G Model
JNC-25340; No. of Pages 16

ARTICLE IN PRESS

Journal for Nature Conservation xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Journal for Nature Conservation

journal homepage: www.elsevier.de/jnc

Habitat availability for multiple avian species under modeled alternative conservation scenarios in the Two Hearted River watershed in Michigan, USA

Kristina Nixon[a,*], Janet Silbernagel[a], Jessica Price[a], Nicholas Miller[b], Randy Swaty[c]

[a] University of Wisconsin at Madison, The Nelson Institute, 550 North Park Street, Madison, WI 53706, USA
[b] The Nature Conservancy, Wisconsin Field Office, 633 West Main Street, Madison, WI 53703, USA
[c] The Nature Conservancy, Global Fire Team, 109 West Baraga Street, Suite B, Marquette, MI 49855, USA

ARTICLE INFO

Article history:
Received 22 September 2013
Received in revised form 11 February 2014
Accepted 19 February 2014

Keywords:
Conservation effectiveness
Forest scenario analysis
Forest management strategies
Habitat assessment
Landscape change
Multiple species
Spatial pattern

ABSTRACT

Due to differences in the responses of species to changing landscape patterns, developing a conservation plan with an optimal outcome of supporting contrasting habitat needs can be difficult. Landscape scenario modeling can provide a means to compare alternative conservation strategies and can reveal tradeoffs of managing for one objective versus another. In order to evaluate the impacts of alternative conservation strategies in a 53,653 ha landscape in Michigan's Upper Peninsula, four scenarios of alternative conservation strategies were modeled 100 years into the future using the VDDT®/TELSA® spatial model suite, and habitat availability was evaluated for five target bird species of local conservation concern under each scenario. The target species were *Dendroica fusca* (Blackburnian Warbler), *Picoides arcticus* (Black-backed Woodpecker), *Dendroica kirtlandii* (Kirtland's Warbler), *Buteo lineatus* (Red-shouldered Hawk), and *Scolopax minor* (American Woodcock). Scenarios were ranked based on relative performance of three habitat metric results (total primary habitat area, average size of habitat patches, and average distance to the nearest neighboring habitat patch) for each species. The final overall rank for each scenario was generally related to harvest intensity; the scenario with the smallest total area of even-aged management ranked the highest. Ranks were not consistent across all response variables. Relative species sensitivity was also evaluated, and the ranks did not match expectations, with the more habitat generalist species showing the highest sensitivity and the most specialist species showing the lowest. The approach here provides a means of projecting and comparing potential long-term impacts of alternative landscape strategies on diverse wildlife habitats. These results, when considered with budget considerations and species' habitat area and population goals, can assist local managers and stakeholders in conservation planning by identifying tradeoffs and compromises aimed at optimizing protection for a variety of target species.

Introduction

As conservation strategies increasingly span large geographic areas and often involve multiple land owners, it is important to understand and anticipate impacts of various management strategies over broad spatial and temporal scales in order to achieve resource and conservation goals (Jin et al. 2010; Price et al. 2012; Shifley et al. 2008; Zollner et al. 2008). For example, the unit area, intensity, and return interval of forest management activities affect the availability of habitat for wildlife species by influencing stand composition and landscape pattern (Jin et al. 2010; Scolozzi & Geneletti 2011; Shifley et al. 2006; Zollner et al. 2008). The ability to project, visualize, and assess the impacts of alternative scenarios of management activities and natural disturbances could benefit the understanding of how long-term forest management strategies affect biodiversity and could aid in conservation planning.

Loss and fragmentation of habitat are two of the greatest threats to biodiversity in forest landscapes (Ohman et al. 2011), and the importance of fragmentation, edge effects, and corridors for species survival and reproductive success have been widely discussed in scientific literature (Knowlton & Graham 2010; Venier et al. 2007). In conservation and metapopulation theories, it is generally accepted that larger and more connected patches can support greater species richness as well as population abundance and

* Corresponding author. Tel.: +1 2188302447.
E-mail address: kristi.nxon@gmail.com (K. Nixon).

http://dx.doi.org/10.1016/j.jnc.2014.02.005
1617-1381/

persistence than smaller, isolated ones (Prugh et al. 2008). Larger patch sizes may reduce a population's probability of extinction by supporting larger population sizes, enabling greater colonization rates, and reducing edge effects and predator invasions (Etienne et al. 2004; Shanahan et al. 2011). Greater patch connectivity may enhance dispersal success, colonization, and population interchange, especially for rare and specialist species in degraded or fragmented landscapes (Davies et al. 2000; Knowlton & Graham 2010; Shanahan et al. 2011). Consequently, conservation plans should consider not only the amount and quality but also the spatial configuration of suitable habitat in the landscape, including properties such as patch size, shape, and connectivity (Larson et al. 2004; Rittenhouse et al. 2007; Shifley et al. 2006; Venier et al. 2007).

Due to the differences in species' responses to landscape patterns, planning an optimal strategy in the face of contrasting habitat needs can be difficult (Gottschalk et al. 2010; Monkkonen et al. 2011; Watts et al. 2010; Zollner et al. 2008). This difficulty explains the tendency of researchers to perform single-species habitat or population assessments or use landscape pattern metrics as proxies for multiple species representation (Edenius & Mikusinski 2006; Nicholson & Possingham 2006; Venema et al. 2005). A suite of species which are sensitive to differing threats can represent the diversity of spatial, compositional, and functional attributes that are of conservation concern in a landscape (Edenius & Mikusinski 2006; Mace et al. 2007; Scolozzi & Geneletti 2011). Landscape modeling may reveal which species among a suite of species, in terms of habitat availability, might be more sensitive to alternative management strategies or landscape changes and therefore may require special or urgent consideration in management planning.

Considering the vast amount of time and resources needed for long term monitoring at broad spatial and temporal scales, landscape simulation models and GIS technologies offer a convenient method of evaluating potential effects of long-term management strategies in landscapes and enable a more timely flow of information to inform management decision making (Ferrier & Drielsma 2010; Jin et al. 2010; Shifley et al. 2006, 2008; Zollner et al. 2008). In recent years, several spatially explicit landscape modeling programs have been developed, used in forest planning, and reviewed (Barrett 2001; Jin et al. 2010; Larson et al. 2004; Mladenoff 2004; Scheller & Mladenoff 2007; Shifley et al. 2008). These models have the ability to simulate forest successional dynamics over long time periods and project future conditions of the landscape. When local knowledge from various stakeholders is incorporated into the modeling through a collaborative process, more plausible outcomes may be realized (Price et al. 2012).

The ability to model alternative scenarios and analyze future landscapes provides a means of assessing potential changes in habitat availability and comparing the potential effectiveness of conservation strategies. Such comparisons could benefit managers who are interested in the impacts of their decisions, provide insight into how and where habitat management could be improved, and allow more adaptive planning.

Our partners at The Nature Conservancy (TNC) were particularly interested in comparing the long-term conservation effectiveness of working forest conservation easements and fee simple ownership of land in the Two Hearted River watershed, a 53,653 ha forested landscape in Michigan's Upper Peninsula. The purpose of working forest conservation easements is to keep land productive while preventing subdivision and fragmentation of land, thus being beneficial for habitat conservation. Since property is not fully purchased, easements are a less costly strategy up front than fee simple acquisition, potentially allowing conservation efforts and resources to be more broadly distributed across a landscape (Silbernagel et al. 2011). They provide tax relief to the land owners and generally allow resource extraction (e.g. sustainable timber harvesting), thus contributing to the local economy. However, they require long-term monitoring and enforcement and may carry added transaction costs of working with multiple landowners and unique ecological conditions (Fishburn et al. 2009; Merenlender et al. 2004). It is not known whether easements can provide the same level of biodiversity protection as acquiring land under fee simple ownership (Fishburn et al. 2009; Merenlender et al. 2004), which may also require continuous human and financial resources to manage the land into the future. Without long-term ecological monitoring, the effectiveness of these strategies, or any conservation strategies that attempt to balance resource extraction with conservation, remains unclear, and there is little evidence that can inform future acquisitions and help gain public and financial support in favor of certain strategies (Rissman et al. 2007; Silbernagel et al. 2011).

To evaluate the potential long-term impacts of four alternative conservation scenarios on habitat availability for five diverse bird species of concern in the Two Hearted River watershed, we performed habitat assessments on the spatial output of 100-year forest landscape models. The scenarios represented current-day management as well as three alternative hypothetical management strategies across the landscape, each informed by the management goals and practices of major forest landowners in the area (Fig. 1). The four scenarios were: A) current management scenario (Current scenario), B) no conservation action (NCA) scenario, C) working forest conservation easement scenario (Easement scenario), and D) ecological forestry scenario (Ecological scenario). Each scenario simulated different amounts, intensities, and general spatial characteristics of forest harvest activities. The Ecological scenario contained the greatest area of TNC managed land, and we expected this scenario to be the most beneficial for target species because of its emphasis on restoration and conservation of native and old-growth habitat, cooperative and broad-scale nature of management, and low amount of even-aged timber harvest. The NCA scenario, on the other hand, contained the largest area of industrially managed private lands, and we expected it to be the least beneficial for target species due to its nature of having a high amount of productivity-driven even-aged harvest, as well as a great number of land owners acting independently in the landscape, resulting in spatially fragmented management. In the Easement scenario, current-day TNC fee title lands were instead placed under a working forest conservation easement, which allows even-aged harvest but restricts subdivision of land and thus provides a spatially aggregated management outlook. We expected this scenario to be more beneficial than the NCA scenario, but not as beneficial as the Ecological or Current scenarios.

In an attempt to identify an optimal scenario, we developed a scoring system to rank scenario outcomes based on three metrics of habitat availability: 1) total area of habitat, 2) average size of habitat patches, and 3) average distance to nearest neighboring habitat patches for each target species. We hypothesized that 1) all of the habitat metric response variables would be significantly influenced by scenarios representing alternative management strategies over 100 years; 2) scenarios with smaller total area of even-aged timber harvest would provide the most beneficial habitat conditions for species overall; and 3) species that have more specific habitat requirements such as a limited number of preferred cover types, a large patch size requirement, or require proximity to additional necessary habitat elements would be the most sensitive to alternative scenarios.

