On-going Research projects related to Kirtland's Warblers as of March 2016											
PI or CONTACT		EMAIL	PROJECT TITLE	CO-PI or COLLABORATOR 1		CO-PI or COLLABORATOR 2		CO-PI or COLLABORATOR 3		COMPLETION DATE
Nick	Anich	Nicholas.Anich@Wisconsin.gov	Evaluation of conspecific playback as a tool to attract Kirtland's Warblers to suitably aged habitat in Northern Wisconsin	Mike	Ward					1-2 years
Nathan	Cooper	nathanwands@gmail.com	Evaluating the cowbird control program to reduce conservation-reliance of the Kirtland's Warbler							~2 years
Nathan	Cooper	nathanwands@gmail.com	Use of geolocators to determine migration and wintering ground locations	Peter	Marra	Dan	Elbert			1-2 years
Greg	Corace	greg_corace@fws.gov	Lake States Fire Science Consortium wildlife-related work	Lindsey	Shartell	Shelby	Weiss			on-going
Greg	Corace	greg_corace@fws.gov	A multi-scaled geographic assessment of Upland Sandpiper occupancy and habitat use	Dan	Kashian					within 1 year
Greg	Corace	greg_corace@fws.gov	Integrating fuels reduction and jack pine barrens restoration in endangered Kirtland's Warbler habitat management.	Dan	Kashian	Charles	Goebel			on-going
Deahn	Donner	ddonnerwright@fs.fed.us	Population viability analysis and modeling effects of potential management change scenarios on population dynamics	Christine	Ribic	Donald	Brown	Carol	Bocetti	paper in revision
Deahn	Donner	ddonnerwright@fs.fed.us	Evaluating jack pine establishment and growth rates under changing climate scenarios in the Great Lakes region, specifically Kirtlands Warbler Management Areas	Christine	Ribic	Donald	Brown	Carol	Bocetti	~ summer 2016
Deahn	Donner	ddonnerwright@fs.fed.us	Evaluating changing climate impacts on Kirtland's Warbler wintering ground habitat availability and quality	Christine	Ribic	Donald	Brown	Carol	Bocetti	~ fall 2016
Deahn	Donner	ddonnerwright@fs.fed.us	Range-wide assessment on the impacts of changing climate on Kirtland's Warbler population	Christine	Ribic	Donald	Brown	Carol	Bocetti	~ spring 2017
Deahn	Donner	ddonnerwright@fs.fed.us	Evaluating cowbird trap efficacy within spatial and temporal framework	Christine	Ribic	Donald	Brown			within 1 year
David	Ewert	dewert@tnc.org	Wintering grounds work and connectivity	Joseph	Wunderle					on-going
Ashley	Hannah	ahannah@wisc.edu	Defining high quality breeding habitat for Wisconsin's population of Kirtland's Warblers	Anna	Pidgeon	Christine	Ribic			2-3 years
Dan	Kashian	dkash@wayne.edu	Assessing 30 years of changes in vegetation and fuels following wildfire in jack pine forests of Northern Lower Michigan	Wayne	Walker					
Darren	Proppe	dsp5@calvin.edu	Effects of noise on Kirtland's Warblers	Keith	Kintigh	Chris	Mensing			~2 years
David	Rothstein	rothste2@anr.msu.edu	A silvicultural system for conserving biodiversity and enhancing ecosystem services in xeric jack pine forests of the Lake States Region	Dan	Kashian					~5 years
Fred	Van Dyke	fred@auisable.org	Comparative habitat use and reproductive success of Kirtland's Warbler in jack pine and red pine plantations in Northern Michigan	Keith	Kintigh					~10 years

1-page Research Summary - February 2016

Kirtland's Warbler Conspecific Playback Experiment

Nicholas M. Anich
Wisconsin DNR

Michael P. Ward
Illinois Natural History Survey

For the past decade, male Kirtland's Warblers have been found singing in suitable habitat in northern Wisconsin. However, females have generally not been found (with the exception of Marinette County) and populations have failed to become established. Although the capability for Kirtland's Warblers to find new suitable habitat is clear, the small number of birds involved and great distances from existing populations means that it is difficult for the few birds on the landscape to find each other, and most birds do not pair or nest, or even stay at the same site very long.

We are exploiting conspecific attraction, the tendency of members of a species to settle near one another, in an attempt to attract and concentrate birds that may are roaming through northern Wisconsin. To do this, we established audio callboxes that broadcast Kirtland's Warbler song at suitable but initially unoccupied sites in northern Wisconsin.

In 2014, we established four sites and attracted one male to a single site. In 2015, we ran the two higher-quality sites, and attracted 3 males to one site, whereas the other site had 3 males, 2 females, and a successful nest!

	Bayfield County Forest			Marinette County Forest			Vilas County Forest			Chequamegon-Nicolet National Forest		
	Males	Females	Nests	Males	Females	Nests	Males	Females	Nests	Males	Females	Nests
2014	**1**	0	0	0	0	0	0	0	0	0	0	0
2015	**3**	0	0	**3**	**2**	**1**	N/A	N/A	N/A	N/A	N/A	N/A

2016 is the final year for which we plan the experimental audio playback. We will likely continue to survey these sites in 2017 to determine whether birds return after we discontinue playback.

Initial results seem to demonstrate this technique has the potential for increasing the likelihood of colonization of a site, though considerably more effort and patience is required compared to studies that used this technique at a shorter distance from existing populations. Given that audio playback does seem to work, even at these distances, we may end up using it in the future to ensure we are getting the most out of conservation dollars. This could include attracting birds to an area we have more management control over, or an area at which we have spent considerable effort managing the habitat. We expect not to need this technique as much once populations are established in the area, but given the challenges with pairing birds several hundred miles from population centers, it so far appears this technique has promise as a useful tool for management.

Evaluating the cowbird control program to reduce conservation-reliance of the Kirtland's Warbler by Nathan Cooper, Ph.D.

Several decades of widespread brood parasitism by cowbirds, combined with extreme breeding habitat limitation, led to the Kirtland's Warbler being declared endangered in 1967. In 1972, the United States Fish and Wildlife Service began removing cowbirds from Kirtland's Warbler breeding areas. The program was costly ($110,000 per year), but successful because brood parasitism rates were quickly reduced from ~70% to ~6%; greatly increasing fledgling production and Kirtland's Warbler potential for population growth. Beginning in 1991, natural forest regeneration and active creation of new breeding habitat allowed Kirtland's Warbler populations to dramatically increase over the next two decades. The cowbird-trapping program was both necessary and effective, but was designed for a critically endangered and spatially isolated population, not the much larger population spread across 6,000 square miles that exists today. Funding uncertainty, along with the current robustness of the population, has led program participants and agency partners to challenge the necessity of the program. Furthermore, it is likely that the effective range of cowbird traps is larger than current guidelines suggest. It is also likely that Kirtland's Warblers could withstand higher rates of brood parasitism and remain sustainable. Our proposal, entitled "Evaluating the cowbird control program to reduce conservation-reliance of the Kirtland's Warbler", seeks to close 12 of 55 traps over two breeding seasons in Michigan to determine the effective range of cowbird traps. This information will allow managers to significantly reduce program costs by decreasing the number of traps run each year. Furthermore, data from our experiment will inform a population viability analysis to determine what rate of parasitism Kirtland's Warblers could withstand. Thus, it may be possible to reduce trapping effort and costs even further while still maintaining a sustainable, but less conservation-reliant, Kirtland's Warbler population.

In collaboration with Chris Mensing at USFWS and Pat Ryan at USDA-Wildlife Services, we closed 12 cowbird traps for the 2015 season. Across our study area, we found 150 Kirtland's warbler nests. To our surprise, we found only one case of brood parasitism, at a nest approximately 8-9 km from the nearest functioning cowbird trap. We also carried out 148 point counts across the study area from June 30 – July 10. Only six cowbirds were detected during these surveys. Due to low detection rate, no proper analysis of cowbird density in relation to the nearest cowbird trap could be carried out. Funding for field seasons in 2016 and 2017 has been obtained.

Use of geolocators to determine migration and wintering ground locations

By Nathan Cooper, Peter Marra, Daniel Elbert

The importance of understanding all periods of the annual cycle (i.e., breeding, non-breeding, migratory) of migratory birds has been increasingly highlighted over the past several decades. Progress in this area has been significantly hindered by the difficulty of tracking birds thousands of kilometers across ecological and political boundaries. However, the use of lightweight geolocators has recently allowed scientists to track smaller birds for longer periods of time than ever before. Using light-level geolocator data from 27 male Kirtland's Warblers (*Setophaga kirtlandii*), we defined the wintering distribution, quantified the strength of migratory connectivity, and described migration routes and the timing of fall and spring migration for the first time. Kirtland's Warblers exhibited strong migratory connectivity with all males wintering in essentially one overlapping region, the Bahama Archipelago, primarily the central Bahamian Islands. All but two males performed a loop migration with a more easterly route in the fall and a westerly route in the spring. It was not possible to precisely determine stopover location and duration during fall migration because of overlap with the equinox. However, we identified potential stopover areas in southern Ontario and the northwestern Mid-Atlantic States. Males also spent time on North and South Carolina coasts prior to migrating across the Atlantic Ocean to the northern islands of the Bahamas. During spring migration, males made ~4 stopovers, spending 58% of their migration at stopover sites. Most males first stopped in Florida just after making landfall, followed by a second stopover just south of the Appalachians, with about of third of males stopping a final time in southern Ontario or northern Ohio. Males departed the breeding grounds from late-September to late-October, arriving on the wintering grounds on average 18 days later. Males departed on spring migration in late-April and early-May, spending ~16 days on migration before arriving on the breeding grounds in early- to late-May. The only significant predictor of fall arrival date was fall departure date. For spring migration, departure date was again the strongest predictor of arrival date, but total time spent on stopover and migration distance was also important. Linking spring departure and arrival dates is important in that it provides a mechanism for the previously established carry-over effects of winter rainfall on reproductive success in this species. Future research will focus on pinpointing stopover locations and identifying habitats used to ultimately determine if stopover habitat is limiting the Kirtland's Warbler population.

