



SUMMARY OF SUSTAINABLE FORESTRY AND OTHER RESEARCH

Fiscal Year 2017

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For information or assistance on this publication, contact the Forest Resources Division, Michigan Department of Natural Resources, P.O. Box 30452, Lansing, MI 48909-7952.

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BACKGROUND

The State of Michigan, under the Michigan Department of Natural Resources (DNR), supports research and development projects that contribute to the management of Michigan's forest lands in such a way as to sustain those resources and associated values for future generations. This document is an annual summary of those projects for the DNR's 2017 fiscal year (October 1, 2016 through September 30, 2017).

The DNR is committed to the continuous improvement of forest management in the state on all forest lands, but specifically state forest lands. Forest management in the state is guided by a hierarchy of plans: the Forest Action Plan (currently called the Forest Resource Assessment and Strategy (2010-2020)); the State Forest Management Plan, 2008 (2008-2018); and three regional state forest management plans (2013-2023). The state and regional plans apply to state forest lands and the Forest Action Plan applies to all forest land in the state.

Research is one of several integral components of a sound forest management program and is one of two critical components of adaptive management (the other being effectiveness monitoring). Together, effectiveness monitoring and research (also referred to as validation monitoring) reach their maximum utility, which is diminished if one is done in the absence of the other. Research or validation monitoring is used to identify and validate or verify the assumptions and causal pathways underlying a conceptual model of how we believe a system or part of a system works. It is critically important that the results of research are integrated back into the forest management process or system through the development of tools, techniques, best management practices, guidelines and policy.

POLICY CONTEXT

Almost all of the state forest land in Michigan is certified under two different sustainable forestry program standards: The Sustainable Forestry Initiative (SFI) and the Forest Stewardship Council (FSC). Implementation of these standards in terms of forest management is interpreted and directed by a suite of 20 work instructions. Work Instruction 5.1 speaks to coordinated natural resource management related research, (https://www.michigan.gov/dnr/0,4570,7-350-79136_79237_80915-331520--,00.html)

The work instruction requires that the DNR, through the division research coordinators, produce a research summary report, report internal and external research funding for the SFI Annual Report and a review of research and implementation needs and opportunities. This research summary report represents partial fulfillment of this work instruction requirement.

RESEARCH SUMMARY

To meet the requirements of certification, the required summary focuses on the research that occurs within forested landscapes considering one or more elements of forested ecosystems and/or associated social and economic systems. Because of research's close association with effectiveness monitoring, the forested landscape research is considered within the monitoring framework for sustainable forests: that is, the criteria and indicator framework of the Montreal Process (<http://www.montrealprocess.org/>). However, since the suite of indicators is more of a moving target than the criteria under which they fall, the research projects are categorized only using the seven criteria. Projects that are related to more than one criterion are listed under the primary criterion with the other linkages being identified.

RESEARCH ADMINISTRATION WITHIN DNR

Research is administered and supported differently in each of the DNR divisions; however, each division has a research coordinator as a point-of-contact. The Wildlife and Fisheries Divisions administer all research activities through their respective research sections. These divisions also have a significant portion of their research efforts funded by a variety of federal grants that have annual reporting requirements. Forest Resources (FRD) and Parks and Recreation Divisions (PRD) do not have dedicated research sections, and consequently the administration and support of research occurs through each program area.

Research that supports sustainable forestry occurs through a variety of mechanisms. The DNR supports many research projects contracted or partnered with several universities within the state and some beyond its

borders. The DNR also supports a Partnership for Ecosystem Research and Management (PERM) program with Michigan State University (MSU). The DNR also employs its own research and monitoring staff in FRD, Wildlife (WD) and Fisheries Divisions (FD).

Research programs and projects are providing useful information to support improvements in our operations and business practices and each division uses a different array of means to communicate those research findings to staff. Division professional development trainings, specialist meetings and ongoing field and program communications are examples of the means used to convey research information to DNR staff.

For more information about specific research programs or projects, interested parties should contact the research coordinator for the appropriate division. The research coordinator for each division is listed below with their respective contact information.

Scott Jones, Forest Management & Certification Planning Specialist, FRD	Joness38@michigan.gov	517-284-5873
Steve Beyer, Research Coordinator, WD	Beyers1@michigan.gov	517-243-5179
Gary Whelan, Research Program Manager, FD	whelang@michigan.gov	517-284-5840
Alicia Ihnken, Research Coordinator, PRD	ihnkena@michigan.gov	517-284-6129

RESEARCH RELATED TO SUSTAINABLE FORESTRY – CURRENTLY ON-GOING

Criteria Framework for Sustainable Forestry and Associated Research-

CRITERION ONE: CONSERVATION OF BIOLOGICAL DIVERSITY

Landscape Diversity:

Assessment of Remsoft Spatial Planning Studio for Forest Management Planning of State Forest Lands in Michigan

Primary Contact: Dr. Mike Donovan, DNR Wildlife Division, Lansing, Michigan

Email: donovanm@michigan.gov

Phone: (517) 243-5514

DNR Financial Support: \$26,293 in FY17, \$42,635 total.

Study Area: Statewide.

Time Frame: 10/01/2016-09/30/2018

Abstract: The Michigan Forest Resource Assessment and Strategy (MDNRE, 2010) states, early in the report, that one of the fundamental issues in management of State forests for many competing uses is that the capacity to provide for these uses in a sustainable manner is finite. Furthermore,

“Provision of one use is often constrained by demands for other competing uses for the same resource and the capacity of the forest base to provide for competing uses is infinite in its variability. Thus, the annual capacity of forest resources must be framed in terms of balancing competing uses. Emphasis should be on the means to enable uses to be compatible with other uses, with the recognition that at any one site, one value or use may predominate over others.”

The current forest management planning process in Michigan embraces the need to balance multiple resources. The foundation for the management schedule for forest cover is the timber harvest calculation, which is driven by the basic premise that, in general, resource values are promoted when the age-class distribution within cover types is balanced in each management area (MDNR, 2013). To determine the target harvest, the approach involves querying the DNR’s inventory systems to determine area by age and cover class. After filtering inaccessible areas, the area to be cut in any given 10-year period is $10/r$ where r is the rotation age. The plan assumes oldest stands are harvested first, unless there are other considerations such as insect or disease issues (see Appendix D of the Northern Lower Peninsula Regional Plan for details). The timber harvest calculation is not explicitly or quantitatively linked with management of other resources. Lands that are hard factor limited (i.e., inaccessible, designated for other purposes, or sensitive) are removed from the calculation. Otherwise, the factors that affect selection of rotation ages implicitly address sustainability concerns, at least when planning at the strategic level.

The strategy in Michigan may be conservative, in that when operational plans are developed that management activity is further constrained by spatial and local concerns that are not incorporated into the strategic planning process. Alternatively, the approach of balancing the age structure may suggest that over the long-term there will be a decline in the area of old forest. In parallel, the lack of a spatial component means that age-class balance is achieved within arbitrarily defined geographic units; for example, in State Forest compartments that can be rectangles organized by year-of-entry, the process of allocating harvest is distributed across the forest. This could lead to decreasing patch size, with related consequences for other resources, as the largest patches (stands) are broken up into smaller patches to achieve the balanced age-class structure on the management area.

The Michigan Forest Action Plan, 5-Year Review (MDNR 2015), identifies a number of areas where opportunities exist and improvements are needed to address landscape patterns. For example, better definition of objectives and criteria for forest cover types and cover type management, greater emphasis on landscape assessment and climate change and an investigation of ways to better consider forest composition metrics, like fragmentation, patch size and juxtaposition. All of these can be addressed through the application of advanced software tools specifically designed for spatial forest management planning.

Boone and Crocket Graduate Student Fellowship: Evaluating the Impacts of Landscape Level Changes on the Abundance and Distribution of Record Book White-Tailed Deer Across a Large Geographic Region

Primary Contact: Dr. Brent Rudolph, DNR Wildlife Division, East Lansing, Michigan

Email: rudolphb@michigan.gov

Phone: (517) 641-4903

DNR Financial Support: \$41,104 in FY17, \$141,170 total.

Study Area: Statewide.

Time Frame: 10/01/2016-09/30/2019

Abstract: The Division collaborates with the Boone and Crockett Chair of Wildlife Conservation to provide a graduate fellowship. The fellowship is dedicated to doctoral-level research to address unmet research needs of the Division. The current project was designed to explore the landscape ecology of white-tailed deer (*Odocoileus virginianus*). This work will examine spatial and temporal patterns in the distribution of older age-class and record-quality bucks harvested within Michigan and surrounding states. Results will be used to inform managers regarding the influence of habitat conditions, harvest regulations and hunting traditions on characteristics of harvested deer.

Variation in white-tailed deer antler conformation and size is noticeable across landscapes and antler characteristics displayed result from complex interactions between the record-book animal and its habitat. When mapped there is obvious spatial heterogeneity in the number of record-book white-tailed deer harvested across the United States, with most record-book harvests occurring in the Midwestern region. Record-book white-tailed deer could represent a particularly sensitive indicator to landscape-level changes that occur over large geographic regions and the variation in Midwest record-book harvests is ideal to evaluate the impacts of these changes on deer populations.

Understanding how landscape-level processes impact the occurrence of record-book deer is important, because there is a strong and growing interest in management practices that improve the overall quality of the deer herd and increase the number of large bucks (Adams and Ross 2015). Organizations, cooperatives and individuals that advocate for these types of approaches endeavor to see these strategies applied across the range of the species. However, previous studies on white-tailed deer antler growth have only been conducted at small spatial scales and have examined landscape influences independently. Our ability to extrapolate these results to an area beyond the extent of the original studies is limited, leaving the relationship between record-book deer populations and these landscape-level changes in the management regime unknown. That limitation is unfortunate because management of white-tailed deer is the responsibility of state wildlife agencies and generally exceeds the spatial extents of previous antler growth studies. The mismatch between the scale of management and the scale at which our knowledge is based makes it difficult to accurately predict outcomes of decisions made by wildlife agencies. Furthermore, no landscape-level research has been conducted to evaluate the variation in the abundance and distribution of record-book white-tailed deer for different management approaches by state wildlife agencies.

Increasing the Resilience of Wildlife Habitat Investments by Considering Multiple Plausible Scenarios

Primary Contact: Christopher Hoving, DNR Wildlife Division, Lansing, Michigan

Email: HovingC@michigan.gov

Phone: (517) 930-7760

DNR Financial Support: \$43,976 in FY17, \$83,000 total.

Study Area: Statewide.

Time Frame: 10/01/2015-09/30/2020

Abstract: Many habitat management projects, such as jack pine planting or conserving deer wintering complexes, require predicting the needs of wildlife 50 to 100 years in the future. These projects also account for relatively large investments of money and staff time on the part of the Michigan DNR Wildlife Division. Changes in climate, land use and technology make those predictions uncertain. We will conduct a series of scenario planning workshops (Rowland et. al. 2014) to help managers plan for multiple plausible futures. Scenarios will involve, but not be limited to, uncertainty related to climate.

Management today for future conifer-dominated wildlife habitat in the Upper Peninsula and the northern Lower Peninsula faces key uncertainties. Managers risk wasting scarce resources on habitat projects that may not meet state goals. Scenario planning offers a way to craft better portfolios of strategies when faced with

uncertainty that will be robust across scenarios. The tool has been widely used in the military and the private sector and has potential to improve natural resource decision-making (Rose & Star 2013; Rowland et. al. 2014). Management strategies that incorporate the best available climate science will be critical in meeting goals of individual on-the-ground managers, the Michigan Deer Management Plan and the Upper Peninsula Habitat Workgroup.

We propose to use scenario planning workshops to help managers assess management strategies that more fully consider the uncertainty in the timing and speed of climate impacts to intensively managed early successional jack pine and associated wildlife.

Status and Trends of Inland Lakes: Methods Development, Program Oversight and Ecological Assessment

Primary Contact: Kevin Wehrly, DNR Fisheries Division, Institute of Fisheries Research, Ann Arbor, Michigan

Email: wehrlyk@michigan.gov

Phone: 734-663-3554 x 0402

DNR Financial Support: \$72,109 Total (25% Game and Fish funds)

Study Area: Statewide

Time Frame: Ongoing

Abstract: The Fisheries Division of DNR initiated the Statewide Status and Trend Protocol (SSTP) for inland lakes during the spring of 2002. The Division-wide SSTP uses a standardized statistically-based sampling methodology to collect and evaluate lake data from a statewide perspective. These data include fisheries information from electrofishing, standardized netting, habitat measurements and water quality sampling that will be used to monitor statewide status and trends of inland lake aquatic resources, develop models on key influences and evaluate fisheries and land management activities.

Status and Trends of Fish Populations and Community Structure in Michigan Streams

Primary Contact: Jan-Michael Hessenauer, DNR Fisheries Division, Lake St. Clair Fisheries Research Station, Mt. Clemens, Michigan

Email: hessenauerj1@michigan.gov

Phone: 586-465-4771

DNR Financial Support: \$31,320 (25% Game and Fish funds)

Study Area: Statewide

Time Frame: Ongoing

Abstract: The Fisheries Division of DNR initiated the Statewide Status and Trend Protocol (SSTP) for streams during the spring of 2002. The Division-wide SSTP uses a standardized statistically-based sampling methodology to collect and evaluate data from a statewide perspective. These data include fisheries information from electrofishing, habitat measurements and water quality sampling that will be used to monitor statewide status and trends of streams, develop models on key influences and evaluate fisheries and land management activities.

Evaluation of Returns of Salmonids to Weirs in Michigan's Waters of the Great Lakes

Primary Contact: Randy Claramunt, DNR Fisheries Division, Oden State Fish Hatchery, Oden, Michigan; and Jory Jonas, DNR Fisheries Division, Traverse City, Michigan

Emails: claramuntr@michigan.gov and jonasj@michigan.gov

Phone: 231-347-4689 x 22 and 231-547-2914 x229

DNR Financial Support: \$28,884 (25% Game and Fish Funds)

Study Area: Selected tributaries and weirs to lakes Michigan and Huron

Time Frame: Ongoing

Abstract: This project provides annual information on returns of adult stocked and wild salmon and trout to selected Michigan rivers that is used in many Great Lakes management and research efforts. Additionally, biological data on age, growth, condition and fish health are also collected at these sites. Since many of these fish are of wild origin, usually from the watershed on which our weirs are located, the information generated from these locations provides baseline data on the effects of fisheries, land and forest practices on recruitment processes for these species.

Statewide Tagging and Tag Recovery Program

Primary Contact: David Clapp, DNR Fisheries Division, Charlevoix Fisheries Research Station, Charlevoix, Michigan

Email: clappd@michigan.gov

Phone: 231-547-2914 x 237

DNR Financial Support: \$108,154 (25% Game and Fish Funds)

Study Area: Statewide

Time Frame: Ongoing

Abstract: This is a support project for all research and assessment projects that uses tagging; the specific results and benefits will vary by study. Coded-wire tags have been used in all Great Lakes to evaluate wild fish production, salmonid stocking methods (e.g., net pens vs. direct stocking), as well as hatchery practices and how these practices influence salmon growth and survival. Coded-wire tag marking has also been an important component of fish restoration projects; e.g., in the case of lake sturgeon marking related to the state lake sturgeon rehabilitation strategy. This study provides information annually that is used to evaluate a broad range of resources issues from the effects of land and forest management practices on wild fish production to better ways to increase salmonid survival following stocking and the feeding ecology and seasonal distribution of Great Lakes fish populations, many of which are dependent on inland streams for recruitment.

Silvicultural Approaches for Promoting Diversity & Sustainability in Michigan's Northern Hardwood Forests

Primary Contacts: Michael Donovan, DNR Wildlife Division, Lansing, Michigan

Email: donovanm@michigan.gov

Phone: (517) 243-5514

DNR Financial Support: \$99,866 in FY17, \$283,777 total.

Study Area: Statewide.

Time Frame: 05/01/2016-09/30/2021

Abstract: Northern hardwoods are intensively managed in Michigan, but declining tree diversity and stocking of desirable tree species has caused concern among natural resource managers. Loss of desirable tree species diversity and stocking levels in Michigan's northern hardwood forests is linked to many interrelated factors, but three that are likely important are the legacies resulting from the long-term use of selection silviculture, herbivory by browsers (most often deer) and pest and pathogen epidemics (e.g., beech bark disease). Other potential factors are likely influential at regional (e.g., climate change) and local scales (e.g., tree seed and substrate limitations, seedling establishment limitations). We suggest that novel changes to the silvicultural management of northern hardwood forests are worth evaluating.

Species Diversity:

Sturgeon Rehabilitation Plan

Primary Contact: Edward Baker, DNR Fisheries Division, Marquette Fisheries Research Station, Marquette, Michigan and Kim Scribner, Michigan State University, East Lansing, Michigan

Emails: bakere1@michigan.gov and scribne3@msu.edu

Phone: 906-249-1611 x 309 and 517-353-3288

DNR Financial Support: \$296,762 (25% Game and Fish Funds)

Study Area: Statewide

Time Frame: Ongoing

Abstract: This study supports Michigan's lake sturgeon rehabilitation activities, as documented in the DNR Lake Sturgeon Recovery and State Wildlife Action Plans and in Great Lakes fish community objectives (see www.glfrc.org). Lake sturgeon require intact river habitat with clean spawning substrate for spawning, both of which can be affected by forest and land management practices. The study has a number of components including stream rearing of lake sturgeon at multiple restoration sites; developing information on the effects of fish culture practices on egg survival and larval lake sturgeon growth and survival; quantify environmental covariates (temperature and discharge both related to forest and land management practices) and their effects on larval recruitment; developing information on effects of stream habitat and the species composition and abundance of predators and alternative prey on lake sturgeon larval survival; and determining stage-specific survival of natural and hatchery age-0 and older juvenile lake sturgeon. All this information is being used to

rehabilitate existing lake sturgeon populations and to provide insights on how land use and forest practices affect the habitat of this state-listed species on a statewide basis.

