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Spatial distribution of coast and dune buckwheat (Eriogonum latifolium & E. parvifolium) in a restoration site on the Fort Ord dunes of California

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Spatial Distribution of Coast and Dune Buckwheat (*Eriogonum latifolium & E. parvifolium*) in a Restoration Site on the Fort Ord Dunes of California

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Abstract

Coast and dune buckwheat (*Eriogonum parvifolium & E. latifolium*) are native plants to the Fort Ord sand dunes which are essential for the survivorship of the federally-endangered Smith's blue butterfly (*Euphilotes enoptes smithi*). Buckwheat was put at risk during the restoration process because the land was stripped of its vegetation in order to remove the lead left behind from bullet shells when the land was used as rifle ranges by the military in the past. The Fort Ord dunes of California have undergone immense restoration treatments in order to increase the abundance of native plants, like coast and dune buckwheat. In order to learn more about buckwheat survivorship I addressed this question: Does location on hillslope and aspect influence the percent cover of planted buckwheats (*Eriogonum latifolium & E. parvifolium*) on the Fort Ord dunes? South-facing slopes had the greatest percent cover relative to north and east-facing slopes. However, there appeared to be no differences in percent cover of buckwheat for upper, middle, and lower hillslope positions. When comparing percent cover of buckwheat over a period of 18 months, an increase in percent cover was found, however, over shorter periods of time (6 and 12 months), no such difference was observed at other ranges. For future replantings, I would suggest planting buckwheats later in the restoration process on south-facing, lower hillslopes, after dune vegetation has been well-established. Based on personal observations, buckwheat crown size varied with aspect and hillslope position and merits further studying. Given a limited survivorship of buckwheat at the assessed ranges, further studies could enhance buckwheat survivorship and help aide in the increase of Smith's blue butterfly populations.

Introduction

The Endangered Species Act (ESA) has been protecting endangered species for over 25 years (U.S. Fish & Wildlife Services, 2002). The ESA was passed in 1973, representing America's concern for the decline in many wildlife species worldwide (U.S. Fish & Wildlife Services, 2002). The purpose of the ESA is to conserve "the ecosystems upon which endangered and threatened species depend" and to conserve and recover listed species. Under the ESA, species may be listed as "threatened" or "endangered", endangered being the more extreme of the two listings (U.S. Fish & Wildlife Services, 2002).

U.S. Military Installations

There are currently many endangered species located on U.S. military bases. Military bases can serve as important havens for these endangered species, because of low development within these areas (U.S. Army Corps of Engineers, 1992). Habitat destruction is occurring everywhere, but in many cases, military land is the only undeveloped land where species can reside due to the military's willingness to help preserve species habitat and to the exclusive nature of the lands. However, there can be negative impacts associated with military activity. Some military bases have been forced to be shut down due to necessary measures taken in part for the protection of endangered species inhabiting the bases (Charles, 1991). Some view closing military bases down as compromising the military's training and readiness for attacks (The Associated Press, 2003). As of recently, President George W. Bush won approval to ease up on the protection of endangered species and marine mammals on military installations, allowing military training to continue. In opposition, environmentalists say that the "nation's natural heritage is being sacrificed under the guise of national security" (The Associated Press, 2003).

For example, conflicts of interest between stakeholders arose when the Fort Bragg Army Base in North Carolina shut down in order to preserve the red-cockaded woodpecker (Charles, 1991). One of the main goals of the Fort Bragg Army Base and the U.S. Environmental Center is to find a way to preserve the home of the endangered woodpecker, while keeping the military training grounds open for military use. The army base has distinctive signs and red tape marking out the territory where the woodpecker resides in hollowed-out trees. Anyone who fails to obey the law protecting the endangered species could result in being fined or spending time in jail. Smaller colonies of the red-cockaded woodpecker are also found at other military bases in Georgia and Louisiana. While the woodpeckers continue to inhabit military land, they face dangers such as tanks, troops, and firing ranges. Current military activity can have a lasting effect on the land and the species that inhabit it. The red-cockaded woodpecker is just one example of a listed species that resides on military grounds which faces extinction and habitat destruction (Charles, 1991).

Fort Ord Army Installation

Endangered species populations inhabiting the former military training grounds of the Fort Ord dunes, near Monterey, CA, have also felt pressure from past military activities similar to those occurring at the Fort Bragg Army Base (Figure 1). Fort Ord became a closed military base in 1994, which was soon followed by the installation of a Habitat Management Plan (HMP) (U.S. Army Corps of Engineers, 1994). The site has been used for small arms training fire since the beginning of the 1940's (Former Fort Ord Environmental Cleanup, 2003). The Fort Ord dunes landscape has been considerably altered by the military's use of the location for decades. The landscape has been disturbed by other human activities besides the construction of the firing ranges, for instance, a sewage treatment plant, roads, and railroads have added to the destruction of coastal dune habitat (Harlen, 1999). Although, the army has protected the Fort Ord dunes from hotels and development, firing range activities have lead to the destruction of endangered species habitat anyway (Harlen, 1999). From 1940 - 1992 the military introduced many exotic species into the community to help stabilize the areas of disturbance (Harlen, 1999). Some of the exotic species include European beach grass, *Ammophila arenaria*, and African ice plant, *Carpobrotus edulis*. Between disturbance from firing ranges and competition by invasive species, several native species are nearing extinction on the Fort Ord dunes.

