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

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Final Report

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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 begin 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

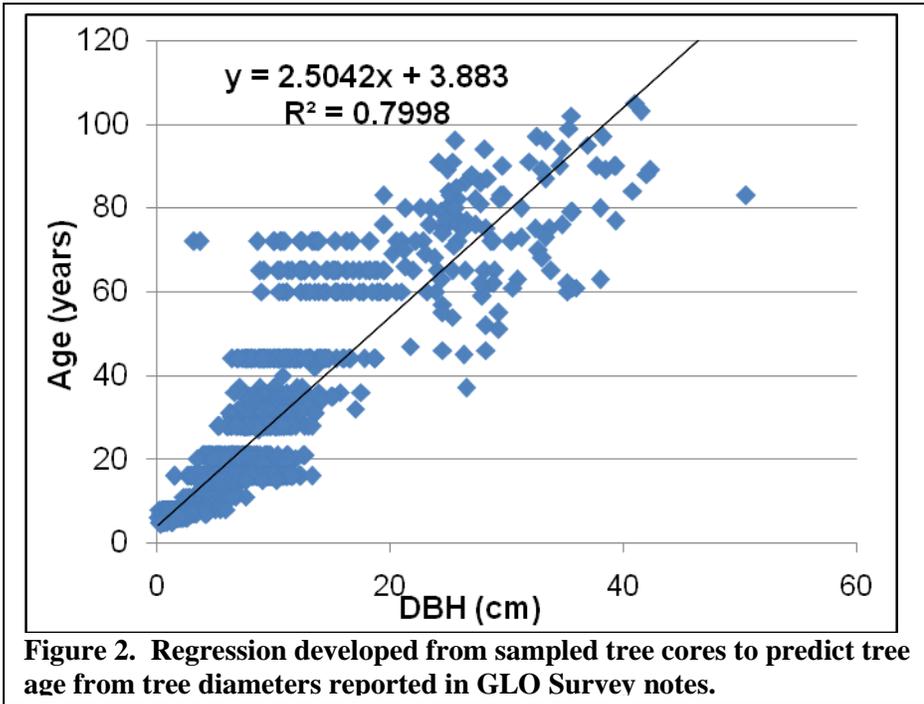


Figure 2. Regression developed from sampled tree cores to predict tree age from tree diameters reported in GLO Survey notes.

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

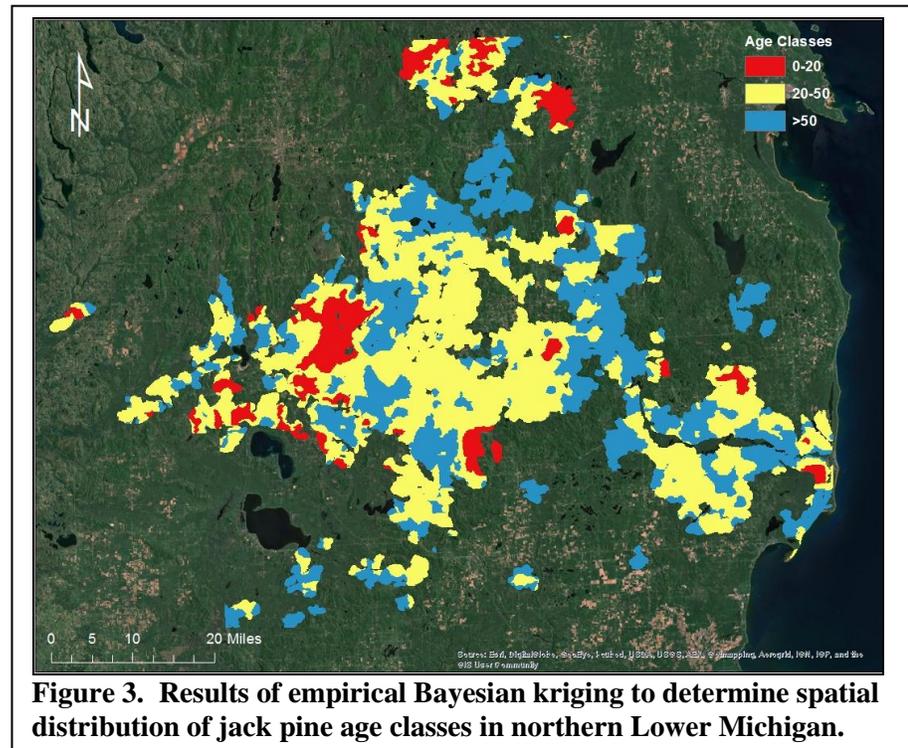


Figure 3. Results of empirical Bayesian kriging to determine spatial distribution of jack pine age classes in northern Lower Michigan.

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.

