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Conservation Biology, Vol. 2, No. 4 (Dec., 1988), 333-339.

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Changes in Wildlife Communities Near Edges

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Abstract: *Wildlife managers and land managers have traditionally considered edges as beneficial to wildlife because species diversity generally increases near habitat edges. Explanations for this edge effect include greater vegetative complexity at edges or the simultaneous availability of more than one landscape element. However, edges can have negative consequences for wildlife by modifying distribution and dispersal and by increasing incidence of nest predation and parasitism. Edges also may be detrimental to species requiring large undisturbed areas because increases in edge generally result in concomitant reductions in size and possible isolation of patches and corridors. Thus, both wildlife and land managers should be cautious when describing the benefits of edges to wildlife, particularly when dealing with species that require forest interiors.*

Changes in wildlife communities associated with habitat edges are not easily assessed because defining edge species and measuring edge dimensions can be difficult in field studies. Also, there is no general consensus as to how edge effect is best measured. Well-designed, long-term studies of edges in various landscapes are needed (1) to better understand the positive and negative impacts of edges on wildlife communities, guilds, or key species, and (2) to effectively quantify edge effect and thereby develop management recommendations to improve the quality of edges for wildlife. Additional studies of edge effect are timely because greater amounts of edge will continue to be created in future landscapes due to extensive agriculture and other land-use practices, and because developing knowledge in conservation biology and landscape ecology will facilitate multidisciplinary approaches to edge and landscape management for the benefit of wildlife.

Resumen: *Tradicionalmente, los expertos en manejo de fauna y uso de la tierra han considerado a las zonas de transición entre diferentes tipos de vegetación del (a los bordes y áreas disturbadas del bosque) como beneficiosas para la fauna porque la diversidad de las especies generalmente se incrementa cerca de estos hábitats. Las explicaciones sobre este efecto de bordes incluyen una mayor complejidad vegetativa en los bordes o una disponibilidad simultánea de más de un elemento del paisaje. Sin embargo, las áreas disturbadas pueden tener consecuencias negativas para la fauna al modificar la distribución y dispersión e incrementar las incidencias de predación y parasitismo. Los bordes pueden ir también en detrimento de especies que requieren áreas extensas e intactas ya que los aumentos en las áreas disturbadas generalmente producen reducciones concomitantes en tamaño y posible aislamiento de pequeñas áreas y corredores. De esta forma, administradores de áreas silvestres deben ser cautelosos al describir los beneficios de áreas disturbadas a la vida silvestre, particularmente cuando se trata de especies que necesitan del interior del bosque.*

Los cambios en las comunidades silvestres asociadas con bordes de hábitats no son fácilmente evaluables debido a que la definición de especies de bordes de hábitats y la medición de dimensiones de los bordes resulta difícil en estudios de campo. También, no hay un consenso general de cómo se cuantifica mejor el efecto de bordes. Estudios bien diseñados y de largo plazo en áreas de borde son necesarios (1) para entender mejor los impactos positivos y negativos de áreas de borde sobre comunidades silvestres, guildas, o especie claves, y (2) para cuantificar efectivamente el efecto de borde y así, desarrollar recomendaciones de manejo para mejorar la calidad de estas áreas para la vida silvestre. Estudios adicionales sobre el efecto de borde son necesarios ya que áreas con esas características continuarán aumentando en el futuro debido a la agricultura extensiva y otras prácticas del uso de la tierra. El desarrollo de la biología de conservación y ecología de paisajes facilitará los aproximaciones multidisciplinarias para el manejo de áreas de borde para el beneficio de la vida silvestre.

Introduction

An edge can be defined as the junction of two different landscape elements (e.g., plant community type, successional stage, or land use) (Giles 1978; Thomas, Maser, & Rodick 1979; Forman & Godron 1986). This junction is either a well-defined boundary or a transition zone (ecotone) where plant and associated wildlife communities grade into one another.

Wildlife communities (defined herein as an assemblage of species in a prescribed area) associated with edges or ecotones (hereafter referred to collectively as edges) have been of considerable interest to wildlife managers and land managers since the early 1930s, when Leopold (1933) reported greater wildlife diversity at edges. He speculated that greater diversity at edges, often termed an edge effect, was due either to the variety of vegetation at edges compared to areas distant from an edge or to the availability of two different habitats in close proximity (see also Johnston 1947). But most evidence for edge effects on wildlife has been circumstantial, and their benefit to wildlife has been elevated to theorem by usage rather than by sound scientific studies (Giles 1978; Reese & Ratti 1988). Moreover, managing for edge habitat in order to maximize wildlife diversity raises aesthetic, moral, and scientific issues because we now recognize that maximum diversity may not always be a desirable objective; for example, it further endangers species that are dependent on extensive stands of undisturbed habitat (Harris 1984). Recent studies also have shown that productivity of certain songbirds is reduced along edges due to high incidences of nest predation and parasitism (Laudenslayer 1986).