When military bases are closed as federal property any threatened or endangered species must be managed through the HMP process. The HMP established guidelines for the conservation and management of wildlife and plant species and habitats that largely depend on the Fort Ord land for survival (U.S. Army Corps of Engineers, 1994). The U.S. Fish & Wildlife Service's opinion on the disposal and reuse of Fort Ord identified that there was a need to develop and implement an HMP to reduce the incidental take of listed species and loss of habitat that supports these species. The HMP addresses impacts resulting from predisposal, disposal, and reuse actions. The HMP is crucial to the survival of most native plants, due to an increase in non-native plants within the area (U.S. Army Corps of Engineers, 1994).

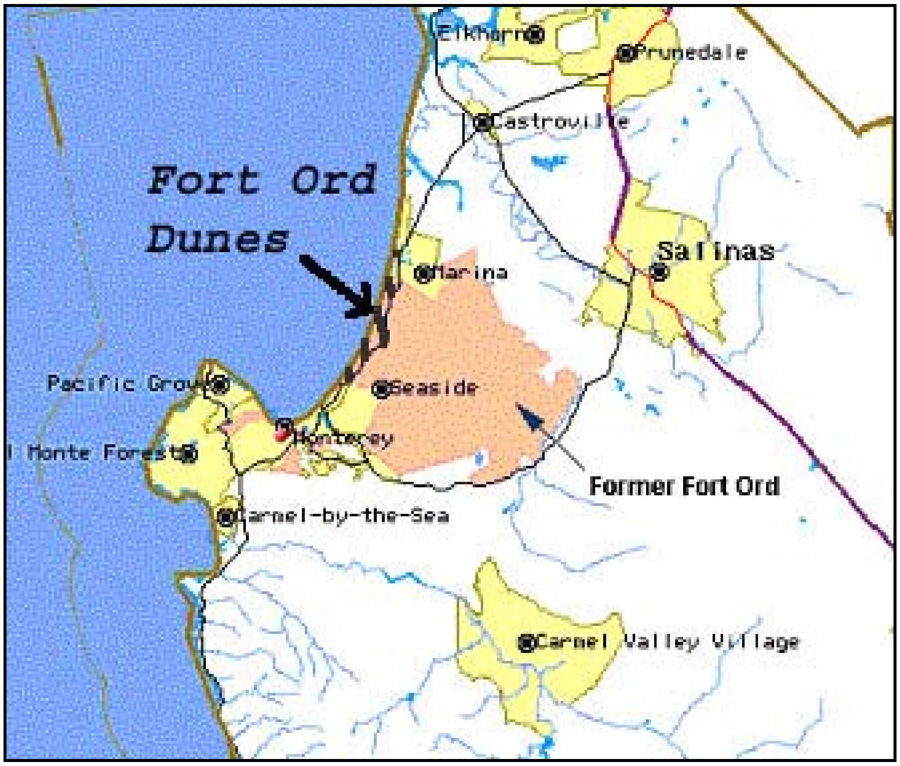

Figure 1: Map of Fort Ord dunes (☐).

Currently, the species of concern on the Fort Ord dunes listed in the HMP consist of the Smith's blue butterfly (*Euphilotes enoptes smithi*), coast and dune buckwheat (*Eriogonum latifolium & E. parvifolium*), Western snowy plover (*Charadrius alexandrinus nivosus*), coast wallflower (*Erysimum ammophilum*), sand gilia (*Gilia tenuiflora ssp. arenaria*), Black legless lizard (*Anniella pulchra nigra*), and Monterey spine-flower (*Chorizanthe pungens*) (Harlen, 1999).

The military left behind a large number of bullets and bullet shells that were contaminating the dunes with lead (Battelle, 1997). Spent bullets had accumulated on the east-facing (leeward) sides of the sand dunes that formed the "backstops" for the targets (Harding Lawson Associates, 1997). To remove the lead from the dunes, the front half of each dune was completely stripped of all vegetation in attempt to clean up the contamination left behind by the military (Harding Law Associates, 1997).

The excavation of lead contaminated soil on this site has been completed. However, during the lead remediation process, the soil excavation further decreased the populations of the many species of concern that reside on the Fort Ord dunes. To remedy this decline in populations, California State Department of Parks and Recreation has been focusing on planting an average of 25,000 native plants throughout a 150-acre lead remediation area (Ian Harlen, pers. comm.). One of the main habitat restoration goals of the California State Parks is to reestablish the acreage of rare plants lost during lead remediation activities. To compensate for this loss, there has been an increase in native plantings in hopes of restoring the plant species to its original population size prior to the lead removal. Restoring the plant community at the dunes to its original state, prior to the lead removal activities, is a concern of the people who are supporting this native restoration. Therefore, the survival rate of the plants being restored is also of concern.

Native plants that can be found on the Fort Ord dunes include the coast and dune buckwheat, *Eriogonum parvifolium & E. latifolium*. Coast and dune buckwheat are perennial plants (Ingram, 1999). Buckwheat can be found thriving in seaside conditions, where there is full sun and sandy environments (Las Pilitas, 2003). Coast buckwheat produces a white flower color with green foliage, whereas dune buckwheat has pinkish-red flowers (Las Pilitas, 2003). Coast and dune buckwheat are important plants to revegetate on the dunes, especially since the federally-endangered Smith's blue butterfly, *Euphilotes enoptes smithi*, spends most of its lifecycle in association with the two buckwheat plants in the genus *Eriogonum* (Dixon, 1999). The Smith's blues' long-term survival is dependent upon the number of buckwheat plants located on the sandy dunes of Fort Ord (Roof, 1997). The Habitat Management Plan created by the Army takes into consideration the impact on Smith's blues' during the loss of native buckwheat habitat due to lead remediation (U.S. Army Corps of Engineers, 1994). Dune experts feel that it is the habitat of the Smith's blue butterfly that is endangered (U.S. Fish & Wildlife, 1984). They say that freeway building and urbanization have destroyed roughly 50 percent of the original dunes (Arnold, 1983).

