Determining Reference Ecosystem Conditions for Disturbed Landscapes within the Context of Contemporary Resource Management Issues

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One of the most important aspects of forest ecosystem restoration is the identification of a reference ecosystem that serves as a guide for planning forest restoration projects as well as a benchmark (i.e., control) for evaluating their success (Society for Ecosystem Restoration [SER] 2002). Generally, reference ecosystem conditions should reflect the compositional and structural attributes that have developed after natural disturbances, and the most useful reference conditions are often those that represent the range of "natural" variability associated with the ecosystem. As a result, silvicultural and restoration strategies that are based on the legacies of natural disturbances are becoming more common (e.g., Harrod et al. 1999, Palik et al. 2002). One reason for this trend is that the resulting compositional and structural complexity after natural disturbances can be striking (see Stephens and Fulé 2005), especially when compared with managed forest ecosystems (Franklin et al. 1997, Palik and Zasada 2003). This complexity is reflected in the composition and structure of forest ecosystems at both local (e.g., diversity of size classes in stand) and landscape scales (e.g., diversity of ecosystem types in a landscape). Thus, the goal of forest ecosystem restoration should be to develop strategies that help disturbed sites and landscapes emulate the attributes and "natural" variability associated with the reference ecosystem and the reference landscape.

Determining the characteristics of reference ecosystems and landscapes, however, often is difficult. In many instances, information related to the composition and structure of forest ecosystems, where natural disturbance regimes are relatively intact, is not available (see Asbjornsen et al. 2005). This is particularly true for highly disturbed or manipulated landscapes, such as many of the areas managed by the National Park Service (NPS) and located across the eastern United States. In these areas, the policy of the NPS is to maintain "natural [ecosystem] components and processes in their natural condition," and where human activities have altered natural biological and physical processes significantly, to "restore them to a natural condition or to maintain the closest approximation of the natural condition in situations in which a truly natural system is no longer attainable" (National Park Service 2001). Generally, the "natural condition" is considered the spectrum of ecosystem conditions, including the composition, structure, and function of ecosystems occurring within a defined area over a specified period of time before European settlement (Landres et al. 1999, Allen et al. 2002).

However, the NPS has been increasingly focused on maintaining important cultural landscapes and the maintenance of these human-modified landscapes has been considered an acceptable management scenario regardless of the policy directive for active ecosystem restoration. Many NPS lands in the eastern United States have historical farmsteads, buildings, and land-use histories that often are maintained in their historical state. Examples include original homesteads, farmsteads, Civil War-era earthworks, and Civilian Conservation Corps (CCC) camps that have been maintained as early successional habitats and support a variety of plants and animals not thought to be found on the pre-European landscape. There also has been increasing interest among some in the NPS to restore anthropogenic (albeit pre-European settlement) disturbances to the landscape

(Underwood et al. 2003, Wray and Anderson 2003).

In this article, we present a framework to assess the potential influence of forest ecosystem restoration on the landscape of Sleeping Bear Dunes National Lakeshore, the core of which is an approach to determine the distribution of forest ecosystems on both the pre-European settlement landscape and the "restored" landscape. Because there has been an increased interest in the conservation and restoration of the cultural landscapes (e.g., particularly late 19th and early 20th century farmsteads) at the Lakeshore, we focus our efforts on understanding the important ecological contributions provided by these cultural landscapes to open land avian bird conservation (see sidebar) and the potential consequences of restoring the Lakeshore's cultural landscapes to a more natural condition. Our analysis, which is a modification and extension of a method first presented by Palik et al. (2000), provides us with a framework to assess the conservation status of individual ecosystems (as expressed by the current and historical rarity) and examine the potential influence of restoration efforts within the context of contemporary resource management issues.

