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Understanding Gilia tenuiflora ssp. arenaria population fluctuations and community relationships

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Understanding *Gilia tenuiflora* ssp. *arenaria* Population Fluctuations and Community Relationships

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Abstract

Around the world, species are being lost to development and invasive species. An endangered species, *Gilia tenuiflora* ssp. *arenaria,* exists within the East Campus Housing area of California State University, Monterey Bay on the former Fort Ord military base. As part of the Fort Ord Habitat Conservation Plan, the *Gilia* must be monitored as part of the Federal Endangered Species Act and for population management. Little is known about this *Gilia* species, and the goal of this study is to establish baseline data on population fluctuations and community structure in the East Campus Housing area in order to better manage the species. Species composition was compared in areas immediately adjacent to *Gilia* plants as well as in nearby areas without *Gilia* plants to determine if there were patterns in species associated with *Gilia tenuiflora* ssp. *arenaria.* Also, population densities were compared to precipitation data from corresponding years to determine if there was an association between the two. There was a higher percent cover of *Eriastrum virgatum* in quadrats with *Gilia* than without. Abundance was higher in 2005, the year with more winter precipitation. These results suggest there may be an association between *Gilia* and *Eriastrum* and higher winter precipitation totals may result in larger *Gilia* populations.

Introduction

"Earth has at last acquired a force that can break the crucible of biodiversity," according to Edward O. Wilson (1999). That force is mankind, and "a fifth or more of plant and animal species on Earth could vanish or be doomed to early extinction by the year 2020" due primarily to habitat destruction, but also through pollution and the introduction of invasive exotic species (Wilson 1999). *Gilia tenuiflora* ssp. *arenaria,* sand or Monterey gilia, is a small, purple-flowered annual of the phlox family (Polemoniaceae) that occurs among coastal sand dunes, and in sandy openings of maritime chaparral and oak woodlands in Monterey County, California and is in danger of being extirpated due to loss of habitat (Dorrell-Canepa 1994, U.S. Army Corps of Engineers 1992, 1994). Historically, it was found all around Monterey Bay, but much of its habitat has been lost to development or invasive exotic species (DOI & FWS 1992). It is now confined to ten separate populations among coastal dunes, ranging from Moss Landing to Spanish Bay (Dorrell-Canepa 1994), and is continually threatened by development, sand mining, vehicles, recreational activities, foot traffic, and non-native plants (CNPS 2007). Because of *Gilia*'s limited range and low population numbers, it is considered threatened or endangered by both state and federal agencies.

Legal Protection

Gilia tenuiflora ssp. *arenaria* is listed as threatened under the California Endangered Species Act (CESA), which prohibits "take" of listed species, defined

as picking or killing (LCC n.d.). Section 2067 of the CESA states that a species is "threatened" when, "although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts (LCC n.d.b)." An endangered species is "in serious danger of becoming extinct throughout all, or a significant portion, of its range due to one or more causes, including loss of habitat, change in habitat, overexploitation, predation, competition, or disease (LCC n.d.b)." Originally, the California Legislature passed the Native Plant Protection Act (NPPA) in 1977 to "preserve, protect and enhance rare and endangered plants in this State (LCC n.d.a)." California Fish and Game Commission has the authority under the NPPA to designate native plants as "endangered" or "rare" and to require permits for collecting, transporting or selling such plants (LCC n.d.a). To enhance protection of listed species and to align with federal regulations, the CESA of 1984 altered the "endangered" or "rare" categories of the NPPA to the "threatened" and "endangered" categories of the Federal Endangered Species Act (CNPS 2007c).

Gilia tenuiflora ssp. *arenaria* has been listed as endangered since 1992 under the Federal Endangered Species Act of 1972 (ESA) (DOI &FWS 1992). The ESA is aimed at protecting certain species that have been established as threatened or endangered because of diminishing population numbers in North American ecosystems. Under the act, it is illegal to import or export, transport, sell or offer for sale in interstate or foreign commerce, remove and possess from federal jurisdiction, maliciously damage or destroy, remove, cut, or dig up any endangered plant species (DOI & FWS 1992). Also under the ESA, federally

authorized and funded actions cannot “jeopardize the continued existence of such a species or destroy or adversely modify its critical habitat (DOI & FWS 1992).” Private landowners, corporations, state or local governments, or other non-federal landowners must obtain an incidental take permit before they can conduct activities that might incidentally harm species that are listed as threatened or endangered (USFWS 1999). In order to obtain an incidental take permit, the landowner must develop a Habitat Conservation Plan (HCP) (USFWS 1999). The HCP is designed to offset harmful effects the activity might have on the species by promoting species conservation while allowing for the proposed development to proceed (USFWS 1999). Currently, *Gilia* is being managed under an HCP on the former Fort Ord military base.

Fort Ord Habitat Conservation Plan

The former Fort Ord military base occupies approximately 28,000 acres of land along the Pacific Ocean in Monterey County, California (Zander Associates 2004). After the closure of the base in 1990, the Fort Ord Reuse Authority became responsible for converting the base to civilian activities (FORA n.d.). As part of the conversion, the area was divided among many different entities, including the Bureau of Land Management, California State Parks, the University of California, Monterey County and the City of Marina (Zander Associates 2004). The Fort Ord land, however, is a biologically diverse area that supports over 700 plant species, nineteen of which are endangered, threatened, or species of concern (BLM 2004). Pursuant to the ESA, every landowner on Fort Ord needs

an incidental take permit and an HCP to conduct activities that might impact threatened or endangered species (USFWS 1999). As an endangered species on Fort Ord, *Gilia tenuiflora* ssp. *arenaria* is managed under the HCP (Zander Associates 2004).

It is estimated that 50-70 percent of *Gilia*'s range is on Fort Ord, and it occurs nowhere else in the world (US Army Corps of Engineers 1992). Therefore, it is important to conserve Fort Ord in order to preserve the integrity of the species. The HCP designates areas where *Gilia* is found for management by landowners as Habitat Reserve Areas, Development with Reserve Areas or Restrictions, or Development (Zander Associates 2004). In Habitat Reserve Areas, land is set aside from development to protect important *Gilia* habitat. In Development with Reserve Areas or Restrictions, small parcels of *Gilia* habitat are protected within larger areas slated for development. Development areas are undeveloped natural lands that are to be transferred to a new landowner specifically for development, or areas where military development already exists. In Development areas, however, the HCP considers any *Gilia* found there a complete loss and not essential to the long-term preservation of the species (Zander Associates 2004).

