Current and historical distribution of the endemic Santa Cruz kangaroo rat, *Dipodomys venustus venustus*

Senior Bachelors Thesis

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Abstract

Over the last century, the range of the endemic Santa Cruz kangaroo rat (*Dipodomys venustus venustus*) has severely contracted and may now be restricted to a single location: Henry Cowell State Park in Felton, California. Although records since 1900 support shrinkage of the range of this kangaroo rat subspecies, few trapping surveys have been conducted in past decades, preventing accurate estimates of their current range. In order to further the sampling efforts for this subspecies, I live-trapped at three potential *D. v. venustus* habitats near Felton, California. My trapping survey found no kangaroo rats. These results, combined with collected historical records, suggest that *D. v. venustus* may be extirpated from all but one remaining site, Henry Cowell State Park. A comparison of *D. v. venustus* habitat in Henry Cowell with surrounding sandhill habitats suggests that potential causes of the extirpation of *D. v. venustus* from these sites may be due to reduced habitat size and encroaching residential development. An expanded trapping effort would help confirm their extirpation outside of Henry Cowell State Park and additional analysis of their potential habitat may provide insight into management practices that will help conserve this kangaroo rat subspecies.

Introduction

Keystone species—species that have a disproportionate effect on their surrounding community—are integral to maintaining thriving ecosystems (Folke et al. 2004; Hooper et al. 2005). The kangaroo rat serves as a keystone species in several ecosystems, including the Chihuahuan desert (Heske et al. 1993) and California grasslands (Brock and Kelt 2004; Prugh and Brashares 2012). The endemic Santa Cruz kangaroo rat (*Dipodomys venustus venustus)* is a nocturnal habitat specialist that requires sandy soil for burrowing, open space to move around efficiently, and seed-producing plants for foraging such as manzanita (*Arctostaphylos* spp.) (Grinnell 1922; Best 1992; Bean 2003; Ahlborn 2005). In Santa Cruz County, *D. v. venustus* occurs only in sandhill chaparral habitats and is most closely associated with Silverleaf Manzanita Mixed Chaparral habitat (i.e. Sand Chaparral). *Dipodomys v. venustus* does not currently occur outside of the County (Lee 1994; Bean 2003).

Santa Cruz sandhill habitat is an edaphic (soil-based) ecosystem defined by its sand soils and found across the world and in many regions of the United States (Lee 1994; McGraw 2004).

Selective pressures created by the characteristic sand-soils produce similar vegetation, a high level of endemic flora and fauna, and dependence on fire regimes across sandhill ecosystems (McGraw 2004). As a result, Santa Cruz sandhills have a unique assemblage of plant and animal species living in their sand-soils comprised of 90% sand, locally termed Zayante soils (Grinnell 1922; Best 1992; Bean 2003; Ahlborn 2005). Plant species found in these sandhill habitats include silverleaf manzanita (*Arctostaphylos silvicola*), ponderosa pine (*Pinus ponderosa*), buck brush (*Ceanothus cuneatus*), silver bush lupine (*Lupinus albifrons*), and Ben Lomond wallflower (*Erysimum teretifolium*). Animal species of the Santa Cruz sandhills include Mount Hermon June Beetle (*Polyphylla barbata*), Coast horned lizard (*Phrynosoma coronatum*), black-tailed hare (*Lepus californicus*), and pocket mouse (*Chaetodipus californicus*) (McGraw 2005). This unique biotic composition is due to the combination of a variable Mediterranean climate and distance from other sandhill regions. This uniqueness allows the Santa Cruz sandhills to be considered a separate conservation entity from other sandhill ecosystems (McGraw 2004).