Refinement of the Aquatic Portion of Michigan's Wildlife Action Plan and Development of Tools to Support the Plan

Primary Contact: Kevin Wehrly, DNR Fisheries Division, Institute of Fisheries Research, Ann Arbor, Michigan

Email: wehrlyk@michigan.gov

Phone: 734-663-3554 x 0402

DNR Financial Support: \$179,020 (25% Game and Fish Fund)

Study Area: Statewide

Time Frame: Ongoing

Abstract: This project developed then provided implementation tools for the aquatic portion of the Michigan's State Wildlife Action Plan (SWAP). This plan will assist the DNR in managing a broad range of aquatic resources and species of greatest conservation need. The products of this project include identifying high priority conservation areas, assessing ecosystem health and identifying key human disturbance factors that are components required by USFWS and SWAP. Additionally, the project is developing the needed GIS spatial framework, databases and decision support tools for carrying out required actions in the plan. Since most of the plan is focused on inland systems, understanding and effectively mitigating the effects of land use and forest management practices will be key components for the successful management of these limited aquatic resources that are critical components of the biodiversity of our forests.

Effects of Protective Stream Regulations in Rehabilitating Adfluvial Brook Trout

Primary Contact: Troy Zorn, DNR Fisheries Division, Marquette Fisheries Research Station, Marquette, Michigan

Email: zornt@michigan.gov

Phone: 906-249-1611 x 308

DNR Financial Support: \$58,373 (25% Game and Fish Funds)

Study Area: Upper Peninsula

Time Frame: Ongoing

Abstract: This study evaluates the effectiveness of protective fishing regulations for rehabilitating adfluvial populations of Brook Trout in eight experimental stream reaches. Experimental regulations were enacted in 2015 and will be in effect for at least 10 years. Electrofishing surveys and a volunteer angler diary program will be used to assess temporal changes in relative abundance of adfluvial Brook Trout. Associations between stream habitat characteristics and Brook Trout population responses will also be evaluated.

Role of Predators, Winter Weather & Habitat on White-tailed Deer Fawn Survival in Michigan – Phase II

Primary Contact: Dr. Dean Beyer, DNR Wildlife Division, Northern Michigan University, Marquette, Michigan

Email: beyerd@michigan.gov

Phone: (906) 228-6561

DNR Financial Support: \$127,000 in FY17, \$1,160,000 total

Study Area: Statewide.

Time Frame: 10/1/2011 - 9/30/2017

Abstract: This research project is designed to investigate the role of predators, winter weather and habitat on white-tailed deer condition and survival across a gradient of ecological conditions (snowfall zones) in the Upper Peninsula. Results from this project will help us understand the interactions among various factors that may limit deer abundance. Specific study components include: 1) estimating pregnancy rates and condition of white-tailed deer; 2) estimating survival and cause-specific mortality of white-tailed deer fawns and does; 3) estimating proportion of fawn mortality attributable to black bear, coyote, bobcat and wolf predation; and 4) comparing vegetation characteristics at fawn birth sites and kill sites with predator habitat use.

Knowledge of limiting factors is the foundation of wildlife management. This study will provide information on the importance and interactions among several factors that may limit deer abundance. Results from this work are intended to help us formulate appropriate harvest and management recommendations for both deer and predators. Results will also help us address increasing public concerns regarding the impact of predators on deer.

Role of Predators, Winter Weather and Habitat on White-Tailed Deer Fawn Survival in the Upper Peninsula of Michigan - Phase III

Primary Contact: Dr. Dean Beyer, DNR Wildlife Division, Marquette, Michigan

Email: beyerd@michigan.gov

Phone: (906) 228-6561

DNR Financial Support: \$457,700 in FY17, \$1,931,600 total.

Study Area: Statewide.

Time Frame: 10/01/2015-09/30/2021

Abstract: Management of wildlife requires an understanding and, in some cases, manipulation of factors that limit wildlife populations. Wildlife managers sometimes manipulate the effect of a limiting factor to allow a wildlife population to increase or decrease. White-tailed deer (*Odocoileus virginianus*) are an important wildlife species in North America providing many ecological, social and economic values. Most generally, factors that can limit deer numbers include food supply, winter cover, disease, predation, weather and hunter harvest. Deer numbers change with changes in these limiting factors.

White-tailed deer provide food, sport, income and viewing opportunities to millions of Americans throughout the United States and are among the most visible and ecologically important wildlife species in North America. They occur throughout Michigan at various densities, based on geographical region and habitat type. Michigan spans about 600 km from north to south. The importance of factors that limit deer populations vary along this latitudinal gradient. For example, winter severity and winter food availability have less impact on deer numbers in Lower Michigan than in Upper Michigan.

Quantifying the relative role of factors potentially limiting white-tailed deer recruitment as well as how the importance of these factors varies across this latitudinal gradient, is critical for understanding deer demography and ensuring effective management strategies. Considerable research demonstrates the effects of winter severity on white-tailed deer condition and survival (Ozoga and Gysel 1972, Moen 1976, DelGiudice et al. 2002). In addition, research has documented the importance of food supply and cover, particularly during winter (Moen 1976, Taillon et al. 2006). Finally, the role of predation on white-tailed deer survival has also received considerable attention (e.g., Ballard et al. 2001). However, few studies have simultaneously addressed the roles of limiting factors on white-tailed deer.

Indices of deer abundance in the western Upper Peninsula of Michigan have suggested the population sharply declined following two consecutive severe winters in mid-1990s (Michigan Department of Natural Resources, unpublished data), but have not since indicated an increase in the population. Factors restricting population growth are relatively unknown. Estimates of deer pregnancy rates from road kills during the 1990s were satisfactory (Michigan Department of Natural Resources, unpublished data) suggesting reproduction has not been regulating population growth in this region. However, predator abundances, particularly gray wolves, have increased in this region (Michigan Department of Natural Resources 2008) which could limit deer population growth. Identification of factors limiting or regulating increased deer population growth is necessary to assist wildlife biologists in managing deer populations in this region. While many studies have assessed biological and environmental factors of deer survival (e.g., DelGiudice et al. 2002), few have concomitantly assessed white-tailed deer survival relative to relationships among weather, physiological condition, habitat characteristics and species-specific predation risk of multiple predators across multiple spatiotemporal scales. The overall goal of this project is to assess baseline reproductive parameters of deer and the magnitude of cause-specific mortality and survival of white-tailed deer fawns, particularly mortality due to predation, in relation to other possible limiting mortality agents along a latitudinal gradient in Michigan. We will simultaneously assess effects of predation and winter severity and indirectly evaluate the influence of habitat conditions on fawn recruitment.

Considering results from Lower Michigan (Pusateri Burroughs et al. 2006, Hiller 2007) as the southern extent of this gradient, we proposed three additional study sites from south to north across Upper Michigan. Because of logistical and financial constraints, we proposed conducting work sequentially across these study areas. In 2009, we initiated the study in the low-snowfall zone, and in 2012 initiated fieldwork in the mid-snowfall zone. This proposal is for the final phase of this overall study, which we propose to conduct in the high-snowfall zone of the Upper Peninsula. We originally identified three study areas to capture the variation in winter severity, vegetation characteristics and the carnivore community (both abundance and species composition)

experienced by white-tailed deer that in turn would affect fawn survival. Further, other factors (e.g., alternate prey) that vary across this snowfall gradient, but do not directly affect deer survival, are having important effects on predation rates of deer. How these factors interact is dynamic and increases the challenge in understanding these predator-prey relationships. We have already observed dramatic variation in these factors and their effects on white-tailed deer populations during the first two phases of this project. Completing the final (third) phase of this project will allow us to better identify and understand the variation in these relationships and the response of white-tailed deer. This understanding will result in improved management of deer, predators and habitat.

American Woodcock Reproductive Rates in Relation to Forest Structure at Local and Landscape Scales

Primary Contact: Dr. Dave Luukkonen, DNR Wildlife Division, East Lansing, Michigan

Email: LuukkonenD@michigan.gov

Phone: (517) 641-4903

DNR Financial Support: \$81,000 in FY17, \$319,000 total.

Study Area: Statewide

Time Frame: 05/01/2015-09/30/2018

Abstract: American woodcock (*Scolopax minor*) breeding population indices in Michigan, the Central Management Unit and range-wide suggest a long-term decline in woodcock abundance since 1968 (Cooper and Rau 2012). Management responses to declining woodcock abundance included restricting harvest opportunities (i.e., reduce season lengths and daily limits: Cooper and Rau 2012) and promoting habitat management to increase early successional forests that benefit woodcock and other wildlife species associated with these habitats (e.g., ruffed grouse: *Bonasa umbellus* and golden-winged warbler: *Vermivora chrysoptera*). Although many biologists believe that loss of breeding habitat quality and quantity was responsible for woodcock population declines (Kelley et al. 2008), there are many uncertainties that may affect woodcock management efficiency and effectiveness; at a continental scale, there is need to “improve understanding of migration, breeding and wintering habitat quality for American woodcock” (Case and Sanders 2010). Existing habitat models for breeding woodcock rely on correlates between presence/absence or abundance of animals on the landscape and these models may fail to capture important processes underlying declines in reproductive rates. We believe that the highest priority information needed to improve management of woodcock in the Great Lakes Region is better understanding the relation between woodcock breeding habitat characteristics and reproductive rates; better understanding the relationship between habitat/landscape attributes and reproductive success would assist managers in targeting habitat treatments to improve woodcock reproductive success.

Available demographic information for woodcock supports the idea that declines in reproductive rates associated with changes in landscape-scale habitat characteristics have contributed to declining woodcock abundance. The DNR’s volunteer woodcock banding program has provided long-term estimates of woodcock survival with adult and juvenile survival being relatively stable while woodcock abundance was declining (Krementz et. al. 2003, Mayhew and Luukkonen 2010). Woodcock wings from a sample of hunters have been collected by the U.S. Fish and Wildlife Service (USFWS) since 1963; and an index to reproductive success derived from this sample (juveniles per adult females) suggests long-term decline in harvest age ratios (Cooper and Rau 2012). However, the relationship between harvest age ratios and more direct measures of reproductive success (e.g., nesting success and brood survival) have not been tested. Woodcock nest early in spring and survival of nests have generally been high (43-67% nest success); and although survival of nests and young can be affected by weather, most nest losses result from predation (Straw et. al. 1994, McAuley et. al. 1996). The degree to which predation rates and nesting success have changed and are tied to landscape characteristics is relatively unstudied; however, changes in landscape-scale habitat characteristics on breeding areas appear to have affected woodcock demographics as woodcock population trajectories varied among broad ecosystem types [i.e., bird conservation regions (BCRs)] with relative population stability in the Boreal Hardwood Transition compared to declines in the Prairie Hardwood Transition and other ecosystems (Sauer et. al. 2008).

Burke Lake Banding Station Support

Primary Contact: Stephen Beyer, DNR Wildlife Division, Lansing, Michigan

Email: beyers1@michigan.gov

Phone: (517) 284-4720

DNR Financial Support: \$10,000 in FY17, \$10,000 total.

Study Area: Statewide.

Time Frame: 10/01/2016-09/30/2017

Abstract: The research takes an integrated approach to better understand land-bird migrant habitat and resource use during passage through central Michigan during fall migration. The project outcomes are:

1. The development and maintenance of long-term data sets on the diversity and abundance of migratory land-birds using DNR's Rose Lake State Wildlife Research Area (SWRA).
2. Knowledge about the diversity, phenology and quality of resources available for land-birds that stop-over within Rose Lake SWRA during fall migration. The bird's ability to replenish depleted fat stores during migration is essential for a successful migration and their survival. This success can depend largely on habitat quality at stop-over sites (Moore et. al. 1995, Dunn 2000). Fruits are an important food source for land-birds during autumn migration (Parrish 1997), including species that are primarily insectivores at other times of their annual cycle.
3. An understanding of the link between resource selection by migrating land-birds and resource availability within the Rose Lake SWRA, which is critical information for the development of effective habitat management recommendations and conservation strategies for migratory land-birds.

Population Dynamics and Management of Wild Turkeys in Michigan: Linking Monitoring, Assessment and Harvest-Policy Evaluation

Primary Contact: Dr. Dave Luukkonen, DNR Wildlife Division, East Lansing, Michigan

Email: LuukkonenD@michigan.gov

Phone: (517) 641-4903

DNR Financial Support: \$44,170 in FY17, \$131,500 total

Study Area: Statewide

Time Frame: 02/01/2015-09/30/2017

Abstract: There are broad public interests and socio-economic benefits associated with sustaining recreational turkey harvests in Michigan and throughout North America. In Michigan, spring turkey hunters increased from around 10,000 hunters in the early 1980s to between 80,000-100,000 hunters over the last decade (Frawley 2013). Likewise, spring gobbler harvest increased from around 5,000 birds per year to between 30,000-40,000 birds over the same period. More broadly, restoration of turkey populations was followed by the resurgence of hunting popularity across the turkey range. By 2006, turkey hunting in the U.S. was second in popularity only to deer hunting, with an estimated 2.6 million hunters spending greater than 250,000 days afield and generating approximately \$4.1 billion in economic output (Harris 2010). However, biologists in many areas are concerned about population declines (Porter et. al. 2011, Tapley et. al. 2011) and it is uncertain that populations can sustain current harvests into the foreseeable future.

Sustaining large recreational turkey harvests will provide societal benefits and is promoted by clear and specific objectives. Michigan has management goals to provide hunting opportunities while maintaining turkey hunter satisfaction (Frawley 2013). We believe that quantitative evaluation of harvest sustainability would be promoted by augmenting existing goals with explicit descriptions of the types of harvest that are desirable to sustain. For example, ongoing analyses suggest harvest strategies aimed at sustaining large harvests of adult gobblers result in different approaches to management than those attempting to sustain harvests of either sex over both spring and fall seasons (Bryan Stevens, unpublished data). Thus, augmenting existing goals with specific objectives or performance measures related to turkey abundance or harvest by age/sex would allow for a more refined analysis of alternative management strategies. Such analyses would permit proactive evaluation of risks to important harvest metrics associated with specific changes to turkey management regulations.

Although turkey populations in Michigan are thought to be relatively stable, a more refined analysis would provide more detailed information on their population dynamics. Turkey populations in Michigan are currently monitored using raw harvest or number of turkeys harvested per unit of effort (catch-per-unit effort [CPUE]) and this approach is widely used across the U.S. Raw harvest (when effort is stable) or CPUE can provide a reliable population index, but interpretation of CPUE data is complicated by the possibility that the proportion of

the population removed per unit effort is not constant (Maunder and Punt 2004). Even if CPUE does index relative abundance, it does not directly provide the biological information necessary to determine sustainable levels of exploitation; this requires more understanding of population drivers and density dependence (Hilborn and Walters 1992, Maunder et. al. 2006). Explicit population assessment models built using both harvest and CPUE data can provide estimates of abundance and sustainable harvest levels. This approach is well developed in commercial fisheries and has been used in terrestrial-wildlife applications (e.g., Conn et. al. 2008). Thus, existing monitoring data should provide a basis for developing assessment models to understand population dynamics and aide management decision making for turkeys in Michigan. Moreover, evaluating the quality of existing monitoring data and the implications of assumption violations for management could be incorporated into model development.

Over the last decade, considerable advancements in computing power and quantitative analyses resulted in development of sophisticated techniques for evaluation of harvest policies for other species (Bence et. al. 2008, Jones and Bence 2009). These techniques use simulation models to forecast the consequences of management decisions while accounting for the uncertainty of both model inputs and projected results. This permits managers to better understand consequences of harvest regulatory policies and facilitates adaptive approaches that continue to evaluate management as monitoring data are collected through time (Irwin et. al. 2011). Specific regulatory policies to be evaluated for turkeys in Michigan will need to be identified collaboratively with DNR Wildlife Division staff to ensure options are relevant to managers; however, this could include simulation of policies that attempt to meet objectives via harvests that maintain constant levels of hunter effort or harvests through time (i.e., no feedback with monitoring data), harvests that attempt to remove a constant fraction of the population based on regular updating of a population-assessment model, or the status quo framework where harvest regulations are updated at three-year intervals after evaluating raw CPUE data. Thus, these techniques link monitoring data inputs to management decisions and can evaluate how both monitoring data type and quality affect our ability to manage turkey harvests effectively. We believe such work would be broadly beneficial to managers making decisions about both monitoring protocols and harvest regulations for turkeys in Michigan.

Eastern Massasauga Conservation: Through Refined Modeling, Habitat Management and Snake Fungal Disease Detection

Primary Contact: Dan Kennedy, DNR Wildlife Division, Lansing, Michigan

Email: kennedyd@michigan.gov

Phone: 517-284-6194

DNR Financial Support: \$46,181 in FY17, \$174,721 total.

Study Area: Statewide.

