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Measuring new growth of kinnikinnick and brown elfin butterfly abundance at the Ma-le'l & Lanphere Dunes: implications for the management of the seaside hoary elfin butterfly

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MEASURING NEW GROWTH OF KINNIKINNICK AND BROWN ELFIN BUTTERFLY ABUNDANCE AT THE MA-LE'L & LANPHERE DUNES:

Implications for the management of the seaside hoary elfin butterfly

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Brown Elfin Butterflies mating on a California Wax myrtle (Myrica californica) (photo by Leila Rahimi, 2023).

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ABSTRACT

The study assessed changes in inflorescence length of kinnikinnick (*Arctostaphylos uva-ursi*) new growth and the abundance of brown elfin butterflies (*Callophrys augustinas)* at the Ma-le'l and Lanphere Dunes. The research took place at the Ma-le'l and Lanphere Dunes in Humboldt County where a surrogate species for the seaside hoary elfin–the brown elfin–is abundant. In the larval stage, the brown elfin feeds on the new growth of kinnikinnick. Our study set out to analyze the food resource availability for brown elfin butterfly larvae, as they are forage on the tender leaves associated with the new growth of kinnikinnick inflorescences. We found a higher abundance of brown elfins was slightly correlated with areas where the average kinnikinnick inflorescence growth rate was higher. Our analysis of several environmental factors in each plot (ant presence, canopy cover, and herbivory) concluded that the variables tested had no significant relationship with the growth of kinnikinnick inflorescences. Future studies should use a longer study interval than the two-week interval used in this study; a longer interval would make it easier to capture changes in the inflorescence length of kinnikinnick. This study has the potential to inform future management strategies that could aid in the recovery of the critically imperiled seaside hoary elfin butterfly, including populations in the Tolowa Dunes State Park in Crescent City, CA.

1. INTRODUCTION

1.1 Butterfly importance

Butterflies are excellent indicators of ecosystem health and function (Robinson et al., 2012). Their relationship to plants is interlinked; co-evolution between individuals has resulted in unique associations (Ghazanfar et al., 2016). Butterflies' physiological tolerances make them more sensitive to changing environmental conditions; light, temperature, and habitat are important environmental factors that can affect these insects (Ghazanfar et al., 2016). Many butterflies rely on a specific plant for oviposition or feeding. Loss of plant species or biomass can put associated butterfly populations at risk (Thomas et al., 2011). The evolutionary history of plant communities and their hosts varies across landscapes (Arnnet, 2014). Therefore, it is critical to understand how plants and butterflies interact in any given environment.

1.2 Ecological and societal value provided by butterflies

A majority of butterfly species in their adult forms consume nectar from plants. Their feeding habits contribute to greater genetic variation among plants via pollination, which occurs when pollen grains become attached to various parts of the butterfly's body when foraging for nectar (Reddi & Bai, 1984). For example, butterfly populations that migrate long distances can potentially spread pollen from plant populations that grow in different climates and habitats (Ghazanfar et al., 2016). The spread of pollen can help plants develop resistance to diseases and it also gives them a better chance at survival if new diseases are contracted (Ghazanfar et al., 2016).

Many anthropogenic factors have negatively impacted butterfly habitats. Land use impacts such as farming, roads, and even forestry can have a great effect on the distribution and richness of butterfly populations (Ghazanfar et al., 2016). Along with these disturbances, climate events have drastic effects on pollinator species environments (Robinson et al., 2012).

1.3 Brown elfin butterfly characteristics and behavior

The brown elfin butterfly (*Callophrys augustinas*) is located along many regions spanning across Northern America, specifically the east and west coast (James et al., 2011). Brown elfin butterflies can typically be found dispersed throughout Washington and Oregon and further north into Canada. The brown elfin prefers open habitats with slight canopy coverage. These habitats include forest openings, tree plantations, heath scrublands, chaparral, and forest roadsides (James et al., 2011).

The brown elfin is a generalist when it comes to finding a larval host plant. Salal (*Gaultheria shallon*), redstem ceanothus (*Ceanothus spp.*), blueberry (*Vaccinium spp*.), madrone (*Arbutus menziesii*), and bitterbush (*Prushia tridentata*) along with many others can be used for nesting eggs and feeding the larvae once they are hatched (James et al., 2011). However, while brown elfins are generalists, local populations of brown elfins tend to specialize on one or two host plants in their area (C. Pogue, pers. comm., 2023). We focused exclusively on kinnikinnick (*Arctostaphylos uva-ursi*) as the host plant for the brown elfin larvae due to kinnikinnick being the brown elfin's host plant in this specific location. (C. Pogue, pers. comm., 2023).

1.4 Range and importance of kinnikinnick

Kinnikinnick (*Arctostaphylos uva-ursi*), also known as bearberry, is a low-lying evergreen, perennial shrub that resides in many regions throughout North America (TWS Staff, Plant database, 2023). It has prostrate and rooting branches that can reach up to 10 cm tall and 100 cm long (TWS Staff, *Plant database*, 2023). Kinnikinnick typically grows in rocky, open woodlands, dry, sandy hills, and in the understory of pine forests (Kaplan, 2012*)*. Kinnikinnick is highly drought tolerant and is adapted to growing in coarse and medium textured soils (TWS Staff, *Plant database, 2023)*. Like many manzanita species, kinnikinnick recovers well after fires, but may be threatened by high severity fires caused by climate change (TWS Staff, *Plant database, 2023)*.

Kinnikinnick is an important and culturally significant plant found within a diverse range of environments. Kinnikinnick is native to North America and is prevalent in the western portion of the continent (Fretwell et al., 2014). Kinnikinnick habitat can be found in mountain meadows, mountain slopes, and open woodland (Sierra Club, 2016). Kinnikinnick produces berries that provide food for different types of birds, bears, coyotes, chipmunks, and squirrels (Brenner, 2021). Kinnikinnick provides protection from erosion through its roots and helps retain soil moisture (Hays, 2020). This species is also utilized in various ways in which berries are collected to produce jams while leaves are gathered in many Indigenous cultures for medicinal purposes (Sierra Club, 2016). Kinnikinnick may be used in landscaping, as it can tolerate a wide range of conditions (Gage, 2020).

1.5 Ma-le'l and Lanphere Dunes

California's biomes are home to many unique ecological assemblages. The state's diverse landscapes host at least 235 species of butterflies (Ghazanfar et al., 2016). One of these unique ecological communities is found in the Ma-le'l and Lanphere dunes of Northern California. The dunes are a dynamic coastal habitat for a variety of flora and fauna (Green, 1999) including kinnikinnick, the larval host plant of the brown elfin; it begins its life stage on this plant, and feeds on new growth (C. Pogue, pers. comm., 2023). Although the brown elfin butterfly population in the Ma-le’l Dune is stable at this time, a close relative, the seaside hoary elfin (*Callophrys polios maritima*) butterfly is currently critically imperiled in Oregon (Oregon Biodiversity Information Center, 2016). A population estimate conducted at Tolowa Dunes State Park in Crescent City, CA in 2022 found approximately 620 adult seaside hoary elfin. The findings suggest a 26% decrease in overall population size since 2009 when the recorded number of adult individuals was 835 (Ross, 2022). A decline in the butterfly population may indicate a decrease in new growth of the kinnikinnick plant, since the butterfly population is thought to feed on the new growth of kinnikinnick (C. Pogue, pers. comm., 2023). The similarities in the life histories of these two butterflies makes the brown elfin of the Ma-le’l and Lanphere dunes a good surrogate species for the seaside hoary elfin (C. Pogue, pers. comm., 2023).

1.6 Study objectives

The main objectives of this project were to measure possible new growth in kinnikinnick vegetation at the Ma-le’l and Lanphere dunes located in Humboldt County, California. If new growth is observed, we can estimate the growth rate to verify food resource availability for brown elfin butterflies in their larval stage. In addition to our main objective, we also examined and documented the presence of the brown elfin butterfly caterpillar on kinnikinnick and surveyed population samples of the adult brown elfin butterflies on new kinnikinnick growth. In addition, we measured other environmental factors such as the presence of ants, woody presence, and canopy cover. The results of the collected data allow us to examine the relationship between the rate of new kinnikinnick growth and the food resource availability for the brown elfin butterfly.

2. METHODS

2.1 Site description

The project site is located in Humboldt County, California and co-managed by the Bureau of Land Management (BLM) and U.S. Fish and Wildlife Service (USFWS). The site encompasses the Ma-le'l Dunes North Unit, and the Lanphere Dunes South unit off Vera Linda Lane (Figure 1). The dunes provide habitat for an abundance of rare and endangered species which include the western snowy plover, beach layia (*Layia carnosa*), Humboldt Bay owl's-clover (*Castilleja ambigua spp. humboldtiensis*), and the Humboldt Bay wallflower (*Erysimum menziesii eurekensii*) (*Natural History*. n.d.). The dunes are also host to a variety of migrating birds, and the nearby wetlands create habitat for many aquatic species *(Natural History*. n.d.). Recreational activities are common in the dunes; individuals may participate in bird watching, learning about the natural ecosystem found in the dunes, taking pictures, playing games, and hiking.

