SUMMARY OF SUSTAINABLE FORESTRY AND OTHER RESEARCH

Fiscal Year 2019

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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 2019 fiscal year (October 1, 2018 through September 30, 2019).

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 but primarily focuses on private forest land.

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 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.

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RESEARCH RELATED TO SUSTAINABLE FORESTRY – CURRENTLY ON-GOING

Criteria Framework for Sustainable Forestry and Associated Research-

CRITERION ONE: CONSERVATION OF BIOLOGICAL DIVERSITY

Landscape Diversity:

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
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DNR Financial Support: $43,486 in FY19, $125,968 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.

Integrating Information to Manage Landscapes for Featured Species
Primary Contact: Dr. Dwayne Etter, DNR Wildlife Division, Lansing, Michigan
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DNR Financial Support: $71,185 in FY19, $144,234 total.
Study Area: Statewide
Time Frame: 10/1/2017-9/30/2020

Abstract:
Current habitat management decisions by MDNR field biologists are often not based on a coordinated, landscape-level context (particularly for species with little known information). Patch- or stand-level decisions are effective, and compartment reviews help provide a larger context of these activities, but effective management for many species requires larger scale considerations (i.e., a landscape perspective). For example, guidance on larger scale management for some featured species is often general, e.g., "maintaining a mosaic of successional stages" or "maintaining connectivity". For many featured species, the larger perspective is critical for long-term sustainability. Additionally, even if individual biologists can envision an overall landscape perspective that guides their management decisions, communicating this to other biologists, land managers, administrators, NGOs and stakeholders can be challenging. Furthermore, landscape level (and even localized habitat) knowledge for a species can get lost over time or in turnover of area biologists and co-managers. A tool is needed to effectively portray existing information and map landscape level decisions and management activities for wildlife (particularly across Management Unit boundaries), and to retain this information to help coordinate future habitat management projects.

Wildlife Division planners and Unit Biologists have indicated that an organized system (that is integrated with other current MDNR information systems) for planning and documenting habitat management beyond the stand-level are needed to improve effectiveness of management activities, gain efficiencies in habitat work, and help ensure that habitat management activities benefit broader animal populations. Whereas Unit staff recognizes the value of a patch-based, bottom up approach to habitat management, they also recognize the value of a top-down, landscape-level approach that provides large-scale context for decision-making

Oak Management in Uncertain Times: Coupled Human and Natural Systems Models of Oak Ecosystems in Southern Michigan (previously titled "Increasing the Resilience of Wildlife Habitat Investments by Considering Multiple Plausible Scenarios")
Primary Contact: Christopher Hoving, DNR Wildlife Division, Lansing, Michigan
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DNR Financial Support: $18,192 in FY19, $105,353 total.
Study Area: Southern Lower Peninsula
Time Frame: 10/1/2015-9/30/2020

Abstract:
There are two schools of thought relative to oak persistence on the landscape in southern Michigan. Oak (*Quercus* spp.) forests and savannas are uniquely vulnerable and threatened (Nuzzo 1985, Hoekstra et al. 2005, Nowacki and Abrams 2008); conversely, projected climate change in Michigan will favor oak systems (Duveneck et al. 2014, Handler et al. 2014). Oak systems might represent a rare opportunity to leverage projected climate changes to benefit society, or climate change and management capacity might exacerbate landscape level conversion away from oaks toward maple (*Acer* spp.). Linked models of habitat management and climate change could provide insight into the likelihood that oak management can scale to future landscape patterns.

Oak systems have many values to contemporary human society (Brose et al. 2014). Oak forests and savannas are important for recreation, aesthetics, habitat for wildlife, and as economically valuable natural resources. Oak systems provide critical winter food via acorns for a wide variety of wildlife, from deer (*Odocoileus virginianus*) to squirrels (*Sciurus* spp.) to turkeys (*Meleagris gallapavo*). Healthy oak forests and savannas contain abundant wildflowers and pollinators. Oak systems are important habitat to several federally endangered species, including the Karner blue butterfly (*Lycaeides melissa sameulis*), which is found only in oak savannas. In addition, oak systems are used by 76 state threatened or endangered species (MNFI Rare Species Explorer 2016). Oak systems are among the most biologically diverse ecological communities in Michigan; they provide high quality habitat for both game and rare species in Michigan, and are consequently a high priority for conservation under the Michigan Wildlife Action Plan (Michigan Wildlife Action Plan 2016). Economically, oak has high timber value, and is used in many products from flooring to furniture to barrels.

Like many areas of the Midwest, oak forests in Michigan essentially stopped regenerating in the first half of the twentieth century (Nowacki and Abrams 2008, Knoot et al. 2015). Oaks in Michigan, as elsewhere in the

Midwest and Northeast, are not regenerating; they are shifting over time from fire-maintained xeric oak systems to fire-suppressed mesic maple systems.

