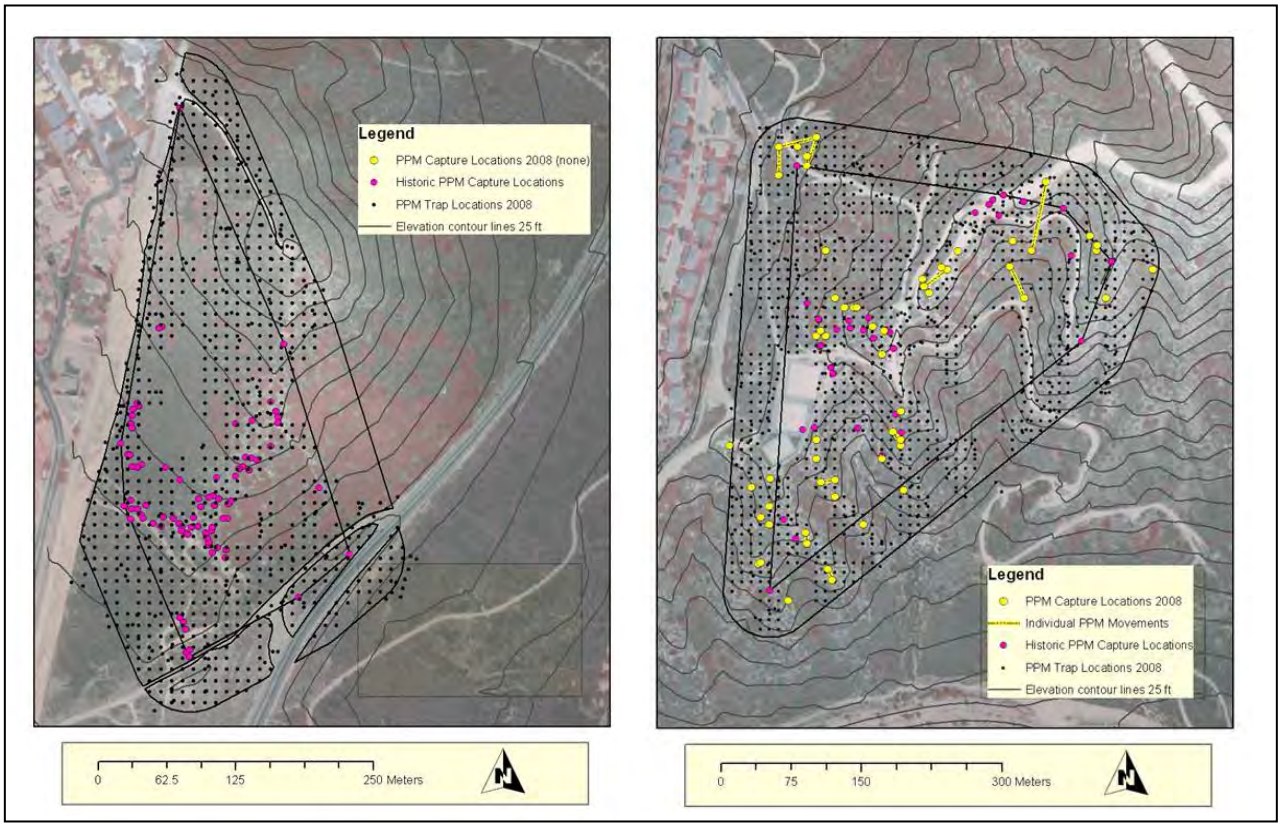
Secondary Identification and /or Statement of Cooperation

2008 Survey Results for the Pacific Pocket Mouse: North and South San Mateo, Marine Corps Base, Camp Pendleton; with additional analyses to inform long-term monitoring design.

By C.S. Brehme and R.N. Fisher



Data Summary

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2008 Survey Results for the Pacific Pocket Mouse: North and South San Mateo Sites of Marine Corps Base, Camp Pendleton; with additional analyses to inform long-term monitoring design.

By C.S. Brehme and R.N. Fisher

Abstract

In preparation for developing a comprehensive long term monitoring plan for the Pacific pocket mouse (PPM), a scientific panel agreed that several preliminary 'pilot' studies were warranted to generate information needed to draft a quality program. This report describes the first short term study identified as a priority, which was to immediately and comprehensively assess the status of North San Mateo (NSM) and South San Mateo (SSM) PPM populations.

From May 5 to June 27, 2008, we conducted surveys for PPM at NSM and SSM. Our main goals were: 1) to assess if there were relatively low or high numbers of PPM and how they were distributed over the study areas. Secondary goals were to evaluate habitat covariate data at both small and large spatial scales (3m diameter around trap vs. 50m plot) to determine what covariates at which scales may be predictive of PPM occupancy, and 2) to evaluate occupancy and detection probability at the level of a 50m plot.

Study areas were defined by minimum convex polygons around all historic captures with an added 50m buffer for both sites, representing 9.7 and 15.3 hectares for NSM and SSM, respectively. All accessible habitat within these areas were surveyed using Sherman live-traps placed 10m apart within 50m X 50m plots. An extra three pairs of traps were also subjectively placed within each plot in microhabitats deemed most suitable for PPM. We trapped a standard of three consecutive nights. However, if there were no PPM captures in the first two nights of a trapping session, we trapped for four consecutive nights.

We captured a total of 45 PPM individuals, all within the SSM study area. PPM captured were evenly distributed by sex and age class. The captures were spatially distributed throughout

South San Mateo, including 16 within the outer 50m buffer area indicating that PPM extend beyond the study boundaries.

The probability of capturing PPM individuals was very low at 0.17 (95% CI; 0.02-0.63). This means that an estimated average of only 17% of the population may be captured on any given night. After three nights, we would expect to encounter 43% of the population. This low probability, along with unmodeled heterogeneity, resulted in very wide confidence limits around the population estimate of 117 (0 – 378). Our data was consistent to that reported from extensive trapping studies of Oscar One and Dana Point by the U.S. Fish and Wildlife Service. These data support their conclusions that many trap nights are needed to accurately estimate PPM abundance.

In contrast, the probability of detecting the presence of PPM within a $50m^2$ plot on a given night was much higher at an estimated 0.70. This resulted in a 0.93 probability of detecting PPM occupancy within a plot after three nights of trapping. Correspondingly, the 95% confidence interval around the estimate of occupancy was more reasonable (0.40-0.67). The occupancy estimate for SSM also falls within the range of occupancy values (0.2-0.8) recommended for design of occupancy studies (MacKenzie et al. 2006). This indicates that the plot size of $50m^2$ is appropriate for this study area.

At the large scale ($2500m^2$, 0.25ha), there were no significant differences in the distributions of habitat covariates and none were predictive of PPM occupancy in the PRESENCE analysis. At the small scale level ($28m^2$), PPM selected areas with more open sandy patches (median value of 20% vs. 5%) and less open ground (median value of 10% vs. 20%). PPM selected plots with an average of 39% (se= 3%) shrub cover. The selected cover values were normally distributed about the mean which differed from the uniform distribution of shrub cover values available across the site. These results suggest that PPM select habitat patches with open sand, which is consistent with their life history characteristics. Sand is needed for dust bathing, communication, and preferred as a burrowing substrate. Additionally, PPM may avoid open areas with compacted substrate and prefer areas with a moderate amount shrub cover.

The different results by spatial scale suggest that even though PPM can move large distances over the landscape, they select and utilize habitat on a smaller scale level. In consideration of a long term spatial monitoring program, this may require the collection of habitat data at multiple spatial scales.

Although this study was not designed to generate data on PPM movements, the marking scheme and limited number of PPM allowed us to track movements of 14 individuals captured on more than one occasion. In our study, 14% (2/14) of animals moved linear distances greater than the plot length of 50m within the three day trapping period. In order to minimize any violations of closure, we recommend this as a minimum plot size for occupancy monitoring.

Our activities had noticeable impacts on habitat in both NSM and SSM. Although we were careful, our repeated passes created open trails and minor landslides on the sandy slopes that could crush PPM burrows. Any long term monitoring plan should seek to reduce this impact.

In contrast to South San Mateo, there were no PPM captures at North San Mateo after 4 nights of trapping. We hypothesize that a combination of stressors is responsible for the apparent decline in PPM numbers at NSM. These include decreased food resources and suitable habitat, along with greater pressure from human impacts and invasive species. In comparison to SSM, NSM had higher cover of shrubs and leaf litter and significantly less cover of forbs, grasses, open ground, and sandy patches. These results were consistent over both large and small scales. In addition, small mammal density and species richness were also reduced at NSM and the invasive Argentine ant was widespread. The area was also heavily impacted by human and canine use.

We recommend restoration of habitat at the NSM site to include creation of sandy patches and thinning of vegetation, particularly focused in and around areas previously inhabited by PPM. For SSM, our recommendations include surveying for PPM over a larger area in order to better understand their actual distribution over this site and to define the study area boundaries for long term monitoring.

Introduction

The primary mission for Marine Corps Base Camp Pendleton (MCBCP) is "to operate an amphibious training Base that promotes the combat readiness of operating forces by providing facilities, services, and support responsive to the needs of Marines, Sailors, and their families" (MCB Camp Pendleton Strategic Plan 2002). In addition, the base has committed to fulfill stewardship and regulatory requirements for the natural resources on base. This includes monitoring and management for the endangered Pacific pocket mouse (*Perognathus longimembris pacificus*, PPM) as described in the MCBCP Integrated Natural Resources Management Plan (October 2001). The U.S. Geological Survey was contracted to develop a scientifically valid, effective, and cost-effective monitoring program for the PPM on MCBCP in 2007. The monitoring program should document trends in the status of PPM on base and identify results criteria for management action.

In 2007, the USGS, representatives from MCBCP, and a scientific review panel reviewed literature on PPM ecology and previous monitoring efforts in order to construct a long term monitoring plan for PPM on MCBCP. A two-day workshop was held on September 6th and 7th in which many independent and agency scientists, consultants, and land managers gave additional input. The major consensus along with workshop materials and panel comments are presented in the document “Pacific Pocket Mouse Monitoring Plan for Marine Corps Base Camp Pendleton: Short Term Studies and Long Term Goals” (2009). In general, the panel agreed upon a ‘proportion area occupied’ (PAO) spatial approach to monitoring the largest population within the Oscar One and Edson training areas. This approach may be used for the smaller San Mateo populations; however, it is suspected that if population sizes are very small, these areas may require a more intensive annual census. In addition, a portion of annual effort should go toward discovery of ‘new’ populations of PPM within suitable habitat less than 5km from the coast. Finally, the panel agreed that the current accepted sampling technique of live-trapping is not ideal, as extensive data from FWS has revealed its limitations; low capture probabilities, high impact, high effort, and high cost. The panel would like to explore the feasibility of alternative methods.

In preparation for developing a comprehensive long term monitoring plan for PPM, the panel agreed that several preliminary 'pilot’ studies were warranted to generate information needed to draft a quality program. This report describes the first short term study identified as a priority,

which was to immediately and comprehensively assess the status of North and South San Mateo PPM populations. Other short term studies identified include assessing effectiveness of alternate sampling methodologies (in 2009) and assessing initial occupancy estimates, sample unit size, statistical power and precision of a pilot PAO program in Oscar One (2010-11).

Pacific Pocket Mouse

The Pacific pocket mouse (PPM) is one of 19 subspecies of the little pocket mouse (*Perognathus longimembris*) in the heteromyid rodent family. This subspecies was historically rare and patchily distributed along coastal southern California. They were thought to be extinct until rediscovered in 1993 on Dana Point. PPM were federally listed as endangered on September 29, 1994 and were subsequently found in three locations within MCB, Camp Pendleton in 1995 (North San Mateo, South San Mateo, and North Santa Margarita or "Oscar One"). These four locations comprise the only currently known extant populations of this subspecies.

PPM have been historically found on southern California marine terraces and alluvial plains within 4 km of the coast. They are typically associated with open patches of sandy soils within coastal sage scrub communities, although vegetation characteristics, such as shrub and grass cover, vary considerably. Their diet is comprised primarily on small seeds of grasses (*Bromus*, other) and herbs/forbs (*Croton californicus, Heterotheca grandiflora, Pluchea sericea, Hordeum murinum, Centaura melitensis, Corethrogyne filaginafolia, Gnapthalium sp., Calacadenia sp*., other) and shrubs (*Eriogumun fasciculatum*, Meserve 1976b, Germano 1997). PPM have a long lifespan for a rodent of up to 8 years in captivity and 3 to 4 years in the wild (French et al.1967, Hayden and Lindberg 1976).