Developing a Framework to Predict the Influence of Restoration

Our framework for making decisions related to forest ecosystem restoration is an integrated process that allows us to assess the historical and current distribution of forest ecosystems and assess the conservation status of individual forest ecosystems under different management or restoration scenarios. The first step is to determine the composition and distribution of forest ecosystems on the pre-European settlement landscape, as well as elucidating the patterns of forest ecosystems associated with natural disturbances such as fire. There are a variety of different methods available to determine this information (e.g., land survey notes, pollen records, dendroecology, historical accounts, and old-growth studies) and the benefits and limitations of these methods have been described in detail elsewhere (see Egan and Howell 2001). The second step is to examine the current composition and distribution of forest ecosystems across the study area. In many instances, this information is readily available from state or organizational spatial data libraries (e.g., cover type maps). The third step is to develop a model to predict the composition and distribution of forest ecosystems on the *restored* landscape. This is perhaps the most difficult step because reference conditions often are "moving targets" influenced by complex biological and cultural legacies. However, in many areas of the eastern United States there are existing multifactor ecosystem classification systems (ECS) that quantify the influence of hierarchical factors on the composition and structure of mature or late-successional forest vegetation. Other sources are also available (see Kenefic et al. 2005); however, we believe that the predictive power that an ECS provides is a beneficial tool for predicting the extent of forest ecosystems on a restored landscape. After acquiring information on the pre-European, current, and future forest ecosystems, the final step is to develop a method to examine the effects of potential restoration efforts that can be used to help prioritize restoration efforts based on the conservation status of individual forest ecosystems. Our approach, which integrates information within a geographical information system (GIS), provides for a flexible platform to examine different restoration and management scenarios within the context of current and future resource management objectives.

Applying the Framework to Sleeping Bear Dunes National Lakeshore

Sleeping Bear Dunes National Lakeshore (approximately 24,000 ha) is located along the northeastern shore of Lake Michigan. The mainland portion of the Lakeshore extends for approximately 60 km along the Lake Michigan shoreline (Figure 1). The Lakeshore is located in a glacially modified landscape dominated by steep, narrow moraines and flat sandy lake plains with elevations from 177 to 350 m (Albert 1995). The most prominent features of the Lakeshore, and those for which it is named, are the perched dunes on glacial moraines. However, the Lakeshore is comprised of a variety of different forest ecosystems, including mixed oak-pine forests on sandy soils, swamp hardwood and conifer forests on poorly drained soils, and extensive upland northern hardwood-hemlock forests.

Pre-European Settlement Forests. The earliest records of the pre-European settlement vegetation of the Lakeshore are provided by the General Land Office (GLO)

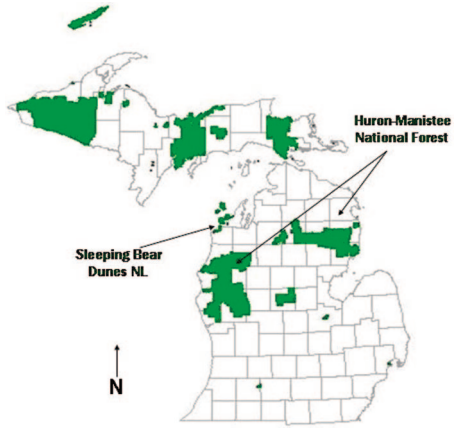


Figure 1. Location of Sleeping Bear Dunes National Lakeshore and other federal lands in Michigan, including the Huron-Manistee National Forest.

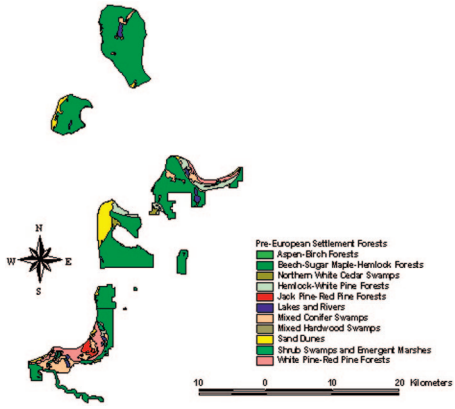


Figure 2. Pre-European settlement vegetation based on interpretations of the GLO survey notes of Sleeping Bear Dunes National Lakeshore, Lower Michigan.

survey notes collected between 1838 and 1851. The pre-European settlement land cover map was delineated and compiled using this information by the Michigan Natural Features Inventory (Comer et al. 1995). This map was interpreted primarily using the locations of GLO dominant tree species and associated landforms, with the boundaries among cover types between section lines interpolated using topographic characteristics and surface geology maps.