POSTER PRESENTATION STUDENT

An Information Exchange for Wildlife in Fire-Dependent Ecosystems of the Northern Lake States

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ABSTRACT

In the northern Lake States, a recent gap analysis of peer-reviewed literature has shown that our knowledge of the interactions among disturbances, vegetation, and wildlife in fire-dependent ecosystems is generally lacking. Some wildlife species may themselves be considered fire-dependent if their regional distribution and abundances were historically (or are currently) linked with fire-dependent ecosystems. Starting in 2013, the Lake States Fire Science Consortium (LSFSC) began an effort to identify what wildlife species should be considered fire-dependent. Our working list of 70 species includes 40 bird, 15 mammal, and 15 reptile species associated with 20 fire-dependent ecosystem types in Michigan, Wisconsin, and Minnesota. To investigate how these species are prioritized for management in the region, their conservation status, game status, and other designations were noted. Additionally, how they and their habitats were addressed in state wildlife action plans was evaluated. We present some of these results and maps showing diversity across space and ownership types for the different taxa. Despite their reliance on fire-dependent ecosystems, our findings suggest that few wildlife species or their primary associated ecosystem types are thought of by wildlife professionals as being fire-dependent, presenting a challenge for future management. Our ongoing efforts will continue to integrate awareness, comprehension, and commitment as it pertains to our fire-dependent wildlife communities in the northern Lake States.

FINAL REPORT: A Multi-Scaled Geographic Assessment of Upland Sandpiper Occupancy and Habitat Use

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Justification

Geographic variation is a common problem facing conservation planners and land managers. Results from local-scale or single species research can only rarely be extrapolated across scales, ecoregions, or species. For multi-species conservation planning, broad-scale information on the distribution of species and habitat affinity and abundance is critical for setting the conservation priorities that guide land management decisions. This is especially true because geographically explicit conservation "hotspots" cannot contain habitat necessary for the conservation of all species. Instead, studying areas outside of these hotspots will provide information needed to make informed management decisions

The distribution and amount of openland (grassland-shrubland)-dominated cover types in the U.S. have been drastically altered relative to pre-European settlement. In particular, the conversion of native prairie to intensively-managed agriculture and secondary succession due to the alteration of natural disturbance regimes have led to declines in the populations of many openland bird species, including many USFWS Conservation Priority Species. In Michigan, between 1850 and 1950, the amount of openland increased as forests were logged, catastrophic wildfires occurred, and many areas were converted to agriculture. During more recent times, the amount of openland—both native openlands such as jack pine (*Pinus banksiana*) barrens and anthropogenic openlands such as low-intensity farmland—have declined due to fire suppression, natural secondary succession, and conversion to other land uses. This loss of habitat threatens not only the biological diversity of Michigan, but possibly biogeographically important populations of openland bird species such as Upland Sandpiper (UPSA, *Bartramia longicauda*), a species of conservation priority for the R3 Migratory Bird Program and Upper Mississippi River-Great Lakes Joint Venture (JV).

Unfortunately, little is known about the relative range-wide value of Michigan openlands as UPSA breeding habitat or UPSA habitat use, abundance, and productivity across Michigan ecoregions, even though Breeding Bird Atlas data seem to indicate the state has a relatively high number of birds that reside in ecoregions that are not openland-dominated. Conservation planning models constructed by JV must therefore extract data from studies conducted elsewhere in the species' breeding range and then attempt to broadly apply these models across space and ecosystem types. However, as described above, such modeling efforts can be problematic. The UPSA model, for instance, seems to apply variables primarily related to agricultural or native grassland ecosystems of the Great Plains. However, most UPSA are presently found in portions of Michigan without intensive farming and where other openland ecosystem types predominate. We therefore suggest that research conducted at multiple spatial scales in this locality is critical to quantify habitat associations for this species in a portion of its geographical range where its habitat characteristics are virtually unknown[11].

In a global sense, this project addresses two of the six breeding ground research needs described in the *Conservation Plan for Upland Sandpiper*: ***1) continue, as well as expand, efforts to monitor UPSA populations and 2) in the Midwest, where Upland Sandpipers have traditionally relied on pastures, determine (sic..to what extent) this species is using additional habitats.***

Accomplishments

- Korte, J. 2013. Landscape attributes of upland sandpiper habitat in Michigan. M.S. Thesis, Wayne State University.
- Corace, R.G. III, Korte, J.L., Shartell, L.M. and D.M. Kashian. 2016. Upland sandpiper: a flagship for jack pine barrens restoration in the Upper Midwest? *Ecological Restoration* 34:49-60.

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INTEGRATING FUELS REDUCTION AND PINE BARRENS RESTORATION IN ENDANGERED KIRTLAND'S WARBLER HABITAT MANAGEMENT

Project ID: 10-1-06-21

Final Report

April 2014

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I. Abstract

Figure 1. Aerial view of Kirtland's warbler habitat: heterogeneous prescribed fire patterns (left) and more homogenous patterns from plantations (right).

An important aspect of the Endangered Species Act (ESA) of 1973 is to "provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved." The endangered Kirtland's warbler (*Setophaga kirtlandii*, hereafter KW or warbler) is a neotropical migratory bird that utilizes young, dense stands of jack pine (*Pinus banksiana*) produced by stand-replacing wildfires. Unfortunately, habitat management for the warbler and other changes in land use have had the unintended consequences of homogenizing landscapes and ecosystems, displacing rarer ecosystem types, and producing fuel conditions that complicate prescribed fire management activities for future habitat management (Figure 1). These alterations, relative to the pre-European settlement landscape, have led to the need for the development of novel, landscape to patch-scale research that guides future multi-agency planning and management and integrates restoration of ecosystems, warbler habitat, and safe, effective fire management. To aid land managers interested in promoting more natural patterns at landscape and patch scales and to promote safer fire management, we addressed three research questions:

1) How does the amount, arrangement, and distribution of young jack pine forests and barrens found on the landscape today (including those resulting from warbler management) fall within the historical range of the same variables?

2) How might restored jack pine barrens function as effective fuel breaks if their spatial arrangement on the landscape emulated their spatial arrangement during pre-European settlement and how would this affect fire behavior?

3) How effective are wildfire, prescribed fire, and silvicultural treatments in reducing fuels while also contributing to barrens restoration and/or Kirtland's warbler habitat?

Research to address these three questions still ongoing, but preliminary analyses at landscape scales suggest that the current coverage of jack pine-dominated and related ecosystems approximates their pre-European coverage, with only slightly higher coverage of jack pine currently. Pre-European jack pine trended older than predicted by a theoretical distribution, suggesting that the assumptions of the theoretical model may not be viable for this landscape. The maps produced for the management areas for pre-European age classes and current age classes suggests that the age distribution of modern forests, including plantations, is predominantly younger than historic, wildfire-produced forests, suggesting that habitat creation has likely altered jack pine coverage across the landscape. At the patch (stand) scale, results suggest that microclimate within "stringers"

(patches of live trees that are retained post-wildfire) was cooler and darker because of the shading effect of larger trees. Young jack pine tree density was highest nearest to the stringer and declined with distance from the stringer's edge, suggesting that surviving mature jack pines are important seed sources for post-fire landscapes. Species richness and Shannon Diversity (H) of plant communities were both higher within the stringers. Herbaceous plants and tree seedlings dominated the ground cover inside the stringer, but shrubs and graminoids dominated further from the stringer where conditions are more extreme. These differing plant communities between the stringer and the surrounding burn area suggest that stringers are an important influence on plant biodiversity, at least in the first few years following a fire. Overall, there is a marked structural difference in forest and plant communities within and outside of stringers.

Finally, in comparisons of young and mature wildfire-regenerated stands we found the overstory and seedling layers to be different (MRPP; $T = -232.65$; $P < 0.001$). Jack pine seedling densities in the young wildfire-regenerated stands were often lower than necessary for adequate stocking levels to support KW, but distribution is spatially heterogeneous within each wildfire. There were differences in stand structural attributes between the young and mature wildfire-regenerated jack pine stands. Specifically, mean overstory basal area and overstory density were lower in the young stands than the mature stands, as were mean overstory height and mean diameter. Despite these differences, results demonstrate that even following stand-replacing wildfire there were areas in the young stands with 'legacy' areas of an intact overstory. Although highly variable between age classes, there were no statistical differences observed in the 10 fuel loading variables measured. Spatial distribution of stand structural and fuel components are highly variable both within individual sample windows (representing individual wildfires) and between windows. This suggests a 'patchy' and discontinuous distribution in structural attributes and fuel loadings following wildfire and as stands develop over time. Spatial analyses suggest that fuel loadings tend to be more spatially variable in the young stands while stand structural features tend to be more spatially variable in the mature stands.

