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Factors affecting stickhouse site selection in Neotoma fuscipes using GIS

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FACTORS AFFECTING STICKHOUSE SITE SELECTION IN *NEOTOMA FUSCIPES* USING GIS

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ABSTRACT

FACTORS AFFECTING STICKHOUSE SITE SELECTION IN *NEOTOMA FUSCIPES* USING GIS

by Jenna C. Patton

Neotoma fuscipes annectens, and the stickhouses it creates and uses, plays an important ecological role in the habitats it occupies. Urban development in the San Francisco Bay area is encroaching on much of the woodrat's habitat, placing woodrats and humans in ever closer contact. This study used a Global Positioning System (GPS) and a Geographic Information System (GIS) to map stickhouse locations in Pulgas Ridge Open Space Preserve in order to analyze the effects of human and canine disturbance on stickhouse locations and microhabitat variables of the stickhouses. Results showed that cover type, percent tree cover, percent shrub cover, and distance to nearest tree were affected by human and canine disturbance. Distance to nearest stream, slope, and aspect were not affected by disturbance, but were influenced instead by the natural topography.

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INTRODUCTION

The dusky-footed woodrat species complex (*Neotoma fuscipes* and *Neotoma macrotis*) is found in a narrow band from the Columbia River in Oregon south through California, into Baja California, Mexico. Within California, the species complex is distributed along the Pacific Coast and the Sierra Nevada foothills, forming a ring around the Central Valley; there is a relict population found in the Mojave Desert. Eleven subspecies have been described (Hooper 1938), based on cranial morphology and pelage color. Matocq (2002a and 2002b) has recently used cranial, glans penes, and molecular characteristics to elevate *N. f. macrotis* to species level distinct from *N. fuscipes*. *Neotoma macrotis* now covers the southern half of the species complex's range, and includes the populations of *N. m. martirensis, N. m. luciana, N. m. simplex,* the southern half of the *N. m. streatori* population in the mid-Sierra Nevada mountains, and an isolated eastern population of *N. m. riparia* (placed in that subspecies due to geographical convenience). *Neotoma fuscipes* now covers the northern half of the species complex's range, and includes the populations of *N. f. monochoura*, *N. f. fuscipes*, *N. f. annectens*, *N. f. perplexa*, *N. f. bullatior*, the majority of the population of *N. f. riparia*, and the northern half of the population of *N. f. streatori*. *Neotoma fuscipes annectens* is found along the coast from San Francisco Bay to Monterey Bay, and is considered a California Species of Special Concern (Hafner 1988). *Neotoma fuscipes annectens* is losing its habitat due to extensive development of the San Francisco Bay and coastal area.

Neotoma fuscipes occupies habitats in dense chaparral; coastal sage scrub; oak woodlands; mixed coniferous and mixed evergreen forests; and riparian habitats: all with well-established understories (English 1923; Gander 1929; Vestal 1938). Within mixed evergreen and coniferous forests, they have been found to be abundant in sapling/brushy poletimber stands, and to a slightly lesser degree, in seedling/shrub and large old-growth stands (Sakai and Noon 1993). *Neotoma fuscipes* has most often been found in habitats with full tree cover without recent fires and least often found in more open areas. "Reported population densities for woodrats, in undisturbed habitat, ranged from 5.1/ha in open habitat to 37.1/ha where the canopy is >90% closed" (Carraway and Verts 1991:5). Home ranges for adult males average 2289 m^2, adult females average 1924 m^2, and juveniles average 1719 m^2. Male-male overlap of home ranges averages 15%, male-female overlap is 28%, and male-female overlap during the breeding season is 57%. Juveniles initially disperse from their maternal home to nearby vacant homes with a home range overlap averaging 62% (Cranford 1976).

