This file was created by scanning the printed publication.
Errors identified by the software have been corrected;
however, some errors may remain.

Adding a Landscape Ecology Perspective to Conservation and Management Planning

Kathryn E. Freemark[1], John R. Probst[2], John B. Dunning[3], and Sallie J. Hejl[4]

Abstract — We briefly review concepts in landscape ecology and discuss their relevance to the conservation and management of neotropical migrant landbirds. We then integrate a landscape perspective into a spatially-hierarchical framework for conservation and management planning for neotropical migrant landbirds (and other biota). The framework outlines a comprehensive approach by which managers can develop plans based on (1) assessing the composition and interspersion of habitats important to species of current or future concern at a variety of spatial and temporal scales by generating and using data with different levels of resolution, and (2) assessing and modeling population dynamics and related ecological processes. We reference our paper throughout with selected studies of birds on temperate breeding areas, and to a more limited extent, on migration and neotropical wintering areas.

INTRODUCTION

Landscape ecology is the study of spatial patterns: what they are, how they develop through natural or anthropogenic influences, how they change over time, how they affect biological systems and ecological processes, and how spatial heterogeneity can be managed for societal benefits and survival (see Risser et al. 1984, Turner 1989, Turner and Gardner 1991, Barrett 1992, Hansen and diCastri 1992, Karr 1993, and the journal *Landscape Ecology*). It is a synthetic intersection of many disciplines including ecology, geography, sociology, and economics. The explicit consideration of spatial heterogeneity and human influences, and the emphasis on spatial and temporal dynamics distinguishes landscape ecology from traditional ecological studies which, until recently, have focused on pristine environments and have assumed that systems are spatially homogeneous or at equilibrium.

In this paper, we briefly review concepts in landscape ecology and discuss their relevance to the conservation and management of neotropical migrant landbirds. We then outline a framework which integrates a landscape perspective into a spatially-hierarchial approach to conservation and management planning for neotropical migrant landbirds (and other biota). We illustrate our paper throughout by reference to the most pertinent scientific literature. At present, our knowledge of landscape-level relationships for neotropical migrant landbirds is limited by the lack of research in more extensively forested temperate landscapes (especially northern conifer, southeastern and western forests), in nonforested temperate habitats (e.g. cropland), and during the nonbreeding season.

Landscape Defined

A landscape is comprised of a mosaic of habitat elements (e.g. patches, corridors and the intervening matrix) and resources generated at various scales (Kotliar and Wiens 1990, Barrett 1992, Dunning et al. 1992). The spatial extent of a landscape and the way it is perceived varies among organisms and ecological processes (Turner 1989, Wiens 1989, Karr 1993,

[1] Environment Canada, Canadian Wildlife Service c/o U.S. Environmental Protection Agency, Environmental Research Laboratory, 200 SW 35th St., Corvallis, OR 97333

[2] USDA Forest Service, North Central Forest Experiment Station, Forestry Sciences Laboratory, P.O. Box 898, Rhinelander, WI 54501

[3] University of Georgia, Institute of Ecology, 724 Biological Sciences Building, Athens, GA 30602

[4] USDA Forest Service, Intermountain Research Station, P.O. Box 8089, Missoula, MT 59807

Pearson et al. in press). For neotropical migrant landbird species, a landscape occupies the spatial scales intermediate between an individual's territory or home range and a species' regional distribution (e.g. 1-100 km^2). By focussing on intermediate spatial scales, the study of landscape-level patterns and processes may form a bridge between local habitat studies that have been commonly done, and larger scale regional and biogeographical studies.

Landscape Structure

Landscape structure can be characterized by the composition and relative availability of habitat elements, and their spatial arrangement or geometry. When particular or combinations of habitat elements are rare or absent from a landscape, bird species that depend on them are also rare or absent (Dunning and Watts 1990, Thomas et al. 1990, Herkert 1991, Probst and Weinrich in press). The richness, composition and abundance of species within a given habitat element are also affected by patch size, amount of edge, the quantity and quality of resources, and how individuals and their resources are affected by natural and anthropogenic disturbances (Stauffer and Best 1980; Karr and Freemark 1983, 1985; Brown and Dinsmore 1986; Freemark and Merriam 1986; Gotfryd and Hansell 1986; Robbins et al. 1989; Askins et al. 1990; Best et al. 1990; Johnson and Temple 1990; Gibbs et al. 1991; Hejl and Woods 1991; Bollinger and Gavin 1992).

