The Role of Urban Forests in Conserving and Restoring Biological Diversity in the Lake Tahoe Basin

Study Plan 2005

Introduction

This study was initiated in 2002 to evaluate the contribution of urban forests to supporting biological diversity in the Lake Tahoe basin. The study was initiated and is collaboratively funded in 2002 by the USFS Lake Tahoe Basin Management Unit, University of Nevada Reno, USFS Sierra Nevada Research Center, and Tahoe Regional Planning Agency. The study includes investigations of the effects of urbanization and human disturbance on landbirds, small mammals, large mammals, ants, and plants. The results of the project will be used to make inferences about the contribution that parcels purchased through the Santini-Burton project contribute to supporting biological diversity in the basin, and the contribution that parcels in the urban forests (i.e., undeveloped parcels of any affiliation) make to supporting wildlife populations and biological diversity in these more urban settings. The "Lake Tahoe Urban Biodiversity" project completed its second season of field data collection during the spring and summer of 2004. The activities conducted and accomplishments achieved to date are described in this report. Additional information on study, including background, objectives, study area, methods, and the 2003 progress report, can be found on the Sierra Nevada Research Center web site: www.fs.fed.us/psw/programs/research_emphasis_areas ecosystem.currentstudies/landscape_watershed/pattern_landscape_laketahoe/shtml.

Science Team

The science team consists of Forest Service scientists and University professors and doctoral students (Table 1). Specifically, the Sierra Nevada Research Center of the Pacific Southwest Research Station, University of Nevada at Reno, and University of California at Davis. The diversity of team members brings a great depth and breadth of expertise to the study, including invaluable ecological insights from a long history of working in the Lake Tahoe basin and the Sierra Nevada.

Table 1. Science team for the Lake Tahoe Urban Biodiversity project.

PSW Sierra Nevada Research Center	University of Nevada, Reno	University of California, Davis
Pat Manley - PI	Dennis Murphy – PI	Matt Schlesinger – song birds and woodpeckers
Lori Campbell – large mammals	Susan Merideth – small mammals	Kirsten Heckmann – plant species and communities
Sean Parks - GIS	Monte Sanford – ants	Marcel Holyoak – advisor
	Peter Brussard - advisor	Michael Barbour - advisor

Study Area

The study area is the Lake Tahoe basin, a physically and biologically unique feature in between the flanks of the Sierra Nevada range of California to the west and the Carson Range of Nevada to the east (Fig. 1).

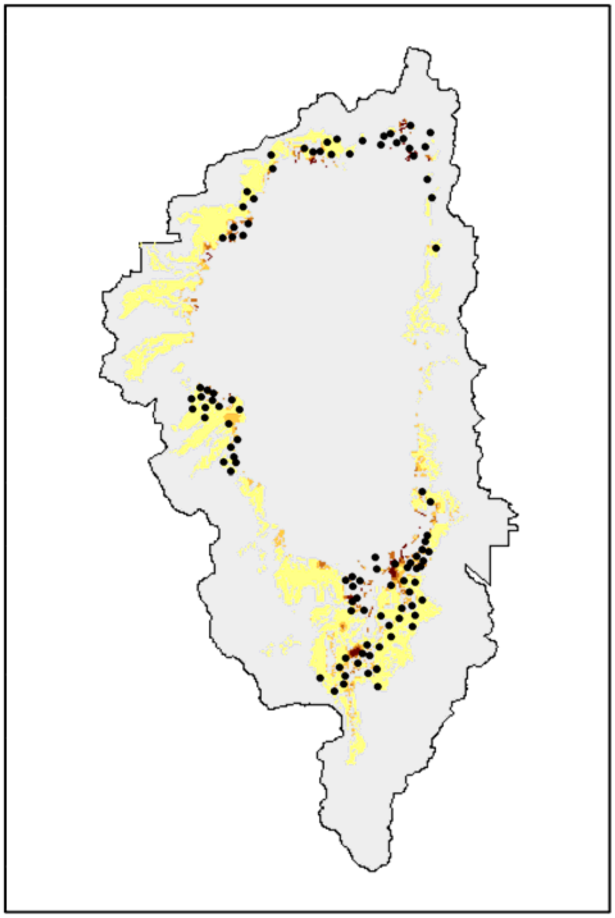

Figure 1. Sample site locations (n = 100) around the Lake Tahoe basin.

Methods

Site Selection

Core sample sites were selected using a development index as the sampling frame. The development index was developed through a number of steps. First, we created a single transportation GIS layer for the basin by combining several transportation GIS data layers provided by the LTBMU, California State Parks, and the Nevada Division of State Parks. To give the transportation features area, we buffered each transportation feature based on the type of transportation feature it happened to be. Highways were buffered 6.9 m (for a total width of 13.8 m), regular paved surface streets were buffered 5.1 m (10.2 m wide), dirt roads were buffered 3.3 m (6.6 m wide) and trails were buffered 0.5 m (1 m wide). The buffering distance was based on the basic width of a traffic lane, the average width of the shoulder (both of these values from the CalTrans highway design manual) and the average number of lanes. The buffered transportation features were then converted to a grid with a pixel size of 3 by 3 m.

Second, a land-use type was assigned to each parcel within the basin using a land-use GIS layer obtained from the Tahoe Regional Planning Agency. Examples of land-use types include: single family dwelling, hotel/motel, service station and animal husbandry services. There were a total of 60,137 parcels within the basin representing 90 different land-use types, so the land-use GIS layer was extremely detailed.

Third, we estimated the proportion of developed land for each land-use type by taking a random selection of parcels from each land-use, and then estimating the proportion of developed land using digital orthographic quadrangles. For land-use types with more than 200 parcels, we randomly selected 30 parcels and estimated the proportion that was developed in each parcel; for land-use types with 51 to 200 parcels, we randomly selected 20 parcels; for land-use types with 10 to 50 parcels, we randomly selected 10 parcels; and for land-use types with less than 10 parcels, we selected all parcels. For each land-use type, we averaged the estimated percent development for all the randomly selected parcels. For instance, the average proportion developed for single family dwelling was 51%.

