Effect of Urban Sprawl on the Diversity of Bird Species in Bay Area Parks

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Abstract Population growth in the San Francisco Bay Area has led to significant urban sprawl. Although habitat destruction has been quantified in the past, the mechanisms through which biodiversity is influenced by different levels of urbanization and how such effects can be quantified and analyzed have been largely unexplored. The effects of three different levels of urbanization associated with urban sprawl (urban, suburban and rural) on avifaunal diversity were examined using three different methods of analysis. Nine parks were selected, three for each level, based on adjacent human population density. Data were collected in the spring, when each site was visited for three two-hour sessions. Methods of data analysis used were: (1) a diversity index and richness value for each park (2) a ratio of generalist species to specialist species present in each park and (3) a diversity index for three regions within each park (the edge, the interior and areas near human disturbance). These methods were employed to determine diversity and special differences based on level of urbanization and region within each park. A significant difference was found between urban/suburban and rural park diversity indices, however no difference in richness was found between parks. A positive correlation was found between the generalist to specialist ratio and adjacent human population density, demonstrating a significant increase in generalist species with increases in population. Differences in diversity were found between park regions, showing urban parks have higher diversity at their edges, and a higher number of generalists near human disturbance, than rural parks.

Introduction

As cities become excessively overcrowded, development begins to spill outward in a pattern known as urban sprawl. The growth of the city within its boundaries already destroys essential habitat for a number of animals, which must then adapt, seek refuge in the surrounding areas, or die. Furthermore, if the surrounding areas are undergoing habitat degradation as well due to urban sprawl, survival options become even more limited (Marzluff 2001). One option for local wildlife is to continue to move outward, as suburban cities develop into urban ones (Blair 1996). Should this be the case, an upsurge in density of wildlife as the human population density decreases would result, following the pattern of urban sprawl, on a radial line outward from the city center. This study examines this assumption's accuracy by testing whether or not this relationship is indeed occurring in the San Francisco Bay Area, California, and to evaluate the efficacy of chosen methods to detect diversity changes in the field.

Urban sprawl is ever-present and increasing in almost every major city in the country. Evaluating any detrimental effect the process has on a community's endemic wildlife may help eventually limit such a growth pattern and assist in implementing policies for regions not yet encroached upon by urban development. Where biologists once worked on ways to evaluate habitat destruction in cities (Gavareski 1976, Janzen 1983, Barrett *et al.* 1994), now the job has become that of the urban planners (Tilghman 1987, Cicero 1988, Lim and Sodhi 2003). The two dissimilar occupations have built a large information base regarding the remaining habitat patches within the human matrix, which will ultimately help create healthier communities for both development and wildlife (Alberti *et al.* 2001). Unfortunately, few studies of this kind have focused on the San Francisco Bay Area, and these studies exhibit a lack of power in analysis methodology. Therefore, what is required at this time is both an accurate assessment of the effect of urban sprawl and a potent study method.

The Bay Area in Northern California is one of the best places in the United States to study urban sprawl. Human population density varies as a function of the distance from the city of San Francisco (Figure 1), generally decreasing in density as one moves away from the city center.

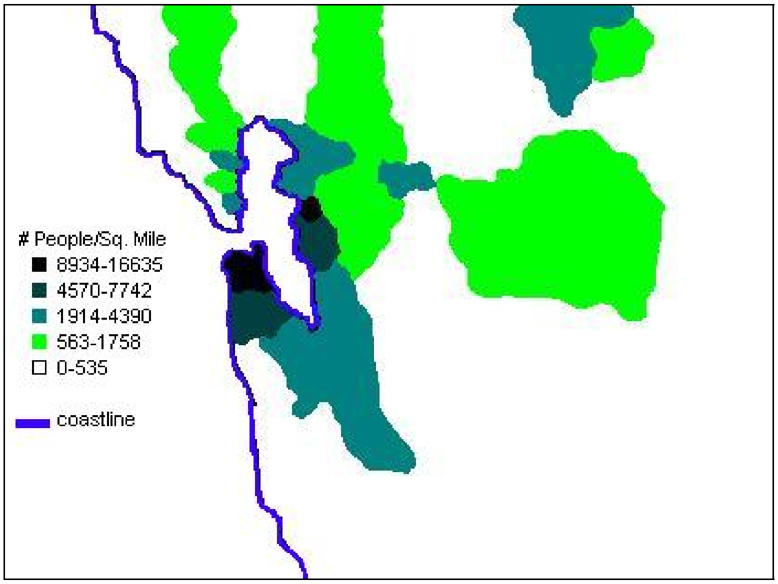

Figure 1: Human population density in the San Francisco Bay Area. Values were obtained from the US Census Bureau's Census 2000 data.

