Relationship between Spatial Distribution of Urban Sprawl and Species Imperilment: Response to Brown and Laband

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Land-use and land-cover change due to sprawl—residential development near and leapfrogging outwards from urban centers and popular amenities (Carrión-Flores & Irwin 2004)—is currently a leading cause of biodiversity loss in the United States (reviewed in Hansen et al. 2005). Deleterious effects of roads, lawns, outdoor lighting, pets, and other aspects of residential development and the spatial and temporal dynamics of sprawl have long been the subjects of study in fields as diverse as conservation biology and land economics (Forman & Deblinger 2000; Bell & Slade 2004).

In light of the consensus that sprawl is a major threat to biodiversity and that rural land-use planning is one of the most important conservation activities today (reviewed in Theobald et al. 2005), we were as surprised as Brown and Laband (2006) at their conclusion that spatial distribution of human activity is not related to species imperilment in the United States. They used U.S. states as minimum spatial units and assessed the effects of human activity levels (people, households, roads, and light intensity at night) and the distribution of human activity on species imperilment (NatureServe database). They conclude that degree of activity but not variation in spatial distribution of activity was the best explanation for observed state-level variation in the proportion of imperiled native species. Hence, the degree to which a U.S. state had clustered or diffuse human distributions was not related to the percentage of imperiled species in the state when human activity levels remained constant.

We agree that higher levels of activity inside any spatial unit will lead to greater conflicts with biodiversity, but disagree with the conclusion that the pattern and process of sprawl is not a leading cause of species imperilment in the United States. Moreover, we are concerned with the apparent lack of relationship between Brown and Laband's methods and results and their strongest conclusion. Our response is based on six concerns: (1) sprawl is analyzed as a static pattern (We believe that degree of clustering at the state level is an inadequate representation of that pattern.); (2) although noted as a limitation, the state was used as the minimum spatial unit for detecting effects of human activity levels, which is problematic in light of the localized nature of sprawl in many densely settled states; (3) the measure used to detect clustering (Ginni coefficient [GC]) detected only <0.5 of the available variation and, therefore, may not have been sufficiently sensitive; (4) the analyses missed potential biodiversity impacts of intensity of nonresidential land uses; (5) the response variable, as gleaned from official species-at-risk lists, failed to incorporate other important measures of biodiversity decline, such as population decline and shifts in community structure, into the analyses; and (6) the abstract overstated the conclusions of the study relative to sprawl, and the discussion suggested that reserves, rather than planning, may be the best solution for conserving biodiversity in human-dominated landscapes.

In their analysis Brown and Laband treat sprawl as a distribution, or spatial pattern, but it is more of a time-dependent process that results in particular sprawling spatial distributions visible at varying spatial scales (Bell & Irwin 2002). Generally speaking human settlement is biased toward water and agricultural land, resulting in

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clustered spatial distributions (Margules & Pressey 2000; Sanderson et al. 2002). In the early stages of sprawl—as in urbanizing western U.S. states—settlement patterns are highly clustered around important resources (i.e., water supply). As settlement expands with time, the general level of human activity at broader spatial scales (e.g., at the state level) increases, and human influence grows throughout the landscape by selecting more biologically rich habitats and fragmenting landscapes with roads (Theobald 2003). This results in increasing conflicts with biodiversity.

Time-series snapshots of any sprawling landscape range from highly clustered to diffuse, as evidenced by the examples of two U.S. states, Vermont and Nevada (Brown & Laband). The authors' comparison of these two states provided an excellent illustration of the inadequacy of state-level analysis. The sprawl in Vermont and Nevada differs in scale, but these scale differences are undetectable at the scale of analysis used by Brown and Laband. For example, although Vermont (GC = 0.58) has a more diffuse settlement pattern than Nevada (GC = 0.96), it has a much higher population density (26/km^2 vs. 8.4/km^2 in Nevada). Vermont has been subjected to the process of sprawl for more than 300 years (Klyza & Trombulak 1999). By contrast, in Nevada the Hoover Dam, completed in 1936, provided power and water for a fledgling city (Las Vegas) in the middle of a desert (Reisner 1993). During the 1990s, Las Vegas was one of the fastest growing cities in the nation, spreading rapidly into the Mojave Desert (northern Las Vegas' population grew by 140% during the 1990s [U.S. Census]). Even so, the process of exurban growth has had far less time to develop a diffuse footprint than long-settled, densely populated states.