My objective is to describe changes in diversity, abundance, and spatial distribution of wildlife communities associated with forest edges, with particular reference to avian and small mammal communities. By examining these changes, which I refer to as edge effects, better insight can be obtained into how characteristics of edges or surrounding landscapes affect wildlife communities, guilds, or key species. Perhaps more importantly, this paper will convince us that additional research is timely and necessary to better understand edge effects for wildlife.

Types of Edges

An edge may be inherent or induced. An inherent edge is a long-term feature of the landscape, such as the junction between two plant community types, that results from local differences in soil type, topography, geomorphology, or microclimate (Thomas, Maser, & Rodick 1979). An induced edge is usually a short-lived, man-made feature at the junction of distinct land uses or successional stages that are either nonlinear patches or

linear corridors. Patches and corridors are termed remnant, disturbed, introduced, or regenerated, and differ in "appearance" from the most connected and extensive element (i.e., matrix) in the landscape (Forman & Godron 1986). Because induced edges are a direct result of management practices or, in some cases, short-term natural phenomena (e.g., fire), they are of considerable interest to both wildlife and land managers.

Methodological Considerations in Edge Studies

Before changes in wildlife communities associated with edges can be described in field studies, we should (1) define edge species, (2) delineate edge dimensions (length and width), and (3) determine the best means of quantifying edge effect.

Defining Edge Species

An edge species can be defined as one that performs all or most daily activities at or near edges, whereas an interior species conducts most daily activities away from edges (Johnston 1947; Forman & Godron 1986). However, we are faced with at least three problems in classifying an edge species and, hence, a wildlife community associated with an edge. First, time spent at edges varies among species because edges serve different purposes. For instance, assume a hypothetical edge with dense shrubs, small trees, and tall trees (e.g., an induced edge created by a disturbed patch or corridor). Gray catbirds (*Dumetella carolinensis*) and yellow-breasted chats (*Icteria virens*) nesting and foraging in the dense shrubs and small trees could conceivably perform all daily activities at the edge (Chasko & Gates 1982), whereas brown-headed cowbirds (*Molothrus ater*) using the tall trees as perches probably go elsewhere to forage (Anderson 1979; Yahner 1987). In farmstead shelterbelts (e.g., induced edge created by an introduced corridor), common nesting birds include mourning doves (*Zenaidura macroura*), American robins (*Turdus migratorius*), common grackles (*Quiscalus quiscula*), gray catbirds, brown thrashers (*Toxostoma rufum*), and song sparrows (*Melospiza melodia*) (Yahner 1982). The initial three species forage extensively in the surrounding landscape (croplands, pastures, lawns), whereas the latter three rarely venture away from the shelterbelts to forage (Yahner 1983a).

Second, defining an edge species can be difficult when intraspecific use of edges varies among seasons. In spring, black-capped chickadees (*Parus atricapillus*) and downy woodpeckers (*Picoides pubescens*) frequently forage at edges between mature and clearcut stands (e.g., induced edge created by a disturbed patch) in central Pennsylvania (Yahner 1987). But in winter, both species seldom occur along edges, presumably because forest interiors provide more favorable microcli-

mates than do edges. In intensively farmed areas of southern Minnesota, eastern cottontails (*Sylvilagus floridanus*) are uncommon in farmstead shelterbelts during summer; however, with crop harvest and less cover in the surrounding landscape during autumn, cottontails become more prevalent in shelterbelts (Swihart & Yahner 1982).

Third, intraspecific use of edges can vary among geographic regions. The northern cardinal (*Cardinalis cardinalis*) is associated with edges in some parts of its range but with forest interiors in other parts (Johnston & Odum 1956). The red squirrel (*Tamiasciurus hudsonius*) is found in northern boreal forests but also occurs in manmade farmstead shelterbelts in southern Minnesota (Yahner 1980). Thus, because of temporal or spatial differences in edge use within and among species, defining edge species can be difficult.