With the Pacific Ocean to the west, there exists a gradual decline in population outward from the city far to the north, south and east, as cities and suburbs spill out into surrounding rural areas. Many local communities support conservation, and there are a variety of nature areas and parks in these areas, each one adjacent to a varying degree of human population density. These parks become ideal locations to perform population analyses, because they are quite similar in climate, vegetation and available recreation, yet differ in their proximity to urbanization and, not coincidentally, in degree of anthropogenic disturbance (Janzen 1983).

Birds were chosen as a measure of wildlife diversity within the chosen ecosystems. Birds are a much utilized indicator phylum in urban studies (Beissinger & Osborne 1982, Tomialojc 1998, Fernandez-Juracic 2000, Marzluff 2001, Lim and Sodhi 2003), primarily due to the ease of data collection, though additional knowledge about these animals makes them ideal study subjects. They are wild animals about which much is known, including habitat requirements, migratory patterns and identification techniques (Cramp 1992, Stokes and Stokes 1996).

Three measurement methods of measuring were employed to quantify the abundance and richness of bird species in nine Bay Area parks (Figure 2) each differing in level of urbanization. The parks chosen, and their specific urbanization categories based on adjacent

HPD, are as follows: Golden Gate Park, San Francisco (urban), Lake Merritt, Oakland (urban), Strawberry Creek Fire Trail, Berkeley (urban), Joaquin Miller Regional Park, Alameda County (suburban), Castle Rock Regional Park, Walnut Creek (suburban), Pt. Pinole Regional Shoreline, Richmond (suburban), Coyote Hills Regional Park, Fremont (rural), Mt. Diablo Black Diamond Trail, Clayton (rural) and Morgan Territory Regional Park, Contra Costa County (rural).

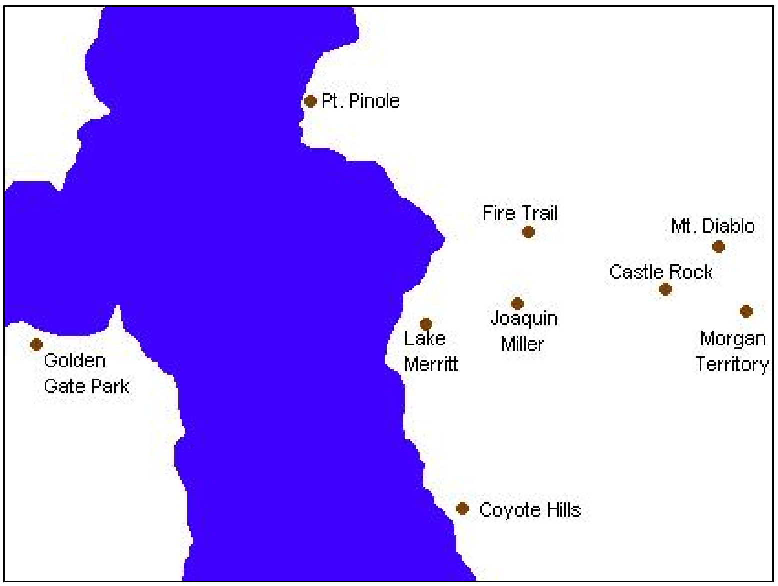

Figure 2: Site locations in the San Francisco Bay Area; map is approximate, not to scale.

Any significant changes in species diversity detected between parks could be used to support theoretical conclusions on the effect of urban sprawl on local wildlife. In addition, if one method or combination of methods proves to be a superior approach, such information could be used when monitoring park diversity in the future.