The sprawl process leads to higher levels of human activity at broader spatial scales (e.g., states). Eventually, as the authors found, higher levels of settlement are associated with higher levels of species' endangerment. Nevertheless, the authors' imply in the conclusion that degree of diffusion of settlement is in and of itself an indicator of sprawl. We believe—at the state level—that it is more instructive to examine degree of diffusion as a stage along the way toward higher and more broadly distributed levels of population density (and hence activity).

The authors themselves recognize that a state-level analysis ignores spatial variation in settlement that is undeniably present at a finer scale. Zooming in on the global human footprint (http://www.wcs.org/humanfootprint) suggests a high degree of spatial variation of human impact even in densely settled landscapes. Within the densely settled northeastern U.S. States, for example, patterns of human influence are highly clustered at the substate level around coasts, rivers, roadways, and cities (Sanderson et al. 2002).

A spatial effect of sprawl may not have been detected because the Ginni coefficient used to measure clustering may have been insufficiently sensitive. The range of spatial effect among states, on a scale of 0–1, was 0.58–0.96; this captured <40% of the potential variation. As for most ecological measurements, the sensitivity of the instrument can influence results. It may be that the failure to detect variation at the lower end of the clustering gradient (i.e., <0.58) was the reason that more densely and evenly populated states (e.g., Vermont) with higher activity values seemed less influenced by clustering in the regression analysis, when in reality there was a high degree of spatial variability within many of those states.

Land-use type varies over space (Sanderson et al. 2002), and different land uses influence resident biota differently. States with highly clumped human settlement (e.g., in the West) may also be characterized by high-intensity resource uses, including arid-land ranching, public-lands timber harvesting, and mining. Such activities are equally likely to be responsible for biodiversity losses (Fleischner 1994; Wilcove et al. 1998). Unfortunately, Brown and Laband omitted these types of human activities from the analyses. It is plausible that if a land-use intensity metric incorporating more variables had been employed, it would have resulted in more even distributions of human activity.

Measures of biodiversity loss that are incorporated into analyses conducted at large landscape scales are usually limited to either numbers of or proportion of extinct or imperiled species or degree of range loss (e.g., Laliberte & Ripple 2004; Cardillo et al. 2006). Biodiversity erosion is a continuum, with local-level population declines on one end and extinction and extirpation/range recession on the other. Lists of imperiled species, by definition, consist of species that are threatened or in danger of vanishing, which means they are on the far end of the continuum. We are concerned that Brown and Laband do not acknowledge that the use of imperiled species as a measure of biodiversity decline in these analyses overlooks more subtle local-level biodiversity impacts that would indicate negative effects of the process and pattern of sprawl.

Finally, Brown and Laband's abstract is of particular concern to us in light of the fact that many readers will read only this section of the paper. The abstract as written is misleading when read in isolation; indeed, methodological weaknesses were presented in the discussion to the point that the authors suggest that their results are "too abbreviated for policy prescriptions." Yet, the abstract concludes, "Our results point to rising levels of human activity—and not some particular (e.g., sprawling) distribution of human activity—as the most relevant factor explaining biodiversity loss in the United States." The statistical result behind this conclusion was that distribution of human activity (whether diffuse or concentrated) "had no meaningful (i.e., statistically zero) impact on species imperilment at the state level."

Planning for biodiversity conservation in urbanizing landscapes is a conservation priority for agencies and nongovernmental organizations throughout North America (e.g., Johnson & Klemens 2005). We need the cooperation of private landowners to achieve conservation planning goals. Smart growth, best development practices, and other planning tools are vehicles for open-space and biodiversity conservation on private lands (Babbit 2005; Calhoun et al. 2005), yet incentives to use such tools are undermined if misleading perceptions about the relationship between patterns of development and biodiversity losses are promulgated in the literature. Messages from the scientific community regarding contrary evidence of sprawl and its effects on biodiversity must be clear and well supported so as not to confuse practitioners who do not have time to read all the way to the discussion section to learn about study weaknesses.

Land-use change due to sprawl is a leading threat to biological diversity in the United States. Local-scale planning to mitigate the effects of this process is equally important as establishment of new nature reserves because no current conservation fund exists to purchase all of the biologically rich lands threatened by sprawl. Although Brown and Laband's paper raises important questions about intensity of human influence on the landscape, it does not, contrary to statements contained therein, provide convincing negative evidence that sprawling distributions of humans are a primary threat to biodiversity or provide adequate reason to step away from exurban planning as a conservation method.

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