Conservation Value of Clustered Housing Developments

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Abstract

Rural counties in the American West are growing at unprecedented rates. Traditionally, exurban lands in Colorado have been subdivided into a grid of parcels ranging from 2 to 16 hectares. This dispersed pattern of development effectively maximizes the individual influence of each home on the land. Clustered housing developments, designed to maximize open space and minimize edges with development, are assumed to benefit plant and wildlife communities of conservation interest. They have become a popular alternative for rural development despite the lack of empirical evidence demonstrating their benefit. Our study examined the conservation value of dispersed housing developments, clustered housing developments, and undeveloped areas in Boulder County, CO using four indicators: 1) densities of songbirds, 2) nest survivorship of ground-nesting birds 3) presence of mammals, and 4) percent cover and proportion of native and non-native plant species. The patterns we observed across these three land uses indicate that the biodiversity attributes of clustered housing developments are more similar to those of dispersed housing developments than to those of undeveloped areas. While clustering development may have great potential, it is currently not as effective as previously assumed.

Introduction

For the first time in over a century the pattern of human migration has reversed. There are now more people moving from urban areas into the country than from rural areas into cities (Johnson 1998). This demographic change greatly shapes the land conversion occurring in the American West, a region that is growing faster than any other part of the United States (Census Bureau 2000).

Exurban development, or growth beyond incorporated city limits, is characterized by widely dispersed, large-lot development, and is therefore highly land consumptive. Exurban development takes up five times more land than all urban and suburban development combined (Theobald 2004), and it is the fastest growing type of development in the country (Crump 2003). Exurban developments have been demonstrated to increase non-native and human commensal plant and animal species (Maestas et al. 2003) and can actually alter the composition of plant and wildlife communities up to 180 meters away from houses (Odell and Knight 2001). These effects may continue for several decades (Hansen et al. 2005). Clustered housing developments have been suggested as an alternative (Theobald et al. 1997; Mitchell et al. 2000; Odell and Knight 2001; Odell et al. 2003), yet to date, no study has examined their conservation value.

Ranch and farmlands being converted to exurban housing developments are disproportionately important habitat for wildlife, as these lands are more productive and well-watered than protected lands (Scott et al. 2000). In fact wildlife populations in protected areas may be sustained by source populations on adjacent privately owned lands (Hansen and Rotella 2002).

Conservation biologists recognize that human development has serious implications for biodiversity (Wilcove et al. 1998; Czech et al. 2000; Marzluff et al. 2001) and that our research needs to encompass the private lands where we live (Knight 1999; Miller and Hobbs 2002; Hilty and Merenlender 2003). There is no reason to think growth trends in the West will diminish. It is therefore crucial that we understand the impacts of our current growth patterns in order to make the future trajectory of development more accommodating of natural communities.

Study Area and Methods

Boulder, Colorado lies at the interface between the Great Plains and the Rocky Mountains (lat. 40°00'54"N, long. 105°16'12"W). The city of Boulder is surrounded by an extensive belt of open space comprised of grasslands, farms, ranches, and exurban development. A Non-Urban Planned Unit Development process has been in place for over a decade, which provides an alternative to the typical 14 hectare division of land. If house lots are restricted to 25% of the land to be developed, and an outlot protected from development is created on the remaining 75% of the total area, the developer is allowed twice the number of houses while still granted exemption from the county subdivision process. Boulder County has more clustered housing developments than any other county in Colorado.

Our study sites were all restricted to one general soil type, a Nederland-Valmont association (USDA 1975). We chose this soil type because it is cobbly, for the most part has never been plowed, and is still largely characterized by natural vegetation. We selected all 6 of the clustered housing developments in this soil type that were not used for row crop agriculture or irrigated hay meadows. These developments raged from 35.5

hectares to 292 hectares, with an average size of 92 hectares. We then selected 6 contiguous areas of dispersed housing development (made up of parcels ranging from 2 to 16 hectares) with total areas ranging from 32 hectares to 121 hectares, with an average area of 65 hectares. Both the clustered and dispersed housing developments had an average of 9.75 hectares per house, differing in pattern of development, but not density. Lastly we chose 6 undeveloped areas made up of City and County of Boulder Open Space and U.S. Department of Commerce properties. These sites ranged from 216 hectares to 1379 hectares, averaging 480 hectares. Most of the undeveloped sites allow public access along trails, allow dogs on leash or under voice command, and permit some seasonal grazing. All 18 study sites were similar in elevation, ranging from 1550 meters to 1900 meters, and were in a mixed-grass prairie ecosystem. For each field season we randomly located 6 evenly distributed transects in each of the 18 study sites. Transects were 200 meters long, at least 200 meters apart, and at a 45° angle from roads and fence lines. All transects were located >50 meters from houses, roads, trails, riparian areas, and edges.

Bird Sampling

We surveyed birds along each of the 108 transects once during each of the breeding seasons (mid-May to the end of June) in 2003 and 2004. We used Distance sampling (Buckland et al. 1993) which provides estimates of bird densities without assuming that all birds present during the sampling are detected. We recorded all bird species seen or heard along the transect, and estimated their distance to the nearest meter, calibrated with a laser rangefinder (Bushnell Corporation, Overland Park, KS). We also measured the sighting angle from our transect line with a large protractor. These detectability-based density estimates are more reliable than traditional index counts (Rosenstock et al. 2002). Sampling occurred between sunrise and approximately 2 hours after sunrise, and was not conducted in inclement weather.