Using these survey notes and a GIS, we determined that the reference pre-European settlement landscape of the Lakeshore was comprised of a diverse assortment of forest ecosystems within a matrix of northern hardwoods (Figure 2). Beech-sugar maple-hemlock (*Fagus grandifolia* L.–*Acer saccharum* Marsh.–*Tsuga canadensis* L.) forest ecosystems comprised approximately 16,515 ha (69.0% of the current Lakeshore) and dominated the higher elevation, well-drained up-

lands (Figure 2). Sand dunes, mixed conifer swamps, white pine-red pine (*Pinus strobus* L.–*Pinus resinosa* Ait.), and hemlock-white pine forest ecosystems were less common along the shore of Lake Michigan, each comprising between approximately 1,200–1,740 ha (5.0–8.0% of the total area) of the pre-European settlement landscape of the Lakeshore (Figure 2). Although rare, five additional forest ecosystems also were found across the Lakeshore, each comprising less than 450 ha (less than 2.0% of the total area) of the pre-European settlement landscape. These included northern white-cedar (*Thuja occidentalis* L.) swamps, jack pine-red pine (*Pinus banksiana* Lam.–*P. resinosa* Ait.) forests, shrub swamp and emergent marshes, mixed hardwood swamps, and aspen-birch (*Populus-Betula*) forests. Most of these less-common ecosystems (those comprising less than 10.0% of the total area) were almost entirely located in the low-lying sandy lake plains.

Pre-European Settlement Disturbance Regime. We acquired spatial data on the pre-European settlement disturbance regimes from the US Department of Agriculture (USDA) Forest Service Great Lakes Ecological Assessment Program (Cleland et al. 1994), which is based on aggregations or subdivisions of different hierarchical levels associated with the *National Hierarchical Framework of Ecological Units* for northern Lower Michigan (ECOMAP 1993, Albert 1994, Comer et al. 1995). Each map polygon was evaluated using a number of GIS data sets, including the Natural Resource Conservation Service (NRCS) digital soil surveys, GLO notes on tree species and diameter, a 30-m digital elevation model, hydrography, and current vegetation. Interpretations based on associations of ecological factors known to influence fire regimes were made, and each polygon was assigned to one of six fire rotation categories. The definitions for each category were based on a synthesis of the available literature (Cleland et al. 2004). In the GIS, we used these spatial data to create a natural disturbance regime map for the Lakeshore.

At the Lakeshore, approximately 77.0% of the landscape is dominated by areas that experienced very infrequent stand-replacing or community maintenance (low-intensity surface) fires, resulting in the dominance of northern hardwood or hardwood hemlock forest ecosystems. Approximately 17.0% of the pre-European landscape, primarily those areas in the low-lying

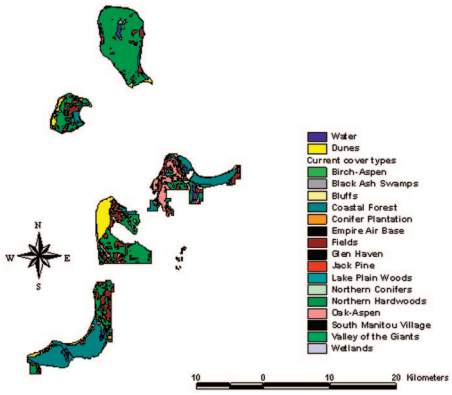


Figure 3. Current vegetation for Sleeping Bear Dunes National Lakeshore, Lower Michigan.

sandy lake plains, experienced relatively infrequent stand-replacing fires; however, low-intensity maintenance fires were relatively common in these areas. These areas were dominated by hemlock-white pine and white pine–red pine forests. A variety of forest ecosystems including northern white cedar, mixed conifers and mixed hardwoods dominated the poorly drained sites. Finally, approximately 6.0% of the landscape historically experienced large, catastrophic stand-replacing fires at shorter intervals than other ecosystems at the Lakeshore. These areas were dominated by white pine–red pine and mixed red pine–white pine–jack pine forests, and they occurred on isolated Holocene sands along protected areas of the Lake Michigan coast.

