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Effects of Fire, Elevation, and Habitat Quality on the Occupancy, Extinction, and Colonization of Coastal California Gnatcatcher

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ABSTRACT We conducted periodic occupancy surveys for coastal California gnatcatcher (*Polioptila californica californica*) from 2004 – 2009 in the San Diego County, focusing on preserve lands associated with Habitat Conservation Plans. We investigated the effects of habitat quality classification, elevation, distance to coast, and heat load on the occupancy, extinction, and colonization probabilities. In addition a wildfire in 2003 burned 17,044 hectares, roughly 1/3 of the area, thus we were able to investigate the recolonization process associated with this unforeseen event. We found that occupancy increased with habitat quality and over time, but decreased with elevation. Extinction probability was at a generally constant rate (~0.13), but colonization varied greatly with probabilities being higher in higher quality habitat and at lower elevations. We suggest that sites categorized as high and very high quality at lower elevations

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should receive priority in terms of conservation actions. Although the burned plots are starting to be recolonized, after 5 years post-burn, these areas are not at pre-burned occupancy levels and monitoring should continue.

KEY WORDS California gnatcatcher, colonization, extinction, fire, *Polioptila californica*¸ habitat conservation plan, San Diego MSCP

Habitat Conservation Plans (HCPs) are commonly used to establish a preserve system for species of concern, while allowing permittees to development land. Monitoring plans for species covered concern within HCP preserve areas are required by the US Fish and Wildlife Service (Section 10(a) of the ESA – 16 U.S.C. §1539(a); USFWS 1996). One attractive aspect of the HCP process for permittees is that if an “unforeseen event” (an event not included in the HCP permit) takes place, the permittees have little or no responsibility for the consequences. Such unforeseen acts might include earthquake, fire, or floods. Understanding, and mitigating, the effects of unforeseen events, would be the responsibility of the Federal government.

In Southern California, the coastal California gnatcatcher (CAGN; *Polioptila californica californica*) serves as both the umbrella species and flag ship species associated with many HCPs and much of the conserved land is predicated on a habitat model (i.e., the TAIC model) that identifies areas of CAGN occupancy (TAIC 2002). This model conditions on the presence of sagebrush (*Artemisia californica*) and then calculates relative habitat suitability into low, medium, high, and very high habitat categories based on patch size, slope, precipitation, and average minimal January temperature. A survey for the CAGN was conducted in 2002 across the range of CAGN in Orange and San Diego counties and the results of that study verified the usefulness of the TAIC categorization with occupancy estimates of 0.00, 0.08, 0.28, and 0.48 in the low, medium, high, and very high categories respectively (Winchell and Doherty 2008).

Following Winchell and Doherty's (2008) study, a similar CAGN survey protocol was established in a specific HCP entitled the Multiple Species Conservation Program (MSCP) located in San Diego County, CA (San Diego 1998) in 2004 and then expanded in 2007 and 2009 to include all quasi-public, public and preserve lands across San Diego County. This survey protocol has been implemented every 2-3 years (2004, 2007, 2009) creating a data set with which to test hypotheses concerning CAGN occupancy and dynamics. However, a large wildfire occurred in 2003 that burned 17,044 hectares, roughly 1/3 of the preserve area. Our monitoring data allows for the investigation of occupancy patterns as the land recovers from the fire; an aspect of particular interest to the USFWS and land managers who are responsible for the repercussions from this fire. We treated some of these burned plots as a separate 5th stratum/category in our analysis as burning was unaccounted for in the original TAIC habitat model.

In addition to estimating occupancy parameters for these strata, we desired to test how underlying permanent landscape features might also influence occupancy. We were particularly interested in testing the effect of elevation and distance to the Pacific coast as elevations < 150 m and areas closer to the coast have been anecdotally suggested to have higher CAGN occupancy rates. Winchell (2009) suggested this might be due to the higher levels of atmospheric moisture in these areas because the marine layer increases humidity levels by evaporation of the ocean near the coast. In addition we tested whether sites with a higher heat load (McCune and Keon 2002) would be more likely to be occupied by CAGN possibly due to these sites being warmer than other exposures.

