Restoration Ecology
THE JOURNAL OF THE SOCIETY FOR ECOLOGICAL RESTORATION INTERNATIONAL

TECHNICAL REPORT

Planning for Implementation: Landscape-Level Restoration Planning in an Agricultural Setting

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Abstract

The conservation of biodiversity in highly fragmented landscapes often requires large-scale habitat restoration in addition to traditional biological conservation techniques. The selection of priority restoration sites to support long-term persistence of biodiversity within landscape-scale projects however remains a challenge for many restoration practitioners. Techniques developed under the paradigm of systematic conservation planning may provide a template for resolving these challenges. Systematic conservation planning requires the identification of conservation objectives, the establishment of quantitative targets for each objective, and the identification of areas which, if conserved, would contribute to meeting those targets. A metric developed by systematic conservation planners termed "irreplaceability" allows for analysis and prioritization of such conservation options, and allows for the display of analysis results in a way that can engage private landowners and other decision makers. The process of systematic conservation planning was modified to address landscape-level restoration prioritization in southern Ontario. A series of recent and locally relevant landscape ecology studies allowed the identification of restoration objectives and quantitative targets, and a simple algorithm was developed to identify and prioritize potential restoration projects. The application of an irreplaceability analysis to landscape-level restoration planning allowed the identification of varying needs throughout the planning region, resulting from underlying differences in topography and settlement patterns, and allowed the effective prioritization of potential restoration projects. Engagement with rural landowners and agricultural commodity groups, as well as the irreplaceability maps developed, ultimately resulted in a substantial increase in the number and total area of habitat restoration projects in the planning region.

Key words: **community engagement, ecological threshold, irreplaceability, landscape-level restoration, restoration implementation, systematic restoration planning.**

Introduction

The loss and fragmentation of habitat is one of the greatest challenges facing the conservation of biodiversity globally, leading to reductions in population size for many wildlife species, in some cases to the point of extinction (Wilcove et al. 1998; Harrison & Bruna 1999; Fahrig 2003). In heavily fragmented landscapes, the effective conservation of biodiversity will require the appropriate application of both cutting edge conservation and restoration techniques (Hobbs 2002). Several decades of successful restoration projects have been reviewed and synthesized to produce frameworks for restoration planning, which include guidelines for planning, implementing, and monitoring restoration projects (Clewell et al. 2005; White et al. 2005; Parks Canada 2007); however, many of these guidelines have been developed primarily for site-level interventions. In highly fragmented landscapes, restoration practitioners need to expand the scope of restoration from individual sites to the landscape level, providing spatially explicit restoration recommendations and social mechanisms to incorporate multiple landowners (Buckley et al. 2002; Hobbs 2002; Sutherland et al. 2006). Although some theoretical direction exists in the literature on incorporating landscape-level processes into restoration planning (Bell et al. 1997; Huxel & Hastings 1999; Maschinski 2006), there are relatively few specific examples where this has been done successfully, perhaps due to the difficulty of restoration planning at a landscape scale (Clewell & Rieger 1997; Hobbs 2002; Holl et al. 2003). The concepts underlying systematic conservation planning (Margules & Pressey 2000) however may provide a useful template for systematically planning restoration projects at the landscape scale.

In the mid- to late-1990s, the field of conservation planning went through a paradigm shift with the development of a process for systematic conservation planning. Systematic conservation planning takes advantage of advances in remote sensing and GIS technology to represent and analyze species and

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doi: 10.1111/j.1526-100X.2010.00666.x

habitat occurrences spatially, supporting rational and ecologically appropriate conservation decisions (Pressey et al. 1993; Margules & Pressey 2000). The process of systematic conservation planning requires planners or resource managers to set clear conservation objectives (such as species, ecosystems, or other biodiversity surrogates), define quantitative targets for their conservation, and identify areas that, if protected, would contribute to meeting these targets (Margules & Pressey 2000). One potentially effective way of measuring contribution value is termed irreplaceability. Irreplaceability accepts that there may be many ways of defining a protected area system, but that some areas may contribute more than others. Irreplaceability can be defined as the extent to which the options for landscape-level conservation become further constrained if a particular site is not conserved. As this value is measured on a zero to one scale, rather than being simply binary, it provides flexibility for decision makers, yet explicitly defines the values and trade-offs associated with each decision (Pressey et al. 1993).