Current Forests. Detailed descriptions and maps of the current vegetation of the Lakeshore are available from the NPS. Based on these data, the current landscape of the Lakeshore is dominated by upland northern hardwood forests (42.3%), coastal forests (18.9%) characterized by birch-maple-aspen and oak-pine (*Quercus-Pinus*) forest types located in the protected bays along the Lake Michigan shoreline, open fields (13.2%) in varying degrees of succession ranging from 0.2 to 165.5 ha in size, coastal sand dunes (8.3%), and early successional oak-aspen forests (5.6%; Figure 3). Several other cover types are less common across the current Lakeshore landscape, including wetlands (1.3%), bluffs (1.0%), conifer plantations (1.0%), birch-aspen forests (0.9%), lake plain forests (0.5%), jack pine forests (0.4%), black ash (*Fraxinus nigra* Marsh.) swamp forests (0.3%), and northern conifer forests (0.2%; Figure 3). In all cases, natural and human-caused surface fires have been actively suppressed for the last 70 years.

Predicting the Future Distribution of Forest Ecosystems. The Ecological Classification and Inventory (EC&I) of the Huron-Manistee National Forests provides an ecological framework for integrated natural resource planning and management on the Huron-Manistee National Forest. The EC&I uses the concepts of ecosystem development and hierarchy theory (similar to those suggested by Palik et al. [2000]) as a preferable framework for prioritizing restoration efforts and stratifies the landscape into a nested spatial hierarchy (Cleland et al. 1993). Upper levels of the hierarchy are defined by macroclimate and regional physiography at a scale of 1:1,000,000, and they are based principally on the regional ecosystem map revised by Albert et al. (1995). Intermediate levels, or land type associations (LTA), are defined by geomorphology and broad differences in pre-European settlement vegetation at a scale of 1:60,000. The lower levels of the hierarchy, ecological land types (ELT), and ecological land type phases (ELTP) are defined by ground-flora composition and abundance, soils, and local physiography at a scale of 1:15,840.

Although developed for the Huron-Manistee National Forest, the information related to individual ecosystems can be applied to most areas of sandy glacial drift characteristic of northwestern Lower Michigan, including the Lakeshore (Cleland et al. 1993). Because the physical and vegetative descriptions of individual ecosystems (e.g., ELTs and ELTPs) in the Huron-Manistee National Forest EC&I are based on sampling mature stands on the current landscape of the Huron-Manistee National Forest, the current composition and structure of these ecosystems reflects not only the influence of climate, glacial geology, physiography, and soils, but also the biological legacies associated with contemporary management systems. Specifically, the composition and structure of the ecosystems described in the EC&I represent the composition and structure of forest ecosystems where fire has been excluded and provide a target for forest ecosystem restoration. It is important to note, however, that using the Huron-Manistee National Forest EC&I as the basis for determining reference conditions is necessary because there are considerable risks associated with restoring surface fires in many areas of northern Michigan where fire was once a common disturbance agent (Haight et al. 2004).

We applied the Huron-Manistee National Forest EC&I to the Lakeshore to predict the future developmental trajectories of forest ecosystems at the Lakeshore under a management regime where surface fires are suppressed. The EC&I was applied to the Lakeshore by following a series of steps whereby relationships among quaternary geology, physiography, soils, and natural disturbance regimes were evaluated using a GIS. First, using a quaternary geology map, the NRCS digital soil survey map, and the previously described natural disturbance regime map acquired from the USDA Forest Service, we merged these spatial data into a single spatial coverage using ArcView version 3.2 software (ESRI, Redlands, CA). Using this information on glacial landforms, soil types, and predominant natural disturbance regimes (which also was considered a proxy for the climatic influences on vegetation associated with the Lakeshore not experienced on the more inland areas of the Huron-Manistee National Forest), we classified individual polygons in the GIS to an individual ELT using the ecosystem classification keys and descriptions provided by Cleland et al. (1993). In all but a few cases, the classification of polygons into one of the Huron-Manistee National Forest EC&I ELT categories was straightforward, with the most common combinations of geomorphology, soils, and natural disturbance regimes "keying out" to a single ELT. However, we did have to modify the classification system for unique ecosystems such as the sand dunes present at the Lakeshore but not included in the Huron-Manistee National Forest EC&I. This application of the Huron-Manistee ECS provided us with a tool to predict the potential distribution of future forest ecosystems.

