Bay Checkerspot Reintroduction

Coyote Ridge to Edgewood Natural Preserve

USFWS Permit TE-30659A-1

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Introduction

The main goal of this project is to re-establish a Bay checkerspot butterfly population in restored habitat in Edgewood Natural Preserve, where the population was extirpated in 2002. Extant populations from Coyote Ridge in Santa Clara County numbering in the hundreds of thousands were the source of these butterflies.

Bay checkerspot larval and adult numbers continue to increase each year at Edgewood, which has high quality habitat. Because numbers are still below replacement rate of introduced individuals, we believe introductions should continue. Our federal permit expires February 5, 2015, which is likely too early to include another year's translocation. We therefore plan to apply for an extension on this permit so we may continue this successful project.

Despite a slow start to the 2014 season based on record drought, the reintroduction project continued on positive notes. We estimated about 4000 larvae in early March, a high number, but below the replacement rate of the 5000 larvae transferred in 2013. By March 12, 2014, 4,105 post-diapause larvae were translocated to Edgewood.

This year monitors saw 800 adults during timed transects, the highest number since this project began. Despite above average March and April temperatures, host plant *Plantago erecta* remained fresh long past the flight season. It appears that even with record low precipitation, the late season rain was sufficient to recharge soils and allow the annual plants to complete their life cycles. We were pleased to see Bay checkerspots perform well at Edgewood and Coyote Ridge during this year's extreme drought.

Funding for this project was provided last year from the San Francisco Bay Wildlife Society, as procured through USFWS. Much thanks to David Kelly for finding this funding and allowing this project to continue. Additional funding must be identified for this project to continue. This project was run concurrently with an enhancement project at Tulare Hill in San Jose, an ongoing project discussed in a separate report.

Project Background

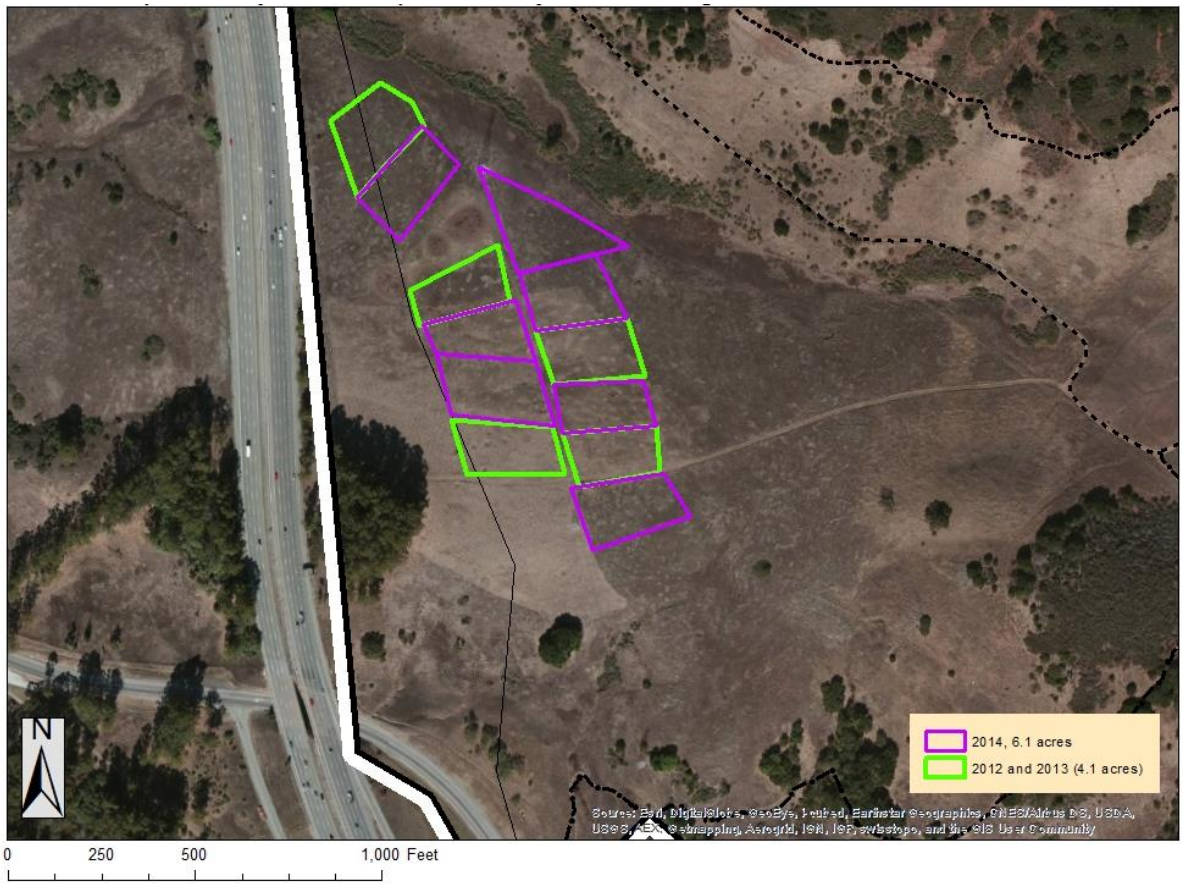
The nutrient poor serpentine grasslands at Edgewood Natural Preserve supported the last remaining population of the federally threatened Bay checkerspot butterfly on the San Francisco Peninsula, along with a dazzling diversity of native wildflowers and bunchgrasses. Maintenance of populations on the Peninsula is a high priority task in the 1998 USFWS Recovery Plan.

The Edgewood population was estimated at 4500 butterflies in 1997, but numbered less than 100 butterflies in 2000, and appeared to be extinct as of 2003. No butterflies or larvae were observed in 2003, 2004, 2005, and 2006. The major cause of the decline has been invasion by introduced annual grasses that choke out the larval hostplants of the butterfly, an invasion that has progressed rapidly since 1997. The grass invasion has been linked to emissions of ammonia and NO_x from 100,000+ cars traveling Highway 280 (Fenn et al. 2010). A reintroduction effort in 2007 was not successful, likely based on a single year effort, a low number of founders (1000 larvae), and a dry, warm, spring season.

Habitat Restoration

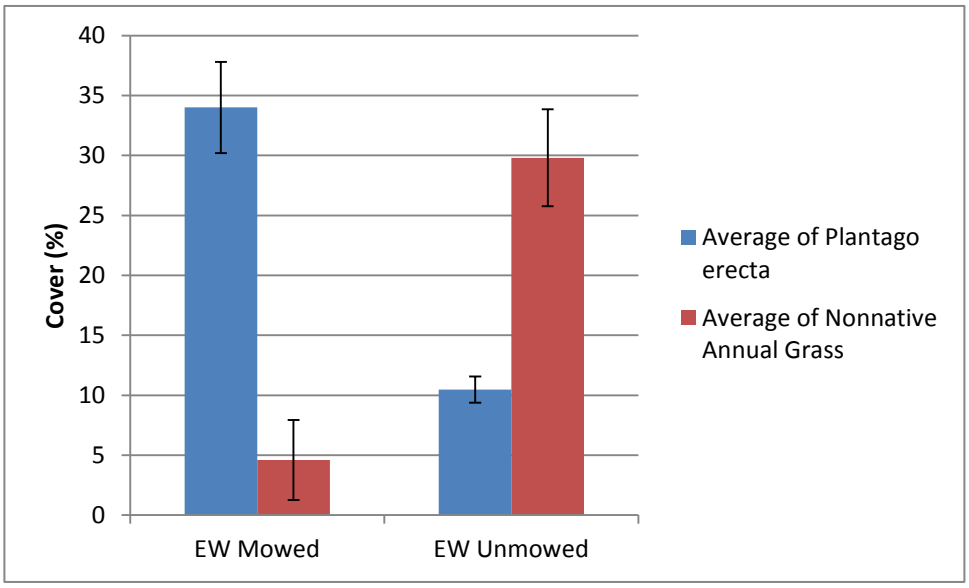
Experiments showed a single, well-timed mow and subsequent fall dethatching can be used on a rotational basis to reduce grass and thatch cover and increase Bay checkerspot host plant and nectar source cover (Weiss 2002). San Mateo County Parks continues to mow and dethatch portions of the butterfly habitat to reduce annual grass and thatch cover and increase native forb cover. In 2012, Creekside installed paired mowed and unmowed plots to better address the potential impact of critical habitat management on the diapausing larvae. About 4 of 30 acres were mowed in spring 2012 and 2013 and dethatched the subsequent fall. In April 2014 a different set of plots totaling about 6 acres was mowed (Figure 1).