Despite continuing advancements in the field of systematic conservation planning, including the development of more sophisticated site selection algorithms, and identification of effective ecological surrogates, systematic conservation planning suffers from an implementation crisis (Knight 2006; Knight et al. 2006). Conservation practitioners (Luz 2000; Knight et al. 2006; Knight et al. 2008) are now suggesting that effective conservation action requires broad-based stakeholder involvement, capacity building in landowners and land use planners, and improved communication with the public and particularly with decision makers. Experience from the world of municipal land use planning demonstrates that plans developed with stakeholder involvement tend to have a more complete resource inventory, more balanced objectives, and tend to be implemented to a greater extent (Brody 2003; Burby 2003).

Systematic conservation planning and stakeholder involvement have potential application to the field of landscape-level restoration planning as well. Although perhaps conceptually more challenging, restoration ecologists may be able to define their restoration objectives, identify quantitative targets for their restoration, and identify areas that, if restored, would contribute to meeting these targets. In fact, several years ago Hobbs and Norton (1996) suggested that restoration ecologists identify and gain understanding of threshold relationships between landscape and ecological process, with the intent of informing restoration decisions. Where such thresholds do exist, they may provide effective and defensible quantitative targets for a systematic restoration planning framework.

Elgin County in southwestern Ontario is perhaps a typical example of the need for landscape-level habitat restoration. Southwestern Ontario is one of the highest priority conservation regions in Canada; not only is this region the most species rich in a number of taxa, but also it suffers from a proportional lack of protected areas (Warman et al. 2004). This region is one with a longer growing season than much of the rest of the country, and with deep fertile mineral soils. These factors, which drive much of the species richness of the region (Hills 1959; Maycock 1962), also make it one of the most agriculturally productive regions in the country (Harry Cumming and Associates 2000). As a result of its agricultural productivity, this region is largely privately owned, and has been converted to agriculture, resulting in a significant loss of forest (Larson et al. 1999) and wetland cover (Snell 1987).

Southwestern Ontario is fortunate in that a number of locally relevant studies have examined the relationship between landscape structure and ecological processes or species occurrences, which could provide a starting point for systematic restoration planning. For example, losses in wetland area below 10% of the area of a given watershed has been demonstrated to lead to exponential increases in the volume of peak floods, and decreases in the amount of time water is retained in the watershed (Johnston et al. 1990; Detenbeck et al. 1999). Furthermore, studies have found that when wetlands drop below approximately 10% of the area of a watershed, noticeable declines in fish communities become evident, including loss in both the abundance of fish as well as an overall species loss (Brazner et al. 2004). Similarly, studies along the north shore of Lake Ontario found that when less than 75% of the riparian area within the upper reaches of a watershed are forested, aquatic communities start to become depauperate. This included the disappearance of a number of fish species, including trout and other predators, although those species that remained tended to have a much greater incidence of parasites (Steedman 1988).

Similar relationships exist between the extent of forest cover and terrestrial wildlife populations. At some point, as landscapes become progressively fragmented, species that are restricted in their dispersal or habitat selection are no longer able to sustain themselves (Villard et al. 1999; Fahrig 2003). Evidence suggests that when more than 30% of a landscape is forested, habitat or population isolation is of little concern (Schmiegelow & Monkkonen 2002). However, as habitat is progressively lost, isolation increasingly becomes a problem and habitat-limited species find the landscape becoming more inhospitable. Thus, migrant songbirds and forest dwelling amphibians living in landscapes with less than 30% forest cover tend to be much less common, and restricted from smaller forests, than those living in more highly forested areas (Freemark & Collins 1992; Gibbs 1998; Villard et al. 1999; Austen et al. 2001; Homan et al. 2004). Furthermore, some species are highly area sensitive. Results from the Ontario Breeding Bird Atlas (Cadman et al. 1987) suggest that the number of area sensitive songbirds in a landscape will increase as interior habitat (i.e. that habitat more than 100 m from a forest edge) and deep interior habitat (i.e. that habitat more than 200 m from a forest edge) increase up to 10 and 5% of the landscape, respectively (Canadian Wildlife Service 2004).

