Bay Checkerspot Butterfly
Reintroduction Feasibility Study At San Bruno Mountain

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Executive Summary

San Bruno Mountain (SBM) is currently home to three species of butterflies listed as endangered or threatened by the U.S. Fish and Wildlife Service (USFWS): the mission blue butterfly (*Icaricia icarioides missionensis*), the San Bruno elfin butterfly (*Callophrys mossii bayensis*), and the callippe silverspot butterfly (*Speyeria callippe callippe*). Habitat for these butterflies at SBM is protected in perpetuity as a part of the San Bruno Mountain Habitat Conservation Plan (HCP). Portions of San Bruno Mountain were identified as critical habitat for the Bay checkerspot butterfly (*Euphydryas editha bayensis*) (BCB) in the HCP based on known historic occurrences of this butterfly. Unfortunately, in the mid-1980s, soon after the HCP approval, the BCB was considered extirpated from SBM.

USFWS staff (David Kelley, Joseph Terry, and others) have expressed interest in investigating whether it is feasible to reintroduce BCB to San Bruno Mountain, given recent success in reintroduction at Edgewood Natural Preserve in Redwood City and Tulare Hill in San Jose by Creekside Science (Niederer and Weiss 2014; Niederer et al. 2015). The purpose of this study was to determine whether sufficient suitable BCB habitat exists on SBM, and consider how such a reintroduction could work.

Habitat surveys in spring 2014 and 2015 mapped numerous small patches of the BCB native annual host plant *Plantago erecta*, while observing near ubiquitous stands of the nonnative perennial *Plantago lanceolata*. The extant patches of *P. erecta* do not provide enough habitat for a viable population of BCB. *P. lanceolata* could likely provide enough habitat to sustain a population of BCB. The last postdiapause larvae (1983) were observed feeding on *P. lanceolata* along the ridgetop road (Weiss pers. obs.), therefore we anticipate that host-switching was already occurring before the extirpation of the BCB from SBM. *Euphydryas editha* ssp. *taylori* populations in Oregon and Washington (Severns and Grosboll 2011) and in the Sierra Nevada (Schneider's Meadow) have adopted *P. lanceolata* as a hostplant (Ehrlich and Hanski 2002). *P. lanceolata* was successfully used in several laboratory experiments with BCB at the Stanford Department of Biological Sciences in 1985 (Weiss pers. obs.). *P. lanceolata* is a robust biennial/perennial species that remains green many weeks longer than the native *P. erecta*.

Assuming that BCB adult females oviposit on *P. lanceolata* in the field (likely given its ubiquity and BCB behavior), and that prediapause and postdiapause larvae survive on it (experimentally confirmed), potential BCB habitat occurs across much of the grassland on SBM. There appear to be sufficient nectar sources during the March-April flight season. The mountain is large and topographically/climatically diverse, similar to Coyote Ridge where a healthy, thriving population of BCB persists. Two BCB reintroduction areas are proposed in this study, and additional areas may be appropriate in the future.

Euphydryas editha is an adaptable species. Reintroducing the BCB to San Bruno Mountain with the expectation they will switch to a non-native hostplant is a conservation experiment that raises many interesting ecological and policy issues in a rapidly changing environment. This project could show that we are able to reintroduce extirpated species without the technical difficulties and expense of restoring all historical conditions.

Funding for this feasibility study was graciously provided by the San Francisco Bay Wildlife Society.

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Background

The Bay checkerspot butterfly (BCB) is a medium-sized butterfly with a wingspan of about 2 inches in the family Nymphalidae, the brush-footed butterflies. BCB forewings have black bands along the veins in the upper wing with bright red, yellow, and white spots (see cover photo). Females lay masses of 20-350 eggs on or near *Plantago erecta* in the spring (usually March-April). The eggs hatch in about 2 weeks, and early instar larvae often live communally in a silken tent through their first couple of instars. Prediapause larvae are in a race to complete their first three molts before the host plants dry out. If their food supply lasts, upon molting into the 4th instar, larvae will enter diapause and "oversummer" under rocks and in the soil. Although triggers for breaking diapause are not completely understood, the larvae typically emerge in November or December when the rains commence, feeding as individuals on suitable native host plants (*P. erecta, Castilleja densiflora* ssp. *densiflora, C. exserta* ssp. *exserta*) until they pupate after their 7th instar. Adults emerge usually 1-2 weeks after pupation, mate immediately, and then females begin laying egg masses. Even before the invasion of non-native plants, this species may have been colonial, occurring in local hotspots where host plants and adult nectar sources were abundant, likely associated with disturbance (Ehrlich and Hanski 2004).

Historically, the subspecies occurred in the vicinity of the San Francisco Bay area from San Bruno Mountain (west of the Bay), Mount Diablo (east of the Bay), to Coyote Reservoir (south of the Bay) and even south to Hollister (Black and Vaughan 2005). The current range of the subspecies is greatly reduced and is now restricted to serpentine grasslands or grasslands occurring on similar soil types. The subspecies is described as having a metapopulation dynamic, which is a group of spatially distinct populations that occasionally exchange individuals (Erhlich and Hanski 2004). Metapopulation dynamics predict that sites that are unoccupied one year may be occupied the next, and vice versa. At the time the recovery plan was published in 1998 for the Bay checkerspot butterfly (Serpentine Soils Species of the San Francisco Bay) there were two metapopulations identified; one in San Mateo County (primarily at Edgewood Park) and the other was scattered across southern Santa Clara County, predominately at Coyote Ridge. The butterfly numbers in San Mateo County decreased annually until the butterfly was presumed extirpated from San Mateo County in 2002 (USFWS 1998, Weiss 2002).

Regulations and Recovery of the Bay Checkerspot

The BCB was listed as a federally threatened species by the USFWS on September 18, 1987. The Xerces society lists this species on its Red List: Critically Imperiled (Black and Vaughan 2005). Predominant threats to the existence of this species are: habitat loss to development, habitat loss due to a lack of disturbance such as fire or grazing, habitat fragmentation, atmospheric nitrogen deposition, and invasive species.

The recovery plan for the Serpentine Soil Species of the San Francisco Bay Area (USFWS 1998) emphasizes the need to protect, restore, and manage habitat for the Bay checkerspot butterfly at San Bruno Mountain. The plan also recommends reintroducing the butterfly at that location, which will be one of three satellite populations in San Mateo County required for de-listing the butterfly (USFWS 1998: Recovery task 2.2.16).

Although the BCB went locally extinct around the time the San Bruno Mountain Habitat Conservation Plan (HCP) was adopted, BCB is one of four covered butterflies listed in the HCP. Host and nectar plants used by the BCB are listed as Species of Concern in Exhibit C of the HCP, thus affording these plants protection under the HCP (San Bruno Mountain Habitat Conservation Plan Steering Committee 1982).

Two successful reintroduction projects with the BCB are currently under way at Edgewood Natural Preserve (San Mateo County) and at Tulare Hill/Metcalf Energy Center (Santa Clara County) (Niederer and Weiss 2014; Niederer et al. 2015). These reintroductions used the large robust population complex on Coyote Ridge as source of thousands of postdiapause larvae for translocation. Both of these reintroductions have been conducted by Creekside Science staff in association with the USFWS and landowners. Creekside Science's experience with these projects uniquely positions their staff to assess reintroduction potential at San Bruno Mountain.

Historical Distribution of Bay Checkerspot on San Bruno Mountain

In pre-European times, the Bay checkerspot butterfly was likely a common butterfly of most open grasslands around the Bay. Introduced annual grasses and forbs became the dominant species in most grasslands since the Mission period. On SBM itself, the coastal prairie historically supported large stands of *P. erecta* among perennial bunchgrasses and forbs.

The BCB population on SBM crashed during the drought of 1975-1977, when no individuals were observed. They were encountered again in 1978, and persisted at low numbers through 1984. TRA (1985b) documents three years with low BCB sightings from 1982-1984, and a change to BCB habitat after a major grassland fire in July 1984:

> "Substantial portions of native host plants, particularly on the extreme west end of the south ridge, appear to have been eliminated and replaced with weeds (Eriodium sp.) [sic].This latter area has effectively been lost as Bay Checkerspot butterfly habitat."

The habitat did not recover from the fire and weed invasion. The distribution and abundance of larval hostplants *P. erecta*, *Castilleja densiflora* and *C. exserta* continued to decline. A study co-authored by Weiss (reported in TRA 1986) proposed the possibility that BCB was extinct on San Bruno Mountain, with no documented sightings since 1984.

Historical observations (early 1980s) of BCB and their two main host plants (*P. erecta* and *Castilleja* [*Orthocarpus*] spp.) are shown in Figures 1a,b,c (TRA 1985a). Butterflies and hostplants were found along the ridgetop, and hostplants extended downslope several hundred meters into open grasslands, and further downslope along roads. The observed butterflies exhibited hilltopping behavior, where males aggregate on hilltops and unmated females fly upslope to mate, thus the mapped distribution of adults may not indicate occupied hostplant habitat lower on the slopes of SBM.

