Commentary

The importance of land uses within the landscape matrix

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Abstract Significant changes in land-use practices, combined with increasing levels of fragmentation within the last century, have made the landscape an important and relevant scale for studies of wildlife ecology and management. However, relatively few landscape-level investigations have explicitly addressed characteristics of the landscape matrix. Even fewer studies have examined how specific land uses within the matrix affect wildlife, and most of these confound the amount and type of disturbances within study designs. Recent research demonstrates that land uses can differ markedly in their effects on wildlife in nearby forests or grasslands—even in landscapes with comparable amounts of habitat. In particular, urban or residential development within the matrix can alter diversity or abundance of some species and can depress avian nesting success even in large forest tracts. Simply the presence of certain land uses, such as agricultural openings, within forested regions can negatively impact some animal communities. Collectively, these studies provide strong evidence that land uses within forested and fragmented landscapes are important influences on wildlife populations and communities. Consequently, biologists and managers involved in the design and management of natural areas, parks, reserves, and other public lands should carefully consider types of land uses occurring within or adjacent to their boundaries.

Key words birds, landscape matrix, land uses, management, reserve design, wildlife

Wildlife biologists are familiar with the pattern: small, isolated habitat patches have less abundant and diverse bird communities (e.g., Forman et al. 1976, Ambuel and Temple 1983, Blake and Karr 1987, Robbins et al. 1989) and lower avian nesting success (e.g., Wilcove 1985, Hoover et al. 1995) than larger patches. From these and other studies has come a central theme in conservation biology and wildlife management: amount, distribution, and arrangement of habitat patches within the landscape profoundly influence wildlife communities.

Current management approaches still emphasize amount or spatial configuration of suitable habitat in conservation and management plans. However, the influence of landscape-level factors on animal communities is more complex than the effects of area and isolation (Dunning et al. 1992, Weins 1994). Landscapes are complex, and wildlife populations can be affected, not only by amount, shape, and spatial distribution of habitat but also by structure and composition of the landscape mosaic (i.e., all landscape elements, including patches, corridors, and matrix) and, in particular, the matrix.

The importance of the landscape matrix

The landscape matrix (the "background" within which patches and corridors are embedded) can

Among the best-demonstrated "matrix effects" is that amount of fragmentation (or, conversely, forest cover) within the landscape can predict structure of forest bird communities (Askins et al. 1987, Askins 1995, Robinson et al. 1995, Drolet et al. 1999, Drapeau et al. 2000, Graham and Blake 2001, Lee et al. 2002, Schmiegelow and Monkkonen 2002). Likewise, types of land uses within the matrix also can have markedly different effects on flora and fauna within adjacent habitat patches. Within a landscape, land uses such as roads (Trombulak and Frissell 2000), exotic tree plantations (Estades and Temple 1999, Renjifo 2001), silviculture (Bayne and Hobson 1997, Rodewald and Yahner 2001a,b), agriculture (Andren 1992, Aberg et al. 1995, Robinson et al. 1995, Saab 1999, Rodewald and Yahner 2001a,b, Guerry and Hunter 2002), grassland or chapparal (Sisk et al. 1997), and urban development (Friesen et al. 1995, Blair 1996, Rottenborn 1999, Cam et al. 2000, Jokimäki and Huhta 2000, Mortberg 2001, Soderstrom et al. 2001) can affect species richness and abundance of animals in nearby habitat patches. Because many public and private lands include or are surrounded by these different land uses, understanding the influence of specific land uses within the landscape on ecological communities is necessary to effectively avoid or mitigate associated impacts.

Variation in matrix effects may be explained in part by structural or temporal differences among land uses (McIntyre and Barrett 1992; Rodewald and Yahner 2001a,b; Rodewald 2002). Structural differences in land uses can directly affect an individual animal's ability to move through a patch, encounter suitable habitat, or find adequate food resources. Consider the ability of a forest-dependent bird or salamander to use a row crop versus a regenerating clearcut. Although neither land use represents suitable breeding habitat, structure of the clearcut provides foraging opportunities and a microclimate that are unavailable in the row crop and may thereby facilitate movement among habitat patches. Such structural differences in land uses and associated resources likely are responsible for differences in dispersal, colonization, population persistence, and population size among patches in contrasting matrices (Estades 2001, Ricketts 2001, Cale 2003). Temporal differences among land uses are less recognized, though these also can influence the likelihood of an individual using a site. For example, certain agricultural uses might persist within a landscape for decades or centuries, and some animals (e.g., nest predators) may find reliable food resources in them, eventually leading to increased numbers within nearby forests. Likewise, urban land uses, such as residential developments, are essentially permanent on the landscape. In contrast, many silvicultural disturbances, like clearcuts, usually regenerate quickly and are temporary on the landscape.