The objective of this study was to develop a framework for identifying and prioritizing restoration opportunities in a primarily privately owned agricultural landscape, in a format that would promote implementation by fostering uptake by the agricultural community.

Methods

Location

Elgin County is located in Southwestern Ontario (42°45′N, 81°14′W) and is approximately 1,880 km^2 in size. The eastern and western ends of the county are underlain by deltaic sand deposits, with a lacustrine clay deposit in the center of the county (Chapman & Putnam 1966).

The relatively level landscape associated with the lacustrine clay plain supports a fairly homogenous forest, which includes tulip tree (*Liriodendron tulipifera*), green ash (*Fraxinus pennsylvanica*), and northern red oak (*Quercus rubra*) interspersed throughout the dominant sugar maple (*Acer saccharum*)–American beech (*Fagus grandifolia*) community. Black ash (*Fraxinus nigra*)–American elm (*Ulmus americana*) wetlands develop in slight depressions. The predominantly sandy soils of the deltaic sand plains often form dune-like patterns due to historic action of wind and waves on the sand. The higher and drier ridges tend to develop a drier type of forest including white pine (*Pinus strobus*), red and black oaks (*Quercus velutina*), and shagbark hickory (*Carya ovata*), whereas the wetter swales tend to develop small wetland communities that include tulip tree, black ash, and American elm. Furthermore, the deep sand deposits in the eastern end of the county have been bisected by a number of watercourses, which have cut deep ravines into the friable soils. These ravines can support shade tolerant species including sugar maple, American beech, and eastern hemlock (*Tsuga canadensis*) (Rowe 1972).

Elgin County has a population of approximately 85,000, and land use throughout the county is dominated by agriculture. Farmers own approximately 86% of the county, and approximately 3% exists in publicly owned protected areas (Statistics Canada 2001). Over the past 50 years, the rural population in the county has remained relatively stable, whereas the urban population has grown steadily. Urban centers in this county include the county seat (population 36,000), one small town (population 7,000), and several small hamlets (Statistics Canada 2001). Despite the relatively constant rural population, the number of farms in the county has declined over the past 50 years, reflecting consolidation of smaller farms, and an increasing number of rural non-farmers. Average farm size in this county is now approximately 96 ha, although approximately one-third of the farms in the county are owned by non-farming rural landowners and the land rented to farmers (Harry Cumming and Associates 2000; Statistics Canada 2001).

Consultation

To develop a planning approach that was acceptable to the rural community as well as being scientifically defensible, this landscape restoration plan was developed with both broad-based and focused consultation. A steering committee made up of equal representation of delegates from conservation organizations and agricultural commodity groups operating locally was convened to provide guidance and feedback as the plan developed. Over a series of workshops, the committee provided input on the restoration objectives, resource inventory, identification of opportunity areas, a review and critique of the science providing the quantitative targets, and a subjective test of successive iterations of model output. All decisions of this steering committee were made on a consensus basis. In cases where consensus could not be reached, the issue was tabled to allow further research and consideration. As draft plans became available, consultation was broadened through a series of public meetings where the process and draft plan were presented and feedback from local landowners was solicited. This feedback was presented to the steering committee for consideration in future iterations of the plan. Later in the process, this committee assisted in the development of simple and comprehensible mapping and other extension materials, which were in turn field-tested with representatives of agricultural commodity groups.

Outreach for implementation to landowners in the planning region was personalized with a map of their subject property, and discussions led by biologists or extension officials about specific restoration options and opportunities on that landowner's property. Where possible, these discussions were initiated on a peer-to-peer basis using members of the steering committee or landowners who had successfully completed restoration projects, and who had existing relationships with the subject landowner.

Model Development

A GIS-based algorithm to identify and prioritize restoration opportunities was developed, based on the identification of objectives, quantitative targets, and potential restoration sites relevant to the planning region.

Existing conditions within the county were described using an IRS LISS-3 satellite image captured in May 1998. The satellite image was classified into the following land cover types: deciduous forest, coniferous forest, open water, early successional scrubland, pasture land, and crop land. Information on water resources such as location and characteristics of watercourses and wetlands were taken from the Provincial Natural Resources Values Information System (NRVIS) database. Information on other features such as the location of roads and public lands was also provided by NRVIS. Soil type and topography were derived from the county soil map (Ontario Ministry of Agriculture and Food 1992) and a digital elevation model (DEM) with 10 m horizontal and 5 m vertical resolution, respectively.