Whereas Winchell and Doherty (2008) could only investigate patterns of occupancy due to having only 1 year of data, we can now investigate processes, namely extinction and colonization, that give rise to the observed occupancy patterns, as well as establish trends in occupancy across the MSCP area. We thought that extinction probabilities could vary by habitat category (low, medium, high, very high, and burned) with higher probabilities in lower quality habitats. We thought that extinction probabilities may also vary by year. We thought colonization probabilities could vary by habitat category (higher quality having higher probabilities), year, elevation (lower elevations having higher occupancy rates) and the distance to a high or very high habitat (as these areas have had higher occupancy rates and possible serve as a source for colonizing CAGNs). Thus, our overall objectives were to estimate occupancy, extinction, and colonization rates of CAGN and to test the above hypotheses concerning habitat classifications and landscape features, while controlling for the observation process.

STUDY AREA

We conducted this research on lands within San Diego County currently designated as public or quasi-public, and some military lands (Fig. 1). In general, this included preserve lands regulated under Habitat Conservation Plans, other public lands regulated by local jurisdictions, and lands separately managed by Marine Corps Air Station Miramar and Naval Weapons Station Seal Beach, Detachment Fallbrook. Marine Corps Base Camp Pendleton was not included because of logistical considerations. Additionally, private lands and Tribal lands were excluded from the sample frame because of access limitations and liability concerns.

METHODS

We used a stratified sampling design across the four TAIC habitat strata and followed the sampling methods in Winchell and Doherty (2008). We had chosen these plots in summer 2003, for surveys the following spring. Large wildfires moved through the area in October 2003, prior to our planned surveys. These fires caused logistic, cost, and management issues that affected our survey effort. Burning a plot in one stratum does not transform the plot into one of the other strata as a stratum designation is most strongly based on factors not affected by fire – namely variation in slope, average annual precipitation, and average annual temperature (TAIC 2002, Winchell and Doherty 2008). Thus, after the fire we considered these burned plots a 5th stratum, but we only chose to survey the previously categorized high and very high plots in the burned stratum (a total of 122 plots) because of cost/logistic issues and because the previously categorized low and medium plots had very low occupancy rates and we did not anticipate large changes in those plots. We surveyed 28, 77, 151, 261 and 122 plots in low, medium, high, very high, and burned strata respectively. Of these 639 plots 488 were in the established MSCP area and 151 were on preserve lands outside the planning boundaries of the MSCP but within San Diego County. All 122 burn plots were within the MSCP planning boundary. We visited each plot a maximum of 5 times in 2004 and 6 times in 2007 and 2009. We made visits between 15 March – 20 April in 2004, from 30 April – 30 June in 2007 and from 13 April – 22 June in 2009. At each visit we recorded whether a CAGN was detected or not over an 18 minute period. During the first 15 minutes an observer detected CAGN either auditorally or visually, while during the last 3 minutes a tape call back was used to aid detection. These records formed an encounter history for each plot.

We utilized an occupancy dynamics model (MacKenzie et al. 2003) to estimate occupancy, extinction, and colonization while also estimating detection. If occupancy at time t, extinction, and colonization are estimated, then occupancy at time t+1 can be derived. Thus we chose to estimate the initial occupancy rate (in 2004), as well as time-specific extinction and colonization probabilities, and derived future occupancy parameters using Program MARK (White and Burnham 1999). Our surveys did not occur at equal intervals (2004, 2007, 2009) and thus our extinction and colonization estimates would apply to different time intervals. To address this situation we standardized the modeling and estimation of extinction and colonization between surveys on an annual basis. Annual extinction and colonization probabilities between surveys need to be considered identical because of the lack of intervening survey data. For example we had to assume extinction probabilities between 2007 and 2008, and between 2008 and 2009 were the same.

The predictor variables we used for each of our dependent variables are listed in Table 1. We set occupancy of burned plots to zero in 2004 as these plots had not recovered enough to have CAGN present. We also set the initial occupancy of the low and moderate strata to zero from examination of the data and from preliminary analyses. By doing so our models converged more easily. From previous work (Winchell and Doherty 2008) we knew that detection probabilities tended to be constant, so we modeled this parameter as either a constant or varying by year. We modeled combinations of factors as additive and used all possible combinations of factors (Doherty et al. 2010) to achieve a balanced model set. We relied upon Akaike's Information Criterion with small sample size correction (AICc) for model selection and for calculating cumulative AICc model weights for each predictor variable across our balanced model set (Burnham and Anderson 2002). We considered variables with cumulative AICc weights > 0.5 (Barbieri and Berger 2004) to have meaning. We present model-averaged parameter estimates (Burnham and Anderson 2002) unless otherwise noted.