Time Frame: 02/01/2015-12/31/2017

Abstract: The Eastern Massasauga rattlesnake (EMR) is one of three Massasauga subspecies in North America and ranges across the Great Lakes region from Iowa to New York and from Ontario to Illinois (Jones et. al. 2012). Today, populations of EMRs have severely declined primarily due to habitat degradation, land development, agriculture and persecution in fragmented areas, leaving many existing populations isolated and/or in decline (Szymanski 1998, Johnson et. al. 2000, Gibbs and Chiucchi 2012). A contributing factor to the decline in habitat quality is that natural processes, such as fires, grazing and flooding events that historically maintained early successional vegetation communities and habitat conditions for EMRs are now beyond their historical range of variability. Today, as with most wildlife species, active habitat management is necessary to maintain habitat quality for the remaining EMR populations.

Effective monitoring of EMR populations is critical for evaluating the success of EMR habitat management practices and to evaluate population trends over time. Because this species inhabits relatively dense vegetation types (e.g., prairies, grasslands with sparse shrub cover, scrub-shrub wetlands) they are often problematic to detect. A greater understanding of the habitat, environmental (e.g., temperature, precipitation) and surveyor (e.g., number, level of training) effects on detection and the effects of survey methodologies (e.g., transects, random walks) is critical for establishing more standardized population survey techniques, ultimately resulting in increased confidence in the survey results. Additionally, with a standardized, effective and efficient survey methodology, biologists could more reliably focus on vital rates (e.g., fecundity, juvenile survival) to evaluate the viability of populations. While demographic rates for the EMR, particularly survivorship of adults, have been assessed (Bissell 2006, Bailey 2010, Bailey et. al. 2011, Jones et. al. 2012), rates related to reproduction and reproductive success such as fecundity and neonate survivorship are limited. Research has

suggested that demographic rates for EMR can vary greatly among populations (Jones et. al. 2012), yet aside from adult survivorship, little is known of other vital rates for many populations. The fragmentation of this species across its range, in addition to the fact that so little is known of the species' demographic rates, creates difficulty for managers interested in monitoring trends and shifts in populations and modeling population viability. Further, the spread of fungal infection (*Ophidiomyces ophiodiicola*) among free-ranging snakes is considered an important potential threat to the viability of EMR populations (e.g., Allender et. al. 2011). An assessment of the prevalence of *Ophidiomyces* sp. in remaining EMR populations is warranted to determine long-term viability of these populations.

Previous work in Michigan led by Dr. H. Campa has quantified habitat suitability requirements for the EMR in southwestern Michigan (Bissell 2006, Bailey 2010) and resource selection patterns in managed landscapes (Bailey et. al. 2012). From this work, an EMR Habitat Suitability Index (HSI) model was initially developed by Bissell (2006) in southwestern Michigan and later modified by Bailey (2010). The HSI model was developed by quantifying vegetation composition and structural attributes at multiple spatial scales and relating these habitat elements to several EMR population "fitness" performance measures. To appropriately validate this model, a range of habitat conditions across southern Michigan should be assessed. Additionally, with the collection of more data as proposed here, other modeling approaches can be explored (e.g., resource selection functions). Having a validated habitat model would help natural resource managers plan and implement more effective habitat management practices to maintain or enhance populations across the species' range.

Local-Scale Assessment and Monitoring of Deer Populations Following a Major Mortality Event

Primary Contact: Dr. Brent Rudolph, DNR Wildlife Division, East Lansing, Michigan

Email: rudolphb@michigan.gov

Phone: (517) 641-4903

DNR Financial Support: \$62,302 in FY17, \$249,917 total.

Study Area: Statewide.

Time Frame: 05/01/2014-09/30/2018

Abstract: Monitoring efforts to support decision making for deer management typically occur at county or regional scales. Numerous factors that influence deer management (e.g., hunting access or intensity, land use and cover, predation rates) vary at a much finer scale, but uniformly monitoring such conditions and associated population responses is not generally feasible or necessary. However, events that significantly impact populations or generate substantial public concern periodically create a need to assess deer abundance or population dynamics at a finer scale. This scale mismatch may disrupt an agency's ability to effectively manage social and ecological process and require organizations to evaluate new monitoring frameworks (Cumming et. al. 2006). In particular, the Michigan Surveillance and Response Plan for Chronic Wasting Disease (CWD) requires localized deer abundance estimates to be generated following any documented outbreak of CWD. Furthermore, an increased frequency of outbreaks of Epizootic Hemorrhagic Disease (EHD) in Michigan is attracting substantial concern among deer hunters and other wildlife enthusiasts in affected areas. A particularly significant EHD outbreak in 2012 created considerable public alarm, but may provide a unique and timely opportunity to assess new monitoring frameworks capable of addressing this management dilemma.

The EHD is an acute, infectious, viral disease that is often fatal in Michigan. It was first identified as a viral disease in 1955 following investigations into the death of several hundred white-tailed deer in both New Jersey and Michigan (Shope et. al. 1960). Since the initial 1955 outbreak, additional die-offs in Michigan attributed to EHD occurred in 1974, 2006, 2008, 2009, 2010, 2011, 2012 and 2013. Most die-offs occurred in isolated areas and resulted in estimates of no more than a few thousand deer dying. However, in 2012, EHD was confirmed in 30 counties and mortalities were reported in 21 other counties where confirmatory laboratory testing of samples was not able to be conducted. In total, EHD was the suspected cause of death in nearly 15,000 reported deer mortalities. To date, these outbreaks do not appear to have influenced regional populations. Because of its high mortality rate in Michigan, however, EHD outbreaks are likely producing highly contrasting localized deer abundance. Hunters and other wildlife enthusiasts in affected areas may observe reduced densities of deer for years to come and these occurrences may influence stakeholder satisfaction. With the greater frequency of EHD outbreaks, such stakeholder experiences are becoming increasingly common.

Forest Compositional and Structural Changes After a Decade of Emerald Ash Borer

Primary Contact: Jordan M. Marshall, Ph.D., Associate Professor, Department of Biology, Indiana University-Purdue University Fort Wayne, Fort Wayne, IN 46805

Phone: 260-481-6038

Fax: 260-481-6087

Email: marshalj@ipfw.edu

DNR Financial Support: None

Study Area: Aloha State Park, Harrisville State Park, North Higgins Lake State Park, Pinckney Recreation Area, Hoffmaster State Park, Seven Lakes State Park, Sleeper State Park, Tawas Point State Park, Young State Park

Time Frame: 08/01/2017 – 10/31/2017

Abstract: Emerald Ash Borer (EAB) is a pest insect that attacks all ash tree species in North America. Ash species (mostly black, green and white) are important trees in defining eight different forest types and are commonly associated with 33 other forest types. Precedence exists for potential changes in these forests due to one genus or species being lost. In 2007, I collected forest structure and composition data at 12 sites in eight Michigan State Parks and one State Recreation Area across the Lower Peninsula. This data included frequency, density and dominance measures for all encountered tree species in the forest. My goal for this project is to return to the same areas at these properties and collect this data again in 2017, which will provide a measure of change for that decade with exposure to EAB. This data will be combined from 47 other sites in Indiana, Michigan and Ohio, to provide a clearer understanding of forest change. In each forest, 4-5 plot locations were established in 2007 associated with EAB trap locations. I used those traps to categorize each site as “low” or “high” density of EAB based on capture rates throughout the growing season. Frequency, density and dominance data for 2017 will be compared to that of 2007 in order to quantify compositional and structural changes. The objectives of this study are to: 1) survey and characterize forest composition and structure at 57 sites in Indiana, Michigan and Ohio, 2) quantify forest changes over the last 10 years of EAB exposure and 3) test the hypothesis that forests with greater densities of both ash and EAB in 2007 will exhibit greater compositional changes in 2017.

Riparian Forest Condition Following the Emerald Ash Borer Invasion

Primary Contacts: Patrick Engelken, Graduate student, Dept. of Entomology, Michigan State University

243 Natural Science Building, 288 Farm Lane, East Lansing, MI 48824

Phone (785) 383-8596; Fax: (517) 353-4354

E-mail: engelke2@msu.edu

Dr. Deborah G. McCullough, Professor, Dept. of Entomology and Dept. of Forestry, Michigan State University

243 Natural Science Bldg., 288 Farm Lane, East Lansing, MI 48824

Phone: (517) 355-7445; Fax: (517) 353-4354

E-mail: mccullo6@msu.edu

DNR Financial Support: None

Study Area: Ionia Recreation Area, Bald Mountain Recreation Area, Barry State Game Area, Portland State Game Area, Rose Lake State Wildlife Area

Time Frame: May 2017 – December 2017

Abstract: Background: Emerald Ash Borer (EAB) (*Agilus planipennis* Fairmaire), a phloem-boring insect native to Asia, was detected in North America in 2002 and populations have since been found in 30 states and two Canadian provinces. This invader, which first became established in southeast Michigan and has caused widespread death of ash (*Fraxinus* spp.) trees across much of its range. Rapid loss of a major overstory tree species can result in cascading ecosystem-level effects.

These effects could be especially significant within riparian forests, which are unique in that they exert influence not only on surrounding forests and waterways, but on downstream conditions as well. Small streams with limited buffering capacity are often highly susceptible to disturbances. As ash trees succumb to EAB in riparian forests, effects of reduced canopy cover and leaf litter and increased light may be most pronounced in first order streams. While numerous studies have documented ash mortality in forests invaded by EAB, no previous work has examined effects of EAB in riparian systems.

In this study, we will identify and delineate canopy gaps caused by ash mortality along selected first order streams across an east-west gradient in southern Michigan representing a temporal gradient of EAB invasion.

We will record species composition, species richness and structure of vegetation, quantify snags and coarse woody debris (CWD) and measure available light within the gaps and in the surrounding forest. We will characterize regeneration to assess whether ash is likely to persist in these systems and to determine if recruits, saplings and seedlings reflect composition of overstory species in the surrounding forest. We will also record species and abundance of shrubs and herbaceous plants. We are particularly interested in evaluating the potential establishment or spread of invasive plants following EAB invasion.

In addition to vegetation and CWD surveys, we will use baited traps to monitor species assemblages of longhorned beetles in the family Cerambycidae. Cerambycid larvae feed and develop in phloem and sapwood of trees, but primarily colonize severely stressed, dying or dead trees. While some invasive woodborers in this group can be pests of live trees (e.g., Asian longhorned beetle), native cerambycids play important roles in decomposition and nutrient cycling. Relatively little is known about cerambycid communities in riparian forests and to our knowledge, the response of cerambycids to EAB invasion has not been previously examined.

Methods: At each location, we will survey vegetation and CWD using a combination of fixed radius plots and linear transects within the canopy gaps and in the forest surrounding the gaps. Variables to be recorded include species, size (DBH, height) and condition of ash and other overstory trees. Regeneration (recruits, saplings, seedlings) will be tallied by species. Species and percent cover will be recorded for shrubs and herbaceous plants. Decomposition status of snags and coarse woody debris will also be evaluated. The work we propose is non-destructive and will not require trees to be felled or wounded.

To assess cerambycid species assemblages and species richness, we will set up two cross vane panel traps near the edge of the canopy gap in each site. One “canopy trap” will be suspended from a branch of a tree while the other “ground trap” will be suspended from a rebar rod (1.5-2 m high). We expect to set up traps by early June 2017. Traps will be baited with a lure containing (R) 3-hydroxyhexan-2-one (3 R*), a non-toxic pheromone known to attract a wide range of cerambycid species, along with a slow-release pouch of ethanol. Non-toxic polypropylene glycol will be used in collection cups. We will check traps at approximately four-week intervals to collect captured insects throughout the summer. Insects will be sorted, screened and identified at the MSU Forest Entomology laboratory. Trapping will conclude in late August or September and traps will be retrieved no later than 31 October 2017.

Characterization and Disruption of Sea Lamprey Sex Pheromone Communication

Primary Contact: Anne M. Scott, Michigan State University, East Lansing, Michigan

E-Mail: anne.scott695@gmail.com

Phone: 517-432-3314

DNR Financial Support: None. Conducted on state land

Study Area: Little Ocqueoc River (N. Silver Creek Road); Atlanta Forest Management Unit

Time Frame: 2013 - Ongoing

Abstract: Modulation of the sea lamprey (*Petromyzon marinus*) pheromone communication system may offer additional effective and environmentally benign approaches to manage the invasive sea lamprey population in the Laurentian Great Lakes where they are predators of large fishes. Pheromones are indispensable cues that mediate sea lamprey migration and reproduction. Mature male sea lamprey release a multi-component sex pheromone that induces upstream movement of ovulated females to the spawning grounds. While the function and potential management implications of one of the sex pheromone component released by male sea lamprey are well-studied, the identity of other putative sex pheromone components and the utility of pheromone antagonists that disrupt sea lamprey pheromone communication remain largely unknown. The fundamental questions to be answered in this study were: (1) do putative sea lamprey sex pheromone components elicit behavioral responses in conspecifics and (2) what antagonists nullify the behavioral responses of sea lamprey to the sex pheromone components. An integrated approach of natural product characterization, neural physiology and behavioral assays resulted in the identification of three components released by mature male sea lampreys. A two-choice maze behavioral assay was used to assess to lamprey's preference for the treatment or vehicle channel of the maze behavior and after odorant exposure. The three identified components attracted ovulated females. Of the nine candidate pheromone antagonists tested in 2017, we identified two compounds that disrupted the pheromone-mediated behavioral response of ovulated female sea lampreys. Taken together, the results on sea lamprey pheromones and pheromone antagonists can help guide an effective, integrated sea lamprey control program.

Eastern Massasauga Translocation at Camp Grayling

Primary Contact: Dr. Bruce Kingsbury, Purdue University Fort Wayne, Dept of Biology, Fort Wayne, Indiana

E-Mail: Bruce.Kingsbury@pfw.edu

Phone: 260-481-5755

DNR Financial Support: None

Study Area: Crawford and Kalkaska Counties, Grayling Forest Management Unit

Time Frame: 2015-04/2019

Abstract: Camp Grayling has a substantial population of Eastern Massasauga (*Sistrurus catenatus*) and thus is an opportune location for studying the species. This snake is federally listed as threatened and is protected. It is also in conservation need. It is venomous and poses some risk if handled or stepped on. Camp Grayling is a training center for military activities with a lot of personnel on the ground and the chances for interactions with people are substantial. Camp staff are also committed to conservation and are interested in guidance on how to manage the snakes. We have consequently conducted research on Massasauga rattlesnake ecology and conservation at Camp Grayling for many years. A recent focus has been on the translocation, i.e., purposeful relocation of Massasauga rattlesnakes from one area of the property to another. This has relevance when individual snakes are a “nuisance” in the sense that they are located concurrent to training exercises or other activities where they or personnel may be at some risk. Translocation is also an emergent tool for augmenting small populations or “repatriating” species that have become extirpated for some reason and we need to learn best practices for the technique.

We relocated several Eastern Massasauga rattlesnakes from one area to another within Camp Grayling (and within one population) and studied how they responded to the move. We compared their behavior and survival to that of residents as a way of learning if the translocations were particularly detrimental to the snakes. We “hard-released” some of the snakes directly into the new location and “soft-released” others into enclosures for about two weeks, before letting them go. Using radio telemetry, we tracked these two groups and a set of residents as controls. The type of release used was at the heart of the study, to see if soft-releasing improved outcomes such as better survival and normal behaviors. This study is ongoing. However, so far, it does not appear that soft-release helps with the survival of snakes that have been moved. The implication then is that hard-releasing is the suitable approach, given the additional costs and logistical challenges of soft-release. We also found that the survivorship of translocated snakes is about half that for residents and this increased mortality would need to be factored into any translocation efforts.

Genetic Diversity:

Support for Research on Seedling, Nursery and Tree Development Projects

Primary Contact: Jason Hartman, DNR, Forest Resources Division

Email: hartmanj@michigan.gov

Phone: 989-732-3541

DNR Financial Support: \$12,000.00

Study Area: Brighton State Forest Nursery

Time Frame: 10/2014 – Ongoing

Abstract: Cooperative research and technical assistance related to nursery improvement and seed orchard management from Michigan State University’s Forestry Department. Work in 2017 included renovation of the jack and red pine seed orchards and continued jack pine seed collection from the best performing families in provenance test sites for use in establishing the next improved jack pine seed orchard. Other work in 2017 included jack pine cone collection for the establishment of the next jack pine seed orchard and evaluation of options for establishing a red pine seed orchard and/or red pine seed production areas out in the forest in the future.

Species and Individual Genetic Identification of Black Bears and other Carnivores

Primary Contact: Dr. Dean Beyer, DNR Wildlife Division, Marquette, Michigan

Email: beyerd@michigan.gov

Phone: (906) 228-6561

DNR Financial Support: \$32,000 in FY17, \$119,538 total.

Study Area: Statewide.

Time Frame: 02/10/2014-01/31/2018

Project 1: NLP Black Bear Abundance Estimation. The DNR has used microsatellite DNA to estimate abundance of black bears in the Northern Lower Peninsula (NLP) of Michigan since 2003. This method involves using barb-wire traps to snare hairs (DNA) from individual bears during a multi-week summer sampling period. Additional tissue (DNA) samples are collected from harvested bears in fall. The resulting capture-recapture histories of individuals are used in capture-mark-recapture (CMR) models to estimate bear abundance. Bear abundance estimates are used to set annual harvest quotas and to assist in additional research projects. Critical to the success of this project is sequencing of DNA hair and tissue samples at a minimum of 5 microsatellite loci (G10X, G10L, G10D, UarMU59 and UarMU50; See Dreher et al. (2007) for a detailed description of this method) for identify individual bears. To address distinguishing pairs of individuals with similar genotypes, additional loci (beyond the listed 5) may need to be added. Any additional loci added to analyses will be agreed upon with the DNR. Additionally, each bear sample is to be genetically sexed.