Methods

Nine sites were selected based on their location with respect to approximate human population density (HPD). Sites were grouped according to adjacency to a number of people per unit area, a value obtained from 2000 census data (Figure 1). Of the nine sites, all of which were local Bay Area parks, three were classified as urban (4500-16700 people per square mile), three as suburban (600-4500 people per square mile) and three as rural (0-600 people per square mile). Selection of population range per category was relative.

Estimates of minimum number of visits necessary to adequately sample bird populations were based on the work of Dr. Fernandez-Juricic (2000) on avifaunal richness in urban parks in Madrid, Spain, all comparable in size and Mediterranean climate with the sites chosen in the present study. He estimates that 3 to 4 visits per site, at a few hours per visit, is enough to sample avifaunal diversity with 95% confidence. Each visit was conducted from 9am to 11am, and each park was visited 3 times for the purpose of data collection. For each survey, a number of species seen vs. time graph was constructed. When enough time passes that the number of species seen begins to level off, it can be concluded with a high degree of certainty that a majority of the species in the area have been observed, ensuring defendable diversity values. The time at which the leveling-off occurred would be the time when further effort would have yielded negligible result, as in a traditional species-accumulation curve. Data shown in these graphs is consistent with adequate observation time.

Species counts were performed during a 2-hour hike through the study area. Hike locations and paths were randomly selected prior to each visit. Each location's aquatic and terrestrial habitats were surveyed in comparable proportions wherever possible. The recorded variables are: species common name, number of that species seen, location of observation (edge, near human activity, or interior) and time of observation.

Statistical Analyses Three different methods of analysis was performed on the data gathered throughout the course of the study:

- Shannon-Wiener Index for Species Diversity
- A Generalist to Specialist Ratio
- Fragmentation "Park" Effect on Diversity

A challenge exists when doing a flat-out analysis of diversity for a site, due to the known adaptability of birds. Therefore, three methods of analysis were chosen. Although some species can acclimate well to anthropogenic disturbance, such as Rock Doves and Fox Sparrows (Rolando *et al.* 1997), many others cannot, due to their species-specific needs. Thus in urban parks and edge areas, there is an abundance of "habituated" birds (Blair 1996) and a decline in species with specific needs (Fernandez-Juricic 2000). If information can be adequately amalgamated, grouping the habituated and the needy, a more reliable value for the diversity of the system can be elucidated. Moreover, if differing values of diversity are seen within the parks, as from edge to interior, those values can be separated as well to better understand any simultaneous HPD and fragmentation effects.

The Shannon-Wiener Index is a simple method for calculating a single value for the species diversity in a given system (Cicero 1988, Molles 1999). The number of species and observed members of that species (richness and abundance) are used to calculate a proportion (p) of the total abundance the particular species comprises. The natural log of the proportion is taken and then multiplied by the proportion to determine an H' value. The H' value for each species is then totaled to make an H' value for the entire community:

$$H'_{community} = -\sum p \log_e p$$

A high H' value indicates a high level of diversity for the system. The H' values for each site can be compared and a detectable difference between sites would reveal a difference in diversity by location. The individual richness values for each site will also be compared. It was hypothesized that significantly higher diversity would be observed in non-urban areas.

Species themselves can be classified by their habitat requirements, such as food and nesting activities that necessitate specific circumstances and availability of resources. A two-letter symbol is given to each species, the first letter denotes their foraging habitat, and the second their nesting habitat. This system groups each species found in the area into a unique guild (Fernandez-Juricic 2000, Lim and Sodhi 2003). For each location visit, the species seen were given a two-letter guild. Each letter is different and represents a species-specific need, such as C for "tree cavity" and S for "scavenger". Each letter was put into either the generalist or specialist category based on the following criteria: specific requirements, such as tree cavity nesting, were considered *specialist*, while more general requirements, such as scavenging, were considered *generalist* through an ability to adapt to numerous habitat situations (EPA 2000). For a species to be considered a generalist, it must display both foraging and nesting requirements in the generalist category. On the other hand, for a species to be considered a specialist, any and/or all of its needs must be in the specialist category.