Neotropical migrant landbirds are also significantly affected by the spatial arrangement or geometry of habitat elements in the landscape. For example, less isolated habitat patches support more area-sensitive species than more isolated patches (Askins et al. 1987, Robbins et al. 1989, Gibbs et al. 1991, Freemark and Collins 1992). The orientation of habitat patches within the landscape may also influence their relative importance to neotropical migrant landbirds during migration and the subsequent breeding season (Gutzwiller and Anderson 1992). The nature and extent of the intervening habitat matrix, the nature of boundaries created by the juxtapostion of different habitats, and the presence of corridors that facilitate the movement of individuals across the habitat matrix or boundaries can also significantly affect the species richness, composition and abundance of neotropical migrant landbirds (Wegner and Merriam 1979, Szaro and Jakle 1985, Temple and Cary 1988, Wilcove and Robinson 1990, Hansen and diCastri 1992).

Metapopulations

Populations within individual habitat patches can decline, go extinct, and become re-established by the dispersal of individuals from other patches. Sets of local populations which interact through the dispersal of individuals have been termed metapopulations (Merriam 1988, Opdam 1991). Because of spatial and temporal dynamics in local populations, the distribution pattern of a metapopulation shifts over time (Opdam 1991, Villard et al. 1992). Landscape structure coupled with a species' life-history characteristics (e.g. dispersal capability, productivity, adult/juvenile survival), affects the number of patch populations that can interact, the size of those patch populations, their temporal variability, and ultimately, the survival of the metapopulation (Merriam 1988, Opdam 1991).

There is some evidence that forest bird populations function as metapopulations within landscapes (Freemark 1989, Stacey and Taper 1992, Villard et al. 1992, Probst and Weinrich in press) and regions (Temple and Cary 1988, Robinson 1992). Within a landscape, the probability of local extinction within a habitat patch is inversely related to the size of the patch population which in turn is proportional to patch size and quality. The probability of recolonisation is proportional to proximity and connectedness to similar habitat patches and the permeability of the intervening matrix.

Some authors have suggested that metapopulations exist in a "source-sink" fashion (Pulliam 1988, Howe et al. 1991). Offspring disperse from populations in source areas where productivity exceeds mortality to populations in sink areas which, in the absence of immigration, would go locally extinct. A given area may oscillate between acting as a source or a sink with environmental variation. Computer-simulation models show that sink areas can be occupied by a large fraction of the metapopulation and can make a significant contribution to the size and longevity of the metapopulation (Pulliam 1988, Howe et al. 1991 but see McKelvey et al. 1993). Field data in support of "source-sink" metapopulation structure for neotropical migrant landbirds are currently limited to temperate forests in the east (Villard et al. 1992, Villard et al. in press) and midwest (Temple and Cary 1988, Gibbs and Faaborg 1990, Robinson 1992, Probst and Weinrich in press).

CONSERVATION AND MANAGEMENT IMPLICATIONS

It is becoming increasingly clear that the species richness, composition, abundance and population dynamics of neotropical migrant landbirds cannot be understood solely from processes occurring within individual habitat patches. Effects from the surrounding landscape also have to be considered. Understanding the relationship between landscape structure, management practices, species' distributions and probabilities of local extinction is an important prerequisite for developing and implementing effective conservation and management plans for neotropical migrant landbirds. The need for a landscape-level perspective in land management has been recognized in the "New Forestry" being developed and evaluated in the Pacific Northwest (Franklin 1989, Hansen et al. 1991) and in the "New Perspectives" (now Ecosystem Management) initiatives of the USDA Forest Service (Kessler et al. 1992 and related papers in the same issue).