The potential distribution of future forest ecosystems under a management regime where surface fires are suppressed is shown in Figure 4 (descriptions of each ecosystem type are listed in Table 1). Based on this analysis, we can examine the conservation status of individual forest ecosystems at the Lakeshore. Specifically, our analysis predicts that under contemporary disturbance regimes (e.g., active fire suppression) 59.1% of the landscape will be dominated by mature upland forests characterized by sugar maple and American beech (Figure 4). Because most of these mature upland forests are found on sites that are classified as beech-sugar maple-hemlock forests that experienced very infrequent surface fires on the pre-European settlement landscape (69.7% of the pre-European landscape), they represent an ecosystem that is on a similar developmental trajectory as the reference pre-European settlement or "natural" ecosystems. Similarly, most of the wetland-dominated ecosystems and dune systems appear to be on a similar developmental trajectory as the pre-European landscape. Consequently, our analyses suggest that under current management scenarios approximately 78.0% of the Lakeshore will reflect the composition of the pre-European settlement landscape if allowed to maintain current ecosystem development trajectories.

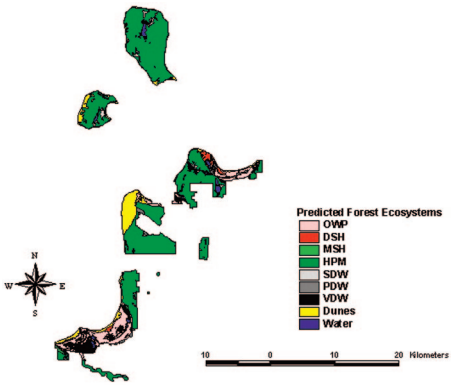


Figure 4. Potential distribution of forest ecosystems of Sleeping Bear Dunes National Lakeshore under contemporary management practices, particularly fire suppression. See Table 1 for predicted forest ecosystem descriptions.

Table 1. Distribution of potential forest ecosystems under contemporary management practices at Sleeping Bear Dunes National Lakeshore, Lower Michigan.

Forest ecosystem	Area (ha)	% of Landscape
HPM—sugar maple and American beech	14,231.26	59.1
Outwash Plains (OWP)—mixed oaks	3,220.90	13.4
Dunes (includes bluffs)	2,503.66	10.4
Poorly drained wetlands (PDW)—red maple, paper birch, black ash	785.40	3.3
Very poorly drained wetlands (VDW)—mixed conifers	748.56	3.1
Somewhat poorly drained wetlands (SPW)—mixed oaks, red maple	611.46	2.5
Dry ice contact and sand hills (DSH)—mixed oaks, red maple	434.41	1.8
Mesic ice contact sand hills (MSH)—red oak, red maple	99.21	0.4
Other[a]	1,428.64	5.9
Total	24,063.50	100.0

[a]Includes developed areas (e.g., Empire Air Base, Glen Haven, South Manitou Village, and water).
OWP, Outwash Plains; PDW, poorly drained wetlands; VDW, very poorly drained wetlands; SPW, somewhat poorly drained wetlands; DSH, dry ice contact and sand hills; MSH, mesic ice contact sand hills.

Our application of the Huron-Manistee National Forest EC&I also suggests that the remaining 22.0% of the Lakeshore landscape will not reflect the pre-European settlement conditions if current ecosystem development trajectories are maintained. For example, only 11.0% (32.9 ha out of a total of 288.5 ha) of the historically rare jack pine–red pine forests of the pre-European settlement Lakeshore landscape that experienced large, catastrophic stand-replacing fires at shorter intervals are currently dominated by either species. Furthermore, based on our application of the EC&I, all of the areas that are characterized by a historically rare jack pine–red pine reference forest type likely will be dominated by mixed oaks and red maple in the absence of fire (Figure 3). Also, it is unlikely that the areas currently dominated by jack pine will be maintained in the absence of fire.

