Analysis of Butterfly Survey Data and Methodology from San Bruno Mountain Habitat Conservation Plan (1982–2000)

1. Status and Trends

Travis Longcore
Christine S. Lam
John P. Wilson

University of Southern California GIS Research Laboratory
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GIS research laboratory
Department of Geography
College of Letters, Arts, and Sciences
University of Southern California
Los Angeles, CA 90089-0255
www.usc.edu/dept/geography/gislab

Prepared for: Thomas Reid Associates
560 Waverly Street, Suite 201
Palo Alto, California 94301

USC Center for Sustainable Cities

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Lupines at San Bruno Mountain, March 2003 (T. Longcore)

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Summary

Managers surveyed for sensitive butterfly species with the San Bruno Mountain Habitat Conservation Plan area between 1982 and 2000 using a haphazard "wandering transect." To extract as much valuable information as possible from the data collected by this suboptimal methodology we analyzed patterns of surveys and butterfly presence and absence within 250 m square cells gridded across the area within a Geographic Information System. While estimates of butterfly abundance were not possible, the data could be tested for trends in butterfly occupancy. For those cells surveyed during at least 10 years, no trends in the total number of occupied cells was evident for either Callippe silverspot butterfly or mission blue butterfly. There were cells, however, that showed positive or negative trends ($p<0.2$) in occupancy for each species (Callippe silverspot butterfly: 14 positive, 15 negative, 6 cells occupied all years; mission blue butterfly: 40 positive; 40 negative, 2 cells occupied all years). The analysis concludes that for the period 1982–2000 the population of each species was stable in overall total distribution, but indicates geographic areas of concern for each, specifically the edges of the northeast ridge for Callippe silverspot butterfly and the northwest of the study area for mission blue butterfly.

Introduction

The Habitat Conservation Plan at San Bruno Mountain was the first of its kind, opening a pathway for this new type of conservation mechanism (Beatley 1994). As part of the management of the reserve established at San Bruno Mountain, yearly surveys were conducted to count listed butterfly species, and butterfly species of regulatory concern (Thomas Reid Associates 2000). These surveys were initiated in the early 1980s and continue today. Recently, the surveys have been digitized and complied in a Geographic Information System, which facilitates in-depth analysis of the status and trends of populations of these sensitive species. This report presents the results of an analysis of these data and an assessment of the survey methodology.

The surveys at San Bruno Mountain record incidence of two species, mission blue butterfly (*Icaricia icarioides missionensis*) and Callippe silverspot butterfly (*Speyeria callippe callippe*). A third species, San Bruno elfin (*Incisalia mossii bayensis*), was surveyed but is not addressed here. The surveys, called "Wandering Surveys" by Thomas Reid Associates ("TRA"), followed no fixed route and were conducted throughout the flight seasons of both species from 1982–2000. Such a methodology presents immediate difficulties for drawing statistical inference or even detecting qualitative trends. The goal of our analysis is to extract the maximum amount of information from the dataset, while acknowledging the flaws inherent in the methodology.

