Ex-urban development in the Rocky Mountain West : consequences for native vegetation, wildlife diversity, and land-use planning in Big Sky, Montana

by Lauren Marie Oechsli

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Biological Sciences
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Abstract:
The inter-mountain west of the United States is the fastest growing region in the country in both population and per capita income. With growth and increased wealth come development and conversion of lands from natural habitats to urban and rural-residential landscapes, directly affecting native biotic communities. As habitat loss is the leading cause of species' extinction and endangerment, it is wise to assess habitat availabilities and roles in biodiversity prior to extensive land change or fragmentation. This study employed a GIS and aerial photographs to model potential species richness, determine the pattern and rate of development, and identify locations of potential conflict between biodiversity and future development in the Gallatin Canyon/Big Sky planning district of Gallatin County, Montana. Species distribution models from Montana Gap Analysis Project were used to classify potential habitat for vertebrate species and assess biodiversity via species richness. 'Hot spots' of richness were identified primarily along watercourses and at lower elevations. Analysis of building locations in relation to vegetation identified those habitats most often chosen for development. Low/moderate cover grassland, montane parkland & sub-alpine meadow, mixed xeric shrub, and riparian were used for development more than expected based upon availability, with low/moderate cover grassland accounting for the 81% of all impacted lands. Variables correlated with development were distance to roads, distance to streams, elevation, slope, aspect, percent conifer, percent riparian, percent rock, percent grass/shrub/meadow, grazing status, vegetation diversity, and neighborhood density. These predictors were used to calculate the Mahalanobis distances for lands in private ownership. The statistic assessed the multivariate similarity between attributes at any given location and the mean vector of attributes from all developed lands. Mapping the statistic identified undeveloped areas in the landscape that resemble developed areas and are, therefore, considered suitable for development. Locations most suitable for development occurred close to streams and at lower elevations, indicating that humans and a majority of wildlife species are competing for habitat. Locations where hot-spots of richness coincided with high suitability for development were identified, providing information useful to human communities wanting to make better-informed decisions regarding conservation, zoning plans, and open-space preserves.

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

The inter-mountain west of the United States is the fastest growing region in the country in both population and per capita income. With growth and increased wealth come development and conversion of lands from natural habitats to urban and rural-residential landscapes, directly affecting native biotic communities. As habitat loss is the leading cause of species' extinction and endangerment, it is wise to assess habitat availabilities and roles in biodiversity prior to extensive land change or fragmentation. This study employed a GIS and aerial photographs to model potential species richness, determine the pattern and rate of development, and identify locations of potential conflict between biodiversity and future development in the Gallatin Canyon/Big Sky planning district of Gallatin County, Montana. Species distribution models from Montana Gap Analysis Project were used to classify potential habitat for vertebrate species and assess biodiversity via species richness. 'Hot spots' of richness were identified primarily along watercourses and at lower elevations. Analysis of building locations in relation to vegetation identified those habitats most often chosen for development. Low/moderate cover grassland, montane parkland & sub-alpine meadow, mixed xeric shrub, and riparian were used for development more than expected based upon availability, with low/moderate cover grassland accounting for the 81% of all impacted lands. Variables correlated with development were distance to roads, distance to streams, elevation, slope, aspect, percent conifer, percent riparian, percent rock, percent grass/shrub/meadow, grazing status, vegetation diversity, and neighborhood density. These predictors were used to calculate the Mahalanobis distances for lands in private ownership. The statistic assessed the multivariate similarity between attributes at any given location and the mean vector of attributes from all developed lands. Mapping the statistic identified undeveloped areas in the landscape that resemble developed areas and are, therefore, considered suitable for development. Locations most suitable for development occurred close to streams and at lower elevations, indicating that humans and a majority of wildlife species are competing for habitat. Locations where hot-spots of richness coincided with high suitability for development were identified, providing information useful to human communities wanting to make better-informed decisions regarding conservation, zoning plans, and open-space preserves.