PPM are nonsocial, nocturnal, and physiologically adapted to warm and dry climates. They go into variable amounts of facultative torpor during the winter and in response to low resource conditions. Above ground activity is thought to coincide with seed availability, which may extend from March through September, but is most dependable in late April, May and June (Meserve 1976a, Shier 2009). The demography of foraging mice has been shown to change within the active season. From early to late season, the dominant demographic group will change from adult males to adult females to young of the year. This is consistent with reproductive activity (Miller and Pavelka 2008, Shier 2009).

The onset of breeding is typically in early spring. Females gestate young for about 2 days and wean young after 30 days. There may be no reproduction in low resource years. However, in

high resource years, adult females may have up to two litters with their female offspring mating and reproducing in a single season (Miller and Pavelka 2008). Because of this, PPM abundance can be highly variable within and among years.

PPM exhibit typical behaviors of heteromyid rodents including sand bathing to keep pelage clean and healthy, collection of seeds in external cheek pouches, and caching of seeds below ground and within burrow systems for sustenance throughout the year.

PPM movements of up to 181m in a single night have been documented, with average movement distances reported of 10m to 30m between successive captures (Dodd et al. 1998, 1999; Miller and Pavelka 2008). The average home range size from 9 individuals was estimated to be 0.017 ha for this species (Shier 2009), which is smaller than that reported for desert *Perognathus longimembris* subspecies (home ranges of 0.12 to 0.56 ha in Joshua Tree (Chew and Butterworth 1964) and 0.3-3.1 ha in Nevada (Maza et al. 1973).

There are many potential threats and stressors to current PPM populations. These include habitat loss (development, soil compaction and associated vegetative loss from heavy use), habitat alteration (overgrowth of non-native grasses or native shrubs), fragmentation (roads, development), increased predation risks (domestic cats, dogs, Argentine ants), and increased competition for seed resources (Argentine ants)(USFWS 1997, Brehme and Fisher 2009).

Study Sites

NSM is within San Onofre State Park (on long term lease from MCBCP). It is a relatively small area bordered by San Clemente golf Course and housing to the northwest and Cristianitos Road and San Mateo Creek (historical agricultural land) to the east. PPM detections from surveys conducted in 1995, 1996, 2000, and 2003 are shown in Figure 1b. A minimum convex polygon around these detections totals 5.6 ha.

The South San Mateo PPM population lies north of Basilone Road and north and east of the San Onofre housing areas. PPM detections from surveys conducted in 1996, 2000, and 2005 are shown in Figure 1a. A minimum convex polygon around these detections totals 8.3 ha.

The extent, timing, placement, and number traps used in previous efforts varied for both sites. PPM detection data was acquired through MCBCP Information Systems Branch and U.S. Fish and Wildlife Service.

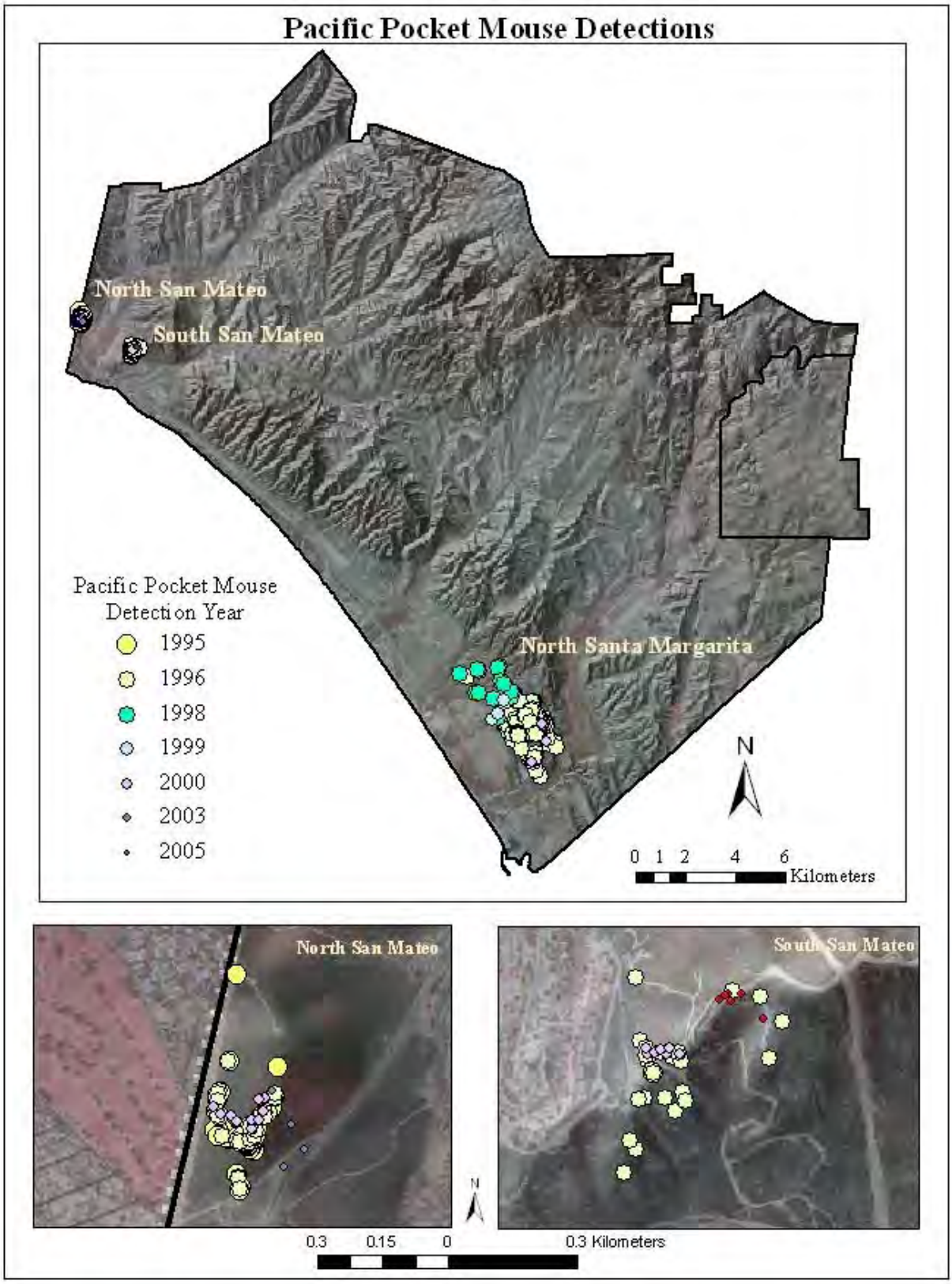

Figure 1. History of PPM Detections on MCB, Camp Pendleton. With insets for a) North San Mateo and b) South San Mateo.

Study Objectives

There were several objectives to this study (Brehme and Fisher 2009):

1. Determine status of North and South San Mateo PPM populations. Are PPM still present? If so, are there few or many? Note: Study not designed to determine "absence" or give precise estimate of population numbers.
2. Determine how these PPM populations are spatially distributed over the landscape.
3. Evaluate habitat covariate data at both small and large spatial scales (3m diameter around trap vs. 50m plot). Determine what covariates at which scales may be predictive of PPM occupancy or habitat use.
4. Evaluate occupancy and detection probability at the level of a 50m plot.

Methods:

Data Collection

Survey areas were defined by drawing a minimum convex polygon around all historic captures with an additional 50m buffer for both North and South San Mateo sites, representing 9.7 and 15.3 hectares, respectively (ArcGIS 9.2, Hawth's Tools). Regular trapping points spaced 10m apart were generated to provide complete trapping coverage of each site. Survey areas were then divided into 50m x 50m plots containing 25 regularly spaced traps to represent our large scale plot size (Figures 2a and 2b).

