of the true lake condition. Sensors mounted on a satellite platform enable frequent remote collection of data to assess environmental conditions over a large area. A variety of remote sensors have been used to monitor a variety of lake attributes, however, there are caveats for using these remotely acquired data as indicators of lake water condition. For example, relationships established in one area between lake water clarity measured with Secchi disk depth (SDD) and sensor reflectance recorded on a particular type and temporal series of satellite imagery cannot be assumed to apply in another area without in situ calibration. Once relationships between SDD and imagery are calibrated, however, archived data enable a spatially comprehensive assessment of recent lake conditions as well as an opportunity for retrospective analysis of lake condition that can be compared to current as well as changing land conditions in the lake watershed. We are comparing satellite imagery and SDD data collected in Maine's lakes to establish relationships between the remotely (Landsat, MODIS) and locally collected data to identify limitations of the remote sensing data for monitoring lake water clarity and trophic condition and to retrospectively assess trends in water clarity in Maine's lakes

Development of algorithms to relate Landsat and secchi disk data is complete, and we currently are developing algorithms based on MODIS imagery. The retrospective analysis of water clarity trends will be completed in early 2012, with thesis completion anticipated in May 2012.

Investigator: Ian McCullough (MS)

Advisors: Cynthia S. Loftin (Co-Advisor)
Steven Sader (Co-Advisor)
William Halteman
Aram J.K. Calhoun

Duration: June 2010—July 2012

Cooperators:

Maine Department of Environmental Protection
U.S. Geological Survey – Maine Cooperative Fish and Wildlife Research Unit
University of Maine – Department of Wildlife Ecology

Conserving vernal pools through community based conservation

1. To coordinate proactive mapping of vernal pools at the municipal level
2. To provide resource materials pertaining to Maine's Significant Vernal Pool legislation
3. To initiate and test a new paradigm in Maine for conserving vernal pools on private property while maintaining local property values for protecting natural resources on private lands

The Vernal Pool Mapping and Assessment Program, developed in response to requests from diverse stakeholders for help in understanding and responding effectively to the 2007 Significant Vernal Pool Law, has continued in its role of providing support to Maine communities through outreach and training programs, web resources, and technical support. Building on the success of this project, we launched an innovative initiative to increase regulatory flexibility at the local level while providing economic incentives for resource conservation that address both landowner and town financial needs. In this process we have identified and partnered with two municipalities (Orono and Topsham) that will serve as models to other Maine municipalities, and established a working group composed of key individuals responsible for natural resource planning decisions that protect environmental quality while supporting healthy economic growth opportunities (MDIFW, MDEP, MSPO, ACOE, EPA). We have engaged both stakeholders (development corporations, realtors, local land trusts, and conservation commissions) and resource professionals (environmental lawyers, resource economists, environmental consultants, and spatial analysts) to help the group to establish a model that will give more planning power to the towns and reduce the enforcement workload of state and federal agencies.

To date, we have established partnerships and set the foundation for a multi-year project that will address both economic and natural resource protection issues at the local level. In the past year we have held 13 stakeholder meetings and formed 4 subcommittees (conservation prioritization and mapping, human dimensions, economic, and regulatory). In addition, we have provided 11 training and outreach workshops for a variety of stakeholders (tax assessors, code enforcement officers, foresters and loggers, land trusts, agricultural community, landowners, etc.) pertaining to this work.

Investigators: Dawn E. Morgan
Aram J.K. Calhoun
Vanessa R. Levesque

Duration: January 2006—January 2011

Cooperators:

University of Maine – Senator George J. Mitchell Center for Environmental and Watershed Research
University of Maine – Department of Wildlife Ecology
University of Maine – Sustainable Solutions Initiative

PUBLICATIONS and presentations

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Lindenmayer, D.B. and M.L. Hunter, Jr. 2011. Some guiding concepts for conservation biology. Conservation Biology 24:1459-1468.

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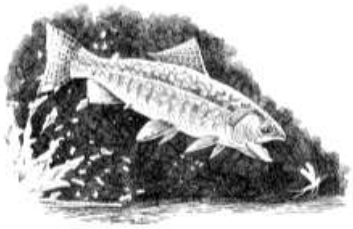

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Krohn, W.B. and C.S. Loftin (eds). 2010. Maine Cooperative Fish and Wildlife Research Unit and Department of Wildlife Ecology. 2010 Report to Cooperators. Maine Cooperative Fish and Wildlife Research Unit, University of Maine, Orono. 43 pp.