If an area has more generalists, which are considered "habituated" to human activity (Blair 1996), than specialists, it would have a higher generalist to specialist ratio. It was hypothesized that a higher ratio frequently would be observed in more densely populated areas. The ratio values were then used in site comparisons to test for a detectable difference and correlate that difference with HPD.

During data collection, the area where the species was seen was recorded as: edge, interior, and proximity to human activity. The calculated H' values and generalist/specialist ratios for species seen at each location within the park were used to evaluate diversity based on inter-park placement. This analysis was used to counter the "park effect". Using parks as study sites, with the exception being adjacency to urbanization, has flaws. It has been suggested that these areas may impact species diversity (Gavareski 1976, Fernandez-Juricic 2001). For example, perhaps Golden Gate Park, being one of the only refuges for birds in that area, has high species diversity within it simply because of the solace it provides. In this way, any diversity value would not be representative of the value of urbanized areas. There could be no birds anywhere *but* there. By breaking down the park into the aforementioned components, the effects of anthropogenic disturbance on diversity may be understood more clearly than by measuring a single diversity value for the park. Diversity indices and ratio values along the edge, interior and human-disturbed areas were compared for each site and level of urbanization category (rural, suburban and urban).

Results

Diversity indices (Shannon-Wiener H' values) did not differ by site (ANOVA, $p>0.800$) or level of urbanization (Figure 4). There was no significant relationship between H' value and adjacent human population density ($r^2=0.008$, $p>0.704$). However, because the H' values per site category were not normally distributed, a non-parametric test was performed and it was found that the median H' value of urban and suburban parks was significantly greater than that of rural parks in the samples measured ($U=17$, $p<0.05$, Mann-Whitney U-test). No significant difference in species richness could be found between site categories (ANOVA, $p>0.112$).

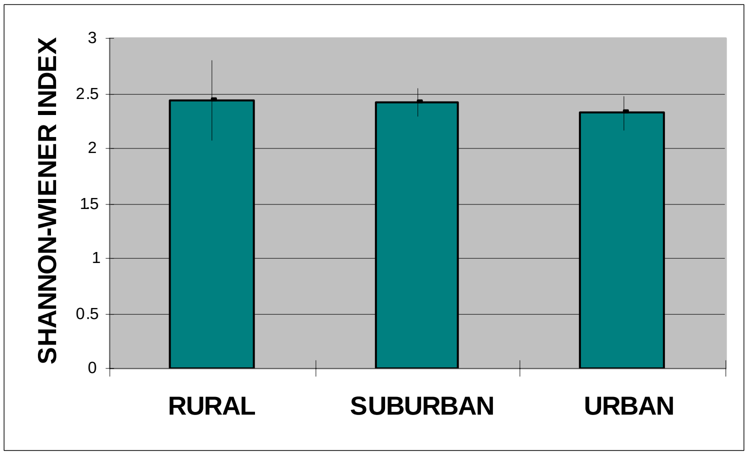

Figure 4: Mean H'value by site category (level of urbanization). Error bars indicate 2* the standard error. There is no significant difference between categories (ANOVA, p>0.676).

The generalist to specialist ratio was significantly different between sites (ANOVA p>0.007). It also showed a highly significant positive correlation with adjacent human population density (Figure 5), increasing with an increase in adjacent HPD.

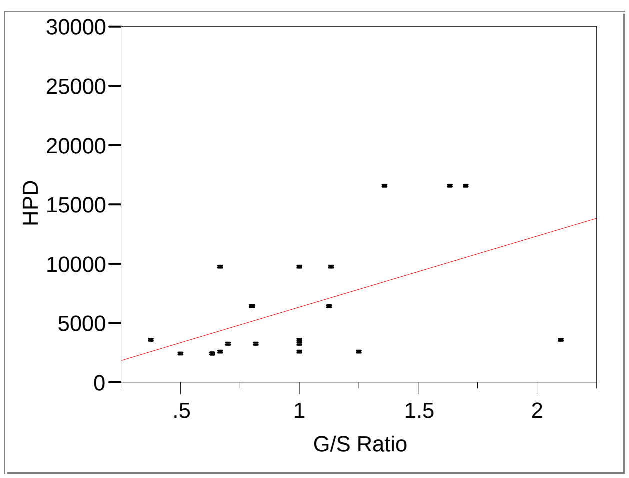

Figure 5: Generalist/Specialist Ratio by HPD (ppl/mi^2). A high ratio indicates more generalists than specialists in the community. There is a significant increase in the generalist/specialist ratio with increases in HPD (r^2=0.272, p>0.015).