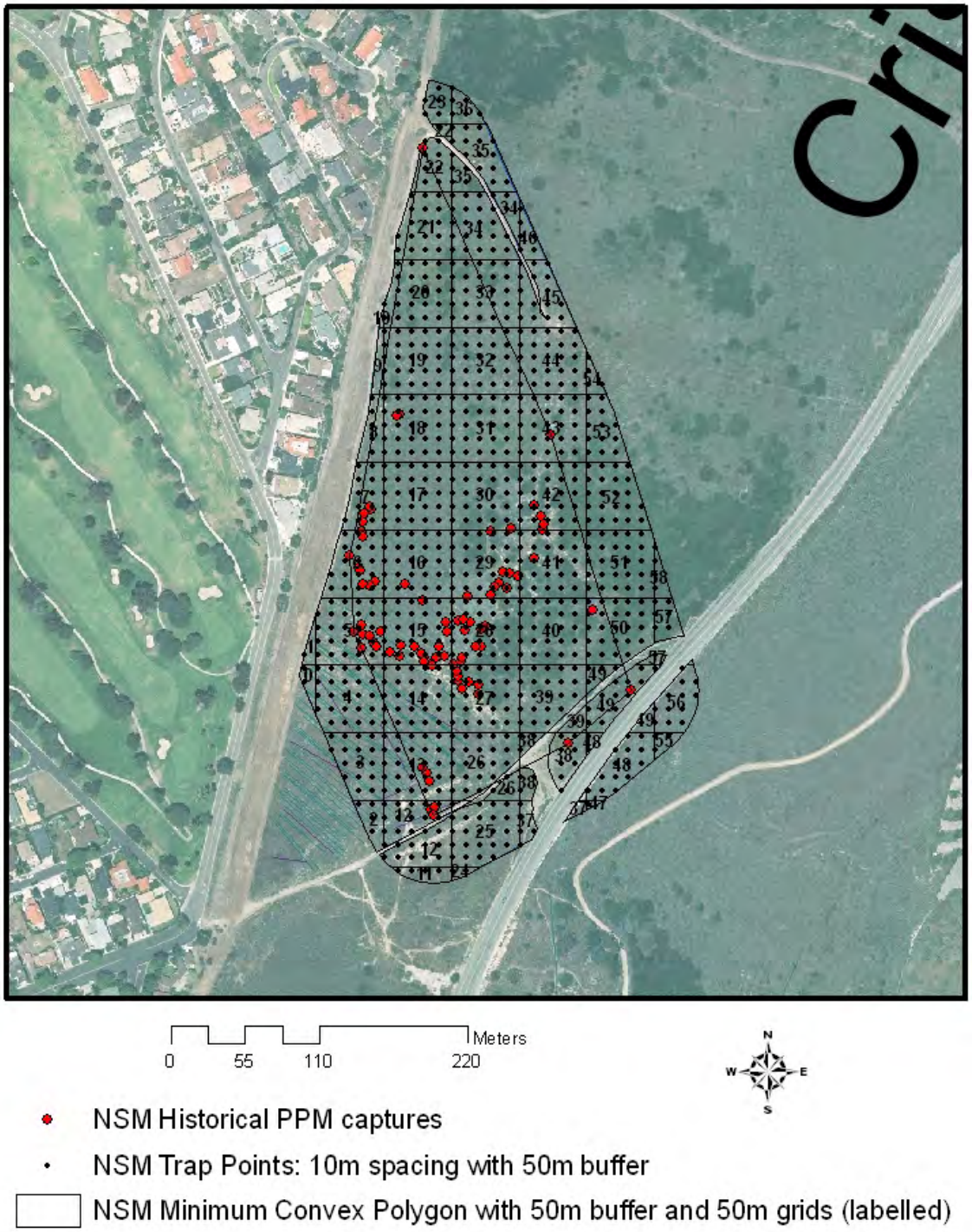

Figure 2a. PPM Trapping plot design for North San Mateo

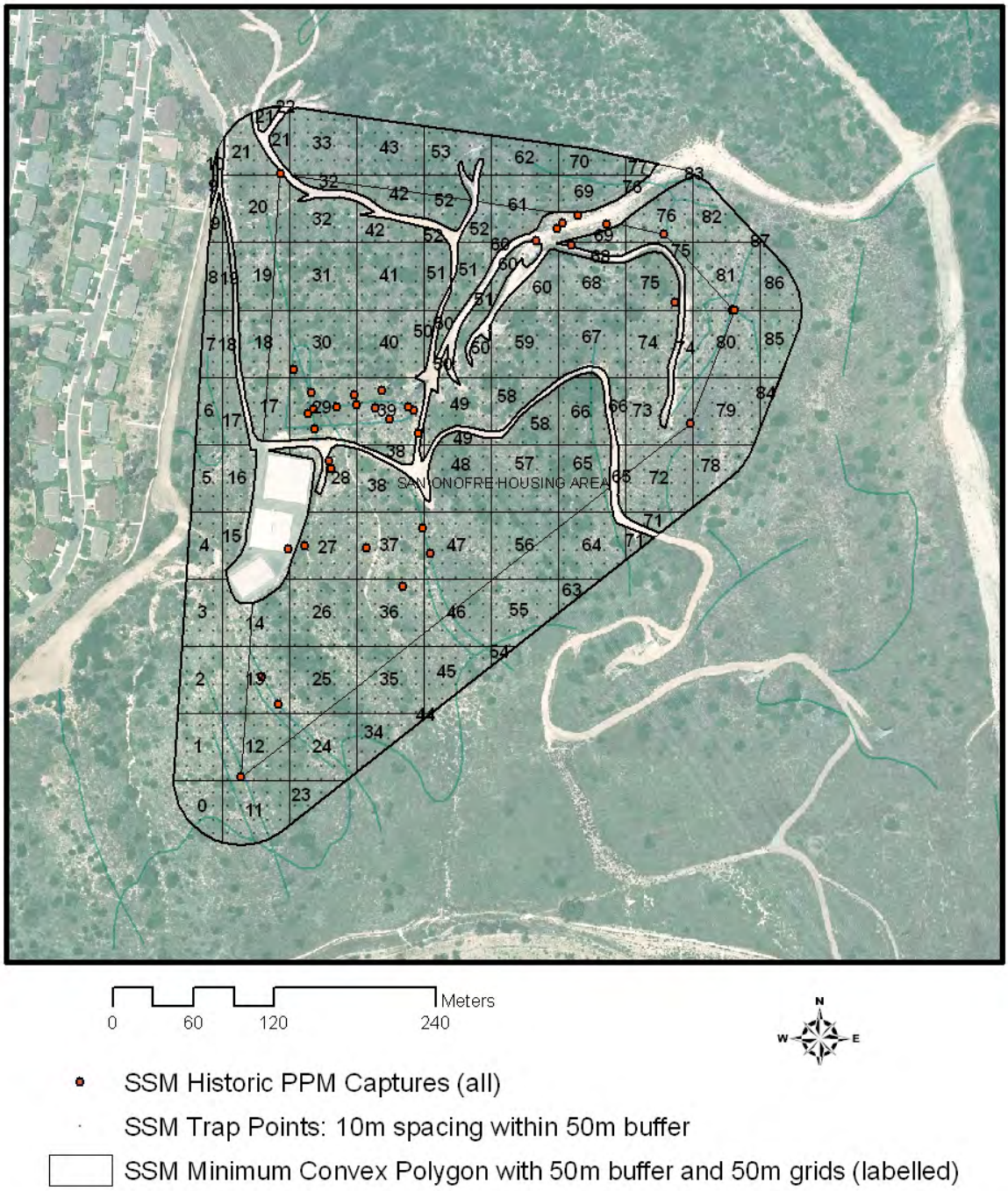

Figure 2b. PPM Trapping plot design for South San Mateo

We live-trapped at all accessible point locations using Sherman live-traps (3x3.5x9"). Some habitat was not accessible due to very steep (and often sandy) terrain or impassable vegetation, such as thick mature stands of laurel sumac (*Malosma laurina*) or prickly pear cactus (*Opuntia littoralis*). We placed traps within 50m x 50m sample plots. First, we located the corners with GPS (Garmin 12XL), we then placed traps around the perimeter and inner potions of the plot, using GPS along with line of sight. This enabled us to keep the plots and traps as even and accurate as possible with a GPS error ranging from 3m to 5m, as well as over uneven and heavily vegetated terrain. We also subjectively placed three pairs of additional traps within each 50m plot. These extra traps were placed near open sandy patches with a shrub cover edge to maximize detectability of PPM. To determine if PPM scent may attract other PPM into the traps, we obtained "PPM sand" (PPM had bathed in) and placed approximately a tablespoon into one of each pair of subjectively placed traps. The other trap received a similar amount of localized substrate. The "PPM sand" was obtained through concurrent behavioral studies being conducted by Debra Shier, San Diego Zoo/CRES.

We conducted all of our trapping efforts in May and June, when PPM are thought to be most reliably active and above-ground. Each week, we trapped different sets of plots as shown in Table 1. We attempted to spread out the sampling spatially over the time period, so that there were no systematic biases in our data collection. The difficulty of the terrain prevented us from doing a complete random selection of plots each week.

Table 1. Dates and plots surveyed in May and June 2008.

Date	No. of trap nights	Site	Grids	No. Traps
5/5-5/8	3	South San Mateo	50E , 54-61	175
5/12-5/15	3	South San Mateo	0-21	363
5/19-5/22	3	South San Mateo	39-53	343
5/27-5/31	4	North San Mateo	0, 1, 3-9, 15-23	298
6/2-6/6	4	North San Mateo	2,11-14, 24-28, 37-40, 47-50, 55-57	386
6/9-6/13	4	North San Mateo	28 (rpt), 29-36, 41-46, 51-54, 58	372
6/16-6/20	3	South San Mateo	23-43	474
6/23-6/26	3	South San Mateo	63-86	387

Each week, we trapped for a standard of three nights. However, we extended the trapping effort to four nights if no PPM were captured by the second night. (Note: FWS recommends a minimum of five nights of trapping for presence/absence surveys. The purpose of these surveys was not to establish absence- see Introduction/ Objectives sections).

Traps were set on the first day and baited with birdseed composed primarily of millet. Each day, traps were checked in the late evening from approximately 11:00PM to 2:30AM and again in the morning from 5:30AM to 10:00AM. Throughout the trapping effort, traps were closed during the morning check and re-opened and baited after 3:00PM. We assessed all animals for age, sex, and reproductive condition. We also recorded hind foot length, ear length, head length, tail length and weight of all PPM. Subadults were identified by the presence of partial grey pelage on the body or legs. We photographed all PPM individuals. Starting in June, we took a very small sliver of the ear to provide to Debra Shier, CRES (Conservation and Research for Endangered Species, Zoological Society of San Diego) as directed by USFWS for genetic research. We used sharp surgical scissors that we sterilized with alcohol before and after each use and took care to avoid any large blood vessels. All animals were temporarily batch marked by clipping a small amount of fur from the hip area to document recaptures. The clips were unique to time and day of trapping (first night/morning = upper/lower right hip clip, second night/morning = upper/lower left hip clip, third night/morning = upper/lower back clip, fourth night/morning = upper/lower back of neck/head clip). We used different color permanent markers under the chin area each week in order to identify any individuals that may have been captured in a previous session.

In addition, we collected habitat covariate data at both large and small scales by visual estimation to determine if any may be predictive of PPM occupancy. The large-scale data were taken at the level of the 50m plot. Smaller scale data were taken in a 3m circumference around each trap. Because we found that we were not able to complete habitat surveys at each and every trap, we surveyed four traps per plot at regularly spaced locations (B2, B4, D2, and D4 locations in a 5X5 plot labeled 1-5 along one axis and A-E along the other axis, Figure 3). We also collected habitat covariate data at all trap locations where we captured a PPM.

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Cheryl Brehme- Independent
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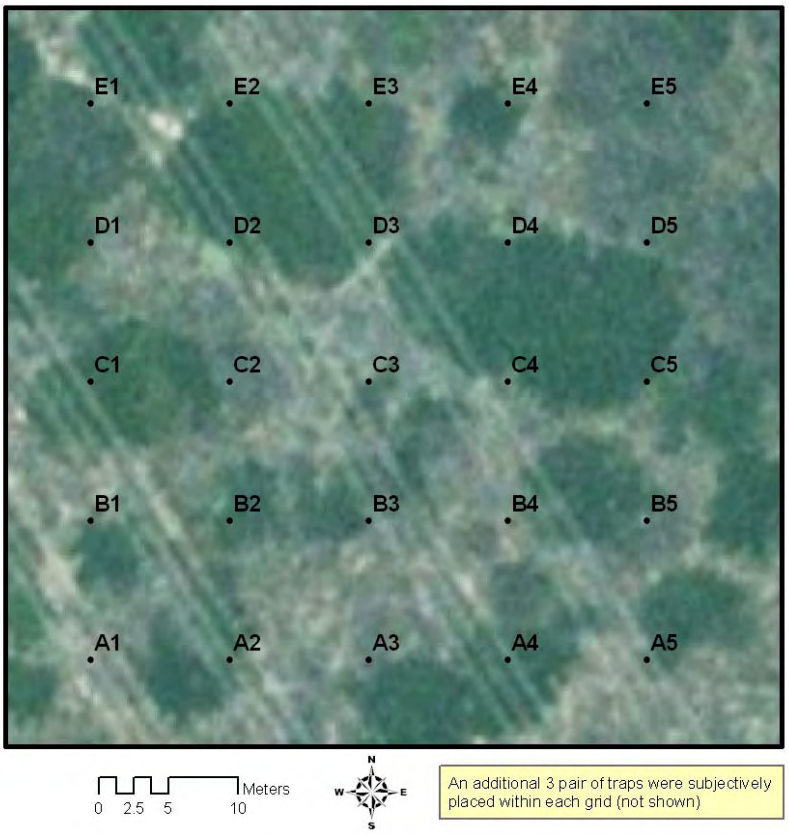

Figure 3. Diagram of trap locations and labeling within a 50m x 50m plot

The following habitat covariate data were collected in the field.

- GPS coordinate (every trap).
- Presence of sandy patches? (Y/N with estimated proportion- small & large scale).
- Vegetative cover (estimated proportion of each growth form: herbs/forbs, grasses, shrubs/trees, open ground, leaf litter; Visual estimates- small & large scale).
- Dominant plant species. Up to three species recorded that comprised at least 20% of cover for each growth form (small & large scale).
- Slope & aspect (small & large scale).
- Other rodent species detected (trap results).

Slope for each trap were figured by using a 10m Digital Elevation Model in Arc-GIS (Drew Decker, USGS). In order to assess observer variability at the small scale, three surveyors conducted separate habitat surveys at 17 trap locations.

Analyses

Abundance

For abundance, we first report minimum number known alive (MNKA), which is simply the number of unique individuals captured.

We then conducted closed capture modeling in Program MARK. We first analyzed models using the complete trapping dataset with both night and morning live-trapping events. These data were not initially pooled since many animals were captured on both night and morning events. However, these models showed evidence of very poor fit to the data (dispersion: c-hat >7). Therefore, we used a condensed dataset for the analysis with night and morning data pooled into a single "session/day".

For abundance analyses, we estimated the probability of capturing an individual PPM over multiple trapping sessions. We tested models where capture probability (p) was constant (.) or varied by sex (sex). We ran heterogeneity models where capture probability varied between "2 groups". These groups are not predefined, but formed from any natural grouping in the data, so could be related to sex, age, or any other unknown factor that may affect trap behavior.

In order to test for a positive or negative behavioral response to being trapped (i.e. "trap happy" or "trap shy"), we also compared models where probability of recapture (c) was equal to the probability of initial capture (p) versus models where p and c were unequal. We followed the information-theoretic approach for model selection (Burnham and Andersen 2002).

Cumulative probabilities of capture over number of trap occasions were calculated using Equation 1. Capture probabilities (p) are conservatively presented with 95% confidence intervals.

Equation 1:

$$\text{Cumulative } \rho = 1 - (1-\rho_1)*(1-\rho_2)*\ldots*(1-\rho_n)$$

where ρ = capture probability

n= trap session

Proportion Area Occupied

Proportion area occupied (PAO) by PPM at North and South San Mateo was estimated using the single-year single season logistic model in program PRESENCE. This program computes detection probabilities from the survey data to produce an unbiased estimate of PAO.

For PAO modeling, we treated night and morning live-trapping sessions as individual surveys in estimating PPM detection probability (ρ) and proportion area occupied (Ψ). These data were not pooled since many animals were captured on both night and morning events which increased our ability to model the data and produce more precise parameter estimates. In modeling detection probability, we compared models where p was constant (.), varied by night and morning trap checks (night_morning), or each individual trapping session (t). Because small mammals may be more likely to enter a trap after a period of acclimation, we tested models where ρ differed between the first two sessions and all subsequent sessions (Day 1_other).

For modeling Proportion Area Occupied by PPM (Ψ), we compared models in which Ψ was constant, varied by site (North v. South San Mateo), slope, and proportion of cover from shrubs, forbs, grass, leaf litter, open ground, and sandy patches. For model selection and inference, we followed the information-theoretic approach (Burnham and Anderson 2002).

Cumulative probabilities of detection over number of trap occasions were calculated in the same manner as cumulative capture probabilities (Equation 1).