Metapopulation theory provides an important context for developing conservation and management strategies based on nodes and networks of breeding habitat within and among landscapes (Dyer and Holland 1991, Hudson 1991, Murphy and Noon 1992). For at least some neotropical migrant landbird species, understanding metapopulation dynamics may be essential if viable regional populations are to be maintained (Temple and Cary 1988, Robinson 1992, Probst and Weinrich in press). Without considering metapopulation dynamics, land managers may misinterpret immigration to and local extinction in sink areas as a population response to management actions. Cumulative impacts of habitat alterations may be underestimated, particularly for productive, source areas. For example, actions that reduce the abundance and size of suitable habitat below extinction thresholds for the metapopulation may lead to the regional extirpation of a species even if some habitat of suitable quality remains (Lamberson et al. 1992). The failure of existing bird-habitat models to adequately predict population density among different locations and times is related, at least in part, to such landscape-level effects (Van Horne and Wiens 1991).

Effective conservation of neotropical migrant landbirds may require the preservation of suitable but intermittently unoccupied habitat. Efforts to identify critical habitat areas and landscapes need to consider differences in population demography and variability, and species-specific dispersal characteristics as well as population density (Van Horne 1983, Pulliam 1988, Murphy and Noon 1992, Probst and Weinrich in press). In the absence of such information, management plans should protect the diversity of habitats and landscapes used by a species, not just where the species is most common. In some situations, a diversity of habitats and landscapes may be maintained by attempting to mimic the composition and geometry of presettlement landscapes (Thomas et al. 1990, Hejl in press).

A Comprehensive Framework for Conservation and Management Planning

In the remainder of this paper, we outline a framework for conservation and management planning for neotropical migrant landbirds (and other taxa) which incorporates a landscape perspective. Our objective is to provide managers with a more comprehensive approach to planning based on (1) assessing the composition and interspersion of habitats important to species of current or future concern at a variety of spatial and temporal scales by generating and using data with different levels of resolution, and (2) assessing and modeling population dynamics and related ecological processes.

The framework (Figure 1) evolved from guidelines in Probst and Crow (1991). It includes assessments of spatial relationships and population demographics of neotropical migrant landbirds measured by extensive and intensive methods at continental to local spatial scales within and between breeding seasons. Initial activities (Figure 1: Activity 1-3) assess species distributions and population trends relative to different geographic areas, physiographic regions, landforms (sensu Swanson et al. 1988), habitats and land ownerships, in order to target species or their habitats because of concerns about limited distribution, insufficient protection of important areas, sensitivity to habitat fragmentation or other landscape alteration, or recent or long-term declines. Existing breeding bird inventory and monitoring data can be used if available and, if necesary, supplemented by specific field surveys. Otherwise, targetted field surveys are required to generate input data. This approach is similar but more comprehensive than that being used in gap analysis to assess the adequacy of habitat protection for maintaining biodiversity (Scott et al. 1987), and by the Partners in Flight program to prioritize species and habitats of concern.

Activities to examine aspects of landscape structure (Figure 1: Activity 4-6) are used to understand spatial distributions of neotropical migrant landbirds in terms of population demographics and metapopulation dynamics. Field studies contrasting existing landscapes need to be done (cf. Freemark and Collins 1992, Pearson et al. in press), and in some circumstances, may be conducted by altering landscape structure experimentally (cf. Franklin 1989, Rodenhouse et al. 1992).

Differences in bird species patterns among landscapes should be measured by population density, productivity and survivorship. Indirect measures of productivity such as population variability within and between years (Villard et al. 1992, Probst and Weinrich in press), mating status of males (Probst and Hayes 1987, Gibbs and Faaborg 1990, Villard et al. in press), and adult:young ratios are most easily used for more extensive surveys, but need to be supplemented with direct measures of nesting success. Juvenile survival rates, while important, are notoriously difficult to measure because juveniles disperse from their natal areas and birds that disappear from a study area may survive elsewhere (Pulliam et al. 1992). Estimating adult survival is easy because most (but not all) adults which nest successfully usually return year after year to the same breeding site. Better field data are needed on dispersal, especially for juveniles (Pulliam et al. 1992, Villard et al. 1992). By understanding the mechanisms underlying population distribution and dynamics, problems associated with nonbreeding habitats (resulting in poor survival) can begin to be separated from problems associated with alteration of breeding habitats (resulting in poor productivity). The information can be used to evaluate, modify or design sampling schemes for population or demographic monitoring of specific neotropical migrant landbird species, habitats, geographical areas or latitudes.

