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Normative standards for land use in Vermont: Implications for biodiversity

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ABSTRACT

The conversion of natural lands to developed uses poses a great threat to global terrestrial biodiversity. Natural resource managers, tasked with managing wildlife as a public trust, require techniques for predicting *how much* and *where* wildlife habitat is likely to be converted in the future. Here, we develop a methodology to estimate the "social carrying capacity for development" – SK_d – for 251 towns across the state of Vermont, USA. SK_d represents town residents' minimum acceptable human population size and level of development within town boundaries. To estimate SK_d across towns within the state of Vermont (USA), as well as the average state-wide SK_d, we administered a visual preference survey (n = 1505 responses) to Vermont residents, and asked respondents to rate alternative landuse scenarios in a fictional Vermont town on a scale of +4 (highly acceptable) to −4 (highly unacceptable). We additionally collected demographic data such as age and income, as well as ancillary information such as participation in town-planning meetings and location of residence. We used model selection and AIC to fit a cubic function to the response data, allowing us to estimate SK_d at a town scale based on town demographic characteristics. On average, Vermonters had a SK_d of 9.1% development on the landscape; this estimate is 68% higher than year 2000 levels for development (5.4%). Respondents indicated that management action to curb development was appropriate at 9.4% development (roughly the statewide SK_d average). Management by local, regional, and state levels were considered acceptable for curbing development while federal level management of development was considered unacceptable. Given a scenario where development levels were at SK_d, we predicted a 16,753 km^2 reduction in forested land (−11.16%) and a 1038 km^2 reduction in farmland (−60.45%). Such changes would dramatically alter biodiversity patterns state-wide. In a companion paper, we estimate how these changes would affect the distribution of wildlife species.

1. Introduction

Around the earth, human population growth leads to increased degradation and conversion of open lands. The conversion of natural lands to developed uses may pose the greatest threat to global terrestrial biodiversity (Vitousek, 1994). As human populations spread from urban centers, existing natural areas, working forests, and traditionally agricultural areas are converted, often permanently, to development. Conversion alters the amount and distribution of wildlife habitat and is the number one cause of decreasing biodiversity worldwide (Convention on Biological Diversity, 2010). With projections of global forest loss between 3 and 9 million km^2 by 2050 (UNEP, 2007), dramatic losses in terrestrial biodiversity can be expected.

Such landscape change affects wildlife in three major ways. First, habitat loss – the outright reduction in total habitat via land conversion – may be the single most important factor influencing wildlife biodiversity at the global scale (Ehrlich, 1995) and the population scale (Fahrig, 2003). Second, habitat fragmentation *per se* can have a large impact on wildlife: even if habitat amount is held constant across a landscape, the arrangement of natural habitat patches on that landscape can significantly affect wildlife population dynamics, particularly when the amount of habitat in the landscape is low (Fahrig, 2003). Finally, roads have been shown to alter wildlife movement patterns, increase mortality, increase

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population isolation, and serve as corridors for invasive species all of which can negatively affect native wildlife species (Forman et al., 2003).

Effectively predicting how and where development may occur in the future is of utmost importance in understanding how humans and wildlife will adapt to a more populated and developed landscape. In the United States, the human population has increased 9.7% between 2000 and 2010, adding 15,800,089 households. Between 1982 and 2003, 142,000 km^2 were converted to development, with 220,000 km^2 expected to be converted to development by 2030 (White et al., 2009). Unlike some areas of the western U.S., where large, publicly owned lands make possible top-down management decisions, landscapes in the eastern U.S. are primarily composed of small parcels owned by private landowners, whose individual decisions collectively determine the distribution and amount of natural habitat across the landscape. Natural resource managers, tasked with managing wildlife as a public trust, face the difficult challenge of being unable to direct management on privately owned lands.

Individual landowners, on the other hand, often have multiple objectives in terms of how to manage their lands. Farmers struggle with maintaining economic viability in their operations weighed against the pressures of development, and a wealth of environmental factors. Owners of forested parcels face trade-offs between managing for timber production, for game and non-game wildlife species, for water quality, and for meeting the economic and housing needs of a growing human population. In addition, the vast majority of landowners rely on services provided in the surrounding area, such as businesses, roads, and schools, and demand for these services can lead to conversion of natural lands to development. The collection of these thousands of decisions made every day by individual landowners and town planners ultimately shape the broader landscape. From the wildlife conservation perspective, there is great need to quantify what levels of development are acceptable to citizens, thus allowing wildlife managers to respond on behalf of wildlife.

