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Response to Bissonette, J. A., and I. Storch. 2002. "Fragmentation: is the message clear?"

Lack of Agreement on Fragmentation Metrics Blurs Correspondence between Fragmentation Experiments and Predicted Effects

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ABSTRACT

The direct correspondence between landscape fragmentation and its effects is still the subject of debate. Many widely accepted hypotheses are not supported by experiments. The issue of fragmentation measurement is addressed here. To predict the effects of fragmentation, it is essential to quantify the pattern of fragmentation. Despite the increased use of spatial analysis and available measures, experts have not yet reached an agreement on how to measure patterns of fragmented landscapes and, thus, unambiguous translation of experimental findings into conservation or management guidelines is hampered.

KEY WORDS: fragmentation, landscape metric, spatial pattern.

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Based on two reviews (Debinski and Holt 2000, McGarigal and Cushman 2002), Bissonette and Storch (2002) suggest that time lags, thresholds, patch−matrix contrasts, and observation scales cause a lack of correspondence between fragmentation effects and straightforward predictions. Differences in response to fragmentation between core- and edge-sensitive species, and between generalist and specialist species, are also assumed to inhibit the predictability of fragmentation effects. Bissonette and Storch (2002) suggest that fragmentation behaves like a complex adaptive system, characterized by deterministic chaotic events, and is thus unpredictable (Denny and Gaines 2000).

This complex message does not take into account another factor introducing variability into fragmentation effect assessment: the measures used to determine to what extent the landscape is fragmented. Different degrees or types of fragmentation will have different effects. This issue should be clarified before a more complicated item, such as matching temporal and spatial domains (Wiens 1989, Bissonette 1997), is dealt with. Measurement of fragmentation has been the subject of many discussions over the years. This paper is not intended to promote one metric above the rest, but rather signals the problem of metric superabundance and redundancy, and urges landscape ecologists, conservation biologists, and landscape managers to agree on suitable measures before drawing conclusions from experiments or observations.

The spatial pattern of habitat has been important in assessing the status of a variety of organisms (Davidson 1998). Landscape ecology hypothesizes that this spatial arrangement has ecological implications: land-use pattern change is considered crucial to an understanding of landscape dynamics and its consequences (Turner and Ruscher 1988). To investigate this relation between pattern and process, patterns should be described in quantifiable terms (Hargis et al. 1997). Consequently, conservation strategies should consider not only amounts of habitat to be retained, but also their spatial configuration (Schumaker 1996). Quantifying the pattern of fragmentation is essential to establish criteria for relating a particular pattern to its consequences (Levin 1992). Pattern maps are useful because they quantify biologically relevant information that is not evident from a land cover map (Riiters et al. 2000). This insight has generated an abundance of landscape indices and concomitant software (e.g., FRAGSTATS, McGarigal and Marks (1995)), and new measures are still being proposed (Bogaert et al. 2002a,b). However, despite the increased use of spatial analysis and available measures, no agreement has been reached on how to measure landscape patterns (Davidson 1998).

This problem of metric abundance is still the subject of debate (Gustafson 1998): many indices have been shown to be correlated (Hargis et al. 1997, Bogaert et al. 1999) and to exhibit statistical interactions (Li and Reynolds 1994). Some metrics simultaneously quantify multiple components of pattern (Li and Reynolds 1994, Riiters et al. 1995). Arguments have been put forward to develop such indices to reduce the number of variables in a multivariate analysis (Scheiner 1992), despite the difficulty already encountered when interpreting indices that measure one single component (Li and Reynolds 1994). One solution would be to define independent components of spatial pattern and develop a suite of metrics to measure them (Li and Reynolds 1994, Riiters et al. 1995). In Li and Reynolds (1995), spatial heterogeneity is divided into number of land cover types, proportion of land cover types, spatial arrangement of the patches, patch shape, and contrast between neighboring patches. Another method to reduce the number of metrics is factor analysis (Riiters et al. 1995). From a statistical point of view, most indices actually measure one or just a few independent dimensions of pattern, and many are redundant, at least across a range of spatial and attribute scales (Cain et al. 1997). Nevertheless, the biological relevance of metrics may be more important than their statistical properties. Moreover, unless there is some biological justification, there appears to be little need to calculate many metrics. One question that a factor analysis cannot answer is the relevance of any metric to the analyst (Riiters et al. 1995). Therefore, indices sensitive to the aspect of landscape pattern of concern should be preferred (Davidson 1998).