Plants and animals that live in coastal dunes are adapted to the scouring effects of wind-blown sand, and extremely drying conditions made worse by salt-spray from the ocean. Most dune dwelling organisms specialize in the sandy life. The evolutionary cost of their specialized adaptations also results in a limited capacity to compete and survive in other adjacent habitats. When 50 percent of the Smith's blue butterfly's habitat is gone and specialized adaptations have excluded the ability to survive in other habitats, this becomes the mechanism of their endangerment (U.S. Fish & Wildlife, 1984).

Biology of Smith's Blue Butterfly

The Smith's blue butterfly is a member of a family of very small North American butterflies known as the Lycenids (U.S. Fish & Wildlife, 1984). The Smith's blue butterfly's range extends along the coast from Monterey Bay south through Big Sur to near Point Gorda, occurring in scattered populations in association with coastal dune, coastal scrub, chaparral, and grassland habitats (Arnold, 1983). Smith's blue butterflies have a wingspan of just under an inch limiting their movement across large areas. In addition to their small size, their lives spent as adult butterflies are very short. It is estimated that individual adults live for only about one week. Their flight patterns are limited to temperatures above 60 degrees and when there are no strong winds. Under the most ideal conditions, butterflies can fly no more than 8 hours per day. That gives the adults a total of no more than 56 hours to find and court a mate, copulate, and lay the eggs of next year's generation. Early season males may have a harder time finding females, since the first-of-the-season females start emerging about a week after the first males. The overall population of adults is active for about 8 to 12 weeks between the months of June to September. In addition, most butterflies fly less than 200 feet from where their lives began as eggs (U.S. Fish & Wildlife, 1984). These limiting factors add to the decline in populations in California.

Adult male Smith’s blue butterflies mate, after emerging in the late summer and early autumn, so that they can lay their eggs on the flowers of their host plants, buckwheat (Arnold, 1983). The eggs hatch soon after, then feed upon the flowers of the coast and dune buckwheat. Buckwheat is a primary food for endangered Smith's blue butterfly larvae (Dixon, 1999). Buckwheat, an important plant species that hosts the Smith’s blue butterfly, continues to be threatened by development and the invasion of non-native plants (Dixon, 1999). On Fort Ord significant acreage of Smith’s blues’ habitat was destroyed during the lead remediation project, therefore making the replanting of buckwheat throughout the 150-acre remediation area a main focus of the CA State Park restoration team in hopes that Smith’s blue butterfly populations will start to flourish once again (Harlen, 1999).

Fort Ord Dune Ecosystem

Due to the Endangered Species Act, the Habitat Management Plan, and restoration organizations, the California State Parks have had the opportunity to help restore habitats that are crucial to the survival of endangered species near extinction. The relationship between the HMP and ESA can be seen diagrammed in Figure 2. The

California State Parks has made numerous attempts to help repopulate Smith's blue butterfly populations on the Fort Ord dunes; the lead removal being one of the biggest and most costly. Although California State Parks have plans to open the Fort Ord dunes to the public by transforming the land into a state park, the California State Parks still have goals to maintain the open space character of the dunes, restore natural land forms, and restore habitat values (California Department of Parks and Recreation, 2004). Opening the dunes for public use could cause negative impacts to plant survival, such as trampling from off trail users and the establishment of parking lots for public use. Not only is dune vegetation threatened by humans, but natural causes such as wind and dune blowouts, iceplant, placement along hillslope, and aspect can also play a role in their survivorship or fatality.

