2018-2019 Unit Report

Vermont Cooperative Fish and Wildlife Research Unit

In Cooperation With

- U.S. Geological Survey
- Vermont Department of Fish and Wildlife
- University of Vermont
- Wildlife Management Institute

Vermont Cooperative Fish and Wildlife Research Unit

2018 - 2019
Report of Activities

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Cover photos clockwise from top: Juvenile lake sturgeon with saddle marks (photo by Ashley Eaton); Moose in the Northeast Kingdom (photo by Josh Blouin); Lisa Izzo holding juvenile lake sturgeon (photo by Ashley Eaton).

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Program Direction Statement

The Vermont Cooperative Fish and Wildlife Research Unit is located at the University of Vermont (UVM) in Burlington, Vermont, and is housed on campus in the Rubenstein School of Environment and Natural Resources. Overall goals of the Unit are (i) to address technical and research needs of federal fish and wildlife agencies, the Vermont Fish and Wildlife Department, the University of Vermont, and other federal, state, and private entities; (ii) to participate in the education of graduate students and advanced undergraduate students at the University of Vermont; and (iii) to disseminate findings of research conducted by Unit personnel, graduate students, and cooperators. Unit personnel coordinate Unit activities with federal fish and wildlife agencies, the Vermont Fish and Wildlife, and other agencies and groups involved in the management of natural resources.

Research by current Unit personnel is directed primarily toward aquatic and terrestrial ecosystems within the state of Vermont. Unit research is conducted in the context of a comprehensive, ecosystems approach that recognizes the importance of ecological and human interactions among species and their habitats. Research activities focus on the biology/ecology of fish, mammal, and bird species, and the biological consequences of human impacts on aquatic and terrestrial systems.

Research in these areas is conducted by Unit personnel who possess technical expertise in fish/aquatic ecology, landscape ecology, species/habitat associations, bioenergetics modeling, population viability modeling, and acoustic/hydroacoustics technology.

To achieve the Unit research goals, Unit personnel pursue funding sources for projects of scientific merit that advance our knowledge of natural resources and their management. This involves both field and modeling studies in which integrated research is conducted with colleagues at UVM and elsewhere. Along with these studies, Unit activities include enhancement of methodological and analytic capabilities at UVM in the areas of fish and wildlife biology.

Unit educational goals are achieved in several ways, including the teaching of formal courses at the graduate and upper undergraduate level. Courses recently taught by Unit personnel include Population Dynamics and Modeling, Conservation Biology and Modeling and participating in the integrative course required of all Rubenstein School graduate students. Several on-line courses have been developed in collaboration with the U.S. Fish and Wildlife Service National Conservation Training Center.

Unit staff also participate in the classroom through presentation of guest lectures and seminars. Unit staff act as advisors for graduate students, and are involved as committee members on graduate research committees. To the extent possible, Unit personnel also participate in training and education programs for personnel in the Vermont Fish and Wildlife Department.

Our vision for this Unit is to provide the best possible science to natural resource management agencies for the restoration of habitats and recovery and sustainability of Vermont's fish and wildlife species. In achieving our vision, we will continue to conduct research that is highly relevant to and valued by managers and policy makers.

Research Project Narratives

Modeling a Mainstem Spawner: American Shad in the Connecticut River…… **7**

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MODELING A MAINSTEM SPAWNER: AMERICAN SHAD IN THE CONNECTICUT RIVER

Principal Investigators: Donna L. Parrish, Martha E. Mather (USGS, Kansas Coop Unit), Elizabeth A. Marschall (The Ohio State University), and David Glover (Illinois Department of Natural Resources)

Project Cooperators: National Marine Fisheries Service and Vermont Department of Fish and Wildlife

Project Period: 1 January 2015 – 30 June 2018

Objective: To model juvenile American shad residence and migration within the mainstem river in order to forecast survival in relation to increased temperature and fluctuating discharges.

We present the results of this study in the publication below. The abstract of this publication is a summary of the study results and their implications.

Citation: Marschall, E.A., D.C. Glover, M.E. Mather, and D.L. Parrish. 2020. Modeling larval American Shad recruitment in a large river. North American Journal of Fisheries Management 40: *in press*.

Abstract: Climate change is altering the spatial and temporal patterns of temperature and discharge in rivers, which is expected to have implications for the life stages of anadromous fish using those rivers. We developed an individual-based model to track American Shad *Alosa sapidissima* offspring within a coarse template of spatially and temporally variable habitat conditions defined by a combination of temperature, river velocity, and prey availability models. We simulated spawning at each river kilometer along a 142-km reach of the Connecticut River on each day (1 April - 31 August) to understand how spawning date and location drive larval recruitment differentially across years and decades (1993-2002, 2007-2016). For both temperature and flow, inter-annual variation was large in comparison to interdecadal differences. Variation in simulated recruitment was best explained by a combination of season-specific spawning temperature and location along the course of the river. Greatest potential recruitment occurred in years in which June temperatures were relatively high. In years when June and July were warmer than average, maximum recruitment resulted from spawning taking place at the upstream portion of the modeled reach. Model scenarios (stationary or passive-drift larvae and dams or no dams) had predictable effects. among spawning sites, relative to stationary eggs and larvae.

We assumed the pools above dams had negative impacts on eggs and yolk-sac larvae that may have been deposited there. Allowing eggs and larvae to drift passively with the current reduced spatial differences in recruitment success among spawning sites, relative to stationary eggs and larvae.

Our results demonstrate the importance of spatiotemporal environmental heterogeneity for producing positive recruitment over the long term. In addition, our results suggest the importance of successful passage of spawners to historical spawning sites upstream of Vernon Dam in the Connecticut River, especially as conditions shift with climate change.