Nest Survivorship

We located nests by dragging a rope (between two observers) over the grasslands in order to flush adult birds off of their nests (Miller et al. 1998). We then located the nests, and marked them with a flag placed about 20 meters away in one of the four cardinal directions (to avoid cueing any predators to nest locations). We visited each nest every 2-5 days until fledging, or the nest failed, and recorded the fate of each nest. We performed searches on a rotation of sites until an equal number of hectares had been searched in each of the three land uses.

Mammal Surveys

Detection frequencies of mammals were determined using scent stations established at a random point along three of the six transects in each site. At each station we sprayed a $1m^2$ metal plate with a solution of 100% ethanol and unscented talcum powder, so that as the ethanol evaporated only a thin film of powder was left on the plate (Zielinski 1995). We secured a sponge to the center of the plate, and poured a liquid lure (Carmen's Pro's Choice, Sterling Trap and Fur, Sterling, OH) over the sponge to attract mammals. Each station was operated for one night during the first field season, for three consecutive days and nights during the first round of the second field season, and along three new transects at each site for one additional night during the second round of the second field season. We identified and recorded tracks daily (Halfpenny 2001), and we replenished lure as necessary.

Vegetation Surveys

We conducted plant surveys during July of 2003. We randomly located a $1 m^2$ plot along three transects in each site. We identified and recorded all species within the plot. We estimated canopy coverage of individual plant species, as well as percentages of rock, litter and bare ground to the nearest percent within each plot. We identified all species as native or non-native to Colorado.

Statistical Analyses

We used program DISTANCE (Thomas et al. 1998) to generate bird density estimates (birds/ha) in each land use category. We modeled each species' detection function, based on exact distance values, using the robust models suggested by Buckland et al. (2001). We selected the best model using Akaike's information criterion (AIC), and by inspecting probability density functions and χ^2 goodness of fit statistics (Buckland et al. 1993). We obtained density estimates for each bird species in each land use by re-running the best model and stratifying by land use. We performed pairwise comparisons of density estimates across the three landuse categories using the z test (Ott and Longnecker, 2001). Densities were considered significantly different at $\alpha = 0.1$, divided by 3 to equal an α' of 0.03, which is Bonferroni adjusted for three pairwise comparisons (we established an α of 0.1 *a priori* for all analyses to avoid committing a type II error).

We calculated nest density for each land use based on the mean number of nests located per hectare searched in each of the 6 sites included in that land use category. To test whether the density of nests varied by land use we conducted an analysis of variance (PROC GLM, SAS Institute). Only when the overall F-test was significant ($p<0.1$) were pairwise comparisons made using the least-significant-difference method (Ott and Longnecker, 2001). .

We used Stanley's (2004) model to estimate stage-specific (i.e. incubation stage, nestling stage) daily survival probabilities for all nests. The Stanley (2004) model, like the Mayfield (1975) method, avoids the positive bias of apparent nest success by estimating daily survival rates using the number of exposure days. The Stanley method goes a step further, by allowing for calculation of stage-specific daily survival rates when transition and failure dates are unknown. We used AIC selection to evaluate competing models of nest survivorship.

We used the data collected from scent stations to estimate the proportion of stations visited by each mammal within each land use. We used Fisher's Exact Test (PROC FREQ, SAS Institute) to test for significant differences among detection frequencies. If the overall test was statistically significant ($p<0.10$), we also used Fisher's Exact test to conduct pairwise comparisons of proportions. We calculated standard errors for the proportions based on the normal approximation to the binomial (Ott and Longnecker, 2001).

We used plant survey data to compare species richness and percent cover for both native and non-native plant species across land use. We tested to see whether native and non-native plant cover varied by land use using an analysis of variance (PROC GLM, SAS Institute), based on an n of 6 sites per land use. When the overall F-test was significant ($p<0.10$), a least-significant-difference means comparison was conducted. Non-native cover was arcsin square root transformed to stabilize variance, while the variance of native cover was more homogeneous without transformation. Both sets of means and errors are presented in the original scale.

Results

Bird Communities

We had a total of 2,179 detections of 57 different bird species over two field seasons. We detected 20 species in dispersed developments, 34 in clustered developments, and 13 in undeveloped areas. Seven species reached significantly higher densities in either dispersed or clustered housing developments when compared to undeveloped areas ($z \geq 2.17$, $p \leq .03$ for all comparisons) (Figure 1). Four species reached significantly higher densities in undeveloped areas ($z \geq 2.47$, $p \leq .02$ for all comparisons) (Figure 2).

We monitored a total of 126 nests over two field seasons. Twenty nests were located in dispersed housing developments, 18 in clustered housing developments and 88 in undeveloped areas. We searched an equal area in each land use, and the density of nests located in undeveloped areas was significantly higher than the density of nests in dispersed or undeveloped areas ($F=19.94$, $p<.0001$) (Figure 3).

We used AIC selection to evaluate competing models of nest survivorship. The best overall model we selected used three nuisance parameters (g23, g24, and g25) and treated daily survival probabilities as equal for all nesting stages ($p0=p1=p2$). This model carried 53% of the AIC weight. We then compared the best overall model to a set of models treating land use separately. The model selected was the one that pooled all three land uses. This model carried 98% of the weight. We therefore considered nest survivorship statistically similar across dispersed, clustered and undeveloped areas. We estimated daily survival probability for all stages and all land uses to be 0.9559 (s.e.m.= 0.006). It should be noted that although nest success did not significantly vary by land use, dispersed and clustered housing developments combined contributed only 30% of the successful nests, while undeveloped areas contributed 70% of the successful nests.