Figure 1. Mow plots in Bay checkerspot butterfly habitat, Edgewood Natural Preserve



Plots mowed in 2012 and 2013 had an average of 34.0% *Plantago erecta* and 4.6% nonnative annual grass this year, while paired unmowed plots only had an average of 10.5% *Plantago* and 29.8% nonnative annual grass (Figure 2). Host plants are clearly responding positively to the management treatment, and nonnatives declining.

Figure 2. Habitat in mowed vs. unmowed plots.



Larval numbers were extremely low in the paired plots in both 2013 and 2014 (in both years the majority of larvae were found outside the paired plots), precluding statistical comparisons. Presence was noted in both mowed and unmowed plots.

Weather Summary

Annual precipitation from 1981 to 2010 averaged 48.1 cm (Westmap 2014). October 2012 to September 2013 had 40.1 cm, 32.1cm of which fell between October and December (Table 1). While the rest of the water year was very dry, the early start to the growing season was considered to be advantageous to the spring 2013 larvae, which in turn is advantageous to the 2014 generation.

Only 21.9 cm fell October 2013 to July 2014 (precipitation in August and September is generally negligible). October-December 2013 saw only 2.7 cm, and January 2014 had zero measurable rainfall (WRCC 2014). By the end of January, the normally green grasslands at Edgewood were still eerily brown. Few annuals had germinated, and many that did died from moisture stress. Those that survived were usually shaded by rocks or small divots in the ground. Perennials were heavily browsed. This very late start to host plant germination is generally considered to be a large disadvantage. Precipitation records for the source population are shown in Table 2 as reference. The source population at Coyote Ridge is about 65 km southeast of Edgewood. Edgewood is about 180 m elevation, and the source population about 360 m.

Table 1. Precipitation records from nearby Pulgas Ridge, 48.1 cm average for 1981-2010 (WRCC 2014)

	Yearly Precipitation (cm)
Oct 2006-Sep2007	31.1
Oct 2007-Sep2008	46.1
Oct 2008-Sep2009	50.2
Oct 2009-Sep2010	70.1
Oct-2010-Jun 2011	72.8
Oct 2011-Sep2012	41.4
Oct 2012-Sep2013	40.1
Oct 2013-Jul2014	21.9

Table 2. Precipitation records from Coyote Ridge, 58.9 cm average for 1981-2010 (WestMap 2014)

	Yearly Precipitation (cm)
Oct 2006-Sep2007	27.1
Oct 2007-Sep2008	37.9
Oct 2008-Sep2009	43.4
Oct 2009-Sep2010	60.8
Oct-2010-Jun 2011	61.2
Oct 2011-Sep2012	29.6
Oct 2012-Sep2013	33.4
Oct 2013-Jul2014	22.4

By mid-March, however, conditions had changed dramatically. Eleven cm of rain in February recharged the soils, and host plants developed with little nonnative grass competition. It appeared that many of the nonnative grasses germinated and then died during the dry January. Those that survived generally lagged behind forbs in growth.

Cool March and especially April temperatures also favor checkerspots, as they allow host plants to stay fresh longer as prediapause larvae race to the fourth instar when they can enter diapause. Edgewood had a particularly warm March 2007, and March 2008, 2013 and 2014 were also above the 30-year average. April temperatures were high in 2013 and 2014 (Table 3). Again, these high temperatures in 2013 and 2014 are not favorable to checkerspots.

Table 3. Pulgas Ridge average maximum temperature (˚C) (WRCC 2014).

	March	April
2007	21.2	20.1
2008	19.1	20.1
2009	18.5	20.4
2010	18.9	18.3
2011	15.8	17.6
2012	16.0	19.5
2013	19.7	22.4
2014	20.4	21.6
Average 1981-2010*	18.6	20.7
*WestMap 2014		

In comparison, Coyote Ridge also had above average March temperatures in 2007, 2008, 2013, and 2014. April temperatures were higher than average in 2007, 2008, 2009, and 2013. The 30-year average temperatures are similar (Table 4).

Table 4. Coyote Ridge average maximum temperature (˚C) (WestMap 2014)

	March	April
2007	21.6	21.1
2008	19.4	21.7
2009	18.1	20.9
2010	18.7	18.2
2011	16.6	19.6
2012	15.9	18.5
2013	19.6	21.7
2014	19.9	20.3
Average 1981-2010	18.2	20.6

Coyote Ridge Source Population

Bay checkerspots are always in a race against their host plants, so an early start to the growing season (i.e., November rather than December), is often key to their survival. With essentially no *Plantago erecta* for them to eat by late January, we questioned whether they would emerge at all, survive a second year of diapause, or emerge late only to not have enough time to complete their life cycle. Prospects seemed grim both at Edgewood and at the source population in Coyote Ridge (Figure 3a-b). We initially canceled larval transfers for the year based on the extreme weather conditions and low larval encounter rates.

Figures 3a and **b.** Photopoint taken Feb. 16, 2013, compared with Feb. 12, 2014

The effects of the February rain and subsequent germination were clear by early March. Large pockets of record-high checkerspot densities (tens of hectares with >1 larva/m^2) were found on Coyote Ridge. While the larvae got a very late start, they developed quickly in the long, sunny days. Larval numbers throughout the source population are shown in Table 5.

Table 5. Kirby Canyon is 250 acres within the larger ~7000 acres of Coyote Ridge. The Kirby numbers are shown with 95% confidence intervals.

	Kirby Reserve	Coyote Ridge*
2011	94,399 ± 32,025	533,426
2012	145,688 ± 37,606	487,406
2013	202,845 ± 46,487	1,208,297
2014	61,221 ± 35,136	745,945

*Confidence intervals across Coyote Ridge have not been calculated.

Larval Monitoring at Edgewood

Monitoring at Edgewood was conducted in February and March 2014, with estimates of about 4,000 larvae, up from about 3,000 last year. This shows that checkerspots were able to complete their lifecycle at Edgewood in large numbers. Both mowed and unmowed areas contained larvae. However, this is still below the replacement rate (5,000 larvae were introduced in 2013). The habitat is still high in host plant and nectar source cover. In order to achieve the high number of butterfly encounters that encourage more sedentary behavior, and because source populations were above 2012 levels, additional larvae were transferred to Edgewood in 2014.