Project 2: Predator-Prey Project. In Michigan's Upper Peninsula (UP), similar genetic based methods are used for estimating abundance of bears and bobcats on a defined project area as part of an intensive study of the interaction of predators (black bear, bobcat, coyote and wolf) and prey (white-tailed deer). This project is hereto referred to as the "Predator-Prey Project". The Predator-Prey Project employs a DNA-based CMR estimator for bears with the exception that no harvest samples are collected and capture histories are based solely on summer hair snare samples. Critical to the success of this project is sequencing of bear DNA hair samples at 5 microsatellite loci (see above) with sufficient variation for distinguishing individual bears (See Dreher et. al. (2007) for a detailed description of this method). Additionally, each bear sample is to be genetically sexed (Ennis and Gallagher 1994). Similar to the method described for bears, an additional DNA-based CMR method was developed for estimating abundance of bobcats. Some differences for the bobcat CMR method include: hair samples are collected in winter (January-March); samples are collected by a single, modified neck snare; and mitochondrial ribosomal RNA is used to screen each hair sample for non-target carnivore species distinction. Critical to the success of this project is the screening of DNA hair samples collected in winter using the mitochondrial 16S ribosomal RNA gene for species distinction of carnivores and sequencing of bobcat DNA hair samples at 7 microsatellite loci with sufficient variation for distinguishing individual bobcats. See Stricker et. al. (2012) for a detailed description of this method. In addition, it is critical to determine sex of individual bobcats following procedures described by Williams et. al. (2011).

The DNR also will collect swabs from puncture wounds observed in white-tailed deer caused by carnivores (hereafter carnivore bite marks). Samples will be collected opportunistically year-round. Mitochondrial ribosomal RNA will be used to screen each swab sample for carnivore species distinction. Critical to the success is use of the mitochondrial 16S ribosomal RNA gene for species distinction of carnivores.

CRITERION TWO: MAINTENANCE OF PRODUCTIVE CAPACITY OF FOREST ECOSYSTEMS

Partnership for Ecosystem Research and Management – Faculty Support

Primary Contact: Dr. Brent Rudolph, DNR Wildlife Division, East Lansing, Michigan

Email: rudolphb@michigan.gov

Phone: 517-641-4903

DNR Financial Support: \$70,618 in FY17, \$70,618 total.

Study Area: Statewide.

Time Frame: 10/01/2016-09/30/2017

Abstract: The DNR Wildlife Division (WD) is responsible for wildlife population-level management (e.g., harvest regulations, game species designations, invasive species designations), but also play a dominant role in many Forest Resources Division and Parks and Recreation Division activities, particularly related to habitat. Often times, information on wildlife responses to management activities or the time to evaluate novel approaches to management is lacking within the DNR. With increased emphasis on accountability (e.g., forest certification), DNR stands to benefit from increased expertise on habitat-wildlife relationships, effectiveness

monitoring and an understanding of how operational activities (e.g., individual timber harvest proposals, prescribed fire on a recreation area) support statewide wildlife strategies. For DNR Wildlife Division to efficiently implement their Guiding Principles and Strategies, collaboration among internal and external professionals is important. Dr. Gary Roloff possesses considerable expertise on topics that support the DNR mission. As such, Dr. Gary Roloff will advise and consult with Wildlife Division on wildlife-habitat relationships, monitoring the effects of habitat management activities on wildlife populations, study design and sampling and integrating research findings into on-the-ground management.

An Analysis of Factors Limiting Reforestation of Abandoned Oil Pads in Northern Michigan

Primary Contacts: Dr. Fred Van Dyke, Au Sable Institute of Environmental Studies, Mancelona, Michigan.

Email: fred@ausable.org

Phone: 231-587-8686

DNR Financial Support: None

Study Area: Abandoned oil pads in Antrim, Crawford and Kalkaska counties of Michigan.

Time Frame: This is proposed as a five-year study (2015-2019).

Abstract: The fundamental questions to be answered by this analysis are: (1) what interaction of tree species and soil surface treatments provide highest rates of growth and survivorship of trees on vacated well pads in forest-dominated landscapes in Antrim, Crawford and Kalkaska Counties in northern Michigan; (2) how do surface treatments affect abundance of non-native invasive plant species; (3) how do soil characteristics differ between pads and surrounding forests; and (4) do soils on pads contain toxic levels of heavy metals or diesel fuel organics associated with extraction of oil and nature gas on these pads? The analysis described will definitively answer these questions, all of critical importance to successful reforestation of abandoned well pads and will answer them, more precisely, in these forms: (1) What tree species will grow and survive at the highest rates on abandoned well pads? (2) Does fertilization or competition from other vegetation limit reforestation of abandoned well pads for any or all these species? (3) Are the effects of fertilization or competition species-specific? (4) Does site treatment affect abundance on non-native invasive plant species on vacated well pads? (5) Do soil characteristics of pads differ from those of surrounding forests? (6) Are pad soils contaminated by heavy metals, diesel fuel organics or other toxins at levels that would inhibit growth and survivorship of plants, particularly native species of forest trees and at higher levels than surrounding forests? The first four questions will be answered through evaluation of the categorical effects of the previously described ANOVA, with questions one and two answered by analyses of fixed effects and question three by analyses of interactions between fixed effects. Questions five and six will be answered through a one-factor (site; pad or forest) ANOVA. Answers to these questions will enable MDNR foresters to make optimal selections as to which tree species and site preparation methods maximize the probability of success in reforesting abandoned well pads and returning their cumulative area to aggregate timber production and evaluate whether surface treatments affect abundance of non-native invasive plant species. Based on answers to questions 5, MDNR foresters will have a greater understanding of differences between pad and forest soils and can then determine if such differences can be remedied by surface treatments. Based on answers to question 6, MDNR foresters will know whether soil toxicity is a contributing factor to failure of natural reforestation on vacated well pads and whether action needs to be taken to detoxify such pads prior to reforestation efforts.

Seasonal Deer Migration Effects on the Distribution of Nutrients in Forest Ecosystems

Primary Contact: Christopher Webster, Ecosystem Science Center, School of Forest Resources and Environmental Science, Michigan Technological University

Email: cwebster@mtu.edu

Phone: 906-487-3618

DNR Financial Support: None

Study Area: Ontonagon & Gogebic Counties – Porcupine Mountains Wilderness State Park

Time Frame: 2010 – Present

Abstract: Twenty-five pellet plots were sampled during the 2014 season providing nine years of continuous sampling of three hemlock stands within Porcupine Mountains Wilderness State Park (PMWSP). These three stands are part of a larger study encompassing 39 stands distributed across the western Upper Peninsula of Michigan. Based on the pellet survey, deer use was higher in 2013 than 2012, but lower than the peak levels observed during the winter of 2008. Use was strongly related to stand area. The greatest use occurred in our largest sample stand. No winter deer activity has been recorded in our smallest sample stand. Our results from

the broader data set suggest that deer use the same areas within stands through time. The level of overall use during any given winter is strongly influenced by the timing and depth of snow accumulation.

Management of Chronic Wasting Disease in Michigan

Primary Contact: Dr. Kelly Straka, DNR Wildlife Division, Lansing, Michigan

Email: StrakaK1@michigan.gov

Phone: (517) 336-5030

DNR Financial Support: \$50,000 in FY17, \$250,000 total.

Study Area: Statewide.

Time Frame: 10/01/2016-09/30/2022

Abstract: Chronic Wasting Disease (CWD) is a transmissible spongiform encephalopathy that infects North American cervids including white-tailed deer (Williams 2005). The infectious agent of CWD is a misfolded protein, a prion, that accumulates in the brainstem and lymphatic tissue of infected animals and results in neurodegeneration and eventual death. In states where CWD is established, it has emerged as a major threat, reducing the health of populations and causing long-term population decline (Edmunds et. al. 2016, Gross and Miller 2001, Manjerovic et. al. 2014).

The occurrence of CWD in Michigan challenges the foundations of wildlife conservation, both in the short term and perhaps more significantly in the longer term. In the short term, CWD is causing reallocation of precious financial and staff-time resources and will be widely disruptive to existing programs. In the longer term, diseases such as CWD pose a threat to the financial cornerstone of fisheries and wildlife programs because sales of deer hunting licenses represent such a large proportion of annual revenue. Recognizing these threats, the Wildlife Division included wildlife disease in its *Guiding Principles and Strategies* (Objective 1.3: Monitor and preserve the health of Michigan's wildlife) and prepared a comprehensive *Surveillance and Response Plan for Chronic Wasting Disease of Free-ranging and Privately Owned Cervids*.

The discovery of CWD in Michigan creates an immediate need for tools that better assess the return-on-investment of funds for surveillance and management of CWD. We propose building on risk assessment and modeling that was previously developed during a CWD outbreak in New York. There, we showed how costs of CWD containment could be reduced dramatically by using risk modeling procedures and mapping areas where management action would have the greatest impact on disease control (Williams et. al. 2014). We plan to expand on those efforts by adapting them to Michigan and drawing on newly emerging tools for population estimation and risk analysis procedures that we have been using on other research (e.g., local-scale monitoring of deer populations using distance sampling and evaluation of wild turkey harvest regulations using statistical risk modeling).

Our objectives address the strategies set forth in the Wildlife Division's *Guiding Principles and Strategies* to "1.3.1: Develop and implement strategies to prevent and control diseases before they occur, 1.3.2: Respond to wildlife disease outbreaks, 1.3.4: Conduct research and monitoring to provide information to make management recommendations regarding wildlife disease, 1.3.5: Raise awareness regarding current and emerging wildlife health issues and 1.3.6: Work with State and Federal agencies and stakeholders to address wildlife health issues." Specifically, we will provide managers with decision tools to: (1) evaluate the risk of spread of disease against the geographic extent of management action and attendant financial and political costs, (2) evaluate management alternatives to control CWD and assess the risk of local cases of CWD transitioning from emergent status to established status (where the disease becomes a self-sustaining reservoir within a population) and (3) monitor management outcomes for deer population abundance and disease prevalence.

CRITERION THREE: MAINTENANCE OF FOREST ECOSYSTEM HEALTH AND VITALITY

Biological Control of Emerald Ash Borer (EAB) in Michigan with Releases of *Oobius agrili*, *Tetrastichus planipennisi*, *Spathius agrili* and *S. galinae*

Principal Investigators:

Leah Bauer, Toby Petrice, Therese Poland, USDA Forest Service, Northern Research Station & Dept Entomol, Michigan State University, Lansing, MI 48910 & East Lansing, MI 48823

Phone: 517-004-8059; Emails: lbauer@fs.fed.us, tpoland@fs.fed.us, tpetrice@fs.fed.us

Jian Duan, USDA ARS, Beneficial Insects Introduction Research Unit, Newark, DE 19713

Phone: 302-731-7330 x 249; Email: Jian.Duan@ars.usds.gov
Juli Gould, USDA-APHIS PPQ Otis Laboratory, Buzzards Bay, MA 02542
Phone: 508-563-0923; Email: Juli.R.Gould@aphis.usda.gov

Overview: Emerald ash borer biocontrol (EAB BC) began in Michigan on state, county and township lands in 2007 with releases of three EAB parasitoid species: *Oobius agrili*, *Tetrastichus planipennisi* and *Spathius agrili*. Release of a fourth parasitoid, *Spathius galinae*, began in 2015 although few have been available for release while rearing methods are developed at APHIS' Brighton EAB BC Rearing Facility in Brighton, MI. For an overview of EAB BC:

https://www.nrs.fs.fed.us/disturbance/invasive_species/eab/control_management/biological_control/

Geospatial data for all parasitoid releases and recoveries by researchers, land managers and other cooperators are posted at MapBiocontrol (MBC): <http://www.mapbiocontrol.org/>. A screen capture from MBC's mapviewer provides information on where parasitoid releases and recovery work has been done in Michigan (Fig. 1). Research in Michigan on parasitoid establishment and the impacts of EAB and BC ash conservation began in 2008 and below are key EAB BC publications from our work in Michigan are listed below. These and others are available at: <https://www.nrs.fs.fed.us/people/Bauer>.

In North America, one or more of these EAB biocontrol agents have been released in most states and provinces where EAB infestations are known (Figs. 2-4). Sites where *T. planipennisi* and *O. agrili* are established are shown in Figs. 3-4. It is too early to know if *S. galinae* is established, but it has been recovered and is spreading in Michigan, Massachusetts and New York. *Spathius agrili* may not be establishing in the U.S.

Parasitoid Releases in 2017 on MDNR Lands: In 2017, relatively small numbers of *S. galinae* adults were released again at DNR lands at study sites in Rose Lake, Maple River and Gratiot-Saginaw State Game areas. The availability of *S. galinae* continues to be limited due to lab-rearing problems, although this species has been found reproducing; and in 2017, we found it had spread from release to control plots at Gratiot-Saginaw.

There are only three addition sites in Michigan where *S. galinae* has been released: Central Park and Harris Nature Center, Meridian Township parks in Okemos and Burchfield County Park in Holt. We strongly recommend that land managers expand releases of *S. galinae* at more sites throughout Michigan because these are large parasitoids can parasitize EAB larvae in ash trees up to 57.4 cm DBH.

Parasitoid Establishment and Impact: *Tetrastichus planipennisi* is establishing and spreading relatively quickly in Michigan. Although parasitoid-recovery work has not been done at all release sites in Michigan, researchers are now confident that *T. planipennisi* will likely established in and around where it was originally released. We have found that this small parasitoid typically parasitizes EAB larvae in young ash trees and saplings up to 16-cm diameter at breast height. In southeast Michigan where the establishment and spread of *T. planipennisi* is now confirmed in the abundant regenerating ash, the density of ash and other native saplings were higher and densities of weedy species lower in closer proximity to study sites where more parasitoids were released. These results suggest that protection of ash saplings by *T. planipennisi* favors the recruitment of native woody species over weedy species in gaps as these forests recover from loss of the overstory ash canopy in the aftermath of the EAB invasion (Fig. 5). Clearly, additional releases are needed on state and other lands in Michigan. As of Dec 2017, *T. planipennisi* has been confirmed on the following MDNR lands: Au Sable State Forest, Bay City, Brighton, DeFord, Gratiot-Saginaw, Ionia, Island Lake, Maple River, Portland, Rose Lake, Shiawassee, Tuscola, Pinckney, Tuscola, Waterloo and Wigwam Bay.

Oobius agrili is establishing but spreading slowly from release to control sites. This minute EAB parasitoid kills the pest in the egg stage, before its larvae bore into the ash phloem and can protect all size ash trees. However, it is exceedingly difficult to detect and evaluate its role in suppressing EAB densities. As of Dec 2017, the establishment of *O. agrili* has been confirmed on the following MDNR lands: DeFord, Edmore, Gratiot-Saginaw, Ionia, Maple River, Rose Lake, Shiawassee, Shingleton, Stanton, Tuscola and Vestaburg.

Spathius agrili is apparently not establishing in Michigan or other northern regions and since 2013, releases are mainly limited to regions south of the 40th parallel.

Spathius galinae was approved for release in the U.S. in 2015 and only limited release have been done in Michigan. The first releases in Michigan were at the Michigan long-term EAB biocontrol study sites (MDNR

lands: Rose Lake, Gratiot Saginaw, Maple River) where ~400 females (+males) were released during August 2015 and similar numbers in 2016 and 2017. Although it is too soon to determine if this species is established, we are recovering it from EAB larvae at both release and control plots, indicating it is reproducing well in southern Michigan and spreading to new areas.

Emerald Ash Borer Parasitoid Rearing

Primary Contact: Nick Barc, USDA – Animal and Plant Health Inspection Service.

Email: nicholas.barc@aphis.usda.gov

Phone: 810-844-2711

DNR Financial Support: None

Study Area: Currently conducted partially on state land in the central and southern Lower Peninsula of Michigan

Time Frame: Ongoing

Abstract: The emerald ash borer (EAB) was likely introduced into Michigan in packing material from China in the 1990s. However, the pest was not detected until 2002 and soon after APHIS and the Forest Service initiated an EAB biological control (biocontrol) effort. Foreign exploration initially identified three biological control agents for EAB consisting of two larval parasitoids—*Spathius agrili* and *Tetrastichus planipennisi* and one egg parasitoid—*Oobius agrili*. The EAB biocontrol agents were first released in 2007 in Michigan. Two years later, APHIS' EAB Program established a dedicated biological control production facility in Brighton, Michigan. In 2015, another larval parasitoid, *Spathius galinae*, was approved for field releases and is being mass reared in Brighton. Today, the EAB Program has a strategic goal to release parasitoids in every infested county (over 700 counties) in the United States. At present, 22 of the 25 infested states have received EAB biocontrol, over 3 million parasitoids have been released since 2009 and approximately 25% of the known EAB-infested counties have performed releases.

The rearing facility produces and stockpiles most of the parasitoids to be released prior to the initiation of the release season in spring. This approach demands a steady supply of EAB during months that EAB is not present in the field. To maintain a constant supply of off-season adult EAB to produce the necessary egg and larval stage parasitoid hosts, the rearing facility harvests infested, mature ash material during winter months when adult EABs are in diapause. Several hundred ash trees are harvested from private and state lands for this purpose, stored in a cold chamber and warmed as needed to facilitate adult emergence. These adults are collected and maintained in enclosures with the appropriate resources to encourage reproduction and oviposition. A portion of EAB eggs from these enclosures are provided to *Oobius agrili* to parasitize. The parasitized eggs are then shipped to cooperators to be placed in the field for natural emergence and release. The remaining EAB eggs are applied to ash bolts and allowed to hatch and develop into 4th instar larvae. Several hundred smaller diameter (2-6 inch) ash trees are harvested from state lands and cut into smaller segments to provide the best EAB host for this stage. Once EAB larvae have developed to the correct stage, they are presented to one of the larval parasitoids. The parasitized larvae within the bolts are then provided to cooperators to be placed in the field for natural emergence and release of parasitoids.