Because oak trees are long-lived, the failure of oak regeneration is not readily apparent. While the large mature oak trees may be aesthetically pleasing, some of the highest quality wildlife habitat in Michigan, not to mention one of the state's most biologically diverse systems, is heading toward collapse (Nowacki and Abrams 2008).

Climate projections suggest, however, that Michigan's climate will shift to more closely resemble that of Missouri, the center of oak diversity on the continent. This should create better conditions for regenerating oaks. Indeed, models of forest growth and succession under multiple climate projection models show increases in oak at the expense of maple (Duveneck et al. 2014, Handler et al. 2014). Thus, we have conflicting models: some showing an increase in oak biomass and some showing a decrease in oak biomass over time. This creates a difficult situation for the Michigan DNR, which seeks to manage landscapes for increasing oak biomass, but is uncertain how much management intervention will be necessary to achieve their goals.

Models that explicitly consider decision-making by land managers and forcing from climate change are needed to shed light on the likelihood and scope of success of any future oak habitat management initiatives on the part of the conservation community in southern Michigan.

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
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DNR Financial Support: $217,394 (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.

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
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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.

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

Primary Contacts: Michael Donovan, DNR Wildlife Division, Lansing, Michigan
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DNR Financial Support: $61,188 in FY19, $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:

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

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DNR Financial Support: $0 in FY19, $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).

Characterization and Disruption of Sea Lamprey Sex Pheromone Communication

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

Critical evaluation of Michigan's spring waterfowl survey

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DNR Financial Support: $30,000 in FY19, $60,000 total.
Study Area: Statewide
Time Frame: 10/1/2017-9/30/2020

Abstract:
Since 1991, the state of Michigan has cooperated with other states, the U. S. Fish and Wildlife Service (USFWS), Canadian provinces, and the Canadian Wildlife Service (CWS) in conducting aerial surveys of breeding ducks and geese. Spring mallard population estimates from Michigan, Minnesota, and Wisconsin are included in estimates of mid-continent mallard abundance and additionally are needed for establishing annual waterfowl hunting season frameworks for the Mississippi, Central, and Pacific Flyways. These population estimates are also used to evaluate habitat management under the North American Waterfowl Management Plan. The Michigan Department of Natural Resources (DNR) has established population goals for mallards, Canada geese, and mute swans and the spring survey has been especially important for evaluating waterfowl population and habitat management for these species. Also, sandhill cranes are becoming a larger management concern due to escalating crane- human conflicts in Michigan and the spring survey is being evaluated as a monitoring tool for cranes.

Standard USFWS protocols for breeding waterfowl surveys involve flying a series of fixed-width transects using fixed-winged aircraft. Since not all birds are seen by observers, estimation of population densities (and total population size) requires surveying a sample of portions of transects from the ground or with helicopters to establish visibility correction factors (VCF or alternatively, detection probabilities).

Michigan has historically estimated VCF's using helicopter surveys approximately every 5th survey year. Helicopters have not been used in place of fixed-winged aircraft due to the historically high hourly cost to contract private helicopter services. More recently, DNR has entered an MOU with Michigan State Police to provide helicopter services at a relatively low cost (but still more expensive hourly than fixed-winged aircraft). However, there may be cost savings and an opportunity to improve precision of population estimates by replacing the traditional fixed-winged transect survey with a helicopter plot-based survey. Historic data from VCF flights could be used to conduct a simulation study with cost/benefit comparison of the traditional fixed-wing and alternative helicopter plot method. In theory, the elimination of a variance component (variance on estimates of VCF's) may provide an advantage in relation to improved precision of estimates based on helicopter plot surveys. If the simulation study supports the conversion to helicopter surveys, then a sampling plan needs to be devised to allocate effort and ensure geographic coverage is comparable to historic surveys.

Effects of Protective Stream Regulations in Rehabilitating Adfluvial Brook Trout
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DNR Financial Support: $49,007 (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.

Population Dynamics and Movements of Mute Swans in Michigan
Primary Contact: Dr. Dave Luukkonen, DNR Wildlife Division, East Lansing, Michigan
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DNR Financial Support: $20,000 in FY19, $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: λ =*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

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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-old).

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
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DNR Financial Support: $397,200 in FY19, $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.

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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.

Sturgeon Rehabilitation Plan
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DNR Financial Support: $339,504 (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.glfc.org). Lake sturgeon requires 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.

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: $30,000.00
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.