Similar trends are observed within those areas characterized by relatively infrequent stand-replacing fires but frequent low-intensity surface fires. For example, few areas (2% or 53.9 ha) at the Lakeshore are currently classified as either a white pine–red pine or hemlock-white pine forest type, both of which were relatively rare on the pre-European landscape (11.0% or 2,707 ha). Currently, most of these areas are dominated by coastal forest species such as northern red oak, black oak, and red maple (76.0% or 2,049.1 ha), with the remaining areas classified as fields, conifer plantations, oak-aspen forests, or developed. Thus, we can surmise that in the absence of fire, these ecosystems are on a developmental trajectory to be dominated by mature stands of mixed oaks and red maple rather than a white pine–red pine or hemlock-white pine ecosystem type.

Implications for Forest Ecosystem Restoration. In terms of the historic open lands or cultural landscapes (as represented by the 458 different fields present on the current Lakeshore landscape), approximately 90.0% of the total area represented by these fields (247 fields; 2,680 ha) is located on sites where the reference forest ecosystem is beech-sugar maple-hemlock—the most common forest ecosystem of the pre-European settlement landscape. The fact

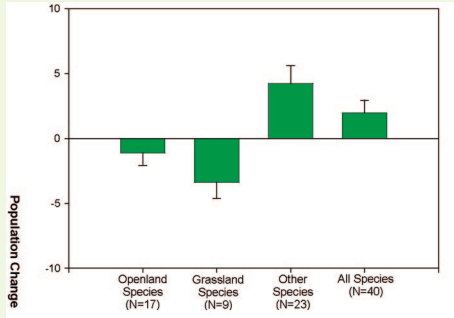
that these same sites are classified as the herb poor moraine (HPM) ecosystem type (Table 1) indicates that they likely will succeed to a beech-sugar maple-hemlock forest type over time. Because of the significant contributions to both local and regional open land avian diversity, which these cultural landscapes provide (see sidebar), maintaining cultural landscapes located on the HPM ecosystem type that dominates the Lakeshore may be an appropriate conservation and management objective. However, there were a considerable number of fields located in ecosystem types that were less common on the pre-European settlement landscape and these sites may have a higher priority and be better candidates for active restoration before resources are committed to restore those historic open lands located in the HPM ecosystem type.

Although the specific protocols for restoration will be unique for each site, there are some general recommendations we can make regarding the restoration of these rarer ecosystems. Perhaps the most important is that low-intensity surface fires should be reintroduced into many areas. The majority of the rare ecosystems at the Lakeshore are characterized by a development trajectory where fire played a pivotal role in the maintenance of specific plant communities, especially the dominance of conifer species. It is likely that the reintroduction of fire to these areas will be slow and may need to be accompanied by the mechanical removal of hardwood species. However, more research on the disturbance history of these forest ecosystems, the relative importance of hardwood species in the pre-European settlement forests, and current fuel loadings is needed before specific restoration programs that emulate natural succession processes (e.g., Harrod et al. 1999, Palik et al. 2002) are developed for these areas.

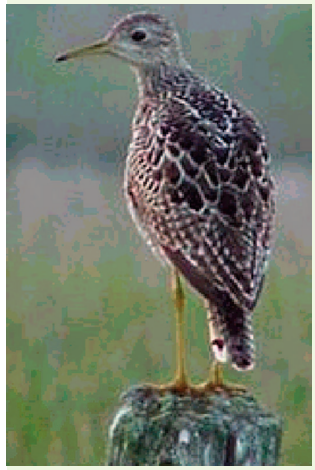
Declining Open Land Avifauna in Upper Midwest

Conservation biologists in the upper Midwest and elsewhere have become increasingly aware of the population declines of birds associated with grasslands, shrub lands, and early successional forests of the region (collectively referred to as open land habitats). The Breeding Bird Survey (BBS) data depict alarming trends for many of these species breeding in grasslands (Sauer et al. 2001). For most, population declines may be attributed to loss of breeding habitat associated with changes in land use and land cover (Brewer et al. 1991).