Fourth, we converted the land-use layer into a grid with a pixel size of 3 by 3 m. For each land-use type, a proportion of the cells were reclassified into a developed category. For example, in areas where single family dwelling was the land-use, 51% of the 3 m^2 pixels in those areas were assigned a value of 1 (developed = 1, non-developed = 0). This was performed on each land-use type in the basin.

Fifth, the land-use GIS grid and the transportation GIS grid, both with a pixel size of 3 by 3 m, were then added together to get a development surface. Finally, we wanted to characterize each 30 by 30 m pixel in the basin by the proportion that it was developed. One hundred 3 by 3 m pixels fit into one 30 by 30 meter pixel. We overlaid a grid (with a pixel size of 30 m) on the entire basin, and for each 30 meter pixel, we counted the number of 3 by 3 m pixels that were developed. Values ranged from 0 to 100. A value of zero implied that there is no development within the pixel, and a value of 100 implied that the entire pixel was developed. This product was our final modeled development.

Once the sampling frame was completed, we randomly selected sites along the development gradient. We created 6 development classes: extremely low = no development within 500 m, very low = no development within 300 m, low = < 15% developed within 300 m, moderate = > 15 to 30% developed within 300 m, high = > 30 to 45% developed within 300 m, very high = > 45 to 60 % developed within 300, and extremely high = > 60%.

Data Collection and Analysis

Birds

We originally used four techniques to determine species composition, density, reproductive success, and behavioral patterns in passerine and other birds that are readily detected by sight and sound: point counts, nest monitoring, behavioral observations, and spot mapping. Point counts enable the estimation of species density and community composition of birds in proximity to count stations, but do not provide information on territories or reproduction (Ralph et al. 1993). Nest monitoring (Martin and Geupel 1993) confirms the breeding status of species and provide estimates of reproductive success and rates of nest predation and parasitism. Observations of foraging behavior were intended to determine the locations and substrates of foraging attempts.

Point Counts

We conducted point counts to characterize the species composition of the sample unit and its landscape context. We established five point count stations; they resided at the center point and at 200 m north, east, south and west of the center point (the “satellite” point counts). Counts were 10 min in duration, during which we recorded all birds seen or heard, noting the location in one of six distance categories (0-25 m, 25-50 m, 50-75 m, 75-100 m > 100 m, and flyovers). We conducted counts three times in the breeding season (mid-May to mid-July), with visits separated by at least one week. We began counts at least 15 min after sunrise and completed them before 9:30 a.m.

We took basic measurements of vegetation structure and human development at each point count station. We measured trees, snags and logs and counted pieces of trash within 17.6 m; measured overall tree and shrub canopy cover and the proportion of that cover that individual species comprise; estimated proportion of the area within 30 m of the point that was occupied by various types of development; and estimated the distance to water, riparian vegetation, and development of various types. We will use data from the plant community team to describe habitat conditions at the center point to relate to center point count results.

Nest Monitoring

We selected focal species that were the primary target of nest searching and monitoring. A focal species approach to nest searching was intended to ensure adequate sample sizes to calculate nest success for at least a few species. Patterns in focal species cannot necessarily be generalized to guilds or the entire bird community. The selection of focal species was guided by the following criteria: they 1) were associated with conifer forest; 2) were common in the Lake Tahoe basin; 3) were associated with the understory for breeding or foraging; 4) nested low enough (< 40 ft off the ground) that the nest was a) likely to be affected by anthropogenic disturbance within sample units, and b) feasibly monitored without climbing trees; 5) had a moderate or better ease of their nests being located; 6) were potentially an indicator of forest condition, including vulnerability to human disturbance and cowbird parasitism; 7) were potentially an indicator of other species or species groups; and 8) were complementary with other focal species such that the suite of focal species represented a diversity of life history characteristics (e.g., nest type, nest location, body size, diet). We determined the above characteristics for each species known to occur in the Lake Tahoe basin (Schlesinger and Romsos 2000) from (Ehrlich et al. 1988, Baicich and Harrison 1997), USDA (2000), and personal knowledge. We selected eight focal species: Mountain Chickadee (*Poecile gambeli*), Dark-eyed Junco (*Junco hyemalis*), Steller's Jay (*Cyanocitta stelleri*), American Robin (*Turdus migratorius*), Northern Flicker (*Colaptes auratus*), Pygmy Nuthatch (*Sitta pygmaea*), White-headed Woodpecker (*Picoides albolarvatus*) and Dusky Flycatcher (*Empidonax oberholseri*). Although focal species were the targets of nest searching, we also located and monitored nests of other species, which will enable analyses of guilds and of all species.

We searched for and monitored nests throughout each sample unit up to 200 m away from the center point. There was no strict time limit on the amount of searching allowed in each sample unit (Friesen et al. 1999, Burke and Nol 2000); our main objective was to find and monitor as many nests as possible, as approximately 20 nests per treatment are necessary for accurate calculations of nesting success (Hensler and Nichols 1981). Generally, we located nests by observing the behavior and movements of individual birds. We revisited nests every 3 to 4 days to record breeding phase (nest building, egg laying, incubating, nestlings, fledged) and reproductive effort (number of eggs and young). We examined nests above eye level and those in cavities using a dental mirror, a small mirror secured to a 5-m telescoping pole, or a video camera mounted to a 15-m telescoping pole. We monitored activity of nests into which we could not see to determining breeding phase and eventual success or failure only. We followed guidelines in the BBIRD protocol (Martin et al. 1997) and (Martin and Geupel 1993) for finding and monitoring nests and avoiding disturbance of nesting birds.

Once a nest had either fledged or failed, we recorded the following characteristics of each nest with confirmed breeding: nest height; substrate species, height, and diameter at breast height; nest orientation; distance from and orientation to roads, trails, and development; canopy cover at the nest; and percent slope. For nests of focal species, we established an 11.3-m radius vegetation plot (Martin et al. 1997), in which we measured all trees and snags and recorded proportions of different categories of ground cover.