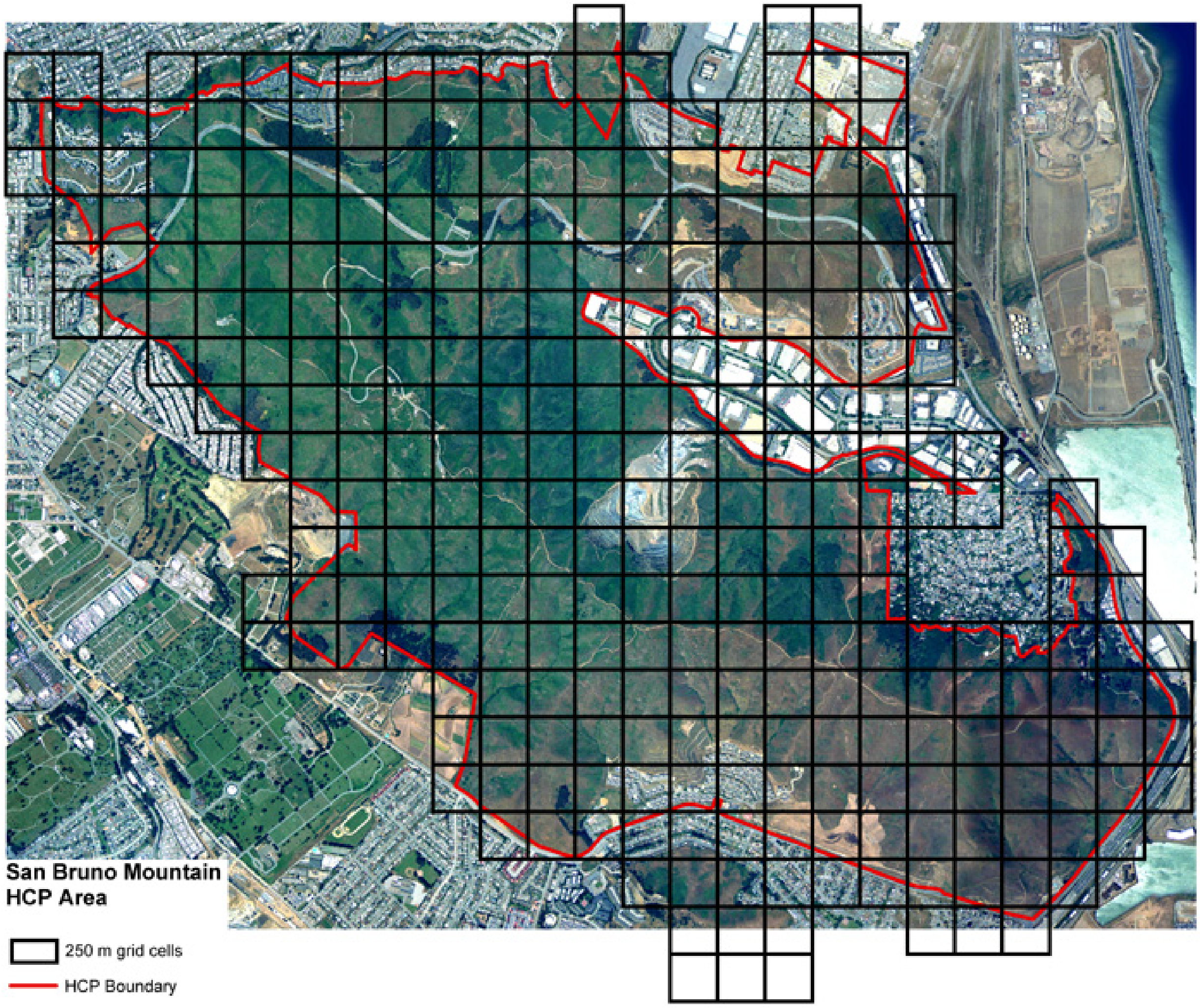


Figure 1. Aerial photograph of San Bruno Mountain HCP area with 250 m grid.

Research Questions

Several challenges are posed by the analysis of the San Bruno Mountain butterfly data. Some can be solved, some are likely intractable. The first problem posed by the dataset is that surveys were not completed in the same geographic locations each year. Most butterfly monitoring schemes involved repeated, fixed transects (Pollard et al. 1975, Pollard and Yates 1993). In this manner, the number of individuals each year can be compared with some degree of confidence. The second problem is that the data provide no obvious way to estimate what proportion of butterflies is being observed each year. The detection probability is a central part of monitoring schemes; for butterflies it can be calculated either from mark-recapture data (Gall 1985) or distance sampling (Buckland et al. 1993). In this *post hoc* analysis, neither option is available. Detection probability is affected by the use of different survey locations each year that may have different habitat features that increase or decrease detection. Because of these two difficulties with estimating butterfly abundance, we chose rather to investigate trends in the distribution of the species.

Knowledge of trends in the geographic distribution of the butterflies on San Bruno Mountain is in some ways superior to knowledge of trends in abundance. Butterflies are notoriously variable in abundance from year to year and wide fluctuations may obscure secular trends (Pollard 1988). Occupancy (or at least observation) and abundance are related: butterflies will be detected in more locations in years when butterflies are abundant if only because the chances of encountering a butterfly are increased. Aside from this statistical result of greater population size, some patches may indeed be colonized during years with many adult butterflies. In either instance, if butterflies are observed in more areas it is a good sign for the species. Indeed, mathematical models of metapopulation persistence often record only the number and occupancy rate of habitat patches, not the number of butterflies at each patch (Hanski 1999).

The research questions therefore involve the distribution patterns of mission blue butterfly and Callippe silverspot butterfly 1982-2000.

- Has each species exhibited secular trends in total area occupied?
- What areas have exhibited secular trends in occupancy?
- What areas have exhibited large and small variability in occupancy?

A second set of research questions address the survey methodology.

- What areas exhibited secular trends in survey coverage?
- What areas were surveyed frequently and infrequently?
- What was the relationship between survey frequency and occupancy?

Methodology

Thomas Reid Associates conducted butterfly surveys in the San Bruno Mountain HCP area (Figure 1) every year since 1982. The surveys were characterized as "wandering" transects, in which the observer did not follow any set route but rather conducted surveys across the mountain and recorded his survey route and location of any butterflies observed. Timing of surveys and weather conditions were also recorded. Surveys were conducted through the adult flight season of both butterfly species. Results from these surveys were digitized by TRA and are managed in a Geographic Information System.

We overlaid a 250 m square grid over the HCP area (Figure 2). The grid size provides a sufficient number of cells to identify differences across the study area but not so many that analysis is intractable. Furthermore, each cell is sufficiently large to incorporate the elements necessary for butterfly reproduction, including foodplants, nectar sources, and potentially ridgelines for hilltopping.