Parasitoid recovery efforts are ongoing. However, to date, cooperators in 10 states (Indiana, Illinois, Maryland, Michigan, Minnesota, New York, Ohio, Pennsylvania, Tennessee and Wisconsin) have successfully recovered the offspring from one or more of the stingless wasps. Because the release sites are continually monitored, we anticipate additional reports of wasp recovery.

Trapping for Detection of Exotic Forest Pests and Evaluation of Native Wood Boring Insect Communities

Primary Contacts: Dr. Deb McCullough and Dr. Sara Tanis, Michigan State University, East Lansing, Michigan

Email: mccullo6@msu.edu

Phone: 517-355-7445

DNR Financial Support: None. Conducted partially on state land.

Study Area: Michigan's Upper and Lower Peninsulas

Time Frame: 2013, 2015-2017

Abstract: Our goals are to survey sites at relatively high risk for exotic forest pest introductions via international and domestic invasion pathways. We were especially interested in woodborers and bark beetles, which could potentially cause widespread damage if they became established. These insects can be

introduced in solid wood packing material, live nursery trees, unprocessed logs and firewood. We developed risk maps for Michigan's Upper and Lower Peninsulas using GIS technology to overlay variables such as forest cover type, number and origin of state park visitors, sawmill and campground locations and linear corridors such as railroads, highways and rivers. Spatial data sets and point data were overlaid to identify industrial and recreation sites at risk for specific forest pests. For example, a state park surrounded by maple-dominated forest would be considered a high-risk site, if the park hosts visitors from locations where Asian long horned beetle (ALB) has been identified. We selected up to 60-62 sites across Michigan's Upper and Lower Peninsulas to survey each year. An array of traps baited with lures for specific target pests are deployed in each site. Insects captured in the traps are collected, sorted and identified to species to ensure non-native target pests are not present. Selected groups of native woodborers are also identified to assess species composition and diversity of insects in specific forest cover types and locations and to evaluate efficacy of specific lures.

White Ash Survival Following Emerald Ash Borer Invasion

Primary Contact: Dr. Deborah G. McCullough, MSU, Dept. of Entomology and Dept. of Forestry

Email: mccullo6@msu.edu

Phone: 517-355-7445

DNR Financial Support: None

Study Area: Conducted partially on DNR lands in southeast and south-central Michigan

Time Frame: Completed

Abstract: Since its discovery in 2002 in southeast Michigan, emerald ash borer (EAB) (*Agrilus planipennis* Fairmaire) has become the most destructive forest insect to invade North America. Catastrophic mortality of white ash (*Fraxinus americana* L.), green ash (*F. pennsylvanica* Marsh.) and black ash (*F. nigra* Marsh.) caused by EAB have been recorded in plots established in southeast Michigan and Ohio (Burr and McCullough 2014, Flower et. al. 2013, Klooster et. al. 2014, Knight et. al. 2014).

We have observed, however, that a notably high proportion of overstory white ash trees remain alive in some sites in southeast and central Michigan, despite the presence of EAB in these areas for more than ten years. White ash tolerates a wide range of soil and site conditions (NRCS 2014), is native to 38 states and is a component of at least 26 forest cover types (Griffith 1991). Given the broad distribution of white ash and the value of white ash timber, understanding why white ash have survived in some sites but not in other sites has potentially important implications.

We quantified the percentage of white ash trees and basal area alive in 28 different forested areas spanning 11 counties in the core of the EAB invasion in southeastern and central lower Michigan from 2015 to 2016. Results showed that 75% of the 821 white ash trees (4 to 18 inches diameter at breast height) and 66% of the white ash basal area tallied in our survey are alive. Nearly all live white ash trees had been colonized by EAB at some point, but 83% of the trees had healthy canopies and trees were laying new wood over old larval galleries. Green ash trees were present in all but one of the 28 sites, but nearly all (92%) had been killed by EAB in previous years. We also assessed regeneration and found white ash dominated seedling, sapling and recruit strata in these sites. This study is reported in a paper that will be published in the Canadian Journal of Forest Research in early 2019.

Trapping for Detection of Exotic Forest Pests and Evaluation of Native Wood Boring Insect Communities

Primary Contact: Dr. Deborah G. McCullough and Andrew Tluczek, MSU, East Lansing, Michigan

Email: mccullo6@msu.edu

Phone: 517-355-7445

DNR Financial Support: None. Conducted partially on DNR lands

Study Area: Michigan's Upper and Lower Peninsulas

Time Frame: 2013, 2015-2019

Abstract: Michigan's diverse forests, major manufacturing industries and popular recreation sites provide many benefits to residents, but also mean the state is at a high risk of non-native forest insects introductions in solid wood packing material arriving with imported commodities from overseas or in logs, nursery trees and firewood originating in other states. We surveyed 45 sites in 2018 considered to be at relatively high risk for exotic forest pest introductions via international or domestic invasion pathways. We were especially interested

in woodborers and bark beetles, which could potentially cause widespread damage if they became established. We have developed risk maps for Michigan's Upper and Lower Peninsulas that overlay variables such as forest cover type, number and origin of state park visitors, sawmill and campground locations and linear corridors such as railroads, highways and rivers. Spatial data sets and point data are combined to identify industrial and recreation sites at risk for specific forest pests. For example, a campground surrounded by maple-dominated forest would be considered a high-risk site if the park hosts visitors from locations where Asian long horned beetle (ALB) populations occur. An array of traps baited with lures for specific target pests was deployed in each of the 45 sites. Almost 10,000 woodboring insects were captured and identification to species level is underway. Thousands of bark beetles are currently being screened by collaborators from the Michigan Department of Agriculture and Rural Development. Selected groups of native woodborers are also analyzed to evaluate species composition and diversity of insects in specific forest cover types and locations and to determine efficacy of specific lures.

Projecting Hemlock Woolly Adelgid Distribution and Risk in Michigan

Primary Contact: Dr. Deborah G. McCullough & Dr. Jeffrey Andresen, MSU, East Lansing, Michigan

Email: mccullo6@msu.edu

Phone: 517-355-7445

DNR Financial Support: None. Conducted partially on state land

Study Area: Michigan's Upper and Lower Peninsulas

Time Frame: 2016 - 2019

Abstract: Data sets from MI DNR and USDA Forest Service cooperators were compiled and used to develop a statewide model to project the likelihood of hemlock distribution. Personnel from the DNR and several other agencies were provided with pdf and shape files of hemlock projections to support ongoing hemlock woolly adelgid (HWA) detection surveys and requests for maps continue to be filled. We are continuing to monitor HWA development and condition (live, dead) year-round at infested sites in western Lower Michigan to determine when life stages such as eggs, mobile crawlers and mature adults are present. We are also monitoring microclimatic variation in temperatures experienced by HWA at two infested sites and four additional hemlock sites using 12 temperature sensors to quantify winter temperatures at three heights and four aspects on individual trees. Winter survival of HWA at the two infested sites will be related to shoot and ambient temperatures. We are continuing to analyze historical and projected extreme minimum temperatures in Michigan and across the Great Lakes region with PRISM data. Influence of the Great Lakes is evident in the frequency, severity and distribution of extreme cold events, with coldest temperatures and most frequent extremes occurring to the west and north of the Lakes and in interior areas away from the Lakes. Hemlock maps, HWA survival and development and winter climate data will ultimately be overlaid to develop HWA hazard maps.

Epidemiology, Biology and Population Genetics of Oak Wilt

Primary Contact: Dr. Deborah G. McCullough, Dr. Monique Sakalidis & Dr. Bert Cregg, Michigan State University, East Lansing, Michigan

Email: mccullo6@msu.edu

Phone: 517-355-7445

DNR Financial Support: None.

Study Area: Michigan's Lower Peninsula

Time Frame: 2016 - 2019

Abstract: Three sites on state forest land in northern lower Michigan with active oak wilt infection centers continue to be monitored to assess abundance, diversity and contamination rates of insects that can be long range vectors of oak wilt. We placed six wind-oriented traps baited with pheromones known to be attractive to tiny beetles in the family Nitidulidae in each of the three sites. A subset of beetles is then cultured by our MSU collaborators to determine if the beetles are carrying spores of the oak wilt fungus (*Bretziella fagacearum*). Beetles with spores are known to be attracted to oak wilt pressure pads, where they contact the spores. Beetles are also attracted to wounds on healthy oaks and can introduce the fungus to the oaks. In addition to identifying and monitoring beetle activity, we collected volatile organic compounds emitted by pressure pads and wounds, as well as the bark of healthy oak trees. Identification of these compounds is underway and could help us learn what chemicals are attractive to the nitidulid beetles. We assessed xylem development using small cores extracted from trees at two-week intervals to determine when earlywood production ceases and latewood production begins. Latewood has thicker cell walls and may be less likely to become infected by oak

wilt fungi. Several hundred beetles were collected in 2019, including beetles from the *Carpophilus* and *Colopterus* genera that have been implicated as oak wilt vectors. Beetle trapping and related work with our collaborators will continue in 2019.

Population Dynamics and Movements of Mute Swans in Michigan

Primary Contact: Dr. Dave Luukkonen, DNR Wildlife Division, East Lansing, Michigan

Email: LuukkonenD@michigan.gov

Phone: 517-641-4903

DNR Financial Support: \$90,000 in FY17, \$201,000 total.

Study Area: Statewide.

Time Frame: 10/01/2015-09/30/2018

Abstract: Mute swans (*Cygnus olor*) are not native to North America and distribution and abundance of this invasive species has increased significantly throughout the lower Great Lakes since their introduction in the mid-twentieth century. There is much concern about negative impacts of mute swans on native waterfowl, waterbirds, submerged aquatic vegetation and wetland habitats (USDA 2012). Given that the species is non-native and projected ecological and social impacts could be large, the Mississippi Flyway Council and DNR established control policies and associated population reduction goals in the mid-1990s.

Swan abundance in Michigan has been monitored via DNR's spring waterfowl survey, but despite initiation of control efforts focused on public lands, the mute swan population continued to grow rapidly through 2010 (i.e., with a long-term 9.3% annual growth rate: $\lambda = 1.093$; DNR unpublished data). The DNR reviewed existing policies and control programs in 2010 in consultation with Federal agencies, local governmental units, animal welfare groups, waterfowl hunting groups, conservation organizations and other stakeholders. Part of the evaluation included critical review of population dynamics and levels of control needed to meet a short-term goal of population stabilization and long-term population goal of no more than 2,000 mute swans in Michigan by 2030.

Recent efforts to control mute swan population growth in Michigan were guided by a model predicting population response to natural and management-induced mortality (Luukkonen 2010: unpublished). This model was based on available literature and mute swan models developed for other regions (Ellis and Elphick 2007) with the primary management alternatives being lethal take of different age classes or reproductive classes (i.e., experienced and inexperienced breeders) and nest/egg destruction. There is considerable uncertainty about reproductive parameter estimates, the sub-adult life cycle of mute swans and the potential for age-varying breeding propensity in relation to breeding densities and management strategies. Inaccurate estimates of vital rates can translate into unrealistic predictions about take of adult mute swans or levels of nest destruction required to meet objectives and this could result in delayed achievement of population goals, causing prolonged impacts to natural resources. Similarly, management efficiency may be compromised by a poorly parameterized model and as mute swan numbers are reduced, it will be increasingly important to efficiently target cohorts that are contributing to reoccupation of breeding sites (e.g., one-, two- and three-year-olds).

Understanding Habitat, Breeding Ecology and Diseases of Feral Swine in Michigan to Inform Effective Management

Primary Contact: Dr. Dwayne Etter, DNR Wildlife Division, East Lansing, Michigan

Email: etterd@michigan.gov

Phone: 517-641-4903

DNR Financial Support: \$115,157 in FY17, \$572,689 total.

Study Area: Statewide.

Time Frame: 12/01/2013-9/30/2018

Abstract: Feral swine (*Sus scrofa*), specifically the Russian boar breed, pose significant threats to habitat, wildlife, human health and the agricultural industry in Michigan. Free-ranging feral swine occur in 76 of 83 Michigan counties as of 2012. The occurrence of feral swine is projected to negatively affect the \$1 billion wildlife value (USFWS and US Department of Commerce 2006) and \$300 million domestic swine industry in Michigan. Additionally, feral swine affect agricultural crop production with potential ramifications that extend to the entire agricultural industry. Furthermore, researchers are just beginning to understand the indirect impacts of feral swine on naturally occurring plant and animal communities.

Feral-swine are opportunistic omnivores known to consume almost any organic material including vegetation, invertebrates and vertebrates (Schley and Roper 2003). Feral swine affect plants and animals through direct consumption and by habitat modification and degradation, competition and invasive species propagation. For example, feral swine can negatively affect forest regeneration through consumption of vegetation and seeds (particularly during low mast periods; Sanguinetti and Kitzberger 2010) and secondarily through soil disturbance and stream bank erosion associated with rooting behavior (Hone 1995). In addition, feral swine compete directly with wildlife for food and water resources (Ilse and Hellgren 1995, Laurance 1997) and can prey on some wildlife species. Direct predation on wildlife is poorly documented in the scientific literature, but ground nesting birds and altricial young are likely susceptible to feral swine predation (Tolleseon et. al. 2003). The scale of ecological damage caused by feral swine has not yet been spatially delineated nor economically assessed for Michigan. An understanding of feral swine space use and activity budgets is needed to help assess and predict risks to plant and animal communities and to help prioritize targeted management actions. Unfortunately, little is known about feral swine ecology in northern climates that can be used to better inform control strategies in Michigan.

Feral swine are reservoirs and potentially amplifiers for >30 viral (i.e. pseudorabies, hog cholera and foot- and-mouth disease [FMD]) and bacterial (i.e. bovine tuberculosis and brucellosis; e.g., Aranaz et. al. 2004) diseases and at least 37 known parasites that can affect humans, livestock and wildlife (Forrester 1991, Davidson and Nettles 1997, Samuel et. al. 2001, Williams and Barker 2001, Hutton et. al. 2006, Wyckoff et. al. 2009). These factors, along with the tendency for feral swine to move throughout landscapes, coupled with their low susceptibility to capture, make it difficult or impossible to eradicate swine diseases. The presence of feral swine in Michigan threatens to compromise the disease-free status of the domestic livestock herds and complicates eradication of bovine tuberculosis (bTB) in free- ranging deer. Bovine tuberculosis is established in portions of Michigan's deer herd and feral swine are a primary reservoir of bTB in many countries around the world. If Michigan's feral swine population became infected with bTB, it could have substantial negative consequences for the cattle industry. Additionally, over the past 17 years, the U.S. has spent about \$200-250 million to achieve a pseudorabies free status for the domestic livestock herd (Hutton et. al. 2006). Feral swine have also been implicated in three outbreaks of swine brucellosis in domestic herds (Feral Swine Subcommittee on Brucellosis and Pseudorabies 2005). Presently, pseudorabies has been reported in 11 states and brucellosis documented in 14 states where feral swine are found (USDA-APHIS 2005). In Michigan, preliminary testing by the DNR of 133 feral swine samples indicated ~10% were positive for pseudorabies; toxoplasmosis has also been confirmed. Feral swine can also transmit some common zoonotic diseases to humans such as leptospirosis, salmonellosis and trichinosis (Tegt et. al. 2011). Collectively, the potential of feral swine as a disease reservoir and vector makes disease monitoring and control a top priority for Michigan's agricultural community.

Feral swine are possibly the most prolific large mammal on earth reaching sexual maturity at a young age, capable of farrowing several times a year, have large litters and high natural survival. In good habitat, population growth and subsequent colonization through dispersal can occur rapidly resulting in irruptive population growth (Waithman et. al. 1999, Bieber and Ruf 2005). Natural predators have little impact on feral swine populations (Sweeney et. al. 2003) and in good habitat; feral swine can endure extremely high rates of hunting harvest with little impact on the overall population (Barrett and Pine 1990). Thus, if Michigan has any chance to locally control and potentially eradicate feral swine, action must be taken swiftly using all available control techniques.

Feral swine trapping in Michigan has been implemented by United States Department of Agriculture (USDA)-Wildlife Services, with support from the Michigan Department of Agriculture (MDA), to control localized populations. However, little is known about the effectiveness of these trapping efforts to reduce or eradicate local populations. Additionally, there is an absence of spatial ecology information (i.e., dispersal capabilities, daily movements, seasonal movements, proximity to domestic swine and feeding behavior) that can be used to inform stakeholders about risk, educate landowners and ultimately better inform population management strategies, including lethal removal. The goal of this project is to quantify feral swine space and resource use, disease status and potential for disease transmission and develop and evaluate effective lethal removal techniques and strategies.

Data Collection and Analysis to Generate Localized Deer Abundance Estimates and Recommended Future Protocols

Primary Contact: Dr. Brent Rudolph, DNR Wildlife Division, East Lansing, Michigan

Email: rudolphb@michigan.gov

Phone: 517-641-4903

DNR Financial Support: \$62,302 in FY17, \$249,917 total.