Criterion Two: Maintenance of Productive Capacity of Forest Ecosystems

An Analysis of Factors Limiting Reforestation of Abandoned Oil Pads in Northern Michigan
Primary Contacts: Dr. Fred Van Dyke, Susan Wilderman, Seth Harju, David Rowley, and Victoria Buchholz, 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: Anthropogenically induced forest fragmentation and perforation is a problem of global significance. In northern lower Michigan (USA), a forest – dominated landscape, fragmentation and perforation have been exacerbated by oil and natural gas development since the 1970s. After extraction has been completed on a given site, (well pad), vacated pads have not reforested naturally and become infested by non-native species. To evaluate pathways to reforestation of now vacant well pads, we evaluated survivorship and growth of four native tree species, Pinus banksiana, P. resinosa, Quercus alba, Q. rubra, planted in four different soil surface treatments – control (planting only, no treatment), disking, fertilization, and disking with fertilization - on vacant well pads. We concurrently determined response of herbaceous vegetation to the same treatments and evaluated differences in soil characteristics between well pads and surrounding forests. P. resinosa displayed highest survivorship regardless of treatment. Survivorship of most species was highest in disked treatment. Well pad soils had higher levels of bray P, Ca, and Mg but lower levels of Fe, organic matter and moisture. Concentrations of eight toxic chemicals and diesel range organics was not different between well pad soils and forest soils or differences remained within levels for plant growth indicating toxicity was not a factor in limiting growth and survivorship. Soil treatment did not affect composition of herbaceous plant communities or abundance of non-native species. In reforestation efforts on well pads, restorationists should plant P. resinosa in disked soil to achieve highest tree survivorship and density.

PERM: Gary Roloff – Applied Forest and Wildlife Ecology
Primary Contact: Michael Donovan, DNR Wildlife Division, Lansing, Michigan
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Phone: (517) 373-1263
DNR Financial Support: $77,658 in FY19, $77,658 total.
Study Area: Statewide
Time Frame: 10/1/2017-9/30/2018

Abstract:
The Michigan Department of Natural Resources Wildlife Division (WLD) handles wildlife population-level management (e.g., harvest regulations, game species designations, invasive species designations), but also plays a dominant role in many Forest Resources Division (FRD) and Parks and Recreation Division (PRD) activities, particularly related to wildlife habitats. Often, information on wildlife responses to management activities or the time to evaluate novel approaches to management by WLD is lacking. With increased emphasis on accountability (e.g., forest certification), WLD will 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 management objectives. Efficient implementation of the Wildlife Division's strategic plan (Guiding Principles and Strategies or GPS) requires collaboration among internal and external professionals.

Although WLD has considerable wildlife knowledge and expertise, staff lack the resources to stay current on the latest advancements in wildlife habitat management. Additionally, WLD lacks the capacity to provide cutting edge research designed to address specific information needs regarding habitat management in Michigan as they arise from field staff. The operational paradigm for WLD has been to pair management

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specialists with research specialists. Although the division has planned for a habitat unit that ideally would consist of at least one habitat management specialist paired with a habitat research specialist, resources have never been available to realize this plan. Consequently, WLD needs additional capacity to interpret research results from the broader conservation community to Michigan specific management practices related to habitat relationships. Additionally, WLD needs additional capacity to design and develop novel wildlife habitat research projects as information gaps and management barriers arise.

Dr. Gary Roloff possesses considerable expertise on topics that support WLD's mission. His position as a tenured faculty at a major university affords access to the latest developments in the understanding of wildlife habitat relations. Consequently, Dr. Gary Roloff is well suited to advise and consult with WLD 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. Duplicating the access to resources, skills, and capacity available to Dr. Roloff would be in inefficient use of WLD's resources and beyond the capabilities of WLD.

CRITERION THREE: MAINTENANCE OF FOREST ECOSYSTEM HEALTH AND VITALITY

Assessing drivers of spread and transmission of Chronic Wasting Disease in Michigan deer
Primary Contact: Dr. Dwayne Etter, DNR Wildlife Division, Lansing, Michigan
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DNR Financial Support: $120,149 in FY19, $502,737 total.
Study Area: South-central Lower Peninsula
Time Frame: 10/1/2017-9/30/2022
Abstract:

The occurrence of chronic wasting disease (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 of the Michigan Department of Natural Resources (DNR). 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 a large proportion of annual revenue for the Division of Wildlife. Recognizing these threats, the Division of Wildlife 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.*

Chronic wasting disease 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, which 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 discovery of CWD in Michigan creates an immediate need for population monitoring and surveillance of at-risk deer populations. Since 2015, nine infected individuals have been identified following collection through state surveillance efforts, representing key successes in targeted disease management. However, the continued discovery of infected individuals in 2016 suggests a high likelihood that additional infected individuals remain on the landscape. The occurrence of a small number of infected animals across a relatively small geographic region in mid-Michigan indicates that the disease is still emerging.

What distinguishes the research proposed here from extensive work done in other states is that CWD is still in an emergent phase in Michigan. Michigan discovered the disease early during a time when transmission of the disease may be more dependent on the density of deer on the landscape because most infections are through direct contact of infected animals with susceptible individuals. This situation is similar only to New York and Minnesota. In all other states where CWD has been discovered, the disease was already well established, and transmission included infection mediated by contact of susceptible individuals with severely contaminated environments. Our research in Michigan is intended to explore management options for the

control of an emerging occurrence of CWD through better understanding of behavior and population dynamics of deer inhabiting areas of known infection.