One of these areas designated for development is the East Campus Housing area of California State University at Monterey Bay (CSUMB), where *Gilia tenuiflora* ssp. *arenaria* is found along intersecting roads and trails through

maritime chaparral (see maps in US Army Corps of Engineers 1992, 1994, S. Worcester pers. communication). There are a few reasons why this area is important. First, the HCP anticipates losing 805 acres of land to development, or 21% of the *Gilia* population on Fort Ord (Zander Associates 2004). Of that 21%, Jones & Stokes estimated that only 4% are high-density stands (Zander Associates 2004). The Jones & Stokes survey (US Army Corps of Engineers 1992, DOI & FWS 1992), however, was conducted during only one year, and high annual population variations, as seen in Fox et al (2006), could account for a large underestimation of the true population. Second, the HCP does allow for small reserves to be created within development areas (Zander Associates 2004). CSUMB has the opportunity to lead the way in setting aside these areas as critical habitat for *Gilia* and other rare and endangered species facing habitat loss. If the Jones & Stokes survey did not result in an accurate representation of the population, CSUMB's reserve could help to protect more of the already endangered species.

***Variations in Gilia tenuiflora* ssp. *arenaria* populations**

Gilia populations are affected by many abiotic and biotic factors, including surface temperature, nutrient availability, wind, precipitation and competition with other species (Dorrell-Canepa 1994). In order to determine which of these factors plays the largest role in determining distribution and abundance, studies have been done on *Gilia* natural history in active dune habitats (Dorrell-Canepa 1994) and on demographic responses to variable environments at the Fort Ord Natural

Reserve on relict dunes (Fox et al 2006). Both of these studies found that rainfall has a significant impact on *Gilia* abundance; as populations increased with average monthly rainfall (Fox et al 2006) and variations in rainfall may shorten or delay the blooming period (Dorrell-Canepa 1994). These studies also found that *Gilia* tends to survive better among other small annuals, such as *Cryptantha leiocarpa* on active dunes and *Chorizanthe pungens* var. *pungens* on relict dunes (Dorrell-Canepa 1994, Fox et al 2006). In relict dune habitats such as Fort Ord, it does appear that *Gilia* tends to occur with *Chorizanthe pungens* var. *pungens* but tends not to occur with exotic annual grasses, *Hypochaeris glabra* and *Erodium botrys* (S. Worcester pers. observation). The goals of this study are to determine if *Gilia tenuiflora* ssp. *arenaria* in the East Campus Housing area 1) occurs with these exotic annuals, 2) which species *Gilia* most commonly occurs with and 3) how the populations differ annually and according to precipitation amounts.

Methods

Mapping Gilia tenuiflora ssp. *arenaria populations*

Gilia tenuiflora ssp. *arenaria* populations in the East Campus Housing area (Figure 1) were mapped in 1992 by Jones & Stokes, and again in 2005 by Dr. Suzanne Worcester. Using knowledge passed along from S. Worcester and the Jepson Manual: Higher Plants of California (1993), *Gilia* plants were identified and mapped in the same locations of those that were mapped in 2005. During May 2006, a Trimble Geo 3 GPS unit was used to categorize individuals into either a single plant, or in patches of 0-10, 10-50, or 50+. Once the data set was

collected, it was plotted in ESRI ArcMap v. 9 with the data from 2005 collected by S. Worcester. These two data sets were plotted together to compare the difference in location and abundance over these two years.

Figure 1: Location of California State University, Monterey Bay (CSUMB) East Campus Housing area on Fort Ord, shown in red square.

Gilia population data from both 2005 and 2006 were also compared to rainfall data from the same years to determine the relationship between abundance and precipitation. Precipitation data was collected from the Western Regional Climate Center Fort Ord #1 weather station, Lat: 36° 37' 37", Long: 121° 47' 53" (WRCC n.d.).

Assessing local community composition near Gilia tenuiflora* ssp. *arenaria

At the end of May 2006, a subset of the identified plants was further surveyed in order to determine which species commonly occur with *Gilia tenuiflora* ssp. *arenaria.* The resulting sample size was small because the *Gilia* plants had a short blooming period (five weeks) during 2006 and few were available at the time of analysis. Three plants were randomly selected from each of five randomly

chosen patches, resulting in 15 sampled plants. Three patches were located adjacent to the trails in the East Campus Housing area and two were in open, sandy spaces where trails intersected.

To assess which species are associated with individual *Gilia tenuiflora* ssp. *arenaria* plants, a 100cm^2 unstrung quadrat was placed around each randomly chosen plant, with the *Gilia* relatively in the center to avoid biased sampling. An unstrung quadrat was used because a strung quadrat might have crushed the plants when the quadrat was placed over them. Control plots (without *Gilia*) were randomly placed in one of the four cardinal directions, directly adjacent to *Gilia* plots in order to determine if there was any difference in percent cover of species in areas with *Gilia* and without (Figure 2). Photographs were taken of the quadrats and inserted into clear sheet protectors so they could be analyzed using the point intercept method to determine percent cover of species. Grids were drawn on the sheet protectors by measuring each length of the quadrat in the photo and dividing by eleven, to get 100 intersections (Figure 3). Percent cover was determined by the number of intersections each species/cover type occurred at, including sand and thatch, defined as dead, dry material, sticks and rocks. Because of the small sample size and the high occurrence of zeros, normality could not be achieved. Therefore, non-parametric Mann-Whitney U tests were used to assess differences in percent cover of the most common cover types between *Gilia* and control plots using SPSS v. 14. Only four of the cover types occurred with enough frequency for statistical analysis.

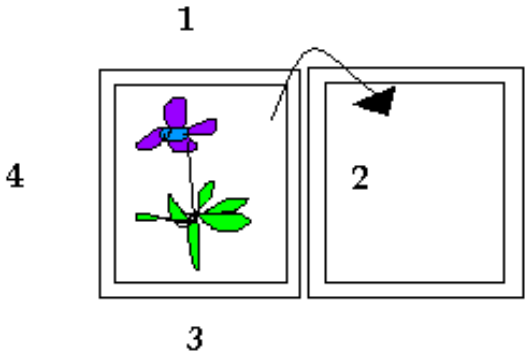

Figure 2: Sampling technique for assessing species nearby. Placement of control plot determined by randomly chosen cardinal direction. Note: Not to scale.