Across the mostly forested portions of the upper Midwest, four open land communities have been identified as important habitats for open land birds: open wetlands, jack pine barrens, other xeric, conifer-dominated ecosystems, and low-intensity managed agricultural lands. Modification of natural disturbances (such as fire), secondary forest succession, declines in low-intensity farming, and conservation into urban development has altered many landscapes that once provided habitats for a suite of open land birds.



Mean annual population change (+/- SE) by breeding habitat group for those species having significant BBS Great Lakes Transition physiographic strata population trend data.



Open land birds (such as those found at Sleeping Bear Dunes National Lakeshore) now represent approximatley 27% of Michigan's bird species of conservation concern and a considerable portion of those birds are deemed of regional concern (United States Fish and Wildlife Service 2002). In a survey of cultural open land landscapes at the Lakeshore, we encountered a total of 83 bird species—36 species (43.4%) were classified as open land species and most of these species had significantly declining population trends (Corace et al. 2003). Thirteen of these open land species are listed as United States Fish and Wildlife Service region three (midwest) conservation priorities, including the upland sandpiper (*Bartramia longicauda*, see left).

Conclusions

Although our framework relies on the conservation status of ecosystems within the boundaries of the study area, resource managers can use this framework to assess how restoration efforts at the Lakeshore will influence regional issues and thus prioritize local restoration activities. In the case of many National Parks in the eastern United States, the landscapes usually are highly fragmented and increasingly challenged by management issues such as invasive species (see Dibble 2005), intensive agriculture, and urban development. Consequently, many national parks will continue to play an important role in the conservation of regional biodiversity. This approach provides resource managers with a framework whereby they can weigh the financial costs of ecosystem restoration with the potential enhancement of both local and regional biodiversity and ecosystem complexity that will likely result from restoration activities.

Literature Cited

ALBERT, D.A. 1995. *Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin: A working map and classification*. USDA For. Ser. Gen. Tech. Rep. NC-178. North Central Research Station, St. Paul, MN. 250 p. + map.

ALLEN, C.D., D.A. FALK, M. HOFFMAN, J. KLINGEL, P. MORGAN, M. SAVAGE, T. SCHULKE, P. STACEY, K. SUCKLING, AND T.W. SWETNAM. 2002. Ecological restoration of southwestern ponderosa pine ecosystems: A broad framework. *Ecol. Appl.* 12:1418–1433.

ASBJORNSEN, H., L.A. BRUDVIG, C.M. MABRY, C.W. EVANS, AND H.M. KARNITZ. 2005. Defining reference information for restoring ecologically rare tallgrass oak savannas in the midwestern United States. *J. For.* 103(7): 345–350.

BREWER, R., G.A. MCPEEK, AND R.J. ADAMS. 1991. *The atlas of breeding birds of Michigan.*

Michigan State University Press, Lansing, MI. 590 p.

CLELAND, D.T., J.B. HART, G.E. HOST, K.S. PREGITZER, AND C.W. RAMM. 1993. *Field guide: Ecological classification and inventory system of the Huron-Manistee national forests*. USDA For. Ser., Huron-Manistee National Forest. 261 p.

CLELAND, D.T., T.R. CROW, S.C. SAUNDERS, D.I. DICKMANN, A.L. MACLEAN, J.K. JORDAN, R.L. WATSON, A.M. SLOAN, AND K.D. BROSOFSKE. 2004. Characterizing historical and modern fire regimes in Michigan (USA): A landscape ecosystem approach. *Landsc. Ecol.* 19:311–325.

COMER, P.J., D.A. ALBERT, H.A. WELLS, B.L. HART, J.B. RABB, D.L. PRICE, D.M. KASHIAN, R.A. CORNER, AND D.W. SCHUEN. 1995. *Michigan's native landscape, as interpreted from the General Land Office Surveys 1816–1856.* Michigan Natural Features Inventory, Lansing MI. 78 p. + digital map.

CORACE, R.G., III, P.C. GOEBEL, AND T.C. WYSE. 2003. *Conservation and restoration scenarios of historic openlands at Sleeping Bear Dunes National Lakeshore from multiple scales.* Report submitted to the National Park Service Great Lakes Inventory and Monitoring Program, Ashland, WI. 56 p.