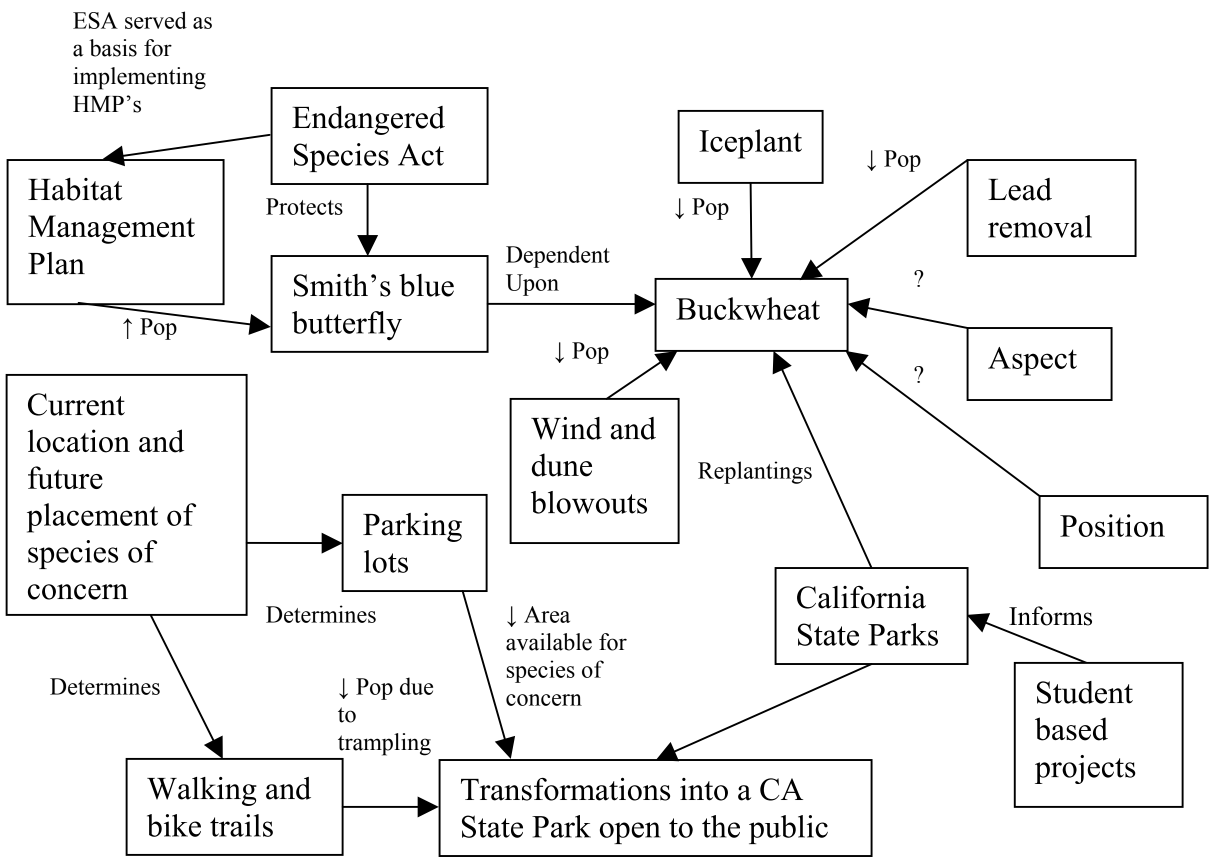

Figure 2: Systems Diagram showing the relationships between major stakeholders such as coast and dune buckwheat, Smith's blue butterfly, and California State Parks.

After the lead removal, the California State Parks have replanted buckwheat through site 3 in various ranges, in general using a haphazard method of placement. I will be surveying the results of their placement decisions by assessing two main factors that may affect the survival of buckwheat, placement with respect to hillslope and aspect. As diagrammed in Figure 2, it is unknown how these factors will affect buckwheat individuals. This study will address the impact of these two factors on the overall survival of buckwheats.

The location of plantings can be crucial to the survival of buckwheat plantings due to different physical environmental characteristics associated with hillslope position and aspect, therefore making efforts to experiment with these factors important. Different sun exposures occur on north, south, east, and west-facing slopes in the northern hemisphere. Due to the inclination of the sun, a south-facing slope in California will always experience greater total insolation than will the north-facing slope of the same region (Barbour et al., 1999). Thus, there will be warmer air and soil, less moisture, and sparser vegetation, in general, on a south-facing slope. North-south slope aspect difference is often manifested in very different plant cover. North-facing slopes never experience direct sun at these latitudes. Shading can have an influence on the different temperatures within microclimates on the dunes. Shaded grounds are cooler during the day in comparison to open areas, if there is little air exchange. Nutrient availability of soil may vary greatly among soil types (even at relatively small spatial scales) and with depth within a particular soil type. Water availability also changes with depth along a hillslope, in response to abiotic and biotic factors (Barbour et al., 1999). Due to water gradients that exist within hillslopes, lower hillslopes positions tend to be wetter than the upper area of hillslopes. These factors are indicators for why it is important to study and understand why north, south, and east-facing slopes and hillslope position (upper, middle, lower) might make a difference in the survivorship of coast and dune buckwheat on the Fort Ord dunes.

By performing transects on the Fort Ord dunes, I was able to assess the survival of buckwheat planting efforts made by the California State Park in their attempt to revegetate the dunes with native plants. Therefore, the purpose of my capstone is to determine whether planted buckwheat are surviving equally well in planted areas on the Fort Ord dunes with respect to aspect (north, east, and south facing) and hillslope position (upper, middle, and lower placement). This leads to the question: Does location on hillslope and aspect influence the percent cover of planted buckwheat? Also since data is available from previous years, I also addressed the question: Does the percent cover of buckwheat on dune faces mirror the expected fraction of total plants based on the total number of buckwheat planted in each range? By determining the environmental characteristics of coast and dune buckwheat, I was then able to assess restoration techniques/practices that are most appropriate for buckwheat planting on the Fort Ord dunes. I also resurveyed the same sites after different periods of time (6, 12, and 18 months) to assess whether percent cover of buckwheat was increasing. Very few studies have been performed to determine the significance of aspect and position along hillslopes, so the results of this experiment are important in determining most of the physical factors that influence buckwheat.

Methods

Site Description

The Fort Ord dunes are found in central CA also referred to as Site 3 by the California State Department of Parks and Recreation (Figure 3). Site 3 extends approximately 3.2 miles along the coastline of Monterey Bay at the western boundary of Fort Ord, where there are sixteen firing ranges present (Figure 4; Former Fort Ord Environmental Cleanup, 2003). Site 3 is currently inactive and no longer used by the military (Harding Lawson Associates, 1997). It is proposed for reuse as a state park consisting of hiking trails, campgrounds, and ancillary facilities (Former Fort Ord Environmental Cleanup, 2003).

Figure 3: California's Fort Ord dunes and Pacific Ocean.

Field Methods

To assess the abundance of *Eriogonum*, I collected my own data as well as used data from the Quantitative Field Methods (QFM) and Biology 1 classes at California State University of Monterey Bay (CSUMB) from Fall 2001 to Fall 2003. In all cases percent cover of *Eriogonum* was determined by transects taken on the rifle ranges represented in Figure 4. The map shown in Figure 4 labels the ranges using the naming system that the Army created and the California State Parks has adopted for the Fort Ord dunes. Note that some of the ranges have been labeled by combining a range with their adjacent range.

