The science of landscape ecology is a relatively new field of study, with a complex character and heterogeneous content (Zonneveld 1990). It is the study of the reciprocal effects of spatial patterns on ecological processes (Pickett and Cadenasso 1995). Whereas ecological studies have traditionally operated with the assumption that systems are more or less homogeneous (Risser et al. 1983), landscape ecology regards spatial heterogeneity as a central causal factor in ecological systems (Pickett and Cadenasso 1995).

Quantifying Landscape Patterns

Landscape ecology is an effective component of land use planning and natural resources management. Landscape ecologists identify and quantify landscape structure in meaningful ways such that the interactions between landscape patterns and ecological processes become tangible. The results provide sustenance to planners and managers as they resolve to make wise land-use decisions.

Traditionally, within-site habitat quality has been used to evaluate habitat suitability. But spatial pattern among sites is also important in determining the suitability of habitat for a range of species (Ritters et al. 1997). The transformation of terrestrial landscapes to landscapes dominated by human uses results in measurable changes to the composition and pattern of habitats, and the fauna and flora that occur in them (August et al. 2001). Species respond differently to habitat changes because of differences in habitat requirements, based on life history and population structure (Hanson and Urban 1992; Wiens et al. 1993), and the scales at which they interact with the environment (Kattan et al. 1994; Koopowitz et al. 1994).

Theory of Island Biogeography

A principal component behind landscape ecology derives from the theory of island biogeography (MacArthur and Wilson 1967), wherein species richness can be predicted by the island’s area and its isolation from the mainland or from other similar islands which function as sources of species (Hobbs 1988). The theory further predicts that species with large patch requirements and low mobility are the first to be lost as a result of landscape changes, whereas species with small patch requirements and high mobility will persist in fragments of suitable habitat (Ritters et al 1997). Studies have shown that native species composition, population sizes, and community structure are severely impacted when native habitat is reduced to small isolated patches in close association with highly disturbed land uses (August et al. 2001). Thus, an important aspect of landscape ecology is to predict, assess, and monitor how alterations to the landscape may impact native biota.

Recent Studies

This paper presents recent research in the field of landscape ecology with a focus on watershed scale changes in natural habitats, how these changes regulate habitat
abundance, and how habitat abundance (or lack thereof) impacts biodiversity. While all of the studies revolve around the implications associated with habitat abundance, the authors examine the topic differently. These studies can be lumped into four areas of research and include: a) impacts of patch size (habitat area/abundance) and context (matrix) on bird populations; b) comparison of the impacts of habitat abundance and fragmentation; c) the quality of the patch; and d) impacts to species resulting from habitat loss and concomitant habitat degradation or disturbance. While studies vary, overwhelming results suggest that habitat abundance, rather than configuration, is the dominant landscape feature controlling biotic integrity.

What are the impacts of patch size and matrix on bird populations?

Van Dorp and Opdam (1987), Opdam et al. (1994), Villard et al. (1999), and Baker et al. (2002) designed studies to assess the influence of landscape structure (patch size, fragmentation, configuration, matrix) on the occurrence and density of bird populations. Van Dorp and Opdam (1987) related the distribution of breeding forest birds to the structure of agricultural landscapes with scattered patches of forest to assess how patch size and isolation impact species. Opdam et al. (1994) conducted studies in a fragmented landscape to determine if breeding birds are affected by the spatial distribution of their habitat. Villard et al. (1999) examine how forest cover and configuration influence the presence and abundance of breeding birds, embedded in a matrix of cultivated fields. Baker et al. (2002) was specifically interested in understanding how local and landscape attributes influenced grassland bird occupation of small and isolated patches.

All of these studies investigate alterations to the size (abundance) and configuration (fragmentation) of landscapes and how the changes impact bird populations. While patch size was found to be the single most important predictor in some instances (Van Dorp and Opdam 1987), others found the pattern of available habitat across the landscape to be most important (Opdam et al. 1994; Villard et al. 1999, Baker et al. 2002).

How do the impacts of habitat abundance and fragmentation compare?