II. Background, Purpose, and Study Location

Historically, wildfires every 5-59 years maintained warbler habitat across glacial outwash-dominated landscapes of northern Lower Michigan. Fire exclusion has created the need for intensive habitat management to produce young (5-25 yr.) jack pine for Kirtland's warbler breeding habitat. Forest managers with the U. S. Forest Service (USFS), Michigan Department of Natural Resources (MDNR), and the U. S. Fish and Wildlife Service (USFWS) now intensively manage approximately 130,000 ac. with the primary objective of producing young jack pine plantations. Contemporary habitat management involves clearcutting mature (>40 year) jack pine, then trenching and planting these sites with 2-yr. jack pine seedlings in an "opposing wave" pattern whereby the pattern of densely (>1,000 stems ac^{-1}) planted trees includes small openings in which birds forage. These plantations are typically occupied by warblers for only a narrow window of time (<20 yr.). At

approximately 50 years of age (~30 years after their last use by warblers), these jack pine plantations would theoretically be clearcut and the management cycle would begins again. At present, no intermediary silvicultural treatments are applied to reduce fuels or enhance stand structural components or landscape complexity following warbler occupancy and abandonment.

The focus on intensive jack pine plantation management has significantly increased the warbler population and has aided in breeding range expansion into the Upper Peninsula of Michigan, Wisconsin, and Ontario. A tradeoff, however, is that these plantations often fail to emulate the structure of young wildfire-generated stands. Although stand-replacing prescribed and managed wildfire would yield "natural" habitat, the large, homogenized fire-prone plantations along with housing developments, an abundance of natural gas wells, and other land use patterns makes broad-scale application of fire difficult. In particular, re-introducing prescribed fire is especially difficult without a spatial framework for establishing fire breaks and the management of other, less fire-prone (and rarer) ecosystem types, such as jack pine barrens. Moreover, existing habitat management for warblers in some areas likely exacerbates the issue of prescribed fire by producing larger, more homogenous blocks of highly combustible fuels (jack pine plantations). As the recovery of Kirtland's warbler continues and management expands to newly occupied ecoregions, and as land managers work with more diverse groups of constituents to provide breeding habitat, integration of warbler management with forest ecosystem restoration and increased prescribed fire management is necessary. Specifically, we are examining whether future management actions can emulate spatial, compositional, and structural patterns of wildfire and pre-European forest ecosystems.

Work was primarily conducted in the Highplains Subsection (VII.2) of the Northern Lacustrine-Influenced Lower Michigan Section (VII) as described by Albert (1995). The Highplains Subsection has the most severe climate of NLM due to its inland location, high elevation, and northern latitude. Late spring freezes are common in the area and the annual precipitation is between 71 and 81 cm. The subsection consists mainly of broad outwash plains with excessively drained sand or sand mixed with gravel (Albert 1995).

III. Key Findings

Examining the historical distribution of jack pine forests

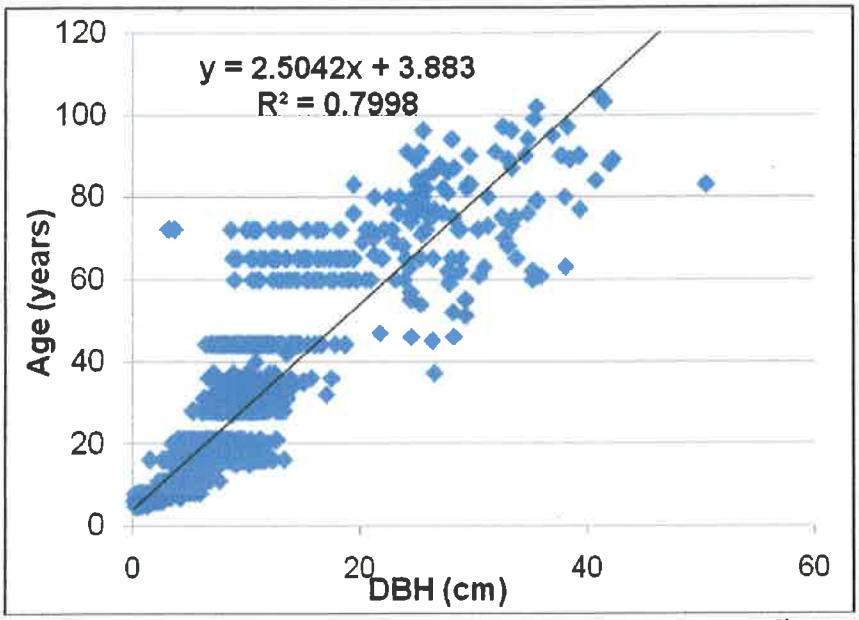


Figure 2. Regression developed from sampled tree cores to predict tree age from tree diameters reported in GLO Survey notes.

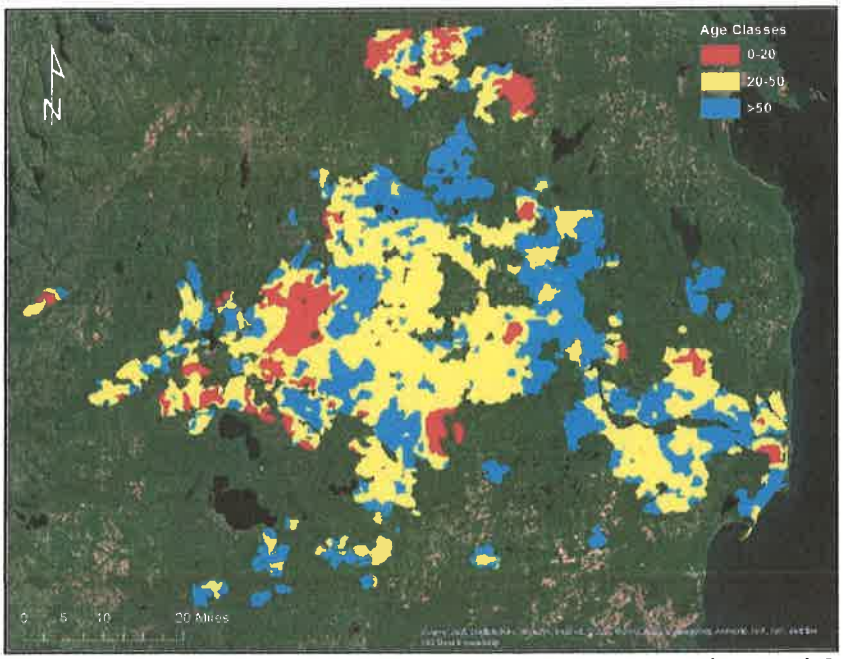


Figure 3. Results of empirical Bayesian kriging to determine spatial distribution of jack pine age classes in northern Lower Michigan.

Jack pine-dominated ecosystems were historically maintained by stand-replacing wildfires, but fire suppression has necessitated the management of jack pine plantations for KW habitat since the 1970s. Given the anthropogenic origin of this conversion and the increase in KWs to twice the original recovery goal, a historic baseline of habitat availability can be used to determine appropriate future management goals. We therefore asked to what degree KW management practices have altered coverage and distribution of jack pine-dominated ecosystems in northern Lower Michigan.

We used GLO Public Land Survey notes (collected between 1835 and 1875) for Michigan to determine the location and size of jack pine trees prior to European settlement. Survey notes produced the species, diameter, and spatial location of every tree that intersection a modern section line. Tree cores and diameters were collected across the geographical range of jack pine in northern Lower Michigan in summer 2012 and 2013; tree ages ranged from 5 to approximately 120 years. Pre-settlement tree age was then predicted from tree diameter using a nonlinear regression equation developed from the sampled trees ($R^2 = 0.8$, $p < 0.001$; Figure 2, above). Once converted to

tree diameters, jack pine age classes were modeled spatially in ArcGIS using empirical Bayesian kriging to develop a map of the spatial distribution of jack pine age classes prior to European settlement. Age classes used were 0-25 yr. (to reflect current jack pine aged used for breeding habitat by KW), 25-50 yr. (to reflect the age of jack pine when no longer used by KW but still under the management of the Recovery Plan), and > 50 yr. (to reflect jack pine stands not currently under the management strategy for KW). We found fewer polygons mapped by the surveyors that were < 20 yr. old than expected; to compensate for this bias, we included interpreted fire polygons mapped from GLO Survey notes by the Michigan Natural Features Inventory. Total data points used to map pre-European jack pine age classes across a 9-county area (Figure 3, above) was > 7000.

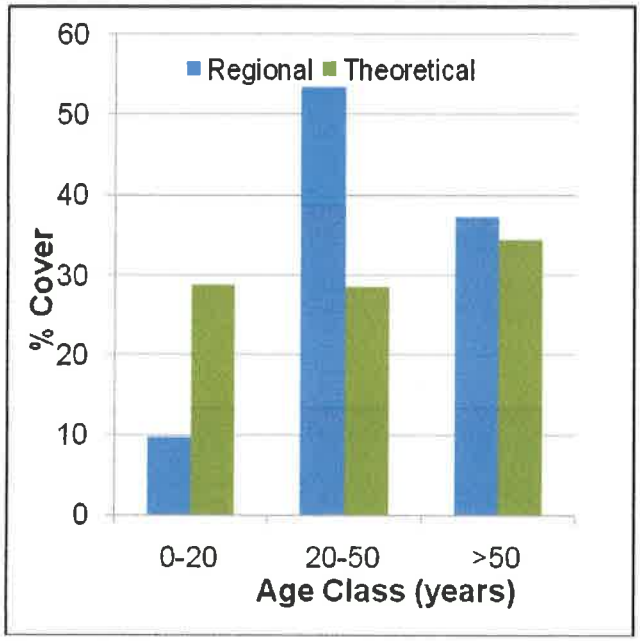
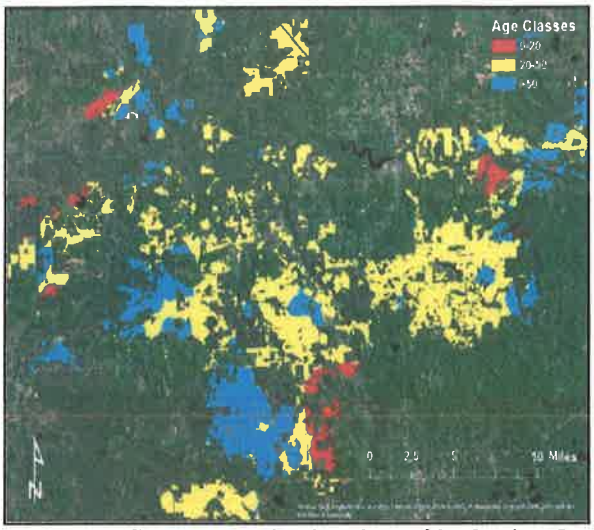


Figure 4. Comparison of van Wagner's theoretical distribution with the estimated age distribution of pre-European jack pine for northern Lower

Current stand age maps were obtained for KW management areas from the MDNR, the USFS, and the USFWS. These maps were re-classified to match those produced with kriging. Landscape metrics were calculated using FRAGSTATS to compare modern and historical landscapes. We also developed a theoretical age distribution using a negative exponential equation suggested by van Wagner (1978) for boreal forests for comparison to current and pre-European age class distributions. Theoretical distributions were based on a fire return interval of 59 yr., determined by Cleland et al. (2004) for northern Lower Michigan.