RESULTS

Our top model modeled occupancy by stratum and as a function of elevation; extinction as a constant; colonization as a function of stratum, elevation and year; and detection as a constant. This model also reflected the variables with the highest cumulative AICc weights across our model set (Table 2) which aligned well with Barbieri and Berger (2004) suggestion to focus on variables with cumulative AICc weights > 0.5.

Occupancy was estimated in 2004 and then derived from extinction and colonization estimates in following years. We found occupancy to be highest in the very high and high strata. Occupancy in the moderate, low, and burned strata were lower with more uncertainty (especially in the low stratum; Fig. 2). We found occupancy to decrease with elevation (Fig. 3).

We found the model-averaged extinction probability to vary little over strata, but our estimates are imprecise (Fig. 4). We found the model-averaged colonization to vary by stratum with the highest colonization rates in the high and very high strata and the lowest is the moderate and burned strata (Fig. 5). The low stratum had the most uncertain estimates (Fig. 5). Annual colonization was highest at lower elevations and higher in 2007-2009 versus the 2004-2007 period (Fig. 6), although confidence intervals for the two periods overlapped substantially. An overall average extinction and colonization rate, from a model with constant extinction and colonization rates (ΔAICc = >65), would be 0.13 (95% CI 0.09, 0.18) and 0.06 (95% CI 0.05, 0.09) respectively.

DISCUSSION

Similar to Winchell and Doherty (2008), we found the strata of the TAIC model to reflect occupancy estimates well (Fig. 2). We also estimated that occupancy within strata has increased from 2004 to 2009. Occupancy estimates, over a wider area, from a 2002 survey (Winchell and Doherty 2008) where higher than 2004 and closer to 2009 estimates. High occupancy rates in 2002 may have been a result from previous years with adequate rainfall during the breeding season. Rainfall in southern California is highly variable, and species are probably impacted by extremes. Population declines may be caused by extreme low rainfall years, whereas population maintenance, or increases, may be a function of rainfall adequate to support plant growth and insect populations, especially during the breeding season. For southern California, the three months receiving the most rainfall are January, February and March, which coincides with nest building and the first-brood eggs laid (Atwood and Bontrager 2001).

Prior to, and during the 2002 survey (July 1 2001 to June 30 2002) was the driest year on record for San Diego County, with 7.6 cm of precipitation at the coast. We assume this lack of precipitation resulted in high rates of nest failure and low juvenile survivorship. Adult mortality post-survey, coupled with poor fecundity, and low juvenile survivorship could have reduced the population to low levels by the 2004 survey. Rainfall during the breeding seasons 2003 through 2009 showed and increasing pattern from 2002, with the lowest year (2007) receiving nearly double the rainfall recorded for this 3 month period during 2002. This pattern of precipitation during the breeding season possibly triggered a recovery of the population that we detected in the 2007 and 2009 surveys.

We found our 5th stratum, the burned high and very high quality plots, to become occupied over time, but at a slow rate. Surveys were conducted on burn points during the 2004 breeding season following the October 2003 fires and no gnatcatchers were observed (we set occupancy = 0 for burned plots in 2004). In 2007, the 3 points within the 2003 fire perimeter at where CAGN were detected were on average 315 m (SD 165) from the fire perimeter and always bordered habitat modeled as “very high”. In 2009, on 9 points, CAGN were detected from 217 m to 1972 m from the perimeter and 6 of these points were adjacent to habitat modeled as “very high”. Recolonization appears to expand in from the fire perimeter and may be aided by the quality of unburned habitat nearest to the burn.

We also found occupancy to decrease with increasing elevation. This was opposite our prediction and we evaluated meteorological data to help explain this result. From average yearly rainfall and average daily minimum low temperature for the month of January for 26 weather stations within the general geography of our sample frame (www.wrcc.dri.edu) we found that low elevation areas receive less annual rainfall (< 30.5 cm) than higher elevations (>40.6 cm) and have milder winter low temperatures (>1.1° C). Lower amounts of rainfall would favor the scrub habitat the CAGN favor and higher amounts of rainfall would favor dense chaparral that CAGN do not favor. Warmer winter temperatures would favor birds with high surface to volume ratios such as CAGN (Root 1988, Mock 1998) and may also influence the abundance of small insects available for food during winter months. Thus the relative amount of precipitation and temperature may explain the occupancy patterns we detected associated with elevation.