The use of spatially explicit computer models is recommended (Figure 1: Activity 5-7) to simulate metapopulation dynamics (e.g. Howe et al. 1991, Lamberson et al. 1992, Pulliam et al. 1992, McKelvey et al. 1993, Thompson in press, also see review by Merriam et al. 1991). Models can be used to help focus research, monitoring, and conservation and management efforts, and to simulate short- and long-term impacts on neotropical migrant landbird populations of current

FRAMEWORK FOR CONSERVATION AND MANAGEMENT PLANNING

Activity	Application
1. Overlay: - Breeding range/abundance maps - Landform/physiographic/habitat maps - Ownership maps	Determine centers of breeding distribution ***Continental Scale***
2. Evaluate species by habitat breadth (from existing data, if available)	Field surveys: - Fill data gaps - Compare observed vs. expected habitat distribution ***Regional Scale***
3. Target habitats/species ° Low frequency - Rare habitat? - Range border? - Poor habitat definition? - Patch area effects? - Isolation/edge effects ° High frequency -Declines in abundance	Field surveys: Improve distribution data ***Landscape-Regional Scales***
4. Test contrasting landscape structures	Field studies: ° Density Differences ° Contrast productivity indirectly (Population σ, % Mated, etc.) ° Perform landscape alteration ***Landscape-Local Scales***
5. Develop Landscape/regional habitat map incorporating metapopulation dynamics (e.g. source vs. sink)	° Model metapopulation dynamics ° Relate to monitoring ° Relate to habitat alterations ***Landscape-Regional Scales***
6. Measure directly: - Habitat productivity (# nests, nest success, etc.) - Survivorship of selected species or within selected habitats - Juvenile/adult dispersal	Calibrate/refine metapopulation models ***Local Scale***
7. Model for desired future condition - Habitat type/interspersion objectives - Succession: abandonment vs. regeneration - Cropping/rotation patterns - Land management practices (e.g. pesticides) - Predicting/planning for global change	
8. Develop/implement/monitor conservation and management plans	
9. Extend to migration and Neotropical areas	
10. Extend to Integrated Resource Management	

Figure 1. — A comprehensive, spatially-hierarchical framework for developing conservation and management plans for neotropical migrant landbird species (and other biota). Relevant spatial scales are indicated in bold.

and alternative management strategies for a landscape (Pulliam et al. 1992, Murphy and Noon 1992). For the greatest accuracy in developing conservationa and management strategies, models should reflect local landscape structure(s) and if possible, use local, habitat-specific information about population demography and bird dispersal behavior (Hansen et al. 1992, Pulliam et al. 1992).

Toward this end, a major innovation is the linkage of computer simulation models with geographic information systems (GIS). Management agencies are increasingly turning to GIS technology to map their holdings. These databases are ideal for generating current and future landscape maps. By linking these maps to a population simulation model, the impact of a change in management strategy (e.g. habitat type/interspersion objectives, cropping/rotation patterns, pesticide use) can be observed for the actual landscapes where the changes have been proposed (Pulliam et al. 1992, McKelvey et al. 1993). If demographic and habitat variation can be linked, then spatially explicit models could also be used to simulate impacts of global change on neotropical migrant landbirds, and to help focus related research, monitoring and conservation activities.

The development, implementation and monitoring of such comprehensive conservation and management plans (Figure 1: Activity 8) will require cooperative efforts among many researchers and land managers from many different organizations. Initially, plans will be superficial because of insufficient data but they will become increasingly more detailed and complex as additional information is generated. Use of landscape-level experiments, demonstration areas and adaptive management strategies should facilitate implementation and refinement of conservation and management plans.