McGarigal and McComb (1995), Fahrig (1997), and Trzcinski et al. (1999) set out to clarify the difference between habitat abundance (loss) and fragmentation (“breaking apart”) since they felt that in many studies the terms are often confounded. The authors conducted comparison studies so that future planning and land protection measures may be appropriately assessed. Specifically, McGarigal and McComb (1995) and Trzcinski et al. (1999) investigated the relationship between forest cover (habitat abundance) and configuration (fragmentation) on breeding birds at the landscape scale. Fahrig (1997) conducted simulation studies to compare the relative importance of habitat loss and fragmentation on population extinction, in general. All of these studies found that impacts associated with habitat loss are much more critical than those associated with fragmentation.

How does the quality of the patch impact species?

Edenius and Elmberg (1996) and Walters et al. (1999) investigated how and if residual effects associated with alterations to habitat patches negatively impact bird species. Specifically, Edenius and Elmberg (1996) addressed whether forestry activities, which lead to a reduction in old growth forest, impact species richness and relative abundance
of forests birds. Walters et al. (1999) addressed whether fragmentation, which leads to habitat degradation (and may lead to disrupted dispersal, reduced fecundity, and reduced food availability) is attributable to a decline in brown treecreepers (*Climacteris picummus*). Both authors found the concomitant effects of forestry activities and fragmentation negatively impacted the focal birds.
**How do habitat loss and concomitant habitat degradation impact species?**

Preiss et al. (1997) and Germaine et al. (1998) consider how the *transformation* of habitat patches impacts associated bird species. Specifically, Preiss et al. (1997) examines how succession, as a result of rural “depopulation”, influences grassland birds. Germaine et al. (1998) examined how breeding birds respond to habitat-disturbance patterns resulting from urban development. The results of both studies suggest (to a degree) a decline in *native* bird species, as a result of alterations to the landscapes. It should be noted, however, that since the landscape examined in Preiss et al. (1997) had been *maintained* in agrarian conditions for hundreds of years prior to “depopulation”, the grassland bird species thus may not be *typical* of this region.

**Monitoring and Adaptive Management**

Since the early 1990’s, managing ecosystem integrity and health has become the operating policy of federal land management agencies, like the U.S. Forest Service and the U.S. Fish and Wildlife Service (Phillips and Randolph 1998). The ecosystem approach has been adopted by many local and regional organizations for environmental management (Yaffe et al. 1996). Landscape ecologists play a key role in land-use planning and policy development, and have the tools to direct ecosystem management programming. An important component in this process is the implementation of monitoring and adaptive management protocols. Through monitoring, we quantify habitat loss, changes in landscape structure, and the loss and gain in species and communities (August et al. 2001). Knowledge gained through monitoring, assist planning, regulatory, and conservation agencies in determining the effectiveness of management programs. Adaptive management is the process by which the abovementioned agencies *adapt* their programs to better suit to the original objectives of ecosystem management.

The research of Bierregaard and Lovejoy (1992) represents a model example of monitoring and assessment. The resulting data of enormous integrity as it presents the results of 12-years of study in the Brazilian rainforests, during which time the authors examined the relationships that exist between habitat abundance and species carrying capacity. The findings have great significance in terms of adaptive management, not only to the future of the Brazilian rainforests, but to forest conservation and land-use planning around the world.

**Landscape Ecology and Land Protection**

The recent studies described above focused on watershed scale changes to natural habitats with a focus on habitat abundance. The results of these studies overwhelmingly suggest that alterations to the natural landscape are pervasive and problematic in terms of maintaining biotic diversity. However, these studies also provide impetus for alternative thinking on the part of planning and land use conversion. Some important elements in managing landscapes to protect biodiversity include: land protection via purchase and conservation easement; maintaining large contiguous blocks of protected land; zoning and enforcement to protect ecologically sensitive areas; creating corridors between patches, where appropriate; and community outreach and education. Landscape ecology is an effective tool in the advancement of our understanding of the earth and the flora and fauna that inhabits it. The results assist us in making informed decisions so that we may do our best to manage the impacts placed upon it.

Hobbs, E. 1988. Species richness or urban forest patches and the implications for urban landscape diversity. Landscape Ecology 1(3)141-152.


Annotated Bibliography


Bakker et al. evaluated the influence of local and landscape (matrix) attributes (landscape composition and land cover) on the occurrence and density of grassland bird species. Results found that some species are associated only with local attributes while others are associated with habitat structure at both the local and landscape scale, thus illustrating the importance of maintaining a local and landscape perspective when managing grasslands for avian species. These findings are important for biologists, planners, and land managers who are in a position to stave off the decline of grassland bird species. In terms of utilizing the concepts of landscape ecology, the authors incorporated the concepts of pattern and process and scale into their evaluation to discern how these factors influence the occurrence and density of grassland bird species.