Larval Transfers

Larvae were collected from record dense populations at Coyote Ridge, transporting the second highest number of larvae since the project began (Table 6).

Table 6. Summary of larval introductions

Year	Larvae introduced
2007	1,000
2011	4,003
2012	4,852
2013	5,000
2014	4,105

Post diapause larvae are the focus of the introduction because they are the easiest life stage to locate, handle, and transfer. Larvae are captured by hand or with a spoon, and placed in groups in vented plastic containers kept in coolers until release. The majority of caterpillars collected on March 11 were transported to Tulare Hill; a low number was moved to Edgewood to show during a meeting with the new resource manager (Table 7).

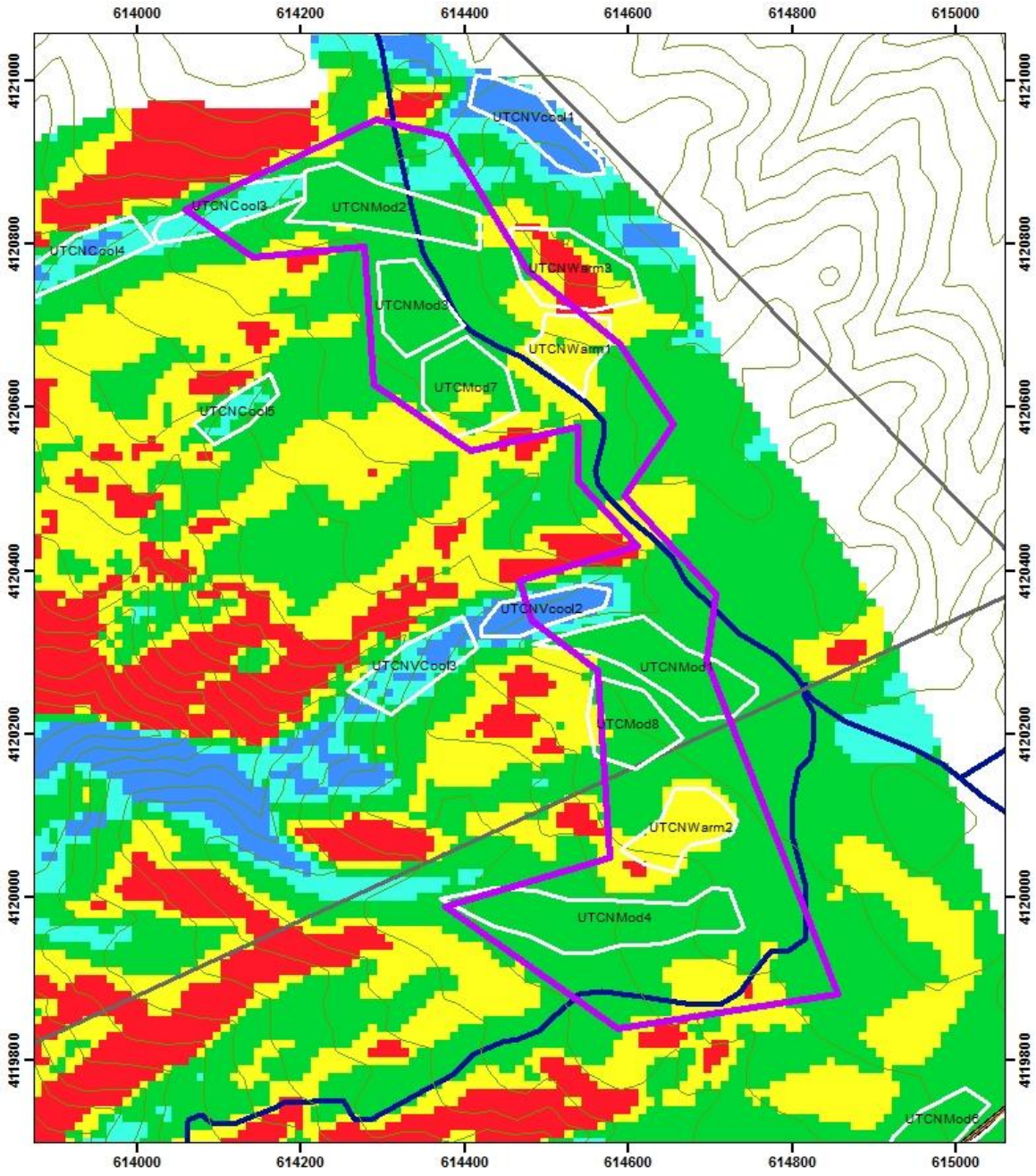
Table 7. Larval Transfers from Coyote Ridge to Edgewood Natural Preserve, 2014

Date	Adults observed	Larvae transported and released at Edgewood	Number injured	Number killed
11-March-14	0	150	0	0
12- March-14	0*	3955	0	0
Total larvae transferred:		**4105**		

*An adult was spotted 9 March, 2014.

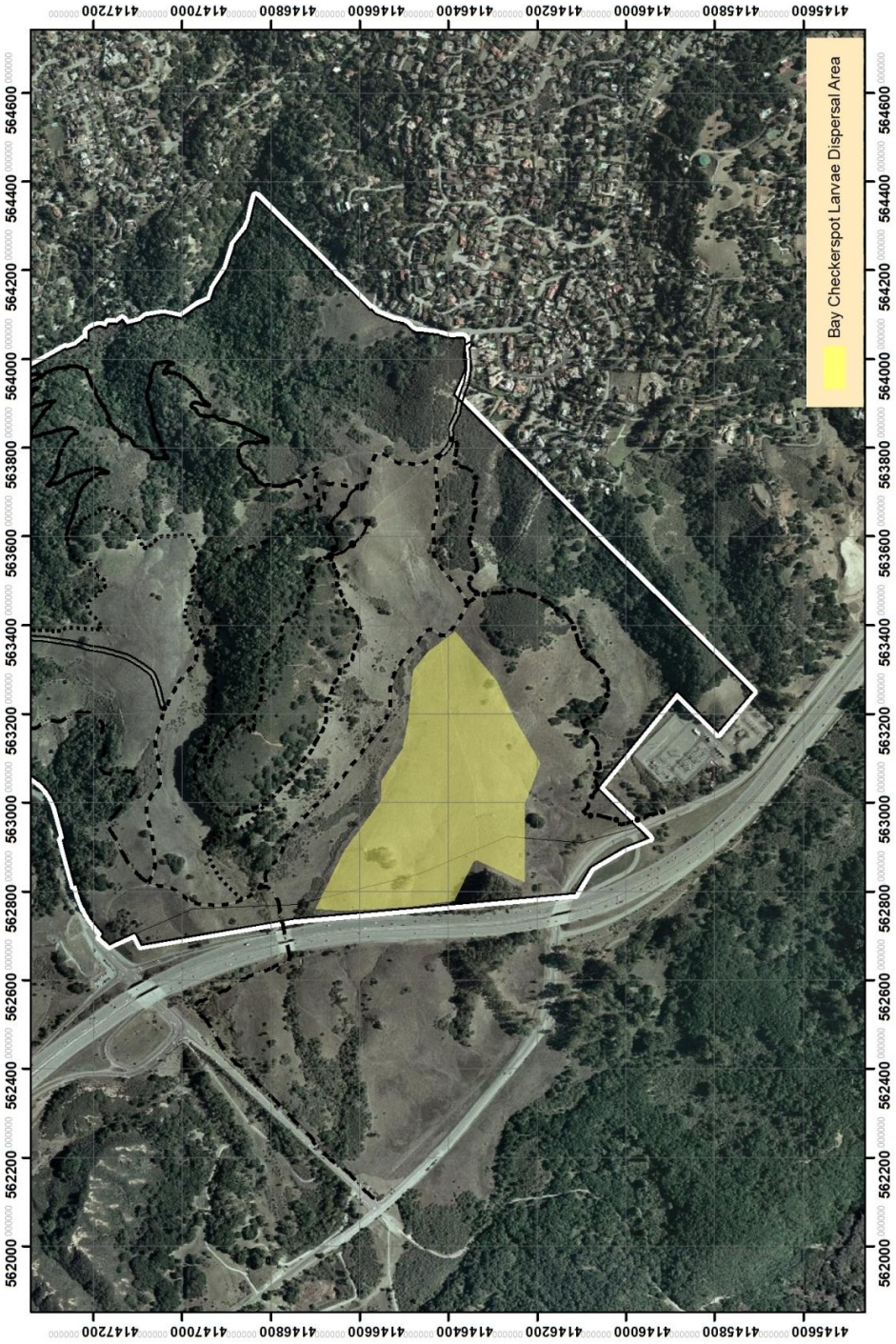
In 2014, 4105 larvae were collected from the area below, estimated to have about 330,000 larvae. All coordinates are NAD83 (Figure 4). (An additional 3450 larvae, 40 adult females, and 20 adult males were collected from this location for the related Tulare Hill translocations.)