Study Area: southcentral Michigan

Time Frame: 5/01/2014-9/30/2018

Abstract: Monitoring efforts to support decision making for deer management typically occur at county or regional scales. Numerous factors that influence deer management (e.g., hunting access or intensity, land use and cover, predation rates) vary at a much finer scale, but uniformly monitoring such conditions and associated population responses is not generally feasible or necessary. However, events that significantly impact populations or generate substantial public concern periodically create a need to assess deer abundance or population dynamics at a finer scale. This scale mismatch may disrupt an agency's ability to effectively manage social and ecological process and require organizations to evaluate new monitoring frameworks (Cumming et. al. 2006). In particular, the Michigan Surveillance and Response Plan for Chronic Wasting Disease (CWD) requires localized deer abundance estimates to be generated following any documented outbreak of CWD. Furthermore, an increased frequency of outbreaks of Epizootic Hemorrhagic Disease (EHD) in Michigan is attracting substantial concern among deer hunters and other wildlife enthusiasts in affected areas. A particularly significant EHD outbreak in 2012 created considerable public alarm but may provide a unique and timely opportunity to assess new monitoring frameworks capable of addressing this management dilemma.

The EHD is an acute, infectious, viral disease that is often fatal in Michigan. It was first identified as a viral disease in 1955 following investigations into the death of several hundred white-tailed deer in both New Jersey and Michigan (Shope et. al. 1960). Since the initial 1955 outbreak, additional die-offs in Michigan attributed to EHD occurred in 1974, 2006, 2008, 2009, 2010, 2011, 2012 and 2013. Most die-offs occurred in isolated areas and resulted in estimates of no more than a few thousand deer dying. However, in 2012, EHD was confirmed in 30 counties and mortalities were reported in 21 other counties where confirmatory laboratory testing of samples was not able to be conducted. In total, EHD was the suspected cause of death in nearly 15,000 reported deer mortalities. To date, these outbreaks do not appear to have influenced regional populations. Because of its high mortality rate in Michigan, however, EHD outbreaks are likely producing highly contrasting localized deer abundance. Hunters and other wildlife enthusiasts in affected areas may observe reduced densities of deer for years to come and these occurrences may influence stakeholder satisfaction. With the greater frequency of EHD outbreaks, such stakeholder experiences are becoming increasingly common.

Development of Management Scenarios for Lake and Stream Habitat and Fisheries Under Current and Future Land Use and Climate Conditions

Primary Contact: Kevin Wehrly, DNR Fisheries Division, Institute of Fisheries Research, Ann Arbor, Michigan

Email: wehrlyk@michigan.gov

Phone: 734-663-3554 x 0402

DNR Financial Support: \$39,510 (25% Game and Fish Funds)

Study Area: Statewide

Time Frame: Ongoing.

Abstract: This project assessed habitat conditions for all lakes and streams statewide under current land use and climate conditions and provided insights on how current habitat conditions influence sport fish populations and fish community structure in lakes and streams. Boosted regression tree models were developed and refined that predicted abundance and growth of fish species in 6,500 lakes. Nutrient loading models and a new temperature model were developed and refined for use in predicting habitat changes in lakes. Recently developed predictions from 14 downscaled climate data were obtained and summarized for all lakes and stream reach catchments in Michigan. Changes in thermal regime and fish species suitability were estimated for a range of lakes. Maps identifying lakes vulnerable to species changes were developed for 14 different climate scenarios for mid-century and late century time steps. These data are key baseline and predictive information for the effects of land use and forest practice changes on fisheries resources.

CRITERION FOUR: CONSERVATION AND MAINTENANCE OF SOIL AND WATER RESOURCES

Protecting Instream Habitat by Development and Support of a Water Withdrawal Decision-Support Tool in Michigan

Primary Contact: Troy Zorn, DNR Fisheries Division, Marquette Fisheries Research Station, Marquette, Michigan

Email: zornt@michigan.gov

Phone: 906-249-1611

DNR Financial Support: \$68,740 (25% Game and Fish Funds)

Study Area: Statewide

Time Frame: Ongoing

Abstract: Land use practices are well known to influence water yields to stream systems that in turn directly influence fish habitat. Michigan's Water Withdrawal Assessment Tool (WWAT; <http://www.miwwat.org/>) is designed to estimate the likely ecological impact of a proposed water withdrawal and potentially land use on nearby streams and rivers. The foundation of the WWAT is the Michigan Rivers Inventory Project that produced statewide models of landscapes, river habitats and fish distributions; an initial ecological rivers segment classification; a statewide model of potential groundwater influx to rivers; a regional classification of riparian ecosystems; and a method for regional assessment of stream condition. This project continues the refinement and improvement of this key regulatory tool that protects Michigan's streams in forested lands.

Assessment of Nearshore Fish Communities in Northern Lake Michigan and Lake Superior

Primary Contact: Troy Zorn, DNR Fisheries Division, Marquette Fisheries Research Station, Marquette, Michigan

Email: zornt@michigan.gov

Phone: 906-249-1611 x 308

DNR Financial Support: \$131,439 (25% Game and Fish Funds)

Study Area: Northern Lake Michigan

Time Frame: Ongoing

Abstract: Inshore areas of the Great Lakes can be affected by riparian land and fisheries management actions and many of the species found in these areas use tributary streams for recruitment which exposes them to the effects of land use actions. This study is providing key information on the population trends in Bays de Noc fish populations that include adult abundance, year class strength, sex and age structure of walleye and yellow perch in northern Lake Michigan. Additionally, the study is developing a database on fish community composition for under-sampled nearshore areas of northern Lake Michigan. These data provide a key baseline to evaluate current and future fisheries, land use and forest management actions.

CRITERION FIVE: MAINTENANCE OF FOREST CONTRIBUTION TO GLOBAL CARBON CYCLES

Michigan Gradient Study on Nitrogen Gradients to Understand the Mechanisms Controlling Carbon and Nitrogen Cycling in the Face of Chronic Nitrogen Deposition and the Long-term Consequences of Nitrogen Saturation

Primary Contact: Dr. Andrew Burton, Michigan Technological University, Houghton, Michigan

Email: ajburton@mtu.edu

Phone: 906-487-3470

DNR Financial Support: None. Use of state forest land and state data.

Study Area: There are two study areas -- One is primarily in the SE 1/4 NW 1/4 NW 1/4 Sec 33 T52N R36W, but a small portion is in the SW 1/4 NE 1/4 NW 1/4 Sec 33 T52N R36W. The other is located in the SW 1/4 NE 1/4 Sec 1 T36N R5W, with a small part of one research plot in the SE 1/4 NE 1/4 Sec 1 T36N R5W.

Time Frame: Ongoing

Abstract: Over the next century, ecosystems in the Northern Hemisphere will be exposed to elevated rates of atmospheric nitrogen (N) deposition, which could theoretically strengthen the terrestrial carbon sink (C) in this region, potentially helping to mitigate the rate of atmospheric CO₂ increase. However, the degree to which anthropogenic N deposition could foster greater forest productivity and C storage remains uncertain. Ecologists at the University of Michigan, Michigan Technological University and the University of Idaho have conducted a long-term, regional, field experiment located in Michigan. To simulate rates of elevated atmospheric N deposition, four sugar maple (*Acer saccharum*)-dominated northern hardwood study sites have received

annual additions of 3 g NO₃--N/m² since 1994. All four study sites rapidly approached N saturation, evidenced by substantial leaching of both inorganic and organic N. Although simulated atmospheric N deposition increased net primary productivity over the 23-year experiment, soil respiration, litter decay and wood decomposition have significantly declined; these responses have rapidly increased C storage living and dead wood and in the organic horizons and surface mineral soil. Greater C in the non-living pools results from a decline in lignolytic microbial activity and a corresponding change in microbial community composition. Given these responses, we hypothesize that: i) simulated atmospheric N deposition will continue to accelerate tree growth, tree mortality and coarse woody debris production, further increasing C storage in woody biomass and soil organic matter; ii) surface soil C will continue to accumulate at a faster rate under experimental atmospheric N deposition; iii) warmer temperatures will accelerate net primary productivity across the climatic gradient encompassed by the study sites; and, iv) climate warming will eventually interact with simulated atmospheric N deposition to differentially increase ecosystem C storage among sites. A series of established core long-term measurements (some stretching back to 1988) enable us to test these long-term hypotheses and to understand how elevated N deposition and climatic variation might affect forest composition and productivity in the long-term.

CRITERION SIX: MAINTENANCE AND ENHANCEMENT OF LONG-TERM MULTIPLE SOCIO-ECONOMIC BENEFITS TO MEET THE NEEDS OF SOCIETIES

Comprehensive Analysis and Improvement of Michigan Statewide Angler Survey Data

Primary Contact: Zheming Su, DNR Fisheries Division, Institute of Fisheries Research, Ann Arbor, Michigan

Email: suz@michigan.gov

Phone: 734-663-3554 x 0407

DNR Financial Support: \$46,315 (25% Game and Fish Funds)

Study Area: Statewide

Time Frame: Ongoing

Abstract: This study examines and improves the catch and effort estimates generated by the Statewide Angler Survey Program by developing methods that will improve the spatial and temporal efficiency of estimates and data use and conceptual and quantitative models that describe fishery dynamics and aid in management decision-making. These data provide key baseline harvest and economic benefits across the state that is required to properly evaluate fisheries management and land use, including forest management practices.

Partnership for Ecosystem Research and Management – Faculty Support

Primary Contact: Dr. Brent Rudolph, DNR Wildlife Division, East Lansing, Michigan

Email: rudolphb@michigan.gov

Phone: 517-641-4903

DNR Financial Support: \$291,062 in FY17, \$291,062 total.

Study Area: Statewide.

Time Frame: 10/01/2015 – 09/30/2016

Abstract: The DNR Wildlife Division (WD) continues to be a national leader in supporting social science relevant to applied wildlife management. More important than the generation of knowledge is the integrated consideration of social science along with biological science when directing wildlife management programs and providing technical advice to policy makers. These efforts require a range of expertise and constant consideration of the best available information plus evaluation and adaption of programs to make use of this information. This is best performed by close collaboration of professionals possessing diverse expertise, both within and outside of the WD.

Dan Kramer – social, economic and policy aspects of wildlife management. Dr. Dan Kramer possesses considerable expertise to advise and consult with WD on data collection, study design and application of findings regarding the social, economic and policy aspects of wildlife management, particularly regarding conservation of biodiversity and changing land use.

Frank Lupi – economic aspects of wildlife management. Dr. Frank Lupi possesses considerable expertise to advise and consult with WD on data collection, study design and application of findings regarding the economic aspects of wildlife management.

Jordan Burroughs – wildlife outreach. Jordan Burroughs possesses considerable experience to draw upon to advise and consult with WD on efforts to engage and improve upon relationships with diverse stakeholders. This project will provide support for program and operations evaluation, diffusion of techniques to integrate

human dimensions of wildlife into programs, improve agency engagement and improve information transfer and professional development for WD personnel.

Shawn Riley – human dimensions aspects of wildlife management. Topics requiring attention in this regard include human dimensions of wildlife health; hunter recruitment and retention; antecedents to and consequences of varying levels of public trust and confidence in DNR WD; human-wildlife interactions; how individuals and communities develop capacity for living with wildlife; application of systems thinking to natural resource policy; and decision-making processes. Dr. Riley possesses considerable experience, expertise and a history of consulting with agency staff on improving capacity to make effective decisions informed by these broad perspectives. This project will provide support for professional development for WD personnel, program evaluation and diffusion of techniques to integrate human dimensions into programs, improve public trust and confidence in the agency and maintain relevance of application of the public trust doctrine to wildlife management.

Elk Responses to Recreational Use and Habitat Potential in Michigan

Primary Contact: Dr. Dean Beyer, DNR Wildlife Division, Marquette, Michigan

Email: beyerd@michigan.gov

Phone: 906-228-6561

DNR Financial Support: \$91,665 in FY17, \$542,000 total.

Study Area: Northcentral Lower Peninsula.

Time Frame: 05/01/2015-09/30/2019

Abstract: Michigan's elk management plan commits to managing for a sustainable elk population in balance with the habitat and supporting quality hunting and viewing opportunities. Over the past 20 years, elk use of areas outside the historic elk range has increased, leading to reduced public viewing opportunities, challenges to continued use of hunting to manage elk and increasing human-elk conflict. Greater elk use of these outlying areas may be a result of seeking refuge from disturbance from off-road recreational use or better habitat. Research is needed to support management decisions capable of focusing habitat management efforts where benefits will be greatest (elk management plan strategy 1.1), using hunting to control elk numbers, herd composition and distribution (elk management plan goal 2), addressing private landowner conflicts with elk (elk management plan action 2.1.1) and providing public viewing opportunities (elk management plan action 3.1.1).

Issues resulting from wildlife–off-road recreational user interactions on public lands are a growing problem throughout North America (Taylor and Knight 2003, Naylor et. al. 2009), as well as in Michigan. Forest and wildlife managers in Michigan are concerned about the potential impacts horseback and mountain bike riding may be having on elk behavior and distribution (S. Whitcomb, B. Mastenbrook, personal communications). The Michigan Elk Management Advisory Team recommended the DNR “study and monitor disturbance factors (including recreational users) that cause elk to move to and from public land into private land where disturbance level is lower...” (Elk Management Advisory Team 2010:9). We propose quantifying the number and relative intensity, frequency and geographic scope of recreational users and assessing their influence on elk movement, habitat selection and subsequent hunting and viewing opportunities. This information will be critical for planning the spatial arrangement of habitat management activities and riding trails and help justify land use regulations for recreational users.

To help plan and evaluate the effects of habitat management designed to benefit elk (and other species), we propose developing a landscape-scale habitat potential model. The elk habitat potential model would help DNR biologists use an “...objective measurement system to plan and monitor the actual status of the elk...range, habitat...” (Elk Management Advisory Team 2010:7) to identify the location of potential vegetation types needed to meet elk habitat management objectives over time. Focusing habitat management practices in these selected areas may also help minimize elk dispersal reducing agricultural damage and facilitating hunting and viewing.

Exploring Causal Factors and Effects of Declining Hunter Participation in Michigan

Primary Contact: Dr. Brent Rudolph, DNR Wildlife Division, East Lansing, Michigan

Email: rudolphb@michigan.gov

Phone: 517-641-4903

DNR Financial Support: \$99,175 in FY17, \$267,310 total.

Study Area: Statewide.

Time Frame: 05/01/2015-09/30/2019

Abstract: Hunters are key constituents in state wildlife conservation in Michigan and the U.S. Hunting, as a form of outdoor recreation, is a valuable part of Michigan's nature-based economy and remains an important element of Michigan's culture and heritage. Activities associated with hunting engage Michiganders with wildlife and connect them to nature and one another. Nonetheless, participation in hunting is declining. The trends are persistent and widespread (Heberlein and Thomson 1996; Duda et. al. 2010). If current declines in Michigan hunter participation are to be countered, better knowledge of underlying socio-demographic causes of the decline are needed. Insights about how macro social factors (e.g., percent of one-parent households), as well as more local meso (e.g., employment) and micro (e.g., personal) factors are affecting hunter recruitment and retention will help focus management efforts tailored toward sustained hunter participation. Similarly, understanding how internal and external migration affect initiation and participation in hunting will allow the DNR to anticipate and adjust to the changing socio-demographic environment of Michigan, which is experiencing increased urbanization. Assessments of opportunities and challenges for retaining involvement in other forms of wildlife-related recreation are also needed to evaluate potential of stakeholders with broader interest in engaging with wildlife supporting conservation. Little is known about this important population of stakeholders in Michigan. Scientifically based insights are needed into alternative or complimentary models of maintaining conservation-minded publics in Michigan and elsewhere. This proposal fully supports Goal 4 of the DNR Wildlife Division's strategic plan (MDNR 2010).

Improving Efficacy of Furbearer Management in Michigan through Assessment of the Nature and Extent of Illegal Fur Harvesting

Primary Contact: Dr. Brent Rudolph, DNR Wildlife Division, East Lansing, Michigan

Email: rudolphb@michigan.gov

Phone: 517-641-4903

DNR Financial Support: \$63,835 in FY17, \$244,538 total.

Study Area: Statewide.

Time Frame: 06/01/2015-09/30/2019

Abstract: State wildlife agencies regulate harvest of game species to meet dual objectives of allowing recreational take while ensuring sustainability of populations. Compliance with harvest regulations and cooperation with accurate reporting of effort and harvest success are important for meeting these objectives. The remote locations and often secretive manner in which hunting and trapping occurs (even when conducted legally) makes patrolling and detecting violations difficult; and the secretive nature and elusive behavior of many wildlife species – especially furbearers – makes population dynamics or abundance trends difficult to monitor. Adjustments in harvest regulations (e.g., annual bag limits, season length) and reporting and registration requirements for furbearers including bobcat, fisher, American marten and otter are common in Michigan (Frawley 2013a and b, Hiller et. al. 2011). Advancements in statistical modeling of age-at-harvest data now allow for furbearer population abundance estimates, which were historically difficult to obtain (Skalski et. al. 2011). Recent population modeling of marten and fisher abundance in the Upper Peninsula of Michigan indicate substantial population declines over the past decade. These declines have been attributed to decreased survival of adults of both species (Skalski et. al. 2011, Skalski unpublished data). Managers possess long-term harvest datasets (e.g., reported adult mortality) for marten and fisher, however, little is known about reliability of these reports and other mortality sources including illegal take by fur harvesters.

Unlike with many other North American game species, the existence of a legal commercial market for fur means harvest of furbearers is partially motivated by economic gain. Participation in trapping is known to increase with fur prices, which may also increase motivation for users to engage in illegal harvest. Trappers may exceed restrictive bag limits by making use of licenses purchased by non-trappers (with success and potentially effort then being falsely reported by individuals that did not actually trap), take furbearers within closed areas or during closed seasons (with harvest location and dates then being falsely reported), or engage in "high grading" by discarding inferior quality fur or smaller-sized animals in favor of higher quality or larger-sized animals. A lack of compliance with legal harvest rules may not only place populations at risk of overexploitation, but also promote generation of falsified data, interfering with assessment of harvest regulation and evaluation of impacts of regulated harvest on population dynamics and viability.