Mammal Communities

We detected domestic dogs and cats, coyotes, red foxes, striped skunks, cows, horses, prairie dogs, rabbits, deer, and field mice at scent stations over the two seasons of sampling (Figure 4). Domestic cats, rabbits, and deer were not detected enough to conduct statistical analyses. We detected domestic dogs more frequently on dispersed and clustered housing developments than undeveloped areas ($\chi^2 \geq 7.49$, $p \leq 0.01$). Detections of red fox, skunk, cow, and prairie dog were higher in dispersed and clustered housing developments than in undeveloped areas, but did not differ statistically. Field mice were detected most frequently in undeveloped areas ($\chi^2 = 5.38$, $p = .093$). Coyotes were more frequently detected in clustered housing developments and undeveloped areas, but this difference was not statistically significant.

Plant Communities

We identified 112 plant species among the three land uses, 39 of which were non-native. Cumulatively, undeveloped areas had 12 more native species than were detected on either dispersed or clustered housing developments, while all three land uses had nearly equal numbers of non-native species (Figure 5). Mean native species percent cover was significantly higher in undeveloped areas ($F = 8.65$, $p = .0032$), and mean non-native species cover was significantly higher in dispersed and clustered housing developments ($F = 6.83$, $p = .0078$) (Figure 6).

Discussion

Our results indicate that the plant and wildlife species composition of clustered housing developments is more similar to that of dispersed housing developments than to undeveloped areas. Dispersed and clustered housing developments were characterized by higher densities of non-native and human commensal species and lower densities of native and human-sensitive species, than undeveloped areas. Other studies examining exurban developments have found similar trends (Odell and Knight 2001; Hansen and Rotella 2002; Maestas et al. 2003, Hansen et al. 2005), as have studies along the urban-rural gradient (Blair 1996; Donnelly and Marzluff 2004).

In the last few decades grassland bird species have experienced serious declines, throughout their ranges, due to habitat loss (Herkert et al. 2003). Western meadowlarks, vesper sparrows, grasshopper sparrows, and horned larks all occurred and nested in lowered densities in dispersed and clustered housing developments. To ensure the persistence of these species we must understand why our current patterns of development seem to be incompatible with their success.

One probable explanation is competition with, and predation by, generalist species. Many of the bird species who reached their highest densities in either dispersed or clustered housing developments are considered human commensal species and were likely attracted by additional resources associated with housing developments. Bird feeders, fruiting trees, flowering shrubs, human garbage, and houses themselves offer enhanced vertical structure, food resources, and nesting sites otherwise unavailable in grasslands. When present, these larger human commensal species can usually outcompete native birds for nest sites and food resources (Blair 1996; McKinney 2002).

Another important factor is the degradation of the native plant community. Recent studies have demonstrated a strong link between grassland bird communities and vegetation composition and structure (Fletcher and Koford 2002; Giuliano and Daves 2002). A recent study in urbanizing Ohio found that nests in exotic shrubs were twice as likely to be depredated as nests in native substrates (Borgmann and Rodewald 2004). Human activities often promote non-native plants. Many landowners have planted non-native pasture grasses, and have horses or livestock grazing in small pastures that may change the plant composition. Roads, which inevitably come along with humans, often act as conduits of exotic species (Trombulak and Frissel, 2000). Native grassland nesting birds may have been present and nested in lower densities in dispersed and clustered housing developments because plant cover was largely non-native in these areas.

Yet another explanation is that human disturbance led to lower densities of native grassland birds and their nests. Gutzwiller et al. (1994) found that a single pedestrian moving through a bird's territory was enough to make the bird stop singing. It seems likely that the frequent presence of humans in an area could result in fewer birds establishing nesting territories (Gutzwiller et al. 1997).

Although we did not detect reduced nest survivorship in dispersed and clustered housing developments, there were fewer nests in those areas than in undeveloped areas. Subsidized predators, like domestic cats and dogs, are known to extend the realm of human influence, and can have a negative impact on wildlife communities (Coleman and Temple 1996; Crooks and Soulé 1999; Miller et al. 2001; Odell and Knight 2001). Dogs were detected frequently in dispersed and clustered housing developments, and were not detected at all in undeveloped areas even though there access is largely permitted. Cat detections were extremely low, even though we regularly saw cats near the houses on our study sites. Crooks and Soulé (1999) found that house cats stayed very close to their homes when coyotes were present. Though coyote detections were also very low, we did observe coyotes on several sites.

Conservation Implications

Today we still face what Leopold called "…the oldest task in human history: to live on a piece of land without spoiling it" (Leopold 1991). There is little disagreement that dispersed, large-lot development does not accomplish this goal. Clustered housing developments are a logical alternative: landowners pool their open space into a larger area that all can enjoy. Unfortunately, the protection of plant and wildlife communities does not automatically accompany this open space.

The clustered developments we studied were not designed to conserve plant and wildlife habitat, and to meet these goals we may need more rigorous ecological guidelines. Clustering homes closer together and away from ecologically sensitive areas, keeping open space contiguous, minimizing road density, and enhancing stewardship practices could all potentially result in clustered developments with higher conservation value.

Clustering might also be more effective if implemented on a larger scale. Clustered housing developments offer a great opportunity to create an interconnected network of protected lands (Arendt 1996, 2003). If each clustered housing development contributed a meaningful portion of open space to a larger protected area, the benefits to plant and wildlife communities could perhaps be synergistic.