We found that the current coverage of jack pine-dominated (and related) ecosystems approximates their pre-European coverage, with only slightly higher coverage of jack pine. KW management practices have successfully targeted areas historically dominated by jack pine forests, and are not adding additional jack pine to the landscape. At a regional scale, pre-European jack pine trended older than predicted by van Wagner's distribution (Figure 4), suggesting that the assumptions of van Wagner's model may not be viable for this landscape.



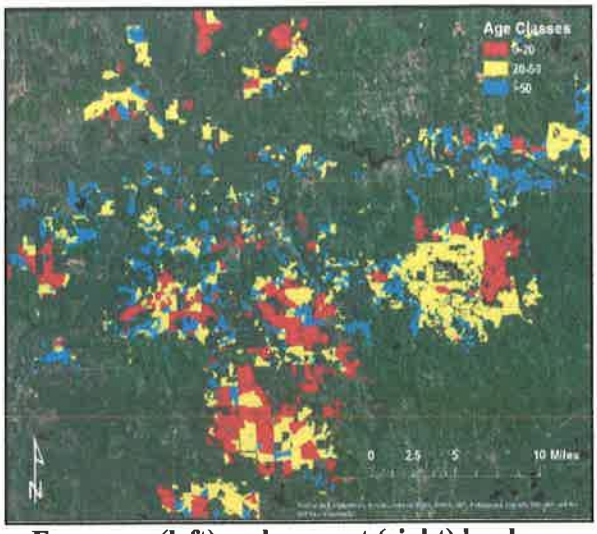


Figure 5. Stand age distribution of jack pine for pre-European (left) and current (right) landscapes in northern Lower Michigan. Red polygons indicate jack pine in the 0-25 year age class, suitable for KW breeding habitat.

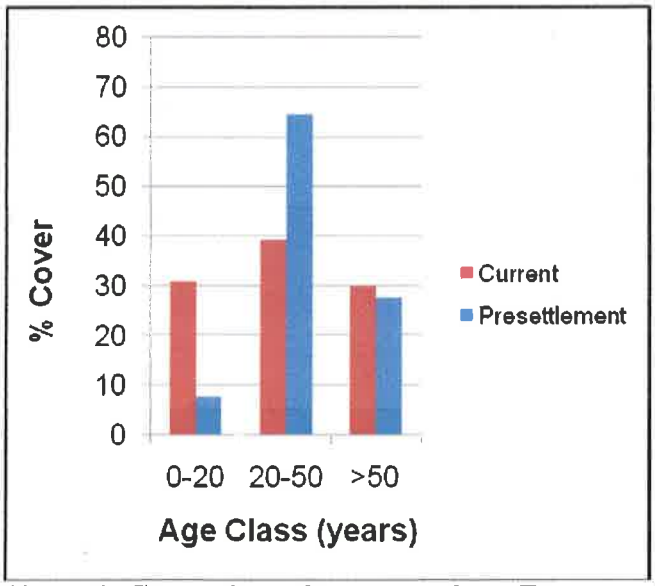


Figure 6. Comparison of current and pre-European coverage of jack pine within KW management

The maps produced for the KW management areas for pre-European age classes and current age classes (Figure 5) suggests that the age distribution of modern forests, including KW plantations, is predominantly younger than historic, wildfire-produced forests, suggesting that KW habitat creation has likely altered jack pine coverage across the landscape. Although the coverage of older jack pine (> 50 yr.) currently approximates that present at the time of the GLO Survey (Figure 6), there is significantly more jack pine < 25 yr. (likely due to the presence of extensive KW plantations) and significantly less jack pine 25-50 yr. Although the GLO Survey notes represent only one point in time for a notably dynamic landscape, these results suggest that age classes jack pine forests in management areas, which are held relatively static compared to a natural landscape, are not currently representative of the landscape prior to European settlement. Effects of such a management regime could include changes in plant communities, nutrient cycling, soil stability, and landscape structure. Given the potential de-listing of KW and the interest from some managers in ecologically-based management strategies, our findings of historic landscape patterns may provide important insights for more sustainable management.

Influence of biological legacies on jack pine regeneration

Large wildfires in jack pine-dominated ecosystems often leave behind unburned patches of forest that represent biological legacies of the pre-fire forest (stringers). These remnants may persist for years, but the effects of their presence on ecosystem processes and patterns are poorly understood. Jack pine-dominated ecosystems of northern Lower Michigan were historically characterized by frequent stand-replacing wildfires, however current forest management practices have disrupted the disturbance regime. Fire exclusion and clear cuts followed by extensive planting of jack pines intended to increase habitat for KW have likely altered the age distribution and range of jack pine-dominated ecosystems across the landscape. Stringers may act as refugia for plant species or as post-fire seed sources to the bordering burned areas, yet are not well represented in plantations. Greater understanding of stringers' effects on the surrounding landscape can lead to better-informed management practices that more closely model natural ecosystems.

To follow this line of reasoning, we initiated an additional field project in Summer 2012 to study and determine the impact of stringers on forest development and biodiversity in jack pine-dominated ecosystems burned by wildfire. We asked (1) How do stringers affect the microclimate (temperature and light intensity) important for plant diversity and structure? (2) What are the effects of stringers on forest structure with increasing distance from the stringer? and (3) How does plant community structure vary relative to the distance from the stringer? Twenty stringers were identified across four burned areas in northern Lower Michigan. Each stringer was sampled using three transects run perpendicular to the stringer. Along each transect, nine plots were located at the center of the stringer, then at 0.5 x, 1 x, 2 x, and 3 x the height of the trees on the stringers' edge on each side of the stringer. Tree diameter, age, and density were measured in each plot, and the aerial coverage of plant species was determined in a 1-m^2 quadrat at each plot center. HOBO data loggers were deployed to record temperature (°C) and light intensity (Lux) at 4-hr intervals between July and November, placed 5 m apart within the stringer, at either edge, and 5 m apart outside both sides of the stringer.

Preliminary results suggest that microclimate within the stringers was cooler and darker because of the shading effect of larger trees. Young jack pine tree density was highest nearest to the stringer and declined with distance from the stringer's edge, suggesting that surviving mature jack pines are important seed sources for post-fire landscapes. Species richness and Shannon Diversity (H) of plant communities were both higher within the stringers. Herbaceous plants and tree seedlings dominated the ground cover inside the stringer, but shrubs and graminoids dominated further from the stringer where conditions are more extreme. These differing plant communities between the stringer and the surrounding burn area suggest that stringers are an important influence on plant biodiversity, at least in the first few years following a fire. Overall, there is a marked structural difference in forest and plant communities within and outside of stringers. Understanding the importance of these features for ecosystem diversity and post-fire successional processes are critical for guiding future forest management in these ecosystems.

Variability in woody plant composition, stand structure & fuel loadings of wildfire-regenerated jack pine stands

We originally proposed a field-based study that would examine the effectiveness of wildfire, prescribed fire, and silvicultural treatments in reducing fuels and promoting structural complexity. After examining available study sites and how that would affect our statistical design, we revised the focus of this objective to center only on the temporal and spatial patterns of wildfire-regenerated jack pine forests. This shift allowed us to more closely examine and quantify the spatial heterogeneity associated with naturally regenerated jack pine forests, which can be used as a guide for future restoration efforts in jack pine forests. This change was reported to JFSP as part of our annual progress reports.

Using records of over 50 wildfires occurring over the past 50 years within the range of Kirtland's warbler in northern Lower Michigan, we identified nine wildfires that met our sampling conditions (e.g., limited impact of forest management activities, including evidence of supplemental jack pine planting, recent harvesting on older wildfires, or other anthropogenic disturbance). Using ArcGIS, we established at least one 100-acre sample window in each wildfire (in three wildfires two windows were established). Sampled post-wildfire jack pine forests were categorized as either young (pre-KW occupancy; < 8 yr.) or mature (post-KW occupancy; > 23 yr.), with three classified as young (total of five sample windows) and six classified as mature (total of seven sample windows). Naturally wildfire-regenerated stands currently occupied by KW were not included in this study.

Within each window, we randomly established 48 sample points where we collected information on the overstory (stems > 10.0 cm dbh and > 2.0 m tall) on a 50.2-m^2 plot (4-m radius circular plot). We identified each tree to species and measured the dbh (cm) and height (m) using a height pole. Both live and dead trees (snags) were recorded. We also sampled the saplings (live stems < 10.0 cm dbh and > 2.0 m tall) and seedlings (stems < 2.0 m tall) on a nested 12.6-m^2 plot (2-m radius circular plot). We identified each sapling and seedling to species and measured the dbh (cm) and height (m) using a height pole.