Potential wetland restoration sites were defined as non-forest and non-wetland areas classified as poorly and very poorly drained soil in the county soil map. Riparian areas were defined as those areas within 30 m of first to third-order watercourses. Riparian areas were considered vegetated if the land cover map classified it as coniferous forest, deciduous forest, or early successional and a potential restoration site if classified otherwise, and not a road. Restoration targets for wetlands and riparian areas were set at 10% of the area and 75% of the riparian zone (within 30 of watercourses) of each watershed, respectively.

Areas that were classified as bare soil, pasture land, or cropland within 100 m of any existing forest provided potential sites for interior forest restoration. Similar areas within 100 m of forests with interior, but no deep interior, habitat were identified as potential restoration sites for deep interior habitat. Any area that was classified as bare soil, pasture land, or cropland and not covered by roads, houses, or other development provided the opportunity area for forest restoration. Forest restoration targets were set as 30% for forest cover, 10% for interior forest, and 5% for deep interior forest within each subwatershed.

The major watersheds in the county and their subwatersheds were modeled using the DEM and the software package Terrain Analysis System (Lindsay 2005). After single pixel pits and peaks were removed from the DEM, the existing drainage network was burned in, as several of the smaller streams in the headwaters fall beneath the vertical resolution of the DEM. Watershed boundaries were defined by calculating the slope between all pixels in the raster dataset and their eight nearest neighbors. This process identified 281 watersheds and subwatersheds within Elgin County. These subwatersheds were consolidated into six major watershed planning regions, which were used as the basis for further analysis.

Parameters describing the existing conditions of the study area (percent land cover for each objective) and irreplaceability scores were calculated within watershed planning regions using raster layers with 30 m resolution in ArcView v3.2 (ESRI, Redlands, CA, U.S.A.). When irreplaceability scores are calculated on a landscape represented by equal sized grid cells, the irreplaceability metric can be simplified to the ratio of the difference between existing conditions and the target for the given objective, to the total area of potential restoration sites for that objective (Pressey et al. 2005). All pixels within a designated potential restoration site for a given restoration objective were given the irreplaceability value for that objective in that watershed planning region (Table 2). Irreplaceability values were then summed across objectives for each pixel to provide a "summed irreplaceability" score. Areas with higher summed irreplaceability thus provided greater contribution to meeting landscape-wide restoration goals than those with lower summed irreplaceability.

Results

Row crop agriculture is the dominant land use in this planning region, accounting for 80% of the land cover within the county. Deciduous and coniferous forests account for 13% of the landscape, with early successional forests contributing an additional 9% of land use. The balance of the landscape is pastureland for beef and dairy farming.

Although forest cover accounts for approximately 13% of the land base of the entire county, it ranges across watersheds, from a high of 20.3% in the Big Otter Creek watershed to 9.4% in the Catfish Creek watershed (Table 1). Similarly, the existing conditions of the natural features identified as restoration objectives tend to vary significantly among watersheds (Table 2), as a result of differences in topography, physiography, and settlement patterns.

Table 1. Percentage of land cover by type in Elgin County, and its six watershed planning regions.

	Elgin County	*Southwest Elgin*	*Thames River*	*Talbot Creek*	*Kettle Creek*	*Catfish Creek*	*Big Otter Creek*
Total area (ha)	191,385	26,555	35,700	16,118	36,927	45,441	27,788
Forest	13.0	15.0	11.5	11.3	11.1	10.8	20.3
Scrub	6.0	4.4	5.4	5.3	5.9	6.5	8.5
Pasture	1.0	0.7	1.0	1.1	1.1	1.0	1.3
Cropland	80.0	80.0	82.0	82.2	81.8	81.7	69.9

Table 2. Existing natural features and irreplaceability scores for each of the target landscape components in the six watershed planning regions in Elgin County.