Fragmentation produces many quantifiable landscape changes: reduced habitat area, increased edges, reduced interior area, patch isolation, and increased number of patches (Davidson 1998). Most can be measured separately. However, there is no single measure that captures all aspects (Baskent and Jordan 1995); even so, a single measure is often mistakenly used as an overall measure (Davidson 1998). The simplest way to summarize the pattern of fragmentation is through a frequency distribution of patch sizes (Groom and Schumaker 1993). A typical size distribution shows skewness towards smaller values. However, this does not provide any information concerning other consequences of fragmentation, such as edge effect or isolation (Groom and Schumaker 1993). Moreover, the spatial distribution of patch sizes is sometimes hard to measure and interpret in a complex landscape (Baskent and Jordan 1995).

Two approaches may be used to account for the lack of an overall measure. The first is to select the aspect of fragmentation that is of most concern to the question being investigated, e.g., patch size (Robinson et al. 1992). However, it should be noted that interpreting single-factor measures has been described as "tricky" (Davidson 1998): perimeter length, patch area, interior area, isolation, and other indicators of fragmentation all interact and may change in contradictory directions as fragmentation proceeds. The second approach to measuring fragmentation is to use several measures, because no single index can capture the full complexity of the spatial arrangement of patches (Dale et al. 1994). This approach is most appropriate when the integrity of the entire ecosystem, rather than the impact on a single species with specific needs (Davidson 1998), is being assessed. The use of multiple measures requires "balancing" the measures, often in different units. A possible solution is to combine multiple metrics as a vector in a hyperspace (Sharpe et al. 1982, Bogaert et al. 2000).

Although there is inherent danger in testing hypotheses formulated in advance (Diamond 2001), it is becoming increasingly necessary to understand the consequences of the destruction and fragmentation of natural habitats (Robinson et al. 1992). The unpredictability of fragmentation effects (Bissonette and Storch 2002) underscores the need to reassess how fragmentation is measured. Until comparison of fragmentation patterns can be executed unambiguously, the effects of the patterns cannot be compared. Many metrics have been defined, and different statistical or methodical approaches have been proposed to limit the number of metrics in the analysis. Agreement exists that a suite of metrics is necessary to cover the complexity of landscape patterns. These metrics ideally each describe a single independent pattern component. However, the choice of which metrics should be calculated still remains undecided, despite the urgent need to develop clear guidelines for landscape conservation and restoration.

RESPONSES TO THIS ARTICLE

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LITERATURE CITED

Baskent, E. Z., and G. A. Jordan. 1995. Characterising spatial structure of forest landscapes. *Canadian Journal of Forest Research* **25**:1830–1849.

Bissonette, J. A. 1997. Scale sensitive ecological properties: historical context, current meaning. Pages 3–15 *in* J. A. Bissonette, editor. *Wildlife and landscape ecology: effects of pattern and scale.* Springer-Verlag, New York, New York, USA.

Bissonette, J. A., and I. Storch. 2002. Fragmentation: is the message clear? *Conservation Ecology* **6**(2): 14. [Online] URL: http://www.consecol.org/vol6/iss2/art14.

Bogaert, J., R. B. Myneni, and Y. Knyazikhin. 2002a. A mathematical comment on the formulae for the aggregation index and the shape index. *Landscape Ecology* **17**:87–90.

Bogaert, J., P. Van Hecke, and R. Ceulemans. 2002b. The Euler number as an index of spatial integrity of landscapes: evaluation and proposed improvement. *Environmental Management* **29**(5):673–682.

Bogaert, J., P. Van Hecke, R. Moermans, and I. Impens. 1999. Twist number statistics as an additional measure of habitat perimeter irregularity. *Environmental and Ecological Statistics* **6**:275−290.

Bogaert, J., P. Van Hecke, D. Salvador-van Eysenrode and I. Impens. 2000. Landscape fragmentation assessment using a single measure. *Wildlife Society Bulletin* **28**:875−881.