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Vashon, J., D. Harrison, A. Fuller, D. Mallet, W. Jakubas, and J. Organ. 2011. Documenting the response of Canada lynx to declining snowshoe hare populations in an intensively managed private forest landscape in northern Maine. Pages 49-51 *in* W.J. Mercier and A.S. Nelson (eds.) Cooperative Forestry Research Unit: 2010 Annual Report, The University of Maine, Orono.

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Kazyak, Dave. 2011. Growth and movement of brook char, (*Salvelinus fontinalis*) in coastal Maine. M.S. Thesis, 116 pages.

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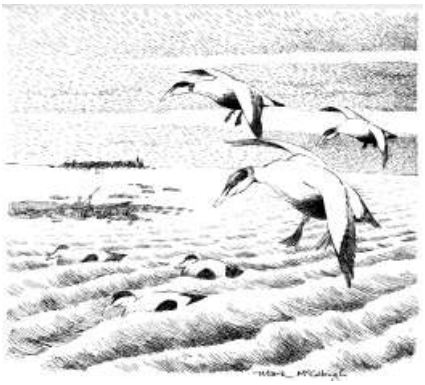

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Call, E.M. 2010. "The ecology of wading birds in the Everglades." Department of Wildlife Ecology Fall Seminar Series, October 18, Orono, ME.

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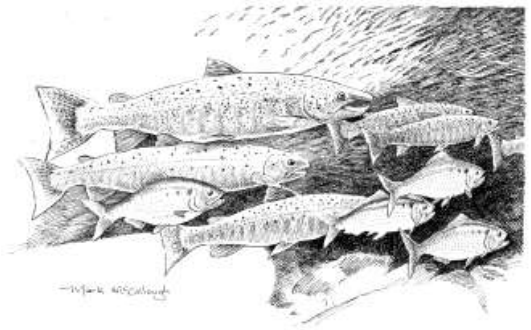
Coghlan Jr., S.M. and W. Ashe. 2011. "Monitoring success of Atlantic salmon fry stocking in the headwaters of the Machias River." Presented at the National Oceanic and Atmospheric Administration's Habitat Connectivity science panel meeting, August 21, Old Town, ME.

Coghlan Jr., S.M., J. Zydlewski, K. Simon, C. Garner, R. Hogg, and R. Saunders. 2011. "Monitoring outcomes of barrier removal in Sedgeunkedunk Stream." Presented at the National Oceanic and Atmospheric Administration's Habitat Connectivity working group meeting, August 21, Old Town, ME.



Coghlan Jr., S.M., R. Hogg, J. Zydlewski, K. Simon, and R. Saunders. 2011. "Barrier removal and range expansion of sea lamprey in the Penobscot River watershed: The importance of habitat conditioning in Atlantic salmon nursery streams." 141th Annual Meeting of the American Fisheries Society, September 5-9, Seattle, WA.

Damkot, P.D. and S.M. Coghlan Jr. 2011. "The influence of riparian forest characteristics on terrestrial invertebrate input and brook trout diet in headwater streams." Presented at the 141st annual American Fisheries Society National Conference, September 5-7, Seattle, WA.

Danielson, T.J, C.S. Loftin, and F. Drummond. 2011. "Comparison of benthic diatom models for estimating nutrient concentrations in Maine streams and rivers." Presentation at the North American Benthological Society annual meeting, May 22-26, Providence, RI.

Danylchuk, A., B. Letcher, J. Zydlewski, A. Whiteley, T. Dubrieul, and S. Hurley. 2011. "Movement patterns of brook trout (*Salvelinus fontinalis*) inhabiting a restored coastal stream in Massachusetts: Preliminary evidence of anadromy." 141th Annual Meeting of the American Fisheries Society, September 4-9, Seattle, WA.

Drahovzal, S., C.S Loftin, and J. Rhymer. 2011. "Hydrological and chemical environment of Maine's circumneutral wetlands supporting Shrubby Cinquefoil (*Dasiphora fruticosa*), host plant of the state endangered Clayton's Copper butterfly (*Lycaena dorcas claytoni*)." Maine Cooperative Fish and Wildlife Research Unit Annual Coordinating Committee Meeting, Wells Commons, University of Maine, April 12, Orono, ME.