Incorporating knowledge about the nature and extent of illegal take of furbearers can improve enforcement efforts and aid calibration of population models and effectiveness of regulations developed and implemented by the state to ensure the furbearer resource remains sustainable. Information about illegal fur harvesting activities can also aid in discussions with stakeholders, many of whom feel illegal take results in significant

negative impacts to the resource. To date, methods for assessing illegal take of furbearers have been limited. Theoretical and methodological developments in conservation criminology (Gibbs et. al. 2010) provide an ideal opportunity to address gaps in understanding about illegal take of furbearers and the relationship between illegal take and management. To this end, the goal of this proposed project is to improve our understanding of the factors that significantly affect furbearer management regarding four limited take species in Michigan: bobcat, fisher, American marten and river otter. Our focus will be to increase knowledge and understanding of the extent and nature of illegal take to inform more effective furbearer management in Michigan (e.g., Gore 2011).

An Evaluation of Moving to a Learning Organization in the Wildlife Division: Measuring Collaboration, Trust, Performance and Effectiveness of Decisions

Primary Contact: Dr. Pat Lederle, DNR Wildlife Division, Lansing, Michigan

Email: lederlep@michigan.gov

Phone: 517-243-0700

DNR Financial Support: \$0 in FY17, \$436,389 total.

Study Area: Statewide

Time Frame: 11/1/2011-9/30/2017

Abstract: The Michigan Department of Natural Resources (MDNR) Wildlife Division (WD) strategic plan for 2010-2015 sets ambitious objectives for becoming an adaptive (thus learning) organization with improved performance arising from, among other activities, collaborative governance and greater accountability to the WD's external stakeholders. Although some of the objectives laid out in the strategic plan – especially the biologically oriented objectives related to habitat and wildlife populations – are straightforward to measure, other objectives relevant to becoming a learning organization are less tangible or easy to measure. To evaluate progress in achieving the desired outcomes of the strategic planning effort relevant to becoming a more adaptive and learning organization, research is needed to clarify measures of success (such as greater trust in the WD among stakeholders and more sustainable, effective decisions), collect baseline information and measure progress.

Increasingly, organizations strive to keep up with environmental changes and philosophies of continuous improvement. A key mechanism for dealing with these issues is to optimize the use of human resources and strengthen collaborative relationships with external stakeholders. In wildlife management, this undertaking must be accomplished within a “messy world” with constantly changing environments and a high level of uncertainty. In the face of uncertainty, trust (we assume trust to include credibility) in the agency on the part of stakeholders becomes crucial to moving forward with decisions, yet systems that accelerate learning must be in place to keep pace with change in physical and social-economic environments. Organizational learning – that is, being adaptive – is a major determinant of sustainably high organizational performance. To thrive, organizations need to learn and change at an increasingly rapid rate. Improving service delivery and effectiveness calls for continual evaluation of the current state of the organization and consideration of future possibilities. A principal way any organization learns and changes is through rigorous assessment, monitoring and evaluation.

Assessing the Viability of Game Meat Sharing as a Strategy to Increase Support for Hunting and Wildlife Conservation

Primary Contact: Dr. Brent Rudolph, DNR Wildlife Division, East Lansing, Michigan

Email: rudolphb@michigan.gov

Phone: 517-641-4903

DNR Financial Support: \$0 in FY17, \$53,336 total.

Study Area: Statewide.

Time Frame: 7/01/2014-9/30/2017

Abstract: Hunters are key stakeholders in state wildlife conservation. Hunting is a valuable part of Michigan heritage and tradition, engaging Michiganders with wildlife and connecting them to nature and to one another. Large societal transformations (e.g., increasing affluence and urbanization) are decoupling humans from nature (Heberlein and Ericsson 2005). If declining attitudes and support for hunting are to be countered and participation increased, insights are needed about how to enhance the relevance, legitimacy and value of hunting to society (Peterson 2004). Evidence exists that sharing and consumption of game meat may function in several ways as a “coupler” that links humans and natural systems (Ljung et. al. 2012). Yet, specific knowledge is lacking about how social networks operate in distribution and sharing of game meat, what effect

game meat sharing has on societal views of legitimacy and relevancy of hunting and whether support for hunting (and more broadly, nature) may be derived from experiences associated with meat sharing and consumption. An estimated 15 million pounds of venison are harvested annually in Michigan, providing >60 million quarter pound servings of venison (>6 servings per Michigan resident annually if distributed equally). The extent to which this meat is shared and any positive impacts associated with this sharing are unstudied benefits of wildlife management. Knowledge and insights regarding game meat sharing's social impact are expected to enable the DNR to facilitate partnerships that will increase the reach and impact of game meat in promoting positive attitudes towards and support for hunting.

Factors Affecting Waterfowl and Hunter Use of Managed Waterfowl Areas

Primary Contact: Dr. Dave Luukkonen, DNR Wildlife Division, East Lansing, Michigan

LuukkonenD@michigan.gov

Phone: (517) 284-4720

DNR Financial Support: \$44,000 in FY17, \$124,000 total.

Study Area: Statewide.

Time Frame: 10/01/2015-09/30/2018

Abstract: Michigan Department of Natural Resources (MDNR) created multiple wetland management areas in the 1960s and 1970s with the purpose of providing high quality waterfowl hunting experiences. These areas are intensively managed to attract waterfowl for hunting and viewing and to provide habitat for a diversity of wetland wildlife. Although managed waterfowl areas have been funded by hunting license fees and fees from managed area use permits purchased by hunters, they are open for anyone most of the year. These areas are unique in that hunting is highly controlled to prevent crowding, maintain safety and maintain high waterfowl use. In addition to managing wetlands on these areas, agricultural crops such as corn, millet and buckwheat are planted and flooded to help increase waterfowl use.

There is a need to regularly evaluate waterfowl and user use of managed waterfowl areas and to adapt management systems to changing conditions to ensure these areas continue to function as intended. Status of important Great Lakes waterfowl populations (e.g., mallards [*Anas platyrhynchos*] and Canada geese [*Branta canadensis*]) have improved since the managed areas were created, and yet statewide numbers of waterfowl hunters has declined in Michigan and other Great Lakes States. Although periodic analyses of monitoring data have been useful to help guide management, it has been many years since a comprehensive assessment of waterfowl and hunter use of managed areas has been completed. Evaluation of historic data and future monitoring is especially important at this time because MDNR, Wildlife Division (under the umbrella of the Waterfowl Legacy Initiative) has recently created explicit objectives related to increasing use of state managed waterfowl areas while maintaining (or improving) high quality hunting and viewing experiences for recreational users. In addition to analysis of existing data, it is important to ensure that future monitoring is conducted in ways to help reduce the most important uncertainties affecting future management decisions; alternative monitoring programs for managed areas should be considered and evaluated considering their rigor, ability to address management needs and sustainability with available staff time.

Social and Economic Benefits and Costs of Elk in Michigan

Primary Contact: Dr. Clay Buchanan, DNR Wildlife Division, Lansing, Michigan

BuchananC1@michigan.gov

Phone: (517) 284-9453

DNR Financial Support: \$17,000 in FY17, \$216,728 total.

Study Area: Statewide.

Time Frame: 07/01/2017-09/30/2021

Abstract: Michigan's elk management plan (adopted April 5, 2012) was developed by considering a variety of positive and negative impacts expected to result across a range of elk population sizes and distribution. A population goal of 500 – 900 animals was established based on a desire to maintain a viable elk population at levels expected to appropriately balance these impacts, but during plan development a need was recognized to improve upon metrics to track these negative and positive effects. Action 3.1.4 of the plan commits to "Measure economic and social factors related to elk" due to the belief that elk management and hunting play a significant role in the local and regional economy. Past elk hunter surveys have indicated that 53– 64% of elk hunters have paid for elk guiding services; and the 2013 survey estimated licensed elk hunters spent an average of \$1,013 ± \$70 on food, travel and lodging. No estimates are currently available regarding other

expenditures by hunters, any expenditures by individuals accompanying licensed hunters or visiting the area to view elk during any time of year, or economic losses from damage to crops and property.

We propose to not only measure these impacts, but to also examine features that influence choices regarding recreational behaviors and expenditures. These features are likely to include elk population size, composition (e.g., age and bull-to-cow ratios) and distribution and other factors such as landscape characteristics and infrastructure. Some recreation occurs out of a specific desire to see or harvest elk – and potentially specific kinds of elk or in a specific manner (e.g., on foot, horseback, or using vehicles) – while other recreation occurs in the elk range but is incidental to elk occurrence. Understanding the relationships guiding how such features influence decisions about how and where to recreate and invest in those activities would allow the DNR to more effectively inform elk population and habitat management, damage mitigation, facility development and educational or marketing efforts to reduce conflict between competing recreational and land uses, enhance enjoyment and potentially maximize benefits to the local and regional economy. We therefore intend to develop quantitative spatial models of recreational uses which could be linked to an elk habitat model to explore how alternative management approaches would influence both elk populations and recreational choices.

Stewardship Motivations and a Collaborative Governance Model for Great Lakes Coastal-Based Wildlife Management Areas for Waterfowl Hunting, Bird Watching and Community Development

Primary Contact: Barbara Avers, DNR Wildlife Division, Lansing, Michigan

Email: aversb@michigan.gov

Phone: (517) 284-4720

DNR Financial Support: \$67,426 in FY17, \$268,949 total.

Study Area: Statewide.

Time Frame: 10/01/2015-09/30/2021

Abstract: Great Lakes coastal wildlife management areas are purchased and managed with funds that represent investments by waterfowl hunters in conservation and wildlife management. These areas are also destinations for non-hunting recreation (e.g., bird and other wildlife watching, fishing, paddling, hiking, etc.). Coastal communities benefit from expenditures generated by waterfowl hunting and non-hunting outdoor recreation activities occurring at or near these areas, yet these economic contributions have not been measured. Differences between hunting and non-hunting stakeholders (e.g., demographics, values, attitudes, behaviors, motivations, etc.) have also been unexamined. As the number of non-hunting recreational users increase and waterfowl hunters decrease, it is unclear how the current model of conservation and livelihoods of coastal communities will be impacted by the changing nature of investments in wildlife management. The livelihood of coastal communities and sustainability of wildlife resources are interconnected and both could benefit from collaborative planning; however, no formal assessment of community planning needs and opportunities exist for evaluating approaches for collaborative governance across public/private landscapes. We propose evaluating economic contributions, characteristics and stewardship motivations of diverse users of coastal wildlife management areas, valuing key ecosystem services provided by these areas and assessing needs and opportunities for collaborative governance of wildlife resources and coastal community development.

Michigan Wildlife Values

Primary Contact: Dr. Emily Pomeranz, DNR Wildlife Division, Lansing, Michigan

Email: PomeranzE@michigan.gov

Phone: (517) 281-4744

DNR Financial Support: \$0 in FY17, \$10,000 total.

Study Area: Statewide.

Time Frame: 07/28/2016-09/30/2018

Abstract: Michigan is experiencing social and demographic changes that have affected and will continue to affect wildlife management. A scientific understanding of how these changes impact public values over time is critical for ensuring that the MDNR Wildlife Division (WD) maintains regulatory authority over wildlife, continues to be relevant to the constituents they serve and can strategically position themselves for future challenges. The WD has performed extensive work to understand attitudes and opinions of hunting constituents; however, little research has been conducted to gather similar information from the general population. The “America’s Wildlife Values Project” (AWVP) is a national project being carried out to address this need. The WD has opted through this Michigan Wildlife Values project to collect additional data on state-specific issues not otherwise addressed through the overall nationwide assessment of wildlife values.

CRITERION SEVEN: LEGAL, INSTITUTIONAL AND ECONOMIC FRAMEWORK FOR FOREST CONSERVATION AND SUSTAINABLE MANAGEMENT

QWC: Research and Biometrics Consultation and Support to Wildlife Division Via the Boone and Crocket Quantitative Wildlife Center at Michigan State University

Primary Contact: Dr. Dave Luukkonen, DNR Wildlife Division, East Lansing, Michigan

Email: LuukkonenD@michigan.gov

Phone: (517) 641-4903

DNR Financial Support: \$95,776 in FY17, \$95,776 total.

Study Area: Statewide.

Time Frame: 10/01/2016-09/30/2017

Abstract: DNR-Wildlife Division's (DNR-WD) strategic plan for 2016-2020 identifies new research directions explicitly aligned with future management needs. These include research to inform regional approaches to habitat and population management as well as expanded use of adaptive management systems that integrate population, habitat and human dimensions of wildlife management. Implied in the plan is the need to make better use of existing data and create new and robust monitoring programs to guide future management decisions. As management becomes more complex, an emerging need of DNR WD is expanding use of new technology and sophisticated quantitative approaches to predict outcomes of management alternatives. Given how rapidly advances occur in these fields, it is impractical to expect full-time DNR WD personnel to maintain working familiarity with cutting-edge tools and techniques. Partnerships with universities provide an excellent means of applying these advanced methods to inform applied research and management.

Presently, it is beyond the capacity of the DNR to maintain a full-time team of experts in biostatistics, so DNR WD is collaborating with Michigan State University (MSU) to fulfill this expanding need. The recently created Boone and Crockett Quantitative Wildlife Center (MSU-QWC) at MSU offers a specific opportunity for establishing a DNR-MSU partnership to help meet DNR WD research and information needs while also training new biologists with a better appreciation and understanding of agency issues and the research/management interface. Also, with the DNR WD's access to extensive historical databases and expanded emphasis on regional and statewide approaches, there is opportunity to conduct research that is broadly based and supported by multiple agencies and institutions.

Application of a Seven-Step Effectiveness Monitoring Design to Aspen (*Populus tremuloides*) in Michigan.

Primary Contact: Scott Jones; Forest Management Planning Specialist, DNR, FRD, Lansing, Michigan

Email: Joness38@michigan.gov

Phone: 517-284-5873

DNR Financial Support: \$2,000 in FY17.

Study Area: Six state forest management areas – two in the Western Upper Peninsula, two in the Eastern Upper Peninsula and two in the Northern Lower Peninsula.

Time Frame: 01/01/2014 – 08/30/2020.

Abstract: Trembling aspen (*Populus tremuloides*) has great biological, social and economic value in Michigan. It is an important timber species (social and economic value), it provides habitat components for a broad suite of wildlife species (biological value), and it provides for a broad suite of recreational values associated with hunting and wildlife viewing (social and economic value). Management efforts need to be monitored to determine or assess their effectiveness in terms of meeting the goals and objectives for trembling aspen management.

But, trembling aspen is considered to be a loser under the current suite of climate change scenarios and could potentially be confined to a few refugia by the end of the century. There is a very high degree of uncertainty associated with climate change and the response of aspen which underscores the need for effectiveness monitoring, but effectiveness monitoring remains an elusive goal: there are no examples of effectiveness monitoring programs at an operational scale and responsible agencies have little hope of finding new resources for effectiveness monitoring in an era of highly stressed budgets.

However, this project proposes to show how a seven-step design process can be used in conjunction with Bayesian networks to develop an effectiveness monitoring program for trembling aspen that uses existing data, accounts for the uncertainty in the system (including climate change), links the monitoring efforts to the aspen decision process, thereby permitting adaptive management and that identifies research priorities and permits the immediate use of research results into the monitoring framework. This will provide for an early warning to impending change and will permit managers to evaluate and decide upon a course of action related to the three broad climate change adaptation strategies: resistance, resilience and response.

Surveillance Projects:

Conduct Forest Inventory and Assessment (FIA) Re-Measurements

Primary Contact: Scott A. Pugh, US Forest Service, Houghton, Michigan.

Email: spugh@fs.fed.us

Phone: 906-482-6303 x 17

DNR financial support: \$40,200.00

Study Area: Forested Landscapes nationwide including Michigan

Time Frame: Long-Term, On-going.

Web Site: <http://www.fia.fs.fed.us>

Abstract: The FIA program has been the nation's continual forest census since 1930. We collect and analyze data collected from permanent sample plots to enable reporting information on the status and trends of America's forests: how much forest exists, where it exists, who owns it, how it is changing and also how the trees and other forest vegetation are growing, how much has died or been removed and how the harvested trees have been used in recent years. This information can be used in many ways, such as in evaluating wildlife habitat conditions, assessing sustainability of current ecosystem management practices, monitoring forest health, supporting planning and decision-making activities undertaken by public and private enterprises and predicting the effects of climate change. The FIA program combines this information with related data on insects, diseases and other types of forest damage to assess the current health and potential risks to forests. These data are also used to project how forests are likely to appear in 10 to 50 years under various scenarios to evaluate whether current forest management practices are sustainable in the long run and to assess whether current policies will enable our grandchildren and their grandchildren to enjoy America's forests as we do today. Although this is a national program, the results can be and are summarized for regions and individual states.

The data from this program can also be used to inform the species diversity indicators and Criterion Two: Maintenance of Productive Capacity and Forest Ecosystems.

A Statewide Survey of Michigan's Licensed Anglers

Primary Contact: Dr. Frank Lupi, Michigan State University, East Lansing, Michigan

Email: lupi@msu.edu

Phone: 517-432-3883

DNR Financial Support: \$66,782 (25% Game and Fish Funds)

Study Area: Statewide

Time Frame: Ongoing

Abstract: This project provides additional fishing effort, catch and catch composition to supplement the direct census information from other surveys through a mail survey of licensed anglers. This study provides information about anglers and their fishing behavior and the ability to track the behaviors over time to assess the status and trends of angling behavior in Michigan. These data provide key baseline harvest and economic benefits across the state that is required to properly evaluate fisheries management and land use, including forest management practices.