Fuel loadings were sampled using a modified US Forest Service Forest Inventory and Analysis (FIA) approach. From each sample plot center, we established three 7.31 m transects arrayed at 30°, 150°, and 270°. All field data were entered into the FFI (FIREMON/FEAT) Data Management System and summarized. Differences in species composition were analyzed using a variety of multivariate statistical analyses, while differences in stand structural and fuel loading attributes between age classes were analyzed using a t-test. Semivariograms were used to examine the spatial variability in stand structural and fuel loading attributes within each sample window, and the overall spatial patterns compared between the two groups.

Preliminary findings include:

- Species composition of the overstory, sapling, and seedling layers were consistent with other studies. Specifically, we found the overstory and seedling layers of young and mature jack pine wildfire-regenerated stands are different (MRPP; $T = -232.65$; $P < 0.001$), with jack pine and northern pin oak the most dominant species.
- Mean seedling density was higher in the young stands than mature stands ($P < 0.01$). Jack pine seedling densities in the young wildfire-regenerated stands were often lower than necessary for adequate stocking levels to support KW, but distribution is spatially heterogeneous within each wildfire.
- There were differences in stand structural attributes between the young and mature wildfire-regenerated jack pine stands. Specifically, mean overstory basal area and overstory density were lower in the young stands than the mature stands, as were mean overstory height and mean diameter. Despite these differences, results demonstrate that even following stand-replacing wildfire there were areas in the young stands with 'legacy' areas of an intact overstory.
- No differences in snag densities were observed between the young and mature stands; however, both age classes had high mean snag densities (890 stems ha^{-1} in young stands and 921 stems ha^{-1} in mature stands).
- Although highly variable between age classes, there were no statistical differences observed in the ten fuel loading variables measured. Mean (± 1 SD) total fuel loading for both age classes ranged from 3.2 (2.2) kg m^{-2} for young stands and 3.4 (1.6) kg m^{-2} for mature stands.
- Spatial distribution of stand structural and fuel components are highly variable both within individual sample windows (representing individual wildfires) and between windows. This suggests a 'patchy' and discontinuous distribution in structural attributes and fuel loadings following wildfire and as stands develop over time.
- Spatial analyses suggest that fuel loadings tend to be more spatially variable in the young stands while stand structural features tend to be more spatially variable in the mature stands.

IV. Management Implications

Our preliminary findings provide initial guidance for land managers wishing to emulate more natural patterns produced by wildfire in jack pine. Specifically, we have documented that the presented composition of the northern Lower Michigan landscape in which we worked is relatively representative of pre-settlement conditions and that most work should be focused on emulating structural patterns of wildfire and not necessarily changing composition. In particular, work within stringers has documented the natural range of variation of patch size and shape and the proportion of landscape represented by this residual structure. Moreover, our work

has identified the "staying power" of these live trees on the landscape, including the fact that retention time may be as greater or greater than the fire return interval of 59 years.

Our work at the stand level has also indicated that jack pine stocking levels in wildfire-regenerated jack pine stands are likely to be low with respect to supporting optimal KW habitat as currently managed using clearcutting and artificial planting methods. Moreover, as wildfire-regenerated jack pine stands develop over time, snags are an important structural component and legacy of the natural disturbance regime. While snag densities near 900 stems ha^{-1} is most likely not possible in managed jack pine stands, our results clearly demonstrate these are important structural components of these forests and should be incorporated into future management activities.

From a spatial perspective, the high variability in both stand structural and fuel loading attributes observed in these wildfire-regenerated jack pine stands regardless of stand age, suggests that a "patchy' environment persists as these forests develop over time. We suggest that this spatial variability is most likely due to legacies of 1) the conditions of the stands prior to the wildfire and 2) the behavior/intensity of the wildfire. Restoration and management efforts should begin to explore ways to emulate this spatial variability on the ground. More information, however, is needed to detangle these complex interactions and spatial relationships, and the effects on other important ecosystem services.

V. Relationship to Other Recent Findings and Ongoing Work

During 2012 treatments to enhance structure of plantations were proposed for a property in Crawford County, MI. Using commercial logging equipment, the treatment was to create enhanced structure-composition relatively to typical plantations and based on published findings (Kashian et al. 2012). However, economic limitations (i.e., the timber could not be sold) stopped this from occurring; bids for the timber sale will go out again in 2014.

Efforts have also been expended in integrating our past and ongoing studies regarding wildfire structural patterns in jack pine ecosystems with migratory bird research and ecological forestry (and restoration) principles. In this vein, a Master's student at Central Michigan University (CMU, B. Cullinane-Anthony) has completed a M.S. thesis with Co-PIs Corace and Kashian and Dr. Nancy Seefelt (CMU) that characterized bird communities among post-fire biological legacy patches (stringers) and the surrounding jack pine stands/plantations. A manuscript is being drafted for submission.

At The Ohio State University, there are several related on-going projects that are directly related to this study:

- M.S. student thesis (E. Monarch, The Ohio State University) using the network of wildfires and sample plots to examine differences and spatial variability associated with ground-flora composition, structure, and diversity between young and mature wildfire-regenerated jack pine stands.

- Portion of Ph.D. student dissertation research (S. Rose, The Ohio State University) using the network of wildfires and sample plots to examine differences and spatial variability associated with spider communities and diversity between young and mature wildfire-regenerated jack pine stands.
- Potential for remotely sensed data (e.g., LiDAR, LANDSAT, aerial photographs) to predict stand structure and fuel loadings in wildfire-regenerated jack pine stands, using field-based data collected in the current study to verify model development. Work being explored in conjunction with environmental modeler at The Ohio State University (K. Zhao).

VI. Future Work

Examining the impacts of barrens distribution on historical fire spread

Progress on remains largely a work in progress and represents most of the remaining work for this proposal. The goal is to model fire spread and behavior under different scenarios of barrens distribution. In completing the work for Question #1 we have realized that the spread of fire across this landscape in the absence of fire suppression is relatively poorly understood. In our conversations with fire managers, one manager suspected that crown fires on this landscape could burn and/or smolder uninterrupted for months and therefore burn very large areas from a single ignition.

We have initiated contact and secured agreements with Brian Sturtevant at the USFS Northern Research Station in Rhinelander, WI for training of the graduate student in use of LANDIS-II, and landscape model suitable not only for modeling fire behavior, but also fire spread under multiple scenarios of landscape structure and climate. The graduate student will attend a 1-2 week training session in Rhinelander during Summer 2014, with hopes of completing the modeling and associate manuscript by September 2015.

Additionally, the results from this study that suggest stand structural and fuel loading components are highly spatially variable requires further investigation to better understand the specific mechanisms responsible for that variability, and how they differ from managed jack pine forests. While no immediate plans are underway to address these issues, the following are potential suggestions for future work that can build off of this work:

- Quantify stand structural and fuel loading complexity in managed systems, including spatial heterogeneity.
- Implement experimental silvicultural treatments that emulate the spatial variability observed in wildfire-regenerated jack pine stands and follow development over time.

VII. Deliverables

Table 1. Deliverables, description, and delivery dates as proposed and current status. See below for specifics.

Deliverable Type	Description	Proposed Delivery Dates	Status
Presentation	Given to Kirtland's Warbler Recovery Team	July 2010	Completed (multiple)
Website	Description and updates of project to Consortium site	December 2010	Completed/in progress
Field tour	Recovery Team tour of field sites	July 2011	Completed
Master's thesis (changed to PhD dissertation)	Wayne State Univ. work	May 2012	In progress
Master's thesis	Ohio State Univ. work	May 2012	Completed
Workshop	Field-based workshop for multiple agencies and the Recovery Team	July 2012	In progress
Conference presentation (oral or poster)	Wayne State Univ. work	December 2013	Completed (multiple)
Conference presentation (oral or poster)	Ohio State Univ. work	December 2013	Completed (multiple)
Refereed publication on spatial patterns	Wayne State Univ. work	December 2013	In progress
Refereed publication on field data	Ohio State Univ. work	December 2013	Completed/in progress

Doctorate Dissertation:

- Tucker, M.M. *In Prep.* Comparison of historic and current characteristics of jack pine-dominated ecosystems in northern Lower Michigan. Wayne State University, Detroit, MI. Expected 2016.

Master's Theses:

- Cullinane Anthony, B.L. 2014. Influence of wildfire-induced stand structure on bird diversity patterns in jack pine ecosystems of northern Lower Michigan. Department of Biology, Central Michigan University, Mt. Pleasant, MI.
- Monarch, E.A. 2014 (May). Composition, structure, and diversity patterns of the ground-flora of young and mature wildfire regenerated jack pine (*Pinus banksiana* Lamb.) forests on northern Lower Michigan. School of Environment and Natural Resources, The Ohio State University, Columbus, OH.
- Myer, M.G. 2012. Characterizing the decision process of land managers when managing for Endangered species of fire dependent ecosystems: the case of the Kirtland's warbler (*Setophaga kirtlandii* Baird). School of Environment and Natural Resources,The Ohio State University, Columbus, OH.

Refereed Papers:

- Kashian, D.M., Corace, R.G. III, Shartell, L.M., Donner, D.M. and P.W. Huber. 2012. Variability and persistence of post-fire biological legacies in jack pine-dominated ecosystems of northern Lower Michigan. *Forest Ecology and Management* 263:148-158.
- Tucker, M.M., D.G. Cleland, R.G. Corace III, and D.M. Kashian. *In Prep.* Comparing current and historical age class distributions of jack pine-dominated ecosystems in the context of endangered species management. To be submitted to Forest Ecology and Management.