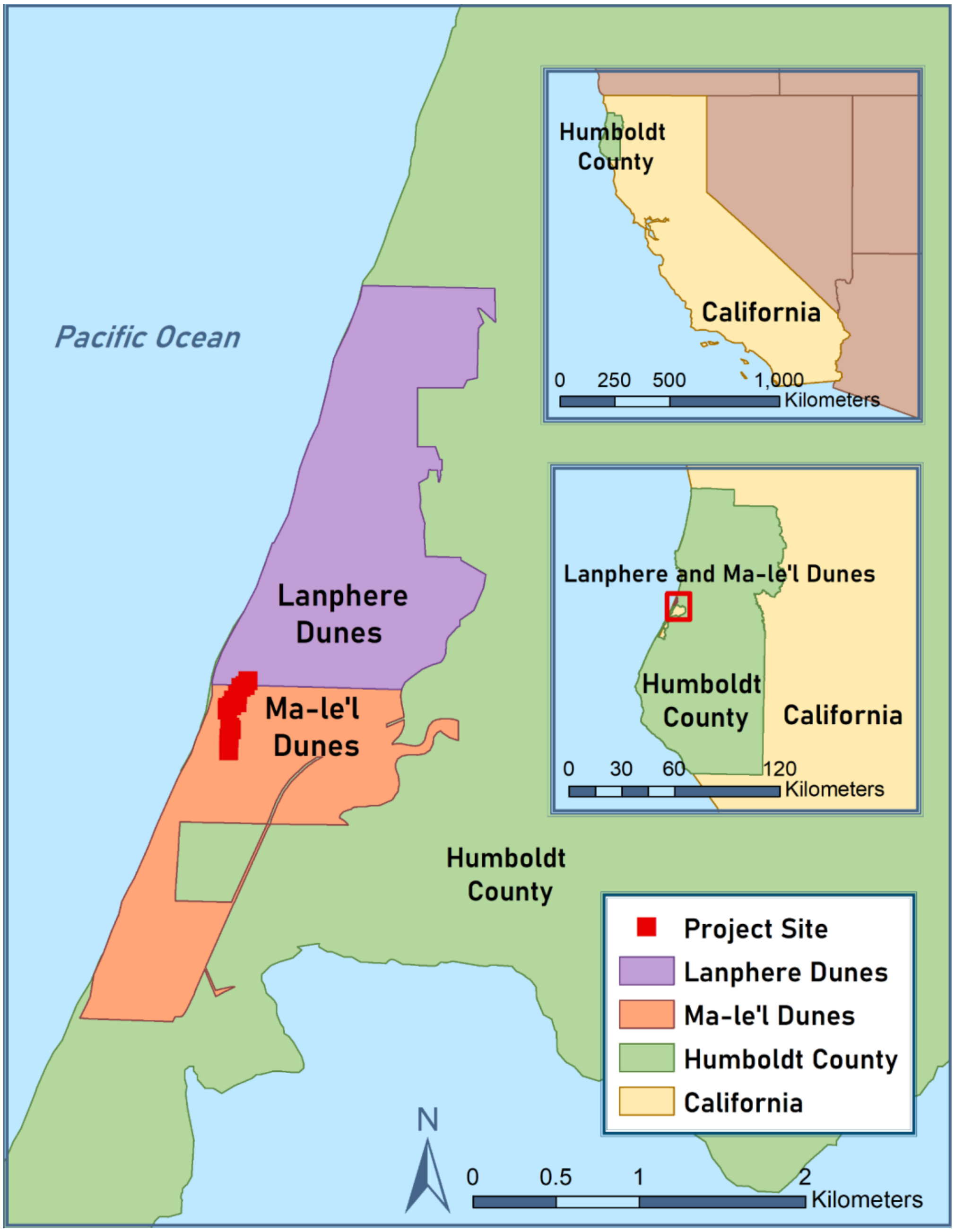

Figure 1: Locator map of project area. The main map on the upper right shows the location of Humboldt County within California. The lower right inset map shows the location of Ma-le'l and Lanphere Dunes in Humboldt County. The main map on the left shows the project site within the Ma-le'l and Lanphere Dunes (map by Leila Rahimi, 2023).

The history of the coastal dunes near Wigi (Humboldt Bay) begins with the Wiyot people who have inhabited the Samoa Peninsula since time immemorial (*History*, Wiyot Tribe, CA. n.d.). The Wiyot people fish, hunt animals, and gather plant materials for food and other utilities in this area (*Natural History*. n.d.). The Samoa Peninsula was inhabited by the Wiyot Tribe until the 1800s when it was forcibly taken and privatized by European colonists. However, the dunes remain integrally important historically, culturally, and spiritually to the Wiyot people (*History*, Wiyot Tribe, CA. n.d.).

Anthropogenic activity has had a significant impact on foredune ecosystems in Northern California. European beachgrass (*Ammophila arenaria*) was introduced to the area in 1880's to stabilize the dunes (Barbour et al., 1997). The plant quickly spread across the landscape, which threatened native foredune and coastal strand communities (Barbour et al., 1997). Native plants are dwindling as a result, and with them important ethnobotanical and traditional food resources of the Wiyot Tribe (Canter, 2023).

Efforts have been made in recent years to restore and protect the habitat found within the dunes. These efforts have included the removal of invasive species, the protection of rare and endangered species, and restoration of the wetlands (Pickart, 2013).

The dominant vegetation at the Mal-el' Dunes is a combination of native coastal dune plants as well as invasive species. On common invasive at this site is European beachgrass (*Ammophila arenaria*) that creates a dense, thick cover that shades out native species as well as disrupts the natural movement of sediment as it over stabilizes dunes ecosystems (*Natural History*. n.d.). Native species found at the dunes include coastal sand verbena (*Abronia latifolia)*, coastal buckwheat (*Eriogonum latifolium),* beach sagewort *(Artemisia pycnocephala),* dune goldenrod *(Solidago spathulata)*, shore pine *(Pinus contorta ssp. contorta)*, and kinnikinnick (*Natural History*. n.d.).

2.2 Field methods and data collection

A series of methods were implemented for this study which could later inform us of new management strategies. We first visited the Ma-le'l Dunes & Lanphere Dunes on February 10, 2023. This initial visit allowed us to gain familiarity with the area and plan out where we wanted to create our plots. In order to create a plot, we sought locations where kinnikinnick covered at least 10 square meters. After finding appropriate kinnikinnick patches to sample, we established 1 m^2 sampling plots for measuring kinnikinnick growth rates.

We used a random number generator in conjunction with a measuring tape to determine the location of each plot along the perimeter of the patch of kinnikinnick. Our plots were limited to the perimeter of each patch to reduce the impacts of our study on the kinnikinnick. Opposite to the interior of the kinnikinnick patches, we assigned a unique waypoint to the edge of each plot via a handheld GPS unit (Figure 2). In total, we created fifteen plots.

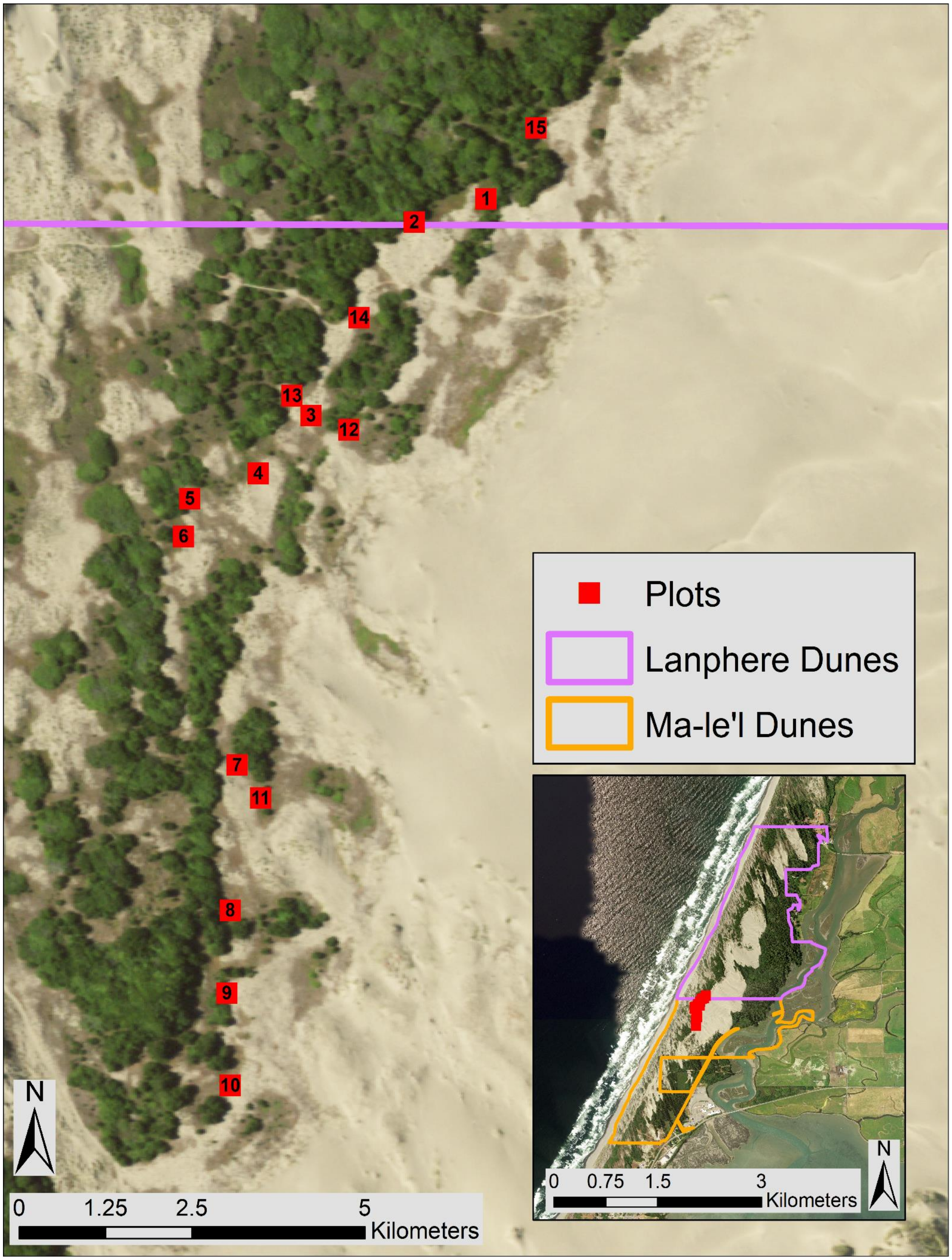

Figure 2: The locations of the 15 plots used in our study of kinnikinnick vegetation plots within the Ma-le'l & Lanphere Dunes unit (map by A.J. Murphy and Magdalena A. Villasenor, 2023).

After plot creation, we moved on to tagging individual branches of the kinnikinnick within each plot. This ensured that we could re-measure the same inflorescence over the course of this study. We tagged the kinnikinnick through the use of flagging tape and permanent marker. After writing a number on a small portion of the flagging tape (a piece 10–20 cm in length), we tied the flagging tape to a kinnikinnick branch directly below the inflorescence. We tagged 20 inflorescences per plot, and in total we tagged 300 inflorescences (15 plots x 20 inflorescences/plot).

When tagging the kinnikinnick, we often selected portions of the plant that demonstrated a non-forked growth pattern to improve the repeatability within our measurements. The kinnikinnick in our plots regularly possessed forked growth–where several inflorescences formed near a branch's tip. Symmetrical forked growth would have inhibited our ability to distinguish the correct inflorescence to measure. We were able to utilize forked growth in our plots when the branches were different in size. This allowed us to tag the individual inflorescence above the fork. It was essential that each tag clearly corresponded to a single inflorescence, ensuring the quality of our repeated measurements throughout the study.

Our study aimed to quantify the rates of new kinnikinnick growth over an eight-week period in the spring of 2023. To address this goal, we begin inflorescence measurements on February 24, 2023. We performed the second set of measurements on March 10, 2023, our third were on March 24, 2023, and our last measurements were completed on April 28, 2023. The first three measurements were performed two-weeks apart from each other, while the last measurement followed four-weeks after the previous measurement. We measured the inflorescences in millimeters using digital Cen-Tech six-inch calipers, and the length of the inflorescence was measured from its tip to the nearest axillary bud (Figure 3).

Figure 3: Measuring the length of a kinnikinnick inflorescence using calipers (photo by Leila Rahimi, 2023).

