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Effects of species ecology and urbanization on accuracy of a cover-type model: A test using GAP analysis

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ABSTRACT

Models of vertebrate distributions based on dominant vegetation cover or land-use classification are commonly used for conservation planning, but these models may be inappropriate for species that choose sites based on criteria other than land cover or within urban areas that are not adequately described by cover-type alone. We compared the accuracy of predicted occupancy of birds for a set of cover-type models—Alabama Gap Analysis Program's (ALGAP) vertebrate distribution maps—between an urban and a rural landscape in east-central Alabama. We performed analysis at two scales of investigation—0.03-km^2 point-count surveys or 28.26-km^2 landscapes—using point counts conducted during summers 2004–2006. We tested ALGAP's ability to predict the occupancy of habitat by birds grouped by life-history parameters: migrant, resident, insectivore, carnivore, and omnivore, forest dweller, and cavity nester. ALGAP performed well at the scale of entire landscapes but poorly at the scale of individual point counts. At the point-count scale, ALGAP was most accurate for species requiring interior forest conditions. At the landscape scale, ALGAP was more accurate in the rural landscape than the urban landscape, and it had higher commission errors in the urban landscape. Variation in the ability of ALGAP to predict species occupancy was likely due to (1) poor model performance when applied to species that choose sites using criteria other than cover type and (2) the inadequacy of ALGAP to describe a heterogeneous urbanized landscape. Our results highlight pitfalls of using land cover information to model species distributions in situations where it may be inappropriate.

1. Introduction

Models relating habitat to the occurrence of wildlife are commonly used to predict locations of animals based on land-cover information collected either remotely or by directly assessing the site (Morrison, Marcot, & Mannan, 1998). Cover-type models are often built using expert opinion and assume that occupancy of an area by a species depends heavily on the response of that species to the dominant vegetation (Schlossberg & King, 2009). These models are commonly used to identify biodiversity "hotspots", to prioritize areas to conserve, and to predict the responses of wildlife to management (Scott et al., 1993). Because a great emphasis is often placed on such models, it is essential to have some means to validate their accuracy. Testing models of animal distributions using independent datasets enables researchers to estimate overall accuracy and error rates (Fielding & Bell, 1997). It would be expected that cover-type models would perform with different rates of success in different contexts, such as rural or urban environments, and for different categories of birds, such as insectivores or omnivores. Thus, it is important to test models for accuracy across different groups of birds in multiple contexts. In this way researchers can assess the contexts in which models are most appropriately used, when models are prone to errors, or even when inferences from the models are likely to be misleading (McPherson & Jetz, 2007).

Weaknesses of models built to predict vertebrate distributions can often be anticipated based on the ecology of a given species (e.g., Kilgo et al., 2002; McPherson & Jetz, 2007; Mitchell, Lancia, & Gerwin, 2001), particularly when the models are built using low-resolution information such as type of cover. Distributions of species associated with fine-scale aspects of habitat that are not readily captured by satellite imagery or land cover classifications may be poorly predicted (Fielding & Haworth, 1995). For instance, models describing distributions of habitat generalists often perform poorly compared to models of specialist distributions (e.g., Hepinstall et al., 2002; Mitchell et al., 2001; Segurado & Araújo, 2004), possibly because generalists respond more to aspects of vegetation structure (Pearson, 1993) that are not captured adequately by land cover classifications or satellite imagery, or because generalists use multiple types of cover, making their distributions difficult to predict. Migratory status also affects performance of models of vertebrate distributions based on land

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cover classifications, with migrant distributions often better predicted than those of resident species in North America (Flather & Sauer, 1996; Mitchell et al., 2001), and resident species distributions better predicted than migrant distributions in southern Africa (McPherson & Jetz, 2007). The difference in ability of models to predict the distribution of migrants versus residents may arise because migrants are adapted to certain cover-types or seral stages that experience seasonal fluctuations in food availability and that are apparent from maps of land cover (Sherry & Holmes, 1995). Further, distributions of species that occupy higher trophic levels may be influenced by biotic interactions that are not captured by models making their distributions difficult to predict using habitat characteristics alone (McPherson & Jetz, 2007).

Models built using classified land cover maps derived from satellite imagery or other remotely sensed data may also be poor at predicting distributions within some types of landscapes. For example, the National Land-Cover Database (Homer, Huang, Yang, Wylie, & Coan, 2004) classifies developed areas as low, medium, and high-intensity according to amount of impervious surface. Broad classification schemes such as those used by the National Land-Cover Database often fail to adequately capture heterogeneity (Cadenasso, Pickett, & Schwarz, 2007) or vegetative cover within urbanized or residential landscapes (Pennington & Blair, 2011). Fine-scale heterogeneity may render areas unsuitable for some species (Wiens, 2000), but such subtle vegetation features may not be apparent on a map of land cover. As a consequence, fine-scale heterogeneity within an urban landscape may increase the chances of falsely classifying an area as suitable for a given species. Therefore, models built using only information from existing land cover maps may be missing key information needed to predict the distribution of some species (Cadenasso et al., 2007; Pennington & Blair, 2011).