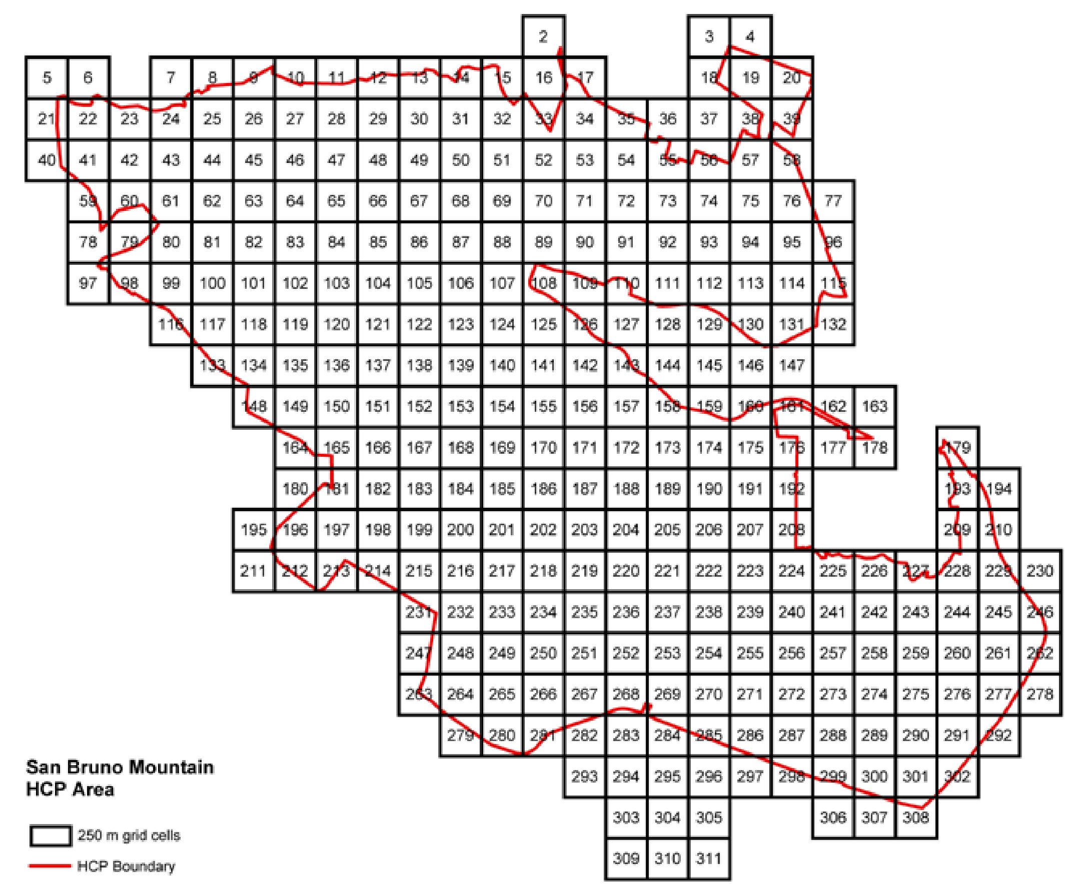


Figure 2. Numbered grid for analysis of butterfly survey data, San Bruno Mountain HCP.

For each 250 m square cell and for each year for each species, the number of visits, total length of surveys, and presence of the butterfly was recorded. For this analysis, we considered that a cell was "surveyed" if a total of 250 m of surveys were conducted within the cell during a particular year. This constitutes a substantial assumption, because detection of butterflies depends on the number, length, and timing of surveys (Zonneveld et al. 2003). The risk of choosing 250 m as a cut-off is that some cells where the butterfly was actually present will be recorded as absences because 1) too few surveys were conducted to detect a small population, 2) surveys were timed improperly to detect adults, or 3) the butterfly was too cryptic to detect because of behavioral or weather conditions. While such false negatives are possible, false positives are not, except for the instance of the misidentification of an adult butterfly. This results, therefore, in a conservative analysis – the situation will not be worse than described based on this assumption, and it may be slightly better. Summary statistics such as the number of years each cell was surveyed, the proportion of years butterflies were observed were also recorded.

For each cell and each butterfly, we completed a logistic regression of occupancy with year as the independent variable. Trends with $p < 0.20$ were recorded. This relatively low confidence threshold serves to provide a conservative analysis that can identify potential areas of change in the distribution of each species. If a requirement to meet a higher significance level is required, then greater confidence can be achieved but the opportunity for remediation would be delayed.

Data collected with each butterfly observation could also be incorporated into the analysis to investigate geographic patterns. These variables include date observed, time, wind speed, temperature, observer, butterfly sex, and butterfly behavior. For example, because of the hilltopping behavior of Callippe silverspot butterflies, one would expect that males are more frequently observed on ridgetops (Shields 1967, Thomas Reid Associates 1982). We analyzed the use of ridgelines by both species to test this hypothesis. Ridgelines were identified by querying the DEM to assign a rank to each cell relative to all other cells within a 30 m radius, using the ElevResidGrid algorthim (written by John Gallant, CSIRO Land and Water). The ranking ranges from 0 (lowest cell within 30 m) to 1 (highest grid cell). The DEM was clipped at the HCP boundary to avoid interference from the urban topography surrounding it. Ridgelines were identified as those cells with a ranking of 0.66 and higher. A higher value (e.g., 0.75) would present few sparse grid cells across the study area to identify contiguous ridgelines. A lower value (e.g., 0.60) would classify an excessive number of cells as ridgelines, including cells that were predominantly hillslopes. We then mapped a 25 m buffer around ridgeline cells and recorded the number of butterflies of each sex found within the buffer area.

Results

During the 19 years of surveys, 295 of 310 cells were surveyed at least one time. Some cells were surveyed significantly less frequently over time. The number of cells surveyed that did not support either endangered butterfly decreased significantly over time, as did the total length of survey routes per year. This change in survey distribution indicates that surveyors directed efforts in locations where butterflies had been found before, and avoided areas that had yielded negative results for a number of years. While some cells were surveyed for many years (>15) with no butterflies of either species found, they were located along routes to sites that support the target species.

Survey distribution for mission blue butterfly (Figure 3) and Callippe silverspot butterfly (Figure 4) both show a concentration in the northeast ridge and along other ridgetops where access is less difficult. The western side of the HCP area has been surveyed somewhat less than the eastern regions, reflecting, among other things, the climatic preferences of the butterflies (Weiss and Murphy 1990). The distribution of surveys included both ridgelines and hillslopes across the HCP study area (Figures 5, 6).

The tendency over time was for the surveyors to stop searching for the butterflies in areas that had been surveyed with negative results several times. Consequently, the number of “empty” cells surveyed decreases significantly during the study period, as seen for Callippe silverspot butterfly (Figure 7). This was accompanied a significant overall decrease in the total length of surveys each year (Figure 8).

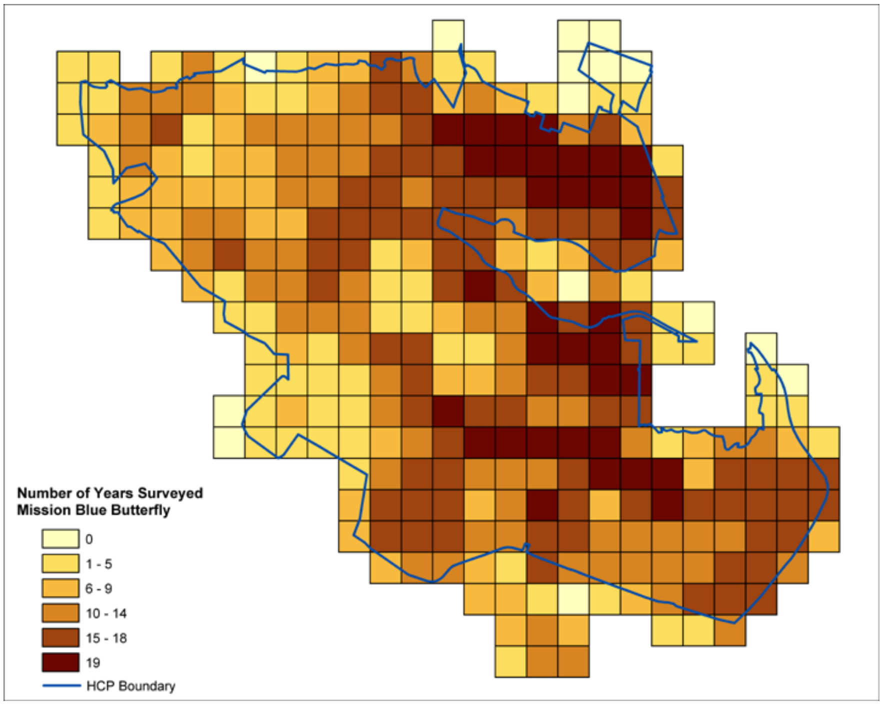


Figure 3. Distribution and frequency of surveys for mission blue butterfly at San Bruno Mountain, 1982–2000.