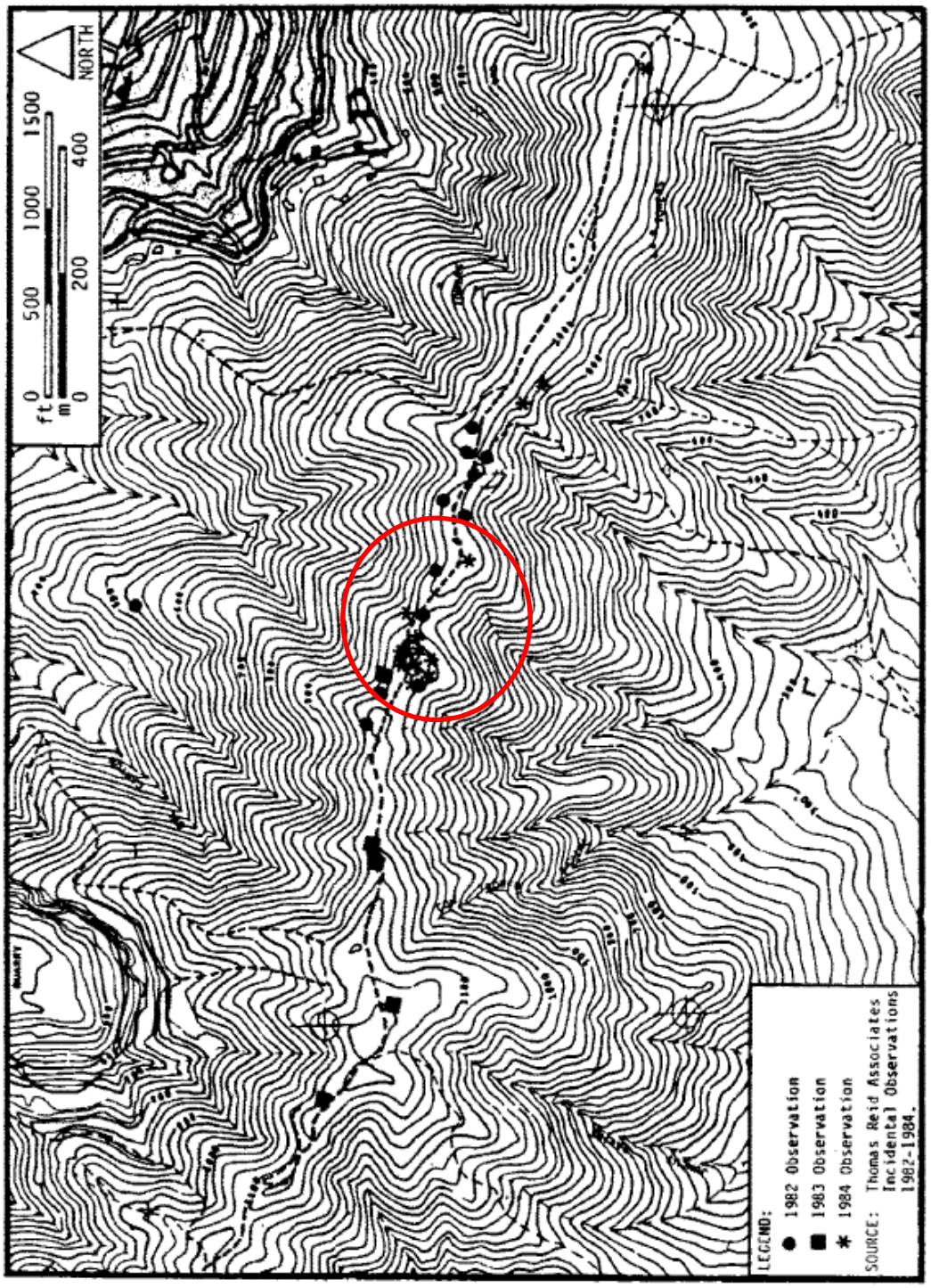
The last postdiapause larvae observed (1983) were feeding on *P. lanceolata* along the ridgetop road at the concentration of adult sightings in the red circle in Figure 1a. This indicates a potential hostplant shift. Postdiapause larvae are opportunistic and can disperse tens of meters per day, and will feed on a

much wider variety of potential hostplants (Plantaginaceae and Orobanchaceae) than prediapause larvae, especially when they need large quantities of fresh food in the final instar. *P. lanceolata* appeared much less abundant (but still widely distributed) across the entire mountain at the time BCB were extirpated, but was locally common along the disturbed fire road (Weiss pers. obs.).

The low number of observations in 1982, 1983, and 1984 indicated a small population in the hundreds (at most) occupying deteriorating and fragmenting habitat, and focused on hilltops. Extremely low numbers of butterflies foiled attempts at mark-recapture studies. Small populations of BCB on small patches of habitat are at high risk of rapid extinction, as observed at Jasper Ridge Biological Preserve in the 1990s and at Edgewood Natural Preserve in the early 2000s. The lack of incidental sightings by R. Langston, S. Weiss, P. Kobernus, and other biologists working in the former habitat over three decades is strong proof of local extirpation.

Figure 1a. From TRA 1985a.

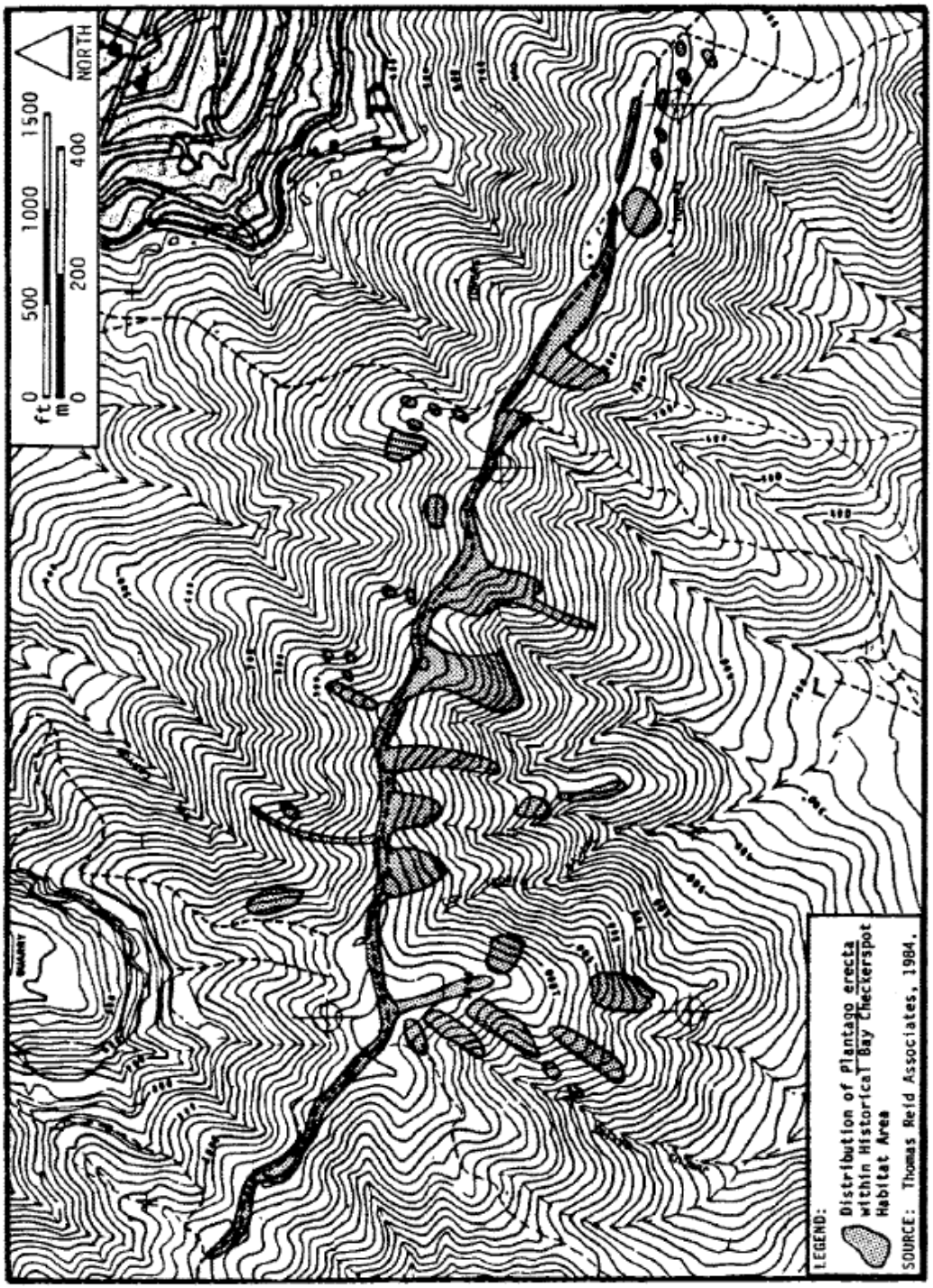
FIGURE IV - 4
INCIDENTAL OBSERVATIONS OF BAY CHECKERSPOT -- 1982-1984



1/30/85 IV - 8

Figure 1b. From TRA 1985a.