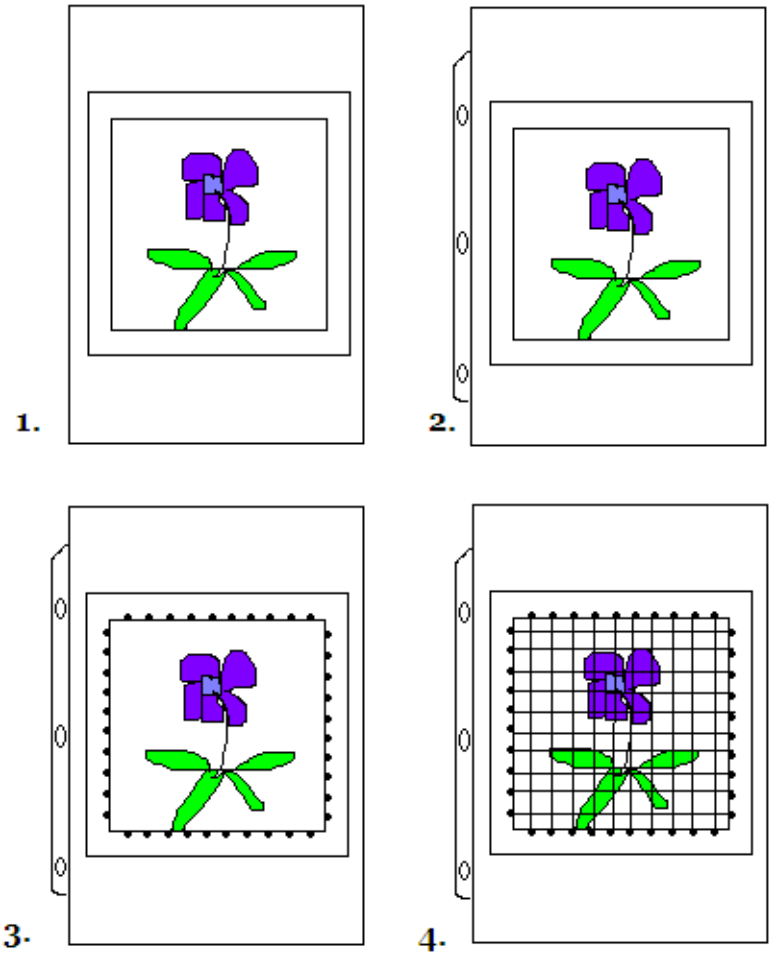

Figure 3: Grid technique for point intercept method. Step 1: The photograph of the sample *Gilia tenuiflora* ssp. *arenaria* plant. Step 2: The photograph was inserted into a sheet protector. Step 3: Each side of the quadrat was measured and divided into eleven sections, or ten dots. Step 4: Dots were connected on opposite sides to create a grid. Note: Not to scale.

Results

Population differences from 2005 to 2006

The 2005 population was larger than the 2006 population in areas south of Imjin Road (Figure 4), east and west of Abrams Dr. near the tennis courts (Figure 5), and north and east of Wainwright Circle (Figure 6). The two populations were comparable in the area east of Abrams Dr. (Figure 7). There were also more patches of *Gilia* plants in 2005 than there were in 2006.

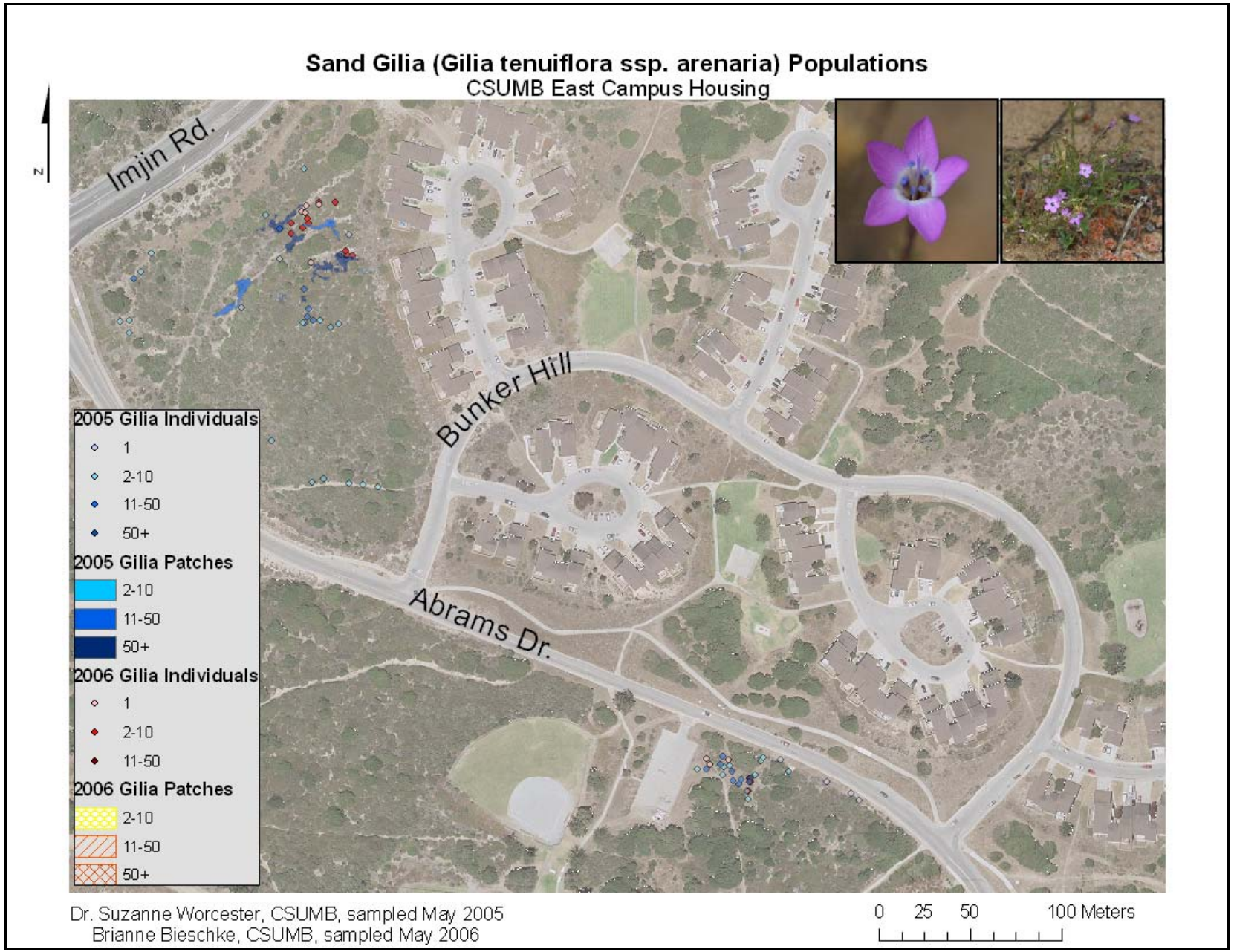

Figure 4: Map of *Gilia tenuiflora* ssp. *arenaria* population abundance near Ord Market at Imjin Rd. and Abrams Dr. in the East Campus Housing area of California State University at Monterey Bay, Marina, California. Blue indicates 2005 populations, red indicates 2006 populations.