Private lands in the West have enormous potential to help conserve our natural heritage. It is essential that land use planners and ecologists work together to design human communities which protect, rather than harm, the natural communities upon which our health and happiness depend.

Acknowledgements

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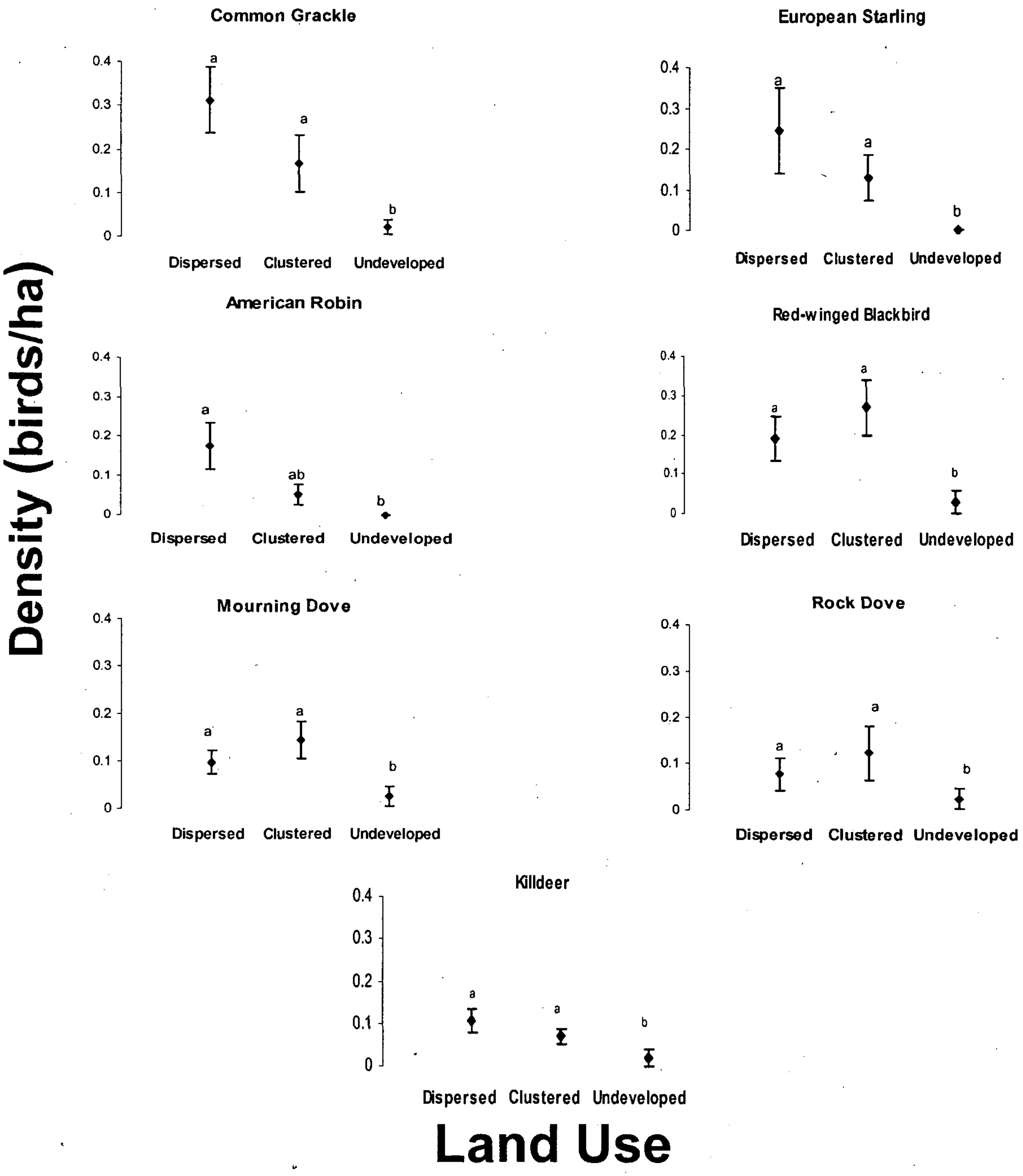

Figure 1. Densities (+/- one standard error of the mean) of bird species that reached their highest densities on either dispersed or clustered housing developments. Different letters above error bars indicate a statistically significant difference at the 0.10 level.