FIGURE IV - 6
DISTRIBUTION OF PLANTAGO ERECTA WITHIN BAY CHECKERSPOT HABITAT AREA

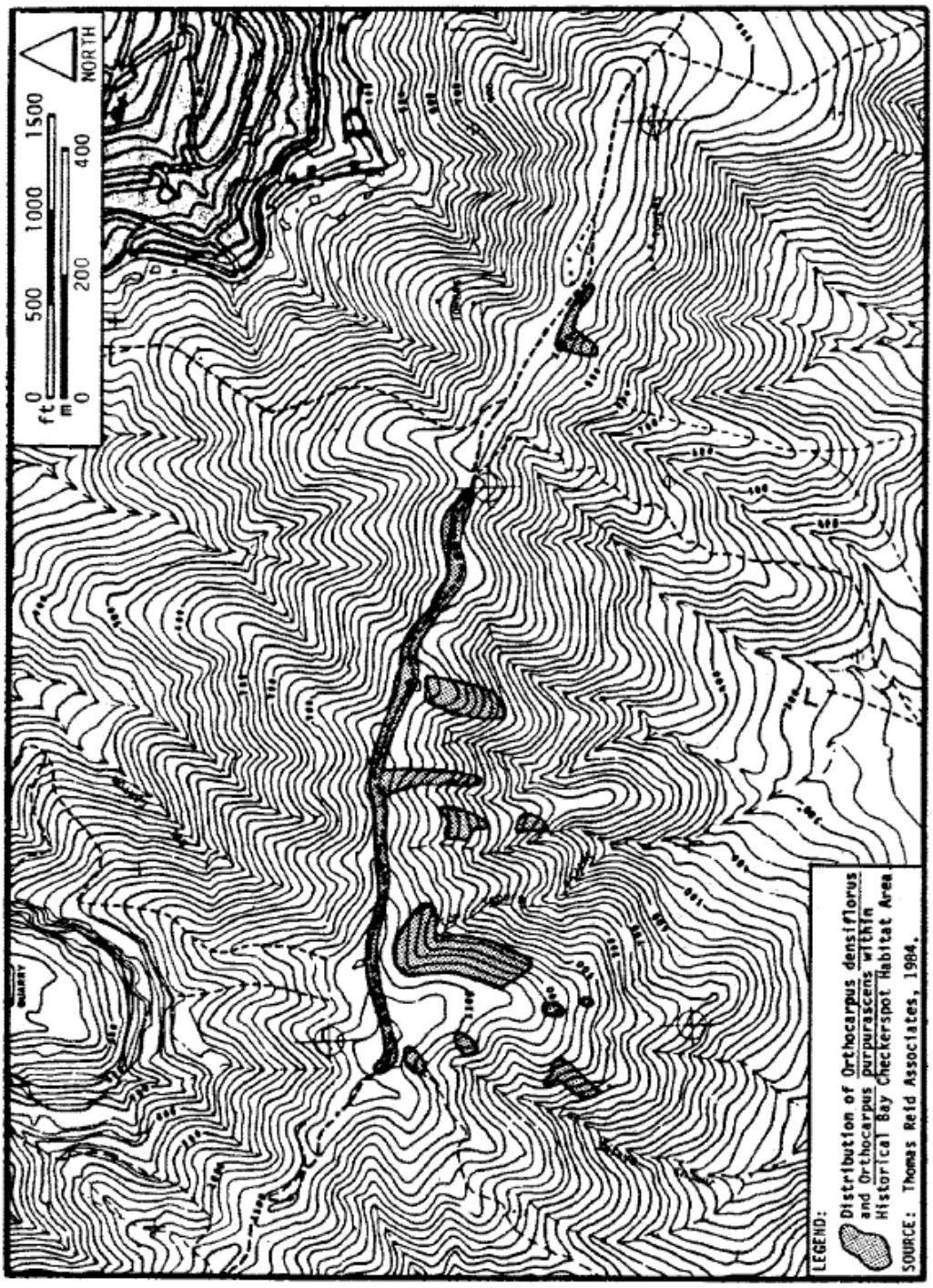


1/30/85

IV - 12

Figure 1c. From TRA 1985a.

FIGURE IV - 5
DISTRIBUTION OF ORTHOCARPUS WITHIN BAY CHECKERSPOT HABITAT AREA

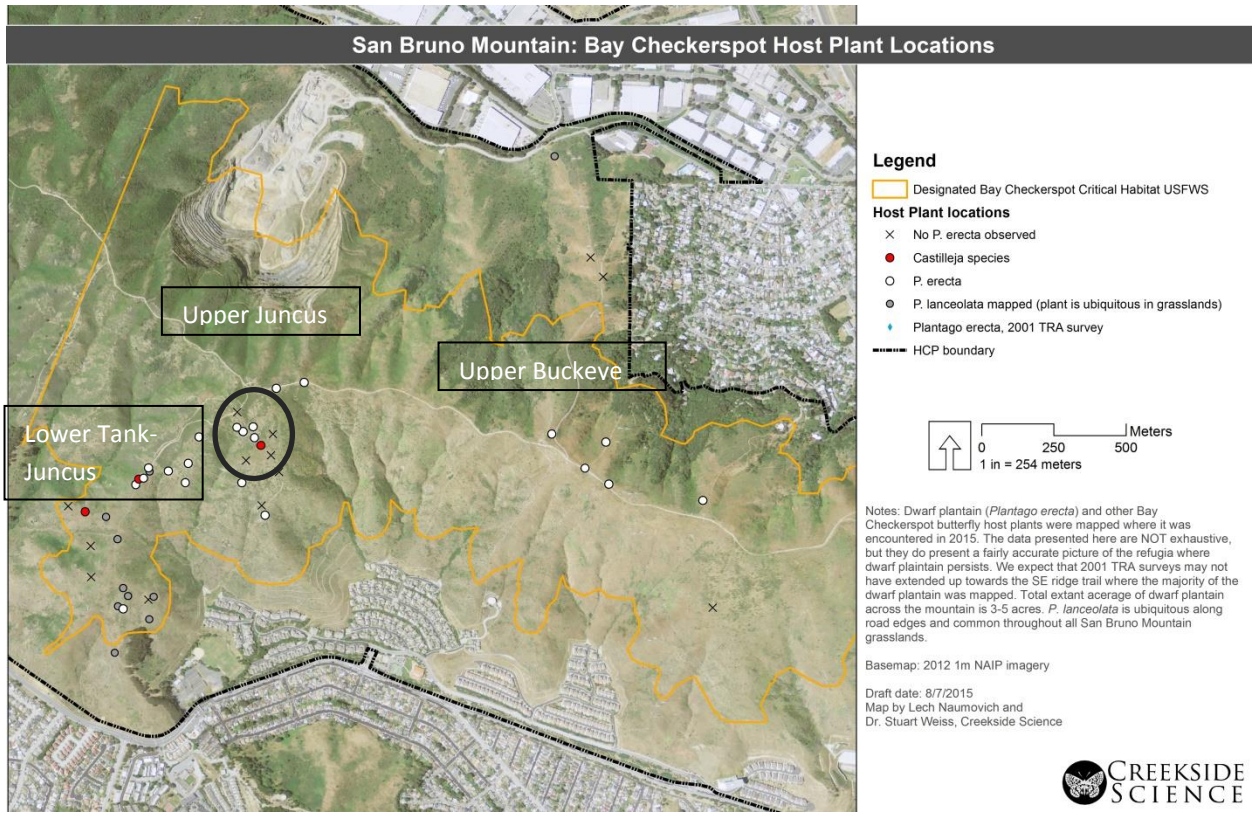


2014-2015 Surveys and Habitat Analysis

BCB Host Plants

Surveys in spring 2014 and 2015 found small discontinuous patches of *P. erecta* on the main ridge (Figure 2). Many of the continuous stands of *P. erecta* from 1984 (Figure 1b above) have been lost, either completely eliminated from scrub and annual grass/*Erodium* encroachment, or persisting as small patches (tens of square meters at most) along the ridge trail. The ridge trail also serves as a fire road that has been occasionally scraped, creating excellent conditions for *P. erecta* and other native annuals. Now, brush encroachment has narrowed the open roadsides in many places. *Erodium* and annual grasses continue to occupy most of the grasslands downslope from the ridgetop, especially on the south slope. *P. erecta* stands, albeit patchy and low density, still exist down on the north-slopes above Owl/Buckeye and Brisbane. *P. erecta* stands off roadsides were generally in high quality coastal prairie with thin eroding soils. The high productivity of native and introduced grasslands greatly restricts *P. erecta* habitat.

Figure 2



Upper Juncus

The largest remnant patch of *P. erecta* found on San Bruno Mountain is located in the black circle to the east of Upper Juncus Ravine, and 2/3 of the way to the summit (Figure 3). This photo illustrates that even the largest patch of *P. erecta* is not very big (~1000 m^2, 0.25 acre). This patch is surrounded by native scrub, which in the absence of disturbance is likely to invade further, but the shallowest soils near

the rocks would likely remain grassland. Several other small stands of *P. erecta* in the nearby scrub/grassland mosaic are mapped as well, and there are likely small patches of *P.* erecta on some of the other ridges to the east.

This patch is high quality coastal prairie; largely native, with many native annual and perennial forbs, most notably *Lupinus albifrons*, and native perennial grasses (Figure 4). *Erodium* sp. is the most abundant non-native, and *Oxalis pes-caprae* was noted at low densities. Many of these small inaccessible openings in the scrub mosaic on the upper South Slope are high quality prairie and likely support some small stands of *P. erecta*.

This area is mapped as lowest priority grassland habitat in the 30-Year Review (Weiss et al. 2015), based on lack of covered butterfly sightings and resources, distance to grassland habitat, and high scrub cover. (Read more on scrub invasion in Risks section below.) This area is also the invasion front for *Oxalis.* Backpack herbicide treatment of the leading edge invasion has occurred (M. Forbert. pers. comm.). The high numbers of *L. albifrons* suggest that this grassland's priority be upgraded.

Figure 3. The largest dense population of *P. erecta* found on San Bruno Mountain. Note author in foreground, and larger context of scrub invasion.

Figure 4. Close-up of same location as above, photograph from upper portion of grassland patch showing *P. erecta* and other associated species. Note also the *L. albifrons* and a high cover and diversity of native forbs, but also some *Erodium*.

Lower Tank-Juncus

Lower Tank-Juncus supports dense stands of *P. lanceolata,* small stands of *P. erecta,* and sparse *Castilleja* spp (Figure 2). The *P. erecta* patches are only found on extremely shallow soils around rock outcrops (Figure 5). In 2001, larger stands of *P. erecta* had been mapped along the roads and trails in this area (M. Forbert pers. comm.), but were not observed in 2014 and 2015.