2.3 Potential influential variables on kinnikinnick growth

To explore the influence of other factors on kinnikinnick growth, we also collected data on variables that might have influence on kinnikinnick growth rates. Vegetative growth may be influenced by the amount of shade or sunlight received (Valladares et al., 2018). Therefore, we recorded overstory vegetation within ten meters of each plot's perimeter, in which we utilized a Spherical Crown Denisometer, Convex Model A made by Forestry Suppliers, to determine the canopy cover at each plot. We conducted the measurements according to the methods described by Paul E. Lemmon (1956, 1957). Four canopy cover measurements were performed per plot, one for each side of the plot facing away with our backs to the plots. In addition, during our second site visit (March 10, 2023) we noted whether ants were present in our plots. Ants can have a positive association to Lycaenid butterflies by providing butterfly larva with protection (Pierce et al., 2002). We were interested in documenting a possible relationship between ant presence and the abundance of larva or adult butterflies. We also wondered if ant presence had any effect on kinnikinnick growth. We also documented if there was woody vegetation present within 10 meters of the plot. We attempted to observe caterpillars and the eggs from which they hatch, combing through the kinnikinnick in our plots with a hand lens. We also regularly reported the time we started data collection in each plot as well as weather conditions for the day (temperature, cloud cover, etc.) for our own reference. Other notes included kinnikinnick health, missing inflorescences, the appearance of potential floral bracts, signs of herbivory, evidence of off-highway vehicle trespassing, and the types of vegetation present within 10 meters of the plot.

2.3 Butterfly surveys

Our community partner, Clint Pogue with USFWS, conducted brown elfin butterfly surveys on March 30 and April 13, 2023. (C. Pogue, pers. comm., 2023). We had the chance to go into the field to conduct one butterfly survey in the Ma-le'l and Lanphere dunes ourselves. The data collected could help enlighten us on how the differing growth rates of kinnikinnick would influence the abundance of brown elfin in the dunes, specifically the ones located near our plots. We went out on April 25, 2023 due to the weather conditions meeting the criteria necessary for conducting butterfly surveys; the wind speed was below 10 mph for most of the day and the temperature was between 15°C–21°C (~ 60°F–70°F) (C. Pogue, pers. comm., 2023). We started the survey at 12:30pm at the Ma-le'l and Lanphere dunes and stayed until 5:00pm. We began at the lower end of the dunes in the south-west and worked our way up north towards our first plots. As we worked our way north, we recorded all brown elfins spotted. Due to there being another species of elfin, the western pine elfin (*Callophrys eryphon*), we had to be careful to not mark this dune butterfly species as a brown elfin. To ensure accuracy, we made an effort to only mark a butterfly as a brown elfin if it was still enough that we could identify its distinct pattern. When it was confirmed as a brown elfin, we used the app Avenza maps to mark the exact location the brown elfin was spotted and then numbered each butterfly on the app according to the order it was spotted.

2.4 Data analysis

Prior to data analysis, the gathered data was digitized. All data sheets were scanned and uploaded as a PDF to a shared Google folder. We then digitized all of the data sheets by entering them into Google Sheets. From there, we transferred the data to Excel, thereby making the data available for use in the program RStudio.

In RStudio, we utilized a variety of packages to explore, wrangle, and analyze the gathered data (see Appendix B for R Markdown document). We examined the data frame properties through both the "summary" and "skim" functions. We used these functions to also check for missing values, and then dropped all missing values (missing inflorescences) from the dataset. Additionally, we generated a Q-Q plot to study the distribution of our data. Data were summarized both by the average inflorescence length by plot and the overall average inflorescence length over our study period. We employed a linear mixed-effect model to evaluate the differences in growth between each plot. We also studied the relationship between the presence of brown elfin butterflies and the growth rate of kinnikinnick. The relationship of inflorescence growth with ant presence, canopy cover, and herbivory was also studied. The generated models were evaluated using Akaike information criterion (AIC) (Akaike H., 1974). Lastly, we created several figures to visualize our data through the "ggplot" package.

3 RESULTS:

3.1 Field observations

There was a wide spectrum of kinnikinnick health observed. The kinnikinnick in some of our plots appeared very healthy with dark green leaves. At times, we noticed the kinnikinnick leaves were a lighter green. In other plots the kinnikinnick appeared to be losing some of its chlorophyll as the leaves were turning red. Over the course of our study, 5% of the inflorescences studied went missing (15 missing out of the 300 originally tagged) due to unknown circumstances. The 5% of missing inflorescences were excluded from the majority of our analysis. It should be assumed hereafter, unless otherwise stated, that these missing inflorescences were excluded from all data analyses. Additionally, we recognized signs of herbivory in 13 of the 300 inflorescences studied (~4% herbivory rate).

We detected an assortment of flora within ten meters of our plot (**Table 1**). Shore pine (*Pinus contorta ssp. contorta*) and rushes (*Juncus spp*) were the most prominent vegetation we observed within the ten meter zone surrounding our plots (>50% presence). The rest of the vegetation was perceived at a much lower rate (<30% presence).

Table 1: Vegetation observed <10 m from kinnikinnick plots in the Ma-le'l and Lanphere Dunes in February, March, and April 2023.

Vegetation <10 m from plot
Shore pine (Pinus contorta ssp. contorta)
Coast buckwheat (Eriogonum latifolium)
California wax myrtle (Morella californica)
Common yarrow (Achillea millefolium)
Coyote Brush (Baccharis pilularis)
Coast Goldenrod (Solidago spathulata)
Strawberry (Fragaria)
Willow (Salix)
Rushes (Juncus)
Grasses (Poaceae)

3.2 Data delivery

Conflicting results were obtained regarding overall average inflorescence length (Figure 4). During our first set of measurements on February 24, 2023, we recorded an average inflorescence length of 9.0 mm. During our second set of measurements on March 10, 2023, we recorded an average inflorescence length of 8.4 mm and during our third set of measurements on March 24, 2023, we recorded an average inflorescence length of 9.0 mm. At our final measurement on April 28, 2023 we observed an average inflorescence length of 10.5 mm. Between March 10 and April 28 we observed an overall average kinnikinnick inflorescence growth of 2.1 mm.

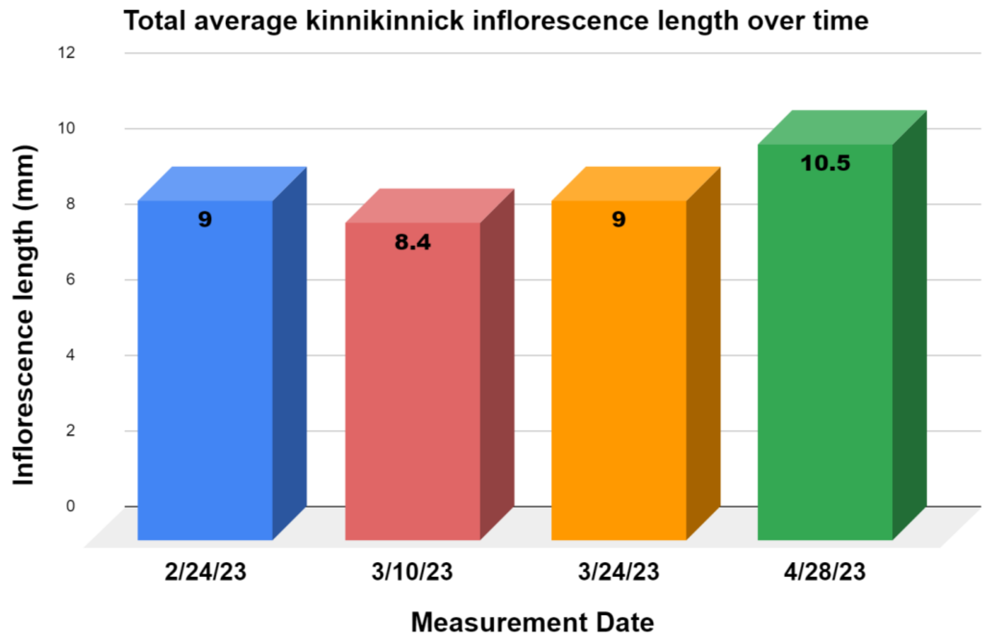

Figure 4: This bar graph illustrates the overall average change in inflorescence length over time

When comparing the average inflorescence length by plot over time, some plots exhibited a decrease in average inflorescence length, while the majority had an increase in average inflorescence length (**Table 2**). For example, in plot 3 we recorded a decrease in the average inflorescence length, from 11.4 mm at the first measurement to 8.8 mm at the second measurement. On the other hand, in plot 4 we recorded an increase in the average inflorescence length, from 8.0 mm to 9.3 mm.

Table 2: Average Inflorescence Length (mm) of kinnikinnick by plot over two-week intervals and one four-week interval in the spring of 2023.

Plot #	*2/24/23*	*3/10/23*	*3/24/23*	*4/28/23*
1	*8.4*	*7.9*	*8*	*9.2*
2	*7.4*	*7*	*7.7*	*10*
3	*11.4*	*8.8*	*7.8*	*10.9*
4	*8*	*9.1*	*9.3*	*13.4*
5	*9.3*	*8.7*	*9.8*	*11.5*
6	*13*	*13.2*	*14.2*	*14.3*
7	*10.4*	*8.4*	*8.5*	*10.2*
8	*9.2*	*9*	*10.5*	*13.5*
9	*10.1*	*10.6*	*11.1*	*12.2*
10	*9.5*	*8.8*	*9.4*	*10.8*
11	*3.9*	*3.3*	*3.9*	*5*
12	*10.9*	*9.7*	*11.1*	*11.2*
13	*7.5*	*6.8*	*7.8*	*9*
14	*7.5*	*7.3*	*7.3*	*8*
15	*7.7*	*6.8*	*7.5*	*8.7*

The kinnikinnick inflorescences evaluated in this study differed greatly in length. The shortest inflorescence we recorded was 1.2 mm in length, while the longest inflorescence we recorded was 20.2 mm in length. We crafted box and whisker plots to visualize the range of kinnikinnick inflorescences observed within each plot. At the third measurement instance, almost all of the plots had a median inflorescence length between 5 and 15 millimeters (Figure 5). Plot 11 is the exception as it is the only plot that had a median inflorescence length of less than 5 millimeters.