- Tucker, M.M, B.R. Sturtevant, R.G. Corace III, and D.M. Kashian. *In Prep.* Behavior of stand-replacing fires on historical landscapes of northern Lower Michigan: influence of barrens and forest stand age. To be submitted to Landscape Ecology, September 2015.
- Tucker, M.M., R.G. Corace III, and D.M. Kashian. *In Prep.* Impacts of postfire biological legacies on forest stand development and plant community structure in northern Lower Michigan. To be submitted to Canadian Journal of Forest Research, May 2015.

Conference or Meeting Presentation-Field Tours-Etc.:

- Corace, R.G. III, Kashian, D.M., Goebel, P.C. and E. Toman. 2011. Wildfire and structural and compositional patterns in jack pine ecosystems of the northern Lower Peninsula of Michigan: implications for restoration and ecological forestry. Fall Field Tour, Michigan Society of American Foresters, Lower Peninsula Chapter.
- Corace, R.G. III, Kashian, D.M., Goebel, P.C. and E. Toman. 2011. Beyond Kirtland's Warbler: Multi-species consequences to jack pine ecosystem management. Jack Pine Symposium, University of Minnesota Tree Improvement Center, Cloquet, MN.
- Corace, R.G. III, P.C. Goebel and D.M. Kashian. 2012. Snag management in pine forest types in northern Michigan. Society for Ecological Restoration-Midwest/Great Lakes Chapter Annual Meeting, Ann Arbor, MI.
- Corace, R.G. III, P.C. Goebel, D.M. Kashian and T. Pypker. 2012. Research-management partnerships and fire-dependent ecosystem restoration: case studies from Seney National Wildlife Refuge, Upper Michigan. Stewardship Network Conference, East Lansing, MI.
- Corace, R.G. III, Kashian, D.M., Goebel, P.C., E. Toman, N.E. Seefelt and B. Cullinane-Anthony. 2012. Integrating fuels reduction and pine barrens restoration in Endangered Kirtland's warbler habitat management: Overview. Kirtland Warbler Recovery Team Summer Meeting, St. Ignace, MI.
- Goebel, P.C. 2012. Complexity, resiliency, and restoration – Lessons from the forests of eastern North America. Invited Presentation, School of Natural Resources, Trinity College. Dublin, Ireland.
- Goebel, P.C. 2012. Restoring and managing for complexity in conifer forests of the Lake States region of the U.S. Invited Presentation, UK Forestry Commission, Northern Research. Roslyn, United Kingdom.
- Goebel, P.C., and J.R. Miesel. 2014. Variability in woody plant composition, stand structure & fuel loadings of wildfire-regenerated jack pine stands. Oral presentation. 2014 Winter Meeting of the Kirtland's Warbler Recovery Team, Roscommon, MI.
- Kashian, D.M., Corace, R.G. III, Shartell, L.M., Donner, D.M. and P.W. Huber. 2011. Variability and persistence of post-fire biological legacies in jack pine-dominated ecosystems of northern Lower Michigan. Annual Meeting of the US Chapter of the International Association for Landscape Ecology, Portland, OR.
- Kashian, D.M., Corace, R.G. III, Shartell, L.M., Donner, D.M. and P.W. Huber. 2011. Variability and persistence of post-fire biological legacies in jack pine-dominated ecosystems of the northern Lower Peninsula of Michigan. Kirtland Warbler Recovery Team Summer Meeting, L'Anse, MI.
- Kashian, D.M. and R.G. Corace III. 2012. Variability and persistence of post-fire biological legacies in jack pine-dominated ecosystems of northern Michigan. Webinar presented to the Lake States Fire Science Consortium.
- Miesel, J.R., P.M. Nelson, P.C. Goebel, R.G. Corace III, and D.M. Kashian. 2012. Forest fuels and vegetation in wildfire-regenerated jack pine (*Pinus banksiana* Lamb.) forests: informing ecological forestry in the Lake States region. Poster presentation. 2012 Annual Meeting of the Ecological Society of America, Portland, OR.

- Miesel, J.R., P.M. Nelson, P.C. Goebel, R.G. Corace III, and D.M. Kashian. 2012. Forest fuels and vegetation in wildfire-regenerated jack pine (*Pinus banksiana* Lamb.) forests: informing ecological forestry in the Lake States region. Poster presentation. 2012 Annual Meeting of the Ecological Society of America, Portland, OR.
- Monarch, E.A., and P.C. Goebel. 2014. Ground-flora composition & diversity of young and mature wildfire regenerated jack pine (*Pinus banksiana* Lamb.) forests. Poster presentation. Science, Practice and Art of Restoring Ecosystems Conference, East Lansing, MI. *Awarded Best Student Poster.*
- Myer, G., E. Toman, G. Corace, P.C. Goebel and D. Kashian. 2011. Integrating fuels reduction and pine barrens restoration in Endangered Kirtland's warbler habitat management. The human dimensions. Kirtland Warbler Recovery Team Summer Meeting, L'Anse, MI.
- Myer, G., E. Toman, G. Corace, P.C. Goebel and D. Kashian. 2011. What Influences the decision process of land managers when managing for Endangered species? School of Environment and Natural Resources Graduate Student Seminar, Columbus, OH.
- Tucker, M.M. 2012. Potential effects of post-wildfire biological legacies on plant community structure of adjacent burned areas. Poster presentation, WSU Biological Sciences Departmental Retreat.
- Tucker, M.M. 2013. Vegetation patterns in post-wildfire biological legacies. Oral presentation, Kirtland's Warbler Recovery Team summer meeting, July 31, 2013. Roscommon, MI.
- Tucker, M.M. 2013. Quantifying presettlement age class distribution of jack pine in northern Lower Peninsula. Oral presentation, Kirtland's Warbler Recovery Team Winter Meeting, March 13, 2013. Bath, MI.
- Tucker, M.M., R.G. Corace III, and D.M. Kashian. 2013. A comparison of presettlement and current jack pine-dominated ecosystems in northern Lower Michigan. Oral presentation, US Regional Association of the International Association for Landscape Ecology (US-IALE) 2013 Annual Symposium, April 14-18, Austin, TX.
- Tucker, M.M. 2013. A comparison of presettlement and current jack pine-dominated ecosystems in northern Lower Michigan. Oral presentation, Seney National Wildlife Refuge, August 15, 2013, Seney, MI.
- Tucker, M.M. 2013. Effects of endangered species management on jack pine-dominated ecosystems in northern Lower Michigan. WSU Biological Sciences Departmental Retreat, November 2013. Bloomfield Hills, MI.
- Tucker, M.M., R.G. Corace III, and D.M. Kashian. 2014. Effects of Kirtland's warbler management on jack pine-dominated ecosystems in northern Lower Michigan. Poster presentation, The Michigan Bird Conservation Initiative Workshop. March 20-22, 2014. Tustin, MI. (Best Student Poster Award)
- Tucker, M.M. 2014. Presettlement age distributions of jack pine-dominated ecosystems in northern Lower Michigan. Oral presentation, Kirtland's Warbler Recovery Team winter meeting, March 19, 2014. Roscommon, MI.
- Tucker, M.M., R.G. Corace III, and D.M. Kashian. 2014. Effects of Kirtland's warbler management on jack pine-dominated ecosystems in northern Lower Michigan. Poster presentation, The Stewardship Network Annual Conference. January, 17, 2014. East Lansing, MI. (Best Student Poster Award Runner-up)

Website:

Summary of project findings – http://oardc.osu.edu/ferel/jackpine.htm

Kirtland's Warbler Research

Dr. Deahn DonnerWright, US Forest Service, Northern Research Station, Institute for Applied Ecosystem Studies, 5985 Highway K, Rhinelander, WI 54501, 715-362-1146

Range-wide assessment on the impacts of changing climate on the endangered, migratory Kirtland's Warbler population

Principal Investigators:
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Christine A. Ribic, US Geological Survey, Wisconsin Cooperative Wildlife Research Unit, Dept. Forest and Wildlife Ecology, University of Wisconsin, Madison, WI

Collaborators:
Donald Brown, Associate Professor, West Virginia University, Morgantown, VA and USFS Northern Research Station
Christie Deloria-Sheffield, Fish & Wildlife Biologist, U.S. Fish & Wildlife Service, Upper Peninsula Sub-Office, Ecological Services, Marquette, MI
Carol Bocetti, Biological and Environmental Science Dept., California University of Pennsylvania, California, PA
Mark Nelson, US Forest Service, Northern Research Station, St. Paul, MN
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*Funding provided by US Geological Survey Science Support Partnership Program and in-kind contributions from US Forest Service, Northern Research Station – Institute for Applied Ecosystem Studies

Background: Currently, little is understood about how changing climate could impact Kirtland's Warbler or how land management should be adapted to minimize potential impacts. A primary concern is the impact of changing climate patterns on the species narrow breeding and wintering ground habitat. Conditions are predicted to become warmer with more extreme heat (i.e., increased drought) and heavy precipitation in the Midwest region and increased drought in tropical wintering grounds in the Bahamas may reduce the amount of good quality habitat. Long-term conservation of long-distance migratory passerines requires a range-wide understanding of stressors on populations. Results will help identify where management adjustments (e.g., spatial planning) may have to occur throughout its geographic range to identify and implement strategies that will mitigate climate change impacts.

Objectives: (1) Develop spatially-explicit models predicting potential habitat distribution shifts based on potential loss of habitat (winter) and jack pine recruitment and survival (breeding) based on low (B1) and high (A2) global climate predictions (IPCC) in both regions, and (2) Develop a population viability assessment by linking how Kirtland's Warbler survivorship and productivity will be altered from changing climate conditions (i.e., drought) and changing habitat availability and distribution from objective 1.