Neotoma fuscipes is widely known for the large, multi-chambered stickhouses it creates and uses. The stickhouses are conical in form, and often exceed three meters in height. They can be found on the ground, in trees, in dense thickets of cactus or poison oak, in old rail fences, or near streams. They are built of sticks, branches and twigs, pieces of bark, and other natural materials the woodrats are able to manipulate. The larger houses are divided into many compartments, serving different functions such as food storage, living room, nursery, bedroom, and waste room. Runways link these inner compartments to one another, and each inner compartment also has many passages that lead outside the house. Families of woodrats often have more than one stickhouse within a close proximity to each other. The stickhouses are added to and enlarged by each generation, and if the population increases faster than the houses can be enlarged, smaller houses are built in the surrounding area (Gander 1929). The location of each stickhouse is determined in part by the availability of food sources in the surrounding area (Carraway and Verts 1991).

The stickhouses of the dusky-footed woodrat play an important ecological role in their habitat. When the houses have been vacated, they serve as refuges for many other species, including shrews, harvest mice, brush rabbits, raccoons, meadow mice, deer mice, lizards, salamanders, and newts. In addition, they contain a large number of arthropods, including beetles, flies, mites, beetles, millipedes, caterpillars, and lepidoptera larvae (Vreeland and Tietje 1999). Often species of shrews and harvest mice have been found to be cohabitating with the woodrats in the stickhouses. *Neotoma fuscipes* is preyed upon by many species, including *Lynx rufus, Canis latrans, Mustela frenata, Bubo virginianus, Tyto alba*, and is the primary food source for the endangered spotted owl, *Strix occidentalis*.

Dusky-footed woodrat ecological and population studies have taken place using both live trapping and stickhousehouse counts (Vreeland and Tietje 1999). Fargo and Laudenslayer (1999) found that in some habitats, stickhouse counts may not be a reliable method for estimating dusky-footed woodrat population size. They concluded that stickhouse counts can be correlated more clearly with habitat quality than population density, where areas with many houses are more likely to indicate high quality habitats that can potentially sustain a large number of woodrats, and areas with relatively few houses indicate low quality habitats. Gerber et al. (2003) found that patterns of habitat use were positively correlated with overstory cover, and animal weight was positively correlated with understory cover. They found that *N. f. riparia* appeared to select den locations on the basis of understory cover, but that it also benefits from dense overstory cover and distance to nearest tree. Balcom and Yahner (1996) found that low levels of human activity near nest sites were not responsible for declines in *Neotoma magister* populations, but instead determined that declines in forest cover had degraded the woodrats' habitat quality, which, in turn caused the population to decrease. They considered human activity not to be responsible due to the fact that distance to roads or clearcut stands did not differ between historical and currently occupied sites of nests, and several sites were located very close to major roads.

This study quantifies the habitat characteristics in and around woodrat stickhouses to determine which habitat parameters are important in selection of stickhouse location in two habitat types within the Pulgas Ridge Open Space Preserve: undisturbed areas, and disturbed areas (i.e., areas with human and canine disturbance). The disturbed areas were further divided into two areas: first, areas within ten meters of all hiking trails on the preserve (and having human and on-leash canine disturbance); and second, human and off-leash canine disturbance (here the dogs can wander far from the trail). This study tested the hypothesis that anthropogenic factors are more influential in determining *Neotoma fucipes annectens'* stickhouse locations than natural topographic factors.

STUDY AREA

The study was performed in the Pulgas Ridge Open Space Preserve, (San Mateo County, California) a property owned by Midpeninsula Regional Open Space District (MROSD). Pulgas Ridge is a 148-hectare (366-acre) property east of Interstate Highway 280 and north of Edgewood County Park (Figure 1). There are four hiking trails in this preserve, with the Hassler Loop Trail enclosing a large off-leash dog area. The landscape consists of oak woodland, chaparral, and riparian vegetation associations. The area appears to be prime habitat for *Neotoma fuscipes annectens*.