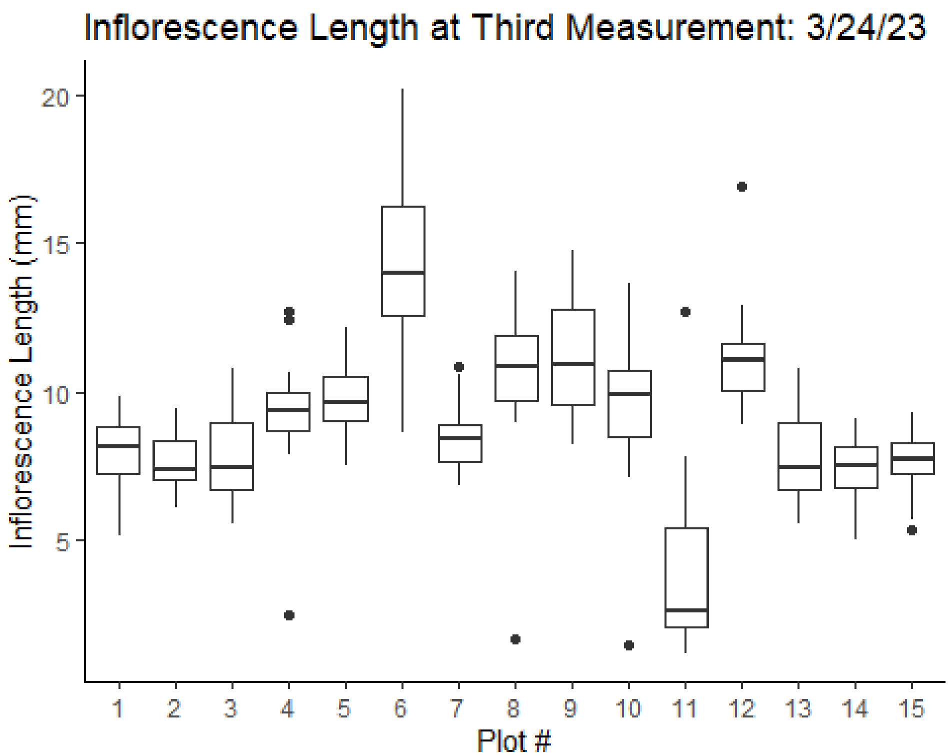

Figure 5: Box and whisker plot of kinnikinnick inflorescence length at the third measurement, faceted by plot.

In creating a scatterplot of the individual inflorescence lengths, we visualized additional characteristics of our data. We plotted individual inflorescence length at the second measurement, (March 10, 2023) along the x-axis and inflorescence length at the fourth measurement (April 28, 2023) along the y-axis (Figure 6). We also color coded the individual measurements by plot. In viewing this scatterplot, we observed variance in inflorescence length by plot.

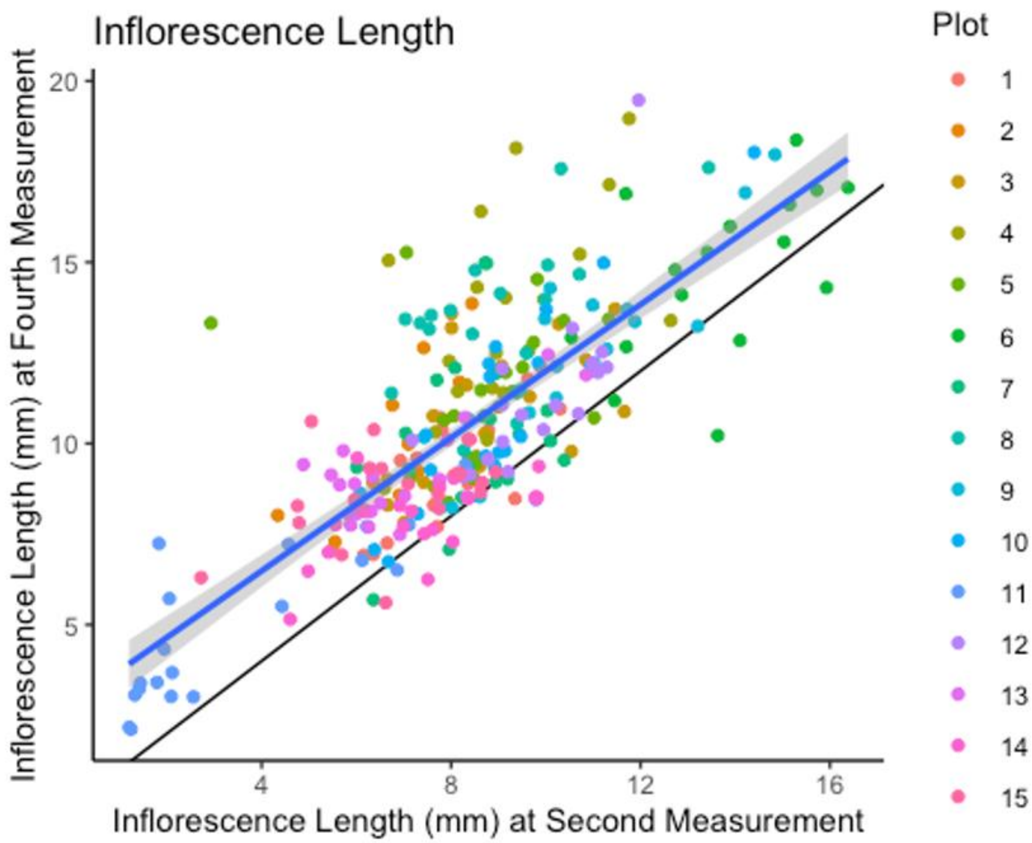

Figure 6: This graph contains both a linear regression (blue) and a 1:1 reference line (black). Points are color coded by plot number from measurements 2 & 4. Points above the 1:1 black line exhibited growth and those below the 1:1 line exhibited a decrease in inflorescence length.

3.3 Results of data analysis

The autocorrelation of inflorescence measurements within the same plot led us to believe that a linear mixed effects model would be appropriate for our analysis. In using a linear mixed effects model, we tested for the effect of plot on inflorescence length against several variables: canopy cover, ant presence, and herbivory. When we compared the models through Akaike information criterion (AIC), the best-fit model included only plot as a random effect on inflorescence length. The result of the model was the same whether or not plot 11 was included—none of our evaluated variables demonstrated a significant effect. As such, other factors that were not explored are likely responsible for the variance by plot in inflorescence length observed.

3.4 Brown elfin butterfly presence

The first survey conducted on March 30, 2023 by Clint Pogue, found that 3 brown elfin individuals were spotted in the evening within our study area. On April 13, 41 brown elfin individuals were spotted by Clint mainly at the northern end of the dunes (C. Pogue, pers. comm., 2023). On April 28th, we spotted 62 brown elfin individuals in total and 13 of those were found within 10 meters of our plots (**Table 3**).

Table 3: Brown Elfin Butterflies spotted within 10 meters of our plots (April 28).
**the same brown elfin individual was spotted at two separate spots (plots 3 & 12).*

Plot #	Brown Elfin spotted within 10 meters
Plot 2	2
Plot 3	1*
Plot 4	3
Plot 6	3
Plot 7	1
Plot 8	1
Plot 12	1*
Plot 15	2

The average growth rate of kinnikinnick inflorescences in the northern half of our plots was 2.1 mm and the southern portion was 1.9 mm. More brown elfin individuals were spotted in the northern portion of our study area compared to the southern portion (Figure 7).

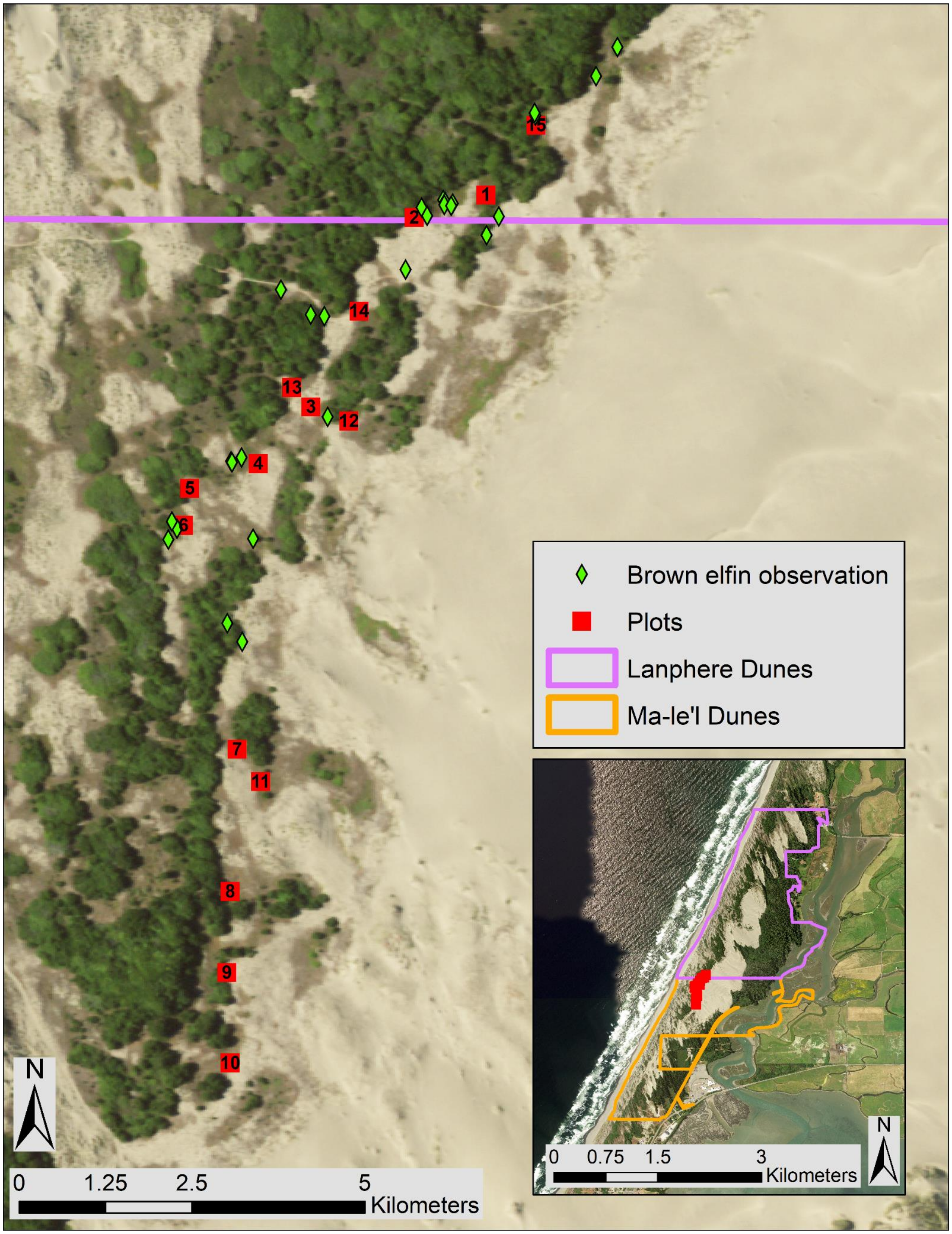

Figure 7: Ma-le'l & Lanphere Dunes unit. This figure shows the locations of the 15 plots (red squares) used in our study of kinnikinnick vegetation and the location of the observed brown elfin (green diamonds) (map by A.J. Murphy and Magdalena A. Villasenor, 2023).