INTRODUCTION

Preservation of biological diversity is of great interest to conservation biologists, governments, and many citizens. Biological diversity is the "variety of life and its processes, including the variety of living organisms and the genetic differences among them, as well as the variety of habitats, communities, ecosystems, and landscapes in which they occur" (Likens 1992, quoted in Christensen et al. 1996). The interest in biodiversity is global, as evidenced by the existence of national and international organizations and legislation designed to protect it – e.g., The United Nations' Educational, Scientific, and Cultural Organization's World Heritage branch (UNESCO 1998), the European Union's Habitat Directive (Williams 1995), the U.S.'s Endangered Species Act (16 U.S.C. 1531-1544), and the National Gap Analysis Program of the USGS Biological Resources Division (Scott et al. 1993).

Recognizing that preserving biodiversity is an important challenge, the logical question follows, "What is the main threat to biodiversity?" The above groups all agree that the main threat to biodiversity is the loss and alteration of habitat, the leading cause of which is anthropogenic impact. Indeed, it has been suggested that in the U.S., the greatest number of endangered species occur in states where high levels of endemism coincide with intense anthropogenic activities such as agriculture and urbanization, i.e., California, Florida, and Hawaii (Dobson et al. 1997).

Concern over anthropogenic change often focuses on urban sprawl, typically a management concern for highly urbanized areas. When human growth threatens the last remaining open spaces or begins to have noticeable ill effects on nearby wildlands, reactionary management is the common recourse. In response to loss of open space in the U.S., state and local governments have devised a variety of reactive and proactive coping mechanisms. For example, funds are actively raised by governments to purchase land and development rights (Daniels and Bowers 1997), new development is encouraged in previously established towns with extant infrastructure as opposed to rural areas, and aggressive growth-management systems designate urban growth boundaries and impose development restrictions (Moore and Nelson 1994; Daniels and Bowers 1997).

In highly urbanized areas, alteration of the landscape is apparent. However, development also degrades rural areas in a variety of ways. Growth of urban land-use (i.e., residential/commercial/industrial/public buildings, parking areas, and transportation) has been found to progress eight times faster than the growth of the human population, leading to a rapid change in a community's appearance (The American Society of Planning Officials 1976; LaGro 1994). Sprawling and second home developments can be an economic burden, as they often do not contribute the additional tax base needed to support schools and infrastructure improvements (The American Society of Planning Officials 1976). Environmental impacts can cause recreation and tourism dependent communities to lose those assets that formerly contributed to their economic stability (Rasker 1994). Resort communities, especially prone to escalating property values and cost-of-living, often evolve into towns whose full-time residents can no longer afford to stay (Culbertson et al. 1992; Gill 1992). Wildlife species sensitive to disturbance retreat to more remote areas (e.g., Mace et al. 1996), while some animals are killed due to interactions with humans. Scenic beauty is compromised as hillsides are marked by homes and roadways, and the ecological health of the area often declines (The American Society of Planning Officials 1976; Gill 1992; Meyer and Turner 1992).

Impacts of urbanization on wildlife from different taxa have been documented across the entire urban gradient, from low-density rural areas to urban centers (e.g., Blair 1996; Bowers and Breland 1996; Blair and Launer 1997; Harrison 1997; Gering and Blair 1999). At moderate levels of development, diversity of certain avian communities increases. This increase is partially due to the influx of generalist, exotic, and urban-adaptable species at the expense of specialists and non-adaptable natives (Blair 1996; Germaine et al. 1998). Higher levels of development, however, cause a decrease in both total and native species diversity (Blair 1996). Some, but not all, generalists benefit from anthropogenic alteration. Large carnivores such as wolves and grizzly bears tend to require vast amounts of relatively undisturbed habitat. Fragmentation and habitat conversion make fulfilling this need progressively more difficult (Mattson et al. 1987; Mech et al. 1988; Mladenoff et al. 1995; Mace et al. 1996). Other development effects can be more subtle. Manicured lawns (Racey and Euler 1983), low-level traffic (Mader 1984), and the presence of bird feeders and pets (Bowers and Breland 1996) can effectively increase the cumulative disturbance effect that low-density developments have on mammal communities. Additionally, vegetation changes can alter microclimate (Mader 1984), habitat structure (Blair and Launer 1997), and, consequently, invertebrate communities.