Cain, D. H., K. Riiters, and K. Orvis. 1997. A multi-scale analysis of landscape statistics. *Landscape Ecology* **12**:199−212.

Dale, V. H., H. Offerman, R. Frohn, and R. H. Gardner. 1994. Landscape characterisation and biodiversity research. Pages 47−66 *in* T. J. B. Boyle and B. Boontawee, editors. *Measuring and monitoring biodiversity in tropical and temperate forests.* Center for International Forestry Research, Bogor, Indonesia.

Davidson, C. 1998. Issues in measuring landscape fragmentation. *Wildlife Society Bulletin* **26**:32−37.

Debinski, D. M., and R. D. Holt. 2000. A survey and overview of habitat fragmentation experiments. *Conservation Biology* **14**:342−355.

Denny, M., and S. Gaines. 2000. *Chance in biology: using probability to explore nature.* Princeton University Press, Princeton, New Jersey, USA.

Diamond, J. 2001. Dammed experiments! *Science* **294**:1847−1848.

Groom, M. J., and N. H. Schumaker. 1993. Evaluating landscape change: patterns of worldwide deforestation and local fragmentation. Pages 24−44 *in* P. M. Kareiva, J. G. Kingsolver, and R. B. Huey, editors. *Biotic interactions and global change.* Sinauer Associates Inc., Sunderland, Massachusetts, USA.

Gustafson, E. J. 1998. Quantifying landscape spatial pattern: what is the state of the art? *Ecosystems* **1**:143−156.

Hargis, C. D., J. A. Bissonette, and J. L. David. 1997. Understanding measures of landscape pattern. Pages 231−261 *in* J. A. Bissonette, editor. *Wildlife and landscape ecology: effects of pattern and scale.* Springer-Verlag, New York, New York, USA.

Levin, S. A. 1992. The problem of pattern and scale in ecology. *Ecology* **73**:1943−1967.

Li, H., and J. F. Reynolds. 1994. A simulation experiment to quantify spatial heterogeneity in categorical maps. *Ecology* **75**:2446−2455.

Li, H., and J. F. Reynolds. 1995. On definition and quantification of heterogeneity. *Oikos* **73**:280−284.

McGarigal, K., and S. A. Cushman. 2002. Comparative evaluation of experimental approaches to the study of habitat fragmentation studies. *Ecological Applications* **12**(2):335−345.

McGarigal, K., and B. J. Marks. 1995. FRAGSTATS: *Spatial pattern analysis program for quantifying landscape structure.* PNW-GTR-351, United States Department of Agriculture, Pacific Northwest Research Station, Oregon, USA.

Riiters, K. H., R. V. O'Neill, C. T. Hunsaker, J. D. Wickham, D. H. Yankee, S. P. Timmins, K. B. Jones, and B. L. Jackson. 1995. A factor analysis of landscape pattern and structure metrics. *Landscape Ecology* **10**:23−39.

Riiters, K. H., J. D. Wickham, J. E. Vogelmann, and K. B. Jones. 2000. National land cover pattern data (Ecology 81:604). *Ecological Archives* **E081**:004.

Robinson, G. R., R. D. Holt, M. S. Gaines, S. P. Hamburg, M. L. Johnson, H. S. Fitch, and E. A. Martinko. 1992. Diverse and contrasting effects of habitat fragmentation. *Science* **257**:524–526.

Scheiner, S. M. 1992. Measuring pattern diversity. *Ecology* **73**:1860–1867.

Schumaker, N. H. 1996. Using landscape indices to predict habitat connectivity. *Ecology* **77**:1210–1225.

Sharpe, D. M., F. W. Stearns, R. L. Burgess, and W. C. Johnson. 1982. Spatio-temporal patterns of forest ecosystems in man-dominated landscapes of the eastern United States. Pages 109–116 *in* S. P. Tjallingii and A. A. de Veer, editors. *Perspectives in landscape ecology: contributions to research, planning and management of our environment.* Pudoc, Wageningen, The Netherlands.

Turner, M. G., and C. L. Ruscher. 1988. Changes in landscape patterns in Georgia, USA. *Landscape Ecology* **1**:241–251.

Wiens, J. A. 1989. Spatial scaling in ecology. *Functional Ecology* **3**:385–397.

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