In all cases the following sampling technique was used to estimate percent cover of buckwheat. Once the general sample area had been selected, a 50 m transect line was randomly placed within each chosen sampling area, recording every 0.5 m. Only one layer of buckwheat was sampled vertically along the transect tapes, because in no cases were there multiple buckwheat individuals within a hit. The method used to record percent cover of buckwheat was a variation of the point intercept method initially created by the California Native Plant Society (CNPS).

To calculate effects of aspect, transects were placed on south, east, and north-facing slopes at each range where feasible. No west facing slopes were sampled, because there are not any in the areas where lead remediation occurred and thus where buckwheat was restored. Table 1 shows the number of transects (i.e. sample size) with respect to each aspect (north, south, and east-facing).

To calculate the effects of hillslope position, the dune faces were divided into thirds and one transect was randomly placed in each of the upper, middle, and lower thirds. Table 2 shows the number of transects with respect to data already collected with respect to position along hillslopes. All data listed in table 2 was collected on south-facing slopes. Not all hillslope positions were done on each aspect due to the nature of the data collected by the Biology I class, Quanitative Field Methods class, and myself.

After buckwheat plantings were completed on the Fort Ord dunes, I was able to pose the question: how long does it take to measure an increase in percent cover of buckwheat within a range? In order to assess this change in percent cover of buckwheat, I compared monitoring data over three different ranges over three different time periods (6, 12, and 18 months).

Ian Harlen, a Resource Ecologist for the California State Parks, recorded the number of individuals planted at each range for the years 1996 through 2002. Using these data, I calculated the expected fraction of total buckwheat plants based on the number of individual buckwheat's planted at a range as a fraction of the total individuals planted for all species at that range. The actual buckwheat percent cover is based on the number of buckwheat hits divided by the total number of plant hits on each transect collected by the Biology I classes, Quanitative Field Methods class, and myself. The sample size of actual values for each range was: Range 1 & 2 (n = 6), Range 5 & 6 (n = 4), Range 11 & 12 (n = 6), and Range 15 & 6 (n = 6).

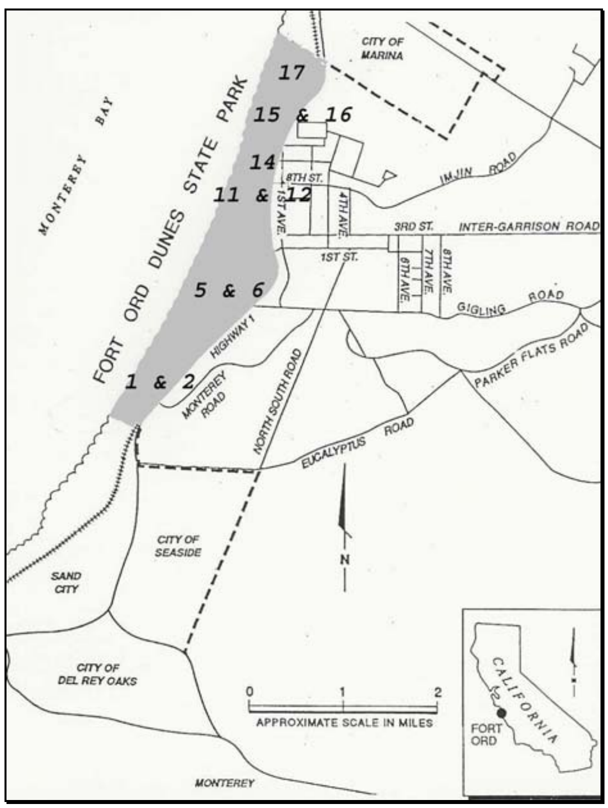

Figure 4: Map of Fort Ord, Site 3, indicating the locations of the restored firing ranges (1 & 2, 5 & 6, 11 & 12, 14, 15 & 16, and 17) surveyed in this study.

Table 1: Distribution of sample size for data collected with respect to aspect on hillslope (North, East, & South facing slopes).

Range #	Date Sampled	# of Transects			Data Collected by
		N-face	E-face	S-face	
5 & 6	Mar 2002	2	1	1	Wallingford & McNulty
11 & 12	Oct 2001	1	4	0	Biology Fall 2001
11 & 12	Oct 2002	5	2	1	Biology Fall 2002
14	Oct 2003	0	0	6	Wallingford
15 & 16	Oct 2002	0	4	0	Biology Fall 2002
17	Apr 2003	0	0	6	Wallingford & McNulty
Total # of transects		8	11	14	

Table 2: Distribution of sample size for data collected with respect to position on hillslope position (upper, middle, and lower). All transects were taken on south-facing slopes.

Range #	Date Sampled	# of Transects			Data Collected by
		Upper	Middle	Lower	
1 & 2	Oct 2003	2	2	2	Wallingford
5 & 6	Oct 2003	2	2	2	Wallingford
14	Oct 2003	2	2	2	Wallingford
17	Apr 2003	2	2	2	Wallingford & McNulty
Total # of transects		8	8	8	

Data Analysis

To assess aspect and hillslope position as well as change in percent cover over time, the percent cover was calculated by adding up the number of buckwheat hits divided by the total number of total hits for each of the transects recorded. The percent cover was calculated from each transect and then compared to past data gathered from previous transects in the same areas. All hillslope position data (Table 2) was based on south-facing slopes data (Table 1). Aspect data in Table 1 was incorporated data from Table 2 as well.

An ANOVA statistical test was performed on the data to compare percent cover of buckwheat as a function of aspect, hillslope position, and date. However, if parametric assumptions were not met, a non-parametric Kruskal-Wallis test was performed on the data. Post-Hoc comparisons between individual ranges were statistically tested using a pairwise Mann-Whitney U on non-parametric dataset (Ott & Lyman, 1993). To compare expected fraction of total plants with actual percent cover within the same range a paired t-test was performed on the dataset.