Habitat

In order to explore whether any habitat variable may be predictive of PPM occupancy or differ significantly among the 2 population sites, we compared three sets of habitat covariate data at two spatial scales. The three sets of data were; 1) all of North San Mateo, 2) all of South San Mateo, and 3) all occupied PPM Sites, which were within South San Mateo. At the small scale level, habitat data for sites were taken from traps 2B, 2D, 4B, 4D within all plots. Habitat data for PPM were taken from all trap locations where PPM were captured. At the large scale level, habitat data were estimated independently for each plot. Data were used from whole plots and only partial plots that were >50% the area of a whole plot (note: partial plots of <100% around perimeters of trapping areas, see Figs. 2a and 2b).

Because the habitat variable data were not normally distributed, we used Kruskall-Wallis (nonparametric equivalent to ANOVA) to test whether the habitat variable differed among all

North San Mateo, all South San Mateo, and/or PPM occupied sites. If this omnibus test was significant, we then did pairwise testing using 2-sample Kolmogorov-Smirnoff tests (nonparametric equivalent to t-test).

To examine observer variability in visual estimations of percent cover, three surveyors conducted separate habitat surveys at 17 trap locations. We performed ANOVAs (response variable= estimated cover, explanatory variable= observer) for each cover type (sandy patches, herbs/forbs, grass, shrubs/trees, leaf litter, and open ground). Because the data were not normally distributed, we did not interpret F statistics, but examined sum of squares to assess proportion of total variance attributed to observer.

Finally, in order to determine if variation increased with percent cover. We used standard deviations to quantify observer variability by site and plotted these against the mean cover estimates. We tested linear, quadratic and hyperbolic curves to determine which best fit the data by r-squared value. We then used this equation to predict standard deviations and 95% confidence intervals across cover values.

Results

Trapping

Over 9450 trap nights, we captured a total of 45 Pacific pocket mice (PPM) in South San Mateo (SSM), but no PPM at north San Mateo (NSM; Table 2, Figures 4a and 4b). The PPM captured were evenly distributed by sex and age class. They were also fairly evenly distributed over the landscape throughout SSM, including 16 mice captured in the outer 50m buffer. Of the 45 mice, we captured 14 on more than one occasion. These individuals moved from zero to 74.5m between successive captures (mean= 10.7, median=3.0) and from zero to 112.8m per individual (mean 23.6, median 11.6).

Table 2. Trapping Results for South and North San Mateo

				Small Mammals		PPM		PPM Sex/ Age Class			
Dates	San Mateo Site	Trap Nights	No. Traps	Captures Total	Capture Rate[1]	Captures Total	new PPM Individuals	Adult Female	Adult Male	Juv/SA Female	Juv/SA Male
May 5-8		3	175	131	0.25	6	4	2	1	1	0
May 12-15	South	3	363	299	0.27	13	11	3	1	3	4
May 19-22		3	343	333	0.32	16	8	1	1	3	3
May 27-31		4	298	214	0.18	0	0	-	-	-	-
June 2-6	North	4	386	180	0.12	0	0	-	-	-	-
June 9-13		4	372	179	0.12	0	0	-	-	-	-
June 16-20	South	3	474	356	0.25	32	15	1	5	4	5
June 23-26		3	387	383	0.33	10	7	2	2	1	2
Totals			2798	2075	0.23	77	45	9	10	12	14

[1]Capture rate= # captures/ (# traps x # nights)

The percentage of PPM captures to available traps was significantly higher for the subjectively placed traps than for the predefined plot traps (8.3% vs 2.7%, respectively; Fishers Exact Test $p<0.0001$). With the subjectively placed trap pairs, PPM captures were more frequent in traps containing the local sand rather than the “PPM sunbathed sand” (12.1% vs. 4.5%, respectively; Fishers Exact Test $p<0.0173$).

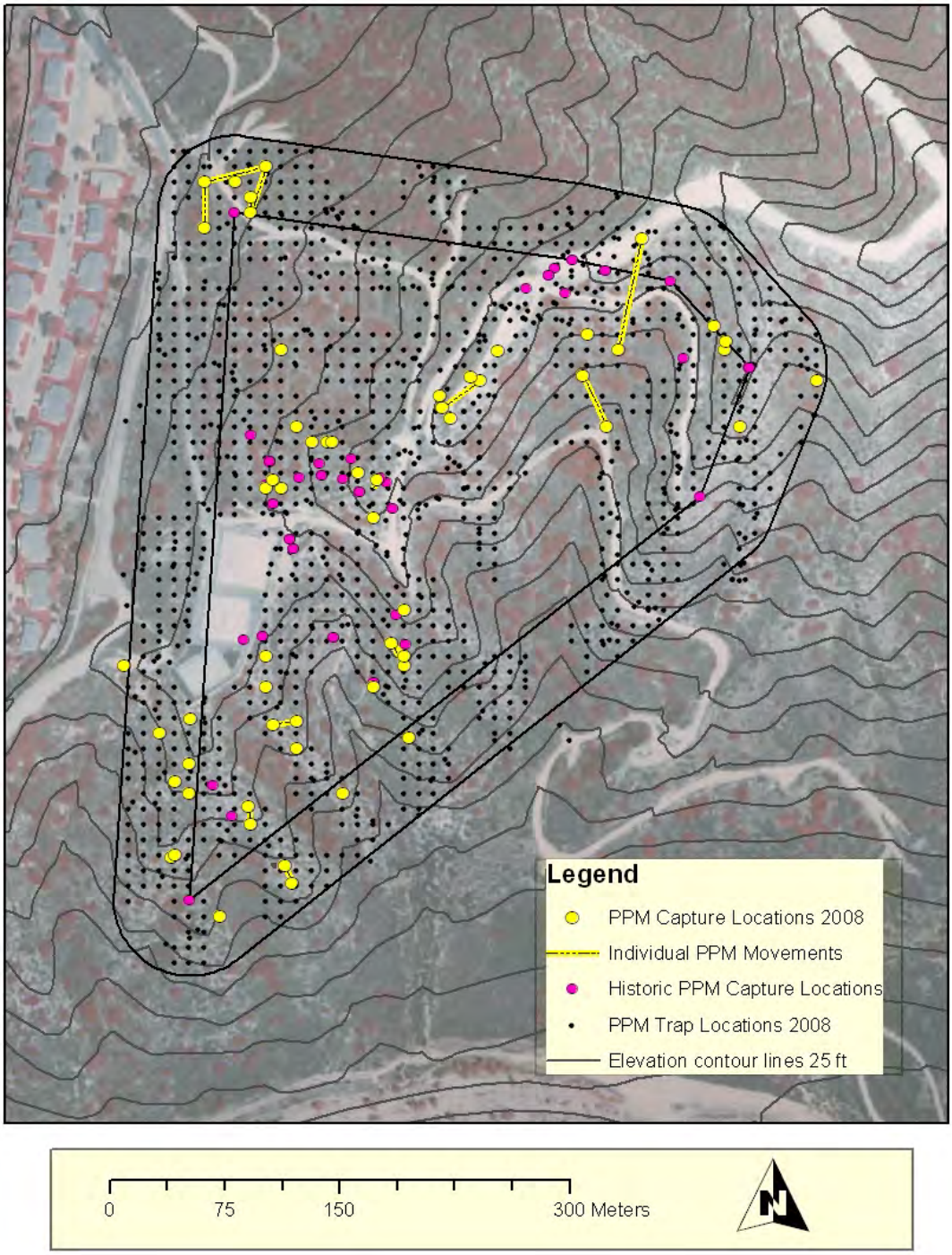

Figure 4a. 2008 Results: Trap and PPM Capture locations in South San Mateo

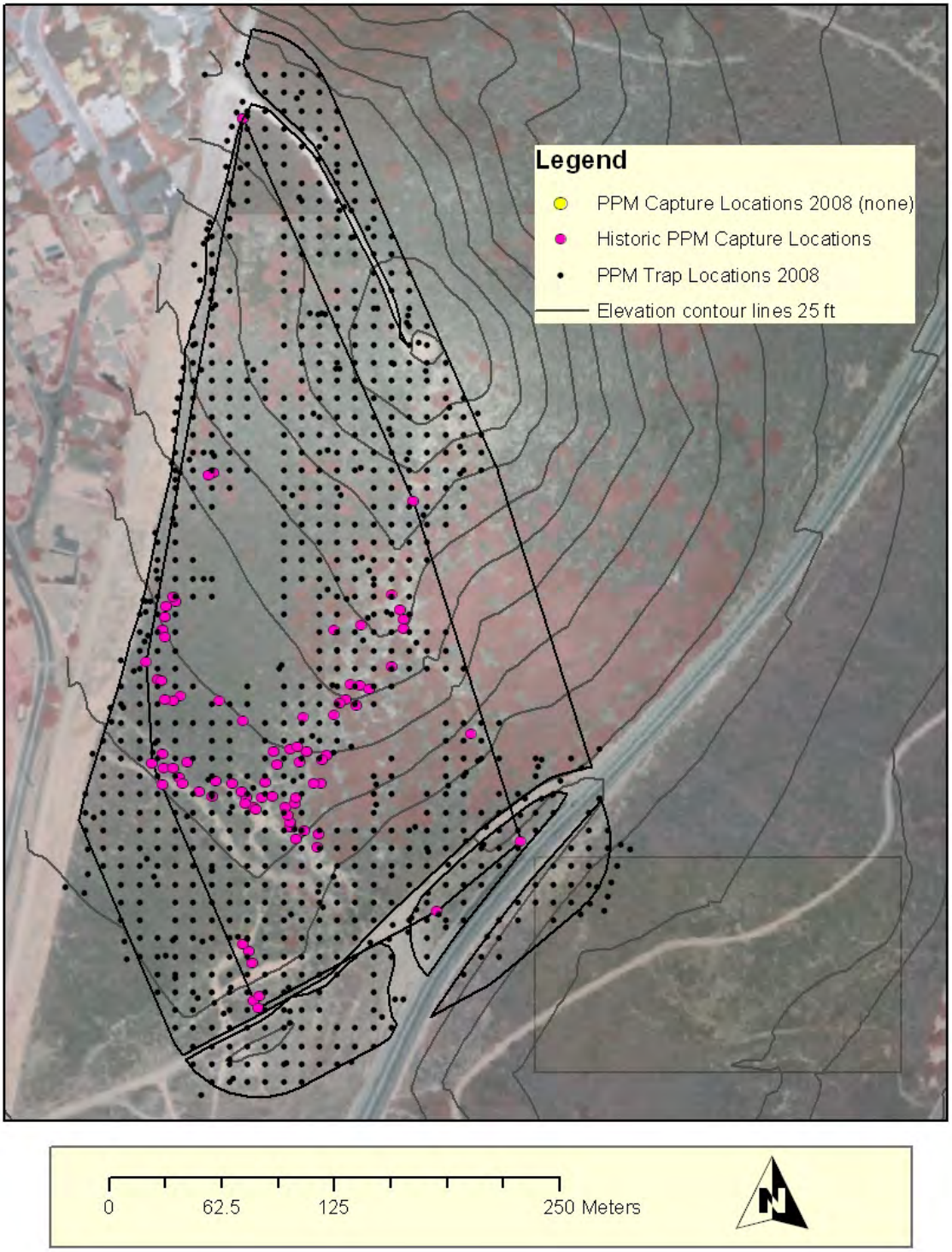

Figure 4b. 2008 Results: Trap locations in North San Mateo (no captures)

Small mammal capture rates and community composition differed between the two sites (Table 3). Overall capture rates were twice as high at SSM in comparison to NSM (weekly mean & std. dev: 28.6% ± 3.9% vs. 13.9% ± 3.5%, respectively). The small mammal community at SSM was dominated by the cactus mouse (*Peromyscus eremicus*) in comparison to the generalist deer mouse (*P. maniculatus*) at NSM.

Of note, was the capture of an adult and subadult long tailed weasel (*Mustela frenata*) at the NSM site. They were apparently predating on small mammals inside the traps, as one contained a half eaten woodrat (*Neotoma lepida*).

Table 3. Small mammal species composition of South and North San Mateo

South San Mateo	
Species	% Total Individuals (n=607)
Peromyscus eremicus	38.5%
Chaetodipus californicus	28.9%
Peromyscus californicus	10.6%
Peromyscus maniculatus	8.6%
Perognathus longimembris	7.4%
Neotoma lepida	3.5%
Reithrodontomys megalotis	2.3%
Mus musculus	0.2%
Notiosorex crawfordi	0.2%

North San Mateo	
Species	% Total Individuals (n=214)
Peromyscus maniculatus	29.9%
Chaetodipus californicus	19.2%
Reithrodontomys megalotis	17.3%
Peromyscus eremicus	15.9%
Neotoma lepida	11.7%
Peromyscus californicus	6.1%

Abundance Estimation

The minimum number of PPM known alive (MNKA) was 45 at SSM and 0 at NSM. The model averaged estimate of abundance was 117.5 (95% CI: 0.0- 378.2) for SSM and inestimable for NSM.