Bierregaard and Lovejoy undertook a 12-year study in the Brazilian rainforests to investigate the relationship between the size of a forest fragment and both the stability and species carrying capacity of that forest fragment. The experiment is based on comparisons of a replicated series of forest fragments of different sizes before and after they were isolated from continuous forest. The data confirm that forest remnants would suffer significant alteration and lose an array of species. In the face of adversity, this study represents an exceptional research opportunity with great significance, not only to the future of the Brazilian rainforests, but to forest conservation/management and land-use planning around the world. The long-term studies associated with this project represent an excellent model to study the ecological effects of habitat loss.

Of note: The authors point out a major weakness of the MacArthur-Wilson model of island biogeography when discussing habitat islands. The concept of island biogeography implies that all species are treated equally, and thus immigration and extinction probabilities are the same for all species. However, since in nature different species have different tendencies to disperse and require different home ranges, such differences, the authors argue, should affect the likelihood that certain species will arrive and persist on an island or in an isolated, protected area.


Edenius and Elmberg studied the effects of large-scale forestry on landscape structure and the structure and composition of boreal bird communities. The study specifically examined whether there were any residual effects attributable to the reduction in old growth forest area. Patch size, forest age, and tree composition were similar throughout 25 x 25 km landscape blocks, a spatial scale decidedly larger than the individual home-range but much smaller than the distribution range of forest bird species. Landscape
blocks differed based on vegetation as a result of forestry impact and included: a) ‘clearcuts’ (trees < 2 m); ‘young forests’ (trees 2-10 m); and ‘maturing forest’ (trees > 10 m). Point counts showed that species richness and relative abundance of forest birds were higher in landscapes with low forestry impact. A significant difference in species richness between impact types indicated an overall negative effect of modern forestry on forest birds in the study region. In terms of providing management baselines for mitigating negative effects of clear-cutting forestry, the authors advocate retention of old-growth patches.


Fahrig suggests the effects of habitat amount (loss) and fragmentation (“breaking apart”) are confounded in many studies, resulting in the frequent use of the term “fragmentation” to mean simultaneously both loss and “breaking apart” of habitats. To test this, the author constructed a simulation model to compare the effects of habitat amount and fragmentation, independent of one another. Results suggest that habitat loss has a much larger effect than habitat fragmentation. To apply the simulation results to real species, Fahrig emphasizes the need to define the scale of the habitat patch relative to the movement and space needs of the species. This important study reinforces the need for conservation efforts to prevent habitat loss and increase efforts in habitat restoration.


Germaine et al. examined the habitat relationships of breeding birds in a rural-urban residential gradient, a relatively under-represented study area (in terms of avian ecology). The authors were interested in determining the influence of habitat-disturbance patterns (natural-undeveloped → highly developed areas) on the avian community. The authors identify several urban development patterns, and demonstrate the affects to bird populations and assemblages. While some native birds were unaffected, several were moderately affected, and some were sensitive to even minor disturbances. These important findings may benefit urban planners and resource managers in the design of sustainable communities.


McGarigal and McComb were interested in testing the hypothesis that landscape structure (i.e. composition and spatial configuration of a landscape) plays an important role in the regulation of populations. Specifically, the authors examined how the independent effects of both habitat loss (composition) and fragmentation (configuration) impacted bird populations. McGarigal and McComb sampled vegetation and birds across 30 landscapes and developed measures of forest configuration that were statistically independent from forest amount. The results showed that variation in abundance among landscapes was more strongly related to changes in habitat area and that configuration was of secondary importance. The findings have important
implications to planning and resource management and encourage careful consideration of the need to prevent habitat loss and protect additional contiguous areas.


Opdam et al. conducted a study to interpret the impacts of fragmentation (including habitat loss) on bird populations in The Netherlands by linking landscape pattern (spatial configuration of habitat patches) to process (flow of energy; movement across the land). Data collected included presence and absence patterns which were then correlated with spatial characteristics; based on metapopulation theory, wherein presence and absence are thought to be influenced by spatial features of the landscape. The results suggest that breeding birds are affected by the spatial distribution of their habitat. The development of such methods and tools enable landscape ecologists to make predictions across landscapes, the results of which can then be applied in land use planning and natural resources management.