Project Status: Completed.

DEVELOPMENT OF METHODS TO ASSESS LAKE STURGEON POPULATIONS IN LAKE CHAMPLAIN

Principal Investigators: Donna L. Parrish, Gayle Barbin Zydlewski, and J. Ellen Marsden

Graduate Student: Lisa K. Izzo (Ph.D.)

Project Officer and Cooperator: Chet MacKenzie, Vermont Department of Fish and Wildlife

Project Period: 1 July 2016 – 31 December 2020

Objectives:

- Develop a remote sensing approach to estimate abundance of adult lake sturgeon from the Winooski River population.
- Determine movements and habitat use of juvenile lake sturgeon in spawning tributaries and in Lake Champlain.
- Investigate the use of the second marginal pectoral fin ray as an aging structure for adult and juvenile lake sturgeon.

Synopsis:

Lake sturgeon *Acipenser fulvescens* are widely distributed in freshwater systems throughout North America, occupying both lake and riverine habitats. In Vermont, lake sturgeon are only found in Lake Champlain, and the species was listed as endangered in the state in 1972 following declines in commercial harvest. Monitoring efforts have confirmed that spawning still occurs in three of the four historic spawning tributaries, but there are no abundance estimates for lake sturgeon in Lake Champlain. Additionally, information on young lake sturgeon in the system is limited. In this study, we plan to document juvenile movements, identify suitable nursery habitat, investigate minimally invasive methods to age lake sturgeon, and develop a method to estimate the population of lake sturgeon in Lake Champlain.

Project Status & Preliminary Results:

Objective 1: Two types of sonar are being investigated to estimate abundance of adult lake sturgeon from the Winooski River population. The first, side-scan sonar, is being used in mobile surveys to count lake sturgeon on the Winooski River delta. Adult lake sturgeon were observed using the side-scan sonar in surveys that took place in September 2018, December 2018, and November 2019, and these observations will be used to estimate adult abundance during the overwinter period. The second sonar type, dual-frequency identification sonar (DIDSON), is being deployed at a fixed location in the Winooski River to count migrating lake sturgeon during the spawning run. Using an integrated Bayesian model, we are combining the sturgeon counts from the DIDSON with acoustic telemetry data to account for fish movement that could influence the abundance estimate. Using this framework, we estimate 119 (58 - 206 95% CI) adult lake sturgeon visited the spawning site during the 2017 spawning season. This represents a preliminary estimate, and additional data collected in 2018, 2019, and 2020 are being used to improve the method

Objective 2: Between April 2017 and October 2019, 29 juvenile lake sturgeon (26 captured in Lake Champlain and 3 captured in the Winooski River) were tagged as part of this project. Tagged sturgeon are currently being monitored by an array of 34 stationary acoustic receivers throughout Lake Champlain and the Winooski River. Data through the fall of 2019 indicated that juvenile lake sturgeon were detected more in shallow, flat habitat in the summer and fall, and then increase their use of deep water in the winter and spring. Additionally, the 3 juvenile lake sturgeon that were captured in the Winooski River in October 2018 (assumed to be age-1 based on size) outmigrated in November 2018 to overwinter in Lake Champlain. Two of these returned to the Winooski River in April/May 2019. Ten juveniles tagged in Lake Champlain were detected in the river mouth from May – June (seven in 2019, two in 2018, & one in both years) after overwintering in the lake. These patterns suggest that the river mouth and lower Winooski River may provide important intermittent habitat for juvenile lake sturgeon in the spring and early summer.

Objective 3: This project is comparing the less invasive 2nd marginal pectoral fin ray to the fin spine, which is the traditional method used to age lake sturgeon. Fin spines and 2nd marginal pectoral fin rays have been obtained from a total of 88 individual lake sturgeon. The majority of the samples came from Lake Winnebago, WI, which is home to the largest population of lake sturgeon remaining in the Great Lakes basin, and is also the site of a large, carefully managed recreational winter spear fishery. All samples have been processed and are currently being aged by three readers to compare age estimates made using the fin spine to estimates made using the 2nd marginal pectoral fin ray.

Project Status: Ongoing.

Unit student (Lisa Izzo) inspecting sutures in a juvenile lake sturgeon following implantation of an acoustic tag in October 2019. (Photo: Ashley Eaton)

INTEGRATED FOREST ECOSYSTEM ASSESSMENT TO SUPPORT SUSTAINABLE MANAGEMENT DESCISIONS IN A CHANGING CLIMATE

Principal Investigators: Jennifer Pontius, Carol Adair, Therese Donovan, Clare Ginger, Gary Hawley, Robert Manning, James Murdoch, Shelly Rayback, and Paul Schaberg

Graduate Student: Schuyler Pearman-Gillman (Ph.D.) (co-advised with Jed Murdoch)

Project Funder: USDA McIntire-Stennis

Project Cooperator: Vermont Fish and Wildlife Department Big Game Team

Project Period: 1 June 2014 - 31 December 2019

Synopsis: Since the 1970's, temperatures across the northeastern US have warmed 0.25 degrees Celsius per decade, accompanied by a wide range of biological changes. Climate change will continue to restructure forests over the coming century, although the details remain uncertain. Understanding the impacts of landscape and climate change on wildlife distributions can help inform decision-making for conservation planning. However, empirical data on distribution is limited for many species.

In this study, we used expert elicitation techniques to develop species distribution models (SDMs) for harvested species in the Northeast, including the region's most iconic species (e.g., deer, moose, and black bear). Expert surveys were conducted with an R package called *AMSurvey*, in which experts identified the probability of occurrence of target species across study sites throughout New England in a web-based application.