Given that habitat loss and alteration resulting from anthropogenic land-use threaten the biodiversity that many are trying to preserve, how will we reconcile rapid growth and development of human societies with the desire to preserve biodiversity?

Reconciliation will likely require adoption of a landscape-level, interdisciplinary approach that incorporates biology, ecology, agriculture, sociology, economics, and urban planning with the aim of developing proactive land management tools. A useful tool would analyze biodiversity, development patterns, and the ways in which they interact (McDonnell and Pickett 1990) such that the information provided could help direct conservation and planning processes. The aim of this project is to develop such a tool.

The intermountain west of the United States is experiencing a range of developmental impacts due to expanding human populations. As a whole, the region lies toward the rural end of the urban gradient, however, human/nature conflicts are becoming apparent. The region is one of the fastest growing in the country in both population and per-capita income (Riebsame 1997), and counties with recreation or retirement communities are growing faster than other rural or metropolitan areas (Anonymous 1994; Johnson and Beale 1994). People are drawn to rural, mountain regions of the west for many reasons, which may be summed as 'quality of life' (Rudzitis and Johansen 1989; Howe et al. 1997). However, increasing human populations threaten the features that attract people to the region (The American Society of Planning Officials 1976).

The Gallatin Canyon/ Big Sky planning district of Gallatin County, Montana, is an ideal location for a case study of the pattern of urbanization and its impact on habitats and species in the intermountain west. The area is representative of other rapidly growing towns in the region, where natural assets and a high quality of life might be affected by an influx of people. Wildlife and scenic beauty are abundant, while skiing, snowmobiling, hiking, fishing, and hunting are just some of the recreation opportunities available year-round. Though the growth rate is high, the level of development is still low on the urban gradient allowing the area to benefit from foresight in land planning. Accordingly, I developed this study to aid interdisciplinary management by providing information on potential vertebrate habitats, biodiversity, and the impact of past and potential future development on vegetation types and species distributions. Specific objectives of the study were,

(1) Use species-habitat models developed by the Montana Gap Analysis Project (Hart et al. 1998) to estimate potential distributions for vertebrate species and obtain species richness measures for the study area,

(2) Quantify the rates, spatial location, and impact of human development on vegetation types and potential species distributions from 1962 to 1998,

(3) Use associations between locations of human development and environmental variables to identify preferred development sites, and

(4) Explore the implication for future conservation, research, and land planning efforts as they relate to species richness.

The results of this study might prove useful to other developing mountain towns in the Greater Yellowstone Ecosystem and the intermountain west, as the information generated might have significant application for groups interested in sustainable management.

Information on vertebrate species distributions and habitat associations can be gathered in a variety of ways, at a variety of scales, and for single and multiple species. In addition to environmental variables, each available technique requires additional species information of varying complexity. Expert-systems models (wildlife-habitat relationships or habitat suitability indices) require compilation of habitat affinities gathered through literature search and expert opinion (Verner et al. 1986; Scott et al. 1993; White et al. 1997). The multivariate Mahalanobis statistic (Clark et al. 1993; Knick and Dyer 1997) and an optimal habitat approach developed for a GIS (Dettmers and Bart 1999) require field data on species presence locations only. Overlap analysis (Brito et al. 1999), a simplified GIS method, requires presence and absence data for each modeled species. Other, more statistically rigorous, models also require data on species presence, absence, and/or abundance – linear regression (Morrison et al. 1987; Iverson and Prasad 1998), logistic regression (Pereira and Itami 1991; Mladenoff et al. 1995, Nadeau et al. 1995; Brito et al. 1999), and multivariate methods – principle components analysis (Debinski and Brussard 1994), canonical correspondence analysis (Blair 1996), classification and regression tree analysis (O'Connor et al. 1996), and discriminant function analysis (Mosher et al. 1986). At the most complex, spatially-explicit demographic models (Noon and McKelvey 1992; Lamberson et al. 1994) require detailed data on vital rates, habitat selection, home range, edge effects, density effects, competition, and other factors.