Beyond occupancy patterns we were able to investigate the dynamics (extinction and colonization) of CAGN across our survey area. We found that extinction rates were relatively constant across our variables of interest. However, colonization rates varied by habitat strata, year, and elevation. Survey points considered high or very high quality had high colonization probabilities, especially at low elevations. Colonization was also higher from 2007-2008 than in previous years. This may be because the population was expanding during our survey period as a result of a decline in 2003 resulting from the 2002 drought. An increasing population would supply dispersing juveniles that would first select very high and high quality habitat in which to establish territories.

We showed occupancy increased within the preserve areas of San Diego County during our study. This may be a combined factor of higher colonization rates for habitat modeled as “high” and “very high” and the removal of 16% of these same habitats due to the 2003 wildfire. The could be explained if the population of CAGN was increasing due to precipitation patterns between 2002 and 2009, then this increase in the population would be concentrating into a smaller area of available preferred habitats.

Our evaluation shows the preserve system established in San Diego County is working with respect to CAGN conservation and HCPs. CAGN are sustained within the preserve and may have demonstrated a recovery if the population did experience a rapid decline as a result of record low rainfall in 2002. Preserve lands support CAGN following the predicted loss of habitat to development and the unpredicted alteration to the landscape due to massive wildfire.

MANAGEMENT IMPLICATIONS

High and very high quality areas (especially at lower elevations) have higher occupancy probabilities and are also more likely to be colonized. Thus these areas should receive priority in terms of conservation and being incorporated into preserve systems. CAGNs will recolonize burned areas categorized as high and very high quality, especially at lower elevations, but to reach pre-burn levels will take many years (> than the five years post-burn we have monitored), at least when no habitat rehabilitation program was implemented. Managers should consider directing habitat rehabilitation efforts towards areas of habitat that are modeled as either very high or high quality prior to a fire to increase recolonization rates or at least assure the habitat reestablishes to pre-fire conditions. If money is limited, then habitat rehabilitation efforts could be concentrated in concentric bands bordering the perimeter of the fire and adjacent to habitat modeled as very high.

Lands supporting very high and high quality habitat should be preserved regardless of the presence or absence of CAGN. This is because of the colonization and extinct rates demonstrated. Decision regarding CAGN conservation should be guided by habitat quality.

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Figure 1. Lands defined as our study area are marked in black on this map of San Diego County

Figure 2. Model-averaged occupancy estimates for the five strata from 2004-2009 in the Multiple Species Conservation Program (MSCP) located in San Diego County, CA and assuming average plot covariate values. Error bars are 95% confidence intervals.

Figure 3. The relationship between occupancy probability and elevation for plots in the very high stratum. The dashed lines are the 95% confidence limits and the estimates are from our top model.

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Figure 5. Model-averaged colonization estimates for the five strata from 2004-2009 in the Multiple Species Conservation Program (MSCP) located in San Diego County, CA and assuming average plot covariate values. Error bars are 95% confidence intervals.

Figure 6. The relationship between colonization probability, elevation, and year for plots in the very high quality stratum in the Multiple Species Conservation Program (MSCP) located in San Diego County, CA.

Table 1. Variables used to model occupancy, extinction, colonization, and detection of California gnatcatchers in the San Diego County, CA.

Variable	Occupancy in 2004	Extinction	Colonization	Detection
Constant	x	x	x	x
Habitat strata (low, medium, high, very high, burned)	x	x	x	
Year (2004, 2007, 2009)	x[1]	x[2]	x[2]	X[3]
MSCP[4] (within plan area or not)	x	x	x	
Elevation (m)	x		x	
Distance to coast (m)	x		x	
Heat load[5]	x			

[1]Occupancy was only estimated for 2004 and then derived in future years using estimates of extinction and colonization. Occupancy was set equal to zero for the low, medium, and burned strata in 2004 based on the data.

[2]Extinction and colonization were considered identical for years between surveys.