In Program MARK, Huggins closed capture models were first analyzed using night and morning trap checks as separate events. With the separate 'night and morning' dataset, all models showed evidence of very poor fit (deviance c-hat >6.5). Capture probability (p) for these models showed unreasonably low estimates (<.001) and grossly inflated standard errors. We then condensed the night and morning trap checks into a single event 'day'. With the condensed 'day' dataset, we were able to run simple models that gave us reasonable parameter estimates (Table 4). Models that included heterogeneity (pi) and capture probability covariates of time, age, or sex*age interaction are not included due to grossly inflated standard errors for parameter estimates.

Table 4. Closed Capture Model Comparisons

	Model Comparison Criteria					
Model	AICc	Delta AICc	AICc Weights	Model Likelihood	No. Par	Deviance
p(.) c(.)	165.427	0.000	0.360	1.000	2	161.334
p(.) c(age)}	166.657	1.230	0.194	0.541	3	160.469
p = c(.)	166.735	1.308	0.187	0.520	1	164.704
p(.) c(t)	167.430	2.003	0.132	0.367	3	161.243
p(.) c(sex)	167.512	2.085	0.127	0.353	3	161.325

All models presented are plausible, as the evidence ratio between the best model and worst model in this set is only 2.8, This means that the best model (p(.), c(.)), where capture probability and recapture probability are both constants) is only 2.8 times more likely to explain the data than the worst model (p(.), c(sex)) where capture probability is a constant and recapture probability differs between males and females.

Model averaged estimates for probability of initial capture (p) and probability of recapture (c) were 0.170 (se 0.172) and 0.406 (se 0.082), respectively. After three days of trapping, the estimated probability of capturing an individual PPM was 0.429 (95% CI: 0.071-0.951, Figure 5).

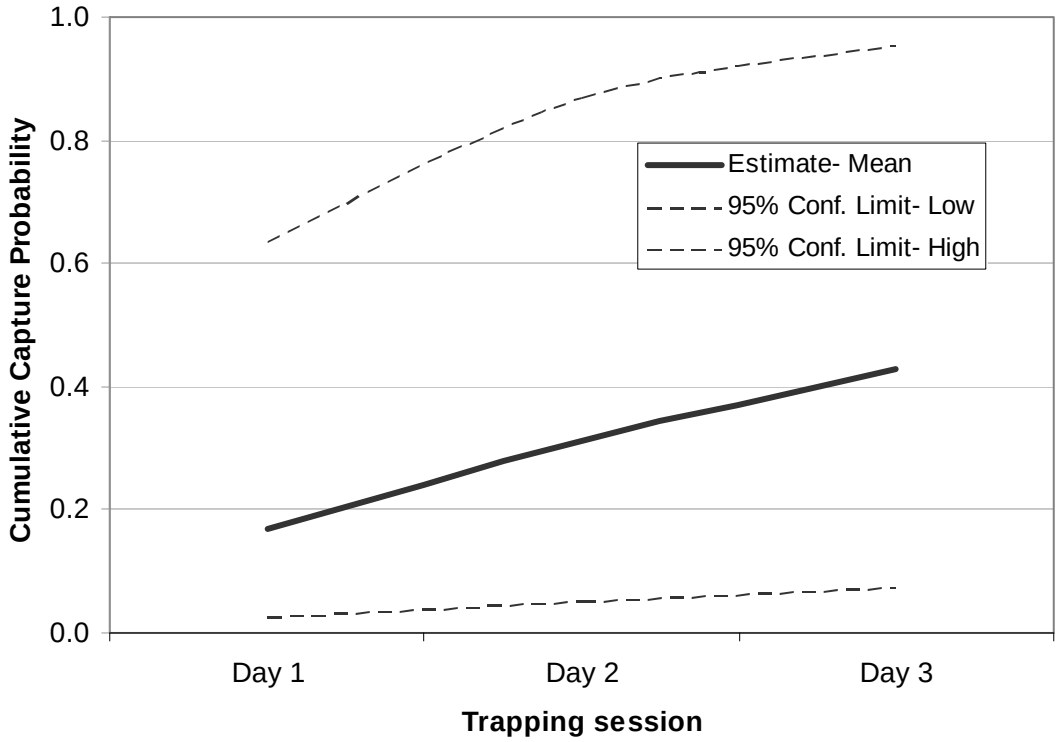

Figure 5. Cumulative Capture Probability for Individual PPM

Confidence limits were very wide for all estimates. Likewise, 95% confidence limits for effects of sex and age on recapture probability all encompassed one or 'no effect'. Adults were an average of 1.7 times (95% CI: 0.5-5.5) more likely to be recaptured than subadults or juveniles. Males were an average of 1.1 times (95% CI: 0.3-3.4) more likely to be recaptured than females.

Occupancy Estimation

In 2008, site was most predictive of PPM occupancy (psi Ψ). Models with this covariate accounted for 100% of AIC weights. Estimates of the percent area occupied by PPM were 53.6% (se= 7.1) for SSM and 0.0% (se= 0.0) for NSM. Although this was the best model for the data, these results are in no way proof of PPM absence in NSM.

There was little to no support for models that included other habitat covariates for predicting occupancy (slope, percent sandy patches, forbs, grass, shrubs, and leaf litter) across sites or within SSM (site*covariate models).

A covariate for night vs. morning trap checks (Night_morn) was significant in modeling detection probability. PPM were more likely to be detected during the morning check (0.443, se= 0.057) than at night (0.179, se= 0.039). Night checks were conducted typically between 11:00PM and 2:00AM, while morning checks were conducted between 5:30AM and 8:30AM, indicating the PPM may have been more active during the early morning hours. There was little to no support for models that included a day for trap acclimation (Day1_other) or time specific estimates (t) in estimating detection probability (ρ). The probability of detecting PPM (if present) on a 50m plot at SSM was estimated to be 0.935 (95% CI: 0.848-0.979) after three days of trapping. Any factors that may have influenced detection probability at NSM were not estimatable due to a lack of PPM detections at that site.

Table 5. Occupancy Model Comparisons

Model	Model Comparison Criteria					
	AIC	delta AIC	AIC wgt	Model Likelihood	No.Par.	Deviance
psi(Site),p(Night_morn)	322.630	0.000	0.999	1.000	4	314.632
psi(Site*slope),p(Night_morn)	337.340	14.710	0.001	0.001	4	329.336
psi(Slope),p(Night_morn)	358.570	35.940	0.000	0.000	4	350.574
psi(.),p(Night_morn)	359.040	36.410	0.000	0.000	3	353.037
psi(.),p(Night_morn, Day1)	360.050	37.420	0.000	0.000	4	352.055
psi(.), p(t)	364.050	41.420	0.000	0.000	7	350.053
psi(.),p(.)	374.620	51.990	0.000	0.000	2	370.619
psi(Site*sand),p(Night_morn)	393.070	70.440	0.000	0.000	4	385.066
psi(Site*shrub),p(Night_morn)	395.240	72.610	0.000	0.000	4	387.244
psi(Site*forb),p(Night_morn)	401.300	78.670	0.000	0.000	4	393.297
psi(Sand),p(Night_morn)	404.200	81.570	0.000	0.000	4	396.200
psi(shrub),p(Night_morn)	404.980	82.350	0.000	0.000	4	396.977
psi(Forb),p(Night_morn)	407.150	84.520	0.000	0.000	4	399.146
psi(Site*leaflitter),p(Night_morn)	408.530	85.900	0.000	0.000	4	400.527
psi(Leaflitter),p(Night_morn)	409.960	87.330	0.000	0.000	4	401.962
psi(Site*grass),p(Night_morn)	411.290	88.660	0.000	0.000	4	403.292
psi(Site*openGrd),p(Night_morn)	412.400	89.770	0.000	0.000	4	404.400
psi(Grass),p(Night_morn)	413.140	90.510	0.000	0.000	4	405.145
psi(OpenGround),p(Night_morn)	413.630	91.000	0.000	0.000	4	405.627

Models did not include partial grids of <0.125ha (<50% whole grid)

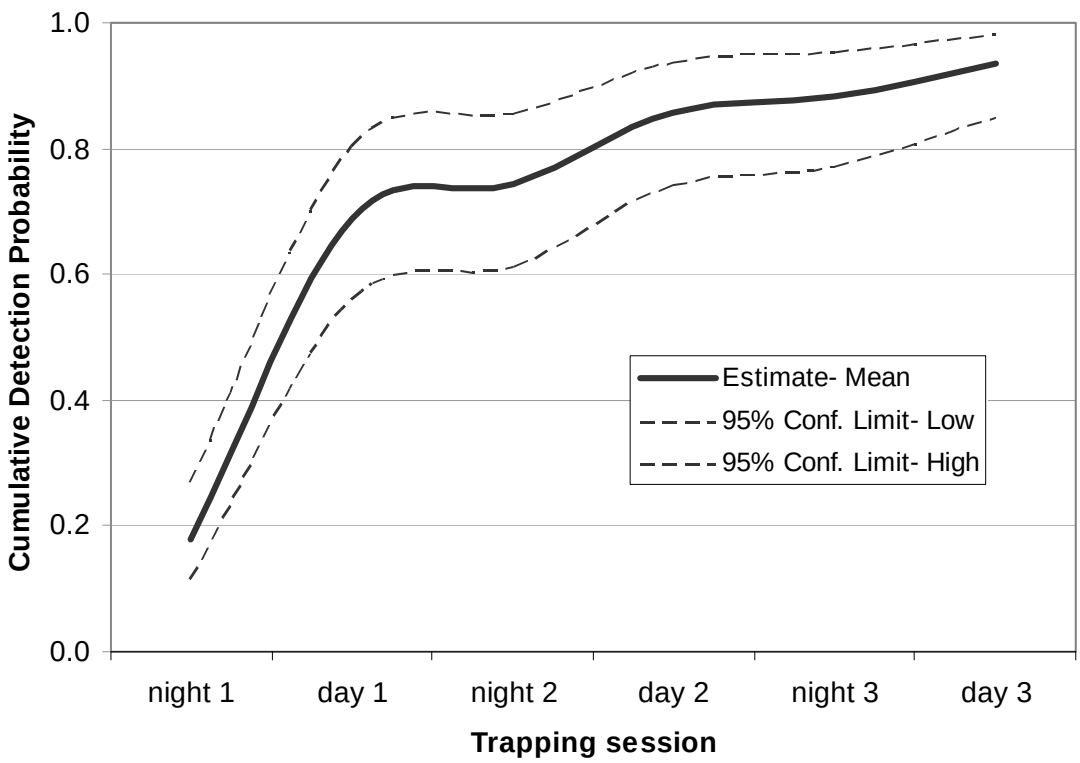

Figure 6. Cumulative Detection Probability of PPM on a 50m plot

Habitat

In comparing habitat covariates for SSM and PPM occupied sites within SSM, we found that percent of sandy patches was significantly higher at PPM occupied sites at the small scale level (3m diameter around trap, median value 20% vs. 5%, p=0.001, Table 6). In contrast, percent of open ground was significantly lower at PPM occupied sites (3m diameter around trap, median value 10% vs. 20%, p=0.001, Table 6). There were no significant differences between the central tendencies for slope, percent cover of shrubs, forbs/herbs, grasses, or leaf litter at the small scale level. However, there was a notable difference in the shrub cover distributions (Figure 7). The distribution over SSM was close to uniform throughout the range (0-85.5), while the distribution of shrub cover values where PPM were detected was normal (mean=38.4, stdev=19.4, normal K-S test p=0.753). There were no significant differences between any of the habitat covariates at the large scale level (50m plot).

In comparison to SSM, NSM had lesser cover of sandy patches, forbs/herbs, and grass, but increased cover of leaf litter and shrubs. These results were significant at both small and large spatial scales (Table 6). Histograms of cover distributions for the different covariates are presented in Figures 7 and 8.

Although both sites are dominated by coastal sage scrub vegetation, dominant forb and herb species differed across the two sites (Table 7). In general, NSM had more dominant cover from California sage (*Artemisia californica*), Figwort (*Scrophularia californica*), wild cucumber (*Marah macrocarpus*), and tocalote (*Centaurea melitensis*), while SSM contained larger amounts of dominant buckwheat (*Eriogonum fasciculatum*), prickly pear cactus (*Opuntia littoralis*), croton (*Croton californicus*), mustard (*Brassica* and *Hirschfeldia* spp.), cryptantha (*Cryptantha spp*.), yellow pincushion (*Chaenactis glabriuscula*), and Brome (*Bromus spp*.). There was no apparent difference between dominant plant species found at PPM occupied sites within SSM versus overall SSM. Dominant plant species results were very similar at the two spatial scales (Table 7).