Results

North, south, and east-facing slopes differ in percent cover of buckwheat ($H = 6.36$; $p = 0.041$; $df = 2$). South-facing slopes had a greater percent cover of buckwheat than either north or east-facing (Figure 5; Mann-Whitney $U \geq 38.00$; $p \leq 0.033$). North and east-facing slopes were not found to be significantly different (Figure 5; Mann-Whitney $U = 33.00$; $p = 0.355$).

Upper, middle, and lower hillslope positions were surveyed to assess the percent cover of coast and dune buckwheat with respect to position. The results of the ANOVA test indicated that there were differences due to hillslope positions (lower hillslope positions had a greater percent cover), but these differences were not significant (Figure 6; $F_{2,21} = 0.67$; $p = 0.514$).

Individual ranges were compared to assess the change in percent cover over time for a given range based on monitoring. When a range is surveyed over a time period of 6 and 12 months, there is no difference in percent cover of buckwheat (Figure 7; 6 mo.: $F_{1,10} = 0.047$; $p = 0.833$; 12 mo.: Mann-Whitney $U = 0.05$; $p = 0.943$; $df = 1$). After 18 months, however, percent cover increased over time (Figure 7; 18 mo.: $F_{1,8} = 17.15$; $p = 0.003$).

Recall that the expected fraction of total buckwheat plants is based on the fraction of buckwheat relative to total number of individuals of all species planted during the restoration by the California State Parks. Whereas, actual percent cover is based on the percent cover of buckwheat using total number of plant hits from the monitoring transects taken at several ranges on the Fort Ord dunes by Biology I students, Katy McNulty, and myself after restoration plantings were completed. It was found that the expected fraction of total coast and dune buckwheat plants greatly exceeded the actual percent cover of buckwheat on the Fort Ord dunes for ranges 1 & 2, 5 & 6, 11 & 12, and 15 & 16 (Figure 8; $t = 3.77$; $df = 3$; $p = 0.033$).

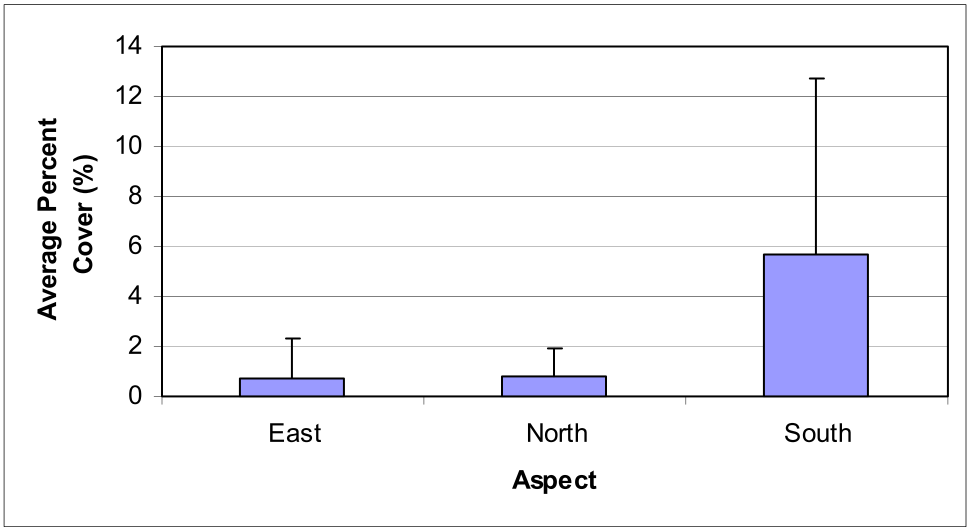

Figure 5: Average (+/- 1sd) percent cover (%) of east (n =8), north (n =11), and south (n =14) facing slopes on the Fort Ord dunes.

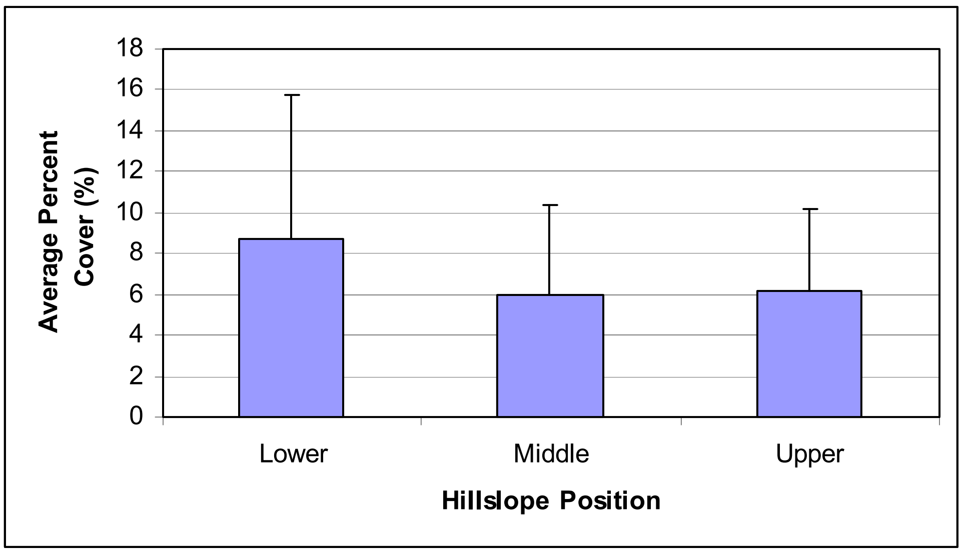

Figure 6: Average (+/- 1sd) percent cover (%) of lower, middle, and upper (n =8) hillslope positions on the Fort Ord dunes.