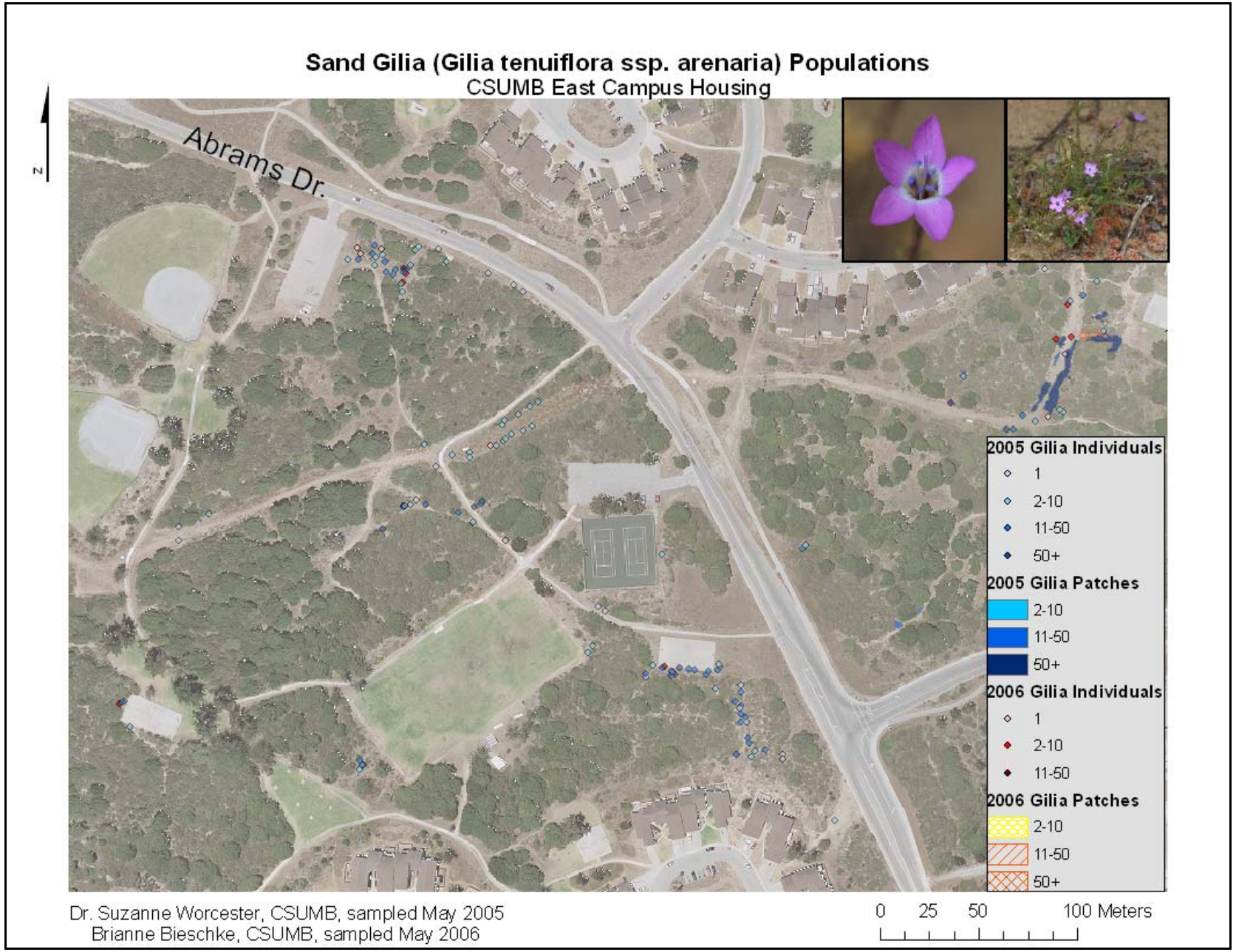

Figure 5: Map of *Gilia tenuiflora* ssp. *arenaria* population abundance near the tennis courts off of Abrams Dr. in the East Campus Housing area of California State University at Monterey Bay, Marina, California. Blue indicates 2005 populations, red indicates 2006 populations.