Species distribution models (n = 10) were developed directly from the expert responses and applied to 4 scenarios that describe potential changes to the New England landscape to the year 2060 (Figure 1). The New England Landscapes Futures Project (NE-LFP) scenarios were built around two primary drivers – Socio-Economic Connectedness and Natural Resource Planning and Innovation – and provide plausible alternatives for how the New England region may change over fifty years (2010 to 2060). Generally speaking, the projections resulted in declines in species occurrence and richness by 2060 (Figure 2). Projected species richness was lowest under the Yankee Cosmopolitan (- 10.1%) and Business-As-Usual (-8.7%) scenarios. The Growing Global (GG) scenario had the highest average regional focal species richness (-4.4%), followed by Go It Alone (- 6.2%) and Connected Communities (-7.2%). Black bear, gray fox, moose, wild turkey, bobcat, raccoon, and striped skunk declined in all or some scenarios. Coyote and white-tailed deer were projected to have minimal change, while red fox was projected to increase across all scenarios.

Current efforts are focused on mapping areas of high resilience, defined as high-quality pixels in the region that are robust to change across the different scenarios.

These results emphasize the importance of integrating both natural resource planning and socio-economic factors to predict change in species distribution patterns, and offer insights that can inform proactive management and conservation planning.

The Coop Unit's role centered on the development of the R package, *AMSurvey*, for collecting and analyzing expert data, developing the species' distribution models and scenario comparisons, and mentoring a PhD student through research activities. Additionally, the Unit played a vital role in developing a rapid prototype of a spatially explicit decision support tool to aid natural resource managers in managing species in an uncertain climate.

Project Status: Completed (Ph.D. pending).

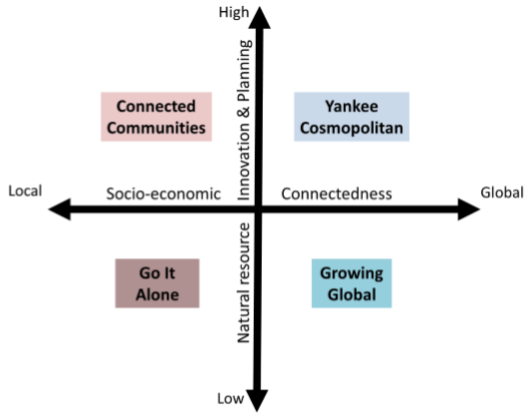


Figure 1. Four alternative scenarios of the future New England landscape based on two main drivers identified by the New England Landscape Futures Project (NE-LFP; https://s3rcn.org/).

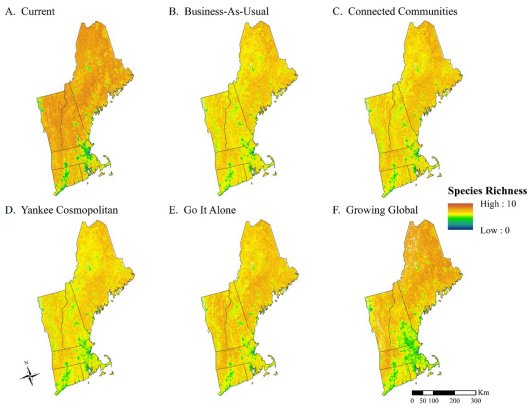


Figure 2. Focal wildlife species richness across New England as projected by A) current (2010) conditions, and each of the NELFP scenarios at year 2060,

ADVANCING ADAPTIVE MANAGEMENT FOR HEALTHY LANDSCAPE INITIATIVES

Principal Investigators: Therese Donovan, Jeff Marshall (National Science Foundation Integrative Graduate Education and Research Training Grant: http://www.uvm.edu/smartgrid/)

Graduate Student: Cathleen Balantic (Ph.D.)

Project Cooperator: Mark Massar, Bureau of Land Management

Project Period: 1 September 2014 - 1 January 2020

Synopsis: The smart grid uses modern information technology to make electric power systems work better – cleaner, cheaper, and more reliable. Rapidly advancing renewable energy sources, including solar and wind energy, are seen as a means of lowering carbon emissions to the atmosphere. Renewable energy projects, however, can impact wildlife species in a variety of ways. For example, Defenders of Wildlife report that "building a single major solar facility in the California desert can require thousands of acres of biologically-fragile land – land that supports a wide range of sensitive and imperiled species (including the desert tortoise, desert bighorn sheep, and Mohave ground squirrel) and unique habitats – to be cleared and leveled. The sheer size and scope of these projects is difficult to comprehend: Some proposed projects could cover a land area a third to half the size of the island of Manhattan when completed." The need to balance energy projection with viable wildlife populations calls for a structured approach for guiding landscape scale solar build-out.

We partnered with BLM to develop a prototype adaptive management framework for managing wildlife in the Desert Renewable Energy Conservation Area in southern California. Adaptive management is a cyclical process by which natural resource goals and objectives are explicitly compared with on-the-ground monitoring data, and the effects of management activities on objectives are quantified (Figure 1a–left). To operationalize the adaptive management framework, we developed *AMMonitor*, an R package that combines resource objectives, data collection, data curation, and analyses (Figure 1a—right). In *AMMonitor*, management objectives are specified, and then data are collected and analyzed with respect to the objective (Figure 1b). Our framework utilized cell phones as a primary data collection tool, where phones collect audio recordings of vocalizing species based on schedules posted in Google calendar. Files are then sent to a Dropbox folder for near real-time analysis in R, in which target species presence-absence are analyzed with machine -learning algorithms (Figure 1c).