Figure 4. Collection location



As in previous years, larvae were dispersed in the area below at Edgewood Natural Preserve (Figure 5).

Figure 5. Dispersal location



After release, larvae were observed basking, crawling, or eating *Plantago erecta*.

While it is too early to determine whether the reintroduction effort will be a longterm success, the relocation effort has been successful based on the following:

1. Sufficient larvae are encountered in source populations and captured for release.
2. Larvae are collected from multiple locations and topoclimates. A range of larval sizes are represented.
3. Larvae are relocated with minimal impact on individuals.
4. Larval densities are increasing at Edgewood.
5. 2014 larval estimates are 80% of 2013 reintroduction cohort.

Adult Transfers

No adults were transferred from Coyote Ridge to Edgewood Preserve this year (Table 8). Based on high number of larvae transferred, lack of chrysalis-damaging storms, and high number of adults spotted, adult transfers were not deemed necessary.

Table 8. Summary of adult introductions

Year	Adults introduced	Females	Males
2007	12	12	0
2011	60	40	20
2012	46	26	20
2013	0	0	0
2014	0	0	0

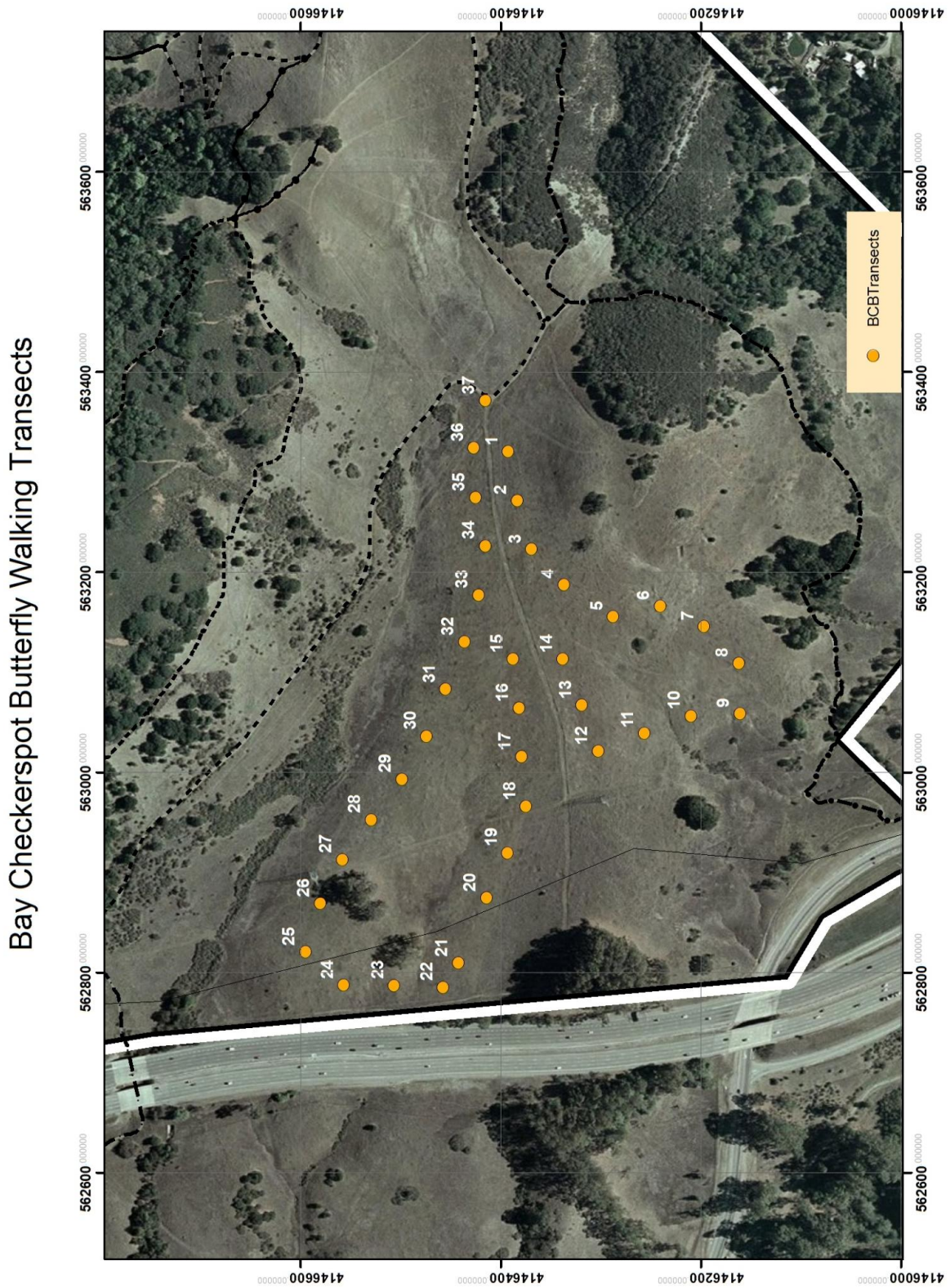
Previous adult transfers have been successful based on the following:

1. Sufficient adults are encountered in source populations and captured for release.
2. Adults are collected from multiple locations and topoclimates.
3. Adults are relocated with minimal impact on individuals.
4. Adult densities are increasing at Edgewood.

Adult Monitoring

Over the course of the flight season, adults are surveyed daily, weather permitting. The adult monitoring consists of a volunteer observer walking through 36 50-m transects set up in the butterfly habitat. The monitoring consists of counting how many Bay checkerspots are seen along each transect. The monitor walks slowly, covering the 50 meters in about 1.5 minutes, looking 5 meters to each side of the transect. The monitor may step off the transect to confirm a sighting (stopping the timer). The course takes about 1.5 hours to walk (Figure 6).

Figure 6. Adult monitoring course



This year, observers saw the highest number of butterflies to date (Table 9).