Drahovzal, S., C.S. Loftin, and J. Rhymer. 2011. "Environmental assessment of circumneutral fens with shrubby cinquefoil (*Dasiphora fruticosa*), host plant of the endangered Clayton's Copper butterfly (*Lycaena dorcas claytoni*)." Northeast Natural History Conference, April 7, Albany, NY.

Drahovzal, S., C.S. Loftin, and J. Rhymer. 2011. "Hydrological and chemical environment of Maine's circumneutral wetlands supporting Shrubby Cinquefoil (*Dasiphora fruticosa*), host plant of the state endangered Clayton's Copper butterfly (*Lycaena dorcas claytoni*)." Maine Water Conference, March 16, Augusta, ME.

Erbland, P.J., G.B. Zydlewski, J. Zydlewski, and J.E. Hightower. 2011. "Fixed, side-aspect acoustic sampling of a diverse diadromous fish community in a tidal river." 141th Annual Meeting, American Fisheries Society, September 4-8, Seattle, WA.

Fuller, A.K., D.J. Harrison, and W.B. Krohn. 2010. "A wildlife-based modeling approach to forest landscape planning." Presentation at The Wildlife Society Annual Conference, October 6, Snowbird, UT.

Greenspan, S.E., A.J.K. Calhoun, and J.E. Longcore. 2011. "Infection and transmission of the pathogen Batrachochytrium dendrobatidis in two Maine anurans: *Lithobates sylvaticus* (wood frog) and *Lithobates catesbeianus* (bullfrog)." Presented to Maine Association of Wetland Scientists, March 24, Hallowell, ME.

Greenspan, S.E., J.E. Longcore, and A.J.K. Calhoun. 2011. "Break on through: Host invasion by *Batrachochytrium dendrobatidis*." Presented to Integrated Research Challenges in Environmental Biology (Emerging Wildlife Diseases: Threats to Amphibian Biodiversity), November 14, Tempe, AZ.

Grote, A., J. Zydlewski, and M. Bailey. 2011. "Establishing baselines for American shad in the Penobscot River." 141th Annual Meeting of the American Fisheries Society, September 4-9, Seattle, WA.

Grote, A., M. Bailey, and J. Zydlewski. 2011. "Establishing baselines for American shad in the Penobscot River." Presentation to The Nature Conservancy, March 22, Brunswick, ME.

Grote, A., M. Bailey, and J. Zydlewski. 2011. "Establishing baselines for American shad in the Penobscot River." Department of Marine Resources, April 14, Bangor, ME.

Grote, A., M. Bailey, and J. Zydlewski. 2011. "Fishway monitoring using DIDSON: Hydroacoustic assessment of American shad at Veazie dam." 2011 Coordinating Committee Meeting of the U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit, April 12, Orono, ME.

Guyette, M. 2010. "The role of marine derived nutrients delivered by anadromous fish in Penobscot River watershed nursery streams." Presentation for the Cunjak Lab, University of New Brunswick, December 9, Fredericton, New Brunswick, Canada.

Guyette, M. 2011. "Evidence of marine-derived nutrient uptake in Atlantic salmon nursery stream communities." Presentation for the Project SHARE Quarterly Meeting, June 9, Whitneyville, ME.

Guyette, M., C. Loftin, and J. Zydlewski. 2011. "Evidence of marine-derived nutrient uptake in Atlantic salmon nursery stream communities." 2011 Coordinating Committee Meeting of the U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit, April 12, Orono, ME.

Guyette, M., C.S. Loftin, and J. Zydlewski. 2011. "Effects of marine-derived nutrients on juvenile Atlantic salmon and their communities." Presented at the UMaine Grad Expo, Wells Commons, April 21-22, Orono, ME.

Guyette, M., C.S. Loftin, and J. Zydlewski. 2011. "Marine-derived nutrient uptake in Atlantic salmon nursery stream communities." Presentation at the Annual Meeting of the North American Benthological Society, May 26, Providence, RI.

Guyette, M., C.S. Loftin, and J. Zydlewski. 2011. "The role of marine derived nutrients delivered by anadromous fish in Penobscot River watershed nursery streams." Presentation for the Maine Bureau of Sea Run Fisheries and Habitat, Department of Marine Resources, February 10, Bangor, ME.

Guyette, M.Q., C.S. Loftin, and J. Zydlewski. 2011. "Evidence of marine-derived nutrient uptake in Atlantic salmon nursery stream communities." Maine Water Conference, March 16, Augusta, ME.