At present, our approach is best developed for temperate breeding areas. However, we recognize that it needs to be extended to stopover areas and neotropical areas (Figure 1: Activity 9) if conservation planning for neotropical migrant landbirds is to be truly effective. Eventually, conservation and management plans for neotropical migrant landbirds need to be incorporated into integrated resource management strategies (Wilcove 1989, Probst and Crow 1991; Figure 1: Activity 10). Mechanisms for doing need to be developed.

Efforts to conserve neotropical migrant landbirds (and other biota) must occur on lands having a variety of uses and ownerships. Consequently, approaches for regional decision-making and cross-boundary management (both administratively and on the ground) need to be developed (Headley 1980, Schonewald-Cox et al. 1992). To be effective, approaches will have to include ecological, socio-economic, legal, cultural, ethical and aesthetic considerations (Nassauer and Westmacott 1987, Dearden 1988, Hansen et al. 1991, Kessler et al. 1992, Schonewald-Cox et al. 1992). The resolution of conflicts will require effective education and communication, and carefully designed mechanisms for planning, co-operation and co-ordination (Grumbine 1992, Schonewald-Cox et al. 1992). In this regard, the Partners in Flight program and this workshop have been important first steps.

ACKNOWLEDGMENTS

We thank R.A. Askins, B.R. Noon, S.M. Pearson, and the editors for helpful comments on an earlier draft. Funding for K.Freemark was provided by an Interagency Agreement (DWCN935524) between Environment Canada and the U.S. Environmental Protection Agency. This paper has been subject to the agency's peer and administrative review, and has been approved for publication. Funding for J.Dunning was provided in part by the U.S. Environmental Protection Agency, the Biodiversity Research Program of the U.S. Department of Energy, and USDA Forest Service Southeast Forest Experiment Station.

LITERATURE CITED

Askins, R.A., J.F. Lynch and R. Greenberg. 1990. Population declines in migratory birds in eastern North America. Current Ornithology 7:1-57.

Askins, R.A., M.J. Philbrick and D.S. Sugeno. 1987. Relationship between the regional abundance of forest and the composition of forest bird communities. Biol. Conserv. 39:129-152.

Barrett, G. 1992. Landscape ecology: Designing sustainable agricultural landscapes. J. Sustainable Agr. 2:83-103.

Best, L.B., R.C. Whitmore and G.M. Booth. 1990. Use of cornfields by birds during the breeding season: The importance of edge habitat. Am. Midl. Nat. 123:84-99.

Bollinger, E.K. and T.A. Gavin. 1992. Eastern Bobolink populations: Ecology and conservation in an agricultural landscape. Pp. 483-496 IN: J.M. Hagan and D.W. Johnston (eds.). Ecology and Conservation of Neotropical Migrant Landbirds. Smithsonian Institution Press, Washington, DC, USA. 609 pp.

Brown, M., and J.J. Dinsmore. 1986. Implications of marsh size and isolation for marsh bird management. J. Wildl. Manage. 50:392-397.

Dearden, P. 1988. Landscape aesthetics, tourism and landscape management in British Columbia. Pp. 183-190 IN: M.R. Moss (ed.). Landscape Ecology and Management. Polyscience Publ., Montreal, Quebec, Canada. 240 pp.

Dunning, J.B. Jr., B.J. Danielson and H.R. Pulliam. 1992. Ecological processes that affect populations in complex landscapes. Oikos 65:169-175.

Dunning, J.B. and B.D. Watts. 1990. Regional differences in habitat occupancy by Bachman's Sparrow. Auk 107:463-472.

Dyer, M.I. and M.M. Holland. 1991. The biosphere-reserve concept: Needs for a network design. BioScience 41:319-325.

Franklin, J. 1989. Toward a new forestry. Am. For. Nov/Dec.:37-44.

Freemark, K.E. 1989. Landscape ecology of forest birds in the northeast. Pp. 7-12 IN: R.M. DeGraaf and W.M. Healy (compil.). Is Forest Fragmentation a Management Issue in the Northeast? USDA Forest Service, Northeastern Forest Experiment Station Gen. Tech. Rep. NE-140. 32 pp.