Table 9. Summary of adult sightings during timed monitoring sessions at Edgewood

Year	Adults sighted*
2007	9
2011	120
2012	310
2013	625
2014	800

*Previous reports had slightly higher numbers, reflecting incidental observations. This table shows individuals reported during timed monitoring sessions, showing a more equal comparison of effort.

The introductions have been successful based on the following:

1. The Edgewood habitat has dense amounts of both host and nectar sources.
2. The adults are dispersing throughout the habitat.
3. An increased number of adults was noted in 2014 compared with previous years.

The timing of the flight season relative to host plant growth and senescence is critical. An early start and/or an early finish increase the likelihood the new generation of larvae will grow large enough to enter diapause before their host plants dry out. The flight season is compared with a reference site at Kirby Canyon Butterfly Reserve on Coyote Ridge in Figures 7 and 8. The asterisk denotes the midpoint of the flight season, when 50% of the year's butterflies had been encountered. Both sites hit their flight season midpoint about April 8, 2014, later than previous years. Also note the relatively long flight season this year at Edgewood, which increases mating opportunities and spreads risk relative to extreme weather events (Table 10).

Note that Kirby is monitored weekly, while Edgewood is monitored daily. Kirby therefore has a much larger population in 2014 and previous years compared with Edgewood. The flight season began late this year, which decreases the likelihood the new generation of larvae will grow large enough to enter diapause before their host plants dry out.

Figure 7. Cumulative counts of adult Bay checkerspots, daily monitoring. * marks the midpoint of the flight season

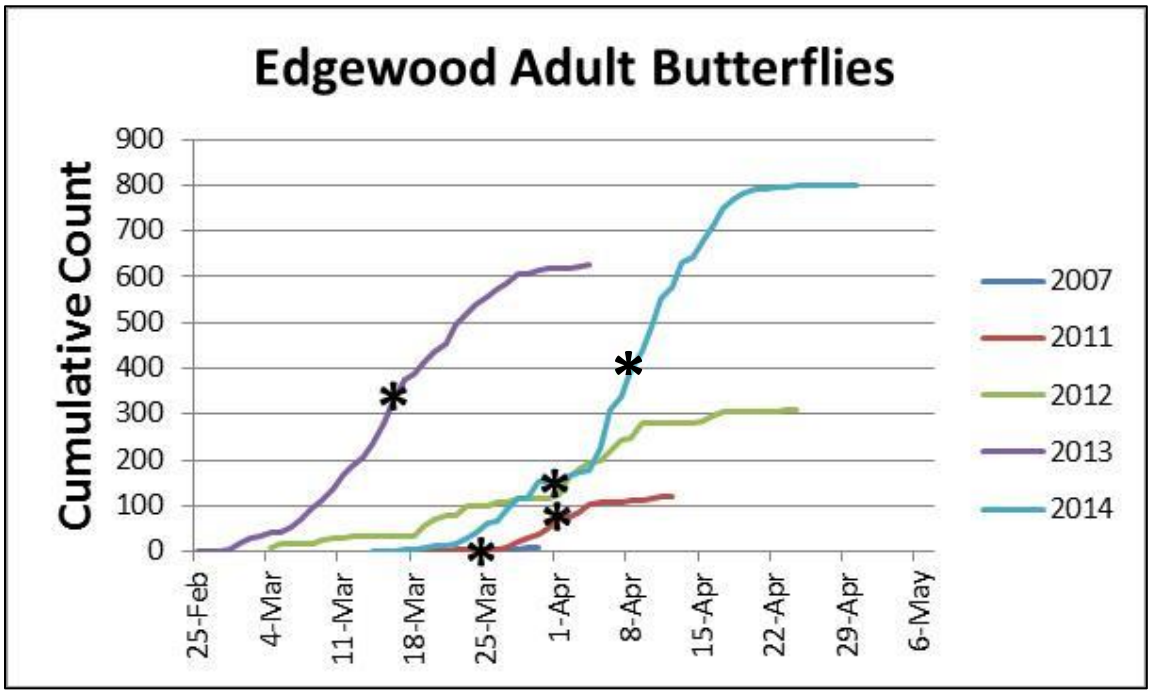


Figure 8. Cumulative counts of adult Bay checkerspots at the reference site, weekly monitoring

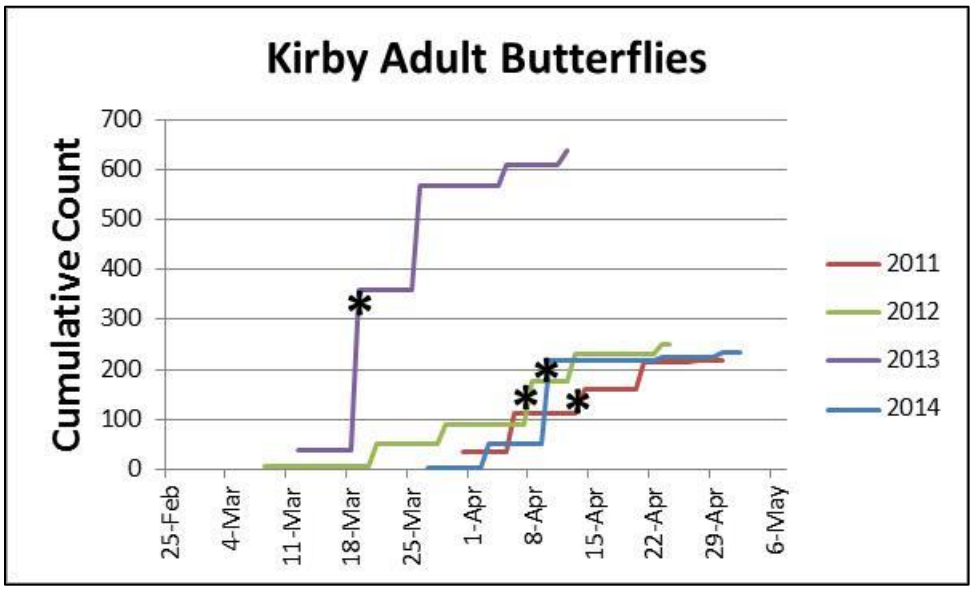


Table 10. Flight season comparisons at Edgewood vs. Kirby. Note 2014 is the latest peak flight recorded for Edgewood.

Year	Weeks of flight, EW	Weeks of flight, Kirby	Peak flight, EW	Peak flight, Kirby
2007	2	n/a	24-Mar	n/a
2011	4	4	1-Apr	14-Apr
2012	7.5	7	2-Apr	8-Apr
2013	6	4.5?	18-Mar	19-Mar
2014	7	5	8-Apr	10-Apr

Host Plant Phenology Monitoring

Again, the timing of the flight season relative to host plant growth and senescence is critical. An early start and/or an early finish increase the likelihood the new generation of larvae will grow large enough to enter diapause before their host plants dry out. Hostplants and nectar sources are monitored along transects at different topoclimates (warm to cool) to determine how long they are available to adult butterflies and prediapause larvae. These data are compared with flight season data to estimate whether most butterflies survived to diapause. Low rainfall is less of a concern than continuing cool temperatures.

As a general rule, prediapause larvae survivorship increases substantially if host plants remain fresh three weeks or more after the midpoint of flight season. The longer the plants stay fresh, the better. We compare phenology at Edgewood with phenology at Kirby Canyon Butterfly Reserve on Coyote Ridge, which has a large checkerspot population. We use its host plant phenology as a reference.