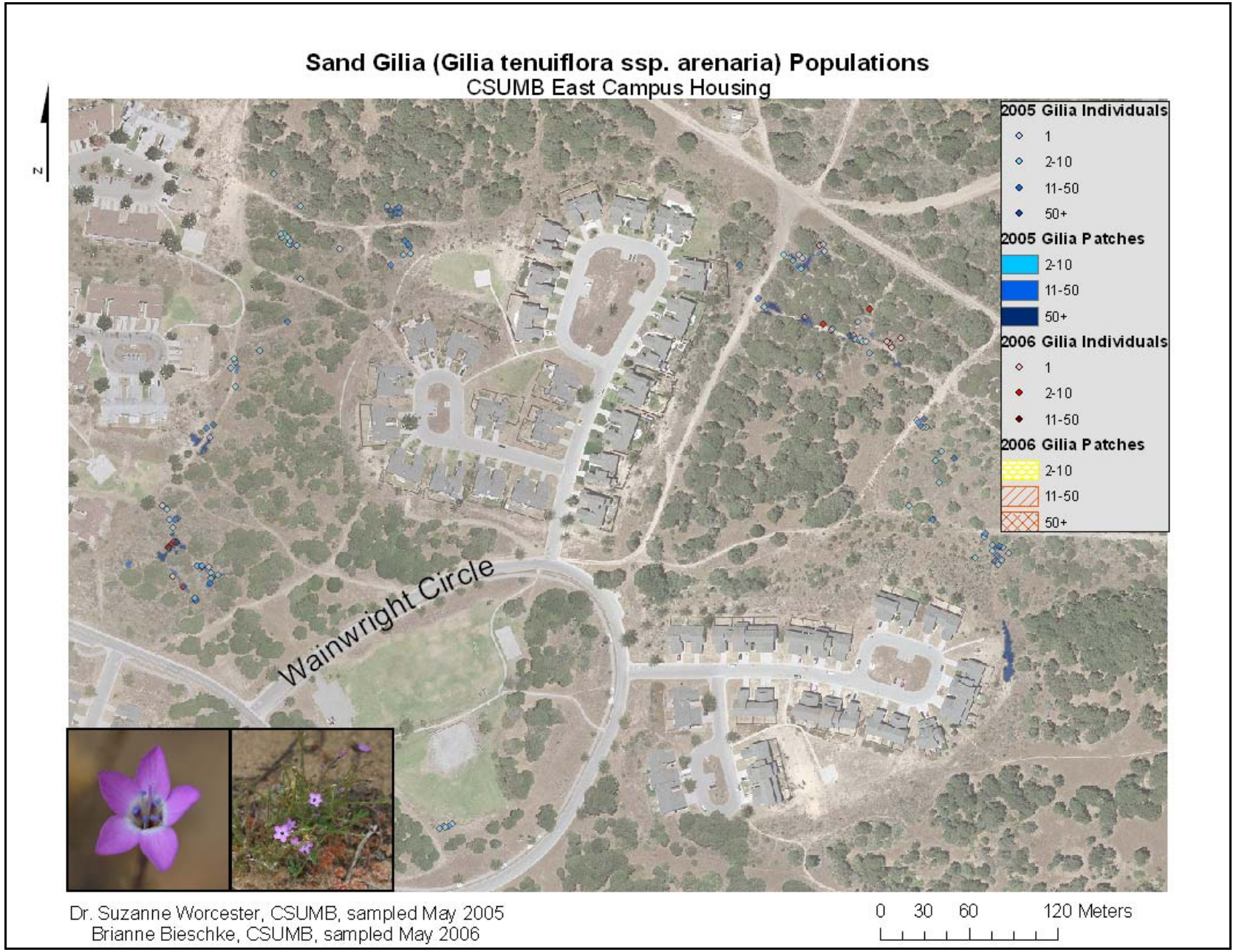

Figure 6: Map of *Gilia tenuiflora* ssp. *arenaria* population abundance behind Wainwright Circle in the East Campus Housing area of California State University at Monterey Bay, Marina, California. Blue indicates 2005 populations, red indicates 2006 populations.

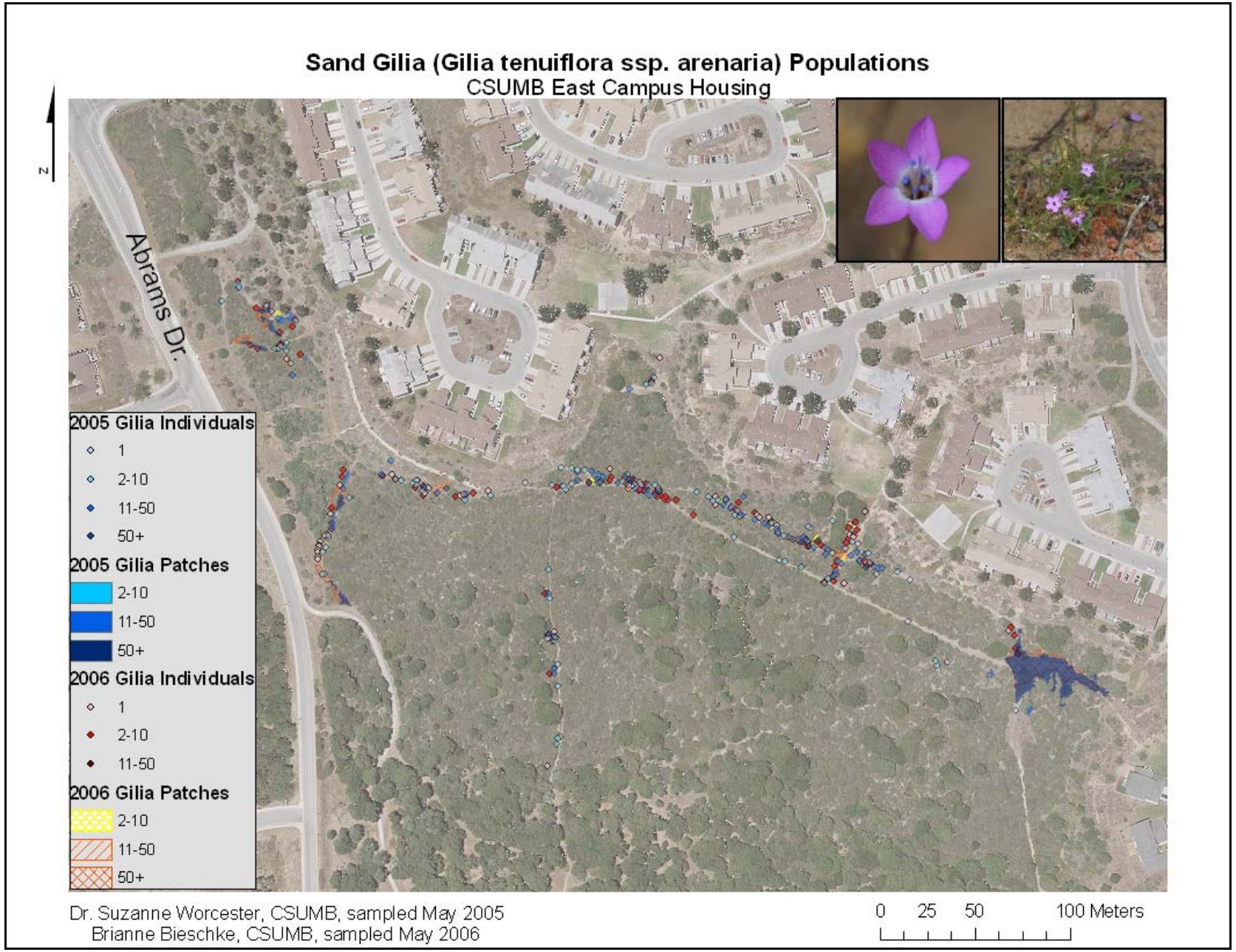

Figure 7: Map of *Gilia tenuiflora* ssp. *arenaria* population abundance east of Abrams Dr. in the East Campus Housing Area of California State University at Monterey Bay, Marina, California. Blue indicates 2005 populations, red indicates 2006 populations

Monthly precipitation data

In 2005, the total rainfall from November through April at the Fort Ord weather station was 15.85 inches and 14.86 inches in 2006 (WRCC n.d., Figure 8). Rainfall totals were similar for both years, but while monthly rainfall tapered off after March in 2005 similar to an average year, both March and April received large amounts of rain in 2006 (WRCC n.d., Figure 9).

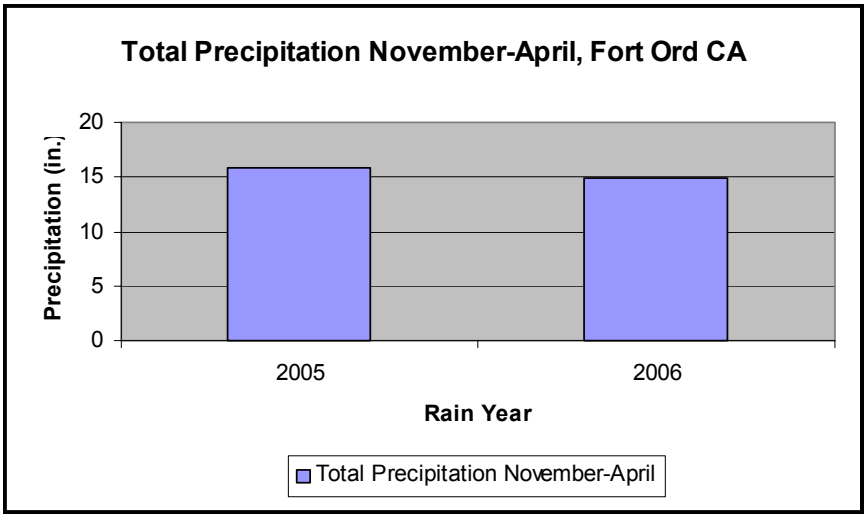

Figure 8: Total precipitation in inches for November through April of 2005 and 2006 (WRCC n.d.).