[3]Detection was set equal to zero for years in which survey were not conducted.

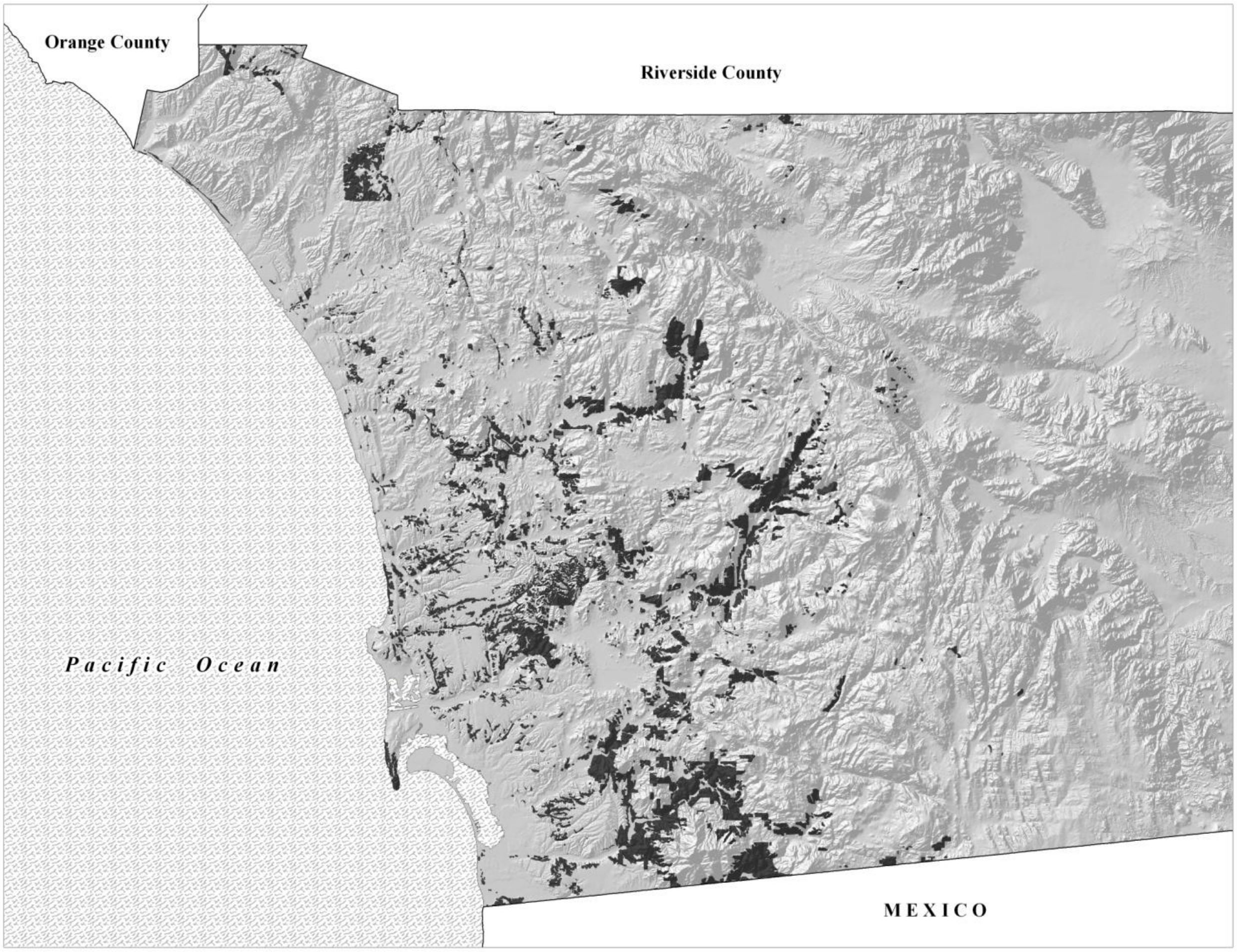
[4]MSCP is the Multiple Species Conservation Plan located in San Diego County, CA.

[5]As defined by McCune and Keon (2002)

Table 2. The cumulative Akaike's Information Criterion (AICc) weight for each predictor variable.