Plantago densities are usually comparable between Edgewood and Kirby, although Kirby was low this year. *Plantago* at Edgewood dried out during the second week of May, while Kirby Canyon dipped below the 10 plants/m^2 critical in the first week of May. It is uncommon for Edgewood's *Plantago* to stay fresh longer than Kirby, because Kirby has more steep, north-facing slopes. Lower total densities at Kirby probably played a role in early senescense. Castilleja was nearly nonexistent this year at Edgewood, with a few plants on Kirby staying fresh into mid-May (Figures 9-12).

The main nectar source, Lasthenia californica, stayed fresh beyond the end of the flight season at both Edgewood and Kirby. *Layia* spp. also stayed fresh beyond the end of the flight season at both sites (Figures 13-16). Nectar tends not to be limiting for Bay checkerspots.

Figure 9. Edgewood host plant phenology. Ten *Plantago* plants/sq meter is a critical threshold for Bay checkerspot larval use.

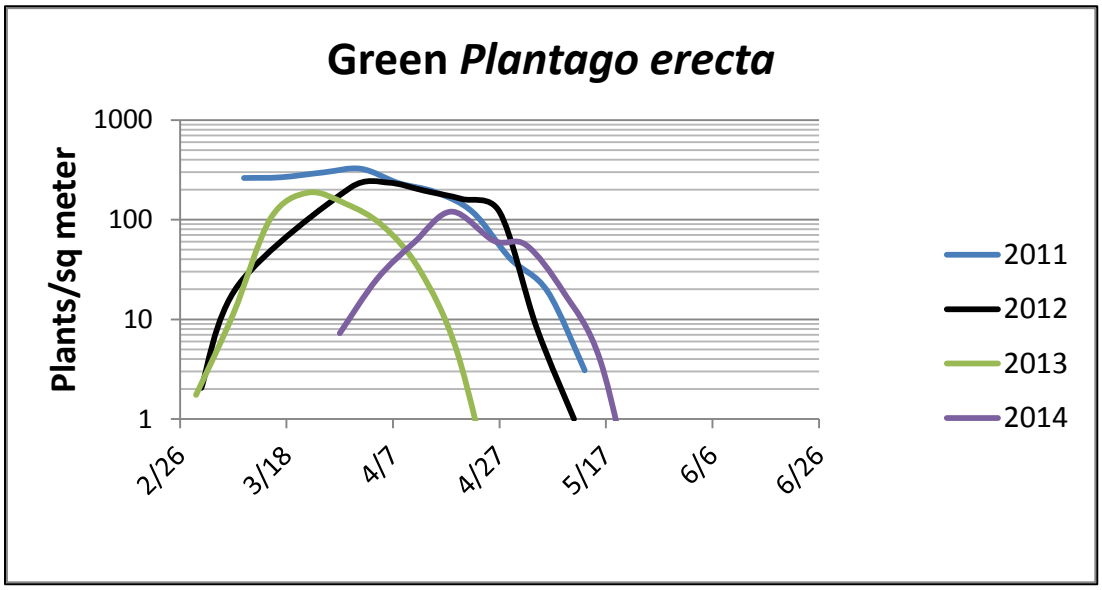


Figure 10. Kirby Canyon host plant phenology

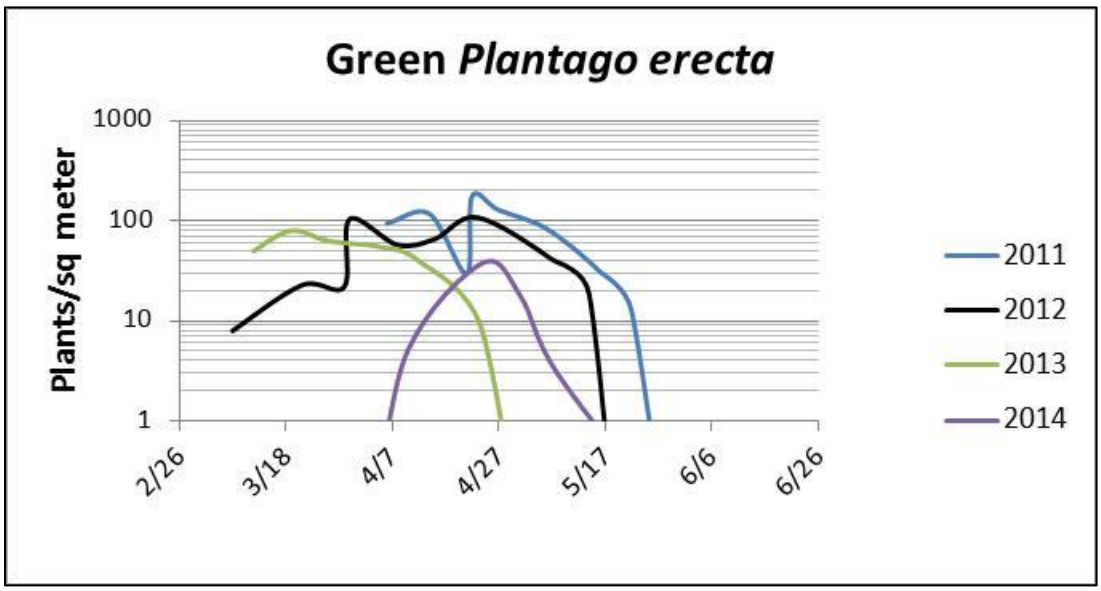


Figure 11. Edgewood host plant phenology

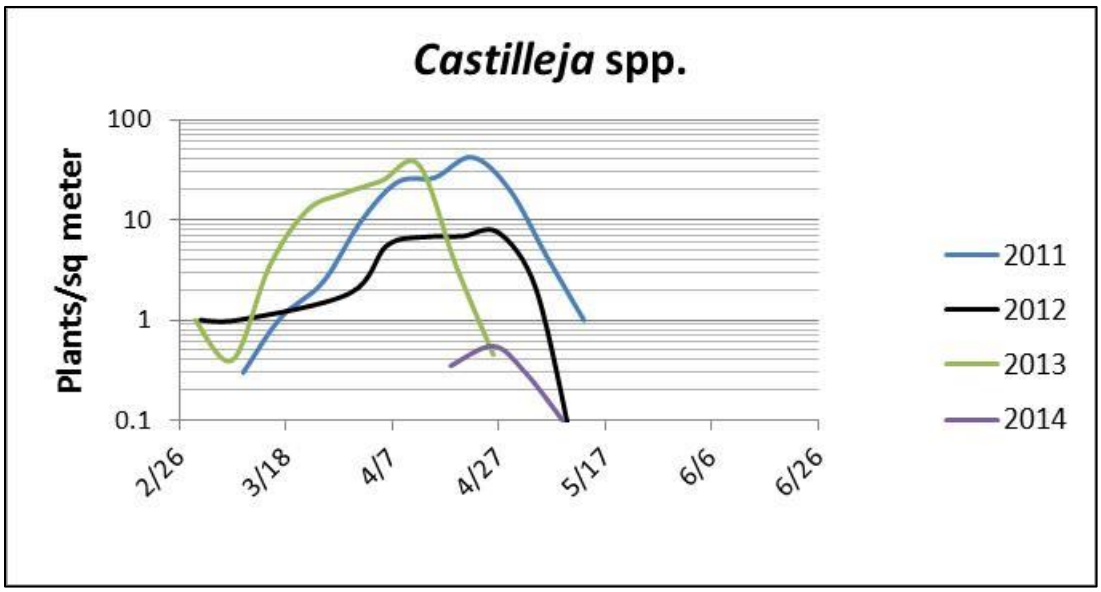


Figure 12. Kirby Canyon host plant phenology

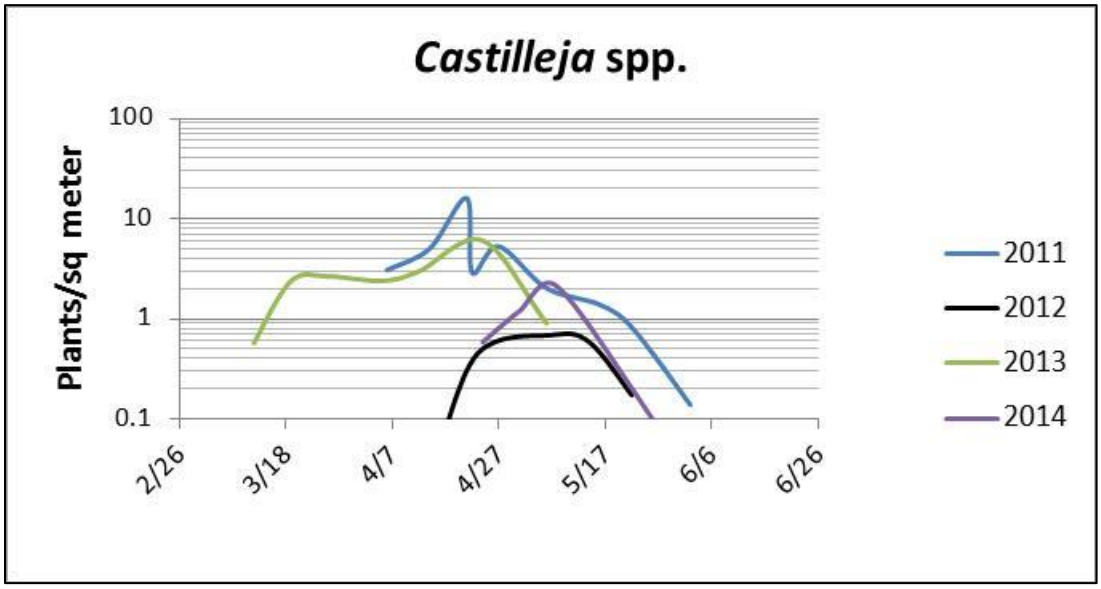


Figure 13. Edgewood nectar phenology

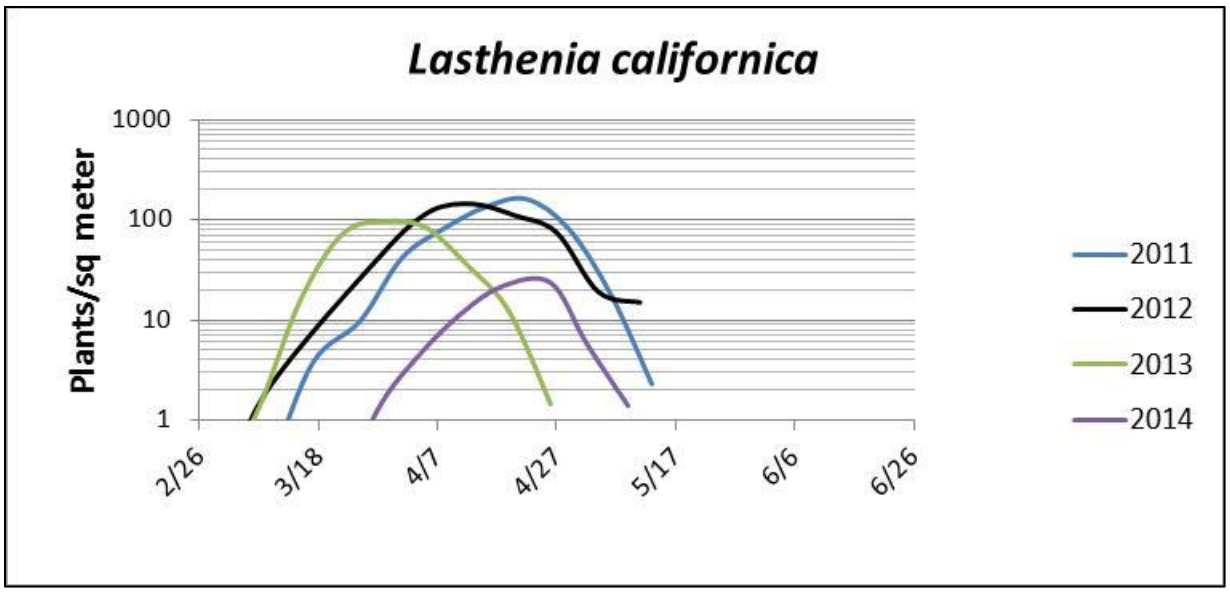


Figure 14. Kirby Canyon nectar phenology

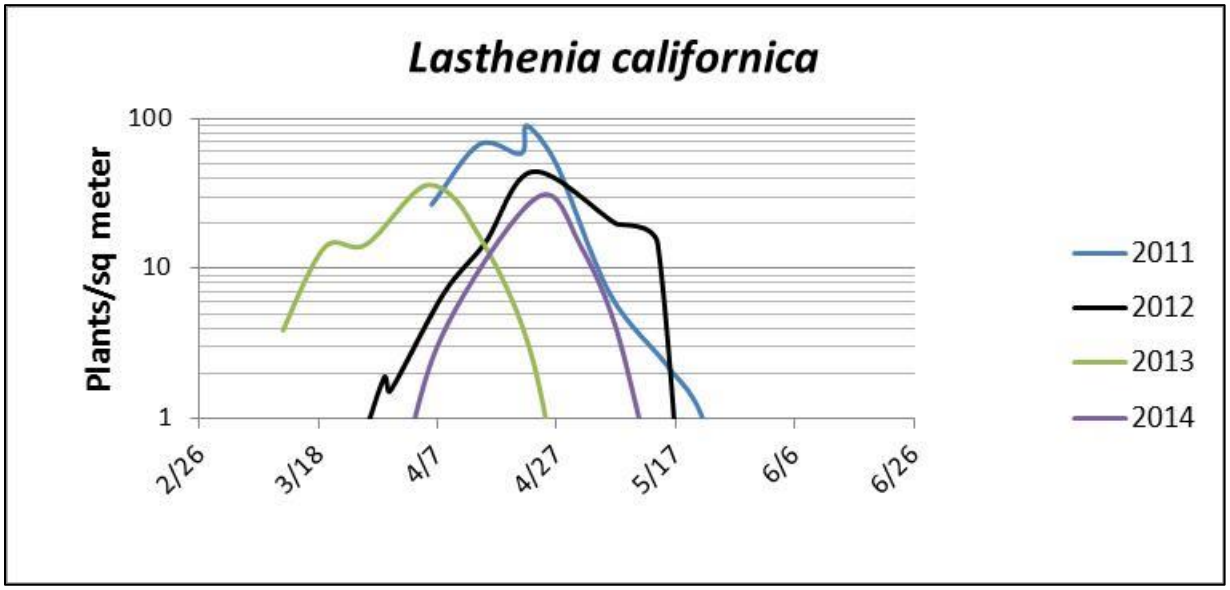


Figure 15. Edgewood nectar phenology

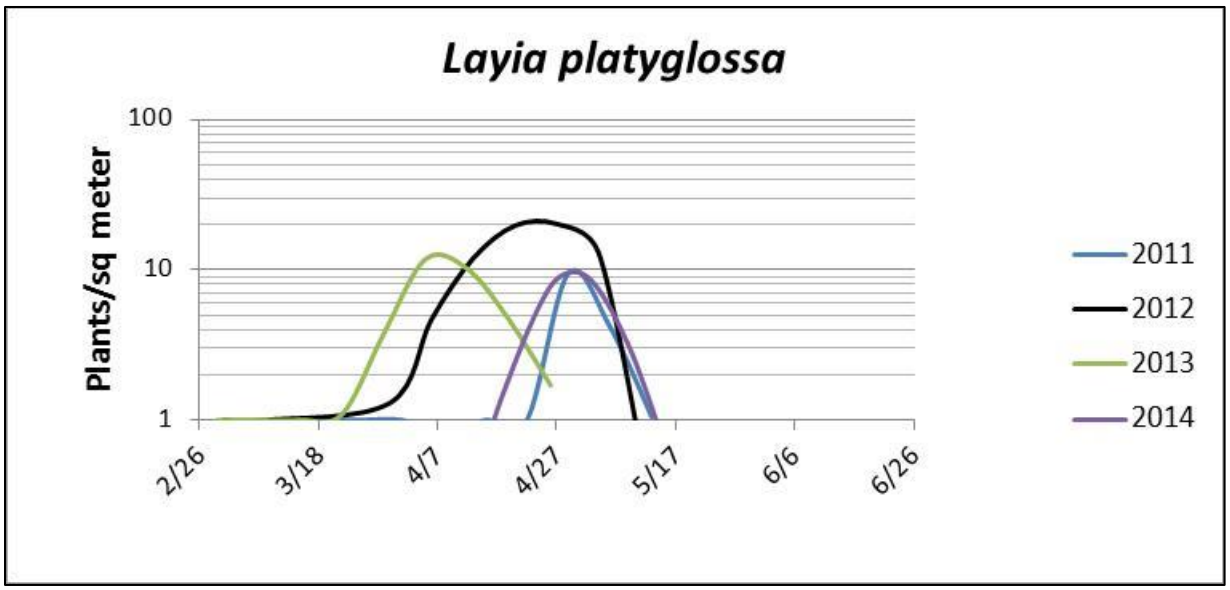
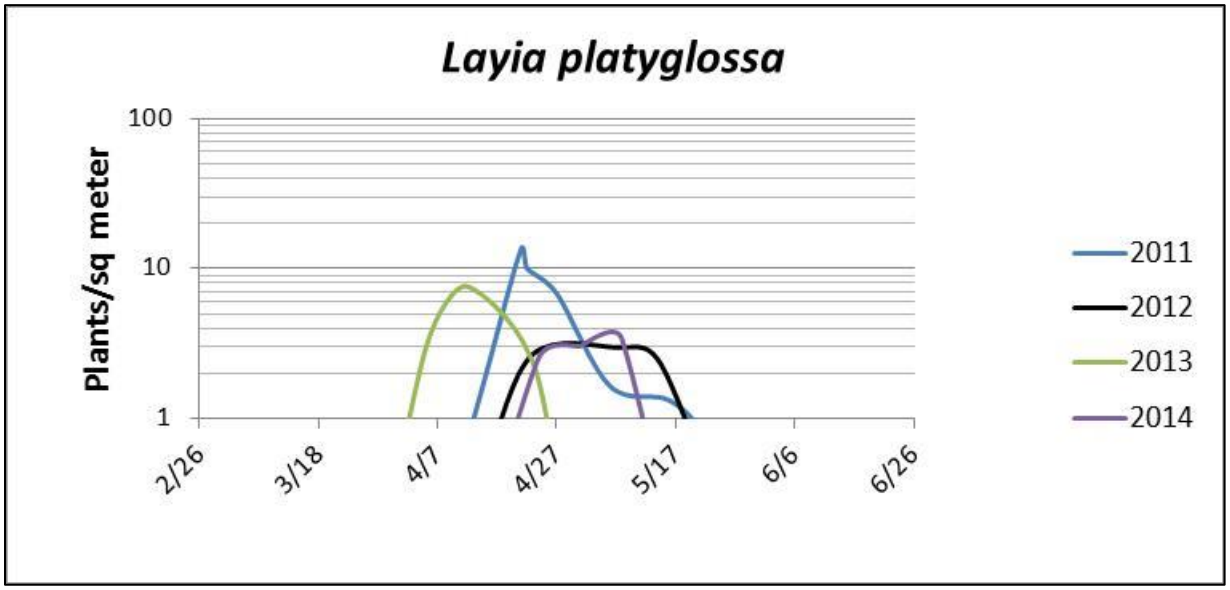