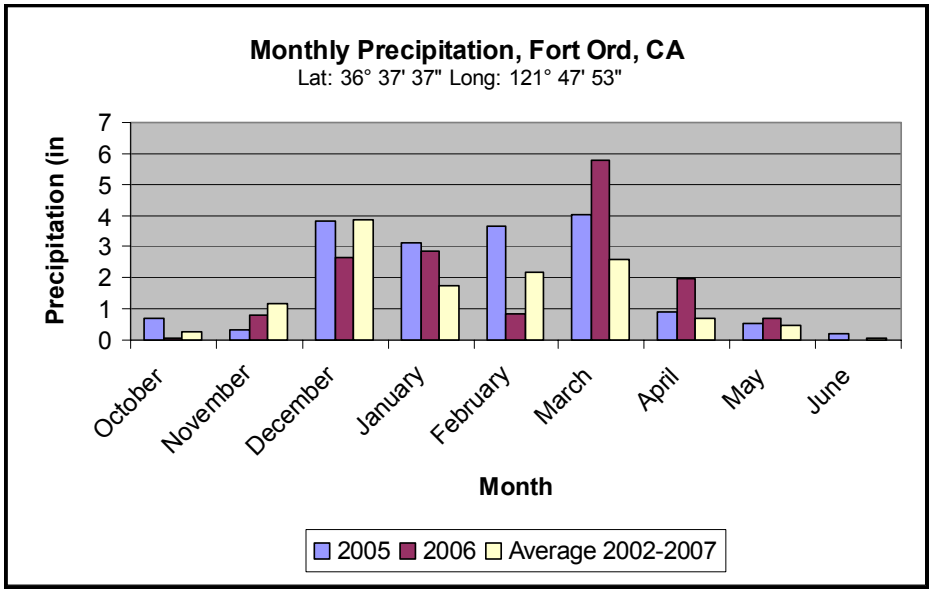

Figure 9: Precipitation data for Fort Ord, CA for 2004-2005, 2005-2006 hydrologic years and the monthly averages for 2002-2007 (WRCC n.d.).

Most commonly occurring species

Table 1 shows the cover types that occurred near *Gilia tenuiflora* ssp. *arenaria,* with sand, thatch, *Chorizanthe pungens* var. *pungens* and *Eriastrum virgatum* occurring the most often. Sand mat was not analyzed because all 15 hits occurred in only one quadrat.

Table 1: Total percent cover of all species found in quadrats with and without *Gilia tenuiflora* ssp. *arenaria*. Sand, thatch, *Chorizanthe pungens* var. *pungens* and *Eriastrum virgatum* occurred the most frequently.

Plant		Total # of hits	
Scientific Name	Common Name	With Gilia	Without Gilia
Sand	Sand	676	805
Thatch	Thatch	616	522
Chorizanthe pun	Monterey Spineflower	35	44
Eriastrum virgatu	Wand Woollystar	26	6
Erodium botrys	Stork's bill	5	0
Hypochaeris glal	Smooth's cat's ear	3	2
rabbit poop	rabbit poop	3	2
Navarretia sp.	Navarretia	3	0
Cardionema ram	Sand mat	15	0
Lotus scoparius	Deerweed	0	3
Unknown sp.	Unknown sp.	0	1

Mean percent cover in quadrats both with and without *Gilia* were compared for the top four cover types, *Chorizanthe pungens, Eriastrum virgatum,* sand and thatch. The percent cover of *Eriastrum virgatum* was significantly higher in quadrats with *Gilia* than without ($p = .04$, $Z = -2.054$, $n=28$, Figure 10). There is no difference in percent cover of *Chorizanthe pungens* ($p = .754$, $Z = -.313$, $n=28$), sand ($p = .476$, $Z = -.713$, $n=28$) or thatch ($p = .550$, $Z=-.598$, $n=28$) in quadrats with *Gilia* and without (Figures 11-13).

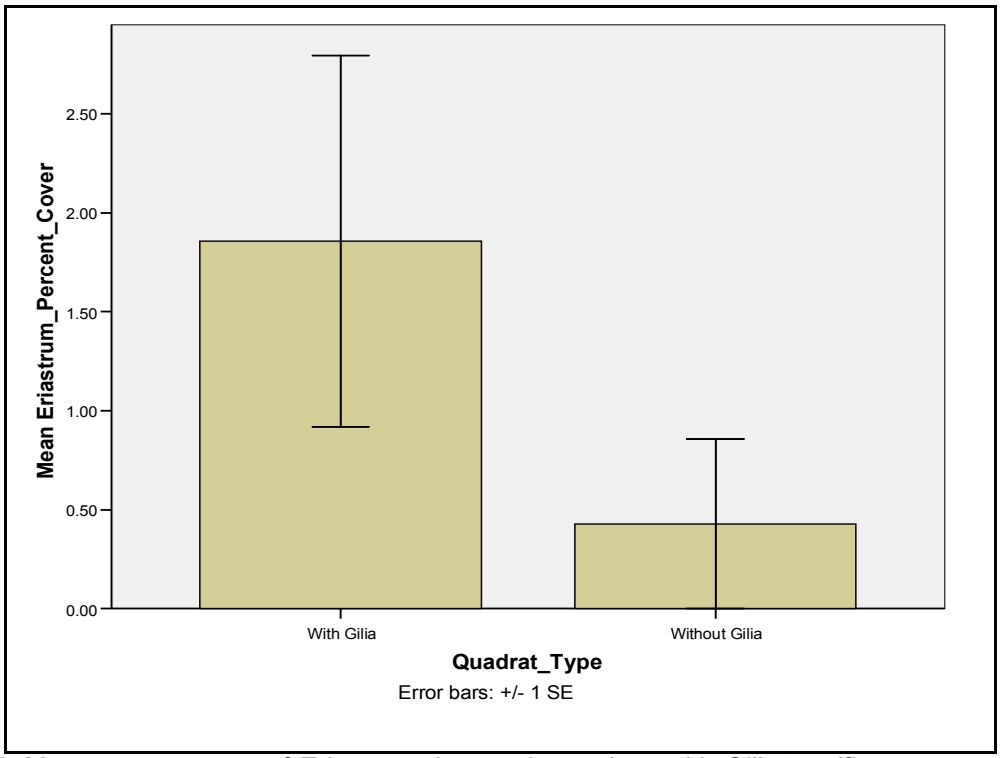

Figure 10: Mean percent cover of *Eriastrum virgatum* in quadrats with *Gilia tenuiflora* ssp. *arenaria* and quadrats without *Gilia*. The mean percent cover is significantly higher (p= .04) in quadrats with *Gilia*.