Behavioral Observations

Behavioral observations were conducted during the course of searching for nests to determine whether patterns of foraging differed along the urbanization gradient. Birds encountered were observed for 20 seconds. For the first 10 seconds no data were taken, to allow time for the bird to return to its activity before being encountered by the observer. During the remaining 10 second period, observers noted the following information: species, time, perch substrate, height, distance from bole, and activity, and if the bird made a foraging attempt during that time, the foraging maneuver, foraging substrate, species, decay or decadence class, height, and diameter at breast height were also recorded. In 2004, data collected consisted of species, time, substrate, substrate species, and height. Observations were allowed to continue for five additional 10-second intervals to increase the chances that a foraging attempt would be observed.

Data Analysis

We conducted simple linear regressions of response variables such as richness of all species and select guilds and abundance of all birds, guilds, and individual species of interest versus human use and 300-m development, and select habitat variables expected to be important. Variables used were in their raw, untransformed state.

We calculated species richness per point as the total number of species detected within 100 m of the observer across the three visits. For this report, we calculated relative abundance as the average number of individuals detected within 100 m per station per visit. Note that raw abundance counts that are not corrected for detectability are subject to some bias if detectability differs among species or across the development gradient (Buckland et al. 2001).

We compared success of nests in different levels of development and human use. For this report, we calculated daily survival rates (Mayfield 1975, Hensler and Nichols 1981, Bart and Robson 1982) of nests of all species, species groups, and three focal species and compared them between development categories or among development/use categories using methods for multiple comparisons of survival rates (Sauer and Williams 1989) in program CONTRAST (Hines and Sauer 1989). We will eventually estimate reproductive success with maximum likelihood estimation models (Rotella et al. 2000, Rotella et al. in press) and evaluate competing models of explanatory variables using likelihood-based information-theoretic methods (Burnham and Anderson 2002).

We investigated whether birds might select nest-site habitat characteristics differently according to development and human use for species groups and individual species. We performed simple linear regression to examine whether nests were located higher off the ground in increasing development or in sites with greater human use.

For analysis of foraging heights, we used only the first observation period in which the bird was foraging, as repeated observations on single birds are not necessarily independent (Raphael 1990). We calculated the proportion of observations of foraging birds in different height classes and substrate types and examined these in relation to categories of development. We examined foraging heights (in two categories, 0-3 m and >3 m) in two categories of development (≤ 30% and > 30%) using chi-square tests for goodness of fit.

Small Mammals

Sherman Live Trapping

Sciurid populations were sampled using Sherman live traps. Trapping grids of 64 Sherman live-traps were established at each site (Fig. 2). Trap stations were configured in an 8 x 8 grid with 15m spacing between stations. Each grid covered ~ 1.1 ha and included a combination of 43 extra-long (3 x 3.75 x 12") and 21 large (4 x 4.5 x 15") Sherman live-traps. Each trap station was uniquely numbered with a fluorescent orange clothes pin located in a visible location near the trap. Traps were baited with a mixture of rolled oats, millet and sunflower seeds, and polystyrene batting was placed in every Sherman trap to provide warmth.

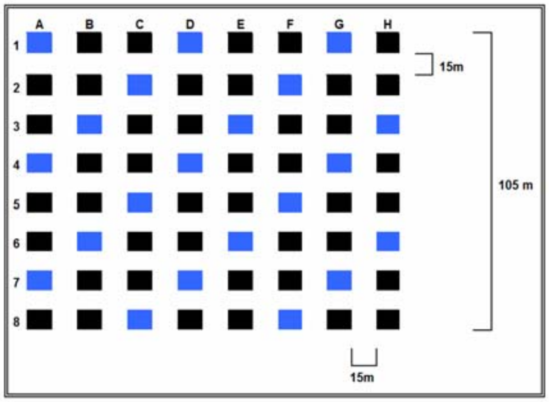

Figure 2. Schematic of the trapping grid configuration. Black squares represent extra-large Sherman traps, and blue squares represent large Sherman traps.

Traps were set and opened before noon on the first day, then checked twice a day (morning before 10 am and late afternoon before 8pm) for four days. Captured individuals were processed and released, and fresh bait was added to traps as needed. Traps were removed after they were checked on the fourth morning. All individuals captured were identified to species. Squirrels and chipmunks were permanently marked in both ears with a uniquely numbered ear tag, and data on sex, age (juvenile or adult), weight, and reproductive status (males: testes enlarged; females: vagina perforate, nipples swollen, enlarged, reddened, lactating, pregnant) were recorded.

Yellow-pine chipmunks, long-eared chipmunks, and the California ground squirrel have been selected for a population genetics study. In 2004, tissue samples (small piece of ear ≤ 50 mg) were collected from all chipmunks (*Tamias spp.*) and California ground squirrels (*Spermophilus beecheyi*) to be used for microsatellite genetic analysis. Samples were dried and are being stored at the Laboratory for Ecological and Evolutionary Genetics at the University of Nevada, Reno. Once DNA is isolated, it will be amplified by polymerase chain reactions (PCRs) using fluorescently labeled primers. Fragments will be analyzed and scored using Applied Biosystems (Perkins-Elmer Corporation) equipment and software available through the Genomics Center at the University of Nevada, Reno.

Data Analysis

Species composition and population estimates for each species at all sampling locations were generated from the trapping data. Sample sites were selected to represent the range of development conditions at the 300m scale. Initially, this data is being analyzed with simple linear regression and one-way ANOVA analysis to determine the effect of development and human use on small mammal species richness and relative abundance. We report results using development values generated at both the 100m and 300m scales, because these levels are most relevant to the small mammal species considered here whose home ranges are typically between 0.4ha and 3.3ha (Seton 1924, Sutton 1992, Best et al. 1994, Clawson et al. 1994, Gannon & Forbes 1995). For analyses at the 300m scale, the sites are categorized to represent low (0-15%, n=32), moderately-low (15.1-30%, n=14), moderately-high (30.1-45%, n=17), and high development (>45%, n=8). As a consequence of selecting sampling locations by considering the 300m scale only, a disproportionate number of sites (n=46 out of 72) are represented by development values less than 10% at the 100m scale. Therefore, for the purposes of ANOVA analysis, we grouped the sites into low (0%, n=19) and high (>30%, n=9) development at the 100m level. The impact of recreational use, as measured by the frequency of human, dog, and vehicle encounters per hour, on small mammal richness and abundance was analyzed by linear regression.