Charter Boat Catch and Effort from the Michigan Waters of the Great Lakes

Primary Contact: Donna Wesander, DNR Fisheries Division, Charlevoix Fisheries Research Station, Charlevoix, Michigan

Email: wes_anderd@michigan.gov

Phone: 231-547-2914 x 223

DNR Financial Support: \$108,154 (25% Game and Fish Funds)

Study Area: Statewide – Great Lakes

Time Frame: Ongoing

Abstract: Fisheries biologists cannot effectively manage sport fish in the Great Lakes without knowledge of the relationship between fish stocks and the fisheries that exploit them. Additionally, some of these stocks are dependent for recruitment on inland streams that can be affected by forest and land management practices. Charter angling is one type of fishery on the Great Lakes. The Michigan charter industry consists of approximately 530 businesses operating 570 boats that catch and harvest a measurable amount of sport fish from the Great Lakes. Charter catch and effort data are generated continuously by this project for a broad range of purposes including wild fish production. Fisheries trends from this group of users provides key insights on how well wild fish are recruiting to our fisheries and these fish can be traced back to inland streams along the land practices that influence them.

Michigan Statewide Angler Survey Program

Primary Contact: Tracy Claramunt, DNR Fisheries Division, Oden State Fish Hatchery, Oden, MI and Zhenming Su, DNR Fisheries Division, Institute of Fisheries Research, Lansing, Michigan

Emails: kolbt@michigan.gov and suz@michigan.gov

Phone: 517-282-2887 and 734-663-3554 x 0407

DNR Financial Support: \$2,547,880 (25% Game and Fish Funds)

Study Area: Statewide

Time Frame: Ongoing

Abstract: The most fundamental requirements for sound management of recreational fisheries are knowledge of the response of fish stocks to fishing and of the contributions of various fish stocks to the fisheries. This knowledge can be obtained only if there is a long-term record of fishing effort, catch and catch composition available for analysis. This project is designed to obtain a continuous record of sport fishing effort, catch and harvest, catch and harvest rates and catch composition for important Great Lakes, tributary and inland fisheries of the State using consistent protocols and data collection and analysis methods. These data provide key baseline harvest and economic benefits across the State that is required to properly evaluate fisheries management and land use, including forest management practices.

Technology Development Projects:

Develop and Implement a Computerized Timber Sale Treatment Tracking System

Primary Contact: Douglas Heym, Timber Sales Specialist, Forest Resources Division

Email: heymd@michigan.gov

Phone: 517-284-5867

DNR Financial Support: \$6,000,000

Study Area: State forest land statewide

Time Frame: Ongoing

Abstract: We are continuing to develop our timber sale computer program, Vegetative Management System (VMS), to work with our forest wide inventory system (MiFI) to better track forest treatments over time. This will help monitor our sustainable forest management. Treatments are tracked from their initial proposal to their final implementation.

After the annual State Forest inventory, areas are designated for treatment. These areas go through a review process and a final treatment boundary and prescription is approved. The boundary is designated on the ground, the area is mapped using GPS and the inventory system is updated. The pre-contract paperwork is developed into a proposal which then receives final approval. When the proposal is approved, MiFI is again updated with the final boundary and the approval status. The VMS advertises the sale, helps conduct the bid opening, awards and creates the contract and handles modifications to the contract. When the contract is closed, MiFI is updated and the forester plans for the 'next steps' within the inventory system. The MiFI is then used to schedule and track any other activities needed to complete the treatment.

We are currently working on having contract changes, e.g., amendments, reflected in the inventory system. Over time and at any point in time, the system will better reflect the condition of the forest. This is complicated technology to design and implement, but the final product will be a model for any land management organization.

Design and Develop Specialized Equipment for Forest Fire Fighting

Primary Contact: Dan Munn, Forest Resources Division.

Email: munnd@michigan.gov

Phone: 989-275-5211

DNR Financial Support: \$172,064.00

Study Area: Roscommon Equipment Center and DNR forest lands

Time Frame: Ongoing since March 2007

Abstract: After action reviews are an important part of wildland firefighter learning and training after an incident has taken place. The MDNR and the Roscommon Equipment Center (REC) have once again worked together to develop an "Electronic Standtable" where the events of an incident can be recreated and digitally stored and shared with other firefighters and their affiliated agencies. The electronic standtable tool is virtually cost free and uses only a computer with internet access and Microsoft PowerPoint installed. A basic knowledge of PowerPoint and completing internet searches for image files are the only skills a user needs to be able to create incident recreations on this system. The REC staff has created a tutorial video and it is found on YouTube at the following link: <https://www.youtube.com/watch?v=qWUjgx0Oy88>.

RECENTLY COMPLETED RESEARCH RELATED TO SUSTAINABLE FORESTRY

Adaptive Management of Sharp-Tailed Grouse in the Eastern Upper Peninsula of Michigan

Primary Contact: Dr. Dave Luukkonen, DNR Wildlife Division, East Lansing, Michigan

Email: luukkonend@michigan.gov

Phone: (517) 641-4903

DNR Financial Support: \$0 in FY16, \$86,500 total.

Study Area: Eastern Upper Peninsula.

Time Frame: 10/19/2011-9/30/2016

Abstract:

Objective 1. Clarify fundamental and means objectives for sharp-tailed grouse management in Michigan and translate those objectives into measurable system attributes. Attributes included final average metapopulation abundance, expected minimum abundance, percentiles of final total abundance and terminal quasi-extinction risk. Because of the importance of maintaining a sharp-tailed grouse population that can support hunting, models including hunter harvest were also evaluated based on cumulative harvest. The habitat management objective of maintaining suitable habitat in township sections important to sharp-tailed grouse was recommended based on resource selection modeling. We recommend this objective to be measured based on the proportion of forest land within a township section, with a goal of maintaining below 50% forest land within managed sections.

Objective 2. Develop alternative models predicting sharp-tailed grouse population dynamics and responses to habitat changes and harvest. Our study found the proportions of open-land, shrubland and forest to be important drivers of sharp-tailed grouse resource selection at the one-square-mile scale in Michigan. Sharp-tailed grouse occurred in sections with higher proportions of shrubland and open-land and lower proportions of forest land than what was generally available in the study region. We found harvest regulations using a localized framework, with harvest limited to no more than 2 times the estimated current rate (approx. 25% harvest) should exhibit low extinction risk for sharp-tailed grouse populations in Michigan's Upper Peninsula. Large habitat patches increased viability more than equal area smaller patches. The addition of habitat patches near important patches in the eastern Upper Peninsula and randomly placed showed similar metapopulation viability. Our analysis also revealed deficiencies in monitoring with some areas of high relative likelihood of occurrence and extensive areas in the western Upper Peninsula without recent survey data.

Objective 3. Identify additional research and monitoring needed to fully implement an adaptive approach to sharp-tailed grouse management in Michigan. Suitable habitat patches not overlapping known sharp-tailed grouse occurrences provide opportunities for additional monitoring locations. Before management actions in the western Upper Peninsula, such as translocation, can be recommended, a better understanding of the current occupancy patterns in the region is needed. In addition, achieving a better understanding of the importance of wetland habitat to sharp-tailed grouse would be useful for modeling and management efforts. Additional simulations modeling the effects of habitat loss on sharp-tailed grouse are needed to further inform habitat management goals within Michigan.

Objective 4. Illustrate the use and utility of structured decision-making approaches to DNR Wildlife Division personnel and the Natural Resources Commission (NRC). Natural Resource Commissioners were invited to the STGAC stakeholder meeting in August 2013. In December 2014, we reconvened the Sharp-tailed Grouse Advisory Committee (STGAC) to discuss expansions to the sharp-tailed grouse hunting area in the eastern Upper Peninsula. This directly involved stakeholders, including key personnel with the DNR Wildlife Division in an adaptive approach to sharp-tailed grouse management. Following this meeting, recommendations were made to the NRC by the DNR Wildlife Division to extend the hunting area, and the NRC adopted these recommendations for the 2015 hunting season. In December 2015, we presented research results to several members of the STGAC, including Wildlife Division personnel and open to NRC members.

Monitoring Mast Occurrence and Production Using Citizen Scientists to Inform Wildlife Management in Michigan

Primary Contact: Sarah Mayhew, DNR Wildlife Division, East Lansing, Michigan

Email: mayhews@michigan.gov

Phone: 517-336-5036

DNR Financial Support: \$17,352 in FY16, \$123,763 total.

Study Area: southcentral Michigan

Time Frame: 5/01/2014-9/30/2016

Abstract:

Objective 1. Develop sampling protocol and reporting system for citizen science observers to collect and submit information on mast occurrence and production in Michigan. Based on our research findings and on interactions with MI-Mast users, we simplified the sampling protocol so that participants were not required to go to the same location every year. Also, rather than restrict sampling to some preconceived notion of the masting season, we opened up the data portal to year-round entries. These changes were made to make the program more user friendly and to encourage year-round interaction.

Objective 2: Implement the mast observation and reporting system with volunteers from 20 counties in the northern Lower Peninsula. As of November 2016, mast observations have been recorded for 31 Michigan counties; 26 in the northern Lower Peninsula and 5 in the Upper Peninsula. Observation dates range from 2014 to 2016.

Objective 3: Develop a seasonal, ecoregional index of mast abundance in Michigan using data collected by citizen science observers. Submitted to MDNR – Wildlife Division as Chapter 2 in the Masters thesis titled “Using Citizen Science to Develop Mast Productions Indices in Michigan”.

Objective 4: Prepare a literature review of wildlife-mast relationships with a focus on the Great Lakes Region. Publication submitted to MDNR-Wildlife Division titled “Literature review on the relationships between mast and wildlife in the Lake States Region”.

Analytical Support Refining Wolf Survival Estimates in The Upper Peninsula and Addressing Action Items in Michigan’s Wolf Management Plan

Primary Contact: Dr. Dean Beyer, DNR Wildlife Division, Northern Michigan University, Marquette, Michigan

Email: beyerd@michigan.gov

Phone: 906-227-1627

DNR Financial Support: \$34,371 in FY16, \$135,333 total.

Study Area: Upper Peninsula

Time Frame: 6/01/2014-9/30/2016

Abstract: Major Findings and Results:

Winter prey distributions exhibited a habitat functional response depending on winter snow conditions, resulting in a geographic prey limitation that affected wolf territory occupancy within the study area. Density-dependence in habitat selection revealed that wolf selection patterns were more consistent with an ideal-preemptive habitat distribution, as opposed to the ideal-free distribution. Density-dependent habitat selection patterns revealed decreasing selection for prey availability at greater wolf densities, while selection for anthropogenic features such as road density increased. However, selection across time exhibited occupancy-dependence as opposed to density-dependence. Wolf annual survival was ~75% and was influenced by sex, age, transient status, agriculture, habitat edge, wolf density and Julian day, as well as several individual factors. Survival declined as wolf density increased, resulting in a shifting mosaic of wolf survival. Similarly, human-caused mortality increased with wolf density.

Human causes contributed to 66% of reported wolf mortality in Michigan and the most common cause of death was illegal killing. This translated to a rate of ~ 17% annual human-caused mortality. The compensatory-additivity statistic was 0.464, suggesting partial compensation and growth rate was affected the most when both human and natural mortality rates were high (less compensation). In addition, human caused-mortality was density dependent. Although evidence for partial compensation is encouraging, informative censoring can bias survival estimates high if human-caused mortality is underestimated. Based on a sensitivity analysis, “cryptic poaching” of up to 20% of censored events could result in survival estimates ~6% lower than expected

based on standard known fate analysis. States with connected populations should consider implementing interstate population models that borrow information from multiple data sources, thereby providing valuable information about immigration, emigration, larger scale population trends and source-sink dynamics that have not been formally quantified.

Management Recommendations:

We provide evidence that ~17% annual human-caused mortality is partially compensated for by decreases in natural mortality and that human-caused mortality increases with subsequent increases in wolf density. Survival rates may have been overestimated due to potential for informative censoring and unobserved mortality, but quantifying these effects remains challenging. Our key recommendations are 1) management efforts should be focused on decreasing and assessing illegal killing and 2) we urge wildlife managers in states with connected populations to consider combining available information from long term monitoring programs and developing interstate population models that borrow information from multiple data sources. Such an effort would provide valuable information about immigration, emigration, larger scale population trends and source-sink dynamics that have not been formally quantified. Legal status has been controversial for species such as wolves, but cooperative multi-state management efforts (i.e., collaborative conservation) have precluded the need for ESA listing in other species. Collaborative conservation at large spatial scales will likely be a necessary and critical component of promoting long-term recovery of large carnivore species.

Geographic Analysis of Age-Period-Cohort Dimensions in Michigan Hunter Participation

Primary Contact: Brent Rudolph, DNR Wildlife Division, East Lansing, Michigan

Email: rudolphb@michigan.gov

Phone: 517-641-4903

DNR Financial Support: \$5,580 in FY16, \$64,230 total.

Study Area: Statewide.

Time Frame: 7/01/2014-9/30/2016

Abstract: Most state wildlife management agencies in the U.S. are grappling with the issue of declining hunting participation. The North American Model of wildlife management was constructed to govern the public ownership of wildlife and serve traditional consumptive users who bore the responsibility of funding state agencies through hunting, fishing and trapping license fees. However, societal changes throughout the 21st Century have altered the social context under which most citizens live, consequently leading to decreasing participation in hunting, fishing and many outdoor recreational activities. The response by many state agencies has been to focus resources on recruitment and retention efforts to try and boost participation rates.

Our research suggests that it is unlikely these efforts will make up for the projected declines in hunter numbers during the next 20 years. An understanding of the contribution of cohort effects shows that, beyond the effects of age, participation has been declining because of generational differences, and it will continue to decline as the Baby Boom generation ages. Two key points emerge from this study: 1) The hunting population in Michigan will continue to decline and 2) The hunter population in Michigan will age dramatically.

It is unlikely that hunter recruitment and retention efforts will be able to reverse these trends, but more targeted efforts marketed toward key demographics may be able to slow the decline. Most importantly, this research shows evidence of an emerging opportunity to increase the role of women in hunting by working to retain the relatively large cohorts of recently recruited young females. State agencies are increasingly recognizing that women are a key stakeholder group that was largely ignored for generations and that could be a potential source of new hunters. As gender norms have changed, so too has the role of women in hunting. State agencies have begun to capitalize on this broader social change by offering hunter education courses specifically for female hunters. Our projections for the State of Michigan show that if recent cohorts of female hunters can be retained, women may constitute 20% of deer hunters within 20 years. Outreach and education efforts targeted toward women have the potential to pay off in terms of wildlife management goals, agency funding and broadening the appeal of hunting to non-traditional demographics.

We also see some potential to promote hunting as a “family-based” activity, which could improve the recruitment of teenagers, as well as increase the retention of middle-aged women and men. Young professionals who were not recruited into hunting as kids but who support the goals of wildlife conservation and value locally sourced food may have the potential to be recruited as young adults as part of broader public hunting education programs. Building bridges between hunters and non-hunters may help appeal to

ecologically-minded or local foods-oriented stakeholders by focusing on local, sustainable sources of food and the benefits to local ecosystems provided by the wildlife management.

A key point is that our research, along with similar evidence from other states (Winkler and Warnke 2013, Chase 2012), indicates that age and cohort effects on hunting participation are operating in similar ways across the United States. These are broad, well-established patterns that will be difficult to change. Further research and planning strategies would benefit from incorporating an understanding of cohort effects when considering future policy changes.

Agencies will require better understanding of differences in the mix of environmental, wildlife, social and food-related values between different generations of stakeholders. Our projections indicate the future hunting population will be smaller, considerably older and potentially shifting to a greater proportion of female participation. This means that future hunting stakeholders may have different values, interests and expectations than the past and present hunting population. Moreover, hunters should be expected to produce less agency revenue if license purchases decline as projected. We encourage agencies to use projections such as ours to explicitly plan how to meet wildlife conservation goals and to engage diverse hunting and non-hunting publics in the face of these changes.

Facilitating Urban-Suburban Deer Management in Michigan: Social, Spatial and Population Considerations

Primary Contact: Dr. Brent Rudolph, DNR Wildlife Division, East Lansing, Michigan

Email: rudolphb@michigan.gov

Phone: 517-641-4903

DNR Financial Support: \$9,000 in FY16, \$583,202 total.

Study Area: southeastern Michigan

Time Frame: 10/18/2011-9/30/2016

Abstract:

Recommendations from this project were:

- 1) A field test for population reduction at the neighborhood scale appears to be feasible from an ecological perspective yet may not be any less contentious from a stakeholder perspective due to heterogeneity of values even at small spatial scales.
- 2) Deer populations are spatially structured and localized management action could take advantage of that structure to control deer populations within portions of a town.
- 3) Heterogeneity of values, beliefs and attitudes – neighbors may hold opposing views about whether deer population management is warranted – detected in Livingston County suburban neighborhoods further suggests even at small spatial scales that consensus may be difficult to attain.
- 4) The fact that local government officials expressed greater potential for conflict indexes related to deer than their constituents as a whole is evidence that the existing deer problem may be inflated and that local government officials likely hear from people who incur costs more frequently than those people who view deer as a benefit.
- 5) Further exploration and experimentation with localized management within an adaptive management context is recommended.