Freemark, K.E. and B. Collins. 1992. Landscape ecology of birds breeding in temperate forest fragments. Pp. 443-454 IN: J.M. Hagan and D.W. Johnston (eds.). Ecology & Conservation of Neotropical Migrant Landbirds. Smithsonian Institution Press, Washington, DC, USA. 609 pp.

Freemark, K.E. and H.G. Merriam. 1986. Importance of area and habitat heterogeneity to bird assemblages in temperate forest fragments. Biol. Conserv. 36:115-141.

Gibbs, J.P. and J. Faaborg. 1990. Estimating the viability of Ovenbird and Kentucky Warbler populations in forest fragments. Conserv. Biol. 4:193-196.

Gibbs, J.P., J.R. Longcore, D.G. McAuley and J.K. Ringelman. 1991. Use of Wetland Habitats by Selected Nongame Water Birds in Maine. U.S. Fish Wildl. Serv., Fish and Wildlife Research 9, Washington, DC. 57 pp.

Gotfryd, A. and R.I.C. Hansell. 1986. Prediction of bird-community metrics in urban woodlots. Pp. 321-326. IN: J. Verner, M.L. Morrison and C.J. Ralph (eds.). Modeling Habitat Relationships of Terrestrial Vertebrates. University of Wisconsin Press, Madison, WI, USA. 470 pp.

Grumbine, R.E. 1991. Co-operation or conflict? Interagency relationships and the future of biodiversity of US parks and forests. Environ. Manage. 15:27-37.

Gutzwiller, K.J. and S.H. Anderson. 1992. Interception of moving organisms: influences of patch shape, size, and orientation on community structure. Landscape Ecology 6:293-303.

Hansen, A.J. and F. diCastri (eds.). 1992. Landscape Boundaries: Consequences for Biotic Diversity and Ecological Flows. Ecological Studies 92, Springer-Verlag, New York, NY, USA. 452 pp.

Hansen, A.J., T.A. Spies, F.J. Swanson and J.L. Ohmann. 1991. Conserving biodiversity in managed forests. BioScience 41:382-392.

Hansen, A.J., D.L. Urban and B. Marks. 1992. Avian community dynamics: The interplay of landscape trajectories and species life histories. pp. 170-195 IN: A.J. Hansen and F. diCastri (eds.). Landscape Boundaries: Consequences for Biotic Diversity and Ecological Flows. Springer-Verlag, New York, NY, USA. 452 pp. Headley, J.C. 1980. The economic milieu of pest control: Have past priorities changed? Pp. 81-97 IN: D. Pimentel and J.H. Perkins (eds.). Pest Control: Cultural and Environmental Aspects. Westview Press, Boulder, CO, USA. 243 pp.

Hejl, S.J. In press. The importance of landscape patterns to bird diversity: A perspective from the Northern Rocky Mountains. Northwest Environmental Journal.

Hejl, S.J. and R.E. Woods. 1991. Bird assemblages in old-growth and rotation-aged Douglas-fir/ponderosa pine stands in the northern Rocky Mountains: A preliminary assessment. Pp. 93-100 IN: D.M. Baumgartner and J.E. Lotan (eds.). Proc. of the Symposium on Interior Douglas-fir: The Species and Its Management. Washington State Univ., Pullman, WA, USA.

Herkert, J.R. 1991. Prairie birds of Illinois: Population response to two centuries of habitat change. Ill. Nat. Hist. Surv. Bull. 34: 393-399.

Howe, R.W., G.J. Davis and V. Mosca. 1991. Demographic significance of sink populations. Biol. Cons. 57:239-255.

Hudson, W. (ed.). 1991. Landscape linkages and biodiversity. Island Press, Washington, DC, USA.

Johnson, R.G., and S.A. Temple. 1990. Nest predation and brood parasitism of tallgrass prairie birds. J. Wildl. Manage. 54:106-111.