Our protoype provides a comprehensive framework from moving to natural resource objectives to monitoring to decision making in a seamless and efficient manner.

The *AMMonitor* package and extensive documentation is available at https://code.usgs.gov/vtcfwru/ammonitor/

Project Status: Near completion.

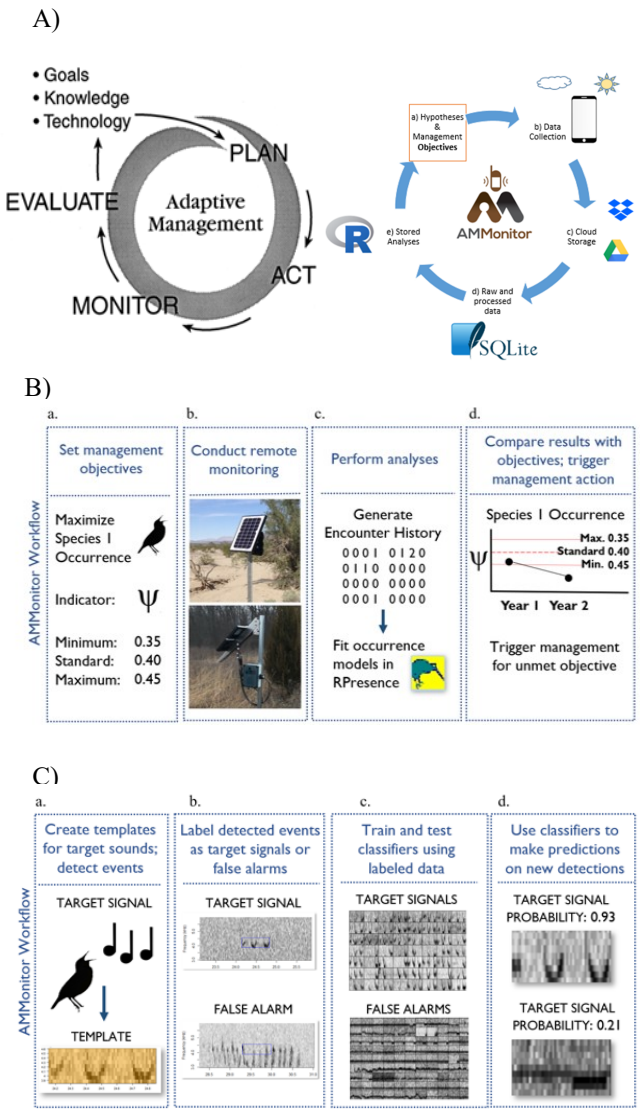


Figure 1.

A) Left. The adaptive management cycle requires managers set goals and monitor the current state of the system with respect to those goals. Management activities can be used to push the system to its intended target; continued monitoring allows managers to understand whether management activities successfully move the target in the right direction. Right. The AMMonitor system operationalizes adaptive management by combining natural resource objectives, data collection, data curation, and data analysis utilizing open source R software.

B) In AMMonitor, monitoring data (audio and images) are collected by autonomously deployed equipment (i.e., cell phones). The data collected are "pit" against the agency's objectives to trigger management activity.

C) AMMonitor 's acoustic analyses employ template matching to search for signals of target species. "Hits" can be true target signals or false alarms; machine learning is used to assign each hit a probability of being the true target, which then form the basis of an analysis that is matched to a natural resource objective (e.g., Figure 1 b).

EFFECTS OF FOREST BIOMASS ENERGY PRODUCTION ON NORTHERN FOREST WILDLIFE AND FOREST SUSTAINABILITY

Principal Investigator: Therese M. Donovan

Graduate Student: Michelle Brown (Ph.D.)

Project Cooperators: Charlie Canham, Cary Institute of Ecosystem Studies

Thomas Buchholz, Gund Institute of Ecological Economics (UVM)

Project Funding: Northeastern States Research Cooperative

Project Period: 1 July 2012 - 31 May 2016

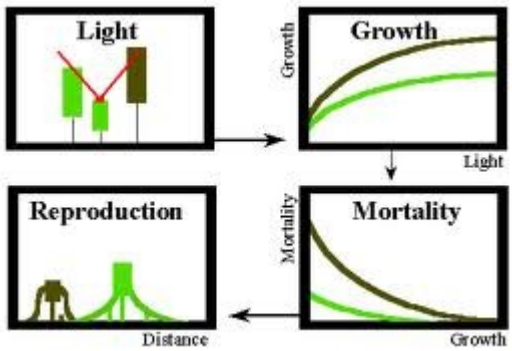
Synopsis: Federal and state governments in the Northern Forest are actively engaged in assessing the potential role of forest biomass in meeting renewable energy portfolios. For example, the governor of Vermont recently announced a goal of meeting 90% of the state's energy needs through renewables by the year 2050). While current rates of timber harvest are generally sustainable, there is considerable pressure to increase the contribution of forest biomass for renewable energy. Maximizing the biomass energy supply could compromise (potentially seriously) other uses and values of forests, including a wide range of ecosystem services and the conservation of native species. What has been missing from this debate is a realistic, regional assessment of these trade-offs through time.

In this study, we critically evaluated the capacity of the Northern Forest (NY, VT, NH, MA) to contribute to the energy needs of the region through forest biomass harvest. We implemented the harvest regimes in SORTIE-ND, an individual-based model of forest dynamics, and simulated the effects of current harvest regimes and five additional harvest scenarios that varied by harvest frequency and intensity over 150 yr. Our analyses indicate that forest biomass can represent a sustainable, if small, component of renewable energy portfolios in the region, although there are tradeoffs between carbon sequestration in forest biomass and sustainable feedstock supply.