Delineating Edge Dimensions

We should establish the physical dimensions (length and width) of an edge before attempting to describe the associated wildlife community. Length of an edge, such as between a powerline corridor and a mature forest, is relatively easy to estimate (Giles 1978; Brooks & Scott 1983). Similarly, width of a corridor, e.g., farmstead shelterbelts in an agricultural matrix, is easy to delineate (Yahner 1983a). But because edge width at two adjoining patches can vary depending on the nature of vegetation in adjoining landscape elements (e.g., old field and mature forest) and because vegetative structure and composition from two adjoining elements can gradually blend together rather than change abruptly, measurement of edge width at the interface of distinct patches is usually subjective. At least in the northern hemisphere, edges exposed to southerly aspects or prevailing winds are usually wider than others because of greater primary production and better seed dispersal (Ranney, Bruner, & Levenson 1981; Whitney & Runkle 1981; Forman & Godron 1986).

I question, however, the continued use of vegetation characteristics to quantify edge width. Gates & Mosher (1981), who examined edge width at field-forest junctions in Michigan, found that width was <13 m based on vegetative structure but >64 m based on the spatial distribution of avian nest sites. Perhaps edge width is best defined, not by the investigator, but by the functional use of edges by wildlife.

Quantifying Edge Effect

Edge effect for wildlife has been quantified in several ways. In a few studies of avian communities, edge effect has been assessed by comparing the distributions of nests (Gates & Mosher 1981) and territories (Kroodsma 1984a) or the incidences of nest predation and parasitism relative to distances from edge (Brittingham & Tem-

ple 1983; Wilcove 1985; Andren & Angelstam 1988). More commonly, edge effect for birds has been quantified using diversity indices (e.g., Strelke & Dickson 1980; Yahner 1987). But there is some concern that managing for high diversity along edges in certain landscapes may be detrimental to habitat-specialist or rare species (Hair 1980; Harris 1984). In short, there is no consensus or standardized protocol for quantifying edge effect; yet development of a protocol is long overdue with continued urban sprawl, intensive agriculture, and forest fragmentation, and, hence, greater amounts of edge habitat in future landscapes. Without a pragmatic means of assessing edge effect, we will continue to have difficulty addressing the positive and negative attributes of different types of edges to wildlife and in managing for "quality" edges for the benefit of wildlife (after Van Horne 1983).

Changes in Wildlife Communities Near Edges

Edge effects for wildlife must be viewed as being a function of spatial heterogeneity in the surrounding landscape (e.g., interspersion of different types of landscape elements), spatial heterogeneity at the edge (e.g., complexity of vegetative composition and structure), and dimensions of the edge (e.g., width, length). But these often are interrelated; for example, edge length increases with greater interspersion of landscape elements.

Edge Effect: Spatial Heterogeneity in the Landscape

Spatial heterogeneity created by increased interspersion of landscape elements (e.g., horizontal patchiness) leads to greater amounts of edge and commonly to increased wildlife diversity (Roth 1976). For example, the checkerboard pattern of small forest stands of different cover type and age throughout a ruffed grouse (*Bonasa umbellus*) management area in central Pennsylvania results in increased breeding-bird diversity over that of a homogeneous control (uncut) portion of the study area (Yahner 1984). Diversity of breeding birds is higher in farmstead shelterbelts adjacent to croplands than in those next to pastures; vegetation in croplands (e.g., corn stalks) presumably provides better foraging and singing substrate than the sparse vegetation of pastures (Yahner 1983a).

Edge Effect: Spatial Heterogeneity at the Edge

Spatial heterogeneity created by complex vegetative structure and composition in the vertical dimension of the interface between two adjoining landscape elements also can increase wildlife diversity (Willson 1974). Morgan & Gates (1982) found higher species richness of breeding birds at interfaces of forests and multiflora rose (*Rosa multiflora*) hedgerows than at interfaces of for-

ests and cultivated fields with lesser vegetative complexity. Mixed-habitat species, such as gray catbirds, were particularly common to these hedgerow-forest interfaces. Conversely, an edge effect may be minimal or absent despite vegetative complexity at edges if abundant brushy vegetation is present elsewhere in the nearby matrix. For example, although common yellowthroats (*Geothlypis trichas*) frequently occur along edges, they use the adjacent matrix when brushy vegetation is available (Kroodsma 1984b; Yahner 1987).

Edge effect may be more pronounced on one side of the interface of two landscape elements than on the other because vegetative complexity differs to each side. For instance, Strelke & Dickson (1980) found higher bird species diversity and occurrences of great crested flycatchers (*Myiarchus crinitus*), eastern woodpeckers (*Contopus virens*), and Carolina chickadees (*Parus carolinensis*) within the initial 25 m of forest edge adjacent to clearcut stands in Texas. They attributed this edge effect to well-developed foliage layers, which provided abundant foraging and singing sites, at the forest edge compared to greater distances from the edge. Yahner (1987) noted that black-capped chickadees and downy woodpeckers in Pennsylvania often occurred in mature forest stands proximal to immature (<7 years since cutting) stands but rarely used the immature stands, which afforded little food and cover.