Large Mammals

Medium to large bodied mammals were surveyed using track and photographic surveys (for carnivores) and pellet-group counts (for deer and leporids). Each sampling array consisted of a total of 4 enclosed track plates, 2 remote cameras and 4 pellet-group plot arrays.

Track and Camera Surveys

Track surveys were conducted using enclosed sooted aluminum track plates (Barrett 1983, Fowler 1995, Zielinski and Kucera 1995). Photographic evidence of species presence was collected using remotely triggered cameras (Zielinski and Kucera 1995). The proximity of the sample sites to residential areas increases the likelihood of the presence in the sample units of domestic dogs and cats. Photographic evidence provides a reliable means by which to distinguish coyote and bobcat detections from those of domestic dogs and cats, which is not possible from tracks due to the overlap in track size. Use of multiple techniques may also improve the probability of detecting resident animals as responses to the track plates and cameras may differ (Campbell, unpublished data). Some larger carnivores like coyotes and bobcats may be reluctant to enter enclosed track plates given the relatively low height of the plastic canopy (opening height 27.5 cm) although others, such as black bears, appear undeterred.

An array was established centered on the identified sample unit center. One track plate station (TP1) was placed near the sample unit center. One camera (TM1) was located 100m from TP1 on a randomly selected azimuth. Three track stations were placed at a distance of approximately 250 m from the center at 0º (TP2), 120º (TP3), and 240º (TP4; Fig. 3). One of the three outer track plate stations was randomly selected to be paired with a remote camera (TM2), which was established 100 m from the track plate station on a randomly chosen azimuth. All devices (track plate stations and cameras) were established a minimum of 30 m from a patch edge or trail/road. Track plates and cameras were baited with chicken (drummettes for track plates, half chickens for cameras) and baby carrots, and a commercial scent was used as a lure.

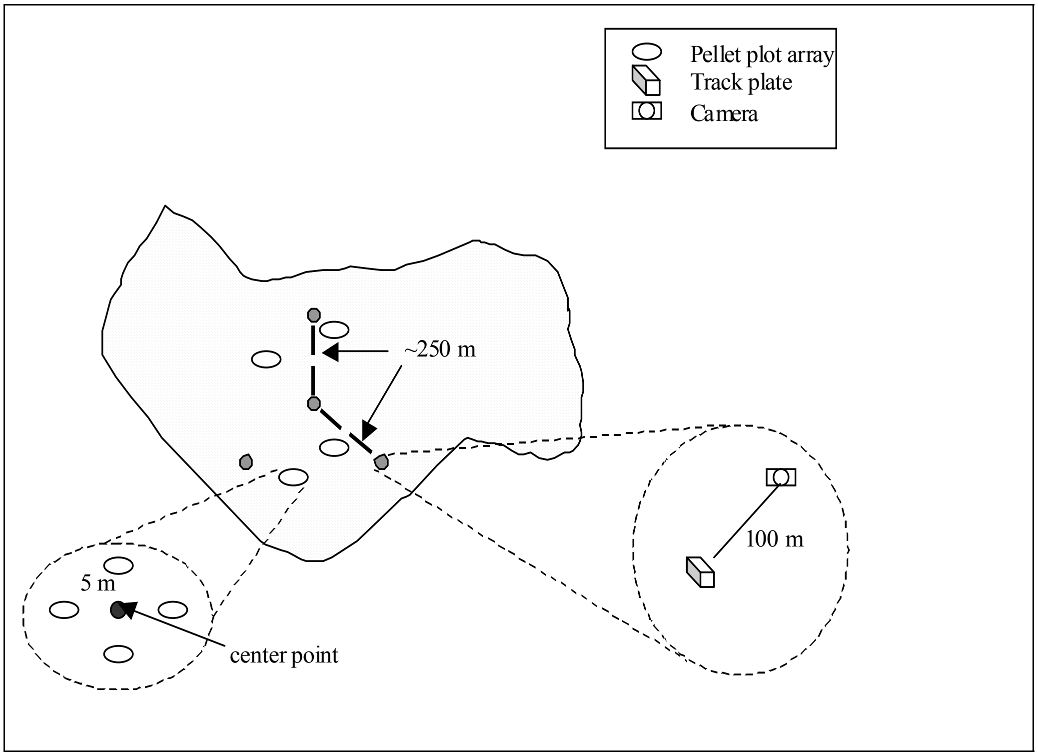

Figure 3. Schematic of the arrangement of survey devices and plots. One camera was paired with the track plate at the center point and the other was randomly paired with one of the remaining track plate station.

Track plates and cameras were visited every two days for a total of five visits. A species was determined to be present in a sample unit if any device within the sample unit recorded a detection during the survey period. The type of data derived from these methods include: species detected/not detected, species identity (species or genus level), date of visit, frequency of visitation, and time of visit (cameras). The response variables include species detected/not detected, species richness, and frequency of use. Frequency of visitation to detection devices within a patch may be used to represent the intensity of patch use (Gehring et al. 2003).

Pellet-group Counts

The presence of deer and leporids such as snowshoe hare are not likely to be adequately sampled with track plates and cameras. Pellet-group counts (Smith 1968, Krebs et al. 1987, McKelvey et al. 2002) were added to the sampling effort to enhance detections of these species.