Status: A population viability analysis manuscript is in review with Journal of Applied Ecology; jack pine growth and establishment model is being developed with intended submission to journal summer 2016, and the spatially-explicit metapopulations models are expected to be completed spring 2017.

Assessing efficiency of Brown-headed cowbird trap locations across ten years

Principal Investigators:
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Christine A. Ribic, US Geological Survey, Wisconsin Cooperative Wildlife Research Unit, Dept. Forest and Wildlife Ecology, University of Wisconsin, Madison, WI

Collaborators:
Chris Mensing, USFWS, Marquette, MI

Background:
Brown-headed Cowbird nest parasitism continues to be a major factor and threat to the Kirtland's warbler populations. In 1972, a partnership of federal, state, and private agencies began controlling cowbirds with large live traps placed in Kirtland's nesting areas. Since 1972, an average of 4,000 cowbirds per year has been removed from the warbler's breeding areas.Kirtland's warbler reproductive success has improved dramatically since cowbird trapping began. The nest parasitism rate has declined from the 1966-71 average of 69% to less than 5%. The average number of young warblers fledged per nest has increased from less than one to almost three birds. From record lows of 167 in 1974 and 1987, the number of singing male Kirtland's warblers increased to a record high of 1,828 in 2011. The U.S. Fish and Wildlife Service installs traps within occupied breeding habitat, and monitors success rates (cowbirds trapped). However, limited spatial analyses have occurred on this data to determine if the spatial location of a trap influences trapping success rate. In addition, how trapping efficiency may change through time.

Objectives:
This study is investigating the spatial and temporal pattern of female Brown-headed Cowbirds trapped across years. If spatial trend is consistent through time, it may reflect physical factors in broader landscapes (i.e., birds in area regardless of Kirtland Warbler abundance). If spatial trend is not consistent through time, it may reflect cowbird population response to host species abundance and distribution (assumes Kirtland's Warbler is major host in the region).

(1) Determine if trap efficiency changes through time based on changing landscape composition and configuration around traps.
(2) Determine if trap type or trap age influences trap efficiency?

Status:
Ten years of trapping data have been quality-checked and verified. Current efforts are focusing on recreating habitat conditions surrounding each trap location to define the broader landscape for each year. Expected manuscript in fall 2016 or spring 2017.

Kirtland's Warbler Research and Training Project by D. Ewert and J. Wunderle

Progress/projected work through July 2015 – April 2016.

- We coordinated with the Bahamas National Trust and National Audubon Society to outline a 3-year plan to transition the Kirtland's Warbler work to Bahamian organizations.
- Manuscript preparation continued.
    - Overview of the ecology of the Kirtland's Warbler on the wintering grounds with suggestions for potential habitat management
    - Isotopes
    - Connectivity
    - Fleming, G.M., D.N. Ewert, and J.M. Wunderle, Jr. In review. Response of Bahamian dry forest to goat grazing and implications for Kirtland's Warbler (*Setophaga kirtlandii*) winter habitat management. Caribbean Journal of Science
- Publications
    - Fleming, G.M., J.M. Wunderle, Jr., and D.N. Ewert. 2016. Diet preferences of goats in subtropical dry forest and implications for habitat management. Tropical Ecology 57(2):279-297.
- Presentations
    - Bahamas Natural History Conference, Nassau. March 2016.
        - Ewert, D.N. et al. The Kirtland's Warbler: Designing conservation programs on the Bahamas archipelago wintering grounds.
        - Wunderle, J.M., Jr. Stable isotopes reveal over-winter increases in the proportion of predaceous arthropods consumed by the endangered Kirtland's Warbler.
    - TNC conference, Austin, Texas. February 2016.
        - Ewert, D. Building conservation capacity in The Bahamas: Kirtland's Warbler Research and Training Project.
- Scheduled field work (through mid-April 2016)
    - Kirtland's Warbler surveys on San Salvador (to evaluate response to hurricane Joaquin), Turks and Caicos (part of an ongoing effort to evaluate distribution and abundance throughout the Bahamas archipelago)
    - Work with OneEleuthera, a Bahamian NGO, to determine application of ecotourism and sustainable agriculture to create Kirtland's Warbler habitat and generate interest in Kirtland's Warbler management.

Ashley Hannah (ahannah@wisc.edu) Master's Research Project University of Wisconsin - Madison
PI's: Anna Pidgeon (apidgeon@wisc.edu), Christine Ribic (caribic@wisc.edu)

Summary of proposed research on habitat use, nest predation, and fledgling habitat use in Wisconsin

Progress/Updates: WI DNR and USFWS permits submitted; applied for grants to purchase equipment; field assistant hired.

Study site: The study area is located in central Wisconsin on red pine dominated stands in Adams County, WI.

Habitat characterization: Nesting phenology will be recorded by WDNR/USFWS nest monitors. Habitat data will be collected within 3 days of a nest becoming inactive to best estimate the features that the warblers may select when nesting. Habitat will be characterized at the nest site, the territory, breeding stand, and at the landscape level. Data will be collected at nests and random points. Vegetation height density, nest concealment, ground cover, tree density and land cover within 1km of the breeding stand will be quantified. To calculate nest success and the influence of habitat variables at multiple scales, I will use the logistic exposure method (1). To compare models and determine important factors, I will use the AIC approach (2).

Nest predation: Video cameras will be deployed on 70% of nests each year to assess causes of nest failure and identify nest predators at the breeding site. While the presence of cameras is not associated with increased nest predation risks, precautions will be taken to reduce scent trails and visual cues around the nest. Nest predators will be identified to the most detailed level possible. I will use observations/ scientific literature to assign each predator to a primary habitat association. I plan to assess the relationship between predation and date within the nesting season and weather, with simple linear models. I will conduct this analysis for predation events as a whole, and by predator species, if possible.

Fledgling habitat use: I will attach a radio-transmitter (Advanced Telemetry Systems, model A2414) weighing 0.3g (~3% of mean weight of 7 day old nestling) to 1-2 of the heaviest nestlings from each nest for up to 15 radioed nestlings each year (30 over both years) in conjunction with banding. Transmitters will be attached to the backs of 7 day old chicks by gluing a transmitter to the feathers with cyanoacrylate glue. Attaching transmitters and banding should take less than 15 minutes. An activator can be used with cyanoacrylate glue to make it set instantly on contact to reduce handling time (3); however no adjustments are possible after. Processing the heaviest nestlings first should facilitate time for attachment and glue-setting, and keep brood handling time down. Transmitters should fall off when the young molt into their first winter plumage (by 43 days old), so they won't carry the transmitters during migration. Juveniles will be tracked until the unit dies or falls off, or the bird dies. Locations will be obtained by homing in on the bird 3 times during daylight and once after dark, daily. Once located each bird will be observed for up to 10 minutes, from the farthest distance at which it can clearly be seen. Once location monitoring is complete, habitat used will be characterized and locations mapped. Habitat used by juveniles will be compared with habitat at randomly selected plots. If the sample size allows, juvenile survival as a function of habitat characteristics at sites used by juveniles will be modeled in a logistic regression framework. If sample size doesn't allow, a separate model will be constructed of juvenile survival as a function of stand characteristics.

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ASSESSING 30 YEARS OF CHANGES IN VEGETATION AND FUELS FOLLOWING WILDFIRE IN JACK PINE FORESTS OF NORTHERN LOWER MICHIGAN

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In the northern Lake States region (northern Michigan, Minnesota and Wisconsin, as well as in southern portions of Manitoba and Ontario), dry, sandy glacial outwash plains support ecosystems dominated by variably dense, high-fuel jack pine (*Pinus banksiana* Lamb.) forests. Accordingly, the natural disturbance regime in jack pine-dominated ecosytems of this region – a regime less altered compared to other forest types in North America – is characterized by large-scale, stand-replacing crown fires. With the onset of a warming climate and the potential for increased periods of drought in this region, these ecosystems are likely to experience more frequent and severe wildfires, with potential impacts on a multitude of ecosystem services. As jack pine-dominated ecosystems are a representative and dominant ecosystem type on the regional landscape of the northern Lake States and elsewhere, there is a need for research that quantifies the dynamics of vegetation structure and fuel loadings in these systems in ways that will inform predictions of successional pathways and/or fire behavior.

I propose to re-measure vegetation structure, fuels development, and plant community composition in jack pine forests of northern Lower Michigan and to integrate these data into a modeling framework to predict potential changes in crown fire behavior in jack pine over time. Permanent plots established in the Mack Lake Burn in 1986, resampled in 1996, and re-located in 2007 will be re-measured to represent a third point along a 30-year successional sequence. Results will then be compared to vegetation and fuels development predictions in the Base Model and Fire and Fuels Extension of the Forest Vegetation Simulator (FEE-FVS). Moreover, field results will be used to parameterize the fire behavior model NEXUS to predict potential fire behavior at each site under similar abiotic conditions. These data will improve the ability of land managers to assess the role of vegetation and fuels development in evaluating the suitability of prescribed fire and other fire management tools on a landscape where such approaches have been non-existent in the recent past. Understanding and implementing data that improve managers' ability to predict fire behavior on an aging landscape is crucial for predicting fire behavior at larger landscape scales, and will provide guidance for future fire risk assessment and management activity.

The overall objective of this project is to understand how stand structure, the fuels complex, and plant community composition change with long-term succession following stand-replacing wildfires in jack pine-dominated ecosystems of northern Lower Michigan. The *central hypothesis* of this study is that vegetation structure and fuel conditions will vary both with time since fire and spatially within a previously burned area. We will test our central hypothesis and accomplish the objective of this research by addressing the following three *specific questions*:

1) How do vegetation structure and fuels change with succession, and how variable are these changes across a large fire-prone landscape?
2) How does plant community composition change with succession, and how variable are these successional pathways across the landscape?
3) Do successional changes in vegetation and fuels have the potential to alter fire behavior and spread across the landscape?