METHODS

The field portion of this study was carried out from July through September 2004. Pulgas Ridge Open Space Preserve was mapped onto a grid of 100-m by 100-m quadrats. Eight quadrats of the grid were randomly selected for study from "undisturbed" areas of the preserve (defined as not being along hiking trails or in the off-leash dog area) to act as a control for comparison with the disturbed areas (along hiking trails and within the off-leash areas). Within each of these selected quadrats, a line transect (100 m) was walked. Every stickhouse observed within 10 m of the transect line was mapped using Differential Global Positioning System (DGPS). DGPS measurements were collected with a Trimble GeoExplorer III. Each stickhouse was determined to be active or inactive based on fresh vegetation clippings at entrances, fresh feces in and around the stickhouse, or direct observation of a woodrat at the house. Measurements of height, length (at longest axis) and width (at shortest axis) were taken for each stickhouse. Data of specific microhabitat parameters were recorded at each stickhouse (Table 1). Latitude and longitude measurements were taken using DGPS. Percent tree cover and percent shrub cover were measured with a densiometer. Distance to the nearest tree was measured and the nearest tree was identified to species level. The location of the stickhouse was identified as being in one of three types of recreational areas: no dogs, dogs on leash, and dogs off leash.

In addition to the eight random transects in undisturbed areas, DGPS measurements of stickhouses were taken within 10 meters of all hiking trails on the preserve (with the exception of the Cordilleras Trail – where the adjacent land is not owned by MROSD) to examine the effects of human and canine disturbance. Activity and size measurements of these stickhouses were recorded, and the same data were collected for microhabitat analyses as for the undisturbed areas (Table 1).

Finally, in order to study the potential effect that dogs may have on woodrat activity, DGPS measurements and microhabitat data (Table 1) were recorded for all stickhouses within the Hassler Loop Trail. This area is designated as an off-leash dog recreational area, so the canine disturbance is likely more pronounced than along the hiking trails where dogs are restricted to a 1.8 meter (6 foot) radius.

At each stickhouse mapped with DGPS, a 1-m by 1-m plot was marked off in a randomly selected cardinal direction one meter from the stickhouse. All vegetation within the plot was identified to species level.

All data were transferred to a Geographic Information System (ArcGIS 8.3). The distance between the nearest stream and each stickhouse was determined by the GIS.

Slope and aspect were derived from a 10-m Digital Elevation Model (DEM) using ArcView Spatial Analyst.

Stickhouse locations were analyzed by categorizing the disturbance level into three types. Areas with minimal disturbance were defined as being more than 10 m from any trail, and not within the Hassler Loop Trail (off-leash dog area). This refers to the eight randomly selected quadrats described above. Areas with moderate disturbance are defined as being located within 10 m of all trails and not within the Hassler Loop Trail. (The MROSD regulation for leash length is 6 feet, but 10 m was used to allow for indirect disturbance such as noise from barking and scents of the dogs.) Areas with severe disturbance are defined as being located within the Hassler Loop Trail.

Disturbance levels were compared against categorical microhabitat variables (cover type and aspect) using Pearson chi-square tests. Tukey HSD Pairwise Comparisons were used to determine the difference between means required for significance across disturbance levels and continuous microhabitat variables (percent tree cover, percent shrub cover, distance to nearest tree, and distance to nearest stream). The Stuart Tau-c Statistic was used to test the two ordinal variables, disturbance level, and slope to determine whether the distributions were linearly related. Due to the exploratory nature of this study, in all analyses $\alpha = 0.10$ was used as the level for statistical significance.