Harrison, D., E. Simons, A. Fuller, and W. Krohn. 2011. "Trends in habitat for forest wildlife in Maine's great north woods: The need for landscape planning." Presentation at U.S. Fish and Wildlife Service Northeast Region Biologists Conference, February 14, Baltimore, MD.

Harrison, D.J. 2011. "Effects of wind power development on American martens and Canada lynx: An issue of scale." Presentation at Wind Energy and Wildlife Forum, The Maine Chapter of The Wildlife Society, May 5, Orono, ME.

Hogg, R., S.M. Coghlan Jr, and J. Zydlewski. 2011. "Barrier removal in Sedgeunkedunk Stream: Sea lamprey recolonization and implications for Atlantic salmon habitat restoration." Penobscot Valley Audubon Chapter, Inez Boyd Environmental Research Award at Bangor Public Library, May 12, Bangor, ME.

Hogg, R., S.M. Coghlan Jr., and J. Zydlewski. 2011. "Barrier removal in Sedgeunkedunk Stream: Sea lamprey recolonization and implications for Atlantic salmon habitat restoration." 2011 Coordinating Committee Meeting of the U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit, April 12, Orono, ME.

Hogg, R., S.M. Coghlan Jr., J. Zydlewski, and C. Gardner. 2011. "Barrier removal in Sedgeunkedunk Stream: Sea lamprey recolonization and resident fish community dynamics." Presented at the 141st annual American Fisheries Society National Conference, September 5-7, Seattle, WA.

Hunter, M.L. 2010. "Designing refuges that are resilient to climate change." National Conservation Leadership Forum, National Conservation Training Center, November 5, Shepherdstown, WV.

Hunter, M.L. 2011. "A conservation biologist's perspective on climate change." School of Biology and Ecology, University of Maine, January 28, Orono, ME.

Hunter, M.L. 2011. "Designing refuges to maintain biodiversity in the face of climate change." National Fish, Wildlife and Plants Climate Adaptation Strategy Team, March 29, Washington, DC.

Hunter, M.L. 2011. "Maintaining forest biodiversity in a period of uncertain climate change." Warnell School of Forestry and Natural Resources, University of Georgia, March 31, Athens, GA.

Jansujwicz, J.S., R. Lilieholm, and A.J.K. Calhoun. 2011. "Spanning boundaries and disciplines: Integrating social science into natural resources conservation to enhance vernal pool management on private lands." International Association for Society and Natural Resources, May 5, MD.

Kiraly, I., S.M. Coghlan, Jr., J. Zydlewski, and D. Hayes. 2011. "Quantifying the effects of dam removal on the structure and function of fish assemblages in the Penobscot River." 141th Annual Meeting of the American Fisheries Society, September 4-9, Seattle, WA.

Loftin, C.S., A.J.K Calhoun, S. Nelson, A. Elskus, and K. Simon. 2010. "Does mercury bioaccumulate in amphibians developing in vernal pools?" Eastern region meeting of the Geological Society of America: Session entitled Mercury in the environment, Maine to Florida, March 13-16, Baltimore, MD.

McCullough, I., C.S. Loftin, and S. Sader. 2011. "Remote monitoring of water clarity of Maine lakes with satellite imagery." Maine Cooperative Fish and Wildlife Research Unit Annual Coordinating Committee Meeting, Wells Commons, University of Maine, April 12, Orono, ME.

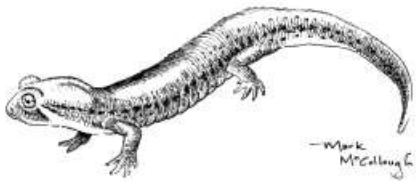
McCullough, I., C.S. Loftin, S. Sader. 2011. "Remote monitoring of water clarity of Maine lakes with satellite imagery." Maine Lakes Conference, Colby College, June 25, Waterville, ME.

Parsons, M., C.S. Loftin, and F. Servello. 2010. "Remotely monitoring seabird responses to disturbance by avian predators, boats and observers during the breeding season." Presentation at The Wildlife Society 2010 Annual Meeting, October 2-6, Salt Lake City, UT.

Ratten, S. and J. Zydlewski. 2011. "Growth and movements of lake whitefish in two Maine lakes." 141th Annual Meeting of the American Fisheries Society, September 4-9, Seattle, WA.