Table 6. Percent Cover of Habitat Covariates across North San Mateo, South San Mateo, and Sites with PPM. Comparison of Small and Large Scale.

PPM represents all traps (small scale) or plots (large scale) where PPM were detected in South San Mateo. The South and North San Mateo values include all 2B, 2D, 4B, 4D trap locations within each plot (small scale, see Fig. 3) or all plots (large scale). Percentage value represents the median percent cover of each habitat covariate. Small scale represents 3m diameter around each trap (28.3m^2, .0028ha), while large scale represents 50m plots (2500m^2, 0.25ha). Results of nonparametric omnibus and pairwise tests comparing site locations (north and south San Mateo) and PPM occupied locations are shown.

					Kruskall Wallis		Two-Sample Kolmogorov-Smirnov		
		Median Values			NSM, SSM, and PPM		NSM vs. SSM	SSM vs PPM	NSM v. PPM
	Variable	NSM	SSM	PPM	statistic	p-value	p-value	p-value	p-value
Small Scale	Sample size (n)	122	190	42					
(3m radius around trap)	Slope (degrees)	12.0	13.0	12.5	3.50	0.174	0.454	0.814	0.740
	%Sandy Patches	5.0%	5.0%	20.0%	24.46	0.000	0.100	0.001	0.000
	%Forb	5.0%	20.0%	15.0%	62.67	0.000	0.000	0.723	0.000
	%Grass	0.0%	5.0%	5.0%	57.26	0.000	0.000	1.000	0.000
	%Shrub	70.0%	40.0%	40.0%	60.20	0.000	0.000	0.232	0.000
	%Open Ground	10.0%	20.0%	10.0%	42.20	0.000	0.000	0.002	0.631
	%Leaf Litter	10.0%	0.0%	0.0%	64.07	0.000	0.000	0.298	0.000
Large Scale	Sample size (n)	39	66	32					
(50m Grid)	Slope (degrees)	11.7	13.5	13.0	5.39	0.067	0.132	0.997	0.331
	%Sandy Patches	3.5%	10.0%	10.0%	14.14	0.001	0.021	0.993	0.013
	%Forb	5.0%	20.0%	20.0%	41.92	0.000	0.000	0.997	0.000
	%Grass	0.0%	5.0%	5.0%	29.45	0.000	0.000	0.672	0.001
	%Shrub	70.0%	40.0%	40.0%	33.88	0.000	0.000	1.000	0.000
	%Open Ground	10.0%	15.0%	15.0%	1.38	0.001	0.023	0.993	0.095
	%Leaf Litter	10.0%	0.0%	0.0%	29.95	0.000	0.000	1.000	0.000

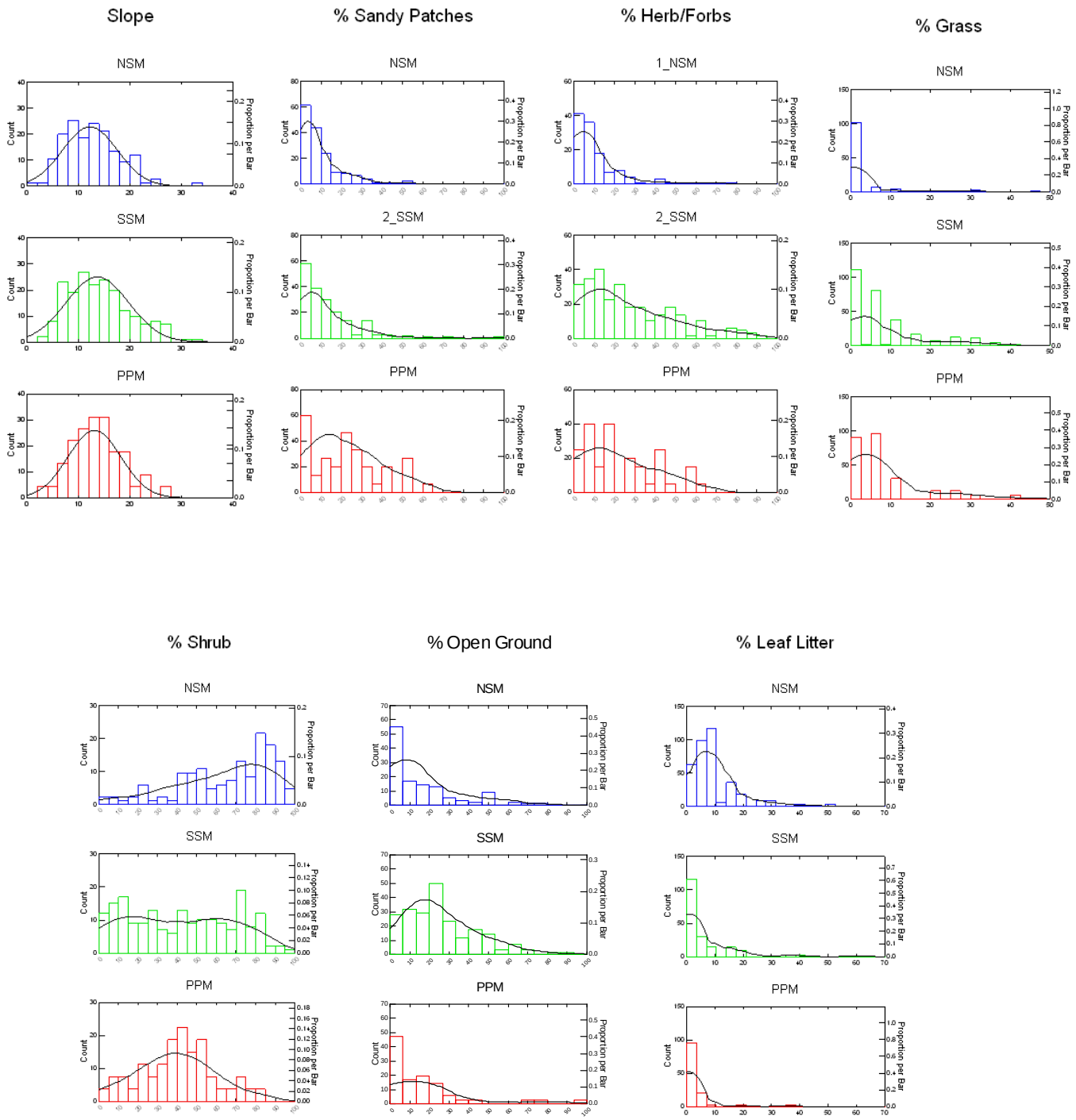

Figure 7. Small Scale Habitat Covariates- Comparison of distributions for each site (South & North San Mateo) and PPM Capture locations.

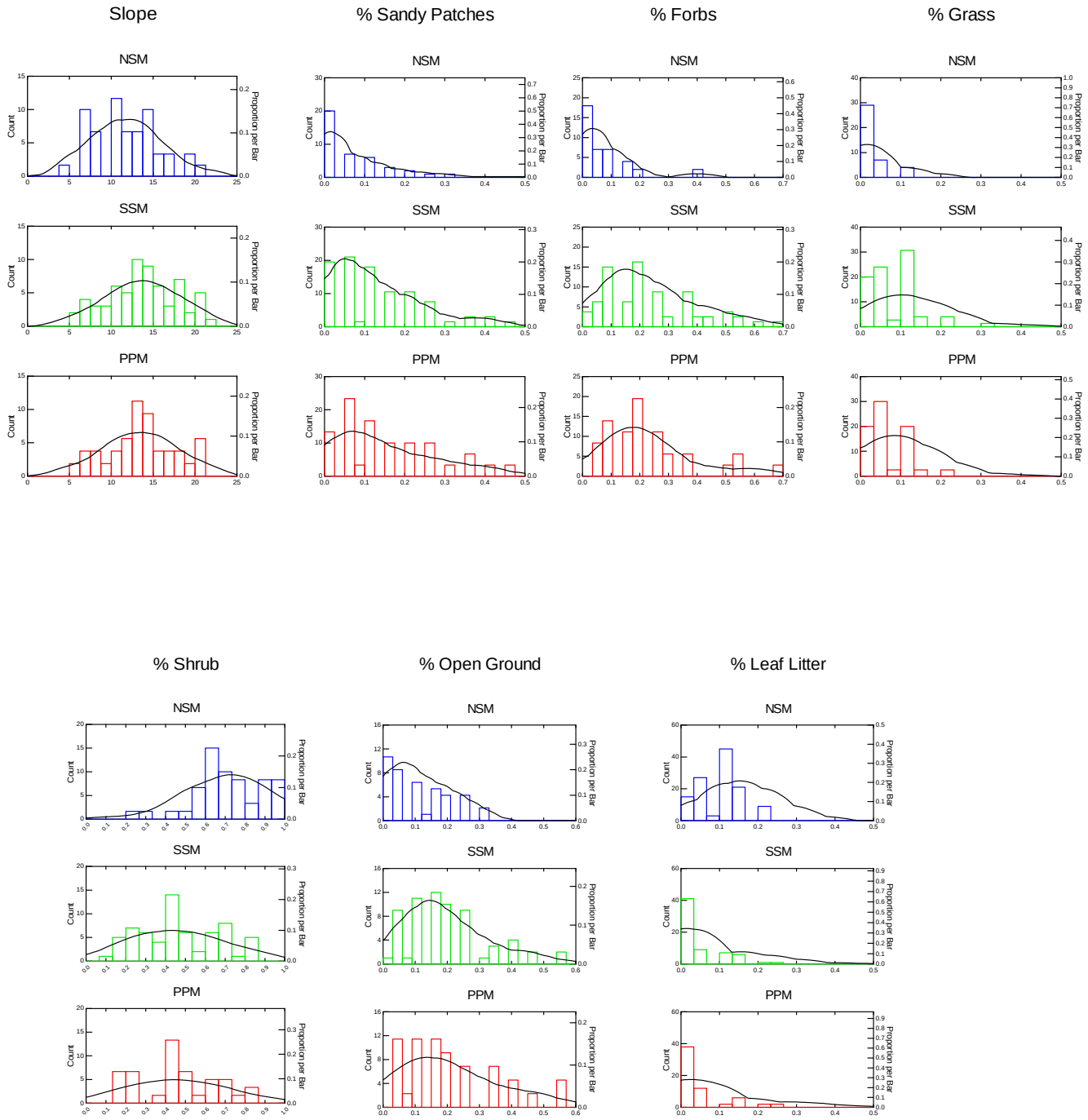

Figure 8. Large Scale Habitat Covariates- Comparison of distributions for each site (South & North San Mateo) and PPM Capture locations.

Table 7. Dominant plants across North San Mateo, South San Mateo, and sites with PPM

PPM represents all traps (small scale) or plots (large scale) where PPM were detected in South San Mateo. The South and North San Mateo values include all 2B, 2D, 4B, 4D trap locations within each plot (small scale, see Fig. 3) or all plots (large scale). Percentage value represents the percent of sites where plant species was recorded as dominant. For each growth form, up to 3 dominant species were recorded. Small scale represents 3m diameter around each trap (28.3m^2, .0028ha), while large scale represents 50m plots (2500m^2, 0.25ha). Appendix contains common and scientific names for plants.