RESULTS AND DISCUSSION

There were 243 stickhouses identified in the study area. Eighty-two stickhouses were in areas with minimal disturbance (33.7%), ninety-two stickhouses were in areas with moderate disturbance (37.9%), and sixty-nine stickhouses were in areas with severe disturbance (28.4%) (Table 2). Of the houses identified in the minimal disturbance areas, most were located under ground cover, covered by shrubs or fallen logs (45.1%), followed by under tree cover, in or against a tree (31.7%), and with no cover (23.2%). With moderate disturbance, again most houses were located under ground cover (41.3%), but this was followed very closely by under tree cover (40.2%), with only 18.5% of the houses found with no cover. In severe disturbance areas, few houses were found with no cover (11.6%), more houses were found under ground cover (33.3%), but most houses were found under tree cover (55.1%) (Table 2). A Pearson chi-square ($X^2 = 9.097$, df = 4, $p = 0.059$) was performed on the null hypothesis that disturbance levels have no effect on house location (cover type). The data indicate cover type is influenced by disturbance level. However, because the stickhouse data collected within 10 m of trails were not randomly sampled in the same fashion as the stickhouse data collected from the 8 randomly selected quadrats, these results should be interpreted with care. The data used were not generated using probability sampling methods and the p -values are presented for exploratory use only.

The results of the chi-square analysis show cover type is influenced by human and canine disturbance rather than topography. In areas with minimal disturbance, most stickhouses were found in ground cover (45.1%) and least were found with no cover

(23.2%). Stickhouses in areas with moderate disturbance (along trails) were almost evenly distributed in ground cover and tree cover (41.3% and 40.2%, respectively) with few being found with no cover (18.5%). In Pulgas Ridge the trails weave in and out among the oak woodland, chaparral and riparian microhabitats. While some trees and shrubs are cleared for safety purposes when trails are made, trails on MROSD properties are designed to preserve the existing vegetation, especially native vegetation. Previous studies have shown a close obligate relation between *N. fuscipes* and several oak species. Smith et al. (2000) found that the degree of overlap between the ranges of *N. fuscipes* and *Quercus agrifolia*, *Q. chrysolepis*, *Q. lobata* and *Q. garryana* was far beyond expectations. "They occur in sympatry in over 69.6% of their combined estimated range of ~404,814 km^2" (Smith et al. 2000:491). The high incidence of stickhouses in ground cover as well as tree cover along trails is likely due to the density of the shrubs offering equal camouflage and protection from humans and dogs as tree cover would.

The fact that similar low numbers of stickhouses were found with no cover in both minimally disturbed and moderately disturbed areas (23.2% and 18.5%, respectively) suggests that human presence along trails appears to have a twofold effect: prevention of direct canine disturbance of nests (where leashed dogs are more able to be controlled by their owners), and indirect prevention of natural predator disturbance (by a coyote or owl's avoidance of humans, for example). Future studies could validate this assumption by determining if trails are actually avoided by the dusky-footed woodrat's natural predators in this area.

Stickhouses in areas with severe disturbance were most likely to be found under tree cover (55.1%), followed by under ground cover (33.3%), and no cover (11.6%). The higher percentage of stickhouses under tree cover in this area might reflect the difference between a direct disturbance such as a dog digging at a stickhouse entrance versus more indirect disturbance such as the noise from dogs barking that might dissuade a woodrat from building a nest in a particular area. It is reasonable to expect that in the off-leash dog areas, if a dog disturbs a stickhouse by sniffing and digging at it, the residing woodrat might abandon that nest and build a nest in a more inaccessible area with more protection. The arboreal nature of woodrats and their use of trees for escape routes and protection from predators (Gander 1929; and Vestal 1938) further support the fact that most stickhouses in undisturbed and off-leash dog areas were found under tree cover.

Tukey HSD Pairwise Comparisons were used to determine the difference between means required for significance across the categorical independent variable disturbance level and one continuous variable. When the continuous variable used was percent tree cover, the Tukey test indicated that there was a significant difference in the way that percent tree cover affects minimal and severe disturbance ($p = 0.059$). Average tree cover differs depending on disturbance level, with more disturbance again associated with a higher percent tree cover. Pairwise groupings show a significant difference between the true means of stickhouses in minimal to moderate disturbance, and moderate to severe disturbance.