Methods

Study Area and Scenario Modeling

The "Forest Scenarios" project team, based at the University of Wisconsin at Madison, has built a set of spatial landscape

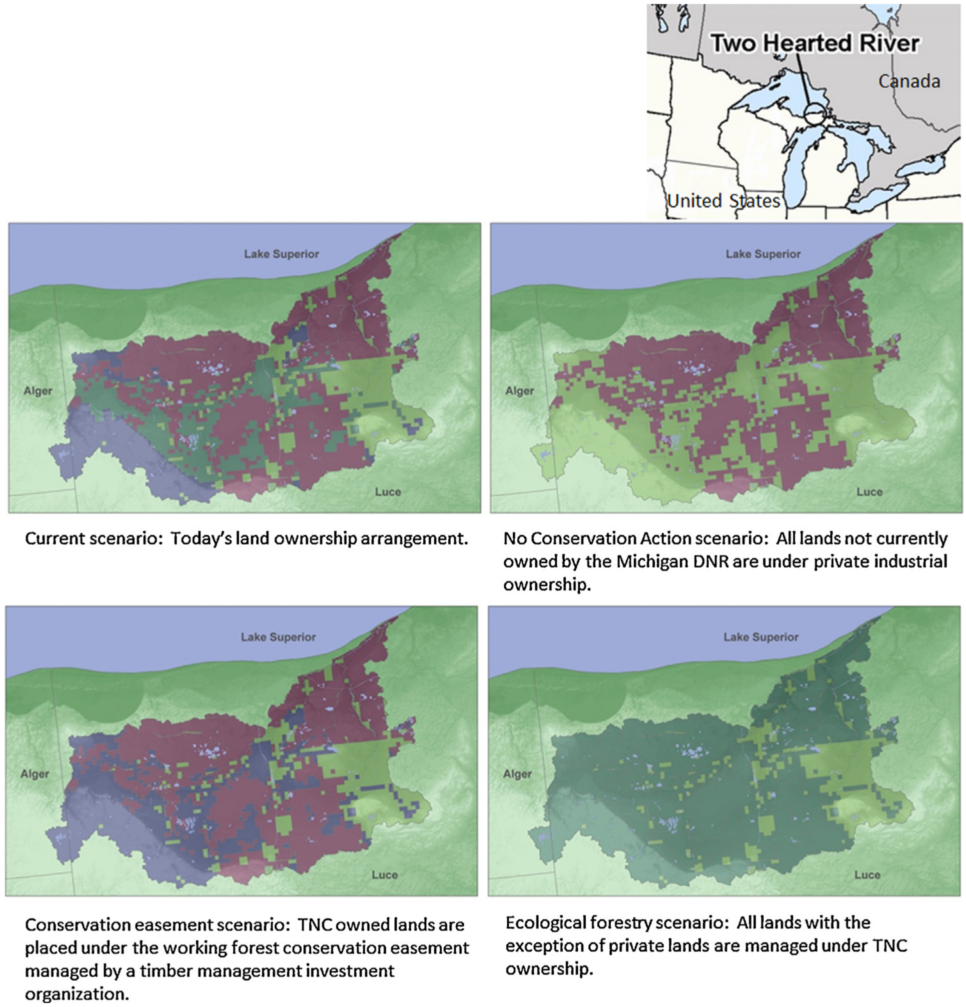

Fig. 1. The management boundaries under four alternative scenarios for the Two Hearted River watershed in Michigan's Upper Peninsula. In all maps, purple represents Michigan Department of Natural Resources (DNR) management, blue represents lands managed under a working forest conservation easement, dark green represents lands managed by The Nature Conservancy (TNC), and light green represent lands managed by private industrial forest operators.

simulation models for the Two Hearted River watershed, a 53,653 ha forested landscape in the northeastern region of Michigan's Upper Peninsula (46–42′06′′ N and 085–24′52′′ W). This landscape contains a mixture of upland hardwood forests, pine stands, coniferous forests, and interspersed wetland systems (Table 1). Together, the Michigan Department of Natural Resources (DNR), The Nature Conservancy (TNC), and a timber investment management organization (TIMO) which owns and manages land under a working forest conservation easement held by The Nature Conservancy, own 80% of the watershed. The remaining 20% is held in small private ownerships. Each ownership holds a unique set

Table 1
Percentages of LANDFIRE biophysical setting (BpS) classes in the 53,636 ha Two Hearted River watershed land cover map.

Biophysical setting	Percentage of the landscape
Boreal Acid Peatland	17.46%
Alkaline Conifer Hardwood Swamp	16.27%
Jack Pine Barrens and Forest	7.29%
Northern Hardwood	16.34%
Northern Hardwood Hemlock	15.45%
Pine Hemlock Hardwood	4.97%
Northern Pine Oak Forest	20.45%
Shrub Herbaceous Wetland	1.77%

Table 2
Management parameters for the four different conservation scenarios aggregated to the landscape level to show annual activity maximum area totals. Parameters were entered into the TELSA® (Tool for Exploratory Landscape Analysis) Spatial Model to be run for 100 years.

Scenario	Activity maximum area (ha/year)				Total managed (ha)
	Thinning	Clearcut	Selection cut	Restoration	
Current	923 for years 1–25; 819 for years 26–50; 715 for years 51–100	429	171 for years 1–20; 789 for years 21–100	60	2129 for years 1–20; 2210 for years 21–25; 2106 for years 26–50; 2002 for years 51–100
NCA	1119	476	871	0	2466
Easement	1089	452	803	57	2401
Ecological	208	249	1006	202	1665

Please cite this article in press as: Nixon, K., et al. Habitat availability for multiple avian species under modeled alternative conservation scenarios in the Two Hearted River watershed in Michigan, USA. *Journal for Nature Conservation* (2014), http://dx.doi.org/10.1016/j.jnc.2014.02.005

of management objectives and activities, including even-aged and uneven-aged timber harvest, as well as restoration activities that maintain and restore forest health. The area, return interval, and spatial arrangement of each management activity was defined and translated into model parameters with the guidance of local experts (Table 2). Refer to Price et al. (2012) for a complete description of the modeling process including the incorporation of local expert and stakeholder knowledge and opinion. In each of the four conservation scenarios, the spatial arrangement of management regimes (labeled as the ownership from which information was gathered) on the landscape was altered (Fig. 1). The Vegetation Dynamics Development Tool and Tool for Exploratory Landscape Analysis (VDDT®/TELSA®) modeling suite (ESSA Technologies, Ltd) were used to model landscape changes over time. VDDT is a non-spatial state and transition model in which the user defines succession, management, and disturbance pathways and transition probabilities and their effects on land cover types. These models developed in VDDT, along with land cover and management boundary maps, serve as input for TELSA, a spatially explicit landscape modeling interface that operates as an extension in ArcMap™. Within TELSA, spatial parameters which include the minimum and maximum area of individual management and natural disturbance events, as well as the total annual area of management activity occurrence, were defined. Together, VDDT and TELSA simulate forest dynamics over time to project future land cover conditions (Beukema et al. 2003; Kurz et al. 2000). We adapted existing Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) Biophysical Setting (BpS) vegetation dynamics models (LANDFIRE 2007), which define successional pathways and probabilities of natural disturbances (i.e. fire and wind), to capture local forest dynamics based on principles of forest and landscape ecology and incorporated knowledge from local experts (Price et al. 2012).

Compass Land Consultants Inc., a local timber management organization, partnered with The Nature Conservancy (TNC) to create a ground-truthed land cover map of the Two-Hearted River watershed, classified according to LANDFIRE's nation-wide biophysical settings and state class scheme (LANDFIRE 2007). Since the map reflected land cover conditions at the year 2000, it was updated to reflect the baseline land cover of the year 2010 by first manually changing the attributes of specific major locations that were known to have been managed from the year 2000 to 2010. Then, the model was run with only natural disturbance for ten years to capture the random spatial dynamics of natural disturbances.

Each scenario simulated 100 years of landscape dynamics, from the year 2010 to the year 2110, and output land cover maps were produced at defined years of 2010 (present year), 2060, and 2110. Ten Monte Carlo repetition simulations were performed for each scenario to capture variability of stochastic natural disturbance events in the model.

It was assumed that conditions were static in the landscape model. For instance, resource demands and harvest goals, as well as the occurrence probabilities of natural disturbance events, remained constant over the 100 year simulation period. We were aware that climate change may alter the frequency and intensity of weather events in the future (Opdam and Wascher 2004). The Forest Scenarios team has also modeled climate change scenarios in this landscape (Price et al. 2012), but these were excluded from this study for the purpose of focusing solely on differences between management regimes.

Target species and habitat assessment

The target species were selected from a list of species of concern developed with input from local managers and researchers during multiple in-person workshops (Price et al. 2012). We drew species habitat information from local or regional studies, species management plans and reports by state and federal natural resource management agencies (e.g. U.S Fish and Wildlife Service, State Departments of Natural Resources), and expert opinion. Many of the studies were found using the NatureServe explorer web application (NatureServe 2013). Habitat information was used to determine habitat composition and configuration characteristics deemed important to the species' life history and survival. Some important habitat characteristics included forest stand composition, age, and canopy cover, while important habitat configuration characteristics included minimum patch size, buffer distance to edge habitat, and minimum distance to other necessary landscape elements.

Assumptions had to be made about the transferability of non-local habitat studies and information to this study location. Although models can reveal areas of potential suitable habitat, they cannot predict the presence of the species in those locations without validation.

We selected target species that had relatively specific habitat requirements and altogether represented diverse cover types and seral stages. In effect, we intended to represent diverse suites of other species from the list with similar or less stringent habitat requirements that could not be included. The target species were: (1) *Dendroica fusca* (Müller, 1776) (Blackburnian Warbler), (2) *Picoides arcticus* (Swainson, 1832) (Black-backed Woodpecker), (3) *Dendroica kirtlandii* (Baird, 1852) (Kirtland's Warbler), (4) *Buteo lineatus* (Gmelin, 1788) (Red-shouldered Hawk), and (5) *Scolopax minor* (Gmelin, 1789) (American Woodcock). Species' habitat requirements are summarized in Table 3. Blackburnian Warblers have a small habitat area requirement and require interior forest and presence of mature, closed canopy conifer or mixed stands. Black-backed Woodpeckers require conifer deadwood primarily found in mature stands and have a relatively large home range. Kirtland's Warblers are specialists of 5–20 year-old jack pine stands. Red-shouldered Hawks are predatory birds that require large tracts of mature deciduous forest with proximity to water and openings in which to hunt. American Woodcocks are ground dwellers that feed on invertebrates in moist soil in young deciduous forests and require proximity to openings in which to roost at night. See Nixon (2012) for more detailed species descriptions and habitat requirements. Using geoprocessing tools within ArcMap™ 10 (ESRI 2011), we classified the landscape output maps into primary habitat, secondary habitat, and non-habitat classes for each species based on species habitat requirements. Primary habitat was defined as areas that could support a breeding pair or a brood, while secondary habitat was defined as additional landscape features required for cover or forage. For the primary habitat class, total area, average patch size, and distance from each patch to its nearest neighbor (nearest neighbor distance) were calculated using the 8-neighbor rule in Fragstats (McGarigal et al. 2012). To visualize potential species habitat resulting from each scenario, maps showing available habitat as well as gains and losses for each species were created in ArcMap™ using the first Monte Carlo simulation as an example.