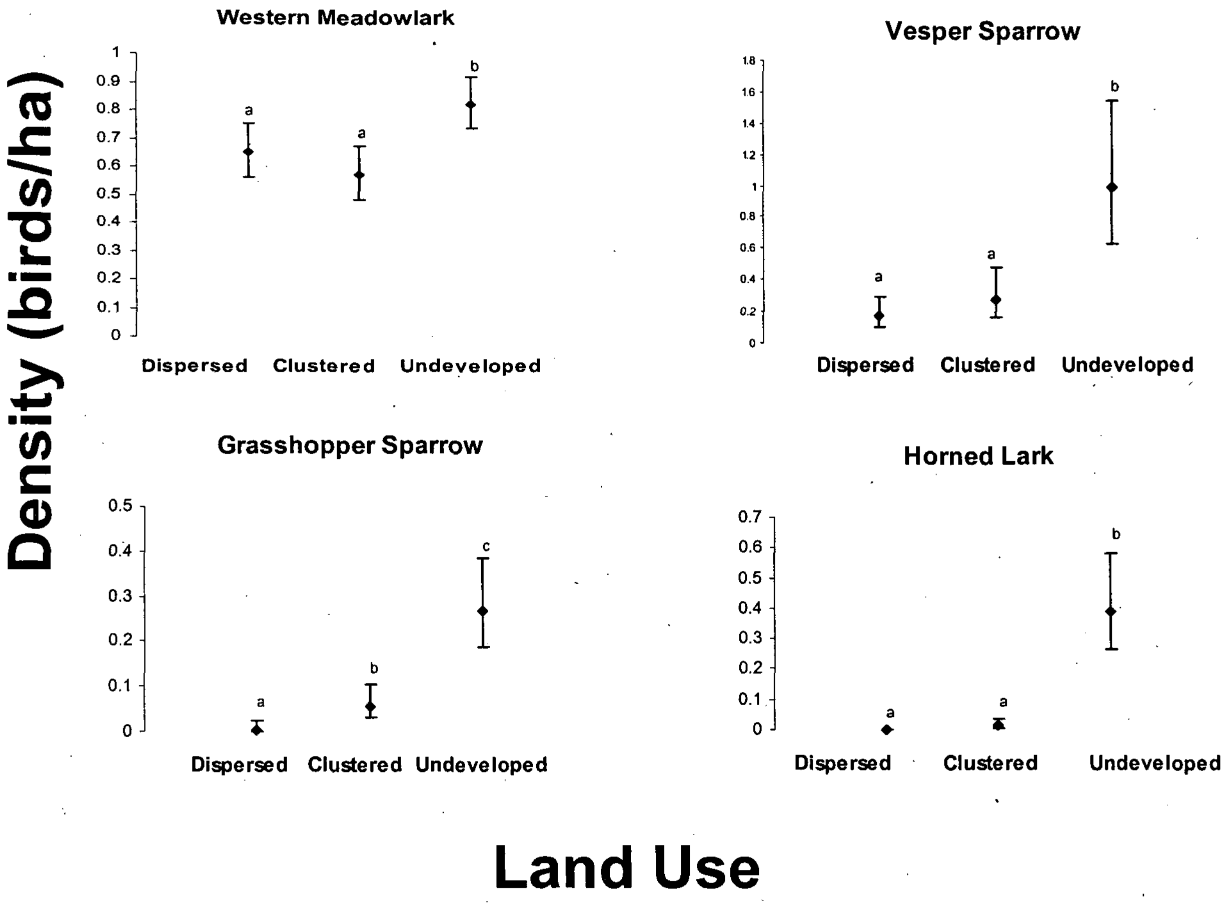

Figure 2. Densities (+/- one standard error of the mean) of bird species that reached their highest densities in undeveloped areas. Different letters above error bars indicate a statistically significant difference at the 0.10 level.

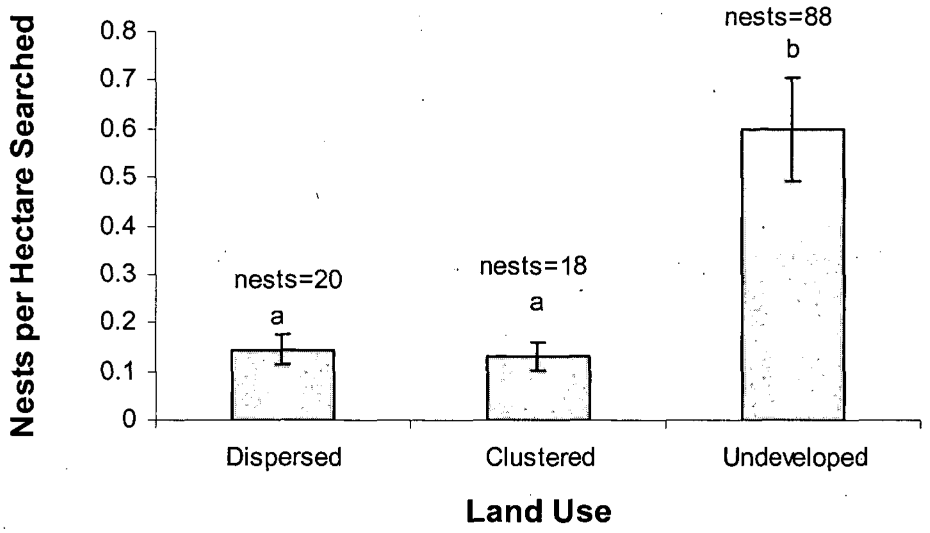

Figure 3. Density (+/- one standard error of the mean) of nests located per hectare searched in each land use. Different letters above error bars indicate a statistically significant difference determined using an F-protected LSD (0.05) method in ANOVA based on a square root transformation of the data to stabilize variance. The means and standard errors are presented in the original scale.