P. lanceolata is particularly dense along trail sides (Figure 6), is nearly ubiquitous in open grasslands, and is thriving in the recent burned areas (Figure 7). Rough visual density estimates in Figure 7 are on the order of 1 plant/m^2 (quantitative surveys are eventually needed).

Tank-Juncus contains a local hilltop with dense stands of *P. lanceolata* that can attract and retain adult butterflies. At the upper end of the open grassland, the scrub perimeter (seen in Figure 5) would likely act as a partial barrier to emigration. BCB moving uphill past the scrub boundary could encounter more *P. erecta* and P. *lanceolata* in openings near the ridgetop, and could join any population established on the ridgetop.

The 30-Year Review (Weiss et al. 2015) classified Tank-Juncus as Essential Grassland for habitat management. *L. albifrons* and *Viola pedunculata* stands support Mission blue and callippe silverspot butterflies. Essential grasslands are priority management areas for covered butterflies and grassland maintenance (native scrub control). This area burned in 2013, with subsequent targeted weed management (*Oxalis,* fennel, and others) and scrub control.

This area is also in the highest nitrogen deposition zone of SBM because of proximity to upwind urban areas (Weiss et al. 2015). N-deposition drives vigorous regrowth of annual grasses (especially *Avena spp.*) and reduces hostplants and nectar sources. *P. lanceolata* will persist in the understory but may be less accessible to BCB adults. Many stands of *P. lanceolata* are in shallow soils and on roadsides and will remain open without additional management.

Figure 5. Rock outcrop at upper end of Juncus/Tank grassland with small stand of *P. erecta* (a few square meters). Note the dominance of scrub on slopes above.

Figure 6. Dense stands of *P. lanceolata* along trailside in Juncus/Tank area.

Figure 7. Lower slopes of Tank-Juncus with *P. lanceolata* throughout the grassland, along with stands of *L. albifrons*. This area had burned the previous summer (2013).

Upper Buckeye

Several hectares of open grassland on northerly slopes above Buckeye Canyon (Figure 8) support patchy but extensive stands of *P. erecta* (Figure 9). *P. lanceolata* is plentiful in the more disturbed grasslands. *Castilleja* spp. were not directly observed here in 2014, but were known to be present in other years (Weiss, pers. obs.). The sparse distribution and abundance of *Castilleja* was likely affected by drought in 2014 and 2015, and it may be more widespread and dense in wetter years.

Upper Buckeye is also classified as essential grassland, because it is a high quality coastal prairie with *Viola* and *Lupinus* that support core populations of callippe silverspot and Mission blue butterflies. Scrub encroachment risks are currently low, because Upper Buckeye is one of several early scrub control areas. The vast majority of scattered interior shrubs have been removed, and the boundaries are secured. Similar scrub control is planned along the main ridge, especially on the north-facing slopes.

Figure 8. Upper Buckeye view towards north. Coastal prairie habitat with patchy low density *P. erecta* throughout grassland. Note the lack of interior scrub and well defined grassland/scrub boundaries because of recent scrub control. Note also the thin rocky soils.

Figure 9. A small but relatively high density patch of *P. erecta* in Upper Buckeye.

Southeast Ridge/Brisbane Acres

Small patches of *P. erecta* were found on thin soils on the north-facing slopes above Brisbane Acres (Figure 10) and can be considered an extension of the Upper Buckeye habitat. *P. lanceolata* was also common on these slopes, especially close to roads and trails. These areas are classified as Essential Grasslands and are a high priority for scrub control.

Figure 10. Upper slopes above Brisbane. Small patches of *P. erecta* are present in the thin soils.

Nectar Sources

Nectar sources were widespread, and included the following species:

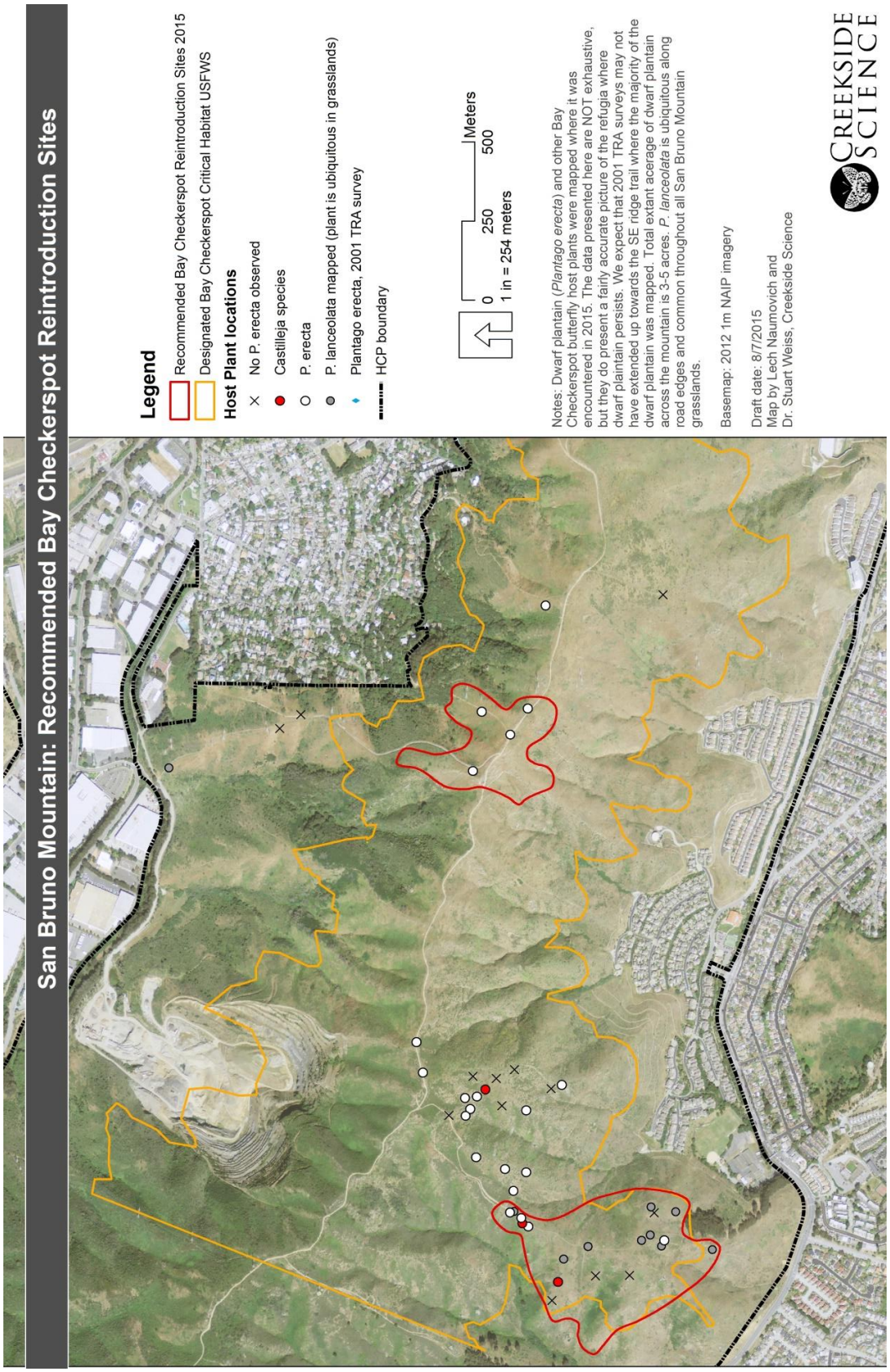
- goldfields (*Lasthenia californica*)
- jeweled onion (*Allium serra*)
- blue dicks (*Dichelostemma capitatum*)
- yarrow (*Achillea millefolium*)
- tidy tips (*Layia* spp.)
- desert parsley (*Lomatium* spp.)
- sanicles (*Sanicula* spp.)

Nectar sources were not explicitly mapped because they were diverse and abundant. In addition, nectar resources are less important for population viability as compared with host plants, and do not appear to be a limiting factor in BCB reintroductions.

Initial Site Selection for Analysis

Based on these field surveys, expert opinion, and initial GIS analysis, two areas were delineated as potential initial introduction sites, Lower Tank-Juncus and Upper Buckeye (Figure 11). Both areas contain hostplants and nectar sources, are within the designated BCB Critical Habitat, and therefore are the foci for further discussion. The emphasis on these two sites should not imply that other sites on SBM are not potential habitat, and a brief discussion of the full potential range is given later in this document.

Figure 11.


San Bruno Mountain: Recommended Bay Checkerspot Reintroduction Sites
Legend
Recommended Bay Checkerspot Reintroduction Sites 2015
Designated Bay Checkerspot Critical Habitat USFWS
Host Plant locations
No P. erecta observed
Castilleja species
P. erecta
P. lanceolata mapped (plant is ubiquitous in grasslands)
Plantago erecta, 2001 TRA survey
HCP boundary
Meters
0 250 500
1 in = 254 meters
Notes: Dwarf plantain (Plantago erecta) and other Bay Checkerspot butterfly host plants were mapped where it was encountered in 2015. The data presented here are NOT exhaustive, but they do present a fairly accurate picture of the refugia where dwarf plaintain persists. We expect that 2001 TRA surveys may not have extended up towards the SE ridge trail where the majority of the dwarf plantain was mapped. Total extant acerage of dwarf plantain across the mountain is 3-5 acres. P. lanceolata is ubiquitous along road edges and common throughout all San Bruno Mountain grasslands.
Basemap: 2012 1m NAIP imagery
Draft date: 8/7/2015
Map by Lech Naumovich and
Dr. Stuart Weiss, Creekside Science
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Topoclimate: Insolation and Wind Exposure

BCB populations respond to local topoclimates (topographically driven microclimates) on scales of tens of meters. Ground-level temperatures are strongly driven by insolation (solar radiation on slopes), and affect larval and hostplant phenology – phenological differences of >4 weeks are possible across extreme north- and south-facing slopes. Wind exposure, an important issue on SBM, can limit adult flight activity. Indices of solar radiation and wind exposure were generated from a 10-m Digital Elevation Model (DEM).