Finally, recent studies have shown that vegetative complexity at ground level reduces the foraging efficiency of predators (Bowman & Harris 1980; Redmond, Keppie, & Herzog 1982; Sugden & Beyersbergen 1986; Yahner & Cypher 1987). Hence, because predators often concentrate foraging activities along edges (Gates & Gysel 1978), management for vegetative complexity at the interface of landscape elements could possibly minimize predation pressure on edge species.

Edge Effect: Relation to the Edge Width and Length

The relationship between edge effect or edge width and wildlife communities has not been well documented (Forman & Godron 1986), perhaps because (1) edges assessed were of insufficient width, (2) edge effects are more a function of length than width, and (3) research on this relationship has focused more on induced edges created by corridors than by patches. For instance, Laudenslayer & Balda (1976) could find no evidence for a distinct breeding-bird community in narrow inherent edges between stands of pinyon pine (*Pinus edulis*)-ponderosa pine (*Pinus ponderosa*)-juniper (*Juniperus* spp.) stands in Arizona (i.e., inherent edge), and O'Meara et al. (1981) reported that only the blue-gray gnatcatcher (*Ptilioptila caerulea*) occurred exclusively within narrow edges created by pinyon-juniper chaining (i.e., induced edge). Emmerich & Vohs (1982) and Yahner (1983a) found that single-row windbreaks and nar-

row shelterbelts (three rows) were of insufficient width to serve as suitable wintering habitat for birds. On the other hand, Harris & McElveen (1981) found higher bird abundance and diversity along narrow abrupt edges than at wider more gradual edges between cypress (*Taxodium distichum*) and pine (*Pinus elliottii*).

Godfryd & Hansell (1986) reported that avian diversity and abundance in small urban woodlots were principally associated with edge length and not width. In farmstead shelterbelts, abundances of 17 bird species were positively correlated with shelterbelt length, whereas abundances of only two species were related to shelterbelt width (Yahner 1983a). In these same shelterbelts, species richness of small mammal communities and abundances of white-footed mice (*Peromyscus leucopus*), meadow voles (*Microtus pennsylvanicus*), masked shrews (*Sorex cinereus*), and northern short-tailed shrews (*Blarina brevicauda*) also were directly correlated with shelterbelt length (Yahner 1983b).

Several recent studies of wildlife associated with corridors have shown a relationship between edge effect and width. Stauffer & Best (1980) reported higher numbers of breeding bird species in Iowa in wider (>200 m) than in narrower habitats. They noted that 10 of 17 species, including hairy woodpeckers (*Picoides villosus*), tufted titmice (*Parus bicolor*), and ovenbirds (*Seiurus aurocapillus*), avoided nesting in narrow riparian habitats. Emmerich & Vohs (1982) examined bird communities in riparian woodlands, multirow farmstead shelterbelts, and single-row windbreaks in South Dakota and reported greater diversity in wider (riparian habitats) than in narrower habitats (shelterbelts and windbreaks) during breeding, migratory, and winter seasons. Anderson, Mann, & Shugart (1977) observed lowest numbers of breeding bird species in 11-m-wide powerline corridors, highest numbers in 31.5-m-wide corridors, and intermediate numbers in 61- and 91.5-m-wide corridors. Kroodsma (1982) found that populations of northern bobwhites (*Colinus virginianus*) and blue-gray gnatcatchers using powerlines increased with greater corridor width. Thus, although some information is available on edge effects in relation to edge dimensions, and particularly in relation to induced edges created by patches, additional data are needed to better understand wildlife community changes along edges and to manage edges for the benefit of wildlife in various landscapes.

Edge Effects: Barriers to Distribution and Dispersal

Induced edges are often characterized by abrupt differences in vegetative structure and composition between two contiguous landscape elements. This edge contrast (e.g., Thomas, Maser, & Rodiek 1979) can act as a barrier to the distribution and dispersal patterns of both birds and mammals. Territorial boundaries of forest

songbirds, such as blue-gray gnatcatchers, summer tanagers (*Piranga rubra*), and black-and-white warblers (*Mniotilta varia*), coincide with boundaries of distinct landscape elements (Kroodsma 1982, 1984a). Some forest birds (e.g., wood thrushes, *Hylocichla mustelina*) nest within 50 m of powerline corridor-forest interfaces but seldom use the adjacent corridor (Chasko & Gates 1982). Eastern chipmunks (*Tamias striatus*) in woodlands seldom traverse fields; conversely, meadow jumping mice (*Zapus hudsonius*) in fields rarely use nearby woods (Wegner & Merriam 1979). White-footed mice associated with even-aged stands in Pennsylvania tend to avoid edges at the junction of clearcut and mature stands (Yahner 1986). Clearcut stands act as a barrier to the distribution of southern flying squirrels (*Glaucomys volans*) (Bendel & Gates 1987). Gottfried (1979) reported few small mammal species and low fall densities of white-footed mice in Iowa woodlots surrounded by cornfields because cornfields serve as dispersal barriers to white-footed mice and to thirteen-lined ground squirrels (*Spermophilus tridecemlineatus*) from grasslands (i.e., introduced patch) (Fleaharty & Navo 1983).