The Tukey HSD test for percent shrub cover also showed that there was a difference in average shrub cover depending on disturbance level ($p = 0.072$) where average shrub cover increased as disturbance decreased. Pairwise groupings show a significant difference between the true means of stickhouses in minimal to moderate disturbance, and moderate to severe disturbance. This is consistent with the results that most stickhouses were found under ground cover in areas with minimal disturbance.

The Tukey HSD test for distance to the nearest tree showed pairwise groupings consistent with the test for percent tree cover: the true means of minimal to moderate disturbance were significantly different from the true means of moderate to severe disturbance ($p = 0.012$). As disturbance increased, a stickhouse's distance to the nearest tree decreased.

The Tukey HSD test for distance to streams did show a significant difference in the average distances depending on disturbance level (139 m for moderate disturbance, 180 m for minimal disturbance, and 270 m for severe disturbance, $p = 0.0$); however, all three means were substantially higher than a woodrat's home range (Cranford 1976) so there was no evidence of an association of nest placement with proximity to streams.

A Pearson chi-square indicates that there are significant differences between disturbance level ($X^2 = 66.756$, df = 12, $p = 0.0$) due to aspect (Table 3). In areas with the lowest and highest disturbance, most stickhouses were found on northeast-facing slopes; in areas with moderate disturbance, most stickhouses were found on north-facing slopes (Table 3). No stickhouses were found on west-facing slopes. These results are likely due to the fact that north-facing slopes have more vegetation which woodrats use for both food and shelter.

The Stuart Tau-c Statistic was used to test the two ordinal variables, slope and disturbance level to determine whether the distributions were linearly related. This test indicated a significant correlation between slope and disturbance level ($T_c = -7.729$, $p = 0.0$). The number of stickhouses found in areas with minimal and moderate disturbance increased as slope increased, up to 59% (see Table 4). In areas with severe disturbance, most stickhouses were found on slopes of 10-19%, though there was a trend of increasing numbers of stickhouses found as slope increased up to 49%. Although some stickhouses were found on slopes up to 69%, it is likely that the stability becomes problematic at very high slopes. However, woodrats are still able to build stickhouses on grades that would be challenging for many animals to navigate, allowing some protection against predators. The fact that only one stickhouse was built on a slope in the 0-9% range suggests that functional stickhouses require some slope, probably to promote sufficient drainage. This test showed a negative correlation exists between slope and disturbance level: as slope decreased, disturbance increased. It is probable that in the case of slope, stickhouse location is more a function of the topography than proximity to humans and dogs, where there are more trails (and consequently more humans and dogs) found in areas with less slope.

In summary, the above analyses largely support the hypothesis that stickhouse locations and microhabitat variables of stickhouses are affected by human and canine disturbance. A chi-square analysis shows the effect of disturbance on cover type is significant, with stickhouses in minimal disturbance areas most often found under ground cover; stickhouses in areas with moderate disturbance most often found under ground and tree cover; and stickhouses in areas with severe disturbance most often found under tree cover. Percent tree cover, percent shrub cover, and distance to nearest tree were affected by human and canine disturbance. As disturbance increased, percent tree cover increased. Percent shrub cover and distance to nearest tree both decreased as disturbance increased. A stickhouse's distance to closest stream, aspect, and slope, however, were not affected by human or canine disturbance, instead being influenced more by the topography of the site.

Neotoma fuscipes annectens appears to be a very adaptable species. When stickhouses have been damaged or destroyed, they can be repaired overnight (Vestal 1938). Woodrats build their stickhouses in such a way as to optimize their safety, both in terms of natural topographic factors as well as due to human and canine disturbance. Dusky-footed woodrats play an important role in the ecosystem, both in terms of the role of stickhouses, and their relationship with the spotted owl. Studies to determine the microhabitat characteristics woodrats require are important for preserving the habitat necessary for woodrats to thrive.