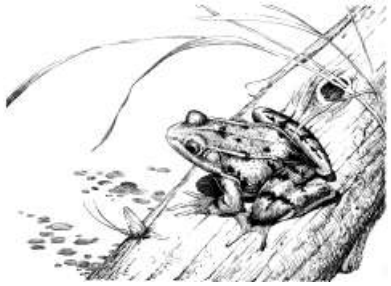
Saunders, R., S.M. Coghlan, Jr., J. Zydlewski, and T. Sheehan. 2011. "Dam removal allows re-colonization of historic habitat by three species of anadromous fish in Sedgeunkedunk Stream, Maine." 141th Annual Meeting of the American Fisheries Society, September 5-7, Seattle, WA.

Shearin, A. 2011. "Vernal pool ecology and conservation." Presentation to Cathance River Education Alliance, May 31, Topsham, ME.



Shearin, A., A.J.K. Calhoun, and C.S. Loftin. 2011. "Improving amphibian audio surveys using automated audio recording devices." American Society of Ichthyologists and Herpetologists Annual Meeting, July 6-11, Minneapolis, MN.

Shearin, A.F., A.J.K. Calhoun, and C. Loftin. 2011. "Frog loggers and fish: Five years of amphibian research in Maine's fishless lakes." Maine Association of Wetland Scientists Annual Meeting, March 24, Hallowell, ME.



Shearin, A.F., A.J.K. Calhoun, and C.S. Loftin. 2010. "Facultative breeding occurrence by vernal pool amphibians in Maine's fishless lakes." The Wildlife Society Annual Conference, October 6, Snowbird, UT.

Shearin, A.F., A.J.K. Calhoun, and C.S. Loftin. 2011. "Using automated audio recording devices to improve listener-based amphibian surveys." Maine Water Conference, March 16, Augusta, ME.

Shearin, A.F., C.S. Loftin, and A.J.K. Calhoun. 2011. "Five years of amphibian research in Maine's fishless lakes." U.S. Geological Survey-Maine Cooperative Fish and Wildlife Research Unit Annual Meeting, April 12, Orono, ME.

Zydlewski, J., A. Firmenich, J. Kocik, and C. Lipsky. 2011. "Preliminary results of an imprinting and estuary release stocking method." Maine Conservation and Hatchery Assessment Team Meeting, Craig Brook National Fish Hatchery, June 30, East Orland, ME.

Zydlewski, J., G. Zydlewski, B. Kennedy, and W. Gale. 2011. "Smolting in coastal cutthroat trout?" 141th Annual Meeting of the American Fisheries Society, September 4-9, Seattle, WA.

PUBLIC TALKS PRESENTED

Ashe, W. and S.M. Coghlan Jr. 2011. "Atlantic salmon (*Salmo salar*) growth and survival as an indicator of habitat quality in tributaries of the Machias River watershed." Poster presented at Maine Water Resource Research Institute – Maine Water Conference, March 17, Augusta, ME.

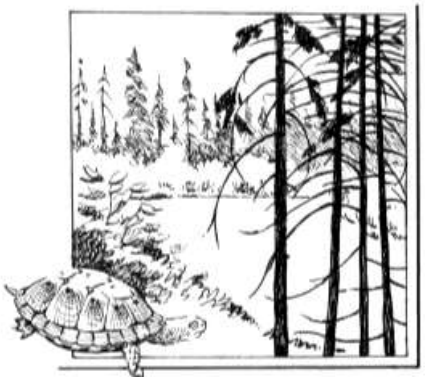
Calhoun, A.J.K. 2011. "The great temperate forest migration: Vernal pools." Maine EPSoR conference, April 15, Orono, ME.

Calhoun, A.J.K. 2011. "Vernal pool conservation in working forests." Kennebec Woodland Partnership, May 3, Wayne, ME.

Calhoun, A.J.K. and D.E. Morgan. 2011. "Conserving vernal pool functions through local collaborative initiatives." Annual meeting of the Wisconsin Wetland Association, February 6, Madison, WI.

Calhoun, A.J.K. and D.E. Morgan. 2011. "Training workshop for vernal pool citizen scientists." April 13, Towns of Wayne and Readfield, ME.

Calhoun, A.J.K. and D.E. Morgan. 2011. "Vernal pool conservation priorities." Annual meeting of the Land Trust Alliance, April 29, Topsham, ME.