March 21 clear-sky insolation was calculated with ARCGIS Solar Analyst (Figure 12). Visual inspection of the maps and the histograms (Figure 13) show a mix of insolation values at both sites. Upper Buckeye has the most cool slopes that coincide with some of the best stands of *P. erecta*. The southern exposure of the *P. erecta* on Upper Juncus makes this area less suitable.

Figure 12.

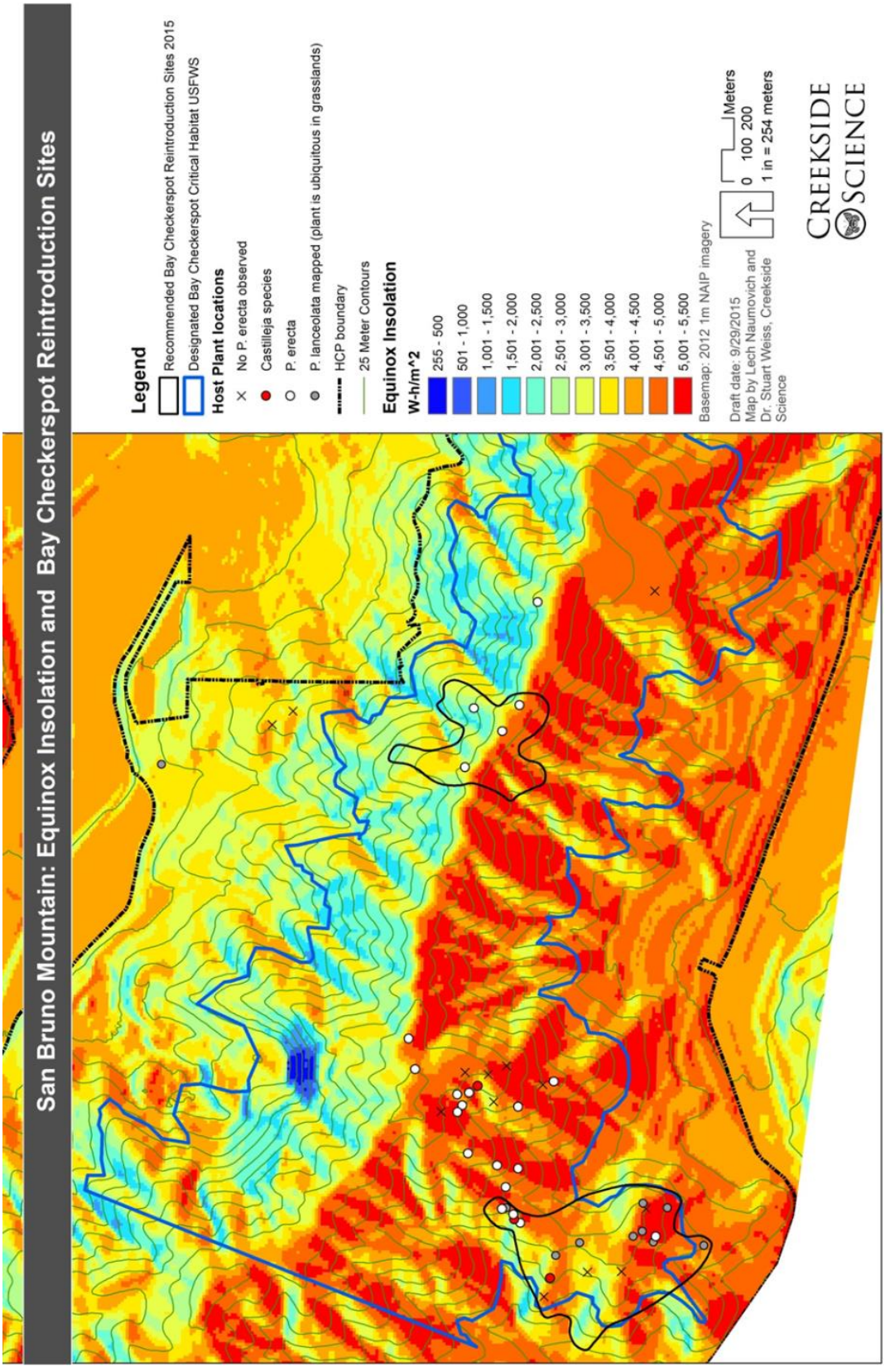
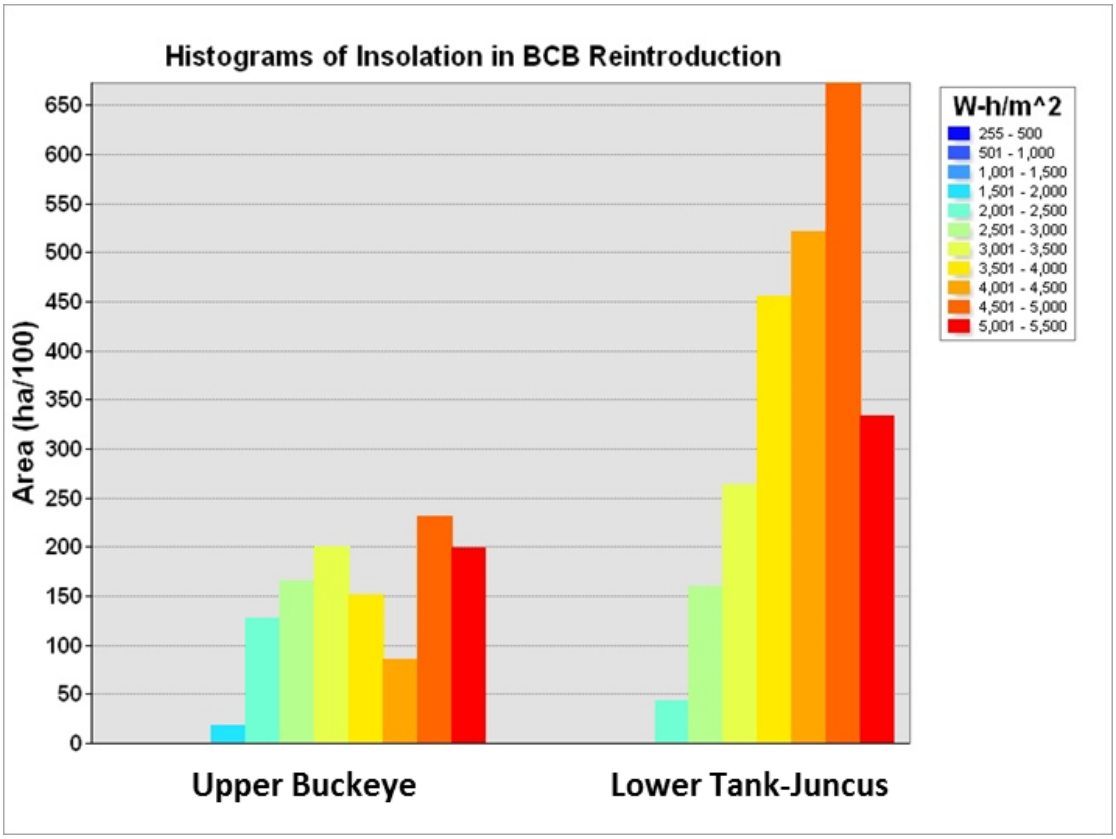

San Bruno Mountain: Equinox Insolation and Bay Checkerspot Reintroduction Sites
Legend
Recommended Bay Checkerspot Reintroduction Sites 2015
Designated Bay Checkerspot Critical Habitat USFWS
Host Plant locations
No P. erecta observed
Castilleja species
P. erecta
P. lanceolata mapped (plant is ubiquitous in grasslands)
HCP boundary
25 Meter Contours
Equinox Insolation
W-h/m^2
255 - 500
501 - 1,000
1,001 - 1,500
1,501 - 2,000
2,001 - 2,500
2,501 - 3,000
3,001 - 3,500
3,501 - 4,000
4,001 - 4,500
4,501 - 5,000
5,001 - 5,500
Basemap: 2012 1m NAIP imagery
Draft date: 9/29/2015
Map by Lech Naumovich and Dr. Stuart Weiss, Creekside Science
Meters
0 100 200
1 in = 254 meters
CREEKSIDE SCIENCE

Figure 13.



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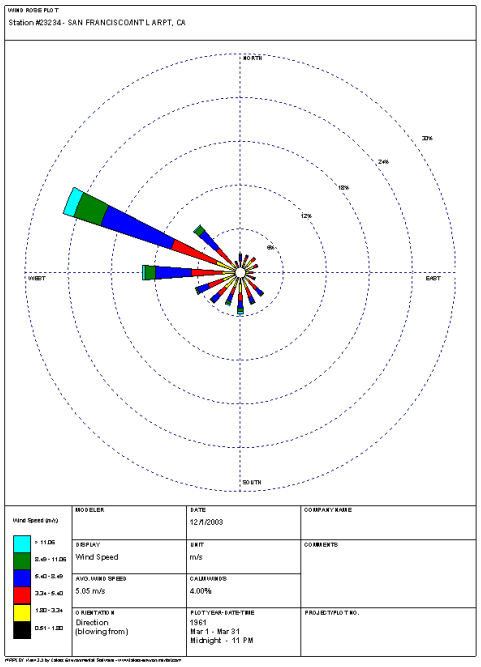
Wind Exposure

Flight time is greatly reduced by high winds, so a topographic wind analysis was done to map patterns of wind exposure and shelter, with a focus on the proposed reintroduction areas. Wind roses for San Francisco Airport (NRCS 2015) and a Wind Exposure Index were combined in a GIS analysis. Wind exposure was calculated as the difference between the elevation of each DEM cell and the mean elevation in a 150 m radius wedge from 270° (W) to 315° (NW) – basically exposure to the NNW at a scale where local wind interacts with terrain.