Statistical analysis and scenario ranking

To characterize primary habitat composition and configuration for each species, the average and standard deviation of the results of 10 Monte Carlo repetitions for each scenario at each time step (2010, 2060, and 2110) were calculated for total area, patch size, and distance to the nearest neighboring patch metrics. For the 2110 maps, we ran analyses of variance (ANOVA) using R (R Development Core Team 2011) to test the influence of alternative scenarios on each habitat metric. We used the Tukey's honestly significant difference post hoc test (HSD) (R Development Core Team 2011) to test for significant differences between pairs of scenario means at

Table 3
Summary of species habitat requirements.

Target species	Cover type	Minimum core area (primary)	Minimum buffer distance to edge (unsuitable)	Proximity requirements
Dendroica fusca (Blackburnian Warbler)[a]	Approx. ≥18 m tall conifer trees in ≥60 years old mature conifer or mixed stands. Canopy closure ≥ 80%.	1 ha	91 m (100 yards)	
Picoides arcticus (Black-backed Woodpecker)[b]	Conifer or mixed stands ≥90 years old (preference for areas disturbed within 5 years not included in this model)	100 ha recommended		
Dendroica kirtlandii (Kirtland's Warbler)[c]	5–20 year old jack pine	32 ha		
Buteo lineatus (Red-shouldered Hawk)[d]	Canopy closure ≥70% with approx. ≥24 m tall deciduous trees in mature deciduous or mixed stands.	101 ha (250 acres) recommended	91 m (100 yards) from human disturbance	800 m from open water or wetland for forage opportunities
Scolopax minor (American Woodcock)[e]	Early-mid successional deciduous stands	Feeding habitat: 2.02 ha (5 acres). Roosting fields: 2.02 ha (5 acres).	Prefers edge	800 m from openings used for roosting

[a] Doepker et al. (1992); GLBC (2006); Meiklejohn and Hughes (1999); Morse (1971, 1976); Niemi and Hanowski (1992); Sargent and Carter (1999b); USFWS (2002); WBCI (2012a); Webb et al. (1977).
[b] Corace et al. (2001); Tremblay et al. (2010).
[c] Meyer (2010); MIDNR (2012a, 2012b); Probst et al. (2003); USFWS (2012).
[d] Cooper (1999); Craighead and Craighead (1956); Jacobs and Jacobs (2000, 2002); King et al. (2011); McKay et al. (2001), Postupalsky (1989); WBCI (2012b).
[e] Sargent and Carter (1999a); WMI (2008, 2009).

year 2110 using a significance level of 0.05. To determine the relative performance of each scenario, we ranked the scenarios using a scoring system based on the results of the Tukey's test of significant differences between scenario means. In this ranking system, each scenario received one point for every other scenario it surpassed in performance based on having significantly more total habitat area, larger average patch size, and closer average nearest neighbor distance. In effect, higher scores were given to scenarios with habitat metric results that represented more favorable habitat conditions. We summed the points across all species and habitat metrics to determine a final overall performance ranking of each scenario. Also, points were summed for each species to determine their relative score contribution, which can be interpreted as their sensitivity to the alternative conservation scenarios.

Results

All species

The amount and configuration of primary habitat patches differed significantly ($P<0.05$) across alternative scenarios for all species (Appendix, Table 2). Total habitat area decreased after 100 years for all species in all scenarios with the exception of the Ecological scenario for the Black-backed Woodpecker and the Red-shouldered Hawk. The results of the relative ranks scoring method revealed that the Ecological scenario ranked the highest, followed by the Current scenario, the Easement scenario, and finally the NCA scenario (Table 4). Average habitat patch size similarly decreased after 100 years for all species in all scenarios except the Ecological scenario for the Black-backed Woodpecker and the Easement scenario for the Red-shouldered Hawk. The scores for the average patch size metric revealed that the Easement scenario ranked the highest, while the Current and NCA scenarios ranked the lowest (Table 4).

The average nearest neighbor distance results varied across species. While average distance decreased in all scenarios for the Red-shouldered Hawk and American Woodcock, it increased in all scenarios for the Kirtland's Warbler. For both the Blackburnian Warbler and the Black-backed Woodpecker, average distance increased in the Easement and NCA scenarios and decreased in the Current and Ecological scenarios; the changes since 2010 were relatively small for the Blackburnian Warbler. The Ecological scenario received the highest rank, while the Easement scenario received the lowest (Table 4).

The overall ranking of scenarios at 2110 was based on the summed scores across all response variables. The Ecological scenario ranked the highest, followed by the Current and Easement scenarios, which tied, and finally the NCA scenario. The Ecological scenario did not receive the highest rank for the average patch size metric. It also ranked the lowest for all three variables for the American Woodcock.

The points contributed by each species were summed across the three metrics (Table 4). The Blackburnian Warbler contributed the most points, the Kirtland's Warbler contributed the least, and the remaining three species contributed similar amounts of points.

Individual species

Blackburnian Warbler

The total habitat area for the Blackburnian Warbler decreased in all scenarios from over 21,000 ha in 2010, ranging from an average of almost 18,000 ha (15.35% decrease) in the Ecological scenario to an average of about 11,000 ha (47.13% decrease) in the Easement scenario (Fig. 2). In the Current and NCA scenarios, area decreased to about 16,000 ha and about 12,000 ha, respectively. Total habitat area was significantly different between all scenarios at year 2110. Average patch size decreased from nearly 77 ha in 2010 in all scenarios by 2110, ranging from an average patch size of about 28 ha in 2110 in the Current scenario to about 18 ha in the NCA scenario (Fig. 2). In the Easement and Ecological scenarios, size decreased to about 20 ha and about 25 ha, respectively. Average patch size was significantly different between all scenarios at year 2110. Average nearest neighbor distance did not change considerably over time within each scenario, although all scenario results were significantly different from each other at 2110 (Fig. 2). Only the Ecological scenario saw decreased average distance of about 117 m in 2110 compared to about 130 m in 2010. Average distance increased to about 150 m in the Easement scenario, to about 137 m

Table 4
Scored results of the four simulated scenarios at model year 100 based on comparisons of the outcomes of three habitat metric response variables for five target species. Scenarios received one point for every scenario that it surpassed in performance based on the Tukey's HSD test at a significance level of 0.05. Higher scores reflect more favorable habitat conditions. Tests were based on ten Monte Carlo model runs per scenario. Species contribution is the sum of points across the scenarios for each species and implies sensitivity to alternative scenarios.

					Species contribution
Total habitat area	Current	NCA	Easement	Ecological	
Blackburnian Warbler	2	1	0	3	6
Black-backed Woodpecker	2	0	1	3	6
Kirtland's Warbler	1	0	1	1	3
Red-shouldered Hawk	2	0	1	3	6
American Woodcock	1	2	3	0	6
Sub-total	8	3	6	10	
Average patch size					
Blackburnian Warbler	3	0	1	2	6
Black-backed Woodpecker	0	0	0	3	3
Kirtland's Warbler	0	0	1	1	2
Red-shouldered Hawk	0	2	3	0	5
American Woodcock	1	2	3	0	6
Sub-total	4	4	8	6	
Average nearest neighbor distance					
Blackburnian Warbler	2	1	0	3	6
Black-backed Woodpecker	1	1	0	2	4
Kirtland's Warbler	0	0	1	1	2
Red-shouldered Hawk	1	0	1	1	3
American Woodcock	0	2	0	0	2
Sub-total	4	4	2	7	
Total	16	11	16	23	
Total species contribution					
Blackburnian Warbler	18				
Black-backed Woodpecker	13				
Kirtland's Warbler	7				
Red-shouldered Hawk	14				
American Woodcock	14				

in the NCA scenario, and remained nearly the same in the Current scenario.

Black-backed Woodpecker

Total habitat area for the Black-backed Woodpecker declined over time in all scenarios except the Ecological scenario, which saw an increase from almost 14,000 ha in 2010 to over 21,600 ha in 2110 (Fig. 2). In the lowest ranked NCA scenario, total area dropped to about 5400 ha. In the Current and Easement scenarios, area dropped to about 9300 ha and about 6700 ha, respectively. Total habitat area was significantly different between all scenarios at year 2110. Average habitat patch size showed similar results to total habitat area, with only the Ecological scenario seeing increased average patch sizes from about 1300 ha to over 4000 ha in 2110 (Fig. 2). There was relatively large variability among the Monte Carlo simulations of the Ecological scenario patch size results ($s = 1307$ ha), possibly due to the lower amount of management activity and therefore more spatial variability of disturbance events in this scenario. The remaining three scenarios saw decreased average patch sizes. In the lowest ranking NCA scenario, average patch size decreased to just below 400 ha, while it decreased to just below 900 ha in the Current and Easement scenarios. Only the Ecological scenario result was significantly different from all other scenarios. Average nearest neighbor distance trends varied from 2010 to 2110 in all scenarios (Fig. 2). In the NCA and Easement scenarios, average distances increased to about 650 m and about 960 m, respectively, while in the Ecological scenario, average distance decreased to about 260 m. The Current scenario average distance did not change considerably since 2010, remaining at around 390 m. Average distance showed large variability in all scenarios, although there were significant differences between all scenarios at year 2110 except between the Current scenario and both the NCA and Ecological scenarios.

Kirtland's Warbler

All scenarios resulted in decreased total habitat area for the Kirtland's Warbler by 2110 (Fig. 2). The NCA scenario resulted in an average of about 83 ha in 2110, a reduction of 90.84% since 2010, and significantly less area than in the other three scenarios. The other scenarios resulted in between about 430 and 530 ha in 2110, compared to about 900 ha in 2010. Noticeably, the Easement scenario contained no suitable habitat in 2060, while habitat increased to over 1300 ha in 2060 in the Current scenario. Scenario outcomes for average patch size at 2110 were generally consistent with the total area results, with all scenarios having decreased patch sizes at 2110 (Fig. 2). The NCA scenario ranked the lowest, having an average patch size of about 44 ha in 2110. The remaining three scenarios resulted in smaller decreases since 2010, during which the average patch size was about 120 ha. The only significant differences between results were between the NCA scenario with the Easement and Ecological scenarios. Average nearest neighbor distance also showed similar trends, having increased distances in all scenarios (Fig. 2). The NCA scenario resulted in increased distance of over 6700 m in 2110, a 385% increase since 2010. Average nearest neighbor distance increased only slightly in the remaining three scenarios, ranging between about 1500 m in the Easement scenario to about 3000 m in the Current scenario. Large variability existed in all habitat metrics for the Kirtland's Warbler, and only results between the NCA scenario with the Easement and Ecological scenarios differed significantly at year 2110.