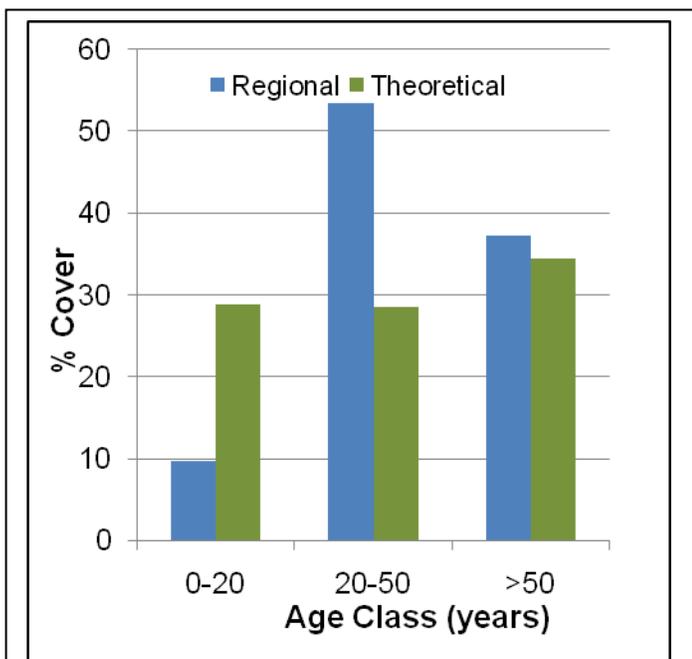


Figure 4. Comparison of van Wagner’s theoretical distribution with the estimated age distribution of pre-European jack pine for northern Lower

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.

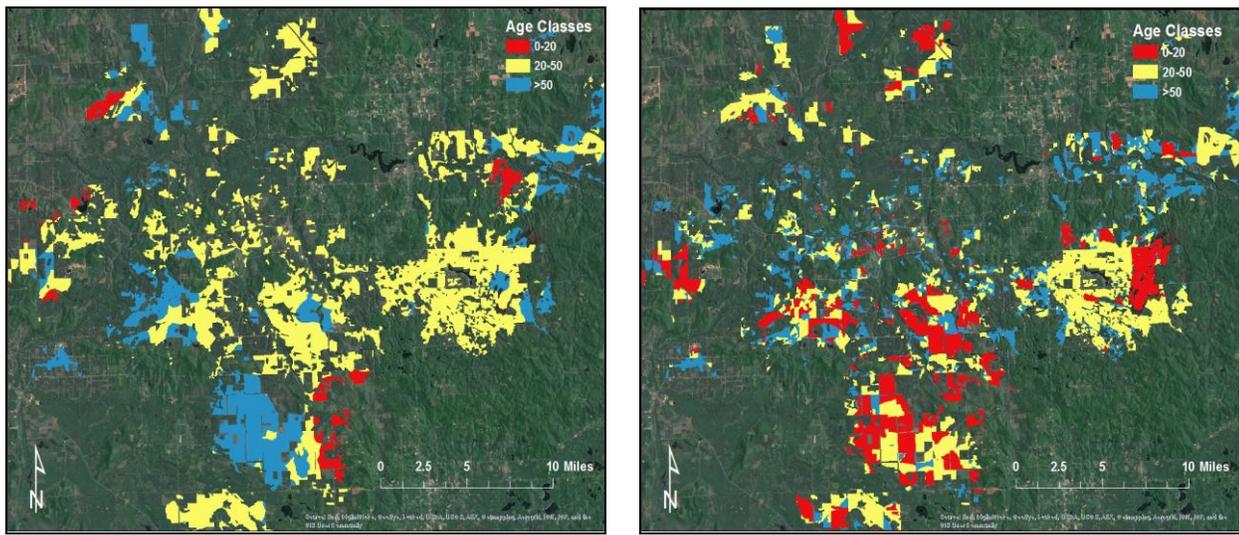


Figure 5. Stand age distribution of jack pine for pre-European (left) and current (right) landscapes in northern Lower Michigan. Red polygons indicate jack pine in the 0-25 year age class, suitable for KW breeding habitat.

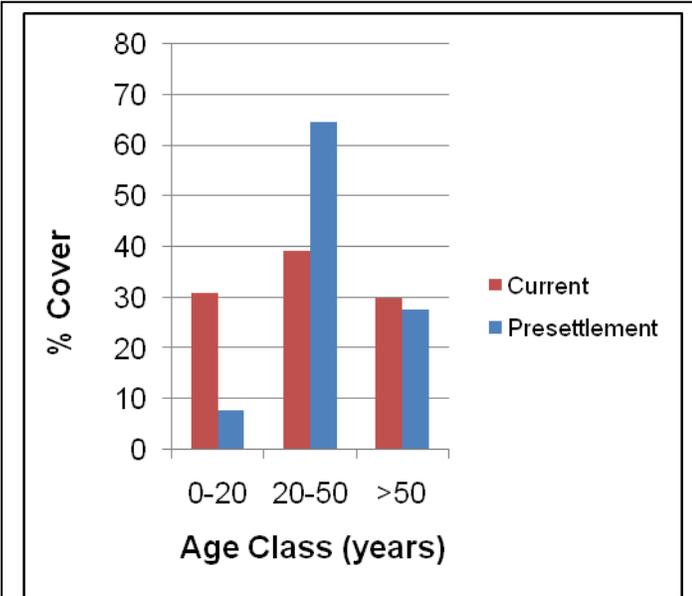


Figure 6. Comparison of current and pre-European coverage of jack pine within KW management

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-m² 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-m² 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-m² 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>