At random distances along the trails between track plate stations, pellet-group count plot arrays were established at a distance of 10 m off the transect (Fig. 3). From the start point at 10 m from the transect, an array of four plots was established, one in each of the cardinal directions at a distance of 5 m. Each plot had a radius of approximately 1.7 m to yield a plot area of approximately 9.3 m^2. A total of 16 plots (4 plots in each of 4 arrays) were established for each sample unit. Pellet-group counts occur once near the beginning of the sampling period for each sample unit. The data recorded were species detected/not-detected. Although the number of pellets /unit area has been used to derive an index of species density in other studies, the index is sensitive to the defecation rate used (number of pellets/individual), which appears to be location-specific (Fuller 1991).

Habitat Characteristics

The location of each track plate and camera station was recorded using a global positioning system (GPS) unit and basic information on microhabitat characteristics was collected. Slope, aspect, disturbance within a 30 m radius were recorded. Vegetation was described using the California Wildlife Habitat Relationships (CWHR) system to characterize the vegetation community, tree size and canopy closure. We noted the presence, size and decay class of trees and stumps and identified to species where possible. We estimated the relative cover by the dominant tree and shrub species and the proportion of cover area in grass, herbaceous, rock, litter or bare soil. Basal area, tree species composition, decay class and diameters at breast height were collected using variable plot methods using a 20-factor prism and a Biltmore stick. Three 30 m transects were established centered on a location 5 m from the track plate or camera station on a random azimuth to sample coarse woody debris and evidence of anthropogenic disturbance such roads, trails or trash. At the center point and at the transect ends, canopy closure was measured by densiometer.

Data analysis

Logistic regression adjusted for species detectability will be used to relate response variables such as species presence or use frequency to explanatory variables. The goal will be to develop a predictive surface for detection probability and species richness. This could also be used to model the possible impacts of alternative development scenarios. Models will be developed based on sample unit characteristics (such as area of intact forest, composition, proportion developed), matrix characteristics using concentric buffers around the sample unit at varying distances (edge "hardness", housing or population density, presence of forested cover), and local characteristics (such as canopy closure, tree and shrub composition and coarse woody debris).

Ants

Sample Sites

We selected 124 core sample sites to represent an urban development gradient in the basin. Since the primary sampling frame focused on larger scale effects of disturbances such as development, we additionally assessed the effects on diversity at a smaller scale. We also assessed the effects of particular types of ground disturbances on ant diversity by measuring richness and abundance at increasing distances away from three disturbance types: highway, OHV trail, and residential areas. We sampled multiple types of disturbances within a single large area. Sites meeting appropriate conditions for the distance from disturbance study were quite limited, so we selected one large area where we could fit three replicates per disturbance type. Within each of these 'site replicates' we placed five traps (distance replicates) along transects at 0, 10, 20, 50, 100, and 200 meters from each disturbance type.

Pitfall Trapping

The sampling design targeted ground-dwelling ants since most species constitute this category rather than tree, shrub, or herb-dwelling species. Quantitative data on species distributions were obtained from standard pitfall trapping methods because it is rapid, repeatable, quantitative, and provides a relatively unbiased sample of ants within an area (Anderson 1990, Agosti et al. 2000). Pitfall traps consisted of 6.5 cm diameter (120 ml) plastic cups. This size of trap was appropriate for sampling ants because traps of a 42-mm diameter have demonstrated the same efficacy as traps of varying diameters (Bestelmeyer et al. 2000). Traps were left open for seven days containing approximately 25 ml of propylene glycol. We used propylene glycol as a standard preservative for ant sampling because it does not differentially attract or repel ants, it is nontoxic to vertebrates, and it kills specimens quickly to prevent specimens from destroying each other (Bestelmeyer et al. 2000).

To assess differences between sites according to the large scale primary sampling frame, we used a 40 x 40-m grid to establish 12 pitfall traps per site. Four traps each were placed along three 40-m transects oriented north-south and centered on the center point in each plot (Fig. 4a). Transects were separated by 20 m. We used systematic random placement of traps along each transect, whereby the first trap was randomly placed along the first 10 m of each transect and each following trap was staggered at 10-m intervals (Anderson 1997). We marked each trap with a pinflag 1 m north of the trap to avoid direct attraction or damage to traps by other animals.

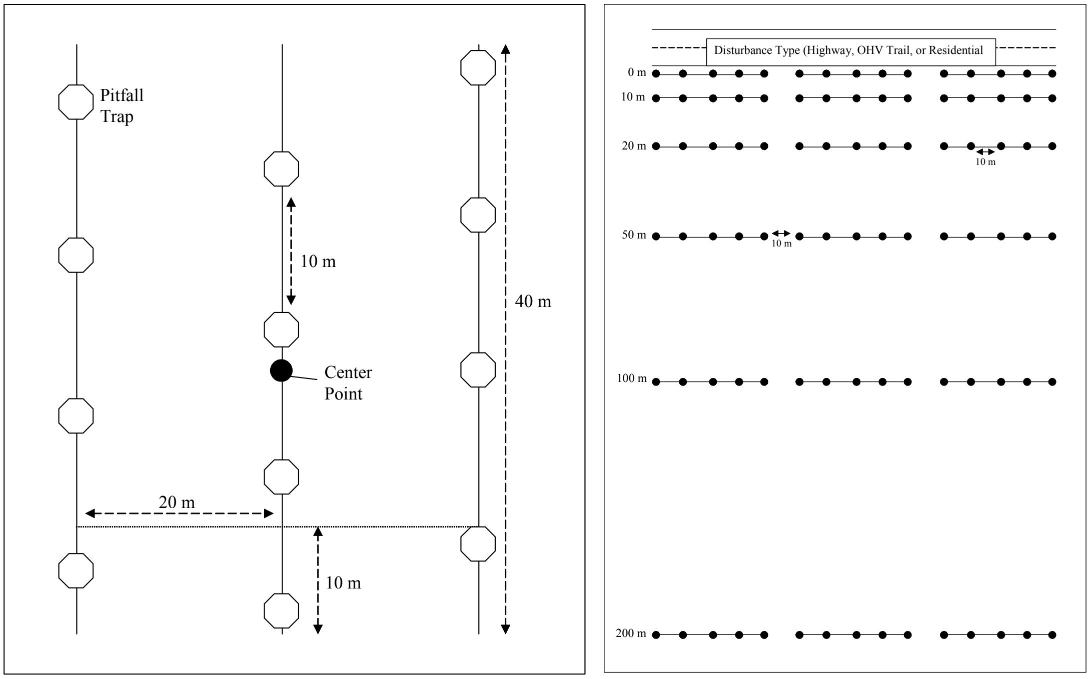

Figure 4. Ant pitfall trapping arrays for (a) the large-scale primary sampling frame and (b) the small-scale disturbance type-distance sampling frame. Distances on graphics are not to scale.