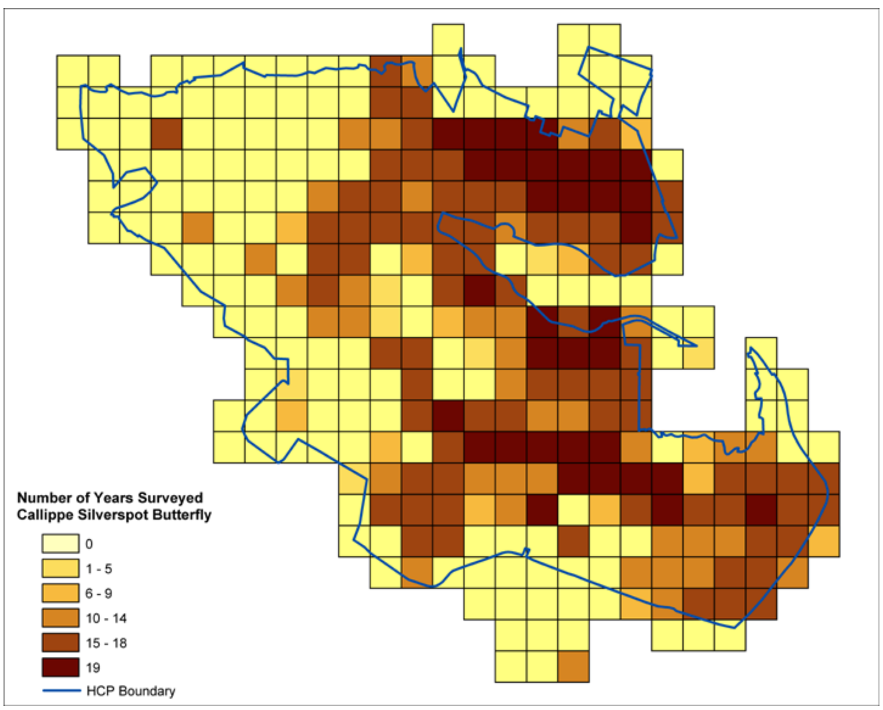


Figure 4. Distribution and frequency of surveys for Callippe silverspot butterfly at San Bruno Mountain, 1982–2000.

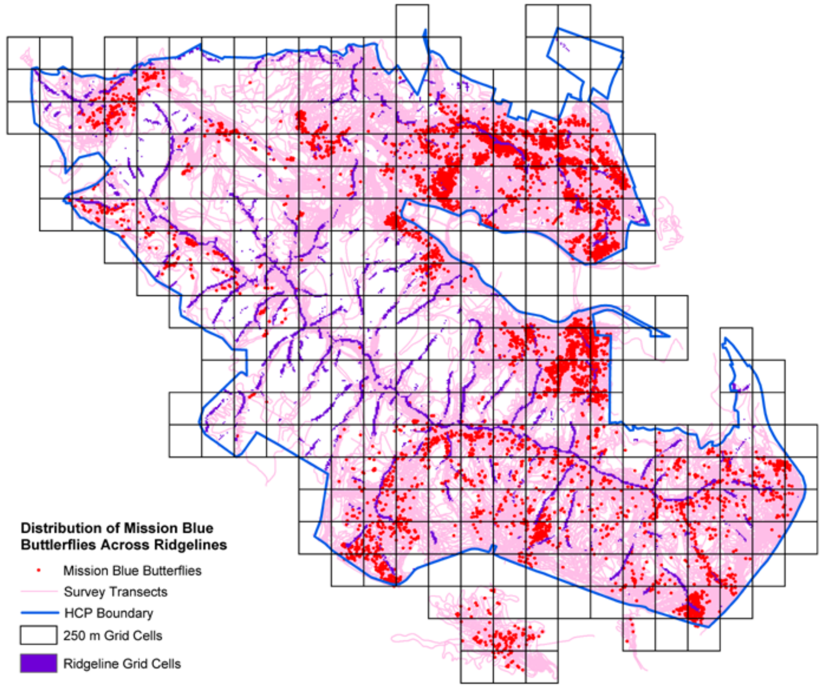


Figure 5. Distribution of surveys and observations of mission blue butterfly relative to ridgelines, 1982–2000.