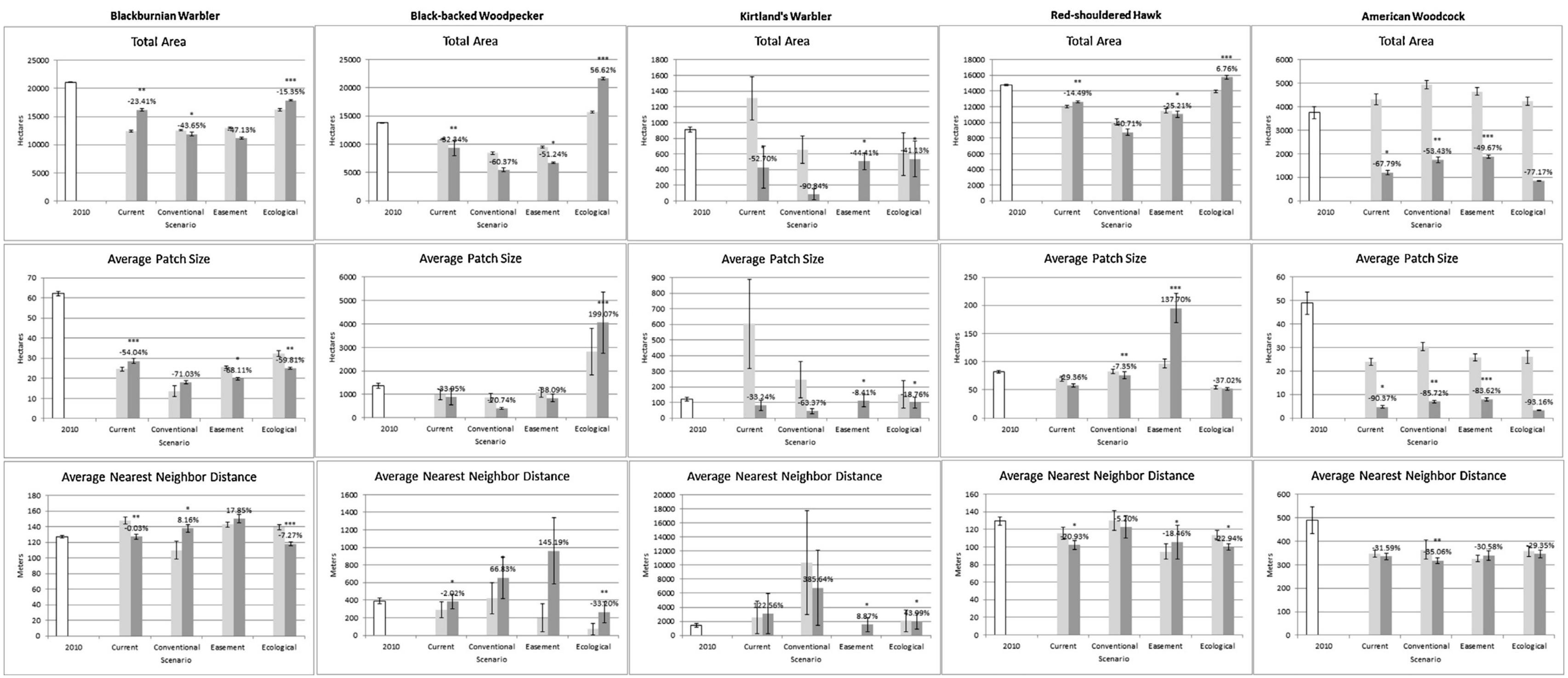

Fig. 2. Three habitat metrics results for the five target species in the Two Hearted River Watershed. Results are averages across ten Monte Carlo simulations in the study landscape at the present year (white bar), 50 years (light gray bar), and 100 years (dark gray bar) into the future under four alternative conservation scenarios. Error bars represent one standard deviation for results of ten Monte Carlo runs. Data labels in graphs indicate percent change from year 2010. Asterisks represent the number of scenarios that performed significantly worse than that scenario.

Red-shouldered Hawk

The scenario results of total primary habitat for The Red-shouldered Hawk ranged from the Ecological scenario, having about 15,700 ha, to the NCA scenario, having about 8700 ha (Fig. 2). Only the Ecological scenario saw increased area (6.67%) at year 2110. All scenario results of total primary habitat were significantly different from each other. Habitat area was lost from year 2010 to 2060 in all scenarios but changed relatively little from 2060 to 2110. Average habitat patch size decreased in all scenarios over time with the exception of the Easement scenario, which saw a large increase in size at year 2110 to about 195 ha compared to about 80 ha at year 2010 (Fig. 2). The Ecological scenario saw the greatest reduction in patch size to about 50 ha. The results were significantly different between all scenarios except between the Ecological and Current scenarios. Average patch nearest neighbor distance decreased in all scenarios by 2110, from nearly 130 m in 2010 (Fig. 2). The NCA scenario saw the smallest decrease in distance to about 122 m, which was significantly different from the remaining three scenarios, in which average distance decreased to about 100 m.

American Woodcock

At year 2060, all scenarios saw slightly increased total habitat area of about 6000 ha for the American Woodcock, but at 2110, all areas dropped to under 2000 ha (Fig. 2). The Ecological scenario resulted in the greatest loss of habitat to have about 850 ha, or about a 77% reduction, since 2010, while the Easement scenario resulted in the smallest reduction of 49.67%. The Current and NCA scenarios resulted in reductions of 67.79% and 53.43%, respectively. Total habitat area at year 2110 differed significantly between all scenarios. Average habitat patch sizes declined similarly to total habitat area (Fig. 2). Patch size gradually decreased over time in all scenarios, changing from about 50 ha to less than 10 ha from 2010 to 2110. The lowest ranking Ecological scenario saw a decrease in patch size of 93.16%, while the Easement scenario, the highest ranked, saw a decrease of 83.62%. The Current and NCA scenarios resulted in reductions of 90.37% and 85.72%, respectively. Average habitat patch sizes were significantly different between all scenarios at year 2110. Average nearest neighbor distance decreased from almost 500 m to about 300 m, with small changes between 2060 and 2110, and did not vary significantly between most scenarios (Fig. 2). Only the NCA scenario resulted in a significantly smaller distance than the Easement and Ecological scenarios.

Discussion

The habitat responses for all five target species in the Two Hearted River watershed varied greatly under alternative management scenarios. All three habitat metrics – total habitat area, average habitat patch size, and average habitat patch nearest neighbor distance – were significantly influenced by the alternative scenarios at model year 100, supporting the hypothesis that management strategies and alternative spatial arrangements of those strategies influenced these habitat characteristics for the five bird species.

Based on the ranking method that accounted for the three habitat metric response variables for five species at model year 100, the scenario rankings generally supported the hypothesis that scenarios with a smaller total area of even-aged management would rank the highest. The rankings generally reflected management activity intensity, particularly the amount of even-aged management (Tables 2 and 4). The Ecological scenario experienced the least amount of even-aged management, and it was the highest ranked. The Easement and Current scenarios experienced similar intermediate amounts of even-aged management, and they tied in rank, while the NCA scenario, which experienced the greatest amount of even-aged management, ranked the lowest. A similar conclusion emerged from Zollner et al. (2008), in which the scenario with the lowest amount of even-aged management had the most positive impacts on habitat for three diverse wildlife species, while the scenario in which the highest amount of even-aged management occurred had the least favorable outcome. Interestingly, in this study, the Current and Easement scenarios scored the same overall, which may imply that habitat for these target species would be similarly impacted if the current day TNC lands were placed under a working forest conservation easement or purchased by TNC. However, if the total habitat area metric was given more weight in the analysis, the Current scenario would rank higher than the Easement scenario, meaning that the fee simple purchase of lands by TNC would be more beneficial for the target species than placing those lands under the easement.

If total habitat area was the primary metric considered, the results would indicate that the purchase of lands by TNC may have positive impacts on habitat for the studied target species and that purchase of additional lands would further increase these impacts. This is seen by comparing the results of the Ecological scenario to the Easement and Current scenarios. In the Easement scenario, current-day TNC lands were placed under working forest conservation easements, and at year 2110, the Easement scenario ranked lower than the Current scenario in terms of total habitat area. The Ecological scenario contained more TNC-owned lands than the Current scenario, and it ranked the highest overall. It may be appropriate to give more weight to the total area metric considering its more direct importance over connectivity for mobile species such as birds.

One notable inconsistency in the results was the ranking of the scenarios for average habitat patch size. Although the Ecological scenario ranked the highest for two of the metrics, it ranked low for average habitat patch size. This may be cause for concern to emphasize retention of larger patch sizes. Interestingly, while the Easement scenario ranked highest in average patch size, it ranked lowest in average nearest neighbor distance (note that high average nearest neighbor distances resulted in low rankings). These two metrics may have been confounded by the variety in species patch size requirements (thus the variable sensitivity of species responses), as well as the random nature of how the TELSA® program places activities in the landscape and determines the size of the activity areas within a specified range. The average nearest neighbor results in particular contained relatively high variability.

Because of the general decline in habitat conditions seen in most scenarios at model year 100, there may be a need to consider applying additional strategies that retain old-growth structure and aggregated habitat areas, such as using longer harvest rotations, establishing old-growth reserves, and reducing harvest intensity. Although aggregated harvests have been suggested to reduce fragmentation, simulation studies suggest that both aggregated and dispersed harvest methods reduce the availability of old growth forest stands over time (Cooke & Hannon 2011).

Differences in scores for species sensitivity to alternative scenarios were small, indicating few potential tradeoffs in prioritizing certain species over others. The only species' responses that were generally opposed to the responses of the others were those of the American Woodcock, a species that prefers younger forest stands. Hence, choosing a scenario that is best for the most species may require separate concern to incorporate management for the American Woodcock. Other studies of multiple species habitat assessments in alternative landscape scenarios suggested similar contrasting species responses (Gottschalk et al. 2010; Jin et al. 2010; Wilhere et al. 2007; Zollner et al. 2008). In these studies, when no scenario was optimal for all species, many of the authors concluded that landscapes with high diversity of cover types and seral stages would provide for the most wildlife taxa.