4 DISCUSSION:

4.1 Summary of kinnikinnick findings

Our study aimed at answering if kinnikinnick was growing at the Landphere and Ma-le'l dunes. Notably, kinnikinnick inflorescence length decreased by an overall average of 0.6 mm in the two weeks between our first and second measurement (Figure 4). Over the six-week period between the second measurement and fourth measurement, the overall average inflorescence length increased by 2.1 mm (Figure 4). When examining only measurements two, three, and four, it appears the kinnikinnick we studied at the Ma-le'l and Lanphere Dunes is in fact putting off new growth. During this study we observed various stages of inflorescence development (Figure 8).

Figure 8: Stages of kinnikinnick inflorescence growth, from early development (left) to flowering (right). These photos are not of the same individual inflorescence (photo by A.J. Murphy, 2023).

4.2 Sources of error

There are several potential factors responsible for the observed decrease in overall average inflorescence length between measurements one and two (Figure 4). One source of error may be differences in how each group member measured kinnikinick growth. Another source may have been the growth characteristic of kinnikinnick. The inflorescences of kinnikinnick often began to curl as they grew (Figure 9). This bent growth presented a hurdle for our measurements. Outside of our plots we performed some practice measurements on inflorescences with curled growth, we attempted to straighten them with our hand to gain an accurate measurement. We found the inflorescences were too fragile for this aggressive handling which generally resulted in the inflorescences breaking off. As such, we avoided straightening the inflorescences, instead we measured the kinnikinnick inflorescences in their natural state.

Figure 9: Curled growth of kinnikinnick inflorescence. This inflorescence was originally straight but began to curl back on itself over time (photo by A.J. Murphy, 2023).

Environmental factors may be responsible for the low growth of kinnikinnick inflorescences in plot 11. We noticed while out in the field that plot 11 was located next to a small, interdunal wetland as well as intertwined with low growing rushes. Kinnikinnick typically prefers dry, well-drained soil and tends to thrive in areas with a small amount of canopy cover, so this plot's habitat was not ideal for producing new growth (Kaplan, B. 2012). We observed that kinnikinnick tends to thrive in areas with a small amount of canopy cover. Plot 11 had no canopy cover and was located in an open space with little to no large vegetation nearby that could possibly cover it throughout the day.

4.3 Interpreting the results

4.3.1 Growth in relation to various environmental factors

The environmental factors we tested for like ant presence, herbivory, and canopy cover had no significant effect on the growth of kinnikinnick. Anecdotally, we noticed the competition occurring in certain plots may have had an effect on the health and growth rates of kinnikinnick. Surrounding vegetation and wetlands may be the biggest drivers of kinnikinnick health, though this needs to be explored in future studies.

4.3.2 Brown elfin abundance

Our study was performed between February 24, 2023 through April 28, 2023. During this period, we observed brown elfin butterflies in the area surveyed only on the last day of measurements. This could be due to several factors such as unfavorable weather conditions, and delayed flowering of the kinnikinnick plant. We did observe signs of herbivory in several plots, which could indicate the presence of butterfly larvae. We documented a possible brown elfin butterfly chrysalis onsite (Figure 10)

Figure 10: Possible brown elfin chrysalis located on tagged branch in plot #5 (photo by Verenice Sanchez, 2023).

Based on the data collected, it seems that higher growth rates did have a correlation with brown elfin abundance. The northern portion of our plots, which had higher growth rates, had higher brown elfin abundance. While the abundance of brown elfin could also be related to other outside environmental factors such as canopy coverage, protection from wind speed, or slope, the data collected still shows that brown elfin tend to gather around areas with more growth.

4.3.3 Food resource availability for brown elfin butterflies

Larval plant host abundance was related to higher observations of brown elfin butterflies. In most non-migratory species, adult butterfly density is related to optimum growth conditions of the available food-plants for its larvae and available nectar for adults (Curtis et al., 2015). We observed a higher number of butterflies near plots with the highest growth rates over the course of the study. The new tender leaves of kinnikinnick are associated with the development of inflorescences. This new growth of kinnikinnick is a food resource for larvae, while the flowers provide nectar for adult brown elfin butterflies. Our observations confirm that food resource availability likely has a significant influence on butterfly population density.

High quality patches of vegetation can support a population through short-term fluctuations, mainly attributed to weather variation, that affect a butterfly population's equilibrium level (Thomas et al., 2011). The extended, wet winter of 2023 created unfavorable conditions for the brown elfin's emergence in our study area. However, it is likely that the brown elfin population at the Ma-le'l dunes used established kinnikinnick patches for feeding and shelter during these weather events.

4.4 Additional implications of our findings

4.4.1 Plant and insect relationship

Our data illustrates a correlation between kinnikinnick patches with higher growth rates and brown elfin presence. We found that healthy patches of this larval food source are a central factor due to the brown elfin being a kinnikinnick specialist in this micro-habitat. We observed more brown elfin individuals in the northern portion of the plot where kinnikinnick was growing at a higher rate.

4.4.2 Influence on brown elfin population

Several factors can play a role in the brown elfin population density we observed near sites 1 and 2. The size and health of the kinnikinnick patch, as well as adequate shelter for adult butterflies seemed to correlate with the brown elfin butterfly abundance near these plots. Variation in shelter can affect butterflies in the immature or adult stages (Thomas et al., 2011). Shore pine and other woody shrubs were in close proximity to all of the kinnikinnick plots we studied, which could potentially influence microclimate conditions such as wind speed and temperature. Although our findings did not show a significant relationship between the woody vegetation and kinnikinnick growth, it may be an important variable related to butterfly population abundance at the Ma-le'l dunes.

4.4.3 Seaside hoary elfin management

Our recommended management plan for the seaside hoary elfin would focus on food resource availability in its habitat. Plant host abundance and quality are of great significance for butterflies in all of their life stages. This is especially important for butterfly species that are habitat specialists. Our study of the seaside hoary elfin surrogate, the brown elfin butterfly, and their mutual larval host plant kinnikinnick has shown a strong correlation between food resource availability and butterfly abundance. We believe the best management strategy will consider the needs of seaside hoary elfin through its life stages; beginning with larvae relationship to its host plant, and following with analysis of adult feeding habits. Since high density populations in habitats with optimum larval food sources are unlikely to become extinct (Thomas et al., 2011); It is necessary to consider the overall health of host plants at Tolowa Dunes State Park in Crescent City, CA.

4.5 Recommendations for future studies

For further research, we recommend exploring other ways to measure new growth. We noticed that the inflorescence started to curve and since they are very delicate, we weren't able to accurately measure the full length of the new growth with calipers. For a more accurate measurement, we suggest the use of string or a flexible tape measure in instances where the inflorescence is curved.

We also recommend that the same person remeasures the same plot every time to reduce user error. We were not able to do this as some of us were unable to make it out to measure every time. We found some variability between the individuals within the plots and that may be due to different group members measuring new growth differently. This caused some readings to show negative growth. It's possible that this problem can be fixed with having assigned plots as well as making instructions on how to properly read the caliper to ensure we are all measuring the same.

We believe that conducting the study over a longer period of time would produce more accurate measurements. Recording data on inflorescence length over longer intervals is recommended for future studies.

We believe for further research other environmental variables should be studied due to the ones we looked at like ant presence, woody vegetation, and canopy cover having no significant relationship to the growth of kinnikinnick.

SUMMARY

In conclusion, this project has determined that kinnikinnick in the Ma-le’l and Lanphere dunes is producing new growth during spring (March & April). Butterfly surveys revealed that there were a greater number of brown elfin butterflies in the northern range of the study area near plots where kinnikinnick growth was greater. The results of this study call for further research into what other environmental factors might be affecting new kinnikinnick growth that were not studied in this research project. This would help identify future potential management strategies for the seaside hoary elfin butterfly at the Tolowa Dunes State Park in Crescent City, CA.

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APPENDIX

Appendix A: R Markdown document

Kinnikinnick Inflorescence Growth at the Ma-le'l and Lanphere Dunes

Aidan Jack Murphy

2022-05-05

R Markdown

This is an R Markdown document. Markdown is a simple formatting syntax for authoring HTML, PDF, and MS Word documents. For more details on using R Markdown see http://rmarkdown.rstudio.com.

Load data and packages

```
library(readxl)
library(dplyr)
library(skimr)
library(mice)
library(ggplot2)
library(tidyr)
library(lme4)
library(lmerTest)
library(MuMIn)
library(knitr)
library(sjPlot)
library(sjmisc)

KKM<-read_excel("Data/kinnikinnick_growth.xlsx", sheet = "data") #Load data
and renamed file as KKM
```

Inspecting Variable Type

```
summary(KKM)

##Reassign variable classes
KKM$ID<-as.character(KKM$ID)
KKM$Plot<-as.factor(KKM$Plot)
KKM$Tag<-as.character(KKM$Tag)
KKM$Herbivory<-as.factor(KKM$Herbivory)
KKM$Woody_veg<-as.factor(KKM$Woody_veg)
KKM$Ants<-as.factor(KKM$Ants)
```

```
##Check levels of unique factors
lapply(KKM[c('Herbivory', 'Densiometer_avg', 'Woody_veg', 'Ants')], unique)
```

Data Wrangling and Summarization

```
##Data Wrangling
KKM_clean<-KKM%>%
  filter(Length_m4> 0)%>%
  drop_na(Length_m4)
  #Filters out selection to not include observations with missing growth buds
(inflorescences). Also excludes two missing measurements.

KKM_no11<-KKM_clean%>% #Filters out plot 11 from KKM_clean dataframe.
  filter(Plot!=11)

KKM_gbm<-KKM%>%
  filter(Length_m4==0) #Examines observations of missing inflorescence buds.

KKM_herb<-KKM%>%
  filter(Herbivory==1) #Examines observations of herbivory

##Summarization
skim(KKM)

skim(KKM_clean)

skim(KKM_gbm)
```

Data Tables

```
##Data Tables
#Table of average inflorescence length by plot, excluding missing
inflorescences:
KKMsum_no_gbm<-KKM_clean%>%
  group_by(Plot)%>%
  summarize("IL1"=mean(Length_m1),
         "IL2"=mean(Length_m2),
         "IL3"=mean(Length_m3),
         "IL4"=mean(Length_m4))

kable(KKMsum_no_gbm, caption = "Table 1: Average inflorescence length (mm) by
plot over two-week intervals.", digits=1)

#Table of overall average inflorescence length by measurement, excluding
missing inflorescenece.
KKMsum_total_no_gbm<-KKM_clean%>%
  summarize("IL1"=mean(Length_m1),
         "IL2"=mean(Length_m2),
         "IL3"=mean(Length_m3),
         "IL4"=mean(Length_m4))
```

```
kable(KKMsum_total_no_gbm, caption = "Table 2: Overall average inflorescence
length (mm) over two-week intervals.", digits=1)

#Table of overall average inflorescence length by measurement, excluding plot
11 and excluding missing inflroescences:
KKMsum_total_no11<-KKM_no11%>%
  summarize("IL1"=mean(Length_m1),
           "IL2"=mean(Length_m2),
           "IL3"=mean(Length_m3),
           "IL4"=mean(Length_m4))

kable(KKMsum_total_no11, caption = "Table 3: Overall average inflorescence
length (mm) over two-week intervals, excluding plot 11.", digits=1)


#Table of overall average inflorescence length by measurement, including
missing inflorescences (excluding 2 missing measurements):
KKMsum_total<-KKM%>%
  drop_na(Length_m4)%>%
  summarize("IL1"=mean(Length_m1),
           "IL2"=mean(Length_m2),
           "IL3"=mean(Length_m3),
           "IL4"=mean(Length_m4))

kable(KKMsum_total, caption = "Table 4: Overall average inflorescence length
(mm) over two-week intervals, including missing inflorescences.", digits=1)
```