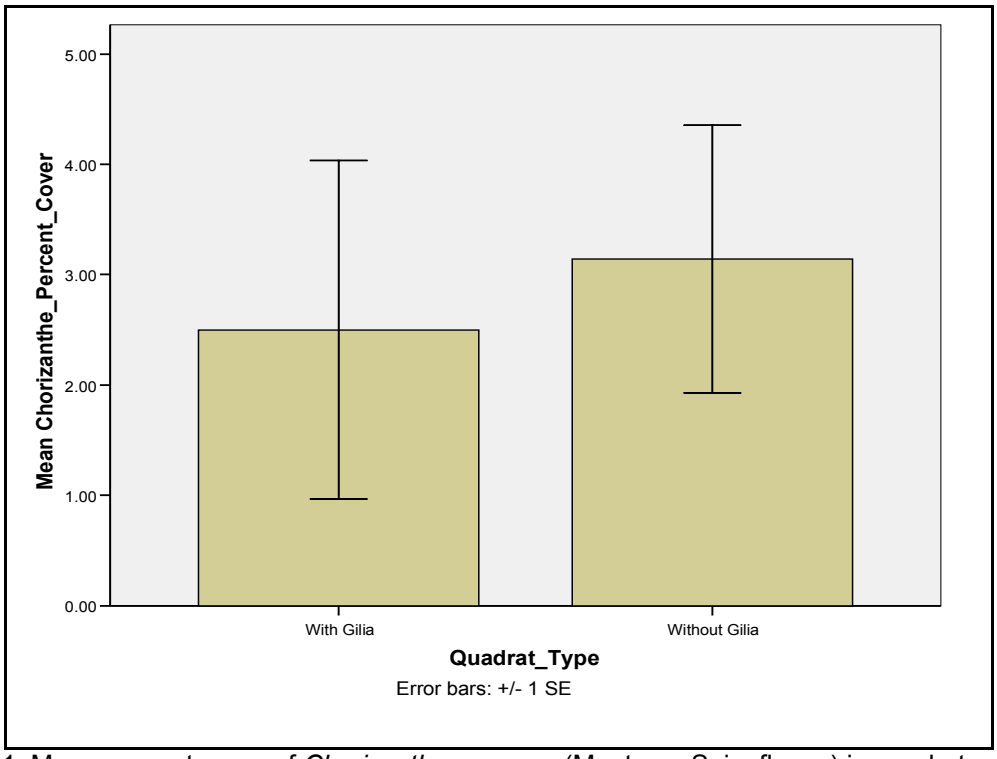

Figure 11: Mean percent cover of *Chorizanthe pungens* (Monterey Spineflower) in quadrats with *Gilia tenuiflora* ssp. *arenaria* and quadrats without *Gilia*. There is no significant difference in mean percent cover of *C. pungens* in quadrats with and without *Gilia* (p=.754).

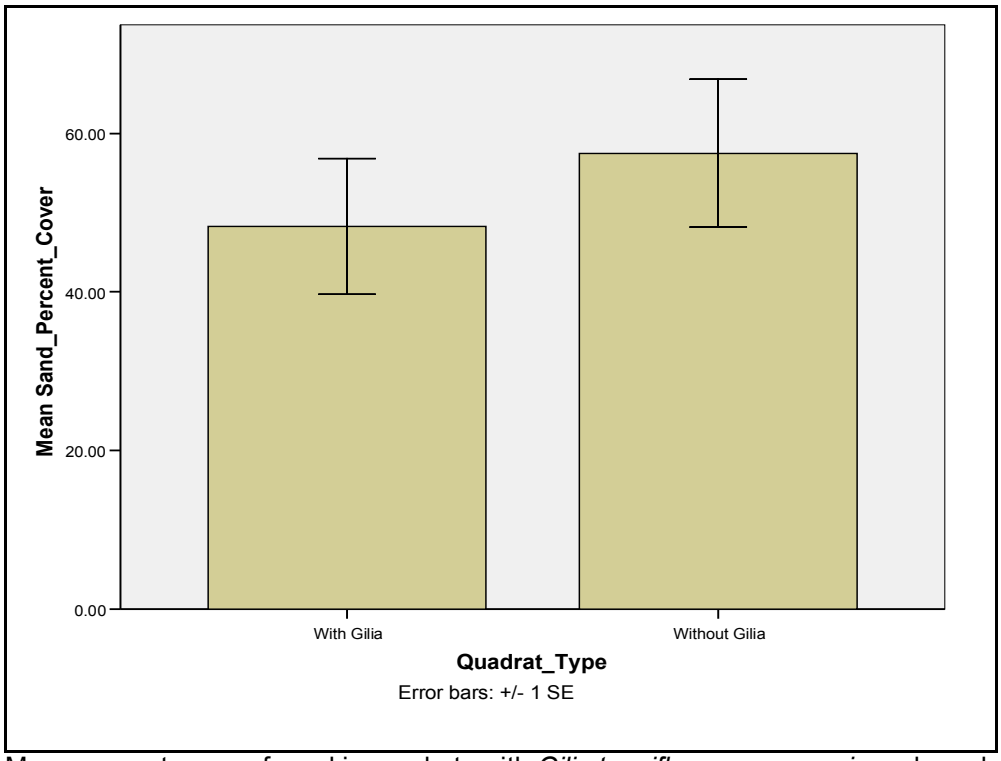

Figure 12: Mean percent cover of sand in quadrats with *Gilia tenuiflora* ssp. *arenaria* and quadrats without *Gilia*. There is no significant difference in mean percent cover of sand in quadrats with and without *Gilia* (p= .476).