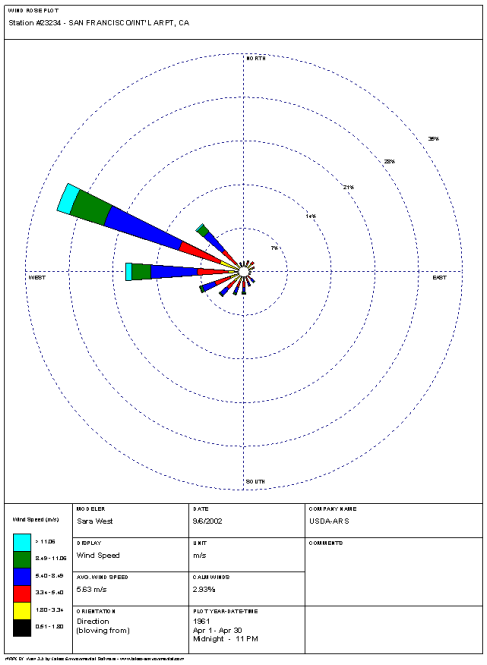
Prevailing winds during the flight season (March-April), especially during clear weather, are strongly NNW (Figure 14). While there are many hours of wind >5m/s (11 mph, the blue-green-cyan parts of the graph) there are many hours of relative calm (the red and yellow).

Figure 14. Wind roses for San Francisco Airport for March and April (NRCS 2015).

March SFO



April SFO



In Figure 15, positive values (red) are more wind-exposed areas on ridgelines. They extend downslope on the NNW-facing slopes. Negative values are in canyons and sheltered slopes (blue). Each proposed reintroduction site has a mix of wind exposure, including sheltered areas (Figure 16). Hilltops naturally are high exposure areas. BCB can fly close to the ground under surprisingly windy conditions under full sun, so wind is not likely to completely suppress flight activity.

Figure 15. Map of Wind Exposure Index (WEI NNW 150m)

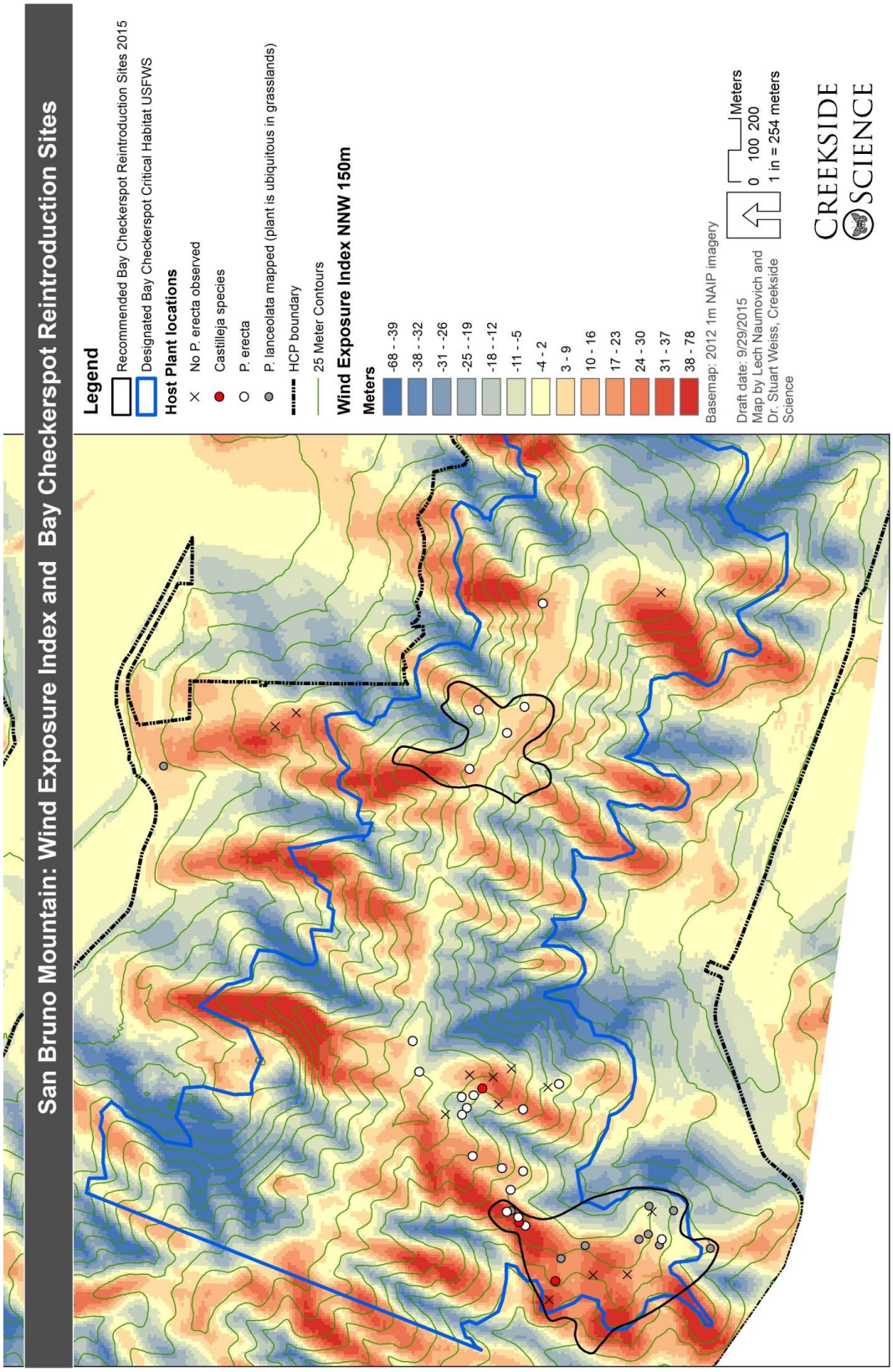
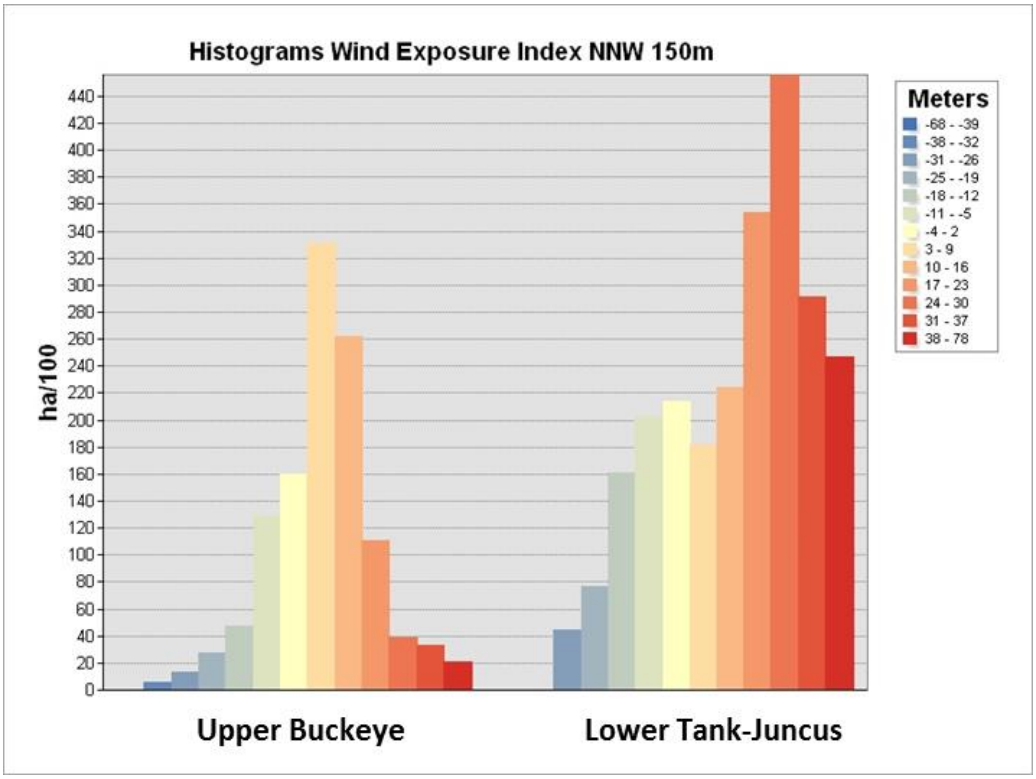


Figure 16. Histogram of WEI values in proposed reintroduction areas.



Summary of Proposed Sites

Characteristics of the two favored sites are compared in Table 1. While Upper Buckeye appears to have the higher habitat quality, we propose releasing at both sites to hedge our bets against interannual weather variability and unknown factors.

Table 1. Comparison of Upper Buckeye and Lower Tank-Juncus as BCB reintroduction sites.