	Southwest Elgin	*Thames River*	*Talbot Creek*	*Kettle Creek*	*Catfish Creek*	*Big Otter Creek*
Wetlands						
Percent of region	3.10	1.62	0.11	0.93	0.72	0.54
Irreplaceability	0.298	0.444	0.812	0.795	0.795	0.795
Riparian buffers						
Percent of region	32.3	32.6	38.6	36.9	40.3	51.1
Irreplaceability	0.705	0.690	0.661	0.677	0.675	0.529
Forest habitat						
Percent of region	15.0	11.5	11.3	11.1	10.8	20.3
Irreplaceability	0.157	0.218	0.345	0.234	0.280	0.086
Interior forest habitat						
Percent of region	3.47	1.47	2.49	1.12	1.56	3.12
Irreplaceability	0.392	0.516	0.802	0.464	0.615	0.360
Deep interior forest habitat						
Percent of region	0.70	0.08	0.25	0.06	0.18	0.33
Irreplaceability	0.380	0.546	0.905	0.715	0.615	0.405

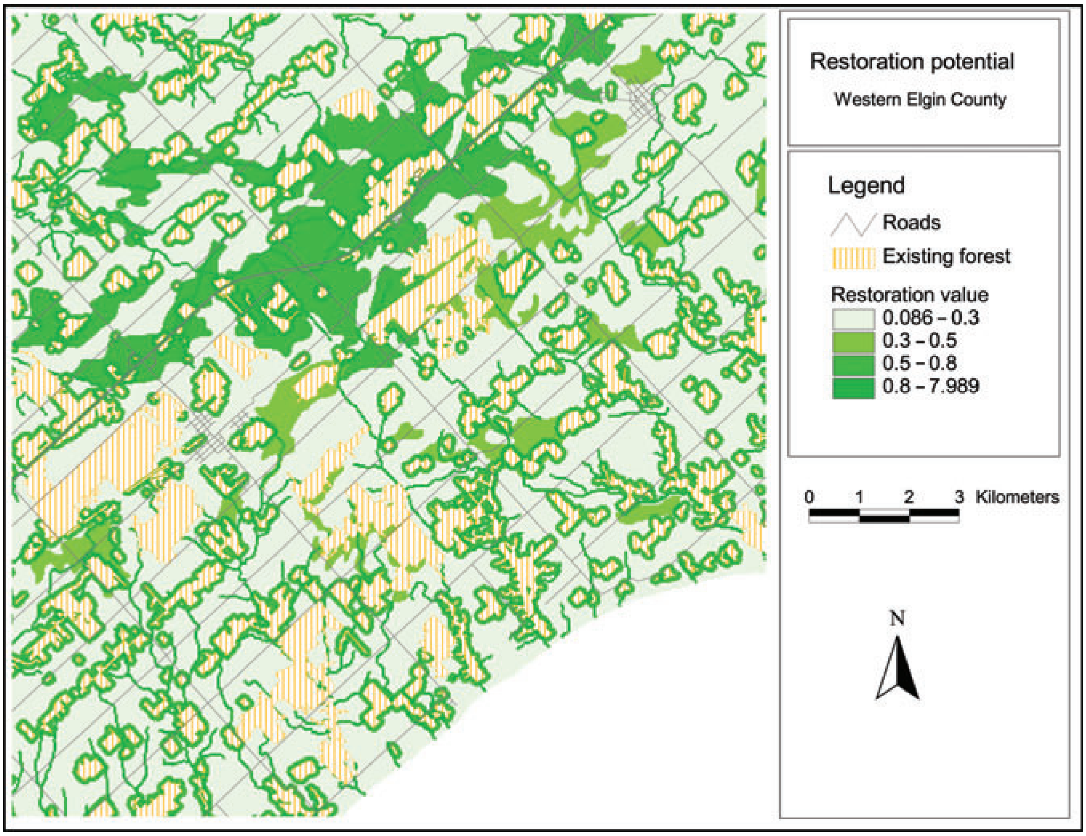

Figure 1. Habitat restoration priorities for portions of the Southwest Elgin and Thames River watershed planning areas in western Elgin County. Areas with darker shading have higher irreplaceability scores. Cross-hatched areas are forests.

Conducting the analysis on a watershed basis in this way allows the identification of the varying needs throughout the county, resulting from physiographic and social differences. Thus, the Southwest Elgin watershed on the Bothwell sand plain (Fig. 1) (Chapman & Putnam 1966) is currently dominated by several large (>150 ha) wetlands. Targets for this watershed put low emphasis on additional wetland habitat ($I = 0.298$) but put more emphasis on additional riparian buffers ($I = 0.705$). Conversely, the Big Otter Creek watershed (Fig. 2), which exists on a deep sand plain, is crossed by several deeply incised ravines, with relatively continuous forest cover along their banks. As such, less emphasis is given to providing additional riparian buffering in this watershed ($I = 0.529$) than in the rest of the county; rather, emphasis is placed on providing additional wetland habitat ($I = 0.795$).