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Table 1. - Stickhouse microhabitat parameters measured.

Parameter	Subscales	Categories
Stickhouse location	Longitude	Continuous
	Latitude	Continuous
Stickhouse location	Leaning against tree	+/-
	On ground, independent	+/-
	On ground, covered by log or shrubs	+/-
	In tree	+/-
Recreation Use	Dogs off leash	+/-
	Dogs on leash	+/-
	No dogs	+/-
Percent Tree Cover (> 0.4 dbh)	Percent	0 – 100%
Percent Shrub Cover (< 0.4 dbh)	Percent	0 – 100%
Slope	Degrees	0 – 90°
Aspect	North, Northeast, East, Southeast, South, Southwest, West, Northwest	+/-
Distance to Nearest Stream, in meters	0 – 25, 26 – 50, 51 – 75, 76 – 100, 101 – 125, 126 – 150, 151 – 175, 176 – 200, 201 – 225, 226 – 250, 251 – 275, 276 – 300, 301 – 325, 326 - 350	+/-
Distance to nearest tree	meters	Continuous

Table 2. -Stickhouse location within cover type and disturbance level.

			Minimal Disturbance	Moderate Disturbance	Severe Disturbance	Total
Cover Type	No Cover	Stickhouse Count	19	17	8	44
		% within Cover Type	43.2%	38.6%	18.2%	100.0%
		% within Disturbance	23.2%	18.5%	11.6%	18.1%
		% of Total	7.8%	7.0%	3.3%	18.1%
	Ground Cover (in shrubs or under log)	Stickhouse Count	37	38	23	98
		% within Cover Type	37.8%	38.8%	23.5%	100.0%
		% within Disturbance	45.1%	41.3%	33.3%	40.3%
		% of Total	15.2%	15.6%	9.5%	40.3%
	Tree Cover (in or under tree)	Stickhouse Count	26	37	38	101
		% within Cover Type	25.7%	36.6%	37.6%	100.0%
		% within Disturbance	31.7%	40.2%	55.1%	41.6%
		% of Total	10.7%	15.2%	15.6%	41.6%

Table 2. -Continued.

		Minimal Disturbance	Moderate Disturbance	Severe Disturbance	Total
Total	Stickhouse Count	82	92	69	243
	% within Cover Type	33.7%	37.9%	28.4%	100.0%
	% within Disturbance	100.0%	100.0%	100.0%	100.0%
	% of Total	33.7%	37.9%	28.4%	100.0%

Table 3. -Stickhouse location within aspect and disturbance level.

			Minimal Disturbance	Moderate Disturbance	Severe Disturbance	Total
Aspect	E	Stickhouse Count	7	8	11	26
		% within Aspect	26.9%	30.8%	42.3%	100.0%
		% within Disturbance	8.5%	8.7%	15.9%	10.7%
		% of Total	2.9%	3.3%	4.5%	10.7%
	N	Stickhouse Count	7	34	18	59
		% within Aspect	11.9%	57.6%	30.5%	100.0%
		% within Disturbance	8.5%	37.0%	26.1%	24.3%
		% of Total	2.9%	14.0%	7.4%	24.3%
	NE	Stickhouse Count	31	22	27	80
		% within Aspect	38.8%	27.5%	33.8%	100.0%
		% within Disturbance	37.8%	23.9%	39.1%	32.9%
		% of Total	12.8%	9.1%	11.1%	32.9%

Table 3. -Continued.

			Minimal Disturbance	Moderate Disturbance	Severe Disturbance	Total
Aspect	NW	Stickhouse Count	0	9	0	9
		% within Aspect	0%	100.0%	0%	100.0%
		% within Disturbance	0%	9.8%	0%	3.7%
		% of Total	0%	3.7%	0%	3.7%
	S	Stickhouse Count	20	6	0	26
		% within Aspect	76.9%	23.1%	0%	100.0%
		% within Disturbance	24.4%	6.5%	0%	10.7%
		% of Total	8.2%	2.5%	0%	10.7%
	SE	Stickhouse Count	11	11	13	35
		% within Aspect	31.4%	31.4%	37.1%	100.0%
		% within Disturbance	13.4%	12.0%	18.8%	14.4%
		% of Total	4.5%	4.5%	5.3%	14.4%

Table 3. -Continued.