Data Visualization

```
##Scatter plots of inflorescence length, excluding missing inflorescences:
#(with linear line of best fit and y=x reference line)

ggplot(KKM_clean, aes(Length_m1, Length_m2))+
  geom_abline(a=0, b=1)+ #adds y=x reference line, to demonstrate growth,
line of best fit should be steeper than this line
  geom_point(aes(color=Plot))+
  labs(title="Inflorescence Length: Measurement 1 and 2", x="Inflorescence
Length (mm) at First Measurement",
  y="Inflorescence Length (mm) at Second Measurement")+
  geom_smooth(method="lm")+
  theme_classic()

ggplot(KKM_clean, aes(Length_m1, Length_m3))+
  geom_abline(a=0, b=1)+
  geom_point(aes(color=Plot))+
   labs(title="Inflorescence Length: Measurement 1 and 3", x="Inflorescence
Length (mm) at First Measurement",
  y="Inflorescence Length (mm) at Third Measurement")+
```

```
  geom_smooth(method="lm")+
  theme_classic()

ggplot(KKM_clean, aes(Length_m1, Length_m4))+
  geom_abline(a=0, b=1)+
  geom_point(aes(color=Plot))+
   labs(title="Inflorescence Length: Measurement 1 and 4", x="Inflorescence
Length (mm) at First Measurement",
  y="Inflorescence Length (mm) at Fourth Measurement")+
  geom_smooth(method="lm")+
  theme_classic()

ggplot(KKM_clean, aes(Length_m2, Length_m4))+
  geom_abline(a=0, b=1)+
  geom_point(aes(color=Plot))+
   labs(title="Inflorescence Length", x="Inflorescence Length (mm) at Second
Measurement",
  y="Inflorescence Length (mm) at Fourth Measurement")+
  geom_smooth(method="lm")+
  theme_classic()

#Scatterplot, excluding plot 11
ggplot(KKM_no11, aes(Length_m2, Length_m4))+
  geom_abline(a=0, b=1)+
  geom_point(aes(color=Plot))+
   labs(title="Inflorescence Length: Measurement 2 and 4, excluding plot 11",
x="Inflorescence Length (mm) at Second Measurement",
  y="Inflorescence Length (mm) at Fourth Measurement")+
  geom_smooth(method="lm")+
  theme_classic()

#The data does appear to be experiencing some variance by plot.




##Box plots of inflorescence length:
#faceted by plot number, excluding missing inflorescences
ggplot(KKM_clean, aes(Plot, Length_m1))+
  geom_boxplot()+
  labs(title="Inflorescence Length at First Measurement: 2/24/23", x="Plot
#",
  y="Inflorescence Length (mm)")+
  scale_x_discrete()+
  theme_classic()

ggplot(KKM_clean, aes(Plot, Length_m2))+
  geom_boxplot()+
  labs(title="Inflorescence Length at Second Measurement: 3/10/23", x="Plot
#",
  y="Inflorescence Length (mm)")+
```

```
  scale_x_discrete()+
  theme_classic()

ggplot(KKM_clean, aes(Plot, Length_m3))+
  geom_boxplot()+
  labs(title="Inflorescence Length at Third Measurement: 3/24/23", x="Plot
#",
  y="Inflorescence Length (mm)")+
  scale_x_discrete()+
  theme_classic()

ggplot(KKM_clean, aes(Plot, Length_m4))+
  geom_boxplot()+
  labs(title="Inflorescence Length at Fourth Measurement: 4/28/23", x="Plot
#",
  y="Inflorescence Length (mm)")+
  scale_x_discrete()+
  theme_classic()
```

Data Analysis

```
##Linear model to examine normality
lm1a<-lm(Length_m4~Length_m1, data = KKM_clean)
plot(lm1a) #plots the residuals to examine violation of assumptions (equal
variance and normality of the residuals)

##Linear mixed effects model:
#Test possible random effects structures
re1a<-lmer(Length_m4~1+(1|Plot), data=KKM_clean)
re2a<-lmer(Length_m4~1+(0 + Densiometer_avg|Plot), data=KKM_clean)
re3a<-lmer(Length_m4~1+(1|Plot)+(0 + Densiometer_avg|Plot), data=KKM_clean)

AIC(re1a,re2a,re3a)
#It appears both the the first and third random effects model (re1a and re3a)
are informative as they are within two whole numbers when compared through
AIC. Yet, the first model is simpler, thus its structure will be used for
further evaluation in the linear mixed effects models below.

null_a<-lmer(Length_m4~1+(1|Plot), data=KKM_clean)
lme1a<-lmer(Length_m4~Densiometer_avg+(1|Plot), data=KKM_clean)
lme2a<-lmer(Length_m4~Herbivory+(1|Plot), data=KKM_clean)
lme3a<-lmer(Length_m4~Ants+(1|Plot), data=KKM_clean)
lme4a<-lmer(Length_m4~Densiometer_avg+Herbivory+(1|Plot), data=KKM_clean)
lme5a<-lmer(Length_m4~Densiometer_avg+Ants+(1|Plot), data=KKM_clean)
lme6a<-lmer(Length_m4~Densiometer_avg+Herbivory+Ants+(1|Plot),
data=KKM_clean)
lme7a<-lmer(Length_m4~Herbivory+Ants+(1|Plot), data=KKM_clean)

AIC(null_a, lme1a, lme2a, lme3a, lme4a, lme5a, lme6a, lme7a)

#The KKM_clean data frame (exclusion of missing inflorescences) was used in
```

```
these models. When viewing the AIC values, the null model, lme3a, and lme7a
have the lowest values and are within two whole numbers of each other. Lme3a
and Lme7a are the more complicated models, thereby it is unlikely that they
are any more informative than the null model. As such it is likely that plot
is responsible for the variance observed--at least when compared to the
evaluated models.

summary(null_a)
plot(null_a) #For the most part, the data is meeting the assumption of equal
variance, though plot 11 does skew the data's distribution.

r.squaredGLMM(null_a) #Use package MuMIn #provides marginal (fixed effects)
r2 and conditional (random+fixed effects) r2
r.squaredLR(null_a)



###Running the same as above but **excluding plot 11**

##Linear model to examine normality
lm1b<-lm(Length_m4~Length_m1, data = KKM_no11)
plot(lm1b) #plots the residuals to examine violation of assumptions (equal
variance and normality of the residuals)

##Linear mixed effects model:
#Test possible random effects structures
re1b<-lmer(Length_m4~1+(1|Plot), data=KKM_no11)
re2b<-lmer(Length_m4~1+(0 + Densiometer_avg|Plot), data=KKM_no11)
re3b<-lmer(Length_m4~1+(1|Plot)+(0 + Densiometer_avg|Plot), data=KKM_no11)

AIC(re1b,re2b,re3b)
#It appears both the the first and third random effects model (re1a and re3a)
are informative as they are within two whole numbers when compared through
AIC. Yet, the first model is simpler, thus its structure will be used for
further evaluation in the linear mixed effects models below.

null_b<-lmer(Length_m4~1+(1|Plot), data=KKM_no11)
lme1b<-lmer(Length_m4~Densiometer_avg+(1|Plot), data=KKM_no11)
lme2b<-lmer(Length_m4~Herbivory+(1|Plot), data=KKM_no11)
lme3b<-lmer(Length_m4~Ants+(1|Plot), data=KKM_no11)
lme4b<-lmer(Length_m4~Densiometer_avg+Herbivory+(1|Plot), data=KKM_no11)
lme5b<-lmer(Length_m4~Densiometer_avg+Ants+(1|Plot), data=KKM_no11)
lme6b<-lmer(Length_m4~Densiometer_avg+Herbivory+Ants+(1|Plot), data=KKM_no11)
lme7b<-lmer(Length_m4~Herbivory+Ants+(1|Plot), data=KKM_no11)

AIC(null_b, lme1b, lme2b, lme3b, lme4b, lme5b, lme6b, lme7b)

#The KKM_no11 data frame (exclusion of plot 11 and exclusion of missing
inflorescences) was used in these models. When viewing the AIC values, the
```

```
null model, lme2b, lme3b, and lme7b have the lowest values and are within two
whole numbers of each other. Lme2b, lme3b, and lme7b are the more complicated
model, thereby it is unlikely that it is any more informative than the null
model. As such it is likely that plot is responsible for the variance
observed--at least when compared to the evaluated models.

summary(null_b)
plot(null_b) #By excluding plot 11 the data better meets the assumption of
equal variance, as the data is no longer skewed by plot 11.

r.squaredGLMM(null_b) #Use package MuMIn #provides marginal (fixed effects)
r2 and conditional (random+fixed effects) r2
r.squaredLR(null_b)
```

Appendix B: Raw Data

ID	Plot	Tag	Length_m1	Length_m2	Length_m3	Length_m4	Herbivory	Densiometer_avg	Woody_veg	Ants
1	1	1	7.73	8.51	8.23	8.98	1	1.3	1	0
2	1	2	5	6.36	6.64	6.94	0	1.3	1	0
3	1	3	6.44	6.65	6.41	7.25	0	1.3	1	0
4	1	4	8.69	8.05	7.89	9.11	0	1.3	1	0
5	1	5	10.37	10.30	9.23	10.96	0	1.3	1	0
6	1	6	5.6	5.49	5.09	7.05	0	1.3	1	0
7	1	7	8.97	9.35	9.6	8.48	0	1.3	1	0
8	1	8	8.77	8.54	8.67	9.64	1	1.3	1	0
9	1	9	9.5	7.81	6.98	10.39	0	1.3	1	0
10	1	10	6.1	6.16	5.93	6.92	0	1.3	1	0
11	1	11	9.93	9.89	9.82	12.12	0	1.3	1	0
12	1	12	10.66	8.79	9.33	10.37	0	1.3	1	0
13	1	13	10.41	7.71	8.58	7.71	1	1.3	1	0
14	1	14	8.00	7.76	8.27	10.72	1	1.3	1	0
15	1	15	9.37	8.36	8.17	8.89	0	1.3	1	0
16	1	16	6.58	7.63	7.64	8.30	1	1.3	1	0
17	1	17	8.88	7.28	7.91	9.60	0	1.3	1	0
18	1	18	6.69	6.93	7.28	9.53	1	1.3	1	0
19	1	19	10.83	9.62	9.32	11.78	0	1.3	1	0
20	1	20	9.28	6	8.09	8.38	0	1.3	1	0
21	2	1	9.24	8.18	9.42	11.69	0	41.86	1	0
22	2	2	6.23	4.34	6.85	8.02	0	41.86	1	0