The model output will be used in a Multi-Criteria Decision Analysis (MCDA) framework to evaluate what different harvest regimes will mean for the Northern Forest in terms of carbon storage, biodiversity levels, energy needs met, and CO_2 emissions. The results will provide decision-makers with regional assessments of the benefits and impacts of biomass energy production to meet state and regional renewable energy portfolios on a landscape level that to date have been largely unavailable.

Primary article: Brown, M., C. D. Canham, L. Murphy, and T. M. Donovan. 2018. Timber harvest as the predominant disturbance regime in northeastern U.S. forests: effects of harvest intensification. Ecosphere 9:1-19. DOI:10.1002/ecs2.2062.

Project Status: Completed. (Ph.D. pending)



VERMONT MOOSE MORTALITY AND RECRUITMENT

Principal Investigators: Therese M. Donovan and James Murdoch.

Graduate Students: Jacob DeBow (M.S.), Joshua Blouin (M.S), and Elias Rosenblatt (Ph.D.—Rubenstein Fellow).

Project Officers: Cedric Alexander and Scott Darling, VFWD

Project Funding: Vermont Fish and Wildlife Department, U.S. Geological Survey, Rubenstein School of Environment and Natural Resources, UVM.

Project Period: 1 September 2017 - 31 December 2021

Synopsis: Concern has risen in Vermont and neighboring states over the past decade regarding higher mortality and lower recruitment rates of resident moose (*Alces alces*) populations. High winter tick (*Dermacentor albipictus*) infestations are considered to be a major cause of these trends. In response, the State of Vermont initiated a 3-year study similar to those in New Hampshire and Maine to investigate rates of moose mortality, productivity, and recruitment of moose populations over a three-year period in Wildlife Management Units E1 and E2 (632 square miles of prime moose habitat).

Since January of 2017, 126 moose have been radio-marked (90 calves and 36 adult cows) and tracked on a daily basis with GPS technology. Cause of mortality was determined through field necropsy and pathology analysis of tissue. Adult annual survival was observed at 90% (n = 27 of 30) in 2017, 84% (n = 38 of 45) in 2018, and 86% (n = 38 of 44) in 2019. Observed winter survival (March-April) of calves fluctuated between 60% (n = 18 of 30) in 2017, 50% (n = 15 of 30) in 2018, and 37% (n = 11 of 30) in 2019. Field necropsy and pathology attributed 74% of all mortalities (91% of calves and 25% of adults) to winter ticks (*Dermacentor albipictus*). Meningeal worm (*Parelaphostrongylus tenuis)* and lung worm (*Dictyocaulus viviparous)* were recorded in 32% (n = 20 of 62) and 63% (n = 39 of 62) of all mortalities respectively.

These low survival rates would not be alarming if births can offset mortalities. However, this is unlikely. Of the 36 adult females captured, 67% (n = 24) were pregnant. Given pregnancy, observed birth rates ranged between 0.53 and 0.67. Analysis of calf survival rate (survival from birth to day 60) are ongoing.

Analysis of fecal glucocorticoid metabolites (fGCM, or stress hormones) over the study period confirmed that winter tick load had a strong positive effect on fGCM levels. Other variables including snow depth, road density, and conifer forest coverage also positively influenced fGMC levels. Investigations between fGMC levels and key fitness parameters (survival and reproduction) are in progress.

Population viability analyses are planned to estimate the probability of extirpation of moose from the study region within 50 years. The GPS data, in conjunction with contemporary maps of land cover types (from the newly available 2016 National Land Cover Database) and fine-scale landscape conditions from 2016 LIDAR (*light detection and ranging*) imagery, are being used to create habitat suitability models throughout Vermont in hopes of identifying habitat features associated with high survival and reproduction.

Our research provides the Vermont Fish and Wildlife Department basic information and a suite of tools to help aid in reversing the decline of this iconic species.

Project Status: Ongoing.

Photo: Moose captured in 2017 and outfitted with a GPS collar. Credit: Josh Blouin

Photo: Necropsy photo of moose with high density of feeding winter ticks. Credit: Jake DeBow.

PILOT STUDY OF ACOUSTIC MONITORING RESEARCH AT THE NDIANA DUNES NATIONAL LAKESHORE

Principal Investigator: Therese M. Donovan

Post Doctoral Fellow: Cathleen Balantic

Project Funding: National Park Service

Project Period: 14 September 2018 - 30 September 2023

Synopsis: The Indiana Dunes National Lakeshore (INDU) was established "in order to preserve for the educational, inspirational, and recreational use of the public certain portions of the Indiana dunes and other areas of scenic, scientific, and historical interest and recreational value in the State of Indiana." The western edge of INDU includes the largest contiguous remnant of a significant historic geological landscape, and the 1,000-acre remnant of the Tolleston strand-plain has biological, recreational, educational, and scientific value and is of historic landform interest. Its reservoir of unique flora, along with the presence of state and federal listed species, makes it of significant value to Americans nationwide.

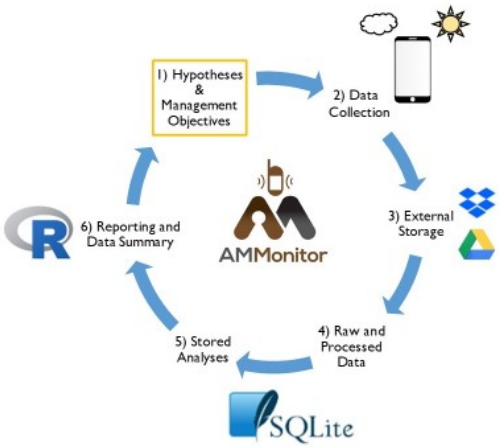
INDU began developing its Resource Stewardship Strategy (RSS) in 2018, and has used this process to expand on and articulate park-wide conservation targets (priority natural resources) based on the Foundation Statement and Enabling Legislation. The RSS process includes identifying desired future conditions for these resources, establishing short-term goals towards achieving desired future conditions, and identifying and prioritizing management actions to be taken towards these goals. INDU has indicated a need to establish attributes and indicators (a way to assess condition) for each conservation target, and to use these attributes and indicators to assess condition and evaluate the success of management actions.