Species sensitivity results did not support the hypothesis that certain species that have more specific habitat requirements would be more sensitive to alternative conservation strategies. The most sensitive species based on contributed points was the Blackburnian Warbler, while the least sensitive species was the Kirtland's Warbler. This outcome may imply that Blackburnian Warbler habitat is the most affected by management, and special consideration may be needed in order to avoid degrading rare habitat areas. Considering the Blackburnian Warbler had the greatest amount of habitat in this landscape, while the Kirtland's Warbler had the lowest and might be the rarest species, it would be misleading to assign priorities based solely on these sensitivity outcomes, especially if habitat for a species decreased in all four scenarios, as it did for the Kirtland's Warbler. In fact, if a species with low sensitivity to management also had sparse habitat, it may imply a strong need for habitat enhancement or restoration efforts.

It was hypothesized that the species requiring larger patch sizes would be the most sensitive to the alternative scenarios, these being the Red-shouldered Hawk and the Black-backed Woodpecker; however, these species scored similarly to the American Woodcock, which required a small patch size, and scored below the Blackburnian Warbler, which required the smallest patch size of all of the species. The proximity requirements for the American Woodcock and Red-shouldered Hawk likely raised sensitivity for those species, although they were not the most sensitive species.

Species sensitivity could also be based on the specialization of a species to a few habitat types. However, the Kirtland's Warbler, undeniably the most specialist of the species, was the least sensitive, while the Blackburnian Warbler, a relatively generalist species based on number of habitat cover types, was the most sensitive. The outcome for the Kirtland's Warbler was similar to that experienced by Zollner et al. (2008), who found no significant influence of alternative harvest scenarios on the warbler, as well as relatively high variation in the amount of the warbler's habitat. They explained that the reason for these outcomes was because Kirtland's Warblers are restricted to one habitat type, and that this habitat was not managed differently between alternative scenarios. This was also the case in this study.

Nearly all of the jack pine cover type required by the Kirtland's Warbler existed on current DNR lands, and these lands remained the same in all scenarios except the Ecological scenario; even in the Ecological scenario, the jack pine cover type was managed similarly as in the other scenarios. The lower sensitivity of the Kirtland's Warbler may also be explained by (1) the larger variability in the results due to the smaller amount of pre-existing habitat in the landscape (because of the small window of time in which Kirtland's Warbler habitat is available, changes may be extreme from decade to decade, especially since available habitat depends on disturbances to keep young stands occurring consistently) or (2) the already-perceived rarity of the endangered bird, motivating existing efforts to maintain habitat for the species. Special habitat management that favors the Kirtland's Warbler is currently being applied in several jack pine stands in the Two Hearted River watershed (Sherry MacKinnon, Michigan DNR, personal communication). In spite of its lower sensitivity, the Kirtland's Warbler had limited area in the landscape that was at risk of completely disappearing in certain years. If Kirtland's Warbler habitat would not exist in 2060, as the model revealed for one scenario, the probability of the population surviving and returning in subsequent years would be decreased. This case contributes to the importance of assessing habitat at intermediate time steps in the model.

Shifley et al. (2006) discovered that the modeled responses of two disturbance-dependent species were more sensitive to management alternatives, while two species associated with old growth forest displayed less variation among scenarios and therefore less sensitivity. Of the species in this study, the American Woodcock and the Kirtland's Warbler are disturbance-dependent species, yet the sensitivity outcome was not similar to Shifley et al.'s results. We wondered if this was due to the relatively small amount of pre-existing cover types for these two species in the landscape, lending toward greater variation in results and therefore lower significant differences between scenarios. Although the Kirtland's Warbler seemed to be impacted by this small amount of habitat, the results for the American Woodcock did not have much variability. This may imply that characteristics of management choices were a strong influence on the habitat results, which may explain the high sensitivity of the Blackburnian Warbler. In the parameters of all management schemes with the exception of the Private management in the NCA scenario, more even-aged harvest occured in conifer and mixed conifer cover types which are used by Blackburnian Warblers than in hardwood cover types.

Limitations and future directions

The outcomes of this study were reliant upon characteristics of the target species chosen, inherent characteristics of the landscape, including the amounts and locations of cover types, as well as characteristics of local management regimes. Therefore, the scenario outcomes may not be generalizable outside the study area.

Most predictive models carry some uncertainty which may accumulate with successive time steps. Additionally, it is difficult to anticipate changes in practices and environmental processes such as climate change that may occur in the future. The methods to evaluate the accuracy of model projections are often not validated (He et al. 2011; Scolozzi & Geneletti 2011); however, in the practice of conservation, it is often necessary to work with incomplete information in order to make a swift, transparent decision in response to an urgent issue (Nicholson & Possingham 2006), and objective-setting is an important step in applying science to policy (Tear et al. 2005). Decisions must be made about tradeoffs between model simplicity and comprehensiveness.

This study demonstrated that simple scoring models to prioritize species for conservation based on their sensitivity to management strategies may not produce expected results and should be examined carefully. Other factors that would be important to consider include species rarity and endemism, species perceived value, and species vulnerability to threats and climate change. Further testing of hypotheses relating to species sensitivity could be performed by theoretically and systematically altering variables related to these characteristics, which was beyond the scope of this study.

While objective modeling and analyses such as presented in this study are convenient and can aid in conservation decision making, additional factors may be important as well. Most prominently, long-term impacts of management on population size and density may vary for different species based on their behavior and life history traits (Thompson et al. 2003). Losing half of the habitat in a landscape may differentially impact a population of a smaller bird such as the Blackburnian Warbler compared to a population of the wider-ranging Red-shouldered Hawk, especially considering that the hawk is territorial. Habitat loss for wider-ranging birds could result in a significant population decline below a threshold level that would sustain a viable population. If specific habitat area or

Please cite this article in press as: Nixon, K., et al. Habitat availability for multiple avian species under modeled alternative conservation scenarios in the Two Hearted River watershed in Michigan, USA. *Journal for Nature Conservation* (2014), http://dx.doi.org/10.1016/j.jnc.2014.02.005

population targets were known, scenarios which reached these targets could be identified, and more objective comparisons and compromises could be made.

Establishing a relationship between habitat availability and population viability (species-area or population density-area relationship) may be beneficial and could inform minimum threshold levels of habitat area or population size that could ultimately be set as conservation targets (Ferrier & Drielsma 2010; Knowlton & Graham 2010; Larson et al. 2004). However, despite the convenience of inferring population size from reported natural population density-area relationships, there likely would be a lack of a direct relationship between habitat amount and population status or carrying capacity (Venier et al. 2007). Additionally, without initial population estimates for the Two Hearted River watershed, the uncertainty surrounding the assumptions precluded the use of simple species-area relationships in this study. Although it would be useful to incorporate population viability analyses or gap crossing models based on empirical data, the amount of time and resources needed to perform these analyses is a drawback. This also suggests why studies tend to have a single-species focus and that a limitation common to multi-species studies is their inability to address population viability (Jin et al. 2010; Nicholson et al. 2006; Scolozzi & Geneletti 2011; Zollner et al. 2008).

In any case, scenario optimization involves not only ecological considerations but also budget constraints. The scenario that is most beneficial for target species does not necessarily indicate the most efficient and optimal strategy, since the financial costs associated with implementing that strategy may be unfeasibly high. In a scenario study of various degrees of management modeled by Marzluff et al. (2002), three wildlife species benefited from forest maturation, yet the forgone revenues from timber harvest were substantial. A scenario with moderate management maintained some habitat with much less forgone revenue. Additional questions may need to be asked about trade-offs. Are there scenarios that would sufficiently maintain healthy populations while also supporting more harvest and recreational activities? Is it acceptable to lose local populations of certain species in order to lower risk of regional extinction for other species? Taken from the concept of conservation triage (Arponen 2012), is it worth allocating resources for a species that is close to becoming locally extinct if the feasibility and chance of success are low? Conservation planning that takes into account factors such as population viability, species rarity and recoverability, land purchase and management costs, timber revenue, and recreational and perceived intrinsic values would be a more comprehensive approach of balancing ecological, economic, and social goals than habitat assessment alone. The need to conduct such an approach can be addressed with further analyses such as population modeling, prioritization, optimization, and reserve design. With an optimal allocation approach, as described by Mace et al. (2007), one can determine how much funding to allocate to maximize a species recovery rate, as well as determine the threshold where additional funds would not result in further gains.

Conclusions and implications for conservation planning

The results in this study reveal that land management decisions will have significant and long term influence on the amount and configuration of habitat for diverse wildlife species in the Two Hearted River watershed and that strategies which are less economically-driven may have more advantages for wildlife. Although one scenario outranked others, it was not the most beneficial across all response variables, indicating a need to adjust for specific objectives and to use a combination of management approaches. Habitat and population status in the landscape and locational factors such as land ownership and potential for areas to improve connectivity of habitat should also be considered. Habitat for some species appeared to shift across current ownership boundaries over time, emphasizing a need for cross-boundary communication and collaboration. Additionally, the differences across species responses to alternative scenarios may make planning more difficult, and, as emphasized previously, a solution (or near-solution) relies upon specific conservation objectives.

The approach here provides a method of evaluating the long-term implications of forest succession, natural disturbance, and management activities on wildlife habitat availability taking into account spatial factors. Although identifying an optimal strategy may be difficult, the model outputs provide helpful insight to local managers who want to foresee the potential long-term outcomes of their practices, compare alternative decisions, understand trade-offs of managing for one objective versus another, and prepare for adaptive management. The map output provides information that may be especially useful for facilitating collaborative discussions about broad-scale spatial considerations in biodiversity conservation across ownership boundaries (Price et al. 2012) and helping answer questions of not only *how much* action to take but *where* it should occur. Finally, assessing habitat can provide a basis for further analyses including population viability analysis, metapopulation modeling, optimization, and prioritization.

Acknowledgements

Funding for this study and for the Forest Scenarios project was provided in part by The Nature Conservancy's Rodney Johnson and Katherine Ordway Stewardship Endowment grant, the USDA Forest Service State and Private Forestry Redesign, the Doris Duke Charitable Foundation, the NSF IGERT Fellowship Program (DGE-0549407), and the University of Wisconsin at Madison. We would like to thank land managers, conservation practitioners, and scientists from the Michigan Department of Natural Resources, Wisconsin and Michigan chapters of The Nature Conservancy, the Forestland Group, Compass Land Consultants, and the LANDFIRE project.

Appendix.

See Tables A1–A3.

Table A1
Averages of three response variables measuring the amount and configuration of potential habitat patches for five target species in four alternative scenarios. Tests were performed on year 100 results of ten Monte Carlo simulations per scenario.