The goal of this research is to improve the cost-efficiency of detecting CWD when it is still rare and removing animals from the landscape to control the spread of disease, by reducing contact among deer and potentially eliminating infectious animals. We intend to take a multi-pronged approach to accomplish this goal and the work described here will complement another study that seeks to develop new methods for detecting and removing diseased animals. The effort described here is designed to accumulate a dataset on movement behavior of deer that is of high temporal and spatial resolution to address questions about dispersal rates, directions and distances; evaluate hypotheses about environmental factors that are likely influences on dispersal behavior; parameterize risk maps of first-order contact for Michigan in concert with data and prior research in New York State; and create models of the interaction of landscape contexts (e.g., suburban, rural) and habitat characteristics that can be used to direct hunters and biologists to increase the efficiency of surveillance and removal actions.

Our objectives address the strategic plans set forth by the Michigan DNR 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."

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

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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 to16-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: Ben Slager, USDA – Animal and Plant Health Inspection Service.
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Phone: 810-844-2704
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 place 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.

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 (*Bretiziella 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.

Management of Chronic Wasting Disease in Michigan
Primary Contact: Dr. Kelly Straka, DNR Wildlife Division, Lansing, Michigan
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Phone: (517) 336-5030
DNR Financial Support: $50,000 in FY19, $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).

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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.

Projecting Hemlock Woolly Adelgid Distribution and Risk in Michigan
Primary Contact: Dr. Deborah G. McCullough & Dr. Jeffrey Andresen, MSU, East Lansing, Michigan
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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 wooly 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.

Quantifying Upper Peninsula deer movements and abundance: preparing for CWD management

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Phone: (906) 228-6561
DNR Financial Support: $117,759 in FY19, $613,001 total.
Study Area: Upper Peninsula
Time Frame: 10/1/2017-9/30/2021

Abstract:
Chronic wasting disease (CWD) occurs in free-ranging white-tailed deer in Lower Michigan, and in our neighboring state of Wisconsin where the disease is endemic. Although wildlife managers have not documented CWD in the Upper Peninsula, managers found infected deer in two Wisconsin captive cervid facilities near the Michigan border. Officials identified the disease in a facility in Oneida County, Wisconsin, about 40 km from our Iron County border and a second positive deer in Oconto County, Wisconsin, about 50 km from our Menominee County border.

While it is not possible to predict if or when we will find CWD in the Upper Peninsula, preparations seem prudent. A scientifically based understanding of deer movements and estimates of population abundance are critical for developing management recommendations in response to CWD. Deer movements and abundance can influence the probability of disease occurrence, contact rates which can affect transmission rate, and geographic extent of an outbreak (e.g., Oyer et al. 2007, Skult et al. 2008, Webb et al. 2010). Importantly, these data take time to gather and managers need this information at the time of first discovery. Thus, waiting for a disease outbreak before gathering these data would put managers at a disadvantage. Important deer movements to understand include seasonal home ranges, migration (especially important in the Upper Peninsula), dispersal, transient, and exploratory.

Information on these movements would inform decisions on identification of CWD management zones. The current strategy is to establish a 16-km radius circle around the location of an infected cervid and include entire counties whose boundaries intersect this circle as part of the CWD management zone. Further, if results from local population surveys or other credible scientific data suggest that cervids from within the radius are likely to move beyond the management zone boundary, the boundary should be expanded accordingly. In the Upper Peninsula, deer can seasonally migrate 50 km (Van Deelen et al. 1998), with overall movements exceeding 80 km (Doepker et al. 2015). These migratory movements, as well as other movements (e.g., dispersal), are currently unknown and certainly not aligned with or contained within county boundaries. Although some information exists on deer movements in the UP, most of this work relied on tag returns that do not provide the needed level of spatial and temporal resolution to inform management responses to a disease outbreak.

Consequently, If CWD was detected in the UP, large areas would likely be under surveillance and management that would not contain infected deer and large areas with potential for infected deer would not be within the prescribed surveillance zone, rendering the current management zone less effective.

The Upper Peninsula Region (UPR), Biological and Social Sciences Section (BSSS), Wildlife Health Section (WHS), and Mississippi State University (MSU) wish to develop a program to address the need for information on deer movements. The core work would entail deploying GPS collars on deer in select wintering complexes and conditional winter range (starting along WI border) and documenting movements over three years. To complete the capture and collaring work, we would work cooperatively with interested sportspersons.

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

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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.

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

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DNR Financial Support: $0 in FY19, $572,689 total.
Study Area: Statewide.
Time Frame: 12/01/2013-9/30/2019
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.

CRITERION FOUR: CONSERVATION AND MAINTENANCE OF SOIL AND WATER RESOURCES

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: $132,960 (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 Bay 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.

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
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DNR Financial Support: $6,638 (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.