The purpose of this pilot research effort was to explore streamlined pathways to incorporate adaptive management methodologies into the Indiana Dunes National Lakeshore's Resource Stewardship Strategy (RSS). This pilot project focused on developing smartphone-based ecological monitoring via audio recordings and photos (Figure 1). We used the AMMonitor approach (Figure 2) to automate acoustic detection methodologies for focal species and soundscapes. The AMMonitor approach is a software system based on R (R Core Team 2019) that encompasses data processing, organization, and analysis, ultimately providing analyses that link INDU's natural resource objectives with the current state of the Park (Figure 2). In a collaboration between the Vermont Cooperative Fish and Wildlife Research Unit (VTCFWRU) and Indiana Dunes National Lakeshore (INDU), we deployed a smartphone-based ecological monitoring network of 21 stations at INDU, and developed analytical tools in R (R Core Team, 2019) that facilitated near real-time analysis of incoming data, including audio and motion-triggered images (Figure 3). This approach could be used to inform management decisions if adopted at a broader scale using a spatially and statistically robust study design in the future.

Project Status: In Progress.

A.

B.



C.

Figure 1.

A. Randy Knutson from INDU setting up a cell phone monitoring station.
B. The AMMonitor system operationalizes adaptive management by combining natural resource objectives, data collection, data curation, and data analysis utilizing open source R software.
C. Motion-triggered image of a pollinator.

Publications

PEER-REVIEWED:

Abouelezz, H. G., **T. M. Donovan**, J. Murdoch, R. M. Mickey, M. Freeman, and K. Royar. 2018. Landscape composition mediates movement and habitat selection in bobcats (*Lynx rufus*): Implications for conservation planning. Landscape Ecology 33: 1301-1318. https://doi.org/10.1007/s10980-018-0654-8

Aylward, C., J. D. Murdoch, **T. M. Donovan**, C. W. Kilpatrick, C. Bernier, and J. Katz. 2018. Estimating distribution and connectivity of recolonizing American marten (*Martes americana*) in the northeastern United States using expert elicitation techniques. Animal Conservation 21: 483-495. https://doi.org/10.1111/acv.12417

Balantic, C., and **T. M. Donovan**. 2019. Dynamic wildlife occupancy models using automated acoustic monitoring data. Ecological Applications 29: e01854. https://doi.org/10.1002/eap.1854

Balantic, C., and **T. M. Donovan**. 2019. Statistical learning mitigation of false positive detections in automated acoustic wildlife monitoring. Bioacoustics. https://doi.org/10.1080/09524622.2019.1605309

Balantic, C., and **T. M. Donovan**. 2019. Temporally-adaptive acoustic sampling to maximize detection across a suite of focal wildlife species. Ecology and Evolution 9: 10582-10600. https://doi.org/10.1002/ece3.5579

Brown, M., C. D. Canham, L. Murphy, and **T. M. Donovan**. 2018. Timber harvest as the predominant disturbance regime in northeastern U.S. forests: effects of harvest intensification. Ecosphere 9: 1-19. https://doi.org/10.1002/ecs2.2062

Cherukuri, A., A. Strong, and **T. M. Donovan**. 2018. Developing a monitoring protocol for least bitterns (*Ixobrychis exilis*) in New England: Detection probability and occupancy modeling. Northeastern Naturalist 25: 56-71. https://doi.org/10.1656/045.025.01045

Donovan, T. M., and J. E Katz. 2018. AMModels: An R package for storing models, data, and metadata to facilitate adaptive management. PLoS ONE 13(2): e0188966. https://doi.org/10.1371/journal.pone.0188966

Donovan, T. M., and R. M. Mickey. 2019. Bayesian statistics for beginners. Oxford University Press, Oxford, UK.

Espenshade, J., J. D. Murdoch, **T. M. Donovan**, R. E. Manning, and C. A. Bettigole. 2018. Public acceptability of development in the Northern Forest of Vermont, USA – the influence of wildlife information, recreation involvement, and demographic characteristics. PLoS ONE 13(12): e0203515. https://doi.org/10.1371/journal.pone.0203515

Publications (Continued)

PEER-REVIEWED:

Farrell, L. E., D. M. Levy, **T. M. Donovan**, R. Mickey, A. Howard, J. Vashon, M. Freeman, K. Royar, and C. W. Kilpatrick. 2018. Landscape connectivity for bobcat (*Lynx rufus*) and lynx (*Lynx canadensis*) in the Northeastern United States. PLoS ONE 13(3): e0194243. https://doi.org/10.1371/journal.pone.0194243

Greenwald, K., A. Stedman, D. Mifsud, M. Stapleton, K. Larson, I. Chellman, **D. L. Parrish**, and C. W. Kilpatrick. 2020. Phylogeographic analysis of Mudpuppies (*Necturus maculosus*). Journal of Herpetology. https://doi.org/10.1670/19-070

Marschall, E. A., D. C. Glover, M. E. Mather, and **D. L. Parrish**. 2020. Modeling larval American Shad recruitment in a large river. North American Journal of Fisheries Management 40: *in press*.