Call, E.M. 2010. "My life with birds: From childhood to career." Adventure Girl program through Hardy Girls Healthy Woman, Fields Pond Audubon Center, October 16, Holden, ME.

Coghlan Jr., S.M. 2011. "Fish / forestry interactions." Summer Field Camp for FTY 101 (Introduction to Forest Resources), Tanglewood Education Center, August 24, Lincolnville, ME.

Coghlan Jr., S.M. 2011. "Fish movements in headwaters streams: The importance of habitat connectivity." Presented at the annual Maine Cooperative Forestry Research Unit stakeholders' funding meeting, April 14, Orono, ME.

Harrison, D., E. Simons, A. Fuller, and W. Krohn. 2011. "Habitat planning and assessment for forest vertebrates in northern Maine." Presentation at Annual Coordinating Committee Meeting of the U. S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit, University of Maine, May 12 Orono, ME.

Harrison, D.J. 2011. "Lynx, forests, and forestry in northern Maine." Presentation at Meeting of The Forest Society of Maine, August 15, Greenville, ME.

Jansujwicz, J.S., A.J.K. Calhoun, and R. Lilieholm. 2011. "Integrating social science into natural resources conservation to enhance management of vernal pools." Maine Water Conference, March 8, Augusta, ME.

Jansujwicz, J.S., A.J.K. Calhoun, and R.J. Lilieholm. 2011. "Communicating sustainability through citizen science: Challenges and (missed) opportunities." Citizen Science Symposium, Wells Conference Center, University of Maine, May 13, Orono, ME.

Krohn, W.B. 2011. "Come back of the snowshoe cat: The story of Canada lynx in Maine." Presentation at the Penobscot County Conservation Association's Annual Sportsman's Show, University of Maine, March 12, Orono, ME.

Morgan, D. and A.J.K. Calhoun. 2011. "Community based approach to mapping and conserving vernal pool resources." Citizen Science Symposium, Center for Research on Sustainable Forests, University of Maine, May 12, Orono, ME.

Morgan, D.E. and A.J.K. Calhoun. 2010. "Conserving Maine vernal pools through collaborative local initiatives." Maine EPSCoR State Conference, University of Maine, November 8, Orono, ME.

Morgan, D.E. and A.J.K. Calhoun. 2011. "Maine municipal guide to mapping and conserving vernal pools." Maine Audubon Society, May 19, Falmouth, ME.

Morgan, D.E. and A.J.K. Calhoun. 2011. "Research-extension partnerships in sustainability science: Bridging research-based knowledge with client-based needs." SSI-UMaine Cooperative Extension Workshop and World Sustainability Teach-in Day. Senator George J. Mitchell Center, University of Maine, December 3, Orono, ME.

Simons-Legaard, E.M., D.J. Harrison, K. Legaard, and S. Sader. 2011. "The effectiveness of zoning to protect deer wintering areas during the period 1975-2007: Does compromising forest productivity to protect deer habitat achieve desired ecological objectives?" Presentation at Advisory Committee Meeting, Maine Cooperative Forestry Research Unit, University of Maine, January 26, Orono, ME.

Witham, J. W. 2011. "Salt marshes of Georgetown – history and function." Georgetown Historical Society, August 16, Georgetown, ME

WORKSHOPS

Calhoun, A.J.K. 2011. "Forest management practices and vernal pools." Quoddy Learning Center and Nature Park, April 11, New Brunswick, Canada.

Calhoun, A.J.K. 2011. "Vernal pool conservation in working forests." Kennebec Woodland Partnership, May 3, Wayne, ME.

Calhoun, A.J.K. and D.E. Morgan. 2011. "Maine Municipal Vernal Pool Mapping Project training workshops for towns of Wayne and Readfield". April 13, Wayne, ME.

Calhoun, A.J.K. and D.E. Morgan. 2011. "Maine Municipal Vernal Pool Mapping Project training workshop for town of Yarmouth". April 12, Yarmouth, ME.

Calhoun, A.J.K. and D.E. Morgan. 2011. "Vernal pool conservation priorities." Annual meeting of the Land Trust Alliance, April 29, Topsham, ME.

Calhoun, A.J.K. and D.E. Morgan. 2011. "Vernal pool mapping and conservation public informational workshop." March 15, Orono, ME.