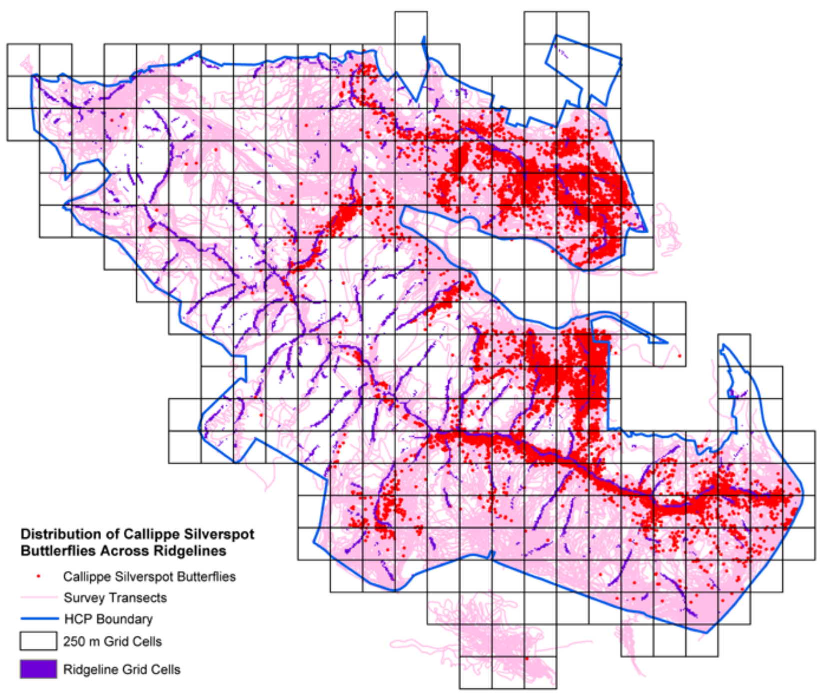
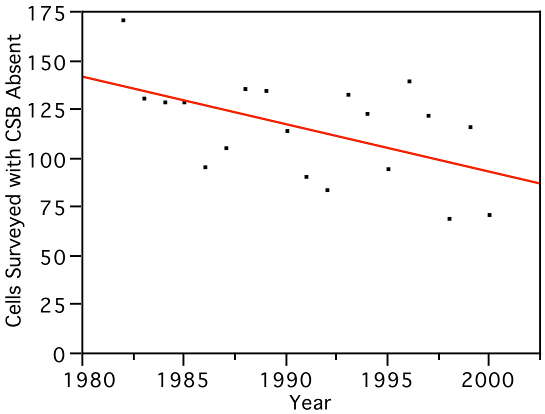


Figure 6. Distribution of surveys and observations of Callippe silverspot butterfly relative to ridgelines, 1982–2000.



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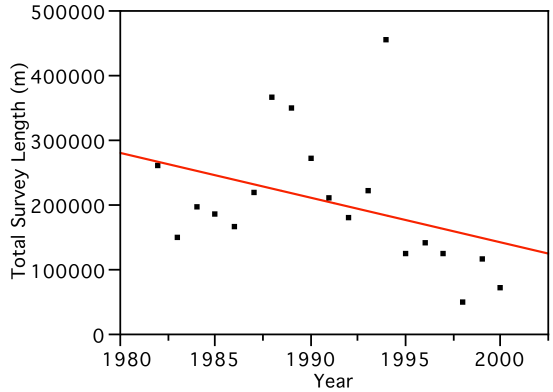

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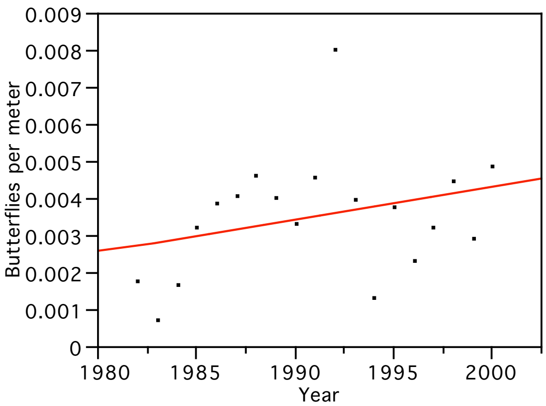

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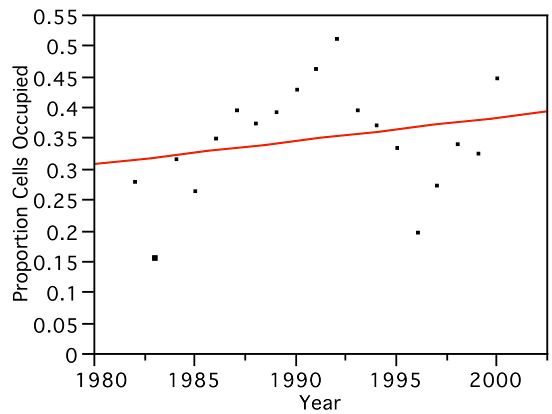

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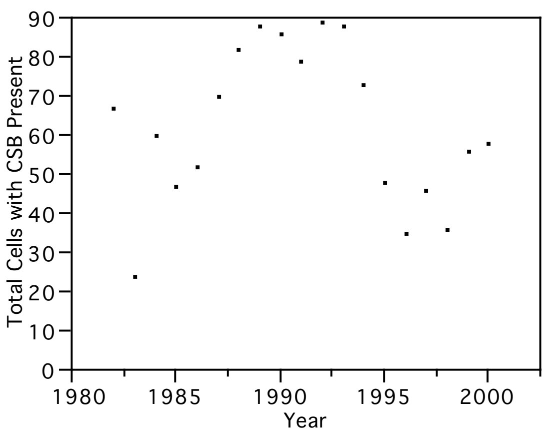

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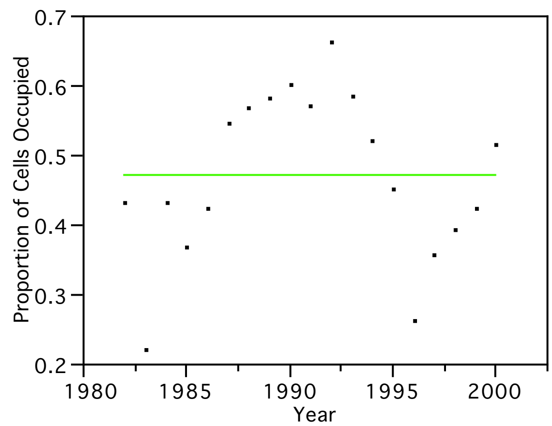

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Figure 7. Number of cells surveyed per year where Callippe silverspot butterfly was not detected, with linear regression ($r^2 = 0.27$, $p < 0.02$). Figure 8. Total survey length per year with linear regression. Figure 9. Number of Callippe silverspot butterflies observed per meter of transect – a spurious measure of population status because transect location and effort were not fixed. Figure 10. Proportion of cells occupied by Callippe silverspot butterfly each year – also a spurious metric because of the changing number of "empty" cells surveyed each year. Figure 11. Total number of cells with Callippe silverspot butterfly present per year. Figure 12. Proportion of cells occupied by Callippe silverspot butterfly of those cells where butterfly was located at least once. The horizontal line indicates the mean (47%).

