Appendix 1: Ecological Background on Landscape Pattern[1]

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February 25, 2008

Forest fragmentation

Loss of natural forests, and the fragmentation of remaining areas into progressively smaller patches isolated by lands converted to other uses (e.g., plantations, agriculture or industrial/urban development), is a significant global trend (Harris 1984) and has received considerable attention in the ecological literature. Studies have identified the composition (abundance of different vegetation types) and configuration (pattern of different vegetation types) of landscapes as important factors influencing ecosystem function and habitat quality (Turner 1989). The sections below provide some background on the ecological relevance of landscape composition (abundance of different vegetation types) and configuration (pattern of different vegetation types). The ecological effects of abundance are difficult to separate from those of pattern. Forest fragments are almost always created by habitat removal and the effects of removing habitat and creating smaller pieces are difficult to separate.

Ecological effects of habitat abundance

The ecological effects of habitat abundance are well documented. Both population size (Fahrig 2002) and species richness (Preston 1962) decrease as habitat abundance decreases. Habitat loss is generally regarded as the biggest single threat to biodiversity (Erhlich 1988). This relationship is most clear when one habitat type is being replaced by a significantly different one (e.g., forest being replaced by agriculture or urban development; Bunnell 1999). A null hypothesis in landscape ecology is that the ecological integrity of a landscape, for a given species, declines linearly with amount of habitat. The degree to which integrity declines non-linearly is an indication of the role that pattern and non-habitat areas play in maintaining or impeding population persistence. A non-linearity at approximately 30% (Andren 1994) suggests that pattern effects may be more important when habitat abundance drops below this threshold.

Habitat abundance also exerts considerable control over landscape pattern. Models find that as habitat proportion decreases, patch size decreases and the distance between patches increases (Andren 1994; Gardner and O'Neill 1991). Furthermore, tradeoffs exist between patch size and spacing (Daust 1994): at a given habitat abundance, landscapes

[1] This summary is based heavily on Daust D, A. Fall, G. Sutherland, D. Steventon and K. Price. 2003. Evaluation of landscape metrics for quantifying fragmentation in the Morice & Lakes IFPA area. Report to the Morice and Lakes IFPA Ecosystem Technical Advisory Committee. 38 pp. http://www.moricelakes-ifpa.com/publications/documents/IFPAMetricReportV3.pdf

can have a few large, widely-spaced patches or many small patches that are closer together (or some combination).

Evaluation of landscape metrics for quantifying fragmentation in the Morice & Lakes IFPA area

Ecological effects of habitat pattern

The effects of ecological patterns are also well documented in some ecosystems. The classic work on island biogeography (McArthur and Wilson 1967) identifies two ecologically relevant aspects of pattern (summarised in Bunnell 1999):

> "*Area*: larger islands contain more species than do small islands. This occurs because small islands experience more extinctions (small populations are more vulnerable to chance events) and receive fewer immigrants (species wandering from the mainland to nearby islands are not as likely to encounter them—a kind of "target size" effect).
>
> *Distance*: islands that are more remote from the mainland or source population will have fewer species because the extinction rate is the same but the immigration rate is lower (fewer immigrants reach the island)."

Other lines of investigation corroborate the importance of area and distance effects. Meta-population theory supports the importance of patch size and isolation on extinction and colonization processes (Levins 1969, 1970, Hanski 1994). Theory on minimum viable populations suggest that species persistence is greatly compromised when habitats support less than 50 individuals (Shaffer 1981). Larger species may have trouble finding habitat in sufficient density to support a home range in heavily fragmented forests (e.g., Chapin et al. 1998).

Area (of a patch) and distance (between patches) effects, however, are poorly documented in forested settings (Bunnell 1999). Some of the studies that have found effects have not controlled for habitat abundance. Many studies that have controlled for abundance have not been able to demonstrate a strong affinity of species to pattern (Bunnell 1999). Bunnell (1999) suggests that findings in managed forests differ from Island Biogeography theory because forest fragments are not true islands and because the non-habitat matrix is not a true sea: in the forest, "islands" share species with the "sea". While many vertebrate species prefer natural old forest, they can often inhabit young forest, particularly young forest with natural structure. This may be less true of other taxa, such as some epiphytic lichens that are correlated with old stands and oldgrowth structure (Price and Hochachka. 2001). When intervening habitat is hostile to both survival and movement, the importance of connectivity is well established (Bunnell 1999). In managed forests, more movement occurs inside of than outside of corridors, suggesting that clearcuts may be somewhat hostile to some species. The blurring of differences between habitat and matrix presents a challenge to researchers to identify the appropriate scales and indicators to assess issues of pattern.

Despite the differences between forest and island settings, some studies (e.g., Jansson and Angelstam 1999, Laurance and Bierregaard 1996) have found effects consistent with Island Biogeography theory. In addition, species-specific simulation models also predict pattern effects (Fahrig 2002).

In addition to area and distance effects, studies have identified a third ecological effect of pattern: edge effects. Edges are places where plant communities meet, or where successional stages or vegetation conditions within plant communities come together (Kremsater and Bunnell 1999). Edge effects include changes in microclimate and consequently in plant distributions; animal distributions also respond to edge for a variety of reasons (Kremsater and Bunnell 1999). Microclimatic effects extend from 100 to 150 m from the edge; the most important effects on biological organisms (e.g., predation) extend 50 m, however, the effects of roads can extend 400 m (Kremsater and Bunnell 1999). Some animals prefer edges, others avoid it. While negative edge effects are well documented where forest patches are isolated by agriculture, they are less well documented along forest to clearcut edges (Kremsater and Bunnell 1999).

Other aspects of pattern such as shape and fractal dimension appear to have less ecological relevance, although some examples of ecological linkages exist (Hamazaki 1996). Future research may provide new information.

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