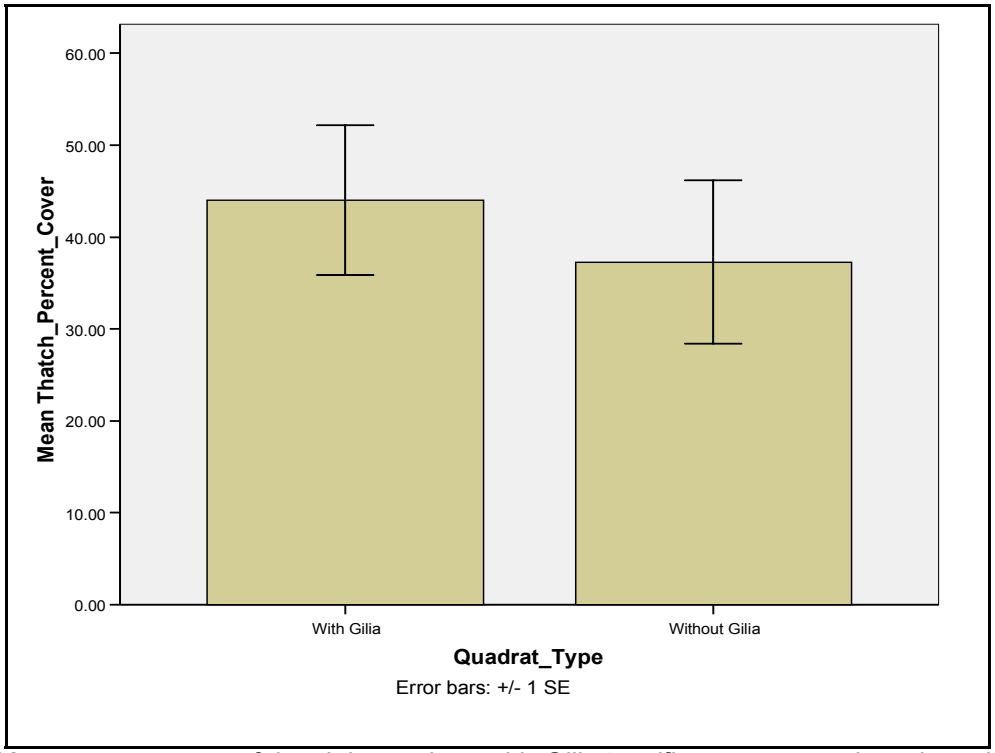

Figure 13: Mean percent cover of thatch in quadrats with *Gilia tenuiflora* ssp. *arenaria* and quadrats without *Gilia*. There is no significant difference in mean percent cover of thatch in quadrats with and without *Gilia* (p= .55).

Discussion

Population differences from 2005-2006

As in both Dorrell-Canepa (1994) and Fox et al (2006) studies, higher precipitation totals during the winter and early spring of 2005 supported larger populations of *Gilia tenuiflora* ssp. *arenaria* than 2006 in the East Campus Housing area of California State University at Monterey Bay. As Dorrell-Canepa (1994) suggests, the low amount of rainfall during winter of 2006 could have resulted in a shorter blooming period, as *Gilia* were not observed blooming until April 11th, and were fading five weeks later (pers. observation). This short blooming period might have resulted in underestimating *Gilia* abundance during 2006. As Fox et al (2006) suggest, El Nino weather patterns may play a large part on population size. El Nino events correspond to high amounts of rainfall during the winter and spring seasons. *Gilia* adult success, and thus seed bank success for subsequent years, is highly sensitive to amounts of spring rain. Spring rain was lower in 2005 than 2006, and thus the 2005 *Gilia* may not have produced a large seed bank that year.

Fox et al (2006) also suggest that *Gilia* abundance is dependent on seed bank history and seed production over many years, not just current conditions, and thus it is difficult to tell what exactly caused the lower population numbers in 2006. Consequently, these studies show that *Gilia* populations are highly variable, and predicting true populations from one year of data may be impractical. Therefore, it is possible that Jones & Stokes (US Army Corps of Engineers 1992, DOI & FWS 1992) might have under or over estimated the true *Gilia* population in the East Campus Housing area by using only one year of data.

Therefore, more research on this species is needed to truly understand population dynamics.

Commonly occurring species

Table 1 shows that the most commonly found cover types near *Gilia tenuiflora* ssp. *arenaria* individuals are sand, thatch, *Chorizanthe pungens* and *Eriastrum virgatum.* Sand and thatch are both naturally found along the trails and paths in the East Campus Housing area, and both *Chorizanthe pungens* and *Eriastrum virgatum* are native species. It is interesting to note that both of these species have special status; *Chorizanthe pungens* is a federally threatened species and *Eriastrum virgatum* is a rare species under the California Native Plant Society Inventory of Rare and Endangered Plants (CNPS 2007). The results of the statistical tests show, however, that only *Eriastrum virgatum* had a higher percent cover in quadrats with *Gilia*. With this data, there does seem to be a relationship between *Gilia tenuiflora* ssp. *arenaria* and *Eriastrum virgatum,* but not between any other species in the East Campus Housing area.

Also, few exotic annuals, such as grasses, *Hypochaeris glabra* and *Erodium botrys*, were found in the quadrats sampled for this study. There are many possible reasons for this. One reason could be that the quadrats used were too small and did not capture an accurate picture of the community surrounding *Gilia,* or that the selected subset was too small and not representative of the true *Gilia* population. Another reason could be that *Gilia* germination does not occur where these exotic annuals are present because of competition, or there are specific physical conditions associated with *Gilia* germination, such as soil characteristics, slope, presence of shade, etc. Future studies could expand the

size of the quadrats and sample size to include a larger area around individual *Gilia* plants. Future studies could also compare abiotic factors, such as soil characteristics, etc, in areas where *Gilia* occurs and in areas where exotic annuals occur to determine if these factors affect where *Gilia* germinates.

Sources of error

The results of this study may have included errors. First, photographs of the quadrats were used in order to avoid crushing the *Gilia* plants. However, some of the photos were taken from an angle to avoid shading the quadrat. With the photograph taken at an angle, it was difficult to determine which cover types were directly under the grid intersections. For future studies, I would recommend taking two quadrats out, one strung and one unstrung, and stacking them on top of each other to get a more accurate sample. If the unstrung one is on the bottom with the strung one on top of it, then the plants will not get crushed and data could be taken immediately in the field. Second, *Gilia* plants are very small, typically the flower is between one and two centimeters wide, and this makes them difficult to find among other chaparral plants. Searching for them was very time consuming, especially in areas not along the trails where chaparral can be very dense, and the search could not commence until they started blooming because they are hard to identify without the flower. Because the blooming period was only about five weeks and the East Campus Housing area was so large, it is possible that some blooming *Gilia* may have withered before they could be counted, resulting in an underestimation of the population size during 2006. Although there is no way to control how long the blooming period is, it might be helpful in

the future to use multiple people to search for *Gilia* while they are blooming to ensure that none are missed.

Accurate and efficient monitoring techniques are essential to understanding a species, and completely understanding a species is essential to effectively creating and implementing management strategies to conserve and protect it. Although the Fort Ord HCP does not explicitly require that *Gilia tenuiflora* ssp. *arenaria* be monitored or conserved in the East Campus Housing area of California State University, Monterey Bay, there is still much that is unknown about the species, and this population may be key to realizing the best management practices. If CSUMB continued to monitor and conserve the *Gilia* populations in the East Campus Housing area, then perhaps it is possible to prevent this species from being yet another lost to development.

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