In an interesting study, Preiss et al. consider the impacts of succession in the Mediterranean region of France, as a result of “depopulation” (phenomenon of abandoning farmland), on avifauna. The landscape includes a mosaic of habitats including cultivation, grasslands, shrublands, and woodlands, having been “human-influenced” for eons. Since the birds typical of this region are restricted to the early stages of succession, the authors were interested in documenting the consequence of succession on the biotic community. Preiss et al. compare the avifauna (point counts) and the vegetation (photo interpretation) between 1978 and 1992 to address changes at both landscape and local scales. The results suggest that if trends continue, there will be a reduction in the abundance and distribution of the regionally distinct avifauna. These findings may assist wildlife biologists in developing open space reserves and management programs to maintain the diverse avifauna typical of the Mediterranean region.

Of note: One might argue that the presence and absence of most Mediterranean bird species in this region is a direct result of human impacts to the vegetation, such that the current trend could lead to a more representative vegetation community, typical of the original landscape pattern. Thus, the results of this study may play a somewhat controversial role in the future planning and resource management decision-making in the region.


Trzcinski et al. build on previous studies by McGarigal and McComb (1995) and by Fahrig (1997) to discern which form of land cover change, fragmentation or habitat loss, has a greater impact to species persistence. The study compares landscapes over a large spatial scale and a short time frame. Fragmentation and habitat loss were
quantified separately for each landscape allowing the authors to determine the separate
effects to avifauna species distribution, while retaining the ability to evaluate relative
impacts and test interactions. Results suggest that negative effects to species
persistence were mainly due to habitat removal and not to habitat fragmentation, thus
couraging resource managers, conservationists, and planners to prevent further land
losses.

*Of note:* The authors acknowledge few empirical studies exist to compare the
independent effects of habitat loss and fragmentation and that this may be due to a lack
of thorough data sets for other fauna across many landscapes.

Van Dorp and Opdam assess the impact of patch size and isolation on forest birds by relating bird distribution to landscape structure. The authors contend that prior species-area studies neglect the role that habitat diversity may play, and that quantifying it should be minimized. Thus, in their study, Van Dorp and Opdam kept habitat variation to a minimum and maximized variation in landscape structure. Results suggest that patch size was the best single predictor of species number and probability of occurrence of most species.

Of note: It is of interest, and somewhat suspicious to me, that the authors suggest habitat diversity values should be kept to a minimum. While habitat size has been shown to play a great role in species composition, absence, presence, etc., the quality of that patch inevitably plays a significant role in these factors, too. I find this study awkward in that it reiterates the importance of diversity that may exist within a patch.


Villard et al. examine the relative influence of forest cover and configuration on the presence and abundance of bird species nesting in forest fragments embedded in a matrix of cultivated fields. Bird surveys were conducted in three forest fragments during the breeding season. Bird presence-absence and landscape pattern were determined among equal-sized portions inside the forest fragments. Results indicate that bird species presence is predictable based on landscape structure. However, configuration effects landscape structure, thus influencing presence-absence in the landscape. This study confirms previous research (Fahrig 1997) and thus encourages conservation efforts toward land protection, but also implies that configuration effects should be considered in land use planning and natural resources management.


Walters et al. attempt to identify the mechanisms responsible for adverse effects of habitat fragmentation on brown treecreepers (Climacteris picumnus) by comparing the foraging ecology of birds in highly fragmented and relatively unfragmented landscapes. The study is designed to analyze whether the decline of a species in a fragmented landscape exceeds that expected from habitat loss alone, but also whether excessive losses are due to habitat degradation (which may lead to disrupted dispersal, reduced fecundity, and reduced food availability) that often accompanies fragmentation. No evidence was found for reduced fecundity, nor reduced food availability, in the more fragmented area compared to the less fragmented area. The results are consistent with the disrupted dispersal hypothesis, wherein more males were unpaired in the more fragmented areas. The authors propose that the decline of C. picumnus in the more fragmented area is driven by the inability of females to locate breeding vacancies, thus leading females to disperse out of remnants at a greater rate than they enter remnants. While the results of this study may be pertinent to future conservation efforts aimed at protecting C. picumnus, further research is warranted on other systems to evaluate the
generality of mechanisms responsible for declines of avian species in fragmented habitats.

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