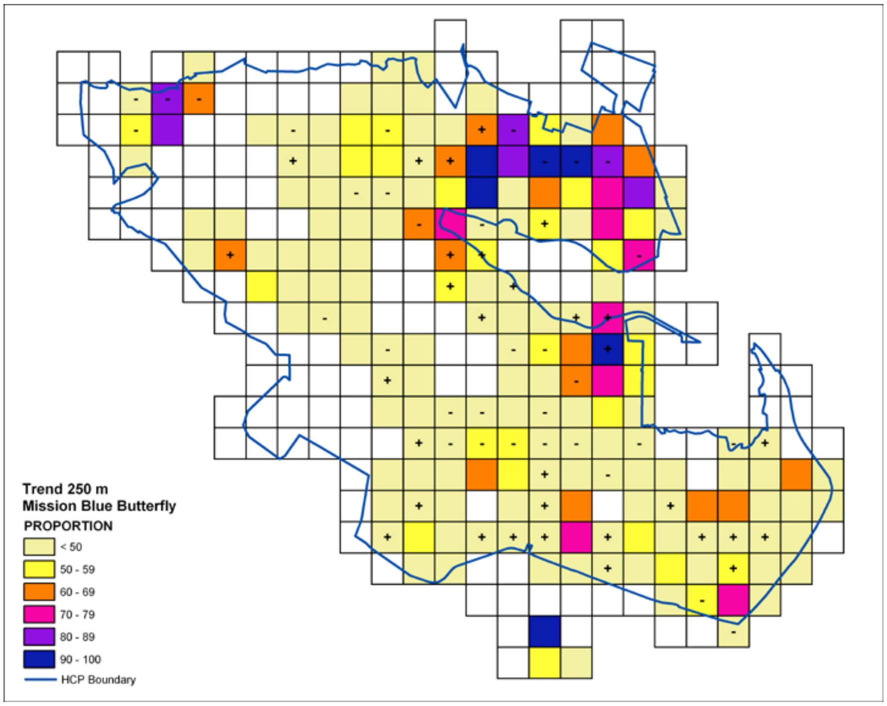

Figure 13. Status and trends of mission blue butterfly at San Bruno Mountain. Proportion of years occupied is depicted for all cells surveyed during 10 or more years 1982–2000. Trends in occupancy (p<0.20) determined by a logistic regression are indicated in each cell.

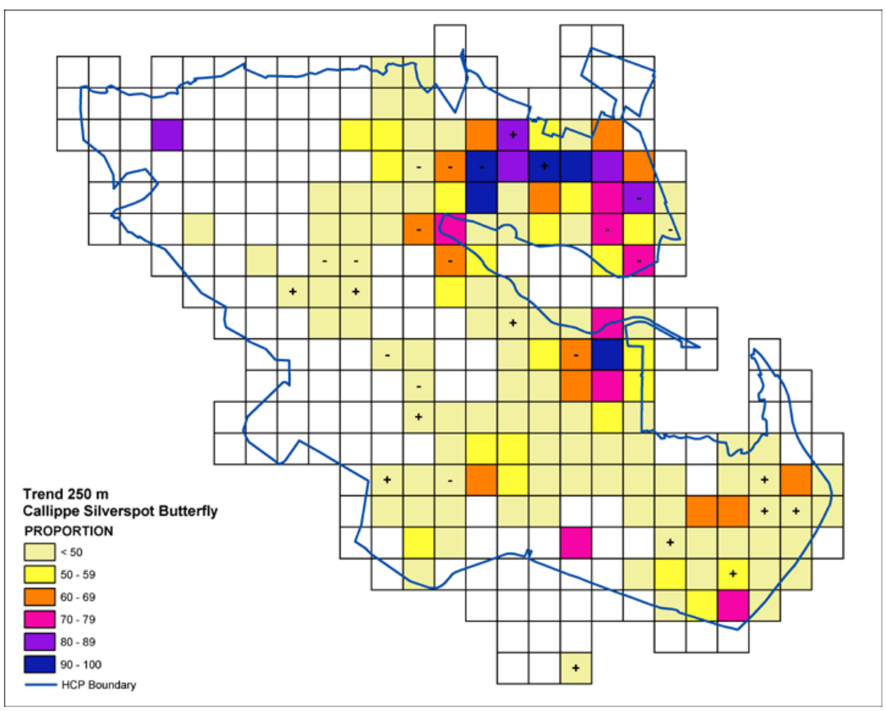

Figure 14. Status and trends of Callippe silverspot butterfly at San Bruno Mountain. Proportion of years occupied is depicted for all cells surveyed during 10 or more years 1982–2000. Trends in occupancy (p<0.20) determined by a logistic regression are indicated in each cell.

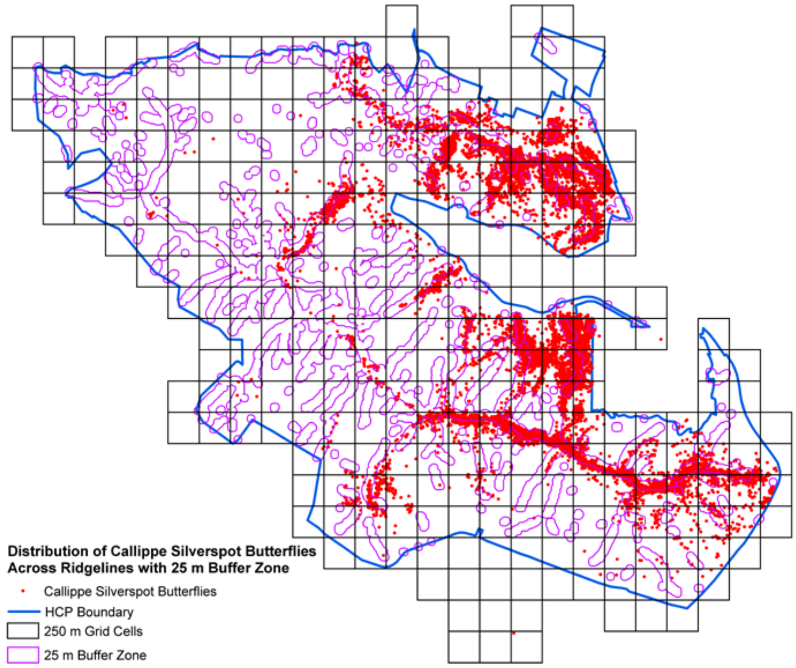

Figure 15. Distribution of Callippe silverspot butterflies relative to ridgeline buffers, 1982–2000.