CRITERION FIVE: MAINTENANCE OF FOREST CONTRIBUTION TO GLOBAL CARBON CYCLES

Michigan Gradient Study to Understand the Mechanisms Controlling Carbon and Nitrogen Cycling in the Face of Chronic Nitrogen Deposition and the Reversibility of Long-term Effects of Nitrogen Saturation Primary

Contact: Dr. Andrew Burton, Michigan Technological University, Houghton, Michigan
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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 portions of the world will be exposed to increasingly elevated rates of atmospheric nitrogen (N) deposition, which could theoretically strengthen the terrestrial carbon sink (C) in those areas, potentially helping to mitigate the rate of atmospheric CO_2 increase. In contrast, ecosystems in the northeast US that experienced decades of elevated N deposition are now seeing declines in the N deposition rate, due to increasingly effect N emissions controls. However, the degree to which anthropogenic N deposition effects remain as deposition decreases is not known. In theory, once an ecosystem becomes N saturated, a lower rate of N deposition could be sufficient to maintain the N deposition effects. From 1994 to 2017, ecologists at Michigan Technological University and the University of Michigan conducted a long-term, regional, elevated N deposition experiment 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 NO_3^--N/m^2 from 1994 to 2017. All four study sites rapidly approached N saturation, evidenced by substantial leaching of both inorganic and organic N. Simulated atmospheric N deposition increased woody growth increment over the 24-year experiment and caused an increase in C stored in the forest floor, surface soil and coarse-woody debris due to reduced litter decay and wood decomposition rates. Greater C in the non-living pools resulted from a decline in lignolytic microbial activity and a corresponding change in microbial community composition. Beginning in 2018, N additions to the four study sites were discontinued. However, ambient N deposition is still somewhat elevated and may be sufficient to maintain a state of N saturation and its effects. Thus, it is not known if growth increases will continue and if the enhanced soil C storage will remain. During the first year after cessation of N addition, the soil microbial community remained suppressed and leaching of N remained elevated, at a level that corresponded to ambient N deposition inputs. Given these responses, we hypothesized that: i) enhanced N cycling from the N deposition period will continue to accelerate tree growth; and ii) surface soil C will continue to accumulate at a faster rate in the former experimental atmospheric N deposition treatment. A series of established core long-term

measurements (some stretching back to 1988) enable us to test these long-term hypotheses and to also understand how climatic variation might affect forest composition and productivity in the long-term. Measurements taken in 2019 indicate: 1) woody growth remains elevated for the former N deposition treatment; 2) mycorrhizal fungal abundances is lower, leading to reduced tree C sharing with mycorrhizae and leaving more C for aboveground woody growth; and 3) soil respiration is lower, likely due to both reduced mycorrhizal abundance and reductions in the biomass of the bacterial and fungal decomposer community, and indicating that the enhanced soil C storage remains.

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

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DNR Financial Support: $55,811 (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.

Elk Responses to Recreational Use and Habitat Potential in Michigan

Primary Contact: Dr. Dean Beyer, DNR Wildlife Division, Marquette, Michigan
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Phone: 906-228-6561
DNR Financial Support: $50,836 in FY19, $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. Emily Pomeranz, DNR Wildlife Division, Lansing, Michigan
Email: pomeranze@michigan.gov
Phone: 517-284-4720
DNR Financial Support: $43,478 in FY19, $314,296 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).

Factors Affecting Waterfowl and Hunter Use of Managed Waterfowl Areas

Primary Contact: Dr. Dave Luukkonen, Michigan State University, East Lansing, Michigan
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DNR Financial Support: $0 in FY19, $124,000 total.
Study Area: Statewide.
Time Frame: 10/01/2015-09/30/2019

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.

Improving Efficacy of Furbearer Management in Michigan through Assessment of the Nature and Extent of Illegal Fur Harvesting
Primary Contact: Dr. Dwayne Etter, DNR Wildlife Division, Lansing, Michigan
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Phone: 517-284-4720
DNR Financial Support: $49,587 in FY19, $244,538 total.
Study Area: Statewide.
Time Frame: 06/01/2015-09/30/2021

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).

PERM: Alexa Warwick - Wildlife Engagement
Primary Contact: Dr. Emily Pomeranz, DNR Wildlife Division, Lansing, Michigan
Email: PomeranzE@michigan.gov
Phone: (517) 284-4720
DNR Financial Support: $26,530 in FY19, $26,530 total.
Study Area: Statewide
Time Frame: 10/1/2018-9/30/2019

Abstract:
The Michigan Department of Natural Resources' Wildlife Division continues to be a national leader in supporting social science relevant to wildlife management. Beyond generation of knowledge, the integration of insights from social science with biological and environmental science is necessary when directing wildlife management programs and providing technical advice to policy makers. Furthermore, engaging stakeholders in wildlife topics generates buy-in and targets management efforts more effectively. As a result, increasing the capacity of DNR staff to conduct and evaluate engagement with stakeholders is critical for Wildlife Division success. These efforts require a range of expertise and constant consideration of the best available information plus development and evaluation of programs to make use of this information. To address these needs requires forming close collaboration among professionals possessing diverse expertise, within and outside of Wildlife Division. Dr. Alexa Warwick possesses expertise to advise and consult with Wildlife Division on engagement-relatedactivities.