		2010	Current 2060	Current 2100	NCA 2060	NCA 2100	Easement 2060	Easement 2100	Ecological 2060	Ecological 2100
Blackburnian Warbler										
Area (ha)	Avg	21,119.4	12,399.7	16,175.0	12,566.4	11,901.2	12,990.9	11.165.5	16.214.7	17.877.0
	SD	42.3	137.0	233.9	144.1	302.9	112.3	132.8	199.8	115.3
Patch Size (ha)	Avg	62.2	24.6	28.6	13.5	18.0	25.5	19.8	32.4	25.0
	SD	1.1	1.0	1.2	2.7	0.7	0.7	0.6	1.3	0.6
ENN (m)	Avg	127.2	147.8	127.2	109.9	137.6	142.6	149.9	139.3	118.0
	SD	1.5	4.1	3.2	11.1	4.6	3.4	5.2	3.5	2.5
Black-backed Woodpecker										
Area (ha)	Avg	13,812.7	10,879.9	9345.5	8452.7	5474.5	9523.5	6734.5	15,673.3	21,633.6
	SD	67.1	99.4	1313.3	263.4	338.5	149.6	139.7	174.1	214.1
Patch Size (ha)	Avg	1357.2	985.8	896.4	856.1	397.1	1073.7	840.2	2811.1	4059.0
	SD	111.3	229.1	342.3	188.2	51.0	204.8	158.7	990.5	1307.0
ENN (m)	Avg	392.0	287.2	384.0	421.1	653.9	199.7	961.1	69.8	261.8
	SD	35.7	90.6	86.1	179.6	235.7	158.4	374.5	63.0	119.5
Kirtland's Warbler										
Area (ha)	Avg	907.8	1308.6	429.4	653.8	83.2	0.0	504.6	598.1	534.4
	SD	32.1	277.6	270.7	174.9	67.4	0.0	105.1	270.3	229.8
Patch Size (ha)	Avg	121.2	603.4	80.9	247.0	44.4	0.0	111.0	152.6	98.5
	SD	12.1	285.6	34.5	116.9	17.3	0.0	38.5	86.5	34.5
ENN (m)	Avg	1391.5	2534.0	3097.0	10,324.6	6757.8	0.0	1515.0	2055.8	2003.6
	SD	279.7	2314.9	2855.8	7407.3	5332.9	0.0	981.2	1518.5	1157.6
Red-shouldered Hawk										
Area (ha)	Avg	14,743.9	11,976.7	12,607.9	10,055.9	8741.4	11,453.5	11,026.6	13,924.23	15,741.06
	SD	90.7	176.8	121.1	409.8	397.2	269.9	406.0	148.7	243.3
Patch Size (ha)	Avg	82.1	69.9	58.0	82.9	76.1	96.5	195.2	54.7	51.7
	SD	2.2	4.6	2.5	3.7	6.2	7.8	25.6	3.0	2.2
ENN (m)	Avg	129.3	115.5	102.3	129.9	122.6	94.7	105.5	113.6	99.7
	SD	4.7	6.7	4.9	11.5	12.8	8.7	19.4	5.4	3.7
American Woodcock										
Area (ha)	Avg	3743.9	4299.8	1205.9	4936.1	1743.4	4647.7	1884.3	4232.3	854.7
	SD	259.3	230.1	98.3	181.6	131.3	169.7	66.7	176.1	17.00
Patch Size (ha)	Avg	48.9	23.9	4.7	30.5	7.0	25.7	8.0	26.0	3.3
	SD	4.8	1.6	0.5	1.8	0.6	1.5	0.7	2.8	0.1
ENN (m)	Avg	489.8	347.0	335.1	364.8	318.1	326.5	340.0	356.8	346.0
	SD	56.4	14.3	13.8	40.8	12.5	13.3	20.00	20.8	16.9

Please cite this article in press as: Nixon, K., et al. Habitat availability for multiple avian species under modeled alternative conservation scenarios in the Two Hearted River watershed in Michigan, USA. *Journal for Nature Conservation* (2014), http://dx.doi.org/10.1016/j.jnc.2014.02.005

Table A2
Analysis of variance results for three response variables measuring the amount and configuration of potential habitat patches for five target species as a function of four alternative scenarios. Tests were performed on the year 100 results of ten Monte Carlo runs per scenario. Groups indicate scenarios, and within groups refers to the 10 Monte Carlo simulations for each scenario.

	Degrees of freedom	Sum of squares	*F*-value	Prob > *F*
Total habitat area				
Blackburnian Warbler				
Between groups	3	318,880,562	2157.20	0
Within groups	36	1,773,845		
Black-backed Woodpecker				
Between groups	3	1,643,710,491	1035.50	0
Within groups	36	19,047,794		
Kirtland's Warbler				
Between groups	3	1,296,752	10.98	0
Within groups	36	1,416,909		
Red-shouldered Hawk				
Between groups	3	259,274,369	784.72	0
Within groups	36	3,964,837		
American Woodcock				
Between groups	3	6,855,957	259.89	0
Within groups	36	316,566		
Average habitat patch size				
Blackburnian Warbler				
Between groups	3	700.49	303.63	0
Within groups	36	27.68		
Black-backed Woodpecker				
Between groups	3	85,552,824	55.39	0
Within groups	36	18,533,201		
Kirtland's Warbler				
Between groups	3	25,157	7.26	0
Within groups	36	41,604		
Red-shouldered Hawk				
Between groups	3	136,375	231.73	0
Within groups	36	7062		
American Woodcock				
Between groups	3	134.81	154.46	0
Within groups	36	10.47		
Average habitat patch nearest neighbor distance				
Blackburnian Warbler				
Between groups	3	5675.30	105.64	0
Within groups	36	644.70		
Black-backed Woodpecker				
Between groups	3	2,894,356	15.97	0
Within groups	36	2,174,689		
Kirtland's Warbler				
Between groups	3	86,275,710	3.95	0.02
Within groups	36	218,339,894		
Red-shouldered Hawk				
Between groups	3	3211.90	6.66	0
Within groups	36	5784.40		
American Woodcock				
Between groups	3	4324	5.04	0.01
Within groups	36	10,299		

Table A3
Results of the Tukey's honestly significant differences tests of multiple comparisons. Components compared were the scenario means of 10 Monte Carlo runs. Tests were performed on the year 100 results of ten Monte Carlo runs per scenario.

Scenarios compared		Mean difference	Lower bound	Upper bound	Adjusted *P*-value
Blackburnian Warbler total habitat area (ha)					
Current	NCA	−4273.82	−4541.18	−4006.47	0
	Easement	−5009.44	−5276.80	−4742.09	0
	Ecological	1702.01	1434.65	1969.37	0
NCA	Easement	−735.62	−1002.98	−468.26	0
	Ecological	5975.83	5708.47	6243.19	0
Easement	Ecological	6711.45	6444.09	6978.81	0
Blackburnian Warbler average habitat patch size (ha)					
Current	NCA	−10.58	−11.63	−9.52	0
	Easement	−8.76	−9.81	−7.70	0
	Ecological	−3.59	−4.65	−2.54	0
NCA	Easement	1.82	0.76	2.87	0
	Ecological	6.98	5.93	8.04	0
Easement	Ecological	5.16	4.11	6.22	0
Blackburnian Warbler average habitat nearest neighbor distance (m)					
Current	NCA	10.42	5.32	15.52	0
	Easement	22.75	17.66	27.85	0
	Ecological	−9.21	−14.31	−4.11	0
NCA	Easement	12.33	7.24	17.43	0
	Ecological	−19.63	−24.73	−14.53	0
Easement	Ecological	−31.96	−37.06	−26.87	0
Black-backed Woodpecker total habitat area (ha)					
Current	NCA	−3870.99	−4747.10	−2994.88	0
	Easement	−2610.91	−3487.02	−1734.80	0
	Ecological	12,288.11	11,412.00	13,164.22	0
NCA	Easement	1260.08	383.97	2136.19	0.002
	Ecological	16,159.10	15,282.99	17,035.21	0
Easement	Ecological	14,899.02	14,022.91	15,775.13	0
Black-backed Woodpecker average habitat patch size (ha)					
Current	NCA	−499.29	−1363.49	364.90	0.416
	Easement	−56.19	−920.38	808.01	0.998
	Ecological	3162.61	2298.42	4026.81	0
NCA	Easement	443.10	−421.09	1307.30	0.519
	Ecological	3661.90	2797.71	4526.10	0
Easement	Ecological	3218.80	2354.61	4083.00	0
Black-backed Woodpecker average habitat nearest neighbor distance (m)					
Current	NCA	269.88	−26.15	565.91	0.085
	Easement	577.03	281.00	873.06	0
	Ecological	−122.21	−418.24	173.82	0.685
NCA	Easement	307.15	11.12	603.18	0.04
	Ecological	−392.09	−688.12	−96.06	0.006
Easement	Ecological	−699.24	−995.27	−403.21	0
Kirtland's Warbler total habitat area (ha)					
Current	NCA	−346.25	−585.20	−107.30	0.002
	Easement	75.21	−163.74	314.16	0.831
	Ecological	104.99	−133.96	343.94	0.641
NCA	Easement	421.46	182.51	660.41	0
	Ecological	451.24	212.29	690.19	0
Easement	Ecological	29.78	−209.17	268.73	0.987
Kirtland's Warbler average habitat patch size (ha)					
Current	NCA	−36.51	−77.46	4.43	0.095
	Easement	30.09	−10.85	71.04	0.215
	Ecological	17.55	−23.40	58.49	0.659
NCA	Easement	66.61	25.66	107.55	0.001
	Ecological	54.06	13.11	95.00	0.006
Easement	Ecological	−12.55	−53.49	28.40	0.842
Kirtland's Warbler average habitat nearest neighbor distance (m)					
Current	NCA	3660.86	−678.91	8000.63	0.122
	Easement	−1582.00	−4862.56	1698.56	0.563
	Ecological	−1093.37	−4373.92	2187.19	0.802
NCA	Easement	−5242.86	−9582.62	−903.09	0.013
	Ecological	−4754.22	−9093.99	−414.45	0.028
Easement	Ecological	488.63	−2791.92	3769.19	0.977
Red-shouldered Hawk total habitat area (ha)					
Current	NCA	−3866.44	−4266.15	−3466.73	0
	Easement	−1581.28	−1980.99	−1181.57	0
	Ecological	3133.19	2733.48	3532.91	0
NCA	Easement	2285.16	1885.45	2684.87	0
	Ecological	6999.63	6599.92	7399.35	0
Easement	Ecological	4714.47	4314.76	5114.19	0

Table A3 (*Continued*)