In addition to site condition data provided by vegetation measurements (see plant section below), we ranked sample site disturbance within our sampling grids at 72 sites in 2003. We defined disturbance to be any form anthropogenic modification of the site and it consisted of recreational use, forest thinning, burning, or trash buildup. We ranked sites as follows: 0 = none to low disturbance - unaffected by recent human land use or had little evidence of vegetation or soil disturbance, with no more than 10% of the site disturbed; 1 = moderate disturbance – vegetation and ground surfaces were noticeably disturbed, with 10 to 50% of the site having evidence of disturbance; and 2 = high disturbance – sites highly modified by human land use practices, with more than 50% of the area appearing disturbed.

A second trapping array was used to assess ant responses to small scale disturbances. We established a trapping array with three replicates per site at distance intervals of 0, 10, 20, 50, 100, and 200 m from the disturbance extending into wildlands (Fig. 4b). At each distance interval, we established a line of five traps spaced 10 m apart and running parallel to the disturbance. We attempted to minimize variation in our samples by minimizing site variability: we selected sites only in the southern part of the basin; selected sites of similar physiognomy; and selected sites where sampling transects ran toward wildlands and not other types of disturbances (e.g., OHV, residential, commercial, roads).

Pitfall trap samples were sorted to species in our laboratory at University of Nevada, Reno. Species abundances were scored (transformed to ordinal scale data) according to standard methods using a 6-point scale (Anderson 1997): 1 = 1, 2 = 2-5 ants, 3 = 6-10 ants, 4 = 11-20 ants, 5 = 21-50 ants, and 6 = >50 ants. This scaling transformation minimizes distortions caused by large numbers of individuals falling into small numbers of traps due to placement near nests and/or foraging trails.

Data Analysis

We conducted analyses (using SYSTAT v. 10) at the individual, functional group, and full community level. For these analyses we calculated species richness (SR) as total species per site and as mean species per trap. Abundance was calculated as the sum of abundance scores at individual traps and was often expressed as a percentage of its maximum (i.e. maximum of 72 for an individual species). We grouped ants into functional guilds that represented body size, nesting strategies, distributional patterns. Body size was measured the mean length of ants measured in mm. Nesting strategies were identified as ground, stone, logs, and thatch according to P.S. Ward (personal communication). I categorized each species' nesting strategies as 1=uses only one nest strategy, 2=uses 2 nesting strategies, and 3=uses 3 nesting strategies. We used elevational range as a proxy for individual species distribution. Elevation range was determined using collection data from Wheeler and Wheeler (1986) and synthesized in M. P. Sanford (2003, unpublished data).

We constructed a species-accumulation curve and point versus site richness curve to assess the ability of our sampling grids to detect species within sites. Species-accumulation curves are often used to identify how well a trapping array worked to detect all or most species within a site. Point versus site species richness curves should indicate the turnover of species between traps (Anderson 1997).

We constructed dominance-diversity curves (May 1975) to examine community evenness over all sites combined and to compare community evenness between high and low development sites. We fitted a linear regression model of logarithmic species abundance against arithmetic species rank order for both high and low development (Bazzaz 1975, Tokeshi 1993). We selected 20 sites for this procedure: 10 sites with lowest percent development and 10 sites of highest percent development according to our 100-m scale of percent development. The regression slope of zero indicates a community where all species have equal abundance, whereas greater slopes (i.e. more negative or more positive slopes) indicate greater dominance of a species subset.

We examined community, guild, and individual-level responses in relation to percent development at varying scales. First, we examined the response of species richness and abundance for all sites over six different scales of development. Second, we examined if species presence/absence similarity changed across the development gradient using the Jaccard Index at a 60-m and 100-m spatial scale. We used the Jaccard Index because it is strongly sensitive to detecting differences in species richness (Jongman et. al. 1995). We also examined whether ant community dissimilarity changed across the development gradient using the dissimilarity metric of Euclidean distance. We used Euclidean distance because it is highly sensitive to species richness, dominant species, and the sample total (Jongman et. al. 1995). Third, we assessed patterns of guild responses to development at the 100-m scale by examining scatter plots. Fourth, we examined how individual species changed in abundance with increasing development at the 100-m scale.

Ant responses to finer-scale disturbances were assessed using two procedures. First, we examined responses of species richness and abundance across site-specific disturbance categories using a one-way ANOVA for each response variable. Second, the effect of disturbance type (i.e. highway) and distance from disturbances was evaluated using a two-way ANOVA. To date, we have processed and analyzed ant diversity from the subsample of 0, 50, 100 m distances.

Under the premise that urbanization leads to recreational use within urban lots, we assessed the potential effects of human recreational use on ant communities. We used simple regression analyses to explore responses of ant richness and abundance against six potential explanatory variables of human recreational use: human detections, dog detections, area of compacted ground, area of trails, area of roads, and total compacted surface. Total area of compacted surface is different from area of compacted ground and was calculated by summing areas of compacted ground, trails, and roads within our sites.

To further understand potential site-specific factors that may be driving changes in ant communities, we examined ant responses to three vegetation characteristics that may result (directly or indirectly) from urbanization. We examined course woody debris (CWD), impervious surface, and tree density. Pearson correlation coefficients were used to test whether these factors may cause changes in ant richness, abundance, and guild composition.