Here, we used normative theory approaches to estimate what levels of forest, agriculture, and development on a landscape are "acceptable" to residents of Vermont, USA. In contrast to traditional land use change modeling, which often uses past trends in population growth and development to predict changes into the future (e.g. Theobald, 2005), we focused on identifying and mapping the acceptability of development (SK_d) by landowners across Vermont. In a companion analysis (Bettigole et al., 2013), we estimated how these levels will affect wildlife species in Vermont.

Estimation of social norms (i.e., what is "acceptable" or "normal" within a cultural context) has become increasingly used in setting management standards in recreation, parks and in broader natural resources settings (Vaske and Whittaker, 2004; Manning, 2007). For example, in a U.S. National Park, the visitor experience may be associated with how crowded the Park is: the quality of the experience declines as the crowd size increases, and at some point people may choose not to visit a park because it is too crowded. A normative standard identifies the size of the crowd that an average visitor finds "acceptable." Studies that estimate such normative standards are invaluable when the standards become incorporated into a management objective. For example, when crowds become too large, the Park may take management actions to reduce the number of people that occur in the same place and time.

A norm curve is estimated by surveying the opinions of people with respect to a given indicator, such as the percentage of development in a town, and recording their responses on a scale from highly acceptable (+4) to highly unacceptable (−4). For example, the hypothetical norm curve in Fig. 1. Fig. 1 indicates that

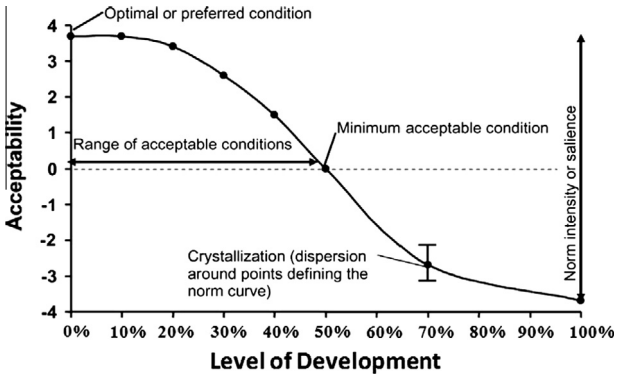

Fig. 1. Hypothetical acceptability curve (social norm curve). These curves are estimated by compiling results of responses to surveys, where respondents rate the acceptability of various conditions. In this example, each point on the curve represents the mean acceptability score for a given level of development on the *x*-axis. The Minimal Acceptable Condition occurs at the level of development where Acceptability = 0. Here, we define this point as the social carrying capacity for development, or SK_d.

acceptability of town-level development begins to drop sharply at a threshold (~30% developed) and begins to level out at an unacceptable level (~70% developed). Of particular interest is the minimum acceptable condition SK_d, the point at which an indicator level shifts from acceptable to unacceptable. Other characteristics of interest include the norm intensity (the range of reported acceptability ratings) and crystallization (the level of agreement among respondents for a given indicator level; Fig. 1). In addition to stated acceptability levels for various levels of town development, respondents can identify their preferred level of development (preference), the level of development where one would move away (displacement), the level of development where managers or town planners should take action (management), and the level of development most like person's town. These are collectively known as "alternative evaluative dimensions" of a norm curve (Manning, 2007). By assessing these standards, or social norms, with respect to different landcover types, we can begin to understand how these collected decisions and perceptions on acceptability may impact a suite of forest dwelling wildlife species in the future.

In this paper, we design a statewide visual preference survey to determine acceptable levels of development, forest and agriculture within Vermont towns. We asked respondents to evaluate a series of three-dimensional simulations of development in a fictional (but representative) Vermont town. Our goal was to measure and map the maximum amount of development that Vermont residents were willing to accept on their landscape, and by doing so understand how these social norms may affect forest dwelling wildlife species in the future. Thus, we evaluate the maximum potential for residential development as valued by current residents of Vermont and do not attempt to predict exactly how land use change will occur in the future. Prediction of future land use change is extremely complex, incorporating human population dynamics issues of immigration/emigration, births/deaths, technology, economics, transportation, and a wealth of other factors that we do not consider here.

Our objectives were to (1) Administer a statewide, mail-based visual preference survey, (2) Estimate acceptability curves for housing and associated development at a statewide level, (3) Measure alternative evaluative dimensions and preferences for scale of management, (4) Estimate the acceptability of development occurring on either forested or agricultural lands, (5) Explore the effects of covariates, such as age of respondents and household income on the shape and position of the acceptability curves within towns,

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