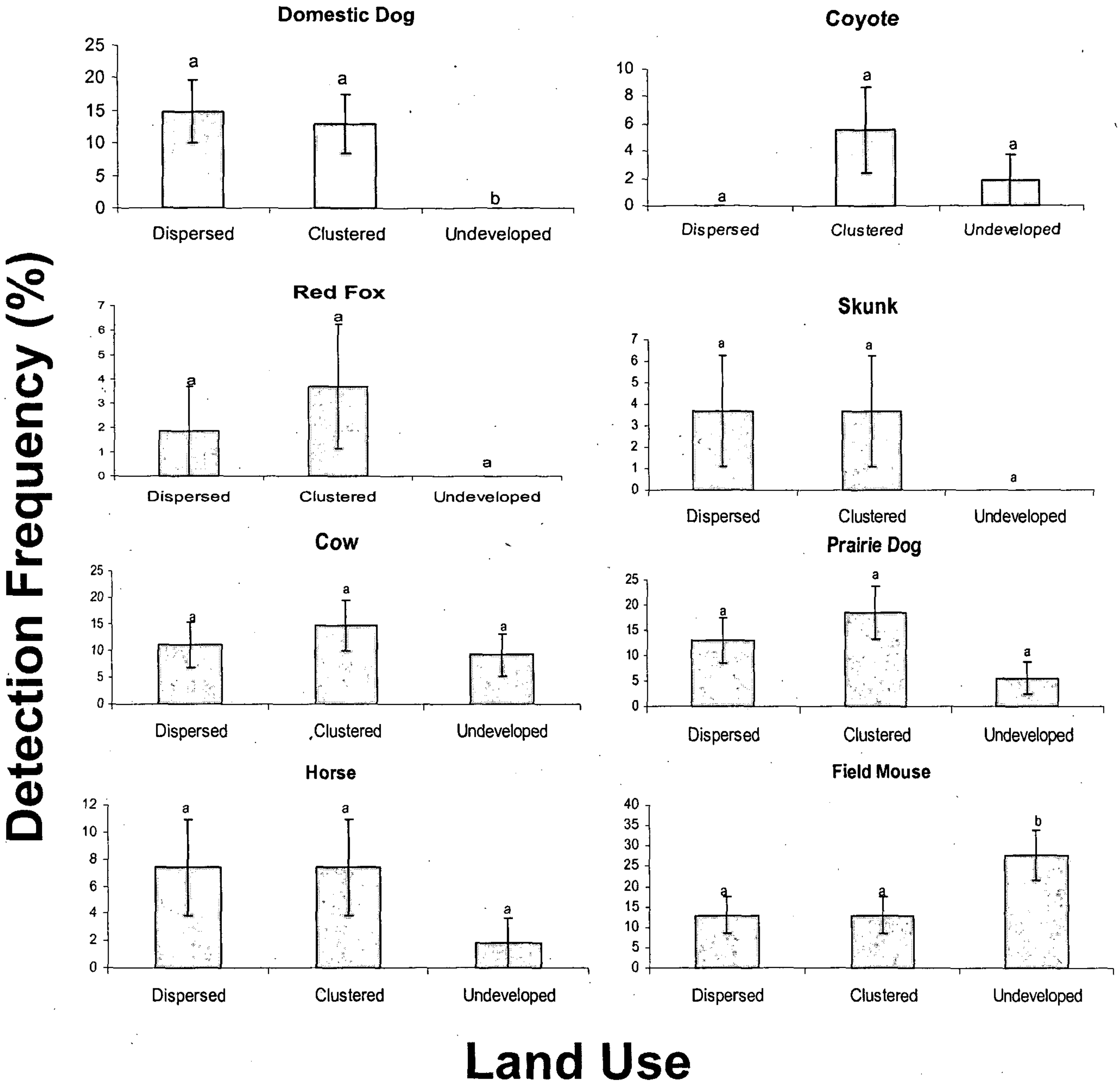

Figure 4. Frequencies (+/- one standard error of the mean) of mammal detections at scent stations. Different letters above error bars indicate a statistically significant difference at α=0.05.

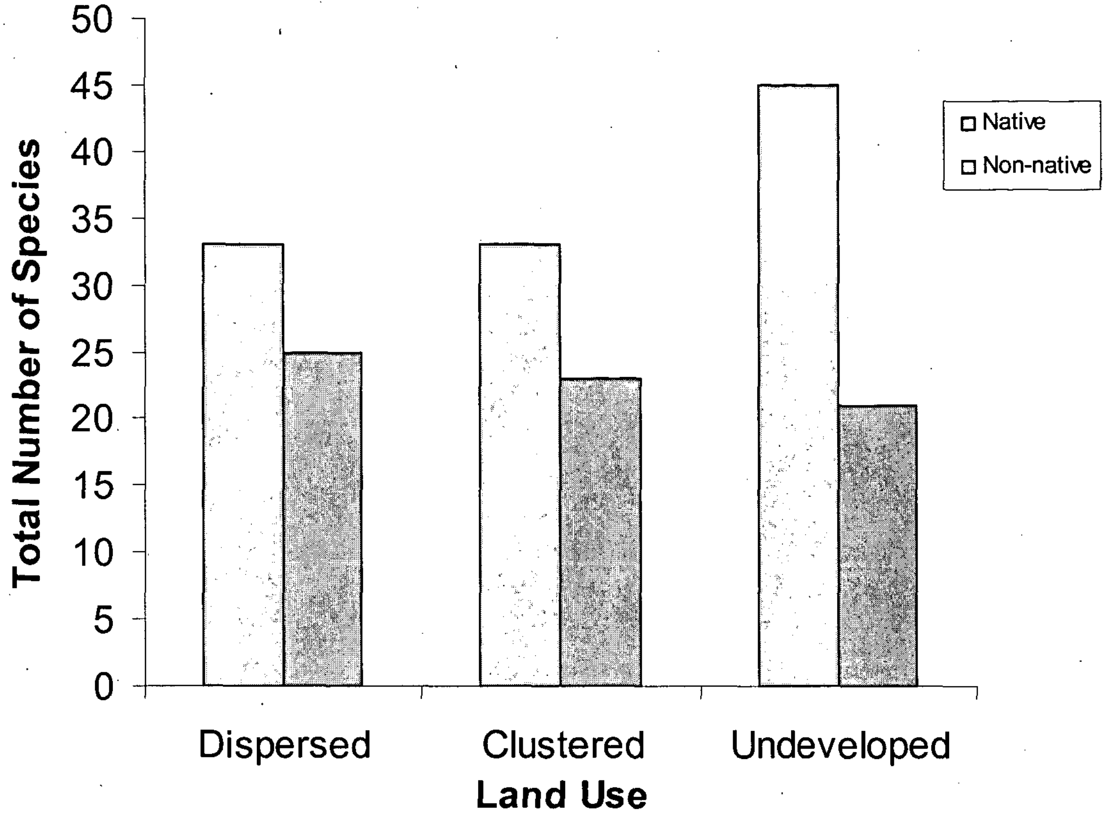

Figure 5. Total number of native and non-native plant species by land use.