Although Wildlife Division has considerable wildlife knowledge and expertise, staff lack the resources to always stay current on the latest advancements for effective stakeholder engagement and associated outreach methods regarding wildlife management. Additionally, Wildlife Division lacks the capacity to provide cutting edge research designed to address specific engagement needs for wildlife conservation in Michigan as they arise from field staff. Consequently, Wildlife Division needs additional capacity to develop and provide engagement processes and outreach evaluation tools specific to wildlife management. Additionally, Wildlife Division needs additional capacity to design and develop novel research projects as information gaps and management barriers related to stakeholder engagement arise.

Dr. Alexa Warwick possesses considerable expertise on developing and evaluating the effectiveness of engagement and outreach efforts. Her appointment in the Department of Fisheries and Wildlife at a major university affords access to the latest developments in the understanding of the role of engagement, outreach, and education in wildlife conservation and policy. Consequently, Dr. Warwick is well suited to assist Wildlife Division with developing effective stakeholder engagement processes, training Wildlife Division staff on engagement, developing effective outreach in support of engagement, and evaluating the effectiveness of Wildlife Division engagement and outreach efforts. Duplicating the access to resources, skills, and capacity available to Dr. Warwick would be in inefficient use of Wildlife Division's resources and beyond Wildlife Division's current staffing capacity.

PERM: Dan Kramer – Social, Economic and Policy Aspects of Wildlife Management
Primary Contact: Dr. Emily Pomeranz, DNR Wildlife Division, Lansing, Michigan
Email: PomeranzE@michigan.gov
Phone: (517) 284-4720
DNR Financial Support: $65,961 in FY19, $65,961 total.
Study Area: Statewide
Time Frame: 10/1/2017-9/30/2018

Abstract:
The Michigan Department of Natural Resources' Wildlife Division 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 Wildlife Division. Dr. Dan Kramer possesses considerable expertise to advise and consult with the Wildlife Division 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.

Although Wildlife Division has considerable wildlife knowledge and expertise, staff lack the resources to always stay current on the latest advancements at the intersection of changing land use and conservation biology. Additionally, Wildlife Division lacks the capacity to provide cutting edge research designed to address specific information needs regarding conservation issues arising from shifting land use patterns they arise from field staff.

Consequently, Wildlife Division needs additional capacity to interpret research results from the broader conservation community to Michigan specific management practices related to conservation biology. Additionally, Wildlife Division needs additional capacity to design and develop novel conservation strategies affecting land use policies as information gaps and management barriers arise.

Dr. Dan Kramer possesses considerable expertise on topics that support WLD's mission. His joint appointment with the James Madison College as well as the Department of Fisheries and Wildlife at a major university affords access to the latest developments in the understanding of complex conservation issues along the human/wildlife interface. Duplicating the access to resources, skills, and capacity available to Dr. Kramer would be in inefficient use of Wildlife Division's resources and beyond the capabilities of Wildlife Division.

Dr. Frank Lupi possesses considerable expertise on topics that support Wildlife Division's mission. His joint appointment in Agriculture, Food, and Resource Economics and Department of Fisheries and Wildlife at a major university affords access to the latest developments in the understanding of the role of economics in wildlife conservation and policy.

Consequently, Dr. Lupi is well suited to advise and consult with Wildlife Division on economic motivations of various user groups towards conservation, impacts of various policy decisions on human behavior, economic study design and sampling, and integrating research findings into management actions. Duplicating the access to resources, skills, and capacity available to Dr. Lupi would be in inefficient use of Wildlife Division's resources and beyond the capabilities of Wildlife Division.

PERM: Frank Lupi – Economic Aspects of Wildlife Management
Primary Contact: Dr. Emily Pomeranz, DNR Wildlife Division, Lansing, Michigan
Email: PomeranzE@michigan.gov
Phone: (517) 284-4720
DNR Financial Support: $51,497 in FY19, $51,497 total.
Study Area: Statewide
Time Frame: 10/1/2018-9/30/2019
Abstract:
The Michigan Department of Natural Resources' Wildlife Division 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 Wildlife Division. Dr. Frank Lupi possesses considerable expertise to advise and consult with Wildlife Division on data collection, study design, and application of findings regarding the economic aspects of wildlife management.

Although Wildlife Division has considerable wildlife knowledge and expertise, staff lack the resources to always stay current on the latest advancements regarding the economics of wildlife management. Additionally, Wildlife Division lacks the capacity to provide cutting edge research designed to address

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specific information needs regarding the economic aspects affecting wildlife conservation in Michigan as they arise from field staff.

Consequently, Wildlife Division needs additional capacity to interpret research results from the broader conservation community on the role of economics to Michigan specific wildlife management practices. Additionally, Wildlife Division needs additional capacity to design and develop novel research projects as information gaps and management barriers related to economics arise.