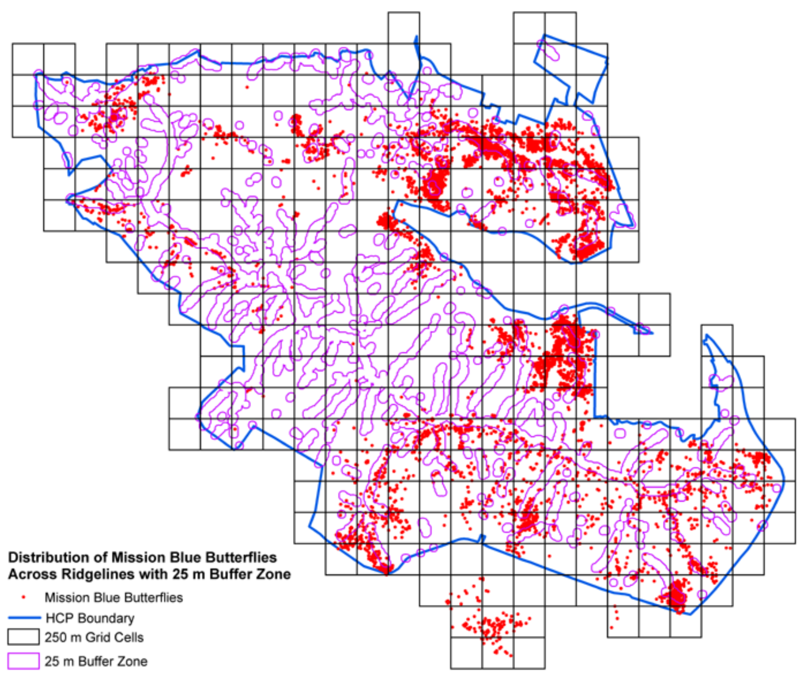

Figure 16. Distribution of mission blue butterflies relative to ridgeline buffers, 1982–2000.

The changing effort and location of surveys each year violates the assumptions of random sampling and uniform methodology. Several of the metrics that might be used to track population status therefore reveal instead artifacts of the methodology. For example, the average number of Callippe silverspot butterflies observed per meter of transect appears to show a positive trend over time (Figure 9). This trend is spurious, because surveys over time concentrated increasingly on cells where butterflies were present. Without surveying marginal habitats with butterflies absent, the apparent density of butterflies increases. All such butterflies per meter estimates derived from these data are similarly useless in evaluating population status because they are not comparable year to year. Similarly, the raw proportion of cells occupied by either mission blue butterfly or Callippe silverspot butterfly is a spurious measure because of the decreasing number of “absent” cells surveyed over time. Therefore, while the proportion of cells with Callippe silversot butterfly present each year increased significantly (Figure 10), the absolute number of occupied cells showed no statistical trend (Figure 11). But the absolute number of occupied cells is also misleading, because of the decreasing number of total cells surveyed over time. We conclude therefore that the best measure of trends in occupancy involves analysis of the proportion of cells occupied, when limited to those cells where the species was observed at least once (Figure 12). For these cells with at least one observation, neither butterfly shows a significant trend in the number of cells occupied over time.

Given that no overall trends in the proportion of the range occupied by either species exist, the analysis concentrates on trends within individual cells over time. The limits of such trend analysis extend to the 218 cells that were occupied at least once by mission blue butterfly, and 165 cells that were occupied at least once by Callippe silverspot butterfly. Figure 13 depicts the cells for each species that were surveyed at least 10 years with each species present at least once, showing the proportion of years the butterfly was present. It also depicts cells where a trend during the study period was detected ($p<0.20$). These results are based on occupancy for years surveyed, and so do not represent differences in survey frequency over time.

The cells with trends ($p<0.20$), including those surveyed fewer than 10 years, were evenly split for mission blue butterfly (40 positive, 40 negative, with 2 cells occupied every year surveyed), and for Callippe silverspot butterfly (14 positive, 15 negative, with 6 cells occupied every year surveyed) (Figure 17). The most stable cells for both species are concentrated in the northeast ridge, but this is also the location with a far greater proportion of the negative trending cells. For Callippe silverspot butterfly, the northern half of the study area (cell numbers < 150) contains 11 of 15 negative trending cells (73%) but only 5 of 14 positive trending cells (36%). A similar, but less dramatic pattern is seen for mission blue butterfly.

Survey data provided adequate data to observe the importance of topographic relief to the two species. For mission blue butterfly (Figure 16), the proportion of male butterflies seen within ridgeline areas was extremely close to the proportion of males in the whole population (68.9% vs. 68.3%), and the same was true for females (26.1% vs. 26.5%). For Callippe silverspot butterfly (Figure 15), males were in slightly greater proportion within the 25-m buffer zones (41.2% vs. 37.8%) while females were present in slightly lower proportion than observed in the population (34.6% vs. 40.6%). The percentage Callippe silverspot butterflies of unknown sex was greater within ridgeline buffers than in the population as a whole (24.2% vs. 21.4%). These results are consistent with the observation that male Callippe silverspot butterfly use hilltops more than females. This use is by no means exclusive, however.