Despite this variance among subwatersheds, some similarities exist as well. In almost all cases, the target of 75% riparian buffer identified these potential projects as the most irreplaceable restoration opportunities. Opportunities to increase total natural habitat reflect the lowest irreplaceability scores in any watershed (Table 2), as opportunities for these projects are essentially unconstrained. Conversely, opportunities for increasing the amount of deep interior forest habitat are strongly constrained by existing forest remnants, thus opportunities for such projects have high irreplaceability regardless of watershed.

Although these recur as important issues, there are no cases where a restoration target has already been met in a watershed, indicating that a wide variety of restoration options exist.

Discussion

The irreplaceability approach to systematic restoration planning provides a useful decision-making framework that accounts for intra-region physiographic differences and promotes uptake in an agricultural setting. As in the current study, a planning region with high internal variation in existing conditions, due to physiography, population density, or other uncontrolled factors, could be subdivided for analysis purposes. Irreplaceability calculated on these subregions allows restoration planners to tailor priority setting to the needs of the local, rather than regional, landscape. Furthermore, planning at a watershed level ensures that effort to improve water quality is distributed appropriately throughout the study region.

Restoration plans developed in this manner, using parameters describing landscape characteristics taken from comprehensive maps or geospatial databases, avoid the concerns about

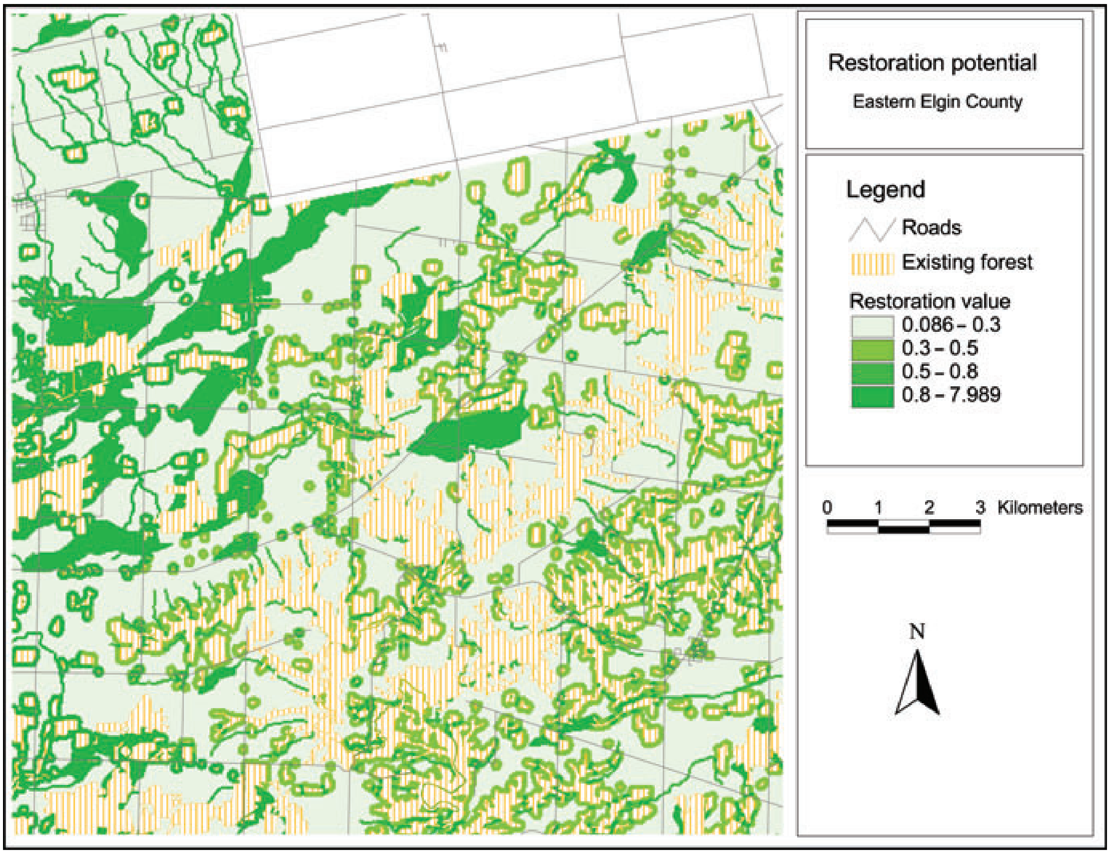

Figure 2. Habitat restoration priorities for portions of the Catfish Creek and Big Otter Creek watershed planning areas in eastern Elgin County. Areas with darker shading have higher irreplaceability scores. Cross-hatched areas are forests.

sampling error or statistical validity that models based on inventory data face. However, the implicit assumption that such databases are completely accurate rarely holds true. Inaccurate land cover maps can provide inaccurate parameters or indices describing initial condition (Langford et al. 2006) and may have significant influence on relative priority of restoration opportunities (Rouget 2003; Grand et al. 2007). In the current study, engaging local landowners in the ultimate site selection process offset the risks associated with inaccuracies in these parameters. In an agricultural setting, farmers often have a detailed and complex understanding of the land they own and the local landscape within which it is situated. Including this understanding in the decision-making process was an important test of the accuracy of the model's input data and allowed revisions to model output where necessary.