BCB Habitat Criteria	Upper Buckeye	Lower Tank-Juncus
In designated Critical Habitat	Yes	Yes
Within last known range of BCB on SBM	Yes	No
Still supports *P. erecta*	Yes, over several acres on north-facing slopes	Only miniscule patches on thinnest soils
P. lanceolata abundant and widespread	Yes	Yes
Mix of insolation, including cool, N-facing slopes	Yes	Yes, but few cool slopes
Wind-sheltered areas present	Some	Yes
Hilltop present for aggregations	Yes	Yes, but local hilltop only
SBM Essential Grassland targeted for scrub control	Yes	Yes
Low N-deposition zone (less need for grass management)	Yes	No
Opportunities for dispersing butterflies to colonize adjacent habitat	High	Medium/Low

Other potential sites

If the host switch is successful, the potential range of BCB across SBM includes nearly all open grasslands that support *P. lanceolata*. We have noted several other areas, including (but not limited to):

1) Northeast Ridge
2) McKesson slopes below Guadalupe Canyon Parkway
3) Lower Owl-Buckeye Canyon
4) Southeast Ridge above Brisbane
5) South Slope

If the reintroduction takes in the first two proposed sites, these additional areas should be considered for subsequent reintroductions after more detailed habitat assessments.

Reintroduction Issues

Our assessment is that the current distribution and abundance of *P. erecta* and *Castilleja spp.* on SBM is insufficient to support a BCB population. The large population complex (10^5-10^6 individuals) on Coyote Ridge occupies several thousand acres of topographically diverse serpentine grassland. At Edgewood Natural Preserve a reintroduced population in the low thousands currently occupies ~15 ha (35 ac) of restored/managed habitat. The small Jasper Ridge populations (2 ha and 10 ha) proved inviable in the long-term, as did a series of populations along the San Francisco Peninsula (Murphy and Weiss 1988). The closest analog to a *Euphydryas editha* population persisting in the existing *P. erecta* habitat would be *Euphydryas editha quino* in Southern California, where diffuse and highly variable metapopulations persist among networks of small patches (100-1000+ m^2) of *P. erecta* spread over hundreds of square kilometers. SBM is too small and *P. erecta* is too patchy for this type of metapopulation dynamics.

Habitat Restoration with Native Hostplants

Could the distribution and abundance of *P. erecta* and *Castilleja spp.* be increased enough to support a BCB population? The maps of historical distributions show multi-acre patches, and a near continuous distribution along the fire road. This distribution has been reduced by an order of magnitude or more. *P. erecta* cannot compete in high productivity grasslands, and either requires nearly continual disturbance by erosion, grazing, fire, or scraping, or the presence of extremely thin soils such as those around rock outcrops. In the context of current financial and management constraints at SBM, seeding and then maintaining additional multi-acre patches of *P. erecta* is not feasible.

Increasing *Castilleja densiflora* and *C. exserta* densities in Upper Buckeye through seeding may be worth considering. *C. exserta,* in particular, is an excellent prediapause hostplant with an extended growing season on SBM (well into May-June). It does not serve as postdiapause food because of low density, high interannual variability, and later vegetative growth (Feb-Mar). However, absent large continuous stands of *P. erecta*, these annual *Castilleja* would play a minor role in providing BCB habitat.

Plantago lanceolata

San Bruno Mountain could support a population of Bay checkerspot butterfly if they were to switch to *P. lanceolata*. The BCB have a good chance to switch to *P. lanceolata* because:

1) Other populations of *Euphydryas editha* have made the switch. At least four populations of endangered Taylor's checkerspot in Oregon and Washington have switched from native perennial *Castilleja hispidus* to primarily *P. lanceolata*. A population in the Sierra Nevada at Schnieder's meadow switched from annual *Collinsia* to *P. lanceolata*. Hostplant use by checkerspots can be quite flexible and has heritable components under strong selection pressure (Ehrlich and Hanski 2004).
2) All BCB life-stages have been reared on it in the lab at the Stanford Department of Biological Sciences (pers. obs. 1985).
3) Adult females will readily encounter it when alighting in grasslands in search of oviposition sites (see density of *P. lanceolata in* Figure 7).
4) The females will likely oviposit on it, especially when/if they do not encounter *P. erecta* or *Castilleja spp.* (Ehrlich and Hanski 2004).
5) The longer lifespan and freshness of this perennial will increase the pre-diapause feeding period and reduce starvation mortality, the critical bottleneck in the life cycle.
6) Postdiapause larvae were observed finding and readily consuming it on SBM in 1983. Postdiapause larvae offered potted *P. lanceolata* on Coyote Ridge in 2015 quickly consumed it.
7) We can introduce thousands of postdiapause larvae, over multiple years, increasing the chances that a population can establish and adapt to it.

Regulatory and Permitting Issues

All necessary permits would be acquired, including a USFWS recovery permit and San Mateo County Research Permit. The experience with Edgewood Natural Preserve provides a template for BCB reintroductions, and all activities need to be consistent with the San Bruno Mountain HCP.

Given the novelty of the situation, it might be worth considering designating a reintroduced BCB population as "experimental" to increase flexibility in management. However, it appears from the language below that it would still be treated as "threatened" and it still is a covered species under the SBM HCP. Some further consideration of this option with USFWS as part of the permitting process is suggested.

> Code of Federal Regulations. Title 50. Wildlife and Fisheries. Chapter I. United States Fish and Wildlife Service, Department of the Interior. Subchapter B. Taking, Possession, Transportation, Sale, Purchase, Barter, Exportation, and Importation of Wildlife and Plants. Part 17. Endangered and Threatened Wildlife and Plants. Subpart H. Experimental Populations
>
> Summary (from https://www.animallaw.info/administrative/us-endangered-species-act-subpart-h-experimental-populations#s82) :
>
> "These ESA (Endangered Species Act) regulations relate to "experimental populations," an introduced and/or designated population that has been so designated in accordance with the procedures of this subpart but only when, and at such times as the population is wholly separate geographically from nonexperimental populations of the same species. The Secretary may designate as an experimental population a population of endangered or threatened species

that has been or will be released into suitable natural habitat outside the species' current natural range (but within its probable historic range, absent a finding by the Director in the extreme case that the primary habitat of the species has been unsuitably and irreversibly altered or destroyed). Any population determined by the Secretary to be an experimental population shall be treated as if it were listed as a threatened species for purposes of establishing protective regulations under section 4(d) of the Act with respect to such population."

The whole law on experimental populations can be accessed at the website above.

Risks

The previous population of BCB on SBM disappeared, and there is always the chance this could happen again with an introduced population. We have a good chance of successfully reintroducing this butterfly to its historical home, albeit on a non-native hostplant.

Our working hypothesis is that a combination of drought, low populations, extensive fire, and nonnative plant invasion extirpated the historical BCB population in the mid-1980s. *P. erecta* diminished to small patches, and at least some postdiapause larvae had begun to use *P. lanceolata*. The small population size (hundreds or less), evidenced by the low number of adults encountered in the final years, reduced opportunities for adaptation and hostplant switching before population extinction. The numbers and distribution of *P. lanceolata* appear to have greatly increased on SBM since that time (Weiss pers. obs.).

P. lanceolata provides the main, if not the only, opportunity for reestablishing a viable population of BCB on SBM. It is widely (and often densely) distributed, has high biomass, is biennial/perennial, and has an extended growing season for prediapause development. High mortality (>95%) at other BCB sites is caused by *P. erecta* senescence before prediapause larvae are large enough to enter diapause. *P. lanceolata* maintains green, edible leaf much longer than *P. erecta,* potentially relieving this population bottleneck. If the BCB population establishes and spreads, it could be a relatively common butterfly on SBM given the distribution and abundance of *P. lanceolata*.

The reliance of BCB on a nonnative host presents many interesting issues (practical and philosophical), of which full discussion is beyond the scope of this report. Some people may be concerned that this represents undervaluing native plant communities, or switching priorities away from managing nonnative plants. The situation is more subtle than that. Many native butterflies use introduced plants, including buckeye butterflies *(Junonia coenia*) on *P. lanceolata*, anise swallowtails (*Papilio zelicaon*) on fennel, marbled whites (*Euchloe ausoinides*) on mustards, Tiger swallowtails (*Papilio glaucus*) on London plane trees, among others. The largest population of Taylor's checkerspot is on a military training range in south Puget Sound, and *P. lanceolata* supports tens of thousands of checkerspots in a few dozen hectares of habitat in which the density of this nonnative host plant is comparable to parts of San Bruno Mountain.

There is not a realistic chance of ridding San Bruno Mountain of all nonnative plants, and managers prioritize both areas to treat and species to target. *P. lanceolata* has not been prioritized as a particularly