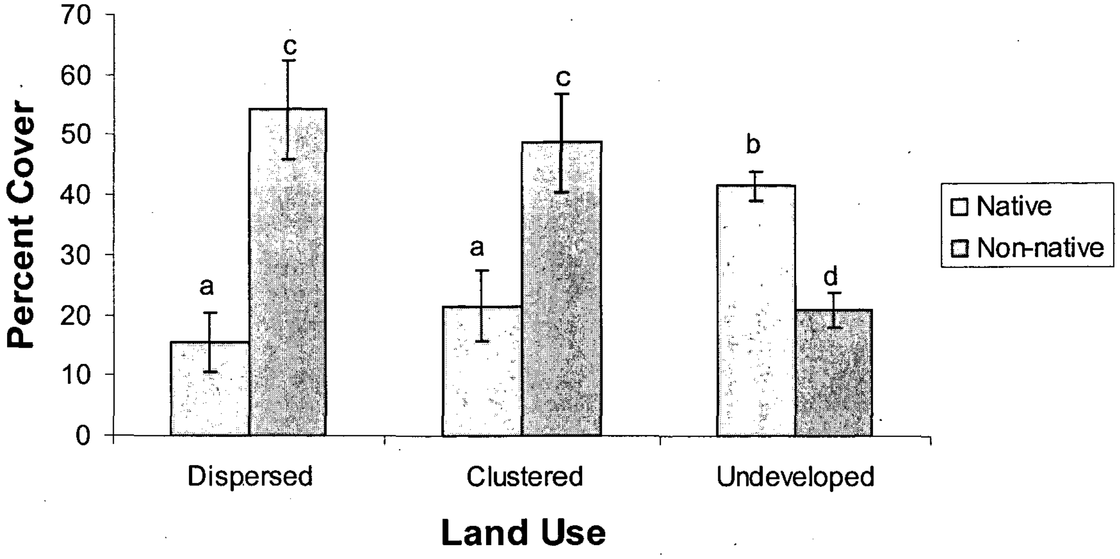

Figure 6. Percent cover, plus or minus one standard error of the mean, of native and non-native plant species on dispersed housing developments, clustered housing developments and undeveloped areas in Boulder County, CO. Different letters above error bars represent a statistically significant difference determined using an F-protected LSD (0.05) method in ANOVA. Non-native cover was arcsin square root transformed to stabilize variance. The variance of native cover was more homogeneous without transformation. Both sets of means and errors are presented in the original scale.

Hastings

Conservation Value of Clustered Housing Developments

Rural counties in the American West are growing at unprecedented rates. Traditionally exurban lands in Colorado have been subdivided into a grid of parcels ranging from 2 to 16 hectares. This dispersed pattern of development effectively maximizes the individual influence of each home on the land. Clustered housing developments, designed to maximize open space and minimize edges with development, are assumed to benefit plant and wildlife communities. They have become a popular new alternative for land use planners despite the lack of empirical evidence demonstrating their benefit. Our study examines the conservation value of clustered housing developments, dispersed housing developments, and undeveloped areas in Boulder County, CO using four indicators: 1)densities of human-commensal and human-sensitive songbirds, 2)nest survivorship of ground-nesting birds 3)occurrence of mammalian mesopredators, and 4)percent cover and proportion of native plant species. The initial patterns we observed across clustered developments, dispersed developments, and undeveloped areas indicate that the biodiversity attributes of clustered housing developments are more similar to those of dispersed housing developments than to those of undeveloped areas. While clustering development may provide an advantage to some sensitive species, it may not be as effective as previously assumed.

(Please see project proposal for more background information)

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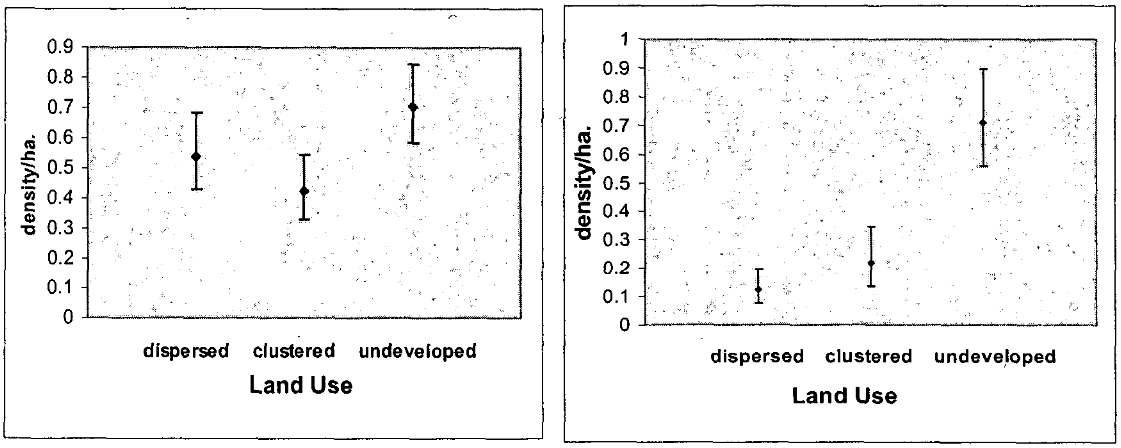
Preliminary Results