Gap Analysis Programs (GAP) use cover-type models to identify areas of high species diversity that are not currently protected by existing conservation lands (Jennings, 2000; Scott & Jennings, 1997). GAP creates models using literature review and expert opinion, then applies these models to vegetation maps such as the National Land-Cover Database (Homer et al., 2004) to predict distributions of species (Csuti & Crist, 1998; Scott & Jennings, 1997). The maps of species distributions created by GAP therefore incorporate cover-type, patch-size, and level of urbanization, among other aspects of an area that are obtainable from satellite imagery (Silvano et al., 2007). GAP's standards call for the correct assignment of the presence or absence of a species within a sample area in 80% of judgments (Crist & Jennings, 2000; Csuti & Crist, 1998). However, a meta-analysis of cover-type models (mostly GAP) by Schlossberg and King (2009) showed that the presence or absence of a species was correctly assigned in only 71% of judgments, on average. GAP models also often perform modestly in predicting species occupancy when compared to empirical models (e.g., Howell, Peterson, & Conroy, 2008; Peterson, 2005) because GAP performs best at coarse spatial extent (1:100,000; Scott et al., 1993).

The developers of GAP acknowledge limitations of the models in predicting the distributions of species that choose sites based on criteria not available from maps of land cover (Csuti & Crist, 1998). They encourage field biologists to test GAP's predictions to determine if certain life-history or behavioral traits are associated with increased accuracy (Csuti & Crist, 1998). Knowledge of the situations in which GAP analysis is best applied would help wildlife biologists and managers to use GAP to its maximum effectiveness. Our goal in this study was to assess and contrast the accuracy of Alabama GAP (ALGAP; Silvano et al., 2007) in predicting the distribution of bird species based on aspects of species ecology such as migratory status, nesting guild, habitat specificity, area sensitivity, and trophic level, as well as to compare ALGAP's predictive abilities in an urban and rural landscape.

We tested ALGAP's predictions at the scale of the individual survey location and at the scale of entire 28.26 km^2 study-sites. We predicted that ALGAP would have higher accuracy rates and lower commission errors in a rural versus an urban landscape. We further predicted that GAP would perform most poorly when predicting distributions of species with certain life history characteristics, specifically generalists, residents, cavity nesters, and species occupying high trophic levels, which we hypothesized choose sites based on characteristics that are not apparent from maps of land cover alone. We also predicted that ALGAP would perform better at the scale of the entire study sites than at the scale of the individual point counts.

2. Materials and methods

2.1. Alabama GAP species distribution maps

The species distribution models from ALGAP are based on literature review and expert opinion. ALGAP incorporates patch size and forest edge/interior characteristics as well as cover-type into the modeling procedure (Silvano et al., 2007). ALGAP habitat models were applied to land-cover maps (Kleiner et al., 2007) to create species distribution maps for bird species within Alabama. The resulting maps are 30 m resolution binary matrices of suitable and unsuitable habitat (Silvano et al., 2007).

2.2. Study sites

Our rural landscape was centered on Tuskegee National Forest (TNF), located on the northern edge of the East Gulf Coastal Plain. Our study site was defined by a 3-km-radius circle centered in the southwest portion of the national forest (32°25.899′N, 85°38.637′W). These sites were selected for a mosquito and arbovirus study with bird surveys added later (Estep et al., 2011). TNF contained a variety of natural habitats including bottomland hardwood forest and upland longleaf pine forest. This study site contained < 0.1% urbanized area (defined as > 60% impervious surface, Donnelly & Marzluff, 2006) and 8% developed area (defined as >20% impervious surface, Homer et al., 2004). Within this study site, 373 bird survey points were established using a systematic grid with each point separated from the next closest point by roughly 250 m. Most survey points were within the national forest boundary, although several points fell within surrounding neighborhoods and farmland.

The urban landscape was the city of Auburn, AL, which is located within the East Gulf Coastal Plain roughly 20 km northeast of our rural site. Our study site was a 3-km-radius circle centered on the campus of Auburn University (32°35.517′N, 85°29.417′W). The study site contained an urban center as well as surrounding neighborhoods, parks, farmland and some forested land. Approximately 18% of it was urbanized area and 63% was developed area. We established a grid of 439 bird survey points, each separated by roughly 250 m.

2.3. Bird surveys

Birds were surveyed by trained observers using point counts (Ralph, Droege, & Sauer, 1995) in which all birds encountered within a 100-m radius were recorded. Each point was surveyed for a total of 16 min. In the rural site all points were surveyed twice using 5-min counts in 2004 and twice using 3-min counts in 2005. In the urban site points were surveyed twice using 5-min counts in 2005 and twice using 3-min counts in 2006. We used 5-min counts during one year because Farnsworth et al. (2002) recommended 5-min counts when using their method to calculate detection probabilities. We used 3-min counts the next year