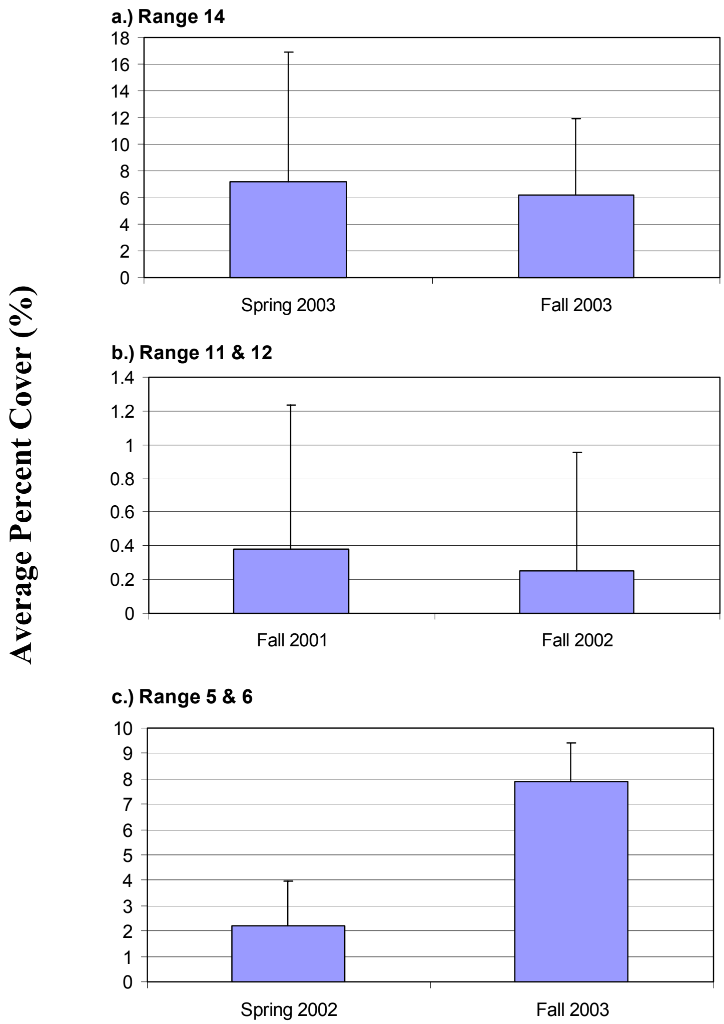

Figure 7: Average (+/- 1sd) percent cover at the same range over time for ranges 5 & 6, 11 & 12, and 14. Note the difference in time scales: a) 6 months, b) 12 months, and c) 18 months.

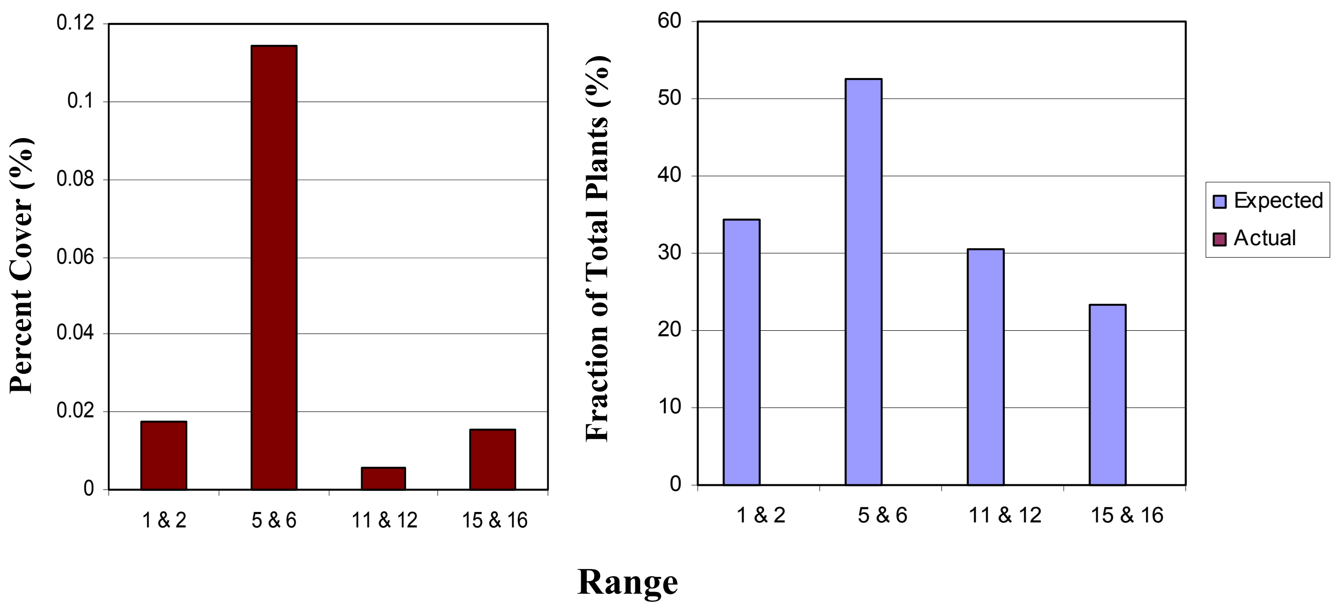

Figure 8: Expected (based on total number of individuals planted from 1996-2001) fraction of total plants (%) and actual (based on monitoring surveys taken from 2001-2003) percent cover (%) graphed for different rifle ranges at Site 3 on the Fort Ord dunes. Note difference in scale along the y-axis for expected and actual values. The sample size of actual values for each range was: Range 1 & 2 (n = 6), Range 5 & 6 (n = 4), Range 11 & 12 (n = 6), and Range 15 & 6 (n = 6).