PERM: Shawn Riley – Human Dimension Aspects of Wildlife Management
Primary Contact: Dr. Emily Pomeranz, DNR Wildlife Division, Lansing, Michigan
Email: PomeranzE@michigan.gov
Phone: (517) 284-4720
DNR Financial Support: $142,463 in FY19, $142,463 total.
Study Area: Statewide
Time Frame: 10/1/2018-9/30/2019

Abstract: The Michigan Department of Natural Resources' Wildlife Division continues to be a national leader in supporting social science relevant to applied wildlife management. More important than the generation of knowledge is the integration of insights from social science with biological and environmental science when directing wildlife management programs and providing technical advice to policy makers. Topics requiring particular attention in this regard include human uses of wildlife; hunter recruitment, retention, and reactivation; antecedents to and consequences of varying levels of public trust and confidence in Wildlife Division; effects of human-wildlife interactions on how individuals and communities develop capacity for living with wildlife; and, application of systems thinking to natural resource policy and decision-making processes. Dr. Shawn 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 continued support for frequent consultation between Dr. Riley and Wildlife Division, professional development for Wildlife Division personnel, program evaluation, and diffusion of techniques to integrate human dimensions of wildlife management into programs, improve public trust and confidence in the agency, and maintain relevance of application of the public trust doctrine to wildlife management.
management.

Social and Economic Benefits and Costs of Elk in Michigan
Primary Contact: Dr. Clay Buchanan, DNR Wildlife Division, Lansing, Michigan
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Phone: (517) 284-9453
DNR Financial Support: $60,983 in FY19, $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: $48,791 in FY19, $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.

Using Social Network Analysis and Social Media Evaluation to Measure and Assess Relationship Building and Partnerships under the Wildlife Habitat Grants Program
Primary Contact: Dr. Clay Buchanan PhD, DNR Wildlife Division, Lansing, Michigan
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Phone: (517) 284-9453
DNR Financial Support: $64,907 in FY19, $115,012 total.
Study Area: Statewide
Time Frame: 10/1/2017-9/30/2019

Abstract: The Michigan Department of Natural Resources (DNR) Wildlife Habitat Grant Program (WHGP) provides funding to local, state, federal, and tribal units of government, profit and non-profit organizations, and individuals to assist the Wildlife Division (WD) in 1) developing and improving habitat for wildlife, particularly game species, and 2) strengthening relationships with and perceptions of the WD. While assessment of the first objective is straightforward and already within the evaluative scope of the WD's Grant Coordinator, there has been no systematic assessment of the perhaps equally important, second objective. This research will focus on evaluating the effectiveness of the WHGP in building successful relationships with and positive perceptions of the WD. The relationships under study will include not only the program's grantees, but collaborators of the grantees as well as the general public.

The proposed research addresses several of the objectives and strategies identified in the DNR's Guiding Principles and Strategies (GPS 2016) but in particular those under *Goal 5: Improve and maintain public communication, strong relationships, and partnerships* and specifically those strategies to measure and evaluate the success of existing partnerships and to design and evaluate effective media communication.

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Wildlife and recreational value of created and enhanced wetlands in Michigan
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Email: Luukkon1@msu.edu
Phone: (517) 355-4478
DNR Financial Support: $209,000 in FY19, $905,000 total.
Study Area: Statewide
Time Frame: 10/1/2017-9/30/2022

Abstract:
Freshwater wetlands are highly productive ecosystems that provide important services, including flood water retention, water purification, erosion control, sites for recreation, and habitats for fish and wildlife. Michigan has lost about 50% of the wetland area present at the time of European settlement, but wetland protection and management has recently stabilized this decline (Dahl 1990, 2011). Based on National Wetland Inventory data, about 70% of Michigan's wetlands are classified as palustrine forested wetlands, 20% palustrine shrub scrub, 10% palustrine emergent, and < 1% palustrine aquatic bed (Fizzell 2015). Although each of these wetland types provide unique values, there has historically been interest in creating or enhancing wetlands to favor certain types by changing wetland hydrologic regimes. The Michigan Department of Natural Resources (MDNR) created or enhanced many wetlands, often called "floodings" in Michigan during the 1950's and 1960's. These wetlands were altered via installation of dikes and dams to hold deeper water, to allow water level control and to create open water areas. Many of these wetland areas do not have management plans, but the assumed goals in creating these projects was to improve wetland bird and/or fish habitat and to therefore enhance associated wildlife recreational opportunities. In some cases, these wetland alterations could be viewed as replacements for values of wetlands normally associated with beaver---created or modified wetlands.