	Parameter			
Variable	**Occupancy in 2004**[1]	**Extinction**	**Colonization**	**Detection**
Habitat strata	0.86	0.21	0.86	
Year		0.34	0.61	0.13
MSCP	0.24	0.24	0.24	
Elevation	0.78		0.69	
Distance to coast	0.33		0.28	
Heat load	0.34			

[1]Occupancy was only estimated in 2004 and then derived in future years from estimates of extinction and colonization.



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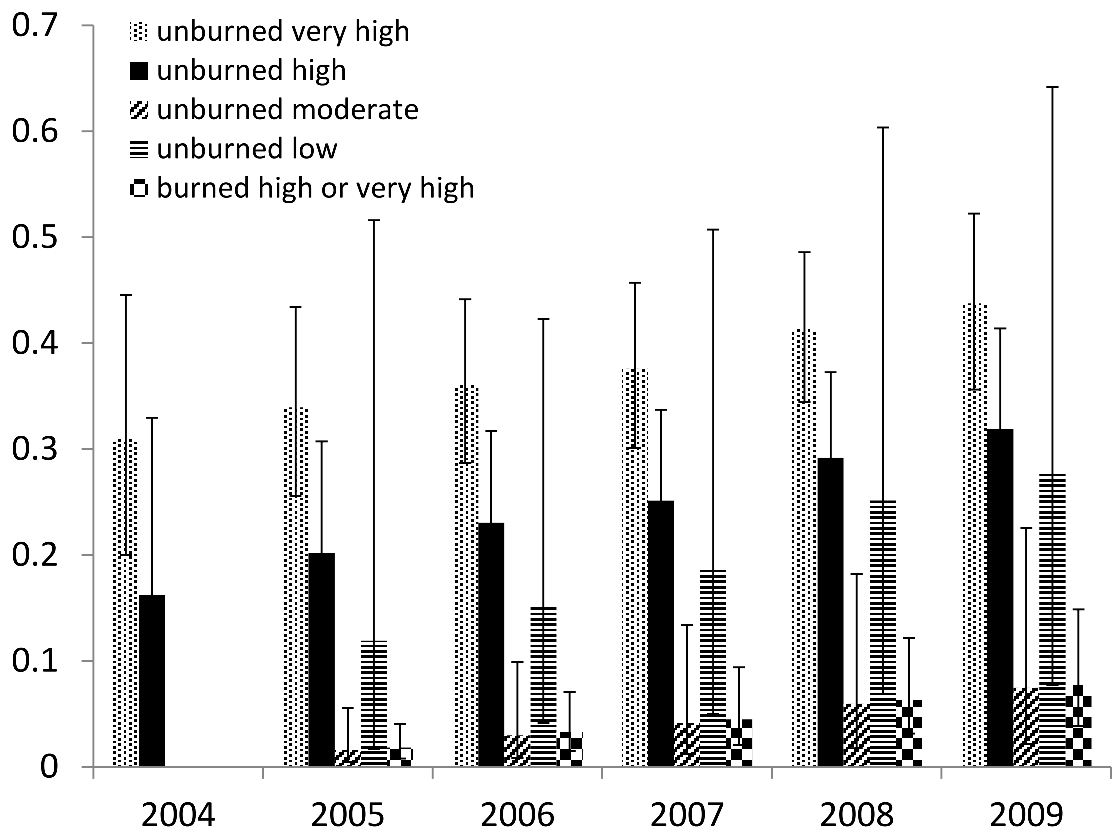

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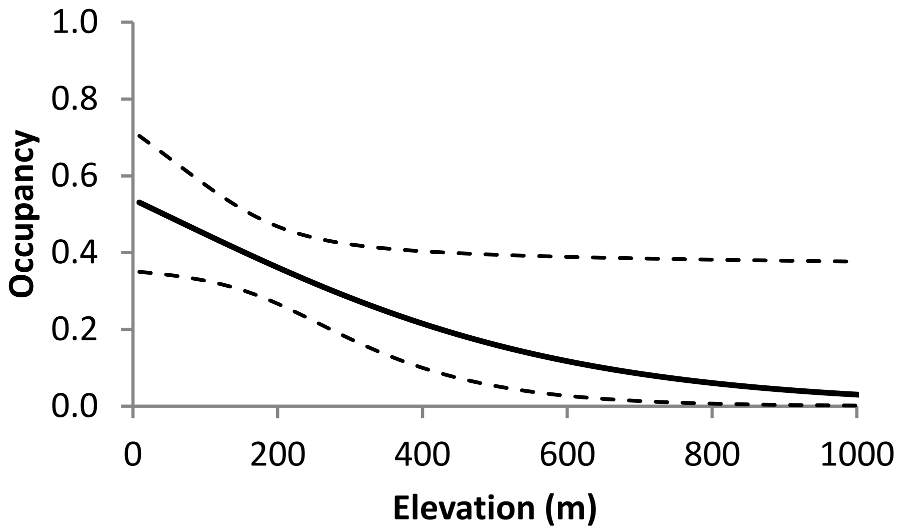