DIBBLE, A.C. AND C.A. REES. 2005. Does the lack of reference ecosystems limit our science? A case study in nonnative invasive plants as forest fuels. *J. For.* 103(7):329–338.

ECOMAP. 1993. *National hierarchical framework of ecological units.* Ecoregions Working Group.US Department of Agriculture, Washington, DC. 20 p.

EGAN, D., AND E.A. HOWELL (EDS.). 2001. *The historical ecology handbook. A restorationist's guide to reference ecosystems*. Island Press, Washington, DC. 457 p.

FRANKLIN, J.F., D.R. BERG, D.A. THORNBURGH, AND J.C. TAPPEINER. 1997. Alternative silvicultural approaches to timber harvesting: Variable retention harvest systems. P. 111–140 in *Creating a forestry for the 21st century*, Kohm, K.A., and J.F. Franklin (eds.). Island Press, Washington, DC.

HARROD, R.J., B.H. MCRAE, AND W.E. HARTL. 1999. Historical stand reconstruction in ponderosa pine forests to guide silvicultural prescriptions. *For. Ecol. Manage.* 114:433–446.

HAIGHT, R.G., D.T. CLELAND, R.B. HAMMER, V.C. RADELOFF, AND T.S. RUPP. 2004. Assessing fire risk in wildland-urban interface. *J. For.* 102:41–47.

KENEFIC, L.S., A.S. WHITE, A.R. CUTKO, AND S. FRAVER. 2005. Reference stands for silvicultural research: A Maine perspective. *J. For.* 103(7):363–367.

LANDRES, P.B., P. MORGAN, AND F.J. SWANSON. 1999. Overview of the use of natural variability concepts in managing ecological systems. *Ecol. Appl.* 9:1179–1188.

NATIONAL PARK SERVICE. 2001. *National Park Service Strategic Plan FY2001–2005*. US Department of the Interior, Washington DC. 52 p.

PALIK, B.J., P.C. GOEBEL, L.K. KIRKMAN, AND L. WEST. 2000. Using landscape hierarchies to guide restoration of disturbed ecosystems. *Ecol. Appl.* 10:189–202.

PALIK, B.J., R.K. MITCHELL, AND J.K. HIERS. 2002. Modeling silviculture after natural disturbance to sustain biodiversity in the longleaf pine (*Pinus palustris*) ecosystem: Balancing complexity and implementation. *For. Ecol. Manage.* 155:347–356.

PALIK, B.J., AND J. ZASADA. 2003. *An ecological context for regenerating multi-cohort, mixed-species red pine forests*. USDA For. Serv. North Central Research Station Research Note NC-382, St. Paul, MN. 8 p.

SAUER, J. R., J. E. HINES, AND J. FALLON. 2001. *The North American breeding bird survey, results and analysis 1966–2000*, version 2001.2 US Geological Survey, Patuxent Wildlife Research Center, Laurel, MD.

SOCIETY FOR ECOLOGICAL RESTORATION INTERNATIONAL SCIENCE AND POLICY WORKING GROUP. 2004. *The SER international primer on ecological restoration*. Available online at www.ser.org and Tuscon: Society for Ecological Restoration; last accessed Aug. 15, 2005.

STEPHENS, S.L., AND P.Z. FULÉ. 2005. Western pine forests with continuing frequent fire regimes: Possible reference sites for management. *J. For.* 103(7): 357–362.

UNDERWOOD, S., L. ARGUELLO, AND N. SIEFKIN. 2003. Restoring ethnographic landscapes and natural elements in Redwood National Park. *Ecol. Restoration* 21:278–283.

UNITED STATES FISH AND WILDLIFE SERVICE. 2002. *Fish and wildlife resource conservation priorities: Region 3*. US Fish and Wildlife Service, Minneapolis, MN.

WRAY, J., AND M.K. ANDERSON. 2003. Restoring Indian-set fires to prairie ecosystems on the Olympic Peninsula. *Ecol. Restoration* 21:296–301.

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