Evaluation of the "park effect" on diversity indices showed the most significant difference was in the diversity at park edges between rural and urban sites. There was a higher diversity value in the edge areas of urban parks than at the edge of rural parks (ANOVA, $p > 0.011$). Analysis of the "park effect" on the generalist to specialist ratio showed the most significant difference was in the ratio near human disturbances between rural and urban sites. There was a higher ratio value in areas near human disturbance in urban parks than in rural parks (ANOVA, $p > 0.019$). The fragmentation analysis shows that there are more generalists near human disturbance and a greater diversity in the edge regions of urban parks when compared with rural parks.

Discussion

There proved to be a significant difference in diversity indices between rural parks and suburban and urban parks when ranking the values and comparing medians. These results suggest that diversity increases with degree of urbanization. These results conflict with the hypothesis that diversity and urbanization are inversely related, but are commensurate with similar findings in other studies (Gavareski 1976, Beissinger & Osborne 1982). The H' value itself did not vary much each time it was evaluated, always being somewhere in the range of 1.9 to 2.9 and was only carried to four significant figures. It would require more data points for each park to diminish the size of the standard error enough that a difference could be found using a parametric evaluation.

Blair (1996) also used the Shannon-Wiener Index and found it insufficient to detect changes along an urban gradient because of contradictory patterns. The changes in the avian community extend beyond overall diversity to the special level, as natives are replaced in urbanized communities by successful synanthropic species (Tomialojc 1970), such as those species that are more widely distributed. Due in large part to this inadequacy of measurement, the generalist to specialist ratio became necessary to determine patterns along the urban gradient. Because it takes into account the species' themselves, the *quality* and *quantity* (Blair 1996), it can be a more effective indicator of changes that occur due to increasing levels of urbanization.

In the present study, the magnitude of the generalist to specialist ratio grew significantly higher as the human population density increased. The ratio is configured as a fraction for ease in data analysis. As the number of generalist species in the area is the numerator, this would mean that the number of generalist species increases more than the number of specialist species with increasing urbanization. Essentially, there are more generalist species where there are more people, an observation that has been confirmed in previous research on the subject (Beissinger & Osborne 1982, Blair 1996, Lim & Sodhi 2003). Because there are numerous generalist species inhabiting urban areas, it has little effect on the species diversity index, but a large effect on the avian community. This point is best noted in the inability to find a significant difference in species richness values. As the number of native species is reduced, the entire ecosystem changes, something difficult to monitor with the lack of formal records relating to original conditions or ecological history of the urban park areas.

Ecosystem change can best be seen in the analysis of the park effect on diversity and the generalist to specialist ratio. The ratio was significantly higher in areas near human disturbance in urban areas, but not in rural parks. Even though no difference was found between site categories, a difference was found inside the parks themselves. Again, there were more generalists where there are more people in urban areas. This may be due to the reliance on people for food that birds in urban areas experience (Blair 1996, Rolando *et al.* 1997). In rural parks, there tends to be a lot more space, unhindered habitat and food availability for all species; thus no increase was observed in generalists near areas humans frequent.

For this same reason, a greater diversity was seen at the edge of urban parks as opposed to the edge of rural parks. The edge of an urban park is where all the people, the trash cans, the sidewalks and the grassy lawns tend to be located. Each of these areas is a good place to find food in an urban environment (Fernandez-Juricic 2001). Many species, considered edge specialists (Campi & Nally 2001), have also found ways to utilize man-made structures, such as buildings, to meet nesting requirements (Gavareski 1976). The edges of rural parks barely qualify as *edges* because there is still habitat beyond those boundaries. Yet, all of the factors seen at the edge of urban parks also appear at the edge of rural parks (picnic grounds, trash cans, etc.), but there is still no greater diversity there than anywhere else in the park. This diversity may be due to the abundance of space and food offered the rural inhabitant.