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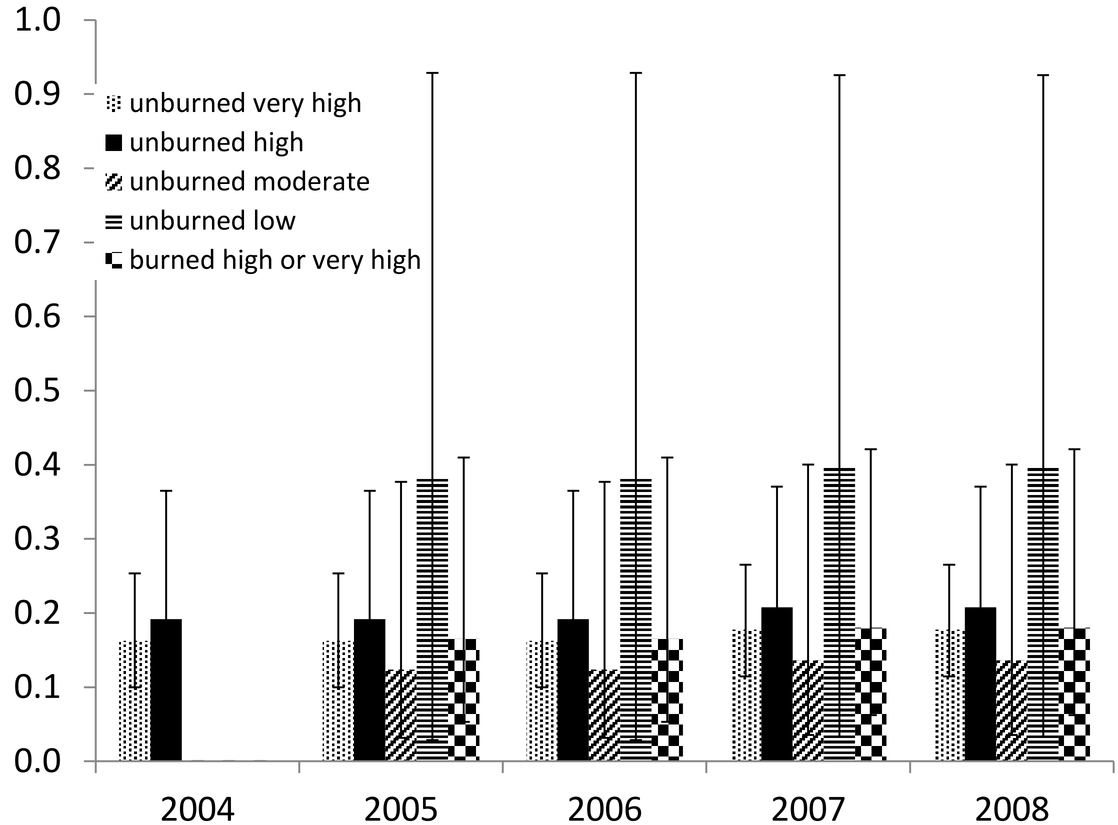