Plants

Data Collection

Vegetation was characterized using a combination of U.S. Forest Service procedures (Casey et al. 1995) and standard botanical survey methods. The sampling design had four primary components (Fig. 5).

- Three line-intercept transects (30 m) to estimate percent ground cover, volume of coarse woody debris, litter depth, soil compaction, and to characterize the physiognomy of vegetation layers.

- Four circular subplots (7.3 m radius) used to estimate percent cover of trees, shrubs, and exotic species.
- Twelve quadrats (1m^2) used to estimate percent cover of herbaceous plants and shrubs.
- Three concentric circular plots (7.3m radius, 17.6m radius, and 56.4m radius) used to describe forest stand structure.

The sampling methods were conducted at each site's center point, which was permanently marked with rebar. This point served as the starting point for all transects and the center of the three concentric circles.

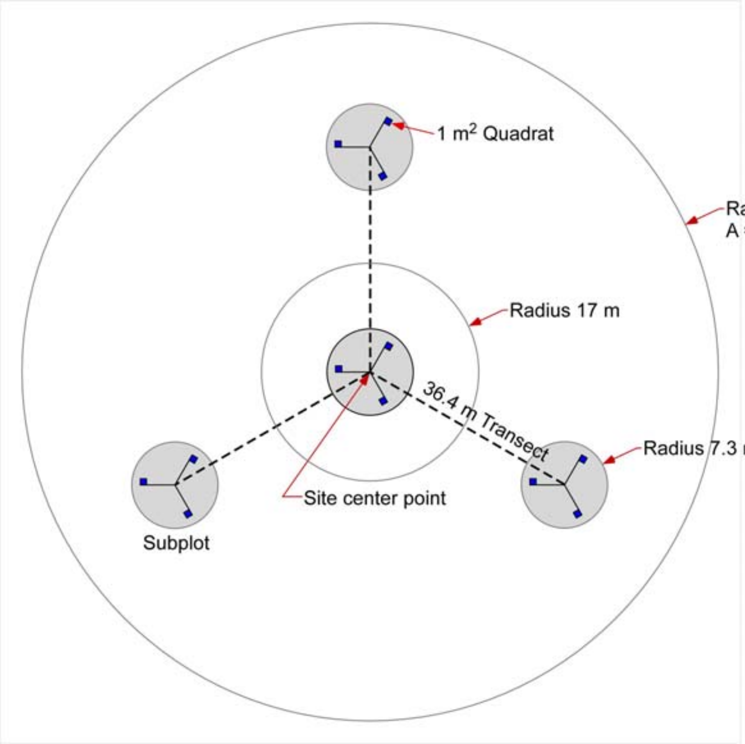

Figure 5. Layout of subplots, quadrats, and transects employed at the center point of Lake Tahoe Urban Biodiversity project in 2003.

At the site center point, the following general information was collected: percent slope angle measured with a clinometer; slope aspect; human disturbance by type within 30 m of center point; distance to all roads or trails within 100 m of the center; distance to water within 100 m; and distance to riparian vegetation within 100 m.

Along each of the three 30 m transects (Fig. 5), the following information was collected:

- Percent Ground Cover. Ground cover estimates were made at every third meter, for a total of 10 one meter long segments along each transect. For each segment, the length of all plant species and non-vegetative ground cover (bare soil, litter, rock, coarse woody debris) that intersected the transect tape was measured.

- Physiognomy. Vertical structure of the plant community was described using the point intercept method along the three transects. Measurements were made every third meter, for a total of 10 sample points. All plant species intersecting the transect tape at any height above the point on the tape were recorded.
- Litter Depth and soil compaction. Litter depth and soil compaction measurements were taken at the same 10 point intercept locations used to sample vertical structure.
- Coarse Woody Debris. Volume and decay class (Casey et al. 1995) of coarse woody debris (logs > 10 cm diameter) were characterized along the three transects. Volume was calculated from the two end diameters and length of the log.
- Anthropogenic Features. The length and type (trail, dirt road, paved road, highway, ski lift, parking lot, house, or campsite) of anthropogenic feature were recorded for each transect.

Four, 7.3 meter subplots were established at each site (Fig. 5). Cover of each tree, shrub, and non-native plant species in the subplot was estimated to the nearest 1%. Each subplot was searched for 15 minutes in order to list all species present. Within each subplot, percent cover of all plant species was estimated in three 1 m^2 quadrats.

Three nested circular plots were used to describe forest tree structure at each site: 1 ha (56.4 m radius circle), 0.1 ha (17.6 m radius circle), and 0.017 ha (7.3 m radius circle) plots (Fig. 5). Within each circular plot, the following information was recorded for trees and snags: species, height to nearest meter using a clinometer, diameter at breast height using a DBH tape, decadence code for live trees (Table 2), and decay class (Casey et al. 1995) for snags. Measurements for the three circular plots are restricted to certain DBH classes of trees and snags: in the 7.3 m radius circle we measured all trees and snags >12.5 cm diameter; in the 17.6 m radius circle, we measured trees > 28 cm and snags > 12.5 cm diameter; and in the 56.4 m radius circle, we measured trees > 61 cm and snags > 30.5 cm diameter. In addition, sapling densities were recorded, by species, in the 7.3 m radius circle. The 17.6 m radius plot was used to measure canopy cover, with a moosehorn device, at four locations; the number of cut stumps by decay class; the number of pieces of trash; and the area occupied (in m^2) by anthropogenic features such as trails, dirt roads, paved roads, highways, and parking lots.

Table 2. Decadence codes for live trees measures in the Lake Tahoe Urban Biodiversity Project sites in 2003.

Decadence code	Decadence feature
1	Conks, bracket fungi
2	Cavities greater than 6 inches in diameter
3	Broken top
4	Large (> 12 inches in diameter) broken limb
5	Loose bark (sloughing)
6	Mistletoe
7	Dead top
8	Split top
9	Thin canopy (relative to neighboring trees)
10	Light foliar color
11	Leaf necroses
12	Frass
13	Sap exudation

Data Analysis

Univariate data analyses were done using JMP, version 5 (2002).