However, in some situations, differences in vegetation between adjoining landscape elements may not be the major factor affecting wildlife distribution or dispersal. Ferris (1979) found that bay-breasted warblers (*Dendroica castanea*), blackburnian warblers (*Dendroica fusca*), blue jays (*Cyanocitta cristata*), and winter wrens (*Troglodytes troglodytes*) avoided forest edges along highways. He suggested that the noise created by vehicular traffic rendered the forest edge unsuitable for breeding for these species.

Edge Effect: Relation to Habitat Fragmentation

Habitat fragmentation will continue to be of concern to conservation biologists as well as to wildlife managers and land managers for at least two reasons. First, extensive fragmentation and increased edge results in less "secure" habitat for nesting birds (Temple 1986). The incidence of nest predation and parasitism is much higher near edges than in forest interiors and in more fragmented than in less fragmented forests (Gates & Gysel 1978; Brittingham & Temple 1983; Wilcove 1985; Andren & Angelstam 1988; Yahner & Scott 1988). There is evidence that the detrimental edge effects of predation on open nests of forest birds may extend 600 m into the forest, requiring forest tracts to be >100 ha in size before forest-interior habitat is found (Wilcove 1985).

Second, fragmentation and increased edge are major factors contributing to the reduced distribution and abundance of wildlife species on a broad geographic scale. Several songbird species that require breeding territories in forest interiors have shown long-term de-

clines in eastern deciduous forests, perhaps because of habitat fragmentation (Whitcomb et al. 1981). Populations of large, mobile carnivores (e.g., mountain lions, *Felis concolor*; grizzly bears, *Ursus arctos*) in western states may be in jeopardy because of reductions in size and the increased isolation of extensive tracts of undisturbed habitat (e.g., Wilcove, McLellan, & Dobson 1986; Wilcove & May 1986).

Finally, limited amounts of habitat fragmentation, for example, small clearcut stands within extensive tracts of otherwise homogeneous forest, can add to the local diversity of wildlife communities. Clearcut stands provide nesting habitat for a variety of edge species, such as chestnut-sided warblers (*Dendroica pensylvanica*) and mourning warblers (*Oporornis philadelphia*) in forested tracts of north-central Pennsylvania (Yahner 1984; Dessecker & Yahner 1987). However, more studies are needed to document the positive and negative consequences of different intensities of habitat fragmentation in various landscapes.

Conclusions

Based on our current understanding of changes in wildlife communities near edges, we must not conclude that creation of more edge in landscapes will always have a positive effect on wildlife. The generality that provision of more edge is good wildlife management needs to be reexamined for at least two reasons. One reason is that types of edges and perhaps "quality" of edges vary markedly, depending on characteristics of both the edge and the surrounding landscape. In short, edges are not created equal, and, hence, their edge effects for wildlife should not be expected to be equal.

A second reason for being cautious in ascribing the benefits of edges to wildlife is that we simply need additional well-designed, long-term studies of edge effects to (1) develop a pragmatic and standardized protocol for measuring and comparing edge dimensions and edge effect in different landscapes, (2) better document and understand both positive and negative impacts of edge effect for wildlife communities, guilds, and key species, and (3) provide both wildlife and land managers with sound management recommendations for the benefit of wildlife associated with edges. Additional studies on edge effect are timely because amounts of edge undoubtedly will increase in the future with continued land-use practices, such as widespread urbanization, agriculture, or silviculture, thereby affecting future trends in the distribution and abundance of wildlife communities. And, finally, with the recent growth of fields such as conservation biology and landscape ecology, future opportunities abound to facilitate multidisciplinary approaches to edge and landscape management for the benefit of wildlife communities.

Acknowledgments

Funding for this paper was provided by the Pennsylvania Agricultural Experiment Station, University Park, Pennsylvania. I thank M. C. Brittingham, R. P. Brooks, R. F. Labisky, K. P. Reese, G. L. Storm, and an anonymous reviewer for comments on the manuscript. This paper is Scientific Journal Series No. 7757 of the Pennsylvania Agricultural Experiment Station.

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