Figure 16. Kirby Canyon nectar phenology



Media

This project continues to attract attention, although on smaller scale this year.

Friends of Edgewood website

http://friendsofedgewood.org/bay-checkerspot-butterfly#latest

Edgewood Explorer

http://friendsofedgewood.org/wp/wp-content/uploads/2014-06.pdf

Related Tulare Hill translocation project

PG&E Currents

http://www.pgecurrents.com/2013/03/12/pge-helps-release-threatened-butterfly-at-san-jose%E2%80%99s-tulare-hill/

Wildlife Habitat Council website

http://www.wildlifehc.org/bay-checkerspot-butterfly/

Discussion and Next Steps

Bay checkerspot larval and adult numbers continue to increase each year at Edgewood, which has high quality habitat. Because numbers are still below replacement rate of introduced individuals, we believe introductions should continue. Our federal permit expires February 5, 2015, which is likely too early to include another year's translocation. We therefore plan to apply for an extension on this permit so we may continue this successful project. Funding sources are also needed.

The Bay checkerspot season at Edgewood began extremely late in 2014, due to another year of record drought. A late start to germination can decrease likelihood of prediapause larvae growing large enough to enter diapause, the main bottleneck in the Bay checkerspot life cycle. The checkerspots did develop quickly, but still had a late flight season, with peak flight 1-3 weeks later than previous years.