Human Use

Disturbance within remnant forests in the form of human use and domestic animals often accompanies development in the surrounding area. The removal of snags for firewood, safety on roads and trails, and defensible space from wildfire are also common practices in undeveloped lands in proximity to urban environments. Fragmentation studies that ignore human disturbance risk confounding these two stresses because population- and community-level effects of recreation mirror those of small patch size and high patch isolation in many cases (Boyle and Samson 1985, Knight and Gutzwiller 1995, Riffell et al. 1996, Fernández-Juricic 2000b, 2002, Gutzwiller et al. 2002). Selective extinctions brought about by human presence may also lead to altered compositional patterns and community dynamics. We characterized use of sites by people and their pets to enable us to distinguish between effects associated with fragmentation and habitat loss from those associated with within-site disturbance, and to describe the nature of the relationship between surrounding development and within-site disturbance in the Lake Tahoe basin.

A 200 x 200-m sample unit (4 ha) was established in association with each sample point. Sampling for each species group occurred throughout areas of varying extents, but the majority of samples were taken within a 4-ha area around the sample point. In standard sample units, 4 ha encompassed the vegetation plots, ant grid, small mammal grid, center point count station, and center trackplate and camera stations. All satellite point count stations and most satellite trackplate and camera stations fell outside the 4-ha area.

Study sites for the LTUB project were subject to dispersed use with multiple access points. Under these conditions, personal observation is the most effective and unbiased sampling method available. Personal observation consisted of an observer moving through the study site and recording data on the type and intensity of use encountered. A total of approximately 1.2 km of survey routes and 5 count stations were established within the sample unit. Some sites were smaller than 200 x 200 m (defined by the extent of the undeveloped area), and at these sites transect lengths were reduced commensurate with the reduced size of the sites. At sites smaller than 1 ha, no transects were conducted; one or two 10-min counts were conducted instead.

Surveys were stratified by day of the week (weekday non-holiday, and weekend and holidays), time of the day (dawn to mid-day, mid-day to evening), and month (May through September) (Table 3). Each study site was surveyed once per week, with one survey allocated to each combination of time of day and segment of week over a four-week period. Observers rotated among sites so that any observer bias that might exist was represented equivalently among study sites. The order in which sites were surveyed within a time slot was rotated.

Table 3. Sampling strata used to partition survey effort to characterize anthropogenic stressors within sample sites.

Type of strata	Number of strata	Description of strata
Month	5	May through September
Segment of week	2	Weekday non-holiday and weekend/holiday
Time of day	2	Morning (dawn to 1300 hrs), afternoon (>1300 to dusk)

Data recorded included observer, date, survey start and end times, start and end locations, route completed, and weather. All encounters were recorded including location of detection with respect to the observer and to the sample unit. Other information regarding encounters included

- type of use (truck, ATV, walking, running, bicycle, stationary, etc);
- if stationary, then type of activity (picnic, sitting);
- number of people in group;
- presence of non-vehicular noise (shouting, music, machinery);
- type and number of domestic animals (restrained/unrestrained); and
- other activities (feeding animals, littering, on/off trail use).

In the course of conducting the walking survey observers stopped at designated points for 3 minutes and recorded all encounters during that time. The distance to detections was recorded, as well as the location inside or outside the sample unit. Counts provided data on the density of use by type, whereas transect data provided frequency of use by type. Observers had the option of conducting a 30-sec traffic count at each count station, if they determined that recording traffic during a 3-min count would be distracting. The 30-sec counts consisted of observers tallying all vehicles at all distances in 30 sec either before or after the 3-min count. At a later date, the frequency and density of use by type will be summarized by segment of day and segment of week for each site.

Data Analysis

The frequency by use type (encounters along transect) and intensity (number and density of detections during counts) of use was summarized by month, per time of day, and for the spring/summer season as a whole. We calculated four variables to describe the use of each site by people, all dogs, unrestrained dogs, and vehicles. We combined data from transects and counts for all analyses. We calculated the total number of people (e.g., walking, running, biking, golfing, standing), total number of dogs, and number of unrestrained dogs detected per hour within the sample unit based on the total number of detections across all visits multiplied by 60 and divided by the total survey time per site.

We also calculated an index of traffic surrounding the sample unit to reflect traffic use and noise around the sample unit. Vehicle tallies consisted of transects, 3-min counts, and in some cases 30-sec counts. If there was a 30-sec count conducted at a particular count station at a particular visit, we multiplied the count by 6 (to arrive at a 3-min estimate) and superseded the number of vehicles detected during the 3-min count. All non-vehicle detections during the 3-min count were retained for other calculations; the 30-sec count could only supersede the vehicle totals for counts. The resulting value for 3-min/30-sec counts was summed across visits for each site and added to the number of vehicles detected during all transect surveys at each site. This value was multiplied by 60 and divided by the total survey time to yield the number of vehicles detected per hour.

We summarized the overall patterns of use in terms of the four use variables and performed simple linear regressions between these variables and development within 300 m.

Data Analysis

The frequency by use type (encounters along transect) and intensity (number and density of detections during counts) of use can be summarized by month, per time of day, and for the spring/summer season as a whole. An index of use frequency and density will be derived for non-motorized human use, motorized use (expected to be minor), and domestic animals. The indices and one or more specific measures will be used as dependent variables relative to development indices, and as independent variables relative to biotic and abiotic descriptors.

Landscape Fragmentation Model

Limited progress was made on the landscape model in 2004. Attempts to integrate with the Tahoe Decision Support System did not yield progress, and funding limitations caused us to be cautious about early expenditures in model development that we could not sustain once all the data were acquired. Instead, we decided to put funding toward data collection, and postpone model development until funding and data acquisition were clarified. The team wanted to hire a post-doctoral student to work on the model, and still hope to do that in the final year of the project. Until then, we are simply exploring ideas for model development. A more detailed explanation of expectations for landscape model development is provided in Appendix A.