Scenarios compared		Mean difference	Lower bound	Upper bound	Adjusted *P*-value
Red-shouldered Hawk average habitat patch size (ha)					
Current	NCA	18.07	1.20	34.94	0.032
	Easement	137.18	120.31	154.05	0
	Ecological	−6.29	−23.16	10.58	0.748
NCA	Easement	119.11	102.24	135.98	0
	Ecological	−24.36	−41.23	−7.49	0.002
Easement	Ecological	−143.47	−160.34	−126.60	0
Red-shouldered Hawk average habitat nearest neighbor distance (m)					
Current	NCA	20.34	5.07	35.61	0.005
	Easement	3.19	−12.08	18.46	0.942
	Ecological	−2.60	−17.87	12.66	0.967
NCA	Easement	−17.15	−32.42	−1.88	0.023
	Ecological	−22.94	−38.21	−7.68	0.001
Easement	Ecological	−5.80	−21.06	9.47	0.738
American Woodcock total habitat area (ha)					
Current	NCA	537.49	424.55	650.44	0
	Easement	678.43	565.48	791.37	0
	Ecological	−351.22	−464.17	−238.28	0
NCA	Easement	140.94	27.99	253.88	0.01
	Ecological	−888.72	−1001.66	−775.77	0
Easement	Ecological	−1029.65	−1142.60	−916.71	0
American Woodcock average habitat patch size (ha)					
Current	NCA	2.27	1.62	2.92	0
	Easement	3.30	2.65	3.95	0
	Ecological	−1.37	−2.02	−0.72	0
NCA	Easement	1.03	0.38	1.68	0.001
	Ecological	−3.64	−4.29	−2.99	0
Easement	Ecological	−4.66	−5.31	−4.01	0
American Woodcock average habitat nearest neighbor distance (m)					
Current	NCA	−16.98	−37.35	3.39	0.131
	Easement	4.95	−15.42	25.32	0.913
	Ecological	10.95	−9.42	31.32	0.479
NCA	Easement	21.93	1.56	42.30	0.031
	Ecological	27.93	7.56	48.30	0.004
Easement	Ecological	6.00	−14.37	26.37	0.857

References

Arponen, A. (2012). Prioritizing species for conservation planning. *Biodiversity and Conservation*, *21*(4), 875–893. http://dx.doi.org/10.1007/s10531-012-0242-1

Barrett, T. M. (2001). *Models of vegetation change for landscape planning: A comparison of FETM, LANDSUM, SIMPPLLE, and VDDT. Gen. Tech. Rep. RMRS-GTR-76-WWW*. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Beukema, S. J., Kurz, W. A., Pinkham, C. B., Milosheva, K., & Frid, L. (2003). *Vegetation dynamics development tool, user's guide version 4.4c*. Vancouver, BC, Canada: ESSA Technologies Ltd.

Cooke, H. A., & Hannon, S. J. (2011). Do aggregated harvests with structural retention conserve the cavity web of old upland forest in the boreal plains? *Forest Ecology and Management*, *261*(3), 662–674. http://dx.doi.org/10.1016/j.foreco.2010.11.023

Cooper, J. L. (1999). *Special animal abstract for Buteo lineatus (Red-shouldered Hawk)*. Lansing, MI: Michigan Natural Features Inventory.

Corace, R. G., Lapinski, N. W., & Sjogren, S. J. (2001). In S. P. Coller (Ed.), *Conservation assessment for black-backed woodpecker (Picoides arcticus)* (p. 21). USDA Forest Service, Eastern Region.

Craighead, J. J., & Craighead, F. C. J. (1956). Hawks, Owls and Wildlife. Harrisburg. In *Pennsylvania and the Wildlife Management Institute*. Washington, DC: The Stackpole Company.

Davies, K. F., Margules, C. R., & Lawrence, K. F. (2000). Which traits of species predict population declines in experimental forest fragments? *Ecology*, *81*(5), 1450–1461. http://dx.doi.org/10.1890/0012-9658

Doepker, R. V., Earle, R. D., & Ozoga, J. J. (1992). Characteristics of Blackburnian warbler, dendroica-fusca, breeding habitat in upper Michigan. *Canadian Field-Naturalist*, *106*(3), 366–371.

Edenius, L., & Mikusinski, G. (2006). Utility of habitat suitability models as biodiversity assessment tools in forest management. *Scandinavian Journal of Forest Research*, *21*, 62–72. http://dx.doi.org/10.1080/14004080500486989

(ESRI) Environmental Systems Research Institute. (2011). *ArcGIS desktop: Release 10, Redlands, CA.*

Etienne, R. S., ter Braak, C. J. F., & Vos, C. C. (2004). Applications of stochastic patch occupancy models to real metapopulations. In I. A. Hanski, & O. E. Gaggiotti (Eds.), *Ecology, Genetics and Evolution of Metapopulations* (pp. 105–132). Helinski: Elsevier Academic Press.

Ferrier, S., & Drielsma, M. (2010). Synthesis of pattern and process in biodiversity conservation assessment: A flexible whole-landscape modelling framework. *Diversity and Distributions*, *16*(3), 386–402. http://dx.doi.org/10.1111/j.1472-4642.2010.00657.x

Fishburn, I. S., Kareiva, P., Gaston, K. J., & Armsworth, P. R. (2009). The growth of easements as a conservation tool. *PLoS ONE*, *4*(3), e4996. http://dx.doi.org/10.1371/journal.pone.0004996

(GLBC) Great Lakes Bird Conservation. (2006). *Blackburnian Warbler*. Retrieved March 2012, from http://www.uwgb.edu/birds/greatlakes/species/blbw.htm

Gottschalk, T. K., Dittrich, R., Diekotter, T., Sheridan, P., Wolters, V., & Ekschmitt, K. (2010). Modelling land-use sustainability using farmland birds as indicators. *Ecological Indicators*, *10*(1), 15–23. http://dx.doi.org/10.1016/j.ecolind.2009.05.008

He, H. S., Yang, J., Shifley, S. R., & Thompson, F. R. (2011). Challenges of forest landscape modeling-Simulating large landscapes and validating results. *Landscape and Urban Planning*, *100*(4), 400–402. http://dx.doi.org/10.1016/j.landurbplan.2011.02.019

Jacobs and Jacobs 2000: unpublished report for the US Fish and Wildlife Service, Wisconsin Department of Natural Resources, U.S. Forest Service, and Northeastern Wisconsin Audubon Society.

Jacobs, J. P., & Jacobs, E. A. (2002). *Conservation assessment for Red-shouldered Hawk (Buteo lineatus): National forests of north central states*. USDA Forest Service Eastern Region.

Jin, L. R., He, H. S., Zhou, Y. F., Bu, R. C., & Sun, K. P. (2010). Assessing the Effects of Management Alternatives on Habitat Suitability in a Forested Landscape of Northeastern China. *Environmental Management*, *45*(5), 1191–1200. http://dx.doi.org/10.1007/s00267-010-9473-7

King, J. C., Dubay, S. A., & Woodford, J. E. (2011). Distribution and nest site selection of red-shouldered hawks (*Buteo lineatus*) in forests of northeastern Wisconsin (USA). *Forest Ecology and Management*, *261*(1), 169–177. http://dx.doi.org/10.1016/j.foreco.2010.10.001

Knowlton, J. L., & Graham, C. H. (2010). Using behavioral landscape ecology to predict species' responses to land-use and climate change. *Biological Conservation*, *143*(6), 1342–1354. http://dx.doi.org/10.1016/j.biocon.2010.03.011

Kurz, W. A., Beukema, S. J., Klenner, W., Greenough, J. A., Robinson, D. C. E., Sharpe, A. D., et al. (2000). TELSA: The tool for exploratory landscape scenario analyses. *Computers and Electronics in Agriculture*, *27*(1–3), 227–242. http://dx.doi.org/10.1016/s0168-1699(00)00109-5

LANDFIRE. (2007). *Homepage of the LANDFIRE project*. , from. http://www.landfire.gov/index.php

Larson, M. A., Thompson, F. R., Millspaugh, J. J., Dijak, W. D., & Shifley, S. R. (2004). Linking population viability, habitat suitability, and landscape simulation models for conservation planning. *Ecological Modelling*, *180*(1), 103–118. http://dx.doi.org/10.1016/j.ecolmodel.2003.12.054

Mace, G. M., Possingham, H. P., & Leader-Williams, N. (2007). Prioritizing choices in conservation. In D. W. Macdonald, & K. Service (Eds.), *Key topics in conservation biology* (pp. 17–34). Malden, MA: Blackwell Publications.

Marzluff, J. M., Millspaugh, J. J., Ceder, K. R., Oliver, C. D., Withey, J., McCarter, J. B., et al. (2002). Modeling changes in wildlife habitat and timber revenues in response to forest management. *Forest Science*, *48*(2), 191–202.

McGarigal, K., Cushman, S. A., & Ene, E. (2012). *FRAGSTATS v4: Spatial pattern analysis program for categorical and continuous maps (version 4)*. Amherst: The University of Massachusetts. Retrieved from http://www.umass.edu/landeco/research/fragstats/fragstats.html

McKay, K. J., Stravers, J. W., Swenson, G. V., Kohrt, C. J., & Lundh, J. S. (2001). Altering forest management plans to accommodate rare or endangereed species – A positive example and approach. In K. L. Bildstein, & D. J. Klem (Eds.), *Hawkwatching in the Americas* (pp. 221–228). North Wales, PA: Hawk Migration Association of America.

Meiklejohn, B. A., & Hughes, J. W. (1999). Bird communities in riparian buffer strips of industrial forests. *American Midland Naturalist*, *141*(1), 172–184. http://dx.doi.org/10.1674/0003-0031

Merenlender, A. M., Huntsinger, L., Guthey, G., & Fairfax, S. K. (2004). Land trusts and conservation easements: Who is conserving what for whom? *Conservation Biology*, *18*(1), 65–75. http://dx.doi.org/10.1111/j.1523-1739.2004.00401.x

Meyer, R. (2010). *Dendroica kirtlandii*. Retrieved March 2012, from http://www.fs.fed.us/database/feis/animals/bird/deki/all.html

(MIDNR) Michigan Department of Natural Resources. (2012a). *D. kirtlandii management area*. Retrieved August 2012 from http://www.midnr.com/publications/pdfs/forestslandwater/Ecosystem/NLP-MA-Briefs/NLP_MA17-Kirtland%27sWarbler.pdf

(MIDNR) Michigan Department of Natural Resources. (2012b). *Kirtland's Warbler (Dendroica kirtlandii)*. Retrieved March 2012 from http://www.michigan.gov/dnr/0,1607,7-153-10370_12145_12202-32591–,00.html

Mladenoff, D. J. (2004). LANDIS and forest landscape models. *Ecological Modelling*, *180*(1), 7–19. http://dx.doi.org/10.1016/j.ecolmodel.2004.03.016

Monkkonen, M., Reunanen, P., Kotiaho, J. S., Juutinen, A., Tikkanen, O. P., & Kouki, J. (2011). Cost-effective strategies to conserve boreal forest biodiversity and long-term landscape-level maintenance of habitats. *European Journal of Forest Research*, *130*(5), 717–727. http://dx.doi.org/10.1007/s10342-010-0461-5

Morse, D. H. (1971). The foraging of warblers isolated on small islands. *Ecology*, *52*, 216–228.