Karr, J.R. 1993. Landscapes and management for ecological integrity. IN: K.C. Kim and R.D. Weaver (eds.). Biodiversity and Landscape: A Paradox for Humanity. Cambridge University Press, New York. In press.

Karr, J.R. and K.E. Freemark. 1983. Habitat selection and environmental gradients: Dynamics in the "stable" tropics. Ecology 64:1481-1494.

Karr, J.R. and K.E. Freemark. 1985. Disturbance and vertebrates: An integrative perspective. Pp. 153-168 IN: S.T.A. Pickett and P.S. White (eds.). The Ecology of Natural Disturbance and Patch Dynamics. Academic Press, New York, NY, USA. 472 pp.

Kessler, W.B., H. Salwasser, C.W. Cartwright Jr. and J.A. Caplan. 1992. New perspectives for sustainable natural resources management. Ecol. Appl. 2:221-225.

Kotliar, N.B. and J.A. Wiens. 1990. Multiple scales of patchiness and patch structure: a hierarchical framework for the study of heterogeneity. Oikos 59: 253-260.

Lamberson, R.H., R. McKelvey, B.R. Noon and C. Voss. 1992. The effects of varying dispersal capabilities on the population dynamics of the northern spotted owl. Conserv. Biol. 6: 1-8.

McKelvey, K., B.R. Noon and R.H. Lamberson. 1993. Conservation planning for species occupying fragmented landscapes: The case of the northern spotted owl. IN: P.M. Kareiva, J.G. Kingslover and R.B. Huey (eds.). Biotic Interactions and Global Change. Sinauer Assoc., Sunderland, MA, USA. In press.

Merriam, G. 1988. Landscape dynamics in farmland. Trends Ecol. Evol. 3:16-20.

Merriam, G., K. Henein and K. Stuart-Smith. 1991. Landscape dynamics models. Pp. 399-416 IN: M.G. Turner and R. H. Gardner. Quantitative Methods in Landscape Ecology. Ecological Studies 82, Springer-Verlag, New York, NY, USA. 536 pp.

Murphy, D.D. and B.R. Noon. 1992. Integrating scientific methods with habitat conservation planning: Reserve design for Northern Spotted Owls. Ecol. Appl. 2:3-17.

Nassauer, J.I and R. Westmacott. 1987. Progressiveness among farmers as a factor in heterogeneity of farmed landscapes. Pp. 199-210 IN: M.G. Turner (ed.). Landscape heterogeneity and Disturbance. Springer-Verlag, New York, NY, USA. 241 pp.

Opdam, P. 1991. Metapopulation theory and habitat fragmentation: a review of holarctic breeding bird studies. Landscape Ecology 5:93-106.

Pearson, S.M., M.G. Turner, R.H. Gardner and R.V. O'Neill. In press. An organism-based perspective of habitat fragmentation. IN: R.C. Szaro (ed.). Biodiversity in Managed Landscapes: Theory and Practice. Oxford University Press.

Probst, J.R. and T.R. Crow. 1991. Integrating biological diversity and resource management: an essential approach to productive, sustainable ecosystems. J.Forestry 89(2):12-17.

Probst, J.R. and J.P. Hayes. 1987. Pairing success of Kirtland's warblers in marginal versus suitable habitat. Auk 104:234-241.

Probst, J.R. and J. Weinrich. In press. Relating Kirtland's warbler population to changing landscape composition and structure. Landscape Ecology.

Pulliam, H.R. 1988. Sources, sinks, and population regulation. Am. Nat. 132:652-661.

Pulliam, H.R., J.B. Dunning, and J. Liu. 1992. Population dynamics in complex landscapes: A case study. Ecol. Appl. 2:165-177.

Risser, P.G., J.R. Karr and R.T.T. Forman. 1984. Landscape Ecology: Directions and Approaches. Ill. Nat. Hist. Surv. Spec. Publ. 2, Champaign, IL, USA. 18 pp.

Robbins, C.S., D.K. Dawson and B.A. Dowell. 1989. Habitat area requirements of breeding forest birds of the Middle Atlantic States. Wildl. Monogr. 103:1-34.