2016 Report to the Kirtland's Warbler Recovery Team

The effects of anthropogenic noise on abundance and reproductive success in the Kirtland's warbler

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This project is currently in the development stages, primary due to lack of sufficient funding. The goal for 2016 is to employ the use of portable sound recording units at increasing distances near 10 noise sources near or within Kirtland's habitat. The data will be used to develop a noise map that can be extrapolated across Kirtland's habitats. By comparing noise levels with the distribution of breeding territories, I will be able to develop a preliminary understanding about how Kirtland's warbler abundance and distribution are effected by anthrophonic noise. Although still under development, I aim to use crowdsourcing to procure the minimal amounts (~$2700) of funding needed for this portion of the project. The developing website can be found here: https://experiment.com/projects/itldgddxkmjdkpmpagal However, recent empirical work suggests that abundance may not be a holistic indicator of bird persistence in noisy areas, as remaining birds may be less healthy or produce fewer young. Because the ultimate measure of success is the productivity of these birds, we continue to seek funds for a larger scale project that will measure reproductive success through noise and nest monitoring. Below I have included excerpts of the work we propose to complete once funding is secured:

Noise is often associated with human economic gain, but its presence causes many songbirds to vacate otherwise good habitats. For example, my previous research suggests that least flycatchers (*Empidonax minimus*), and red-breasted nuthatches (*Sitta canadensis*) avoid areas with elevated noise levels (Proppe et al. 2013, Glob. Change. Biol.). In addition, species that remain may be less likely to produce healthy offspring. Recent work shows that songbirds in high noise environments suffer from reduced body condition (Ware et al. 2015, PNAS), lowered reproductive success (Halfwerk et al. 2011, J. Appl. Ecol.), and potentially reduced lifespan (Meillere et al. 2015, Biol. Lett.). Despite the challenge that noise presents for many songbird species and the increasing pressure to develop near Kirtland's habitats, biologists currently have no specific information about how noise affects the Kirtland's warbler. Without data, managers are forced to make regulation decisions with limited information – decisions that cannot easily be reversed once development begins. As a result already limited habitats may become increasingly scarce or function as sinks, where reproductive success is inhibited by high noise levels. To facilitate a more informed management strategy, I aim to directly test the effects of noise on the Kirtland's warbler and the four regional priority species. Specifically, I aim to test the following hypotheses:

Hypothesis 1: The abundance of Kirtland's warblers will decrease in noise-affected areas.
Hypothesis 2: Kirtland's warbler nests in noise-affected areas will contain fewer eggs and be subject to lower rates of hatching and fledging.

Because noise signatures differ dramatically for each of the three most prevalent noise sources present in or near Kirtland's warbler habitat I plan to assess each hypothesis independently in relation to roads, compressor stations, and ORV trails. I will assess abundance and nest placement across a range of distances from each source and noise levels. Using this information I will be able to fulfill two applied objectives:

Objective 1: Determine *if* noise is a significant factor that must be regulated to facilitate the persistence of Kirtland's warblers and other priority species within suitable habitat.
Objective 2: Where needed, establish specific *threshold* distances and noise levels that must be maintained to facilitate continued Kirtland's warbler success in suitable habitat.

March 21, 2016
Research Summary for the Kirtland's Warbler Recovery Team

Project Title: A silvicultural system for conserving biodiversity and enhancing ecosystem services in xeric jack pine forests of the Lake States Region

Lead PI: David Rothstein, Department of Forestry, Michigan State University

The purpose of this project is to develop and evaluate new approaches to managing jack pine forests across the Lake States that will enhance their potential to deliver: 1) climate-change mitigation; 2) biodiversity; 3) higher-value forest products; and 4) opportunities for ecosystem management on public forest lands. This is a four-year project that began in February 2015. Herein I report on progress for the calendar year 2015.

Activities

We established three separate time-series of KW plantation stands varying in age from 2 to > 30 years, in Ogemaw, Alcona, and Presque Isle counties. We conducted stand inventory measures and destructive sampling of 2 trees per site in the summer of 2015. We are currently working on development of allometric equations necessary to quantify stand growth and biomass production in jack pine plantations planted at high density for KW habitat. We have also prototyped a Life Cycle Assessment for high density jack pine using two scenarios: thinning post warbler occupancy and whole-tree harvest and planting immediately following warbler occupancy. We instrumented one site harvested in 2015 with lysimeters, which were sampled throughout 2015 to determine nutrient losses associated with clearcut harvesting. We set up full-factorial nutrient (N, P and base cations) addition experiments at two young plantations (~10 years old), and measured height growth at the end of the summer. Finally, we compared nitrogen mineralization, nitrification and nitrate leaching between young jack pine stands regenerated by wildfire vs harvesting at four pairs of sites.

Findings to Date

Our preliminary data suggest that jack pine, planted at high density for KW habitat could produce 50-70 Mg ha^{-1} of biomass if managed on a 20-30 year rotation. Preliminary data from our LCA modeling work suggests greater financial returns from short rotation biomass harvests compared to post-warbler thinning. There was no current-year growth response to fertilizer that was applied in May 2015. Harvest-origin stands had markedly greater rates of nitrification and nitrate leaching compared to wildfire-origin stands. For agencies considering creating KW habitat by fire vs harvesting, these data indicate another dimension on which ecological effects of harvesting differ from those of fire.

Future Directions

We will be continuing to refine models of biomass production of different jack pine management scenarios. We will also be developing nutrient budgets to assess long-term sustainability. Finally we will work on landscape and regional scale scenarios of alternative approaches to jack pine management.

COMPARATIVE HABITAT USE AND REPRODUCTIVE SUCCESS OF KIRTLAND'S WARBLER IN JACK PINE AND RED PINE STANDS IN NORTHERN MICHIGAN

Michigan Department of Natural Resources and Au Sable Institute of Environmental Studies
Principal Investigator: Fred Van Dyke

A cooperative study of the Michigan Department of Natural Resources (MDNR) and the Au Sable Institute of Environmental Studies (AIES) will initiate, beginning May 2016 through 2018, an examination of comparative breeding and reproductive success of Kirtland's warbler (*Dendroica kirtlandii*) in red pine (*Pinus resinosa*) stands with structural characteristics similar to traditional Kirtland's warbler habitat in jack pine (*Pinus banksiana*) stands. Traditionally described as a habitat specialist of young, even-aged jack pine, Kirtland's warblers were historically known to use red pine (Mayfield 1960, Anderson and Storer 1976, Walkinshaw 1983, Probst and Weinrich 1993), and recent investigations have shown that Kirtland's warbler can use red pine as breeding habitat with high rates of fledgling success (Anich et al. 2011). In one red pine stand in Adams County, Wisconsin, eight Kirtland's warbler nests produced 33 young (4.1 fledgling/nest) (Anich et al. 2011), productivity comparable to or exceeding nesting success in jack pine habitats (Probst and Hayes 1987).

Red pine is a commercially valuable species in the US Lake States, planted on more than 200,000 ha in Michigan alone (Abella 2010). More shade intolerant than jack pine (Rudolph 1990), red pine is valued for its capacities for rapid growth, uniform wood characteristics, high yields and excellent pulping qualities (Johnson and Rogers 1995). Although harvests from jack pine stands can yield substantial revenue (MDNR et al. 2014:3), red pine stands generally have higher economic value which can be produced through shorter rotations, and revenue from their harvests could be directed to fund management and recovery activities for Kirtland's warblers, as has been previously proposed for jack pine (MDNR 2104:3). When both ecological and economic elements are considered, there is warrant to evaluate red pine as a potential complement to jack pine as breeding habitat for Kirtland's warblers.

From 2016-2018, the MDNR, in partnership with the AIES, will establish 2,200 acres that will provide suitable KW nesting habitat for at least 20 years. Approximately, 1,650 acres will be planted to jack pine and 550 acres to a mixture of jack and red pine. Jack pine and jack pine-red pine stands will, in some cases, be created in isolation from one another and, in other cases, adjacent to one another. Existing stands of jack pine and red pine potentially suitable for breeding habitat for Kirtland's warbler with similar structural characteristics will also be monitored by AIES for the purpose of evaluating Kirtland's warbler and vegetation response to this habitat management.

Questions answered by this study will be (1) does Kirtland's warbler breeding success differ in jack pine, red pine, and mix of jack/red pine of equivalent size; (2) does juxtaposition of jack pine, red pine, and a mix of jack/red pine habitat create changes in use and breeding success of Kirtland's warblers; and (3) are there differences in structural and understory characteristics of jack pine, red pine, and mixed jack/red pine habitats associated with differences in breeding success of Kirtland's warblers?

Stands will be surveyed from 31 May through 30 June each year from 2016 through 2018. Surveys will determine densities of singing male Kirtland's warblers. Areas surrounding singing males will be searched for active nests which will be monitored to determine clutch initiation, hatching, and fledging dates. To determine differences in understory vegetation in each stand type, understory vegetation will be sampled in five 50 m X 50 m non-overlapping plots, ("macroplots") established on each sampled site with transects placed in each macroplot at random intervals. Understory plant species composition and percent cover will be determined from microplots placed randomly along transects. Densities and reproductive success of Kirtland's warblers in different stand types will be evaluated through repeated measures multiple ANOVA, with age of stand, stand type (jack pine, red pine, or mixed) as independent variables. Understory plant communities in different stands will be similarly compared with different but appropriate analytical techniques.

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