23	2	3	8.61	8.06	7.05		0	41.86	1	0
24	2	4	6.55	7.3	7.21	9.24	0	41.86	1	0
25	2	5	8.24	6.32	7.38	0	0	41.86	1	0
26	2	6	8.27	8.44	8.70	13.86	0	41.86	1	0
27	2	7	7.45	6.18	7.47	8.16	0	41.86	1	0
28	2	8	8.07	0	0	0	0	41.86	1	0
29	2	9	9.28	1.45	0	0	0	41.86	1	0
30	2	10	5.56	5.55	6.07	7.29	0	41.86	1	0
31	2	11	8.1	0	0	0	0	41.86	1	0
32	2	12	6.61	6.35	6.89	8.93	0	41.86	1	0
33	2	13	7.54	7.42	8.95	12.64	0	41.86	1	0
34	2	14	7.37	7.1	7.01	9.98	0	41.86	1	0
35	2	15	7.62	7.23	7.45	8.10	0	41.86	1	0
36	2	16	6.75	6.91	7.39	8.58	0	41.86	1	0
37	2	17	8.24	8.88	9.02	11.93	0	41.86	1	0
38	2	18	9.1	1.9	0	0	0	41.86	1	0
39	2	19	7.1	0	0	0	0	41.86	1	0
40	2	20	6.62	6.76	7.95	11.06	0	41.86	1	0
41	3	1	13.42	7.62	7.73	10.76	1	13	1	1
42	3	2	7.13	9.07	9.13	12.14	0	13	1	1
43	3	3	16.27	7.01	7.15	7.82	0	13	1	1
44	3	4	9.41	9.66	8.31	11.29	0	13	1	1
45	3	5	7.78	7.42	6.78	8.93	0	13	1	1
46	3	6	6.92	10.27	10.46	13.30	0	13	1	1

47	3	7	12.07	6.65	7.25	9.01	0	13	1	1
48	3	8	10.26	8.6	8.06	9.37	0	13	1	1
49	3	9	8.59	11.46	7.34	13.71	0	13	1	1
50	3	10	12.62	9	7.05	11.01	0	13	1	1
51	3	11	16.18	6.67	4.04	8.30	0	13	1	1
52	3	12	9.03	8.71	8.67	10.28	0	13	1	1
53	3	13	9.16	8.01	8.49	13.58	0	13	1	1
54	3	14	12.85	8.77	9.42	10.21	0	13	1	1
55	3	15	18.25	10.85	11.52	12.30	0	13	1	1
56	3	16	17.85	8.01	8.89	13.19	0	13	1	1
57	3	17	8.03	11.66	10.51	10.88	0	13	1	1
58	3	18	7.13	8.29	8.03	0.00	0	13	1	1
59	3	19	13.74	10.54	8.36	9.78	0	13	1	1
60	3	20	10.16	8.33	7.38	11.61	0	13	1	1
61	4	1	7.86	8.55	9.38	14.31	0	1.04	1	1
62	4	2	4.93	7.64	8.36	8.81	0	1.04	1	1
63	4	3	6.4	12.64	9.23	13.39	0	1.04	1	1
64	4	4	11.52	11.76	12.4	18.96	0	1.04	1	1
65	4	5	6.88	7.96	9.32	12.27	0	1.04	1	1
66	4	6	8.86	9.96	2.47	13.97	0	1.04	1	1
67	4	7	8.21	6.68	9.79	15.05	0	1.04	1	1
68	4	8	4.82	4.26	0	0	0	1.04	1	1
69	4	9	5.44	7.66	7.88	10.31	0	1.04	1	1

70	4	10	7.54	8.95	8.72	12.50	1	1.04	1	1
71	4	11	7.83	8.14	9.68	11.44	1	1.04	1	1
72	4	12	8.53	8.63	10.03	16.40	0	1.04	1	1
73	4	13	8.09	9.37	10.64	18.15	0	1.04	1	1
74	4	14	9.53	10.72	9.89	15.22	0	1.04	1	1
75	4	15	7.41	9.1	8.94	11.40	0	1.04	1	1
76	4	16	11.52	11.34	12.71	17.14	0	1.04	1	1
77	4	17	6.11	6.59	8.68	8.76	0	1.04	1	1
78	4	18	8.89	8.87	9.96	11.53	0	1.04	1	1
79	4	19	8.17	8.76	8.46	10.10	0	1.04	1	1
80	4	20	9.06	9.15	10.38	14.02	1	1.04	1	1
81	5	1	9.02	8.63	10.05	11.47	0	0	1	1
82	5	2	10.94	11.33	11.95	13.43	0	0	1	1
83	5	3	8.65	8.06	8.15	10.76	0	0	1	1
84	5	4	10.18	9.74	9.08	12.79	0	0	1	1
85	5	5	12.39	7.06	9.65	15.27	0	0	1	1
86	5	6	7.35	7.85	7.54	10.65	0	0	1	1
87	5	7	10.35	9.82	9.05	14.53	0	0	1	1
88	5	8	8.37	2.93	11.54	13.32	0	0	1	1
89	5	9	8.46	9.15	8.6	11.96	0	0	1	1
90	5	10	7.89	8.53	10.31	9.62	0	0	1	1
91	5	11	10.61	9.29	8.98	11.43	0	0	1	1
92	5	12	8.69	7.13	9.02	9.02	0	0	1	1
93	5	13	9.66	11.02	10.13	10.71	0	0	1	1
94	5	14	8.36	8.46	9.59	9.05	0	0	1	1
95	5	15	8.5	10.38	11.09	13.39	0	0	1	1

96	5	16	8.58	8.38	10.27	9.61	0	0	1	1
97	5	17	6.88	7.94	8.47	8.37	1	0	1	1
98	5	18	12.1	9.51	11.01	12.10	0	0	1	1
99	5	19	11.24	9.64	12.13	12.57	0	0	1	1
100	5	20	8.25	8.52	9.11	9.45	0	0	1	1
101	6	1	12.71	13.89	17.54	15.99	0	9.36	1	0
102	6	2	13.16	12.73	13.9	14.79	0	9.36	1	0
103	6	3	14.79	15.29	19.01	18.37	0	9.36	1	0
104	6	4	13.25	15.03	16.53	15.56	0	9.36	1	0
105	6	5	11.86	15.72	15.68	16.99	0	9.36	1	0
106	6	6	18.1	16.38	16.41	17.06	0	9.36	1	0
107	6	7	12.71	14.1	14.84	12.84	0	9.36	1	0
108	6	8	12.22	11.7	14.1	12.67	0	9.36	1	0
109	6	9	13.15	11.69	12.92	16.89	0	9.36	1	0
110	6	10	14.37	15.15	20.2	16.59	0	9.36	1	0
111	6	11	16.01	13.41	15.03	15.27	0	9.36	1	0
112	6	12	13.38	12.87	13.01	14.10	0	9.36	1	0
113	6	13	11.15	10.54	11.74	12.92	0	9.36	1	0
114	6	14	11.04	11.45	12.41	11.18	0	9.36	1	0
115	6	15	7.99	8.7	8.59	10.75	0	9.36	1	0
116	6	16	13.51	13.63	9.81	10.22	0	9.36	1	0
117	6	17	15.18	15.93	13.56	14.30	1	9.36	1	0
118	6	18	9.62	0	0	0	0	9.36	1	0
119	6	19	14.82	3.05	0	0	0	9.36	1	0
120	6	20	10.2	9.39	9.93	11.40	1	9.36	1	0
121	7	1	9.46	8.72	10.83	14.98	0	1.82	1	1

122	7	2	11.33	8.08	8.88	12.09	0	1.82	1	1
123	7	3	10.28	8.94	8.73	8.94	0	1.82	1	1
124	7	4	9.13	0	0	0	0	1.82	1	1
125	7	5	8.63	7.96	7.2	7.08	0	1.82	1	1
126	7	6	9.77	6.36	7.37	5.69	0	1.82	1	1
127	7	7	10.85	10.03	10.2	10.91	0	1.82	1	1
128	7	8	12.96	7.7	10.59	11.75	0	1.82	1	1
129	7	9	13.45	9.44	9.4	10.26	0	1.82	1	1
130	7	10	9.63	9.19	8.37	9.02	0	1.82	1	1
131	7	11	8.77	6.01	6.82	9.34	0	1.82	1	1
132	7	12	9.78	8.82	7.93	10.68	0	1.82	1	1
133	7	13	8.2	8.36	7.34	9.35	0	1.82	1	1
134	7	14	8.94	10.1	8.88	10.07	0	1.82	1	1
135	7	15	12.25	7.04	8.03	10.28	0	1.82	1	1
136	7	16	9.82	7.12	7.32	9.28	0	1.82	1	1
137	7	17	7.61	8.23	8.14	8.51	0	1.82	1	1
138	7	18	13.5	8.95	8.29	11.94	0	1.82	1	1
139	7	19	10.79	10.39	8.79	9.54	0	1.82	1	1
140	7	20	11.03	8.75	8.87	14.97	0	1.82	1	1
141	8	1	12.55	10.32	12.11	17.58	0	1.82	1	0
142	8	2	9.92	7.54	10.17	13.15	0	1.82	1	0
143	8	3	6.86	0	0	0.00	0	1.82	1	0
144	8	4	9.23	8.51	11.66	14.78	0	1.82	1	0
145	8	5	8.86	7.58	9.35	13.54	0	1.82	1	0
146	8	6	6.99	6.74	8.94	11.39	0	1.82	1	0

147	8	7	10.44	10.04	12.2	14.92	0	1.82	1	0
148	8	8	11.92	13.44	10.86	17.61	0	1.82	1	0
149	8	9	6.54	0	0	0	0	1.82	1	0
150	8	10	8.58	9.39	10.07	10.55	0	1.82	1	0
151	8	11	11.77	8.45	10.86	13.02	0	1.82	1	0
152	8	12	7.24	8.27	12.28	9.81	0	1.82	1	0
153	8	13	9.33	9.99	10.82	13.97	0	1.82	1	0
154	8	14	9.01	7.99	9.57	13.67	0	1.82	1	0
155	8	15	8.88	9.04	9.38	14.14	0	1.82	1	0
156	8	16	8.06	7.35	11.31	13.32	0	1.82	1	0
157	8	17	8.27	9.59	13.99	12.49	1	1.82	1	0
158	8	18	7.1	9.46	10.44	11.47	0	1.82	1	0
159	8	19	6.58	7.03	11.05	13.43	0	1.82	1	0
160	8	20	11.42	10.71	14.08	14.67	0	1.82	1	0
161	9	1	8.05	8.91	10.73	9.40	0	0.78	1	1
162	9	2	10.63	11.02	11.41	12.21	0	0.78	1	1
163	9	3	7.52	7.77	9.73	8.22	0	0.78	1	1
164	9	4	10.31	10.95	12.7	12.15	0	0.78	1	1
165	9	5	8.18	8.02	8.33	8.23	0	0.78	1	1
166	9	6	5.18	9.65	9.44	10.85	0	0.78	1	1
167	9	7	11.56	11.72	12.82	13.70	0	0.78	1	1
168	9	8	14.92	1.79	0	0	0	0.78	1	1
169	9	9	11.35	10.99	10.9	13.82	0	0.78	1	1
170	9	10	10.84	11.29	10.1	12.60	0	0.78	1	1
171	9	11	8.14	7.43	8.32	10.17	0	0.78	1	1