Even with the warm March and April (compounded with low rainfall), *Plantago erecta* at Edgewood stayed fresh later than previous years. It appeared that even with record low precipitation, the late season rain was sufficient to recharge soils and allow the annual plants to complete their life cycles. The annuals appeared to need a certain minimum time to complete their life cycle, and their extremely late start concurrently seemed to extend their senescence date.

As a general rule, prediapause larvae survivorship increases substantially if host plants remain fresh three weeks or more after the midpoint of flight season, which was on April 8. April 29 is three weeks from that, and *Plantago erecta* plants at Edgewood were fresh beyond May 15. *Castilleja*, the secondary host, was present at its lowest numbers this year. Nectar again appeared abundant during the flight season.

We were very pleased to see even higher numbers of adults at Edgewood this season. The extremely dry season, the late start of host plant germination, the late flight season, and warm spring temperatures are concerns, but the persistence of host plants well beyond the flight season bodes well for reduced probability of prediapause mortality. Again, critical data will be collected in February 2015, when we see how many postdiapause larvae have emerged.

We remain grateful to our many partners who help with permitting, funding, management, and volunteer hours: U.S. Fish and Wildlife Service, San Mateo County Parks, Friends of Edgewood, California Native Plant Society, PG&E, and San Mateo County Parks Foundation.

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