Morse, D. H. (1976). Variables affecting the density and territory size of breeding spruce-woods warblers. *Ecology*, *57*, 290–301.

NatureServe. (2013). *NatureServe explorer: An online encyclopedia of life [web application], version 7.1*. Arlington, VA. U.S.A.: NatureServe. Retrieved, from http://www.natureserve.org/explorer

Nicholson, E., & Possingham, H. P. (2006). Objectives for multiple-species conservation planning. *Conservation Biology*, *20*(3), 871–881. http://dx.doi.org/10.1111/j.1523-1739.2006.00369.x

Nicholson, E., Westphal, M. I., Frank, K., Rochester, W. A., Pressey, R. L., Lindenmayer, D. B., et al. (2006). A new method for conservation planning for the persistence of multiple species. *Ecology Letters*, *9*(9), 1049–1060. http://dx.doi.org/10.1111/j.1461-0248.2006.00956.x

Niemi, G.J., Hanowski, J.M. (1992) Appendix 4: Detailed species descriptions - forest birds. In Forest wildlife. A technical paper for a generic environmental impact statement on timber harvesting and forest management in Minnesota, Jaakko Poyry Consulting, Raleigh, NC. Compiled by Natural Resources Research Institute. Retrieved online, March 2012 from http://www.nrri.umn.edu/mnbirds/accounts/BLBWa2.htm

Nixon, K. E. (2012). *Assessing habitat availability for multiple wildlife species under alternative conservation strategies for the Wild Rivers Legacy Forest and surrounding protected areas in Michigan's Upper Peninsula*. Retrieved from http://forward.library.wisconsin.edu/catalog/ocn823319473

Ohman, K., Edenius, L., & Mikusinski, G. (2011). Optimizing spatial habitat suitability and timber revenue in long-term forest planning. *Canadian Journal of Forest Research*, *41*(3), 543–551. http://dx.doi.org/10.1139/x10-232

Opdam, P., & Wascher, D. (2004). Climate change meets habitat fragmentation: Linking landscape and biogeographical scale levels in research and conservation. *Biological Conservation*, *117*, 285–297.

Postupalsky, S. (1989). *Past and current nesting status of the red-shouldered hawk in Michigan*. Michigan Department of Natural Resources.

Price, J., Silbernagel, J., Miller, N., Swaty, R., White, M., & Nixon, K. (2012). Eliciting expert knowledge to inform landscape modeling of conservation scenarios. *Ecological Modelling*, *229*, 76–87. http://dx.doi.org/10.1016/j.ecolmodel.2011.09.010

Probst, J. R., Donner, D. M., Bocetti, C. I., & Sjogren, S. (2003). Population increase in Kirtland's warbler and summer range expansion to Wisconsin and Michigan's Upper Peninsula. *USA. Oryx*, *37*(3), 365–373. Available online at http://www.nrs.fs.fed.us/pubs/4165

Prugh, L. R., Hodges, K. E., Sinclair, A. R. E., & Brashares, J. S. (2008). Effect of habitat area and isolation on fragmented animal populations. *Proceedings of the National Academy of Sciences of the United States of America*, *105*(52), 20770–20775. http://dx.doi.org/10.1073/pnas.0806080105

Development Core Team, R. (2011). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from http://www.R-project.org

Rissman, A. R., Lozier, L., Comendant, T., Kareiva, P., Kiesecker, J. M., Shaw, R. M., et al. (2007). Conservation Easements: Biodiversity protection and private use. *Conservation Biology*, *21*(3), 709–718.

Rittenhouse, C. D., Dijak, W. D., Thompson, F. R. I., & Millspaugh, J. J. (2007). *Development of landscape-level habitat suitability models for ten wildlife species in the central hardwoods region, Gen. Tech. Rep. NRS-4*. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.

Sargent, M. S., & Carter, K. S. (1999a). *Woodcock. Managing Michigan wildlife: A landowners guide*. , from. http://www.dnr.state.mi.us/publications/pdfs/huntingwildlifehabitat/landowners_guide/species_mgmt/Woodcock.htm

Sargent, M. S., & Carter, K. S. (1999b). *Woodland birds. Managing Michigan wildlife: A landowners guide*. , from. http://www.dnr.state.mi.us/publications/pdfs/huntingwildlifehabitat/landowners_guide/Species_Mgmt/Woodland_Birds.htm

Scheller, R. M., & Mladenoff, D. J. (2007). An ecological classification of forest landscape simulation models: Tools and strategies for understanding broad-scale forested ecosystems. *Landscape Ecology*, *22*(4), 491–505. http://dx.doi.org/10.1007/s10980-006-9048-4

Scolozzi, R., & Geneletti, D. (2011). Spatial rule-based assessment of habitat potential to predict impact of land use changes on biodiversity at municipal scale. *Environmental Management*, *47*(3), 368–383. http://dx.doi.org/10.1007/s00267-011-9613-8

Shanahan, D. F., Miller, C., Possingham, H. P., & Fuller, R. A. (2011). The influence of patch area and connectivity on avian communities in urban revegetation. *Biological Conservation*, *144*(2), 722–729. http://dx.doi.org/10.1016/j.biocon.2010.10.014

Shifley, S. R., Thompson, F. R., Dijak, W. D., & Fan, Z. F. (2008). Forecasting landscape-scale, cumulative effects of forest management on vegetation and wildlife habitat: A case study of issues, limitations, and opportunities. *Forest Ecology and Management*, *254*(3), 474–483. http://dx.doi.org/10.1016/j.foreco.2007.08.030

Shifley, S. R., Thompson, F. R., Dijak, W. D., Larson, M. A., & Millspaugh, J. J. (2006). Simulated effects of forest management alternatives on landscape structure and habitat suitability in the Midwestern United States. *Forest Ecology and Management*, *229*(1–3), 361–377. http://dx.doi.org/10.1016/j.foreco.2006.04.030

Silbernagel, J., Price, J., Swaty, R., & Miller, N. (2011). The next frontier: Projecting the effectiveness of broad-scale forest conservation strategies. In C. Li, R. Lafortezza, & J. Chen (Eds.), *Landscape ecology in forest management and conservation: Challenges and solutions for global change* (pp. 209–230). New York: Springer.

Tear, T. H., Kareiva, P., Angermeier, P. L., Comer, P., Czech, B., Kautz, R., et al. (2005). How much is enough? The recurrent problem of setting measurable objectives in conservation. *Bioscience*, *55*(10), 835–849. http://dx.doi.org/10.1641/0006-3568

Thompson, I. D., Baker, J. A., & Ter-Mikaelian, M. (2003). A review of the long-term effects of post-harvest silviculture on vertebrate wildlife, and predictive models, with an emphasis on boreal forests in Ontario, Canada. *Forest Ecology and Management*, *177*(1–3), 441–469. http://dx.doi.org/10.1016/s0378-1127(02)00453-x

Tremblay, J. A., Ibarzabal, J., & Savard, J. P. L. (2010). Foraging ecology of black-backed woodpeckers (Picoides arcticus) in unburned eastern boreal forest stands. *Canadian Journal of Forest Research*, *40*(5), 991–999. http://dx.doi.org/10.1139/x10-044

(USFWS) U.S. Fish and Wildlife Service. (2012). *Kirtland's Warbler (Dendroica kirtlandii). Environmental conservation online system*. Retrieved March http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=B03I

(USFWS) U.S. Fish Wildlife Service. (2002). *Blackburnian Warbler habitat model, USFWS Gulf of Maine watershed habitat analysis*. Retrieved March 2012, from http://www.fws.gov/r5gomp/gom/habitatstudy/metadata2/blackburnian_warbler_model.htm

Venema, H. D., Calamai, P. H., & Fieguth, P. (2005). Forest structure optimization using evolutionary programming and landscape ecology metrics. *European Journal of Operational Research*, *164*(2), 423–439. http://dx.doi.org/10.1016/j.ejor.2003.11.011

Venier, L. A., Pearce, J. L., Wintle, B. A., & Bekessy, S. A. (2007). Future forests and indicator-species population models. *Forestry Chronicle*, *83*(1), 36–40.

Watts, K., Eycott, A. E., Handley, P., Ray, D., Humphrey, J. W., & Quine, C. P. (2010). Targeting and evaluating biodiversity conservation action within fragmented landscapes: An approach based on generic focal species and least-cost networks. *Landscape Ecology*, *25*(9), 1305–1318. http://dx.doi.org/10.1007/s10980-010-9507-9

(WBCI) Wisconsin Bird Conservation Initiative. (2012a). *Blackburnian Warbler (Dendroica fusca). The Wisconsin All-bird Conservation Plan, Version 2. 0. web application*. Madison, WI: Wisconsin Department of Natural Resources. Retrieved March 2012, from http://www.wisconsinbirds.org/plan/species/blbw.htm

(WBCI) Wisconsin Bird Conservation Initiative. (2012b). *Red-shouldered Hawk (Buteo lineatus). The Wisconsin All-bird Conservation Plan, Version 2. 0. web application*. Madison, WI: Wisconsin Department of Natural Resources. Retrieved March 2012, from http://www.wisconsinbirds.org/plan/species/rsha.htm

Webb, W. L., Behrend, D. F., & Saisorn, B. (1977). Effect of logging on songbird populations in a northern hardwood forest. *Wildlife Monographs*, *55*, 6–35.

Wilhere, G. F., Linders, M. J., & Cosentino, B. L. (2007). Defining alternative futures and projecting their effects on the spatial distribution of wildlife habitats. *Landscape and Urban Planning*, *79*(3–4), 385–400. http://dx.doi.org/10.1016/j.landurbplan.2006.05.001

(WMI) Wildlife Management Institute. (2008). In J. Kelley, S. Williamson, & T. R. Cooper (Eds.), *American Woodcock conservation plan: A summary of and recommendations for woodcock conservation in North America* (p. 162). WMI.
(WMI) Wildlife Management Institute. (2009). *Best management practices for woodcock and associated bird species: Upper Great Lakes Woodcock and young forest initiative*. WMI.
Zollner, P. A., Roberts, L. J., Gustafson, E. J., He, H. S., & Radeloff, V. (2008). Influence of forest planning alternatives on landscape pattern and ecosystem processes in northern Wisconsin, USA. *Forest Ecology and Management*, *254*(3), 429–444. http://dx.doi.org/10.1016/j.foreco.2007.07.038