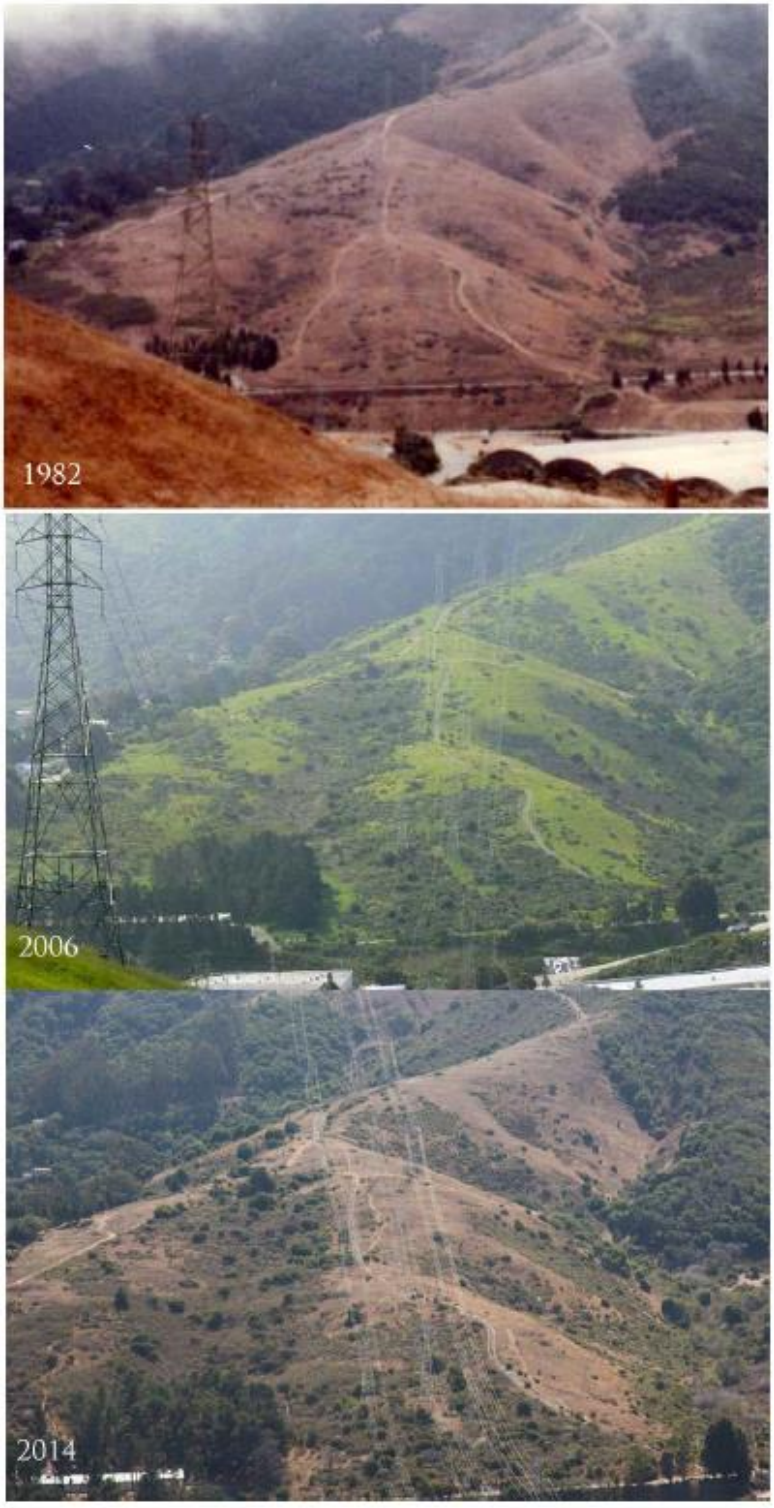
problematic weed. Certainly it is common enough that it is displacing some natives (and other non-natives), but it does not create monocultures as do some invasive plants. There may still be areas where controlling *P. lanceolata* is appropriate. The presence of BCB known to use *P. lanceolata* should not create a mountain-wide policy of not treating it, nor should every individual or stand of *P. lanceolata* be "protected" should BCBs be reintroduced and spread.

While there are risks in any reintroduction project, our best scientific assessment is that this reintroduction has a good probability of success if we expose enough BCB to large stands of *P. lanceolata* in the near absence of *P. erecta*. The experience with Taylor's checkerspot in particular can inform the discussion of many of the broader questions (Weiss et al. 2013a and references therein).

Coastal Scrub Issues

Loss of grassland habitat to native scrub is a primary concern throughout San Bruno Mountain. Weiss et al. (2015) estimated 1180 or fewer acres of grassland remained on San Bruno Mountain, down from 1960 in 1932. An example of this conversion is shown in Figure 17. In the absence of explicit scrub control efforts, grasslands, especially moister coastal prairie with high value to covered species, will continue to disappear. San Mateo County Parks and the San Bruno Mountain Technical Advisory Comittee understand the problem and have a newfound commitment to maintaining grassland habitat. The essential grasslands identified in Weiss et al. (2015) are the highest quality grasslands and will be targeted for scrub removal. With this commitment, the BCB and other covered species will benefit.

Figure 17. Photopoint showing scrub invasion of grassland on Buckeye Canyon and Transmission Line Ridge. The photos from 1982 and 2006 are from the 2007 San Bruno Mountain Habitat Management Plan (TRA 2008), the 2014 photo is by Lech Naumovich/Creekside Science.



Grazing and Fire

Grazing and fire are two management tools suggested for SBM, and properly implemented could greatly enhance habitat for covered species. BCB populations thrive under managed grazing on Coyote Ridge, which effectively keeps the annual grasses down and allows for large stands of *P. erecta* under high nitrogen deposition (Weiss 1999). An additional benefit at SBM could be control of native scrub. In any grazing trial on SBM, consideration of the effects on BCB habitat would be part of the study design.

Fires could lead to direct mortality of active prediapause larvae in late spring after the grassland has largely dried out, and a hot fire may lead to mortality of diapausing larvae in shallow cracks in the soil. Light, fast-moving ground fires pose a minimal risk during diapause, based on persistence of BCB at Tulare Hill in San Jose after a fire May 2004 (Weiss et al. 2013b) and experiences with Taylor's checkerspot (Weiss et al. 2013a). Fire can have positive effects by reducing scrub cover and increasing densities of native annuals and perennials (in the short-term), but also can lead to increased invasive plants. *P. lanceolata* obviously is thriving in a recently burned area, as it does in burned prairies in Puget Sound.

Climate Change

Given the historical sensitivity to weather and climate exhibited by the BCB, climate change needs to be considered over the long term. In the short-term, high interannual variability in weather predominates and obscures long-term trends. There is likely to be aridification of the landscape over decades that may favor grasslands (Weiss et al. 2015). With *P. lanceolata* as the primary hostplant, the annual phenological issues with *P. erecta* are largely avoided so the population would likely be less sensitive to interannual weather.

Chalcedon Checkerspots

Another checkerspot is already present on San Bruno Mountain, the chalcedon (*Euphydryas chalcedona*). These congeners do not interbreed. The chalcedon has a later flight season, although there is some overlap. They would not compete for resources, as the chalcedon uses bee plant (*Scrophularia californica*) and bush monkeyflower (*Mimulus aurantiacus*) as host plants.

Habitats for both species overlap, although the chalcedon has a much wider distribution of habitats. Anyone monitoring for BCB should be able to differentiate them from chalcedons. Chalcedon adults are slightly larger, although sizes can overlap. Chalcedon adults have more and less red/orange on the top of their wings, but more on their underside. Chalcedon larvae have more gray than BCB (Figure 18).

Figure 18. Bay checkerspot larva (top left) vs. chalcedon larva (top right). Bay checkerspot adult (top left) vs. chalcedon adult (top right).

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Proposal for Reintroduction

Creekside Science Butterfly Reintroduction Experience

Creekside Science has spearheaded successful BCB reintroductions at Edgewood Natural Preserve in Redwood City (Niederer and Weiss 2014) and Tulare Hill in San Jose (Niederer et al. 2015). Populations in the thousands have been established at each site as of 2015. We have also led reintroductions of Mission blue butterfly (*Icaricia icarioides missionensis*) from San Bruno Mountain to Twin Peaks (Weiss et al. 2014), and have consulted with Taylor's checkerspot (Weiss et al. 2013a) and Quino checkerspot management.

The MOU for this feasibility study states "The Service [USFWS] recognizes the contribution of Creekside Science and considers the past and future work proposed by this organization to be invaluable to the recovery the Bay checkerspot butterfly." It also states "As mentioned previously Creekside Science has successfully completed a re-introduction of the butterfly into Edgewood Park and is one of the best teams of biologists to determine the feasibility of a re-introduction of the Bay checkerspot butterfly into a site in San Mateo County. Creekside Science also holds a 10(a)1(A) permit for conducting habitat restoration and translocation of the Bay checkerspot butterfly. "

Translocation and Monitoring Proposal

Methods for this location will be similar to the Edgewood and Tulare Hill introductions. We anticipate collecting up to 5000 larvae from source populations in Coyote Ridge. At no point will more than 5% of the local source population be collected. Larvae will be transported in vented containers in coolers, and distributed by hand through the habitat, likely in February. Up to 60 adult supplements (40 female, 20 male) are also requested. We would like the option to do this annually for at least five years. We have not had any injuries or deaths during the project, and don't anticipate any with a new location. We do not anticipate the need for laboratory rearing.

Monitoring will consist of postdiapause larval estimates, adult walking transects, and vegetation phenology plots (as in Niederer and Weiss 2014). Volunteers could be used for some monitoring efforts, especially adult transects where weather is critical (similar to the volunteer efforts at Edgewood) and for repeat phenology observations.

Additional monitoring is recommended in the first year or two to document postdiapause feeding, adult BCB oviposition, and growth of prediapause larvae on *P. lanceolata*. Releasing adult females on *P. lanceolata* under a veil secured with rocks, as with adult Mission blue butterflies at Twin Peaks (Weiss et al. 2014), would provide the opportunity to track egg masses through the spring and understand some mortality factors.

The project milestones would be as follows, with further details included if the project moves forward:

1) Permitting
2) Identify initial funding
3) Finalize plans

4) Collect up to 5000 postdiapause larvae from Coyote Ridge (Jan-Mar) for release same day
5) Release roughly half of larvae at Tank-Juncus and half at Upper Buckeye
6) Monitor adult butterflies on a simple transect system, optional egg monitoring (Mar-May)
7) Monitor phenology through the end of the prediapause period (April-June+)
8) Interim Report (Dec)
9) Postdiapause density surveys (Jan-Mar)
10) Second round of introductions (Jan-Mar), consider additional areas if local populations establish
11) Repeat monitoring
12) First full report with adaptive management plan
13) Establish yearly adaptive management cycle and repeat.

Funding

The development of a full funding proposal is not within the scope of this feasibility study. If USFWS, San Mateo County, and other stakeholders want to move forward then a full 5-year proposal will be developed, and likely funding sources for the initial years identified.

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