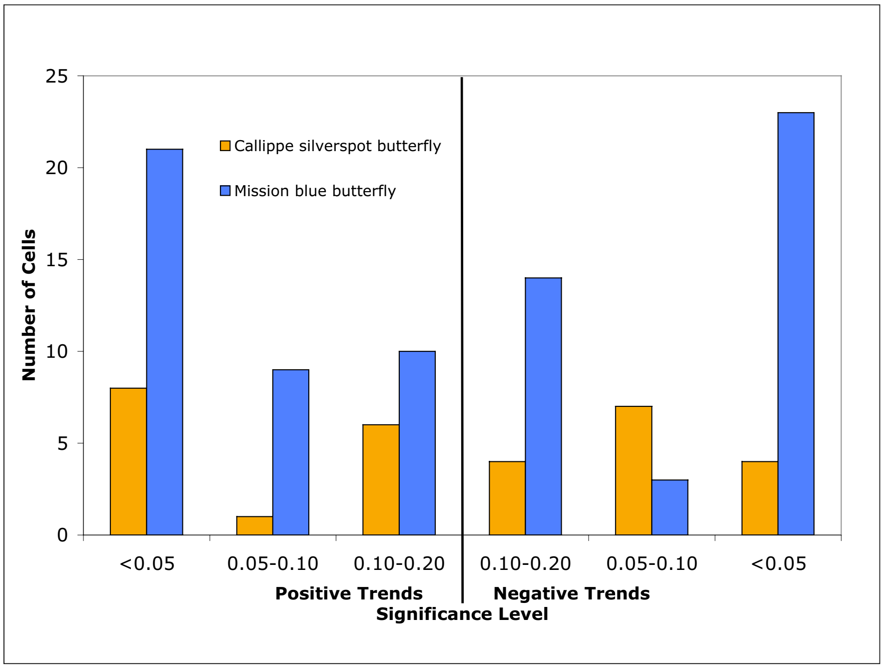

Figure 17. Significance of trends in presence by cell for Callippe silverspot butterfly and mission blue butterfly.

Discussion

The wandering transects violates most tenets of survey design. It is "convenience sampling" (Anderson 2001), providing no replication for comparison. This does not suggest that the surveys were easy to complete — to the contrary, fieldwork on San Bruno Mountain is notoriously difficult and physically taxing. Rather, the design was opportunistic rather than pre-structured, making it haphazard rather than random. Ample scientific literature was available at the time that the survey technique was designed to indicate the value of replication in the form of fixed, repeated transects (Pollard et al. 1975, Pollard 1977). Failure to follow such methods, or to develop a statistically rigorous sampling scheme, reduced the scientific value of the monitoring program. The lack of regularly repeated transects also hampers the application of subsequent techniques to estimate population size and other flight period characteristics (Zonneveld 1991). When techniques to estimate search efficiency became available, these were not incorporated into the survey design (Buckland et al. 1993, Brown and Boyce 1998). The wandering surveys may have other benefits for those managing the natural resources at San Bruno

Mountain, such as detection of invasive plants. They are nevertheless deficient as a technique to gather data about butterflies from which statistical inferences can be made.

The purpose of this analysis, however, is to evaluate what information can be gained from the wandering transect surveys. Notwithstanding the deficiencies in survey design, we believe that sufficient information can be gained from the surveys to describe, however imperfectly, the distribution of the two butterfly species over time. Some researchers believe that survey data that lacks an estimate of search efficiency is useless for scientific analysis (Anderson 2001, 2003), but we do not subscribe to this extreme view. The assumptions that we have made, most importantly that a survey length of 250 m within a cells is sufficient to detect the butterflies if present, provide a conservative analysis of the situation. As discussed above, false negatives are possible, but false positives will be very rare. By switching from emphasis from abundance to occupancy, the effects of search efficiency on the results is diminished, but not eliminated. The analysis does not allow inference to cells that were not surveyd. In contrast, had the survey routes been chosen randomly, and repeated, inference could have been drawn about areas not surveyed.

For the period 1982–2000 the distribution of Callippe silverspot butterfly and mission blue butterfly in those areas surveyed at San Bruno Mountain was stable. The distribution of the population experienced changes as certain areas were colonized (or were more regularly occupied) and others exhibited trends toward local extinction.

Many of the significant trends in occupation for both Callippe silverspot butterfly and mission blue butterfly were located in cells that were occupied fewer than 50% of the times surveyed. These trends can be caused by a single year or two of presence at the end of the survey period for a positive trend or at the beginning for a negative trend. While interesting if connected to known changes in habitat conditions, they are of less interest to an assessment of the overall health of the population. Of considerably more interest are those cells where the butterfly has been located for a significant proportion of years surveyed (> 70%) and yet is exhibiting a negative trend.

For Callippe silverspot butterfly a series of cells with greater than 70% occupancy show negative trends, all of which are found in the northern portion of the study area (70, 71, 95, 113, 131, 107, 125). In comparison, only two cells in this northern region showed positive trends (54, 73).

The mission blue butterfly also exhibited negative trends in a number of the cells that were occupied a large proportion of surveyed years. These include the northwest portion of the study area (24, 25), the northeast (54, 73, 74, 75, 131, 107) and one in the southern portion of the site (190). Many of the trends detected for mission blue butterfly were found in cells where the butterfly was present less than 50% of the time.

The Northeast Ridge appears to be an important location for both butterflies, but especially Callippe silverspot butterfly. Here is the greatest concentration of cells that reliably support the butterfly. Yet, it seems that the edges of this area have become degraded, for example the western end of the industrial park and directly north from it, and the eastern edge of the HCP boundary. The scope of our analysis, which does not include any vegetation information, does not allow explanation for these trends.

The cell-by-cell trend analysis similarly reveals areas of concern for mission blue butterfly. A cluster of cells in the northwestern corner of the study area exhibits negative trends. The core of the northeast ridge area has negative trends, but several positive trending cells are found to its east, and south of the industrial park.

While information relevant to the management and conservation of these species has been extracted here from the wandering transects, it is evident that the survey methodology can be improved. A companion report addresses this issue in detail. This report, however, provides our best analysis of the survey data, and we believe that it has yielded sufficient information to identify areas in need of management action, as well as those areas important to the survival of these two listed butterfly species.

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