Key differences were found between areas with varying degrees of urbanization; but alone, each result would have been lacking in much strength or explanation. It appears to be invaluable, when studying diversity along an urban gradient, to have more than one means of measurement, preferably a diversity value and others that are more species or spatial specific.

Almost all the parks in the study are state parks, so there is little fear of their development. However, nothing is certain pertaining to development at their edges. Judging by the rate of development lately experienced juxtapose to the rural sites, I would estimate all three will be considered suburban parks within the next ten years. The suburban sites are in more prevalent danger of becoming urban, as the east Bay suburbs are undergoing a population explosion, rife with commercial and residential development of open space. Ironically, the parks in the best shape for the future are urban parks. Along with this mass exodus from the city by its human population is an overwhelming concern by local community organizations to rehabilitate and maintain urban parks. One site is having culverts and concrete removed and more natural buildings and walkways installed, while another is quelling all out-cry for any new construction. However, people moving out of the city and/or keeping the parks intact does not make the native habitat return, so dramatic change in urban parks for the avifaunal community may be unlikely.

Although this study served to compare current methods of population assessment, much work is still warranted in this area. Time and monetary constrictions have minimized this effort to a "brief survey", yet differences were still found. If the scope of this study were expanded, there is an invaluable data set to be had, and one that could enlighten the community in its efforts to better regard the effect of urbanization on avifaunal diversity. Such a study could also influence policy so the best smart growth plans could be devised to save these diminishing resources. Urban sprawl has many unknown effects on avifaunal community structure, and future research in this area will no doubt explore these effects in more detail.

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Noise levels, for instance, negatively affect birdsâ€™ behavior and social communication, while the presence of green areas promotes bird diversity. The effects of urbanization could differ according with the level of urbanization, and our goal was to understand how bird species assemblages are related to urban features in an intermediate stage of urbanization (a city in Brazil with 2,470 inhabitants/kmÂ²).Â It was apparent that the railway stations bear a positive effect on the bird species assemblages, which can be sustained through proper environmental management planning inclusive of urban greening. View.Â Urban sprawl has taken over the wetlands along the lakes in the past decades, which places tremendous pressure on wetland ecosystems and, therefore, on bird communities. Urban sprawl refers to the migration of a population from populated towns and cities to low density residential development over more and more rural land. It is basically another word for urbanization. Lets take a look at various causes, effects and solutions to urban sprawl.Â New Urbanism is a vital principle that helps check the problem of urban sprawling to a great extent. As is said by Ball State University, â€œWhen the focus turns from the suburbs and toward the inner city, growth can happen without the pollution and landscape destruction that comes with sprawl,â€ and that is the philosophy of New Urbanism. It decreases pollution as well as protects the natural environment. 2. Imparting Proper Education. Migratory behavior in birds may affect spatial patterns in genetic diversity depending on where samples were taken, and whether they were sampled during the breeding season. Therefore, we also ran these models separately for non-migratory birds only (7 species, 129 sites; Table S1).Â The lack of consistent evidence for genetic effects of urbanization on birds could in part be due to differences in movement ability. Cities and their surrounding areas are characterized by disjoint patches of habitat interspersed among paved surfaces, buildings, and grassy or agricultural areas (26). Birdsâ€™ ability to fly may buffer against the effects of habitat fragmentation and allow for gene flow from undisturbed populations (27) in situations where mammal movements would be more restricted. Bird species incidence as a function of park area and distance. Conservation implications. Speculation: natal dispersal, landscape complementation, and supplementation.Â high species diversity because these protected areas are the habitat â€œfragmentsâ€ of highly diverse ecosystems (Schaefer 1994). Increasing urbanization adjacent to natural areas and parks often results in simplified habitats and a community of birds with fewer species dominated by abundant non-native species (Marzluff et al. 1998).Â The distribution of birds in urban areas has been investigated in relation to at least three dominant ecological theories.