172	9	12	8.84	10.22	8.17	11.26	0	0.78	1	1
173	9	13	11.78	10.09	11.71	14.28	0	0.78	1	1
174	9	14	14.54	14.84	13.95	17.97	0	0.78	1	1
175	9	15	13.61	14.21	14.73	16.92	0	0.78	1	1
176	9	16	6.76	8.61	8.23	8.53	0	0.78	1	1
177	9	17	9.97	9.98	11.26	13.44	0	0.78	1	1
178	9	18	13.18	11.88	14.21	13.36	0	0.78	1	1
179	9	19	10.87	13.21	12.97	13.24	0	0.78	1	1
180	9	20	10.39	10.23	10.89	12.13	0	0.78	1	1
181	10	1	8.73	8.73	8.57	9.65	0	0.75	1	0
182	10	2	7.67	7.3	9.45	8.06	0	0.75	1	0
183	10	3	11.47	11.22	11.05	14.98	0	0.75	1	0
184	10	4	9.48	8.92	9.93	9.33	0	0.75	1	0
185	10	5	6.08	6.68	8.15	6.74	0	0.75	1	0
186	10	6	14	14.4	16.44	18.03	0	0.75	1	0
187	10	7	13.76	8.8	10.84	12.20	0	0.75	1	0
188	10	8	5.69	6.38	9.77	7.07	0	0.75	1	0
189	10	9	8.05	7.47	10.57	10.24	0	0.75	1	0
190	10	10	9.12	9.47	8.65	10.19	0	0.75	1	0
191	10	11	8.38	9.14	8.07	9.80	0	0.75	1	0
192	10	12	12.18	9.84	12.29	12.22	0	0.75	1	0
193	10	13	9.74	10.01	13.64	13.70	0	0.75	1	0
194	10	14	8.63	8.94	10.86	12.67	1	0.75	1	0
195	10	15	6.37	6.08	7.13	8.62	0	0.75	1	0
196	10	16	11.15	8.37	9.94	10.67	0	0.75	1	0
197	10	17	12.76	0	0	0	0	0.75	1	0
198	10	18	8.45	7.57	8.32	9.27	0	0.75	1	0

199	10	19	9.68	8.82	9.87	11.84	0	0.75	1	0
200	10	20	11.09	9	10.2	9.75	0	0.75	1	0
201	11	1	9.13	7.11	7.59	7.76	0	1.03	1	0
202	11	2	6.4	4.57	5.08	7.22	0	1.03	1	0
203	11	3	9.23	8.3	7.79	9.41	0	1.03	1	0
204	11	4	5.89	6.22	6.38	7.71	0	1.03	1	0
205	11	5	6.99	6.86	12.71	6.51	0	1.03	1	0
206	11	6	3.01	1.94	2.83	4.33	0	1.03	1	0
207	11	7	1.48	1.98	2.32	0	1	1.03	1	0
208	11	8	2.41	2.09	2.05	3.02	0	1.03	1	0
209	11	9	1.47	1.24	1.71	2.12	0	1.03	1	0
210	11	10	3.06	2.56	2.33	3.01	0	1.03	1	0
211	11	11	1.28	1.32	2.33	3.06	0	1.03	1	0
212	11	12	1.75	2.05	2.07	5.72	0	1.03	1	0
213	11	13	2.06	1.2	2.57	2.17	0	1.03	1	0
214	11	14	1.95	2.11	1.39	3.68	0	1.03	1	0
215	11	15	1.42	1.44	1.16	3.39	0	1.03	1	0
216	11	16	5.99	4.43	5.06	5.51	0	1.03	1	0
217	11	17	2.32	1.79	2.63	3.41	0	1.03	1	0
218	11	18	2.78	1.83	2.79	7.24	0	1.03	1	0
219	11	19	6.74	6.12	6.24	6.78	0	1.03	1	0
220	11	20	1.89	1.41	1.67	3.22	0	1.03	1	0
221	12	1	10.53	11.29	10.92	12.10	0	5.2	1	0
222	12	2	10.24	10.98	11.13	12.22	0	5.2	1	0
223	12	3	12.07	11.19	11.93	12.52	0	5.2	1	0
224	12	4	11.76	9.08	12.88	12.06	0	5.2	1	0
225	12	5	12.74	11.96	16.92	19.47	0	5.2	1	0

226	12	6	9.93	8.78	10.07	9.56	0	5.2	1	0
227	12	7	12.12	9.08	11.52	11.06	0	5.2	1	0
228	12	8	12.23	9.49	10.27	10.79	0	5.2	1	0
229	12	9	12.78	9.09	11.2	10.05	0	5.2	1	0
230	12	10	12.16	10.56	11.99	13.18	0	5.2	1	0
231	12	11	13.41	7.66	12.15		0	5.2	1	0
232	12	12	9.27	8.25	8.88	9.09	0	5.2	1	0
233	12	13	11.61	11.1	10.8	11.96	0	5.2	1	0
234	12	14	8.18	9.2	9.87	9.22	0	5.2	1	0
235	12	15	8.95	10.69	10.49	10.82	0	5.2	1	0
236	12	16	11.72	9.79	11.3	8.45	0	5.2	1	0
237	12	17	9.54	7.18	9.64	10.09	0	5.2	1	0
238	12	18	10.39	10.21	11.29	11.05	0	5.2	1	0
239	12	19	9.98	8.4	10.06	9.14	0	5.2	1	0
240	12	20	9.39	9.95	9.15	10.38	0	5.2	1	0
241	13	1	8.19	8.34	8.53	8.53	0	13.52	1	1
242	13	2	7.42	7.02	7.01	8.55	0	13.52	1	1
243	13	3	7.29	6.01	6.53	8.06	0	13.52	1	1
244	13	4	6.88	0	0	0	0	13.52	1	1
245	13	5	7.03	6.51	7.18	8.35	0	13.52	1	1
246	13	6	6.13	5.47	5.5	9.13	0	13.52	1	1
247	13	7	7.26	6.26	6.42	7.70	0	13.52	1	1
248	13	8	8.63	10.05	10.07	12.45	0	13.52	1	1
249	13	9	6.76	5.96	9.6	8.89	0	13.52	1	1
250	13	10	7.42	5.72	7.43	9.80	0	13.52	1	1
251	13	11	7.12	6.92	7.76	7.49	0	13.52	1	1

252	13	12	5.55	5.88	7.82	7.75	0	13.52	1	1
253	13	13	6.34	6.31	6.29	8.13	0	13.52	1	1
254	13	14	6.12	5.65	6.8	8.86	0	13.52	1	1
255	13	15	10.43	8.29	9.29	10.72	0	13.52	1	1
256	13	16	10.39	4.88	7.83	9.42	0	13.52	1	1
257	13	17	7.33	7.76	7.39	9.01	0	13.52	1	1
258	13	18	6.36	5.86	10.55	8.02	0	13.52	1	1
259	13	19	7.22	6.34	5.55	9.08	0	13.52	1	1
260	13	20	10.44	10.85	10.8	11.89	0	13.52	1	1
261	14	1	7.6	6.92	8.17	8.29	0	1.82	1	0
262	14	2	9.3	7.92	8.82	10.10	0	1.82	1	0
263	14	3	7.76	6.02	6.89	9.60	0	1.82	1	0
264	14	4	5.54	5.41	4.96	7.00	0	1.82	1	0
265	14	5	7.95	9.82	8.11	8.52	1	1.82	1	0
266	14	6	7.46	7.76	7.6	8.81	0	1.82	1	0
267	14	7	8.06	8.04	8.33	7.29	0	1.82	1	0
268	14	8	8.88	9.78	8.95	8.52	0	1.82	1	0
269	14	9	6.9	7.43	7.42	7.51	0	1.82	1	0
270	14	10	6.96	6.16	7.38	8.13	0	1.82	1	0
271	14	11	8.7	9.85	7.7	9.37	0	1.82	1	0
272	14	12	6.19	4.98	6.99	6.48	0	1.82	1	0
273	14	13	5.33	4.6	5.4	5.15	0	1.82	1	0
274	14	14	8.15	8.36	7.86	8.48	0	1.82	1	0
275	14	15	10.53	6.99	7.54	7.71	0	1.82	1	0
276	14	16	9.43	8.06	9.08	9.04	0	1.82	1	0
277	14	17	6.78	7.16	6.98	8.14	0	1.82	1	0

278	14	18	7.01	7.51	5.43	6.25	1	1.82	1	0
279	14	19	4.1	5.56	6.28	7.76	0	1.82	1	0
280	14	20	6.8	7.61	5.97	7.62	1	1.82	1	0
281	15	1	6.15	8.94	6.47	9.21	0	1.82	1	1
282	15	2	6.98	2.72	5.34	6.30	0	1.82	1	1
283	15	3	7.77	6.28	7.22	9.32	0	1.82	1	1
284	15	4	7.47	4.79	7.26	7.81	0	1.82	1	1
285	15	5	8.05	7.74	7.93	8.21	0	1.82	1	1
286	15	6	7.82	7.09	8.35	8.88	0	1.82	1	1
287	15	7	7.04	6.53	8.28	9.31	0	1.82	1	1
288	15	8	6.92	5.69	5.9	6.93	0	1.82	1	1
289	15	9	9.72	5.96	7.37	8.45	0	1.82	1	1
290	15	10	7.22	4.76	7.21	8.28	0	1.82	1	1
291	15	11	8.92	5.05	7.23	10.61	0	1.82	1	1
292	15	12	8.46	8.66	8.23	8.92	0	1.82	1	1
293	15	13	8.15	8.4	8.83	10.11	0	1.82	1	1
294	15	14	7.84	7.73	8.37	8.58	0	1.82	1	1
295	15	15	8.31	8.19	8.19	9.16	0	1.82	1	1
296	15	16	8.76	6.37	9.39	10.38	0	1.82	1	1
297	15	17	5.03	6.62	5.66	5.61	0	1.82	1	1
298	15	18	6.61	8.15	7.86	9.19	0	1.82	1	1
299	15	19	7.33	8.36	8.26	10.12	0	1.82	1	1
300	15	20	8.53	8.62	7.6	8.65	0	1.82	1	1