Pearman-Gillman, S., J. E. Katz, R. Mickey, J. Murdoch, and **T. M. Donovan**. 2020. Predicting wildlife distribution patterns in New England USA with expert elicitation techniques. Global Ecology and Conservation 21: e00853.

Puchala, E.A., **D. L. Parrish**, and D. H. Ogle. 2018. Size and age of Lake Champlain Stonecats; estimating growth at the margin of their range. North American Journal of Fisheries Management 38: 1316-1323. https://doi.org/10.1002/nafm.10230

Simonin, P. W., L. G. Rudstam, **D. L. Parrish**, B. Pientka, and P. J. Sullivan. 2018. Piscivore diet shifts and trophic level change after Alewife establishment in Lake Champlain. Transactions of the American Fisheries Society 147: 937-947. https://doi.org/10.1002/tafs.10080

Simonin, P. W., L. G. Rudstam, P. J. Sullivan, **D. L. Parrish**, and B. Pientka. 2019. Early mortality and freshwater forage fish recruitment: nonnative alewife and native rainbow smelt interactions in Lake Champlain. Canadian Journal of Fisheries and Aquatic Sciences 76: 806-814. https://doi.org/10.1139/cjfas-2017-0571

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Educational Contributions

Principles of Modeling On-line Course

http://www.uvm.edu/rsenr/vtcfwru/spreadsheets/?Page=pom/pom.htm
Co-instructed by Tony Starfield and Terri Donovan. This course was developed in concert with the BLM National Training Center and the National Conservation Training Center. It is offered as a semester-long on-line course via UVM and the National Conservation Training Center, targeting university graduate students and federal biologists. It consists of instructional videos, paired with weekly group modeling challenges.

Conservation Biology and Modeling On-line Course

http://www.uvm.edu/rsenr/vtcfwru/spreadsheets/?Page=conbio/cb.htm.
Co-instructed by Jed Murdoch and Terri Donovan with support from the BLM National Training Center. This on-line course material pairs lectures, spreadsheet exercises, R exercise, structured decision making case studies, and homework to provide students a foundation in the principles of conservation biology. The Conservation Biology videos are used extensively by the University of Vermont undergraduate Conservation Biology course taught by Michael McDonald.

R for Fledglings Self-Paced Course

R for Fledglings is a self-paced introduction to R that is targeted for natural resource practitioners. Available at https://www.uvm.edu/rsenr/vtcfwru/R/?Page=fledglings/fledglings.htm

R Packages and Documentation

- AMModels—an R package for storing models, data, and metadata. Available at https://code.usgs.gov/vtcfwru/ammodels
- AMPop—an R package that allows the simulation of wildlife populations through time, given the annual cycle of an organism. Available at https://code.usgs.gov/vtcfwru/ampop .
- AMMonitor—an R package for the remote monitoring of biodiversity through time and space, particularly with audio recording and photographs. Available at https://code.usgs.gov/vtcfwru/ammonitor

COURSES OFFERED:

- NR 385. Principles of Modeling, UVM. Spring 2018. Donovan.
- NR 385. Conservation Biology and Modeling, UVM. Spring 2019. Donovan.
- NR 395. Scientific Communication for Natural Resource Professionals, Spring 2019. Parrish.

Presentations

Cummings, J., and **T. M. Donovan**. Structured decision making provides insight when selecting a preferred population monitoring program. Joint meeting of the American Fisheries Society and The Wildlife Society, Reno, Nevada, 29 September - 3 October 2019.

Balantic, C., and T**. M. Donovan**. Landscape-scale monitoring using smartphones and the R package AMMonitor. 75th Annual Northeast Fish and Wildlife Conference, Groton, Connecticut, 14-16 April 2019.

Balantic, C., **T. M. Donovan**, J. Katz, and M. Massar. Machine learning mitigation of false positives in automated acoustic wildlife monitoring with the R package AMMonitor. 74th Annual Northeast Fish and Wildlife Conference, Burlington, Vermont, 15-17 April 2018.

Balantic, C., **T. M. Donovan**, J. Katz, and M. Massar. Temporally-adaptive acoustic sampling to maximize detection across a suite of focal wildlife species with the R package AMMonitor. 74th Annual Northeast Fish and Wildlife Conference, Burlington, Vermont, 15-17 April 2018.

Balantic, C., **T. M. Donovan**, J. Katz, and M. Massar. Temporally-adaptive acoustic sampling to maximize detection across a suite of focal wildlife species with the R package AMMonitor. Northeast Regional Environmental Acoustics Symposium, University of New Hampshire, Durham, New Hampshire, 20 March 2018.

Blouin, J., DeBow, J., E. Rosenblatt, **T. M. Donovan**, J. Murdoch, and C. Alexander. Assessing moose habitat suitability in Vermont using GPS radio-collar data and LIDAR imagery. 53rd Annual North American Moose Conference, Carrabassett Valley, Maine, 10-14 June 2019.

Brown, M. L., C. Canham, L. Murphy, and **T. M. Donovan**. Effects of forest biomass energy production on long-term Northern Forest structure, composition and wildlife. 74th Annual Northeast Fish and Wildlife Conference, Burlington, Vermont, 15-17 April 2018.

Chen, Y., J. J. Hoover, D. Chapman, J. R. Jackson, J. Killgore, D. Chen, Z. Li, Q. Phelps, M. Eggleton, D. Infante, K. Irons, C. Paukert, E. Rutherford, H. Zhang, **D. Parrish**, and L. Wang. 2018. Moving the Mississippi-Yangtze Fisheries Network forward: past, current, and future. 148th annual meeting of the American Fisheries Society, Atlantic City, New Jersey, 19-23 August 2018.