In fact, systematic restoration planning using an irreplaceability algorithm lends itself well to engagement and empowerment of rural landowners. Rather than developing a definitive resolution of the most efficient restoration sites, irreplaceability allows resource managers to present information to rural landowners, allowing them to participate in the final decision-making. Interaction with farmers and other rural landowners during the current study found that the irreplaceability maps make conceptual sense; farmers tended to view their farms as having varying value for crop production within and among fields. The irreplaceability maps developed as described here were presented to these landowners as maps of the varying value for wildlife habitat and water quality. These maps were used as a tool to foster collaborative site selection by landowners and resource managers, which acted as a first step in the site-level restoration planning including design and species selection based on abiotic conditions and landowners preferences (Clewell et al. 2005; White et al. 2005). This approach was found to be a clear and understandable starting point to discuss restoration needs and opportunities, and to build capacity within the community. In fact, the empowering and consultative approach exercised during the current study did significantly assist with implementing habitat restoration projects. During the 4-year period this landscape plan was being developed, field-tested, and rolled out, uptake of site-level restoration projects on an annual basis increased more than 20-fold.

Including unmapped, unmappable, or intangible knowledge held by landowners, with the spatially explicit guidelines developed by technical specialists based on peer-reviewed literature, allowed the development of a more flexible restoration planning tool. Expert-based conservation planning can become overly pragmatic and focused solely on site availability

(Cowling et al. 2003), whereas purely GIS-based approaches can be overly prescriptive and difficult to implement (Meir et al. 2004; Knight & Cowling 2007). However, a GIS-based information tool that supports decisions made collaboratively with landowners is equitable and transparent and is able to take an approach of informed opportunism (i.e. it is able to take advantage of opportunities as they arise, while being aware of trade-offs; sensu Noss et al. 2002).

Furthermore, a landscape-scale restoration plan that identifies the range of all possible projects and their relative value can be used both in top–down and in bottom–up planning. In cases where funding becomes available for particular projects (e.g. for wetland restoration), landscape managers could examine an irreplaceability map for their jurisdiction to identify areas where wetland projects are the most irreplaceable. In bottom–up planning, biologists or extension professionals can use an irreplaceability map in working with landowners to identify priority habitat restoration opportunities.

Systematic conservation planning often includes an analysis of both conservation value and vulnerability to external threats, allowing decision markets to prioritize actions (Margules & Pressey 2000; Noss et al. 2002). Although a similar analysis may be appropriate in systematic restoration planning, priority may be better given to those sites with low expected vulnerability. With the uncertainty and risk inherent to any restoration project (Hilderbrand et al. 2005), giving priority to sites with relatively high risk to additional external factors, such as development pressure or novel invasive species, may dramatically increase the costs and effort necessary to successfully implement landscape-level restoration.