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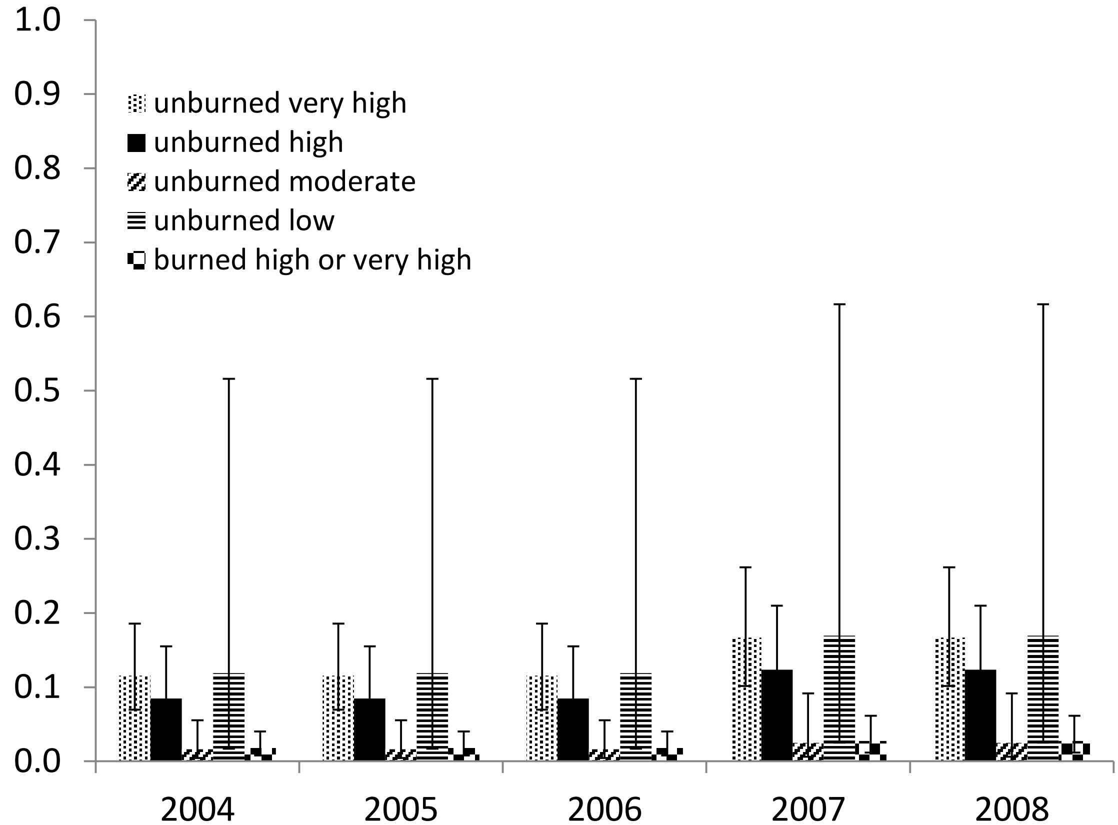

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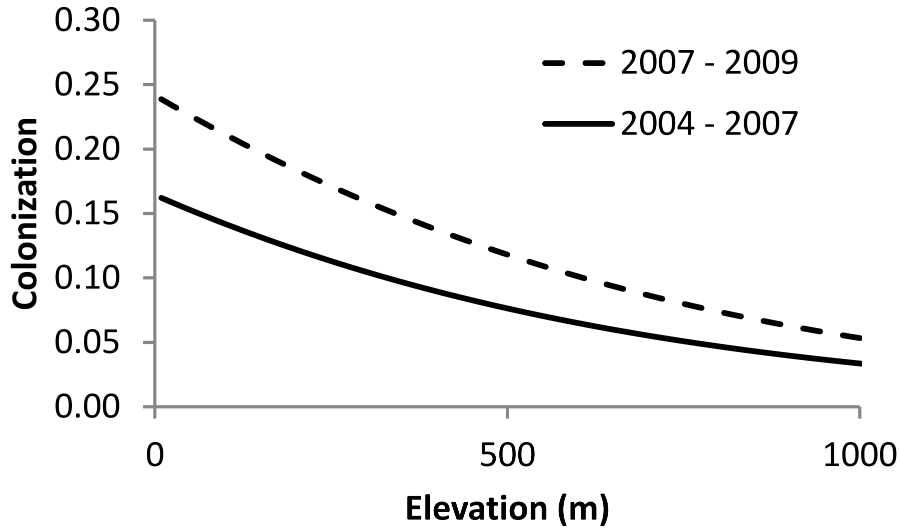

Figure 6. The relationship between annual colonization probability, elevation, and year for plots in the very high quality stratum in the Multiple Species Conservation Program (MSCP) located in San Diego County, CA.