DeBow, J., E. Rosenblatt, J. Blouin, C. Alexander, **T. M. Donovan**, and J. Murdoch. Parasite induced moose decline in northeastern Vermont: Year three update. 53rd Annual North American Moose Conference, Carrabassett Valley, Maine, 10-14 June 2019.

DeBow, J., J. Murdoch, **T. M. Donovan**, and C. Alexander. Overview of moose mortality and productivity research in northern Vermont. 74th Annual Northeast Fish and Wildlife Conference, Burlington, Vermont, 15-17 April 2018.

Izzo, L. K., **D. L. Parrish***, G. B. Zydlewski, and C. MacKenzie. Using sonar to estimate lake sturgeon abundance in a river and lake delta in the northeastern USA. 4th Mississippi-Yangtze River Basins Symposium, Chongqing, China, 15-20 October 2018. *Presenter. (Invited).

Izzo, L. K., **D. L. Parrish**, G. B. Zydlewski, and C. MacKenzie. Combining dual-frequency identification sonar (DIDSON) and acoustic telemetry to estimate abundance of spawning lake sturgeon. 148th annual meeting of the American Fisheries Society, Atlantic City, New Jersey, 19-23 August 2018. (Invited).

Presentations (Continued)

Izzo, L. K., **D. L. Parrish**, G. B. Zydlewski, and C. MacKenzie. Combining dual-frequency identification sonar (DIDSON) and acoustic telemetry to estimate abundance of spawning lake sturgeon. 44th Annual Meeting of the Atlantic International Chapter of the American Fisheries Society, Basin Harbor, Vergennes, Vermont, 23-25 September 2018.

Izzo, L. K., **D. L. Parrish**, G. B. Zydlewski, and C. MacKenzie. Estimating abundance of spawning lake sturgeon in the Winooski River, VT using dual-frequency identification sonar (DIDSON). 74th annual Northeast Fish and Wildlife Conference, Burlington, Vermont, 15-17 April 2018. (Invited).

Izzo, L. K., **D. L. Parrish**, G. B. Zydlewski, and J. E. Marsden. Seasonal movements and habitat use of juvenile lake sturgeon in Lake Champlain. Joint meeting of the American Fisheries Society and The Wildlife Society, Reno, Nevada, 30 September-3 October 2019.

Marschall, E. A., D. C. Glover, M. E. Mather, and **D. L. Parrish**. Modeling the effects of climate change on larval cohort success in anadromous fish populations in the mainstem of a large river. 4th Mississippi-Yangtze River Symposium, Chongqing, China, 15-20 October 2018. (Invited).

Mather, M. E., J. M. Dettmers, **D. L. Parrish**, R. A Stein. and E. A. Marschall. 2018. A portfolio of integrated monitoring and research can advance successful science-based conservation and fisheries management. 148th annual meeting of the American Fisheries Society, Atlantic City, New Jersey, 19-23 August 2018. (Invited).

Mather, M. E., J. M. Dettmers, R. A. Stein, **D. L. Parrish**, and D. C. Glover. A portfolio approach to integrated assessment and research can provide a larger context for the successful evaluation of fisheries harvest regulations. 79th Midwest Fish and Wildlife Conference, Cleveland, Ohio, 27-30 January 2019. (Invited).

Parrish, D. L. Pelagic fish community in Lake Champlain. Lake Champlain Sea Grant Site Review, University of Vermont, Burlington, Vermont, 19 March 2019.

Parrish, D. L., B. Pientka, L. G. Rudstam, P. W. Simonin, and P. J. Sullivan. Hydroacoustic surveys of the pelagic fish community in Lake Champlain. 74th annual meeting of the Northeast Fish and Wildlife Conference, Burlington, Vermont, 15-17 April 2018. (Invited).

Pearman-Gillman, S., J. Murdoch, and **T. M. Donovan**. Wildlife in a future New England landscape: Estimating species distributions under projected climate and landscape change. 75th Annual Northeast Fish and Wildlife Conference, Groton, Connecticut, 14-16 April 2019.

Pearman-Gillman, S., **T. M. Donovan**, J. Murdoch, and J. Katz. Estimating wildlife distributions using expert elicitation techniques: an assessment of harvested species in the Northeastern United States. 74th Annual Northeast Fish and Wildlife Conference, Burlington, Vermont, 15-17 April 2018.

Rosenblatt, E., **T. M. Donovan**, and J. Murdoch. Novel wildlife population estimates using pedigree reconstruction: exploring applications with moose (*Alces alces*). 74th Annual Northeast Fish and Wildlife Conference, Burlington, Vermont, 15-17 April 2018.

Professional Service and Technical Assistance

Donna L. Parrish

- World Council of Fisheries Societies, Co-Vice President, 2016-2020.
- AFS Fellows Committee, 2017-2020.
- Rubenstein School Graduate Student Advisory Board, Faculty Liaison, 2014-2018.
- University of Vermont, Graduate Executive Committee, 2015-2018.
- Lake Champlain Fisheries Technical Committee, Strategic Plan Revision Subcommittee, 2017-2019.
- Lake Champlain Federal Partners Working Group, 2004-present.

Therese M. Donovan

- University of Vermont, Faculty Senate Financial and Physical Planning Committee, 2017-present.
- Conservation Leaders for Tomorrow, RSENR Representative, 2013-present.
- Principles of Modeling, National Conservation Training Center, Coach/Mentor (alternating years since 2015).
- Vermont Fish and Wildlife Department, Project Support Team., 2018-present.
- University of Vermont Board of Trustees Budget, Finance and Investment Committee Representative, 2019-present.

Vermont Cooperative Fish & Wildlife Research Unit