Though expert-systems models are not based on statistical methods (Dettmers and Bart 1999) and cannot incorporate spatial dynamics of interaction between animals and their habitats (Turner et al. 1995), they do have advantages over the other techniques that require a substantial amount of presence/absence data to build and test models. Typically, these data are acquired via an extensive field survey of the study area and focus on one species or an assemblage of species from one taxonomic class. When biodiversity is the focus, it is desirable to analyze a wider range of species, given that areas harboring large numbers of different species (hotspots of species richness) might not coincide for different taxa and that rare species might not be found in any hotspot (Prendergast et al. 1993; Harcourt 1999). Collecting field data for many species requires time and economic investment. Expert-systems models, on the other hand, can be generated for many species from different classes with reasonable investment. These models are typically generalized for application across a broad geographic area, allowing them to be employed by a variety of users. Though simplistic compared to the more rigorous, statistical methods, expert-systems models incorporate findings from previous field studies, as well as the cumulative knowledge of professionals. Additionally, when many species of interest are either wide-ranging or generalists, even a large amount of field data might not result in a statistical model with higher predictive ability than an expert-systems model.

Combining information on species habitats and richness with information on the pattern of human development can greatly enhance conservation efforts by identifying species and habitats most at risk of anthropogenic impact. Municipal records, or more commonly remotely sensed data of the same area at different time points, can provide source information for assessing land-cover change and impact (Wear and Flamm 1993; Thibault and Zipperer 1994; Turner et al. 1996). Studies of land-cover change and urbanization have identified several variables associated with development: ownership, slope, elevation, distance to roads or markets, population, position on urban gradient, and neighborhood density (Wear and Flamm 1993; Turner et al. 1996; Poudevigne et al. 1997; Wear et al. 1998; Maxwell et al. 2000). While slope, elevation, distance to road and market, and presence of other buildings (and infrastructure) might account for some of the economic drivers of development, a biological reality is that human development is also tied to water availability. It is likely, therefore, that vegetation types and species occurring in close proximity to water and roads, at lower elevation, and on more level ground have been and will continue to be impacted by development to a greater degree than others, causing them to be at greater risk of local extinction. Assessing the pattern of past development, therefore, is a useful method for predicting where future development might occur, thereby allowing concerned communities to influence where it will occur (Alig and Healy 1987; Wear et al. 1998).

STUDY AREA

The study area was the Gallatin Canyon/Big Sky planning district of Gallatin County in southwestern Montana (Figure 1: NW corner 470776 m, 5021966 m; SE corner 496930 m, 5002291 m; UTM; Zone 12). The county planning department was responsible for establishing zoning ordinances within the planning district. The study area was 53,195 ha and contained portions of the Gallatin and Upper Yellowstone River watersheds, portions of the Gallatin and Madison mountain ranges, and a section of the Lee Metcalf / Spanish Peaks Wilderness unit. The environmental conditions of the district were spatially highly variable. Elevation ranged from 1,750 m – 3,200 m. The lowest elevations in the study area were dominated by shrub/grass communities and Douglas-fir (*Pseudotsuga menziesii*). The predominant vegetation in the study area was lodgepole pine (*Pinus contorta*), while the treeline community was dominated by sub-alpine fir (*Abies lasiocarpa*), Englemann spruce (*Picea engelmannii*), and whitebark pine (*Pinus albicaulis*). Rock and alpine meadows existed above the treeline. Riparian communities were associated with the many streams found in the district. The climate was dry and temperate. Mean annual precipitation was 0.49 m while mean annual snowfall was 3.5 m; mean minimum/maximum temperatures were -14.7/-1.6°C and 3.6/25.6°C for the coolest and warmest months respectively (years 1984-2000; Western Regional Climate Center 2000). A wildlife assessment of the area suggested potential for the presence of ~200 species of amphibians, reptiles, birds, and mammals (Picton 1976). The Montana Gap Analysis Project suggested the number might be closer to 350 (Hart et al. 1998). The area was settled by European Americans as recently as 1898, with a low