The targets relating landscape structure and ecological process used in this study were reviewed, summarized, and widely disseminated throughout southern Ontario by the Canadian Wildlife Service (2004). As a result, these targets have been adopted by a number of planning authorities, including a number of government agencies operating locally. Despite the cautions raised by authors in the primary literature about using "one size fits all" percentage targets for habitat protection (Fahrig 2001; Schmiegelow & Monkkonen 2002), the 30% quantitative target for forest cover used in this study has been found to hold true for a number of species in this planning region (Gibbs 1998; Villard et al. 1999; Austen et al. 2001; Homan et al. 2004). These threshold targets also provide a stretch goal, a highly ambitious long-term goal that may inspire innovation and creativity in both concerned landowners and the conservation community (Manning et al. 2006). They may also represent a "first approximation," allowing more species- and context-relevant targets to be developed later under an adaptive management paradigm. The ultimate value of these targets and restoration planned and implemented under their paradigms however will need to be determined by studies on how changes in biodiversity and water quality relate to eventual changes in landscape composition (Boesch et al. 2001; Twedt & Wilson 2002).

Much of the primary research suggesting that threshold relationships exist between land cover and wildlife distribution is based on presence–absence studies. Other authors (Burke & Nol 2000; Austen et al. 2001) who examined reproductive success and population densities respectively in southern Ontario have suggested that size of individual forest patches are in fact more important determining factors for songbird conservation. A planning approach built upon an objective of increasing size of extant forests however would tend to focus action on particular landowners who owned, or were adjacent to, relatively large forest remnants (i.e. those remnants slightly below the target area). The steering committee reviewing drafts of this landscape plan felt that an approach that put such emphasis on a minority of landowners did not empower the community sufficiently. In fact, the acquisition and restoration of large core habitat patches such as these may be an important role for public agencies in primarily privately owned landscapes, leaving private landowners with the challenge of improving the state of the "matrix" intervening core habitat areas.

The techniques developed to solve landscape-level conservation planning problems can also be applied to landscape-level restoration planning. The systematic identification and prioritization of potential restoration projects within a planning region are possible if restoration planners can identify restoration objectives, define quantitative targets for their restoration, and identify areas that, if restored, would contribute to meeting these objectives. The concept of irreplaceability as developed by Pressey and others (Pressey et al. 1993; Ferrier et al. 2000; Margules & Pressey 2000) is an applicable one for restoration planning as it allows planners to either identify an effective and efficient solution-set to the restoration planning problem in a transparent and replicable way, or alternatively to develop clear and comprehensible communication tools to promote understanding and foster implementation on a primarily privately owned landscape. Engaging landowners and key environmental and resource-based stakeholders in the development and dissemination of systematic restoration plans developed using an irreplaceability paradigm can further promote its implementation in a privately owned landscape.

Implications for Practice

- The process of systematic conservation planning can be easily modified to provide a starting point for landscape-level restoration planning.
- The relative simplicity of calculating an irreplaceability value of some proposed future land cover type suggests that irreplaceability may be a valuable tool for restoration planners.
- Threshold relationships between the ecological structure and function of landscapes, where they exist, provide defensible targets for conservation or restoration planning.

- The constraints and opportunities provided by topography and soil conditions will define, to a great extent, the type of restoration project that is suitable at a site level, and will tend to cluster like projects at a landscape level.
- The audience for the plan (i.e. the decision makers or primary landowners in the planning region) should be kept in mind when developing a landscape-level conservation or restoration plan.
- Engaging landowners and other decision makers in the planning process promotes ownership and ambassadorship of the resulting plan. Landowner ambassadors can be critically important in communicating with their peers and leveraging buy-in in a rural community.

Acknowledgments

I thank Mark Emery and Kit Brown for their direction and support in the development of the Elgin Landscape Strategy, as well as Leora Berman, Brent Clutterbuck, Tony Difazio, Pud Hunter, Alan McKillop, Bill Prieksaitis for their contributions to the steering committee, and the Elgin County Stewardship Council for their vision in developing this project and seeing it through to its successful conclusion. This project was made possible with the generous support of the Ontario Trillium Foundation. This article was improved substantially with the input of Eric Higgs and two anonymous reviewers. Thanks are also due to the dozens of rural landowners who commented on the Elgin Landscape Strategy during its development, and particularly to those who have voluntarily taken on habitat restoration projects on their farms.

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