Discussion

In order to increase Smith's blue butterfly populations on the Fort Ord dunes, it is first necessary to fully understand the biology of the host population coast and dune buckwheat. The purpose of this study was to determine whether there is a difference in percent cover of buckwheat with respect to aspect and hillslope position in order to help monitor the success of buckwheat plantings on the Fort Ord dunes by the California State Parks. This study will help aide in the future placement of buckwheat plantings in an attempt to repopulate the federally-endangered Smith's blue butterfly. For this study, more transects were taken on south-facing slopes. However, there appears to be more plants surviving on south-facing slopes than either north or east based on these monitoring surveys. In general, south-facing slopes are characterized by warmer air and soil, less moisture, and sparser vegetation, which may be a more suitable habitat for buckwheat to reside. There were no differences found between upper, middle, and lower hillslope positions. However, from my observations in the field, buckwheat plants appear to be greater in size and be more successful on lower hillslope positions. Ian Harlen, a California State Parks Ecologist responsible for replantings, also observed this pattern, creating planting bias on some ranges by his placement of buckwheat along the hillslopes. During the past replanting, on ranges 8 and 9 there was a tendency to plant along lower hillslopes in dense stands of buckwheat in comparison to upper hillslopes placements where little buckwheat growth was observed, in hopes of greater survival. To eliminate this bias, ranges 8 and 9 were not sampled, because of possible biases created during the planting of buckwheat. In general, there was a trend toward more buckwheat individuals at lower hillslope positions (Figure 6), but there was considerable variation between ranges in percent cover. When testing for differences in percent cover along hillslope position, it was expected for more plants to be located lower on the dunes, since the plants could access water from the water table with more ease. However, this was not a strong enough significant relationship to be detected with the level of sampling taken in this study.

In this study, the actual percent cover based on monitoring surveys of buckwheat concluded to be less than the calculated expected fraction of total buckwheat plants based on the total number of individuals planted at a range (Figure 8). No actual percent cover values were greater than one percent (Figure 8). Plant hits were used instead of total hits to calculate actual percent cover of buckwheat in Figure 8. Total number of plants hit were used to calculate the data used in Figure 8, rather than total hits along the transect.

Total hits include the plants only hit every 0.5 m for 50 m, whereas plants hits include only the number of plants that fall along the transect line. In no cases were there multiple buckwheat individuals within a hit. Ian Harlen, a Resource Ecologist for the California State Parks at the Fort Ord dunes, found that the success rate of buckwheat experienced a low growth rate in approximately 30% of the planted areas (Harlen, 2003). His study concluded that low growth rates were associated with higher hillslopes where dessication was caused by percolation rates, exposure to drying winds, wind-blown sand, and intense sun. During the period of active use of the training ranges, the upper hillslopes were often areas where buckwheat patches were able to survive, however, after the extensive excavation work and recontouring of the dunes, these areas were no longer suitable for buckwheat plants or Smith's blue butterflies (Harlen, 2003).

Since plantings at higher hillslopes where very little if no vegetation is present have been unsuccessful, it is hypothesized that coast and dune buckwheat grow larger in older, dense stands. During the replanting of buckwheat some of the individuals were planted on bare ground, causing an exclusion from vital organic matter, nutrients, possibly mycorrihizae, and other factors only found in established dune vegetation for available plant growth. By planting buckwheat individuals into an established dune vegetation could promote these species to reach their optimal growing ability for the location. In general, buckwheat plants were observed to be found largest in size and abundance where vegetation cover was the densest along south-facing slopes. For future plantings, it is suggested that buckwheat be planted along lower, south-facing hillslopes where vegetation is densest.

From these observations it appears that coast and dune buckwheat are late successional species, due to observations of greater buckwheat plant sizes in dense stands on lower hillslopes and observations made by Ian Harlen (Harlen, 2003). Therefore, buckwheat should be planted later in the restoration process in later plantings since they were observed to grow larger in older, denser stands during this study. The Fort Ord dunes restoration was a five year plan. In the future, California State Parks should lengthen the restoration time from five years to ten years, for more experiments and the opportunity to plant late successional species later in the restoration process, such as buckwheat. By lengthening the allotted restoration time for replantings, it can create time for early successional species to become established, creating a preferred environment for buckwheat to flourish and grow to their optimal size for the location. The hypothesis that buckwheat is a late successional species needs to be tested further.

Buckwheat plantings by the California State Parks were haphazardly planted along the hillslopes of the dunes. When performing the transects in the field, young buckwheat plants planted by the California State Parks were seen, but with little growth since the re-plantings took place. Therefore, the transects resulted in a low percent cover of buckwheat. For future experiments, in addition to this study, there should be studies performed to monitor the growth and size of buckwheat plantings on the Fort Ord dunes. If plantings conducted by the California State Parks are not successful in increasing the number of adult buckwheat individuals in the future, this will affect the population size of the Smith's blue butterflies since they lay their eggs on buckwheat flowers.

Conclusion: Management Suggestions

In conclusion, it is suggested to plant buckwheat along lower, south-facing hillslopes where plant species can be observed in dense stands. It is recommended that buckwheat be planted later in the restoration process since buckwheat appears to be a late successional species. The restoration process has taken five years, however, for late successional species the process should take closer to ten years, allowing vegetation to be established for species that prefer dense stands for plant growth. This will allow more experiments and studying to be done within site 3, creating a greater knowledge of the Smith's blue butterfly host species.

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