	North San Mateo (all)			South San Mateo (all)			PPM occupied		
Growth Form	Plant Species	Small Scale	Large Scale	Plant Species	Small Scale	Large Scale	Plant Species	Small Scale	Large Scale
Shrubs	California sage	86.1%	97.5%	California sage	54.1%	60.6%	California sage	58.1%	40.6%
	Lemonade berry*	25.4%	52.5%	White sage*	30.4%	39.4%	White sage*	44.2%	30.4%
	White sage*	23.8%	27.5%	Lemonade berry*	29.4%	65.2%	California buckwheat*	37.2%	26.3%
	California brittlebush	13.1%	7.5%	California buckwheat*	26.3%	31.8%	Lemonade berry*	18.6%	56.3%
	Monkeyflower	12.3%	7.5%	Prickly pear cactus	15.5%	28.8%	Deer weed*	16.3%	0.0%
	Bladderpod	10.7%	12.5%	CA Brickellbush	13.4%	18.2%	Prickly pear cactus	16.3%	37.5%
	Coyote brush	9.0%	20.0%	Deer weed*	5.7%	0.0%	CA Brickellbush	11.6%	28.1%
	CA brickellbush	7.4%	2.5%	Laurel sumac	4.1%	9.1%	Black sage	4.7%	12.5%
	Prickly pear cactus	4.1%	5.0%	California brittlebush	3.6%	3.0%	Laurel sumac	4.7%	6.3%
	Elderberry	4.1%	12.5%	Black sage	0.0%	6.1%	sawtooth goldenbush	0.0%	6.3%
	Tree tobacco	0.8%	5.0%	Sawtooth goldenbush	2.0%	3.0%	Goldenbush	2.0%	0.0%
Forbs/ Herbs	Figwort	22.1%	32.5%	Shortpod mustard	43.3%	68.2%	Cryptantha spp.*	41.9%	59.4%
	Wild cucumber	19.7%	50.0%	Cryptantha spp.*	31.4%	51.5%	Shortpod mustard	27.9%	59.4%
	Tocalote*	15.6%	27.5%	Yellow pincushion	15.5%	22.7%	California croton*	11.6%	9.4%
	Cryptantha spp.*	9.0%	20.0%	Horseweed	13.4%	10.6%	Black mustard	11.6%	9.4%
	Shortpod mustard	6.6%	7.5%	Black mustard	11.3%	12.1%	Horseweed	11.6%	9.4%
	Black mustard	6.6%	10.0%	Figwort	10.8%	3.0%	Yellow pincushion	9.3%	15.6%
	Evening primrose	6.6%	10.0%	Tocalote*	7.7%	6.1%	Wild morning glory	7.0%	0.0%
	Tarweed	2.5%	2.5%	California croton*	6.7%	4.5%	Crown daisy	2.3%	0.0%
	Fennel	0.8%	0.0%	Tread lightly	5.2%	3.0%	Tocalote*	2.3%	3.1%
	Coyote gourd	0.8%	0.0%	Wild cucumber	3.6%	0.0%	Tread lightly	2.3%	3.1%
	Storks bill filaree*	0.0%	2.5%	Evening primrose	3.6%	6.1%	Woollystar	2.3%	0.0%
	Smallseed Sandmat	0.0%	2.5%	Fennel	3.0%	6.1%	Fennel	0.0%	9.4%
Grass	Brome*	11.0%	22.5%	Brome*	56.7%	86.4%	Brome*	56.7%	84.4%
	Oats	3.0%	2.5%	Oats	9.3%	21.2%	Oats	9.3%	15.6%
	Nasella	1.0%	0.0%	Nasella	0.5%	0.0%	Nasella	0.5%	0.0%
	Stipa	1.0%	0.0%	Stipa	0.5%	6.1%	Stipa	0.5%	9.4%

*known food resource (Meserve 1976b, Germano 1997). Note: Grass & forb seeds are primary food resource for PPM

Observer Variability

For small scale visual estimates of percent cover, observers accounted for 2.1 to 10.5% of the total variation among sites (Table 8). The remaining 89.5- 97.9% of the variation can be attributed to actual site to site variability in percent cover and model error. Individual observer estimates over the range of cover values are shown in Figure 9. Standard deviations of all estimates are shown in Figure 10. A quadratic equation was the best fit for the standard deviation data, showing that observer variability was greatest in the middle of the range (30-60% cover; Figure 10). Using the standard deviations from observers, total sample sizes required to yield a significant result at the 95% confidence level are presented in Table 9. The sample size represents additional samples required to overcome the error associated with observers.

Table 8. Observer as a Component of Variance by Cover Type

Percent Cover Variable	Range	Median Value	Proportion of Variation due to Observer*
Grass	0 - 5	0	0.087
Herbs/Forbs	0 - 30	3	0.050
Leaf Litter	0 - 30	9	0.105
Open Ground	0 - 50	10	0.081
Sandy Patches	0 - 50	10	0.021
Shrubs/Trees	25 - 95	75	0.022

sum of squares (observer) ÷ Total sum of squares

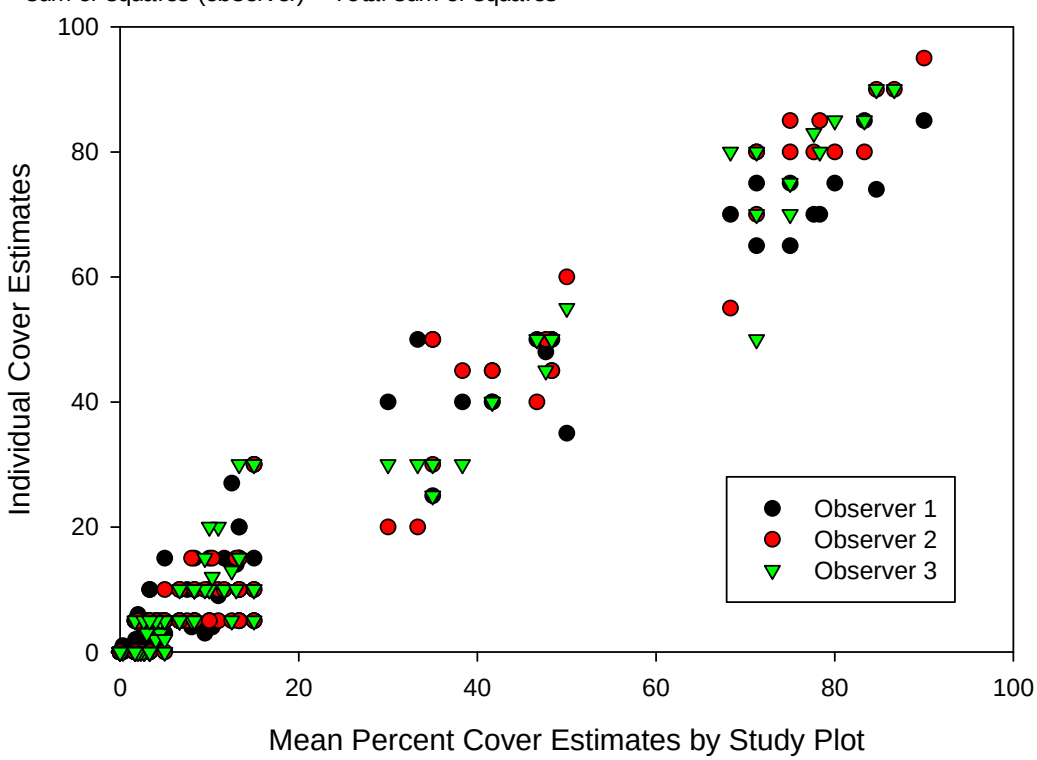

Figure 9. Observer Variability in Visual Percent Cover Estimates across Vegetation Cover Types

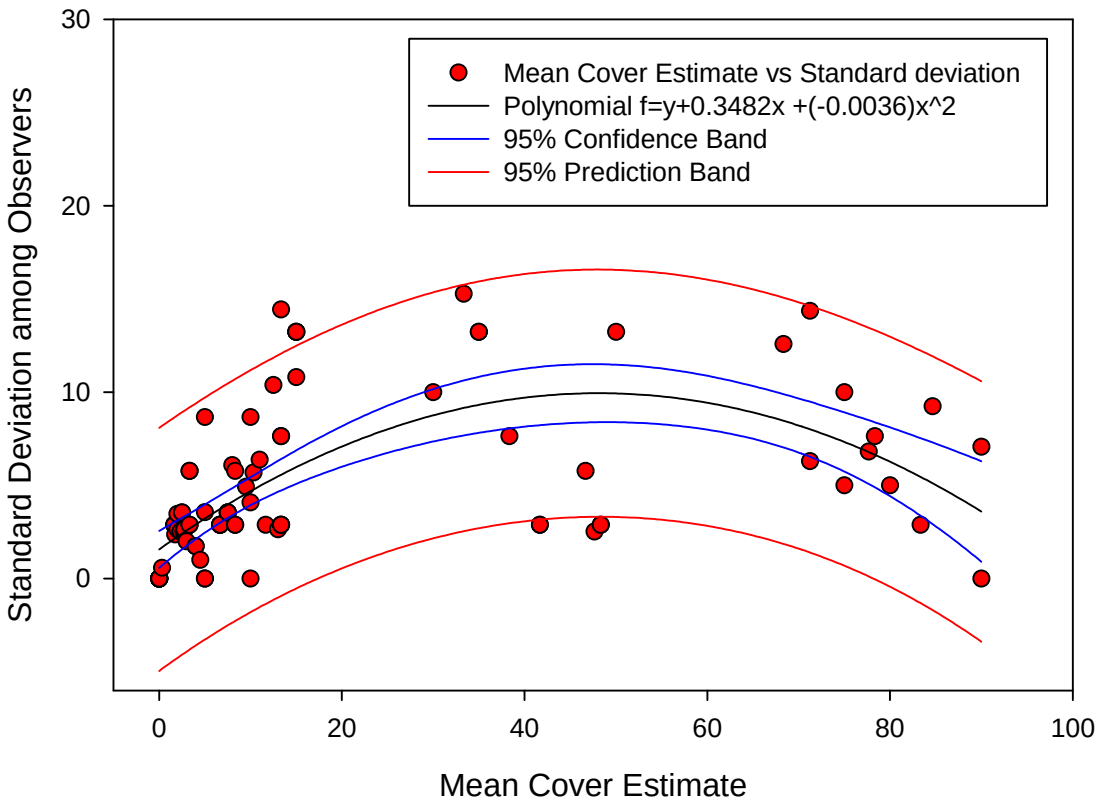

Figure 10. Standard Deviations vs. Individual Site Cover Estimate Means

Table 9. Visual Cover Estimates: Sample Size vs. Effect Size

		Sample Size Estimates for 3 Effect Sizes*		
% Cover	Std Dev	5%	10%	20%
1	0.3	8	6	6
5	1.7	16	10	8
10	3.1	28	12	8
15	4.4	42	16	8
25	6.5	74	20	8
50	8.4	92	26	6
75	5.9	46	14	6
95	0.6	-		

*Power 0.80, Alpha 0.50, 2-sample t-test

Discussion

In 2008, the south San Mateo (SSM) PPM population appeared to be successfully reproducing and well distributed throughout the trapping area. The number of individuals captured (45) exceeded all historically documented PPM captures at this site (28). We captured roughly similar numbers of males and females, as well as adults and young of the year. Our captures along the outer perimeter indicate that PPM likely extend beyond the historically known population boundaries. Since the time of this trapping effort and report, there have been two occasions where PPMs were captured well outside of these boundaries (south and southeast, USGS and Philip Vergne, respectively). These data are promising in that the PPM population at SSM is larger and more widespread than previously known.

In contrast, we did not capture a single PPM at NSM after over 4000 trap nights. There was no reason to believe that PPM would be in torpor during the time of trapping, as PPM activity was concurrently high on Oscar One and Dana Point (D. Shier, LeeAnn Carranza pers. comm.) and we captured PPM both before and after the trapping period at SSM. Therefore, these data indicate that, at best, PPM numbers were low at this site. Absence cannot be inferred from this effort, as many more nights would be necessary, and there were several small areas within the preserve that appeared to be suitable for PPM.

Concurrent studies of PPM at south Santa Margarita (Oscar One) and Dana Point showed that PPM were successfully reproducing and numbers were relatively high in comparison to previous years (D. Shier, LeeAnn Carranza pers. comm..). Therefore, we expected that any climatic factors that may influence PPM abundance were favorable.

Absence of PPM captures from NSM: Comparison of North and South San Mateo

We hypothesize that a combination of stressors is responsible for the apparent considerable decline in PPM numbers at NSM. These include decreased food resources and suitable habitat, along with greater pressure from human impacts and invasive species.

In comparison to SSM, NSM had higher cover of shrubs and leaf litter and significantly less cover of forbs, grasses, open ground, and sandy patches. These results were consistent over both large and small scales. PPM are known to rely on sandy patches for sandbathing and other social

activity and their primary food sources are seeds of grasses and forbs. Therefore, it appears that resources for the mice are lower at NSM. In addition, the area is heavily impacted by human and canine use. Dogs were seen during every morning survey and off leash within the preserve. We did not find evidence of digging, but shallow PPM burrows in sand would be susceptible to digging or other disruption. Human and dirt bike trails were also prevalent. Although trails provide some open ground which may benefit the mice, they also compact the soils which may be detrimental to the habitat by reducing potential for PPM burrowing or sandbathing.

Both the density (as measured by capture rate) and species richness of the small mammal community at NSM was reduced in comparison to SSM. This may be reflective of the increased shrub cover, reduced plant species richness, increased disturbance, or other inherent characteristics of the site. A possible indicator of ecological disturbance was the dominance of the deer mouse, *P. maniculatus*. This species is a habitat generalist shown to increase in response to disturbance in southern California (Brehme 2003, Clark et al. *in review*). This was in contrast to SSM, where the dominant species was the cactus mouse (*P. eremicus*), a coastal scrub specialist in this part of their range.