Wildlife Division field staff have uncertainty about wildlife and recreational values of maintaining floodings and there is a need to better understand biological and recreational values of MDNR floodings in relation to maintenance costs. Decisions about maintenance are sometimes complex as removal of dams can be controversial and many of these areas are co--- managed with Forest Resources or Fisheries Divisions. Maintenance costs of managed wetland infrastructure can be high as repair or replacement of water control structures, drainage tubes and dikes commonly range about $175,000---$450,000 per project and dam removals can be much more expensive (see FY2017 Field WIP requests for examples). When engineering consultation is required, this also adds significantly to maintenance cost. Many have questioned if floodings maintained by WLD provide population---level enhancements to wetland wildlife, or even local---level wildlife enhancements. Also, it is not clear to what extent use of floodings by outdoor recreationists helps justify the costs of maintaining them. Although the values of diked and un-diked coastal wetlands for breeding birds has been studied in Michigan (e.g., Prince 1985, Monfils et al. 2014), most floodings do not have a Great Lakes coastal orientation and these wetlands are typically not managed to enhance breeding bird communities; providing breeding bird habitat is important to the mission of MDNR, but the management focus for floodings has been on providing waterfowl habitat that attracts ducks and geese during migration. Although field staff have conducted opening---day waterfowl hunter interviews to gauge relative use and hunter success, there is little else known about recreational use of floodings throughout the year.

The Wildlife Division is currently responsible for over 130 dams; however, we currently lack a complete inventory of floodings and associated attributes as classification of these areas has not been consistent (e.g., "flooding," "dams," and "State Wildlife Management Areas") and many projects lack management plans. Wildlife Division is investing in a Memorandum of Agreement with the Department of Environmental Quality (DEQ), Water Resources Division to conduct a comprehensive portfolio assessment of WLD's dams comprised of an engineering and biological assessment (Appendix A). The DEQ responsibilities include the inventory and assessment of WLD's dams while Wildlife Division is responsible for the biological assessments. This project
would fulfill Wildlife Division's responsibility for a biological assessment while also providing an assessment of recreational values.

There is need to use information obtained from historic wetland creation to strategically plan future floodings projects that will meet objectives for wildlife habitat and recreation. This is particularly relevant now because there is interest in creating new wetlands via "wetland banking" which provides a new mechanism for

developers to mitigate for destruction of regulated wetlands by creating or enhancing wetlands on state lands. There is uncertainty about climate and effects of wetland hydrology and there is need to consider different climate scenarios and how relative importance of wetland habitats with water control capability might change in the future. Also, with the potential for more frequent heavy rain events, dams and other infrastructure may need to be adapted to accommodate greater stresses and potential for more frequent flood events.

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

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: $0 in FY19.
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.

Trembling aspen, however, is 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.

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, Michigan State University, East Lansing, Michigan
Email: luukkon1@msu.edu
Phone: (517) 3554478
DNR Financial Support: $132,504 in FY19.
Study Area: Statewide.
Time Frame: 10/01/2016-09/30/2020
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.

Surveillance Projects:

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: $73,719 (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.

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 FY19, $10,000 total.
Study Area: Statewide.
Time Frame: 10/01/2018-09/30/2019
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.

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: $122,517 (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.

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.

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: $76,216 (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

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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.

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: $2,516,080 (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.

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: $43,261 (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.

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: $86,264 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.

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: $92,287 (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.

Technology Development Projects:

Design and Develop Specialized Equipment for Forest Fire Fighting
Primary Contact: David Stockoski, Forest Resources Division.
Email: stockoskid@michigan.gov
Phone: 989-275-5211
DNR Financial Support: $226,376.40
Study Area: Roscommon Equipment Center and DNR forest lands
Time Frame: Ongoing since March 2007

Abstract: The Forest Fire Experiment Station (FFES) and Roscommon Equipment Center (REC) focus on the development of specialized equipment for forest-fire control. Activities include engineering new equipment, designing modifications for existing equipment and testing commercially available equipment. One of the keys for forest-fire control is prevention - FFES and the REC have developed the 'Campfire Embers Game' –This project was conceived by REC & Michigan DNR staff to interactively educate the general public - especially young people - about the danger of campfire embers and how they can start fires. The completed project was used at DNR demonstrations at various events across the state of Michigan. The FFES also developed and produced three wildland engines on F550 chassis to support wildland fire control activities for the State of Michigan.

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: $1,521,333
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.

RECENTLY COMPLETED RESEARCH RELATED TO SUSTAINABLE FORESTRY

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: $13,928 in FY18, $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.

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 Michigan Department of Natural Resources' Wildlife Division maintains regulatory

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authority over wildlife, continues to be relevant to the constituents they serve and can strategically position themselves for future challenges. The Wildlife Division 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 Wildlife Division 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.

PERM: Jordan Burroughs – Wildlife Outreach
Primary Contact: Dr. Emily Pomeranz, DNR Wildlife Division, Lansing, Michigan
Email: PomeranzE@michigan.gov
Phone: (517) 284-4720
DNR Financial Support: $21,707 in FY18, $21,707 total.
Study Area: Statewide
Time Frame: 10/1/2017-9/30/2018
Abstract:
The Michigan Department of Natural Resources' Wildlife Division 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, stakeholders, and the public. 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 Wildlife Division. Jordan Burroughs possesses considerable experience to draw upon to advise and consult with Wildlife Division 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 Wildlife Division personnel.