			Minimal Disturbance	Moderate Disturbance	Severe Disturbance	Total
Aspect	SW	Stickhouse Count	6	2	0	8
		% within Aspect	75.0%	25.0%	0%	100.0%
		% within Disturbance	7.3%	2.2%	0%	3.3%
		% of Total	2.5%	0.8%	0%	3.3%
Total		Stickhouse Count	82	92	69	243
		% within Aspect	33.7%	37.9%	28.4%	100.0%
		% within Disturbance	100.0%	100.0%	100.0%	100.0%
		% of Total	33.7%	37.9%	28.4%	100.0%

Table 4. -Stickhouse location within slope and disturbance level.

			Minimal Disturbance	Moderate Disturbance	Severe Disturbance	Total
Slope	0-9% Slope	Stickhouse Count	0	0	1	1
		% within Slope	.0%	.0%	100.0%	100.0%
		% within Disturbance	.0%	.0%	1.4%	.4%
		% of Total	.0%	.0%	.4%	.4%
	10-19% Slope	Stickhouse Count	2	6	24	32
		% within Slope	6.3%	18.8%	75.0%	100.0%
		% within Disturbance	2.4%	6.5%	34.8%	13.2%
		% of Total	.8%	2.5%	9.9%	13.2%
	20-29% Slope	Stickhouse Count	10	12	15	37
		% within Slope	27.0%	32.4%	40.5%	100.0%
		% within Disturbance	12.2%	13.0%	21.7%	15.2%
		% of Total	4.1%	4.9%	6.2%	15.2%

Table 4. -Continued

			Minimal Disturbance	Moderate Disturbance	Severe Disturbance	Total
Slope	30-39% Slope	Stickhouse Count	22	20	18	60
		% within Slope	36.7%	33.3%	30.0%	100.0%
		% within Disturbance	26.8%	21.7%	26.1%	24.7%
		% of Total	9.1%	8.2%	7.4%	24.7%
	40-49% Slope	Stickhouse Count	17	21	11	49
		% within Slope	34.7%	42.9%	22.4%	100.0%
		% within Disturbance	20.7%	22.8%	15.9%	20.2%
		% of Total	7.0%	8.6%	4.5%	20.2%
	50-59% Slope	Stickhouse Count	22	28	0	50
		% within Slope	44.0%	56.0%	.0%	100.0%
		% within Disturbance	26.8%	30.4%	.0%	20.6%
		% of Total	9.1%	11.5%	.0%	20.6%

Table 4. - Continued.

			Minimal Disturbance	Moderate Disturbance	Severe Disturbance	Total
Slope	60-69% Slope	Stickhouse Count	9	5	0	14
		% within Slope	64.3%	35.7%	.0%	100.0%
		% within Disturbance	11.0%	5.4%	.0%	5.8%
		% of Total	3.7%	2.1%	.0%	5.8%
Total		Stickhouse Count	82	92	69	243
		% within Slope	33.7%	37.9%	28.4%	100.0%
		% within Disturbance	100.0%	100.0%	100.0%	100.0%
		% of Total	33.7%	37.9%	28.4%	100.0%

Figure 1: -Pulgas Ridge Open Space Preserve. Printed from Midpeninsula Regional Open Space District © 10-2003. Pulgas Ridge Preserve map provided courtesy of MROSD.