Calhoun, A.J.K. and G. Moore. 2011. "The biology of and habitat management guidelines for timber harvesting near vernal pools." Workshop for the Kennebec Valley Land Trust, May 3, Augusta, ME.

Coghlan Jr., S.M. 2011. "Ecology, natural history, and collection of Maine fishes." Trout Unlimited's Youth Trout Camp, July 1, Solon, ME.

Coghlan Jr., S.M. 2011. "Penobscot River fish community: Past, present, and future." Northaven High School's Field Experience in Ecology summer program, September 14, Chesuncook, ME.

Coghlan Jr., S.M. 2011. "Ecology of sea lamprey in Maine." Dirigo Pines evening seminar series, September 14, Orono, ME.

Coghlan Jr., S.M. and K.S. Simon. 2011. "Winter ecology of lake fishes and techniques of ice fishing." Maine Audubon community program at Field's Pond Nature Center, January 21, Holden, ME.

Coghlan Jr., S.M., J. Zydlewski, R. Hogg, C. Gardner, R. Saunders, and K.S. Simon. 2011. "Barrier removal and range expansion of sea lamprey: Effects on Atlantic salmon nursery streams". Maine Sportsmen's Show / Kennebec Valley Chapter of Trout Unlimited, April 2, Augusta, ME.

Fuller, A.K., D.J. Harrison, and W.B. Krohn. 2010. "Required steps to develop a habitat classification and structured decision-making framework for use in planning for multiple biodiversity and forest objectives on TNC's St. John Lands." Presentation at Workshop on Managing Working Forest Landscapes for Multiple Biodiversity and Fiber Objectives Using American Martens and Canada Lynx as Focal Species, University of Maine, November 10, Orono, ME.

Fuller, A.K., D.J. Harrison, and W.B. Krohn. 2010. "Results from a structured process for deciding among alternative management scenarios on TNC's St. John lands: Trends in habitat supply for martens and lynx and resulting inventory and forest-related metrics." Presentation at Workshop on Managing Working Forest Landscapes for Multiple Biodiversity and Fiber Objectives Using American Martens and Canada Lynx as Focal Species, University of Maine, Orono, November 10, Orono, ME.

Harrison, D.J. 2010. "The need for landscape planning on commercially managed landscapes in Maine." Presentation at Workshop on Managing Working Forest Landscapes for Multiple Biodiversity and Fiber Objectives Using American Martens and Canada Lynx as Focal Species, University of Maine, November 10, Orono, ME.

Hunter, M.L. Jr. and A.J.K. Calhoun. 2011. "Advice on attending a professional meeting." Society for Conservation Biology Annual Meeting." December 5-9, Auckland, New Zealand.

Moore, G. 2011. "Habitat management guidelines for timber harvesting at or near vernal pools." Workshop for the Piscataquis County Soil and Water Conservation District, April 23, Dover-Foxcroft, ME.

Moore, G. 2011. "Vernal pool and wetlands biology and management." Presentation for the Maine Conservation Corps, August 26, Dover-Foxcroft, ME.

Moore, G. 2011. "Vernal pool habitat management and water quality best management practices for timber harvesting activities." Workshop for Wagner Timberlands, Great Northwoods Timberlands, Foresters and Contractors, Ragmuff Camps, June16, Northeast Carry Township, ME.

Morgan, D.E. and A.J.K. Calhoun. 2010. "Research-extension partnerships in sustainability science: Bridging research-based knowledge with client-based needs." SSI-UMaine Cooperative Extension Workshop and World Sustainability Teach-in Day, Senator George J. Mitchell Center, University of Maine, December 6, Orono, ME.

Witham, J. W. 2011. Many Rivers One Estuary: Collaborations, Connections and Challenges. Translating Knowledge into Action: A symposium connecting stakeholders and researchers within the Androscoggin and Kennebec watersheds. "Welcome and introductory remarks." Bowdoin College, November 17, Brunswick, ME.

TELEVISION, RADIO, AND NEWSPAPER INTERVIEWS AND ARTICLES

Coghlan Jr., S.M. 2011. "Lamprey thriving in Sedgeunkedunk Stream". Bangor Daily News, July 24. http://bangordailynews.com/2011/06/24/outdoors/misunderstood-lamprey-thriving-in-sedgeunkedunk-stream/

Harrison, D.J. 2011. "The Forest Society of Maine and Canada Lynx". Community News, September 1.

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