Robinson, S.K. 1992. Population dynamics of breeding Neotropical migrants in a fragmented Illinois landscape. Pp. 408-418 IN: J.M. Hagan and D.W. Johnston (eds.). Ecology and Conservation of Neotropical Migrant Landbirds. Smithsonian Institution Press, Washington, DC, USA. 609 pp.

Rodenhouse, N.L., G.W. Barrett, D.M. Zimmerman and J.C. Kemp. 1992. Effects of uncultivated corridors on arthropod abundances and crop yields in soybean agroecosystems. Agr. Ecosyst. Environ. 38:179-191.

Schonewald-Cox, C., M. Buechner, R. Sauvajot, and B.A. Wilcox. 1992. Cross-boundary management between national parks and surrounding lands: A review and discussion. Environ. Manage. 16:273-282.

Scott, J.M., B. Csuti, J.D. Jacobi, and J.E. Estes. 1987. Species richness: A geographic approach to protecting future biological diversity. BioScience 37:782-788.

Stacey, P.B. and M. Taper. 1992. Environmental variation and the persistence of small populations. Ecol. Appl. 2:18-29.

Stauffer, D.F., and L.B. Best. 1980. Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. J. Wildl. Manage. 44:1-15.

Swanson, F.J., T.K. Kratz, N. Caine and R.B. Woodmansee. 1988. Landform effects on ecosystem patterns and processes. BioScience 38:92-98.

Szaro, R.C., and M.D. Jakle. 1985. Avian use of a desert riparian island and its adjacent scrub habitat. Condor 87:511-519.

Temple, S.A. and J.R. Cary. 1988. Modeling dynamics of habitat-interior bird populations in fragmented landscapes. Conservation Biol. 2:340-347.

Thomas, J.W., E.D. Forsman, J.B. Lint, E.C. Meslow, B.R. Noon, and J. Verner. 1990. A Conservation Strategy for the Northern Spotted Owl. Report of the Interagency Scientific Committee to address the conservation of the Northern Spotted Owl. United States Government Printing Office 1990-791-171/20026, Washington, DC, USA.

Thompson, F. In Press. Simulation response of a forest-interior bird population to forest management options in the Central Hardwoods of the United States. Conservation Biology.

Turner, M.G. 1989. Landscape ecology: the effect of pattern on process. Annu. Rev. Ecol. Syst. 20:171-197.

Turner, M.G., and R.H. Gardner. 1991. Quantitative Methods in Landscape Ecology. Ecological Studies 82, Springer-Verlag, New York, NY, USA. 536 pp.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Manage. 47:89-101.

Van Horne, B. and J.A. Wiens. 1991. Forest Bird Habitat Suitability Models and the Development of General Habitat Models. U.S. Fish and Wildlife Service, Fish Wildl. Research 8, Washington, D.C. 31 pp.

Villard, M.-A., K.E. Freemark and H.G. Merriam. 1992. Metapopulation theory and neotropical migrant birds in temperate forests: An empirical investigation. Pp. 474-482 IN: J.M. Hagan and D.W. Johnston (eds.). Ecology and Conservation of Neotropical Migrant Landbirds. Smithsonian Institution Press, Washington, DC, USA. 609 pp.

Villard, M.A., P.R. Martin and C.G. Drummond. In press. Habitat fragmentation and pairing success in the Ovenbird. Auk

Wegner, J.F. and G. Merriam. 1979. Movements by birds and small mammals between a wood and adjoining farmland habitats. J. Appl. Ecol. 16:349-357.

Wiens, J. A. 1989. Spatial scaling in ecology. Funct. Ecol. 3: 385-397.

Wilcove, D.S. 1989. Protecting biodiversity in multiple-use lands: Lessons from the US Forest Service. Trends Ecol. Evol. 4:385-388.

Wilcove, D.S. and S.K. Robinson. 1990. The impact of forest fragmentation on bird communities in eastern North America. Pp. 319-331 IN: A. Keast (ed.). Biogeography and Ecology of Forest Bird Communities. SPB Academic Publ., The Hague, The Netherlands. 410 pp.