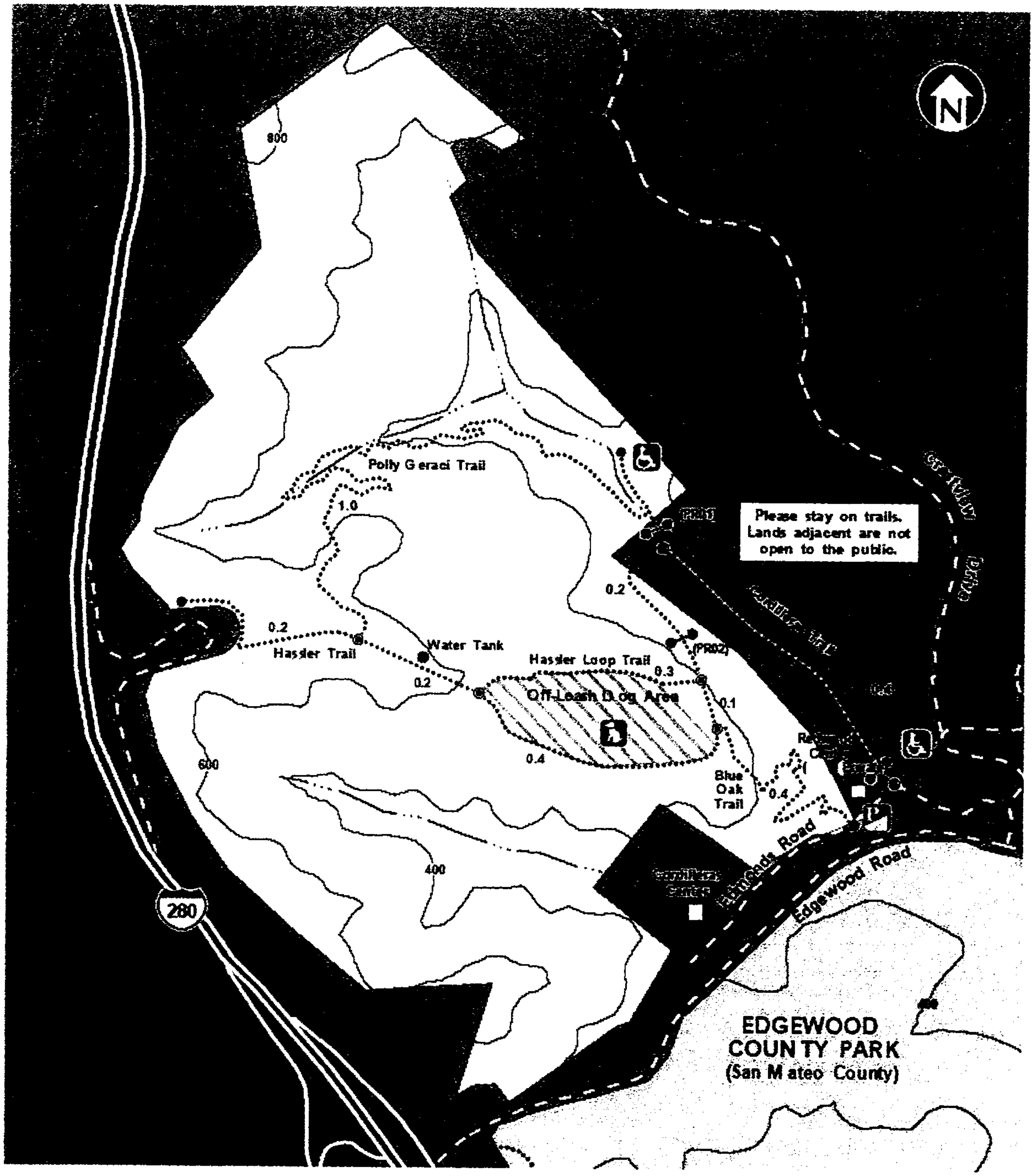

Figure 2: -GIS 3-dimensional representation of the study area showing the locations of stickhouses in areas of minimal, moderate, and severe disturbance.