Avian Communities

I am currently using program Distance 4.1 to estimate bird densities (birds/ha) for species that have reliable detection functions. I have selected models for detection functions by using Akaike's information criterion (AIC) and by inspecting probability density functions and chi-square goodness of fit statistics. Figure 1 shows preliminary density estimates for the Western Meadowlark, Vesper Sparrow and Grasshopper Sparrow across three land uses.



Western Meadowlark

Vesper Sparrow

Grasshopper Sparrow

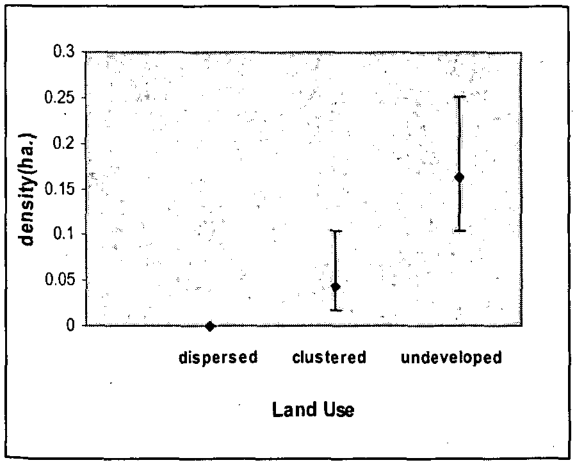


Figure 1. Densities plus 90% confidence intervals of bird species across dispersed housing developments, clustered housing developments, and undeveloped areas.

Plant Communities

We identified 109 plant species among the three types of land use, 39 of which were non-native species. Cumulatively, land in dispersed development, clustered development, and undeveloped areas had roughly equal numbers of non-native species (Figure 2), but non-native cover was much higher in dispersed developments and clustered developments than in undeveloped areas.

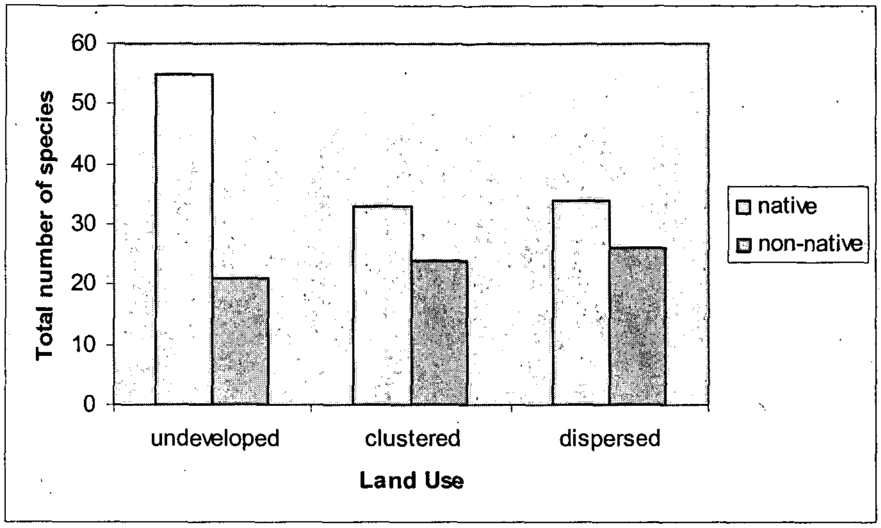


Figure 2. Cumulative number of native and non-native plant species by land use. The same number of microplots (n=144) were sampled in each land use.

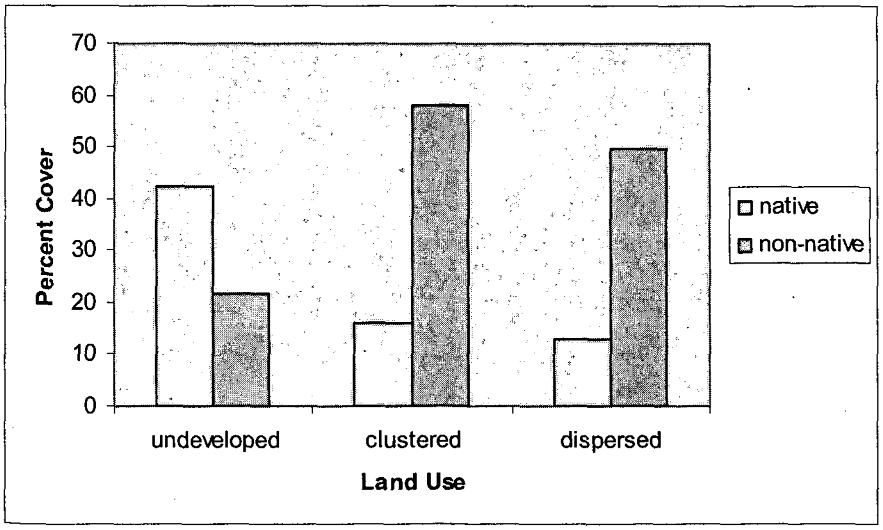


Figure 3. Percent cover of native and non-native plant species by land use.