Finally, the abundance of Argentine ants *(Linepithema humile*) observed at NSM is of concern. Although there was no formal survey for the ants, this species was observed to be abundant across the site. These ants act as a supercolony in the region (Tsutsui et al. 2000). They tend to displace native ants within 200m of urban edges and can be relentless predators of small mammals, reptiles, juvenile birds, and other arthropods (Holway et al. 2002, Mitrovich et al. *in press*). Because they are not efficient dispersers of seeds, like the harvester ants they displace, their presence can alter the vegetation community (Rodriguez-Cabal et al. 2009). Therefore, an Argentine ant invasion can have large consequences for the ecosystem. The nearby housing development, golf course, and layer of woodchips, maintained along the north road immediately adjacent to the preserve, create favorable moist conditions for these ants to colonize the area. Removal of water sources will reduce the distance of Argentine ant invasions (Menke and Holway 2006).

Implications for Monitoring:

Capture Probability vs. Detection Probability.

The probability of capturing PPM individuals was very low at 0.17 (95% CI; 0.02-0.63). This means that an estimated average of only 17% of the population may be captured on any given night. After three nights, we would expect to encounter 43% of the population. This low probability, along with unmodeled heterogeneity, resulted in very wide confidence limits around the population estimate of 117 (0 – 378). Our data was consistent to that reported from extensive trapping studies of Oscar One and Dana Point by the U.S. Fish and Wildlife Service (Miller and Pavelka 2008). These data support their conclusions that many trap nights are needed to accurately estimate PPM abundance, particularly at low population densities.

In contrast, the probability of detecting the presence of PPM within a $50m^2$ plot on a given night was much higher at an estimated 0.70. This resulted in a 0.93 probability of detecting PPM occupancy within a plot after three nights of trapping. Correspondingly, the 95% confidence interval around the estimate of occupancy was more reasonable (0.40-0.67). The occupancy estimate for SSM also falls within the range of occupancy values (0.2-0.8) recommended for design of occupancy studies (MacKenzie et al. 2006). This indicates that the plot size of $50m^2$ is appropriate for this study area.

Subjective Traps

Capture success for traps placed subjectively within each plot was three times higher than those traps placed at predefined plot coordinates. As previously defined, PPM field biologists placed three extra pairs of traps within each plot in areas that appeared most suitable for PPM. These were typically in areas with open sandy patches, small PPM sized burrows (if present), *Croton californicus,* and other herbs and forbs. These results support the addition of at least a subset of subjectively placed traps to any monitoring scheme in order to enhance detection of the species.

The presence of sand with PPM scent appeared to detract PPM from the traps. PPM may avoid traps with PPM scent due to intraspecies competition, dominance, or other factors. Since the sex and reproductive status of the PPM that bathed in sand used was not well documented by USGS, we cannot further theorize or make generalizations based on these results.

Habitat Surveys and Covariates

We collected visual habitat survey data at two spatial scales in order to determine if there were any habitat characteristics that may be predictive of PPM occupation of a site. Since we did not capture any PPM at NSM, here we focus on habitat features selected for by PPM within SSM. At the large scale ($2500m^2$, 0.25ha), there were no significant differences in the habitat covariate distributions nor were any predictive of PPM occupancy in the PRESENCE analysis.

At the small scale level ($28m^2$), there were significantly more open sandy patches in areas selected by PPM (median value of 20% vs. 5%) and significantly less open ground (median value of 10% vs. 20%). In addition, PPM selected plots with an average of 39% shrub cover. PPM selected shrub cover values were normally distributed about the 39% mean. This differed from the uniform distribution of shrub cover values available across the site.

The results support the hypothesis that PPM select patches of habitat with open sand (P. Meserve pers. comm.), which is consistent with their life history characteristics. Sand is needed for dust bathing, communication, and preferred as a burrowing substrate. They also suggest that PPM may avoid open areas with compacted substrate and prefer areas with a moderate amount shrub cover.

The different results by spatial scale suggest that even though PPM can move large distances over the landscape, they select and utilize habitat on a smaller scale level. In consideration of a long term spatial monitoring program. It might require the collection of habitat data at multiple spatial scales.

Statistical significance for these tests are largely based upon effect size, sample size, and observer variability. The results showed that observer variability was a small component of the overall variation in cover values. Observer variability did not greatly effect the required sample sizes to detect an effect size of 10-20%. In this study, we report effect sizes of 10-15% differences in cover for sand and open ground (>95% confidence level).

The different results by spatial scale were also influenced by lower statistical power. This is due to an inherently smaller sample size for the large plots and perhaps a greater variability among observers, although this was not specifically tested. Because the study sites were chosen to represent known PPM habitat, the range of values within each site may be limited. That said, the large scale habitat covariates were almost all significantly different between the two sites, SSM and NSM, and small scale patterns were generally reflected to a lesser extent at the plot level.

PPM Movements

Although this study was not designed to generate data on PPM movements, the marking scheme and limited number of PPM captured allowed us to track movements of 14 individuals captured on more than one occasion. While most PPM moved 10m between subsequent captures, a few mice moved larger distances (74.5 m, 112.8 m (or 56m linear)). This is not dissimilar to PPM movement data from over 200 individuals captured 8 or more times in Oscar One reported by the US Fish and Wildlife Service (Miller and Pavelka 2008). They reported median within-bout movements of approximately 11m, 95% of PPM movements ranged between 0 and 36 m, and a small percentage of movements of over 100m. In 2008, Brylski et al. reported mean movement distances of 31.3 and 40m (Range 12-64m) at Dana Point Headlands. Similar mean movement distances and longer range movements of up to 181m have been previously documented at Dana Point (Dodd et al. 1998, 1999). These data reveal the possibility that PPM movements may vary by population locations, landscape characteristics and/or other unknown demographic factors.

The range of PPM movements has implications regarding monitoring study design. A plot that is much smaller than an individuals home range will tend to result in very poor detection probabilities because an animal may only move into the plot on occasion (K. Burnham pers. comm.). Additionally, if individual animals regularly move across several plots within a sampling period, this would violate the assumption of closure. This can be dealt with by defining the monitoring parameter as animal “resource use” instead of “occupancy”, if the presence of the species within a plot at the time of a survey can be regarded as completely random (MacKenzie 2006). However, the effect of a small plot size in lowering probabilities of detection still could be problematic by resulting in poor precision of parameter estimates. Therefore, plot size for “occupancy” modeling should err on the side of too large rather than too small (i.e. greater than 1 or more home range size). In our study, 14% (2/14) animals moved linear distances greater than the plot length of 50m within the three day trapping period. Therefore, we recommend this as a minimum size for long term occupancy monitoring.

Habitat Impacts from Field Surveys

In order to conduct trapping activities, one to two field personnel must traverse habitat three times per trap night in order to set/open traps and check traps in the evening an morning sessions. For three trap nights, this means a minimum of traversing the habitat nine times. The impacts from

our 2008 activities were quite apparent during and after trapping activities. A 10m plot of trails were created over both sites. The destructive impact was most apparent on the sandy slopes in SSM, where it was impossible to walk the slopes without causing minor landslides downslope and the impact increased after every pass (see Figure 11). Besides the immediate destruction of habitat, the trails may increase access to large predators. Any long term monitoring plan should seek to reduce this impact.

Figure 11. Photos showing habitat impact at south San Mateo from 3 nights of trapping effort.

Management Recommendations:

In order to increase the population size of PPM for NSM, our results suggest effective restoration activities include:

1. Thinning of vegetation in patchy framework, particularly focused in and around areas previously inhabited by PPM.
2. Consideration of creating more open sandy patches by addition of suitable sand substrate or possibly loosening small areas of hardpacked sand.
3. Remove woodchips from north dirt road to reduce favorable habitat conditions for Argentine ants.
4. A comprehensive survey of the ant community to determine the extent and severity of Argentine ant invasion.
5. Greater presence of rangers and signage in areas to inform residents of leash laws and discourage off trail activities.
6. Fence off particularly vulnerable areas known to be previously occupied by PPM.

Considerations and Recommendations for Monitoring:

1. Survey suitable PPM habitat outside of the 2008 SSM trapping area to better understand PPM distribution at this site and establish initial boundaries for long term monitoring.
2. Occupancy monitoring using a 50m X 50m plot appears to be reasonable for Proportion Area Occupied recommendations and for relatively high probability of detecting PPM.
3. 50m X 50m is the minimum recommended plot size in consideration of PPM movements and home ranges and to minimize violations of closure for occupancy analysis.
4. Live-trapping to accurately estimate PPM abundance will require many nights of trapping.
5. Habitat destruction from trapping must be considered, particularly in PPM areas with sandy slopes.
6. Include subjectively placed traps (or other detection technique) to survey and monitoring programs to maximize detection of PPM.
7. Record habitat data at multiple spatial scales.
8. Coordinate with surveys and monitoring of PPM at Dana Point. Collaborate on data collection and forms, such as habitat data covariates, and other aspects of monitoring, if possible.

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Appendix: Common and Scientific Names of Plants

Type	common name	scientific name	Family	Nativity
Shrub/Tree	Black sage	*Salvia mellifera*	Lamiaceae	Native
Shrub/Tree	Bladderpod	*Cleome isomeris*	Brassicaceae	Native
Shrub/Tree	California brickellbush	*Brickellia californica*	Asteraceae	Native
Shrub/Tree	California Brittlebush	*Encelia californica*	Asteraceae	Native
Shrub/Tree	California buckwheat	*Eriogonum fasciculatum*	Polygonaceae	Native
Shrub/Tree	California sage	*Artemisia californica*	Asteraceae	Native
Shrub/Tree	Coyote brush	*Baccharis pilularis*	Asteraceae	Native
Shrub/Tree	Deer weed	*Lotus scoparius*	Fabaceae	Native
Shrub/Tree	Elderberry	*Sambucus nigra*	Caprifoliaceae	Native
Shrub/Tree	Goldenbush	*Isocoma menziesii*	Asteraceae	Native
Shrub/Tree	Laurel sumac	*Malosma laurina*	Anacardiaceae	Native
Shrub/Tree	Lemonade berry	*Rhus integrifolia*	Anacardiaceae	Native
Shrub/Tree	Monkeyflower	*Mimulus aurantiacus*	Scrophulariaceae	Native
Shrub/Tree	Prickly pear cactus	*Opuntia littoralis*	Cactaceae	Native
Shrub/Tree	Sawtooth Goldenbush	*Hazardia squarrosa*	Asteraceae	Native
Shrub/Tree	Tree tobacco	*Nicotiana glauca*	Solanaceae	Non-Native
Shrub/Tree	White sage	*Salvia apiana*	Lamiaceae	Native
Forb/Herb	Black Mustard	*Brassica nigra*	Brassicaceae	Non-Native
Forb/Herb	California Croton	*Croton californicus*	Euphorbiaceae	Native
Forb/Herb	Coyote Gourd	*Cucurbita palmata*	Cucurbitaceae	Native
Forb/Herb	Crown Daisy	*Chrysanthemum coronarium*	Asteraceae	Non-Native
Forb/Herb	Cryptantha spp.	*Cryptantha sp.*	Boraginaceae	Native
Forb/Herb	Evening Primrose	*Camissonia sp.*	Onagraceae	Native
Forb/Herb	Fennel	*Foeniculum vulgare*	Apiaceae	Non-Native
Forb/Herb	Figwort	*Scrophularia californica*	Scrophulariaceae	Native
Forb/Herb	Horseweed	*Conyza bonariensis*	Asteraceae	Non-Native
Forb/Herb	Shortpod Mustard	*Hirschfeldia incana*	Brassicaceae	Non-Native
Forb/Herb	Smallseed Sandmat	*Chamaesyce polycarpa*	Euphorbaceae	Native
Forb/Herb	Storks bill filaree	*Erodium sp.*	Geraniaceae	Non-Native
Forb/Herb	Tarweed	*Hemizonia fasciculata*	Asteraceae	Native
Forb/Herb	Tocalote	*Centaurea melitensis*	Asteraceae	Non-Native
Forb/Herb	Tread Lightly	*Cardionema ramosissimum*	Caryophyllaceae	Native
Forb/Herb	Wild cucumber	*Marah macrocarpus*	Cucurbitaceae	Native
Forb/Herb	Yellow Pincusion	*Chaenactis glabriuscula*	Asteraceae	Native
Grass (annual)	Brome grass	*Bromus sp.*	Poaceae	Non-Native
Grass (perennial)	Giant Stipa	*Achnatherum sp.*	Poaceae	Native
Grass (perennial)	Native bunch grass	*Nassella sp.*	Poaceae	Native
Grass (annual)	Non-native oats	*Avena sp.*	Poaceae	Non-Native