Limitations to understanding matrix effects

Some studies of edge effects on avian communities have recognized the importance of type of disturbance or land use (e.g., Ratti and Reese 1988, Yahner et al. 1989, Suarez et al. 1997, Keyser 2002), but landscape-level studies have been slower to suf-
Matrix effects in fragmented landscapes

Matrix effects are relevant to management in fragmented landscapes, especially for those shifting from agricultural to urban matrices. While numerous studies report direct impacts of urbanization due to local habitat alteration (e.g., Emlen 1974, Bessinger and Osborne 1982, Mills et al. 1989, Blair 1996, Germaine et al. 1998, Fernandez-Juricic 2000, Marzluff et al. 2001, Pickett et al. 2001) or habitat fragmentation (Bolger et al. 1997, Haire et al. 2000), few have assessed how the amount of urbanization surrounding undisturbed habitat patches influences animal populations or communities (Miller et al. 2001). Only a handful of studies examine these landscape-level questions, but they generally are unable to "control" for levels of fragmentation in study designs (i.e., as urbanization increases within a landscape, the amount of habitat decreases). For example, Haire et al. (2000) examined grassland open spaces of Boulder, Colorado, USA and found that the amount of urban development within a 40-ha landscape centered on the grassland was negatively related to abundance of several grassland nesting bird species. They reported, however, that urban development was negatively correlated with amount of grassland (i.e., habitat for grassland birds) within the landscape, thus confounding urbanization and habitat availability (i.e., as urbanization increased, amount of habitat decreased). Soderstrom et al. (2001) showed similar patterns in diversity of plants, insects, and birds in seminatural pastures in Sweden, but their study shared confounding of landscape and habitat variables. Thus, ecologists have relatively few data to support the common perception that a farmland is preferable to residential development in terms of biodiversity of a nearby forest reserve.

Despite inherent and sometimes unavoidable limitations of many "natural experiments" of matrix effects, there is some compelling evidence that residential or urban developments surrounding suitable habitat patches can impact birds irrespective of habitat area. Friesen et al. (1995) compared bird communities within woodlots of 3 sizes and considered number of houses ≤100 m as an explanatory factor. Diversity of forest-bird communities was influenced more by presence of adjacent residential development than by woodlot size. Specifically, small woodlots lacking nearby houses had more diverse bird communities than large woodlots.
surrounded by houses. Rottenborn (1999) suggested that variation in avian species richness, density, and community structure within riparian woodlands was best explained by the amount of urbanization ≤ 500 m of the plot center. However, interpretation of those results was complicated by the survey method employed because it included birds occurring in woodland and matrix habitats (i.e., urban areas). In an ongoing study on riparian forest birds in Ohio, A.D. Rodewald (unpublished data) found that amount of urbanization ≤ 1 km of riparian forests strongly affects avian community structure and nesting success across landscapes with comparable amounts of forest cover and forest widths.

**Matrix effects in forested landscapes**

Another gap in our understanding of matrix effects is whether land uses are important in relatively natural landscapes or, in contrast, if effects are apparent only in highly disturbed areas. Most studies have examined matrix effects in fragmented landscapes, and there is less recognition that land uses can have pronounced effects in forested landscapes. For example, in the forested landscapes of Maine, Hagan and Meehan (2002) found that landscape-level variables, such as landscape composition and contrast, generally were poor predictors of avian distribution. In contrast, Rodewald and Yahner (2001a, b) demonstrated that bird communities within forested landscapes of Pennsylvania were influenced by perforations of silvicultural and agricultural disturbances in the forest matrix. Mature forests within landscape matrices disturbed by small amounts of agricultural land uses (e.g., pasture, cropland, fallow fields) had fewer forest-dependent and long-distance migratory bird species, higher numbers of nest predators, and lower nesting success than forests within landscapes disturbed by similar amounts of silvicultural land uses (i.e., clearcuts with residual trees; Rodewald and Yahner 2001a, b). Although other studies have shown that fragmented agricultural landscapes have greater abundances of generalist predators and lower nesting success than in more forested silvicultural landscapes (confounding type and amount of disturbance), a pattern had not been established in forested systems (Hartley and Hunter 1998, Chalfoun et al. 2002). Thus, even within forested landscapes, types of land uses can influence bird communities and should be considered in management plans.

**Management implications**

Findings that support matrix effects have several implications for the acquisition and management of parks, reserves, and other public lands. First, because most privately and publicly owned forests in North America contain or are surrounded by some agricultural or urban land, effects of adjacent land uses on wildlife need to be seriously considered in conservation plans, even within forested regions. For example, maintenance of agricultural areas, such as wildlife food plots, in forests with high value for forest-nesting songbirds may negatively affect reproductive success of some species (Rodewald and Yahner 2001b). Second, managers can better prioritize land acquisitions and conservation easements by targeting forests that have the greatest potential to provide quality wildlife habitat. In the studies mentioned above, forests in areas without substantial urban, residential, or agricultural development presumably would have greater wildlife value than those in more developed landscapes. Third, establishment of low-development or "natural" buffer zones adjacent to habitat reserves, especially for those in urbanizing landscapes, may be necessary to protect their value for wildlife. Fourth, despite frequent public controversy associated with even-aged forest management (Cubbage et al. 1993), it appears to be associated with fewer landscape-level effects on wildlife than other common land uses (Hanski et al. 1996, Bayne and Hobson 1997, Morse and Robinson 1999, Rodewald and Yahner 2001a, b, Yahner et al. 2001).

As a whole, interactions between ecological communities and the landscape matrix are complex, and our understanding of the gap in our knowledge does not result from technological or methodological constraints; we already have many of the spatial and analytical tools required to answer the important questions (e.g., Landsat Thematic Mapper Imagery, various ARC/VIEW extensions, FRAGSTATS; Bissonette 1997, Alberti et al. 2001). Instead, a central problem is simply that an important question is not being asked. To remedy this, investigators can explicitly consider land uses within the landscape matrix when designing their studies. While empirical evidence for matrix effects continues to grow, biologists must be sensitive to gaps in our knowledge that constrain our ability to make appropriate management decisions. At the same time, a cautious approach to developing lands (especially for
agricultural or urban purposes) within or adjacent to forest reserves seems warranted. Such multi-scale approaches that consider land uses ultimately should be central to the successful conservation of wildlife.

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