In the Santa Cruz Mountains, organisms occurring in sandhill ecosystems with *D. v. venustus* are likely influenced directly or indirectly by the subspecies, as they can play an important role removing and caching seeds. Additionally, they burrow in the sand, turning the soil and disrupting the growth of grasses and providing refugia for other animal species (Brock and Kelt 2004; Prugh and Brashares 2012). In the Santa Cruz Mountains, sandhills are patchily distributed, occurring in isolated islands surrounded by evergreen and mixed-evergreen forest. Over the past century, the range of *D. v. venustus* has been drastically reduced due to habitat loss and other anthropogenic effects (Bean 2003; McGraw 2004). This has led to their listing as a Critically Imperiled subspecies by California Fish & Wildlife; this listing does not, however, impart any legal protections (California Fish and Wildlife 2016).

Dipodomys v. venustus originally occurred in habitat patches spread over the counties of Santa Cruz, Santa Clara, and San Mateo but may now persist only within Henry Cowell State Park (formerly called SRL or Save-the-Redwoods-League Parcel) (Bean 2003; Franco 2012). In order to determine the change of this subspecies' distribution from its historical range to the present, my study consisted of four main objectives: 1) Evaluate historical collection records, publications, and reports to determine locations where *D. v. venustus* are known to have occurred in the Santa Cruz Mountains, 2) determine presence of intact potential habitat, at sites where *D. v. venustus* have been found in the past or where sampling has never occurred but suitable habitat

is present, 3) create a map that overlays historic distribution on top of intact suitable habitat, and 4) conduct live-trapping at three accessible sandhill sites that have intact sandhill habitat. I hypothesize that *D. v. venustus* is restricted to Henry Cowell State Park, possibly due to a combination of anthropogenic factors. My study serves to gather much of the existing data on *Dipodomys venustus venustus* and further the efforts to study and conserve this subspecies.

Materials and Methods

Historical Records and Intact Habitat

I collected historical locality data of *D. v. venustus* distribution from published literature, environmental reports, and from natural history museums' online databases of voucher specimen records (mammal collections of Museum of Zoology at Berkeley and California Academy of Science) (Grinnell 1922; Roest 1984, 1988; Biosearch Wildlife Surveys 1996; Bean 2003). These records were gathered in a summarizing table.

I downloaded GIS (Geographic Information Systems) shapefile data for Santa Cruz County sandhill habitats, originally produced by McGraw (2004) and published by the Santa Cruz County GIS department (Garcia and Price 2015). To evaluate the potential for kangaroo rat habitat within these areas, I used images from Google Earth, Google Maps, and online historical aerial photography, looking for habitat that was not developed, overgrown with trees, or cleared of shrubs.

To identify sites that potentially support *D. v. venustus* I first used ArcGIS 10.4.1 to transform all geographic data into the datum WGS 84. I then overlayed historical record locations onto the sandhill map in Google Earth. I used this map, descriptions of habitat presence and destruction from literature (Lee 1994; Bean 2003; McGraw 2004), and aerial images of vegetation and development to identify potentially suitable habitat that had not been surveyed recently or at all. After I conducted trapping, I used the same methods to compare characteristics of sites with and without *D. v. venustus* in the last two decades (Biosearch Wildlife Surveys 1996, 2014; Bean 2003; Franco 2012).

Assessing Presence Absence at Three Potential Sites

I live-trapped small mammals at three sandhill habitats in Santa Cruz County (Figure 1). Sites were chosen based on known habitat requirements for *D. v. venustus*, as well as accessibility and proximity to Henry Cowell State Park (Bean 2003), the only known extant population. The habitat requirements I used to determine whether sites were suitable for trapping were the presence of Zayante soils for burrowing, presence of silverleaf manzanita and other seed-producing plants for foraging, and some level of open space for locomotion (Bean 2003; McGraw 2004).

Ben Lomond Sandhill Preserve

Trapping was conducted for three consecutive nights in March 2017 using 100 folding Sherman traps. The size of 89 of the traps was 7.62 x 9.525 x 30.48cm (3 x 3.75 x 12") while 11 of the traps were 7.62 x 8.89 x 22.86cm (3 x 3.5 x 9").

Bias Property

Trapping was conducted three consecutive nights in April 2017 using 87 folding Sherman traps on the first night and 100 on each following night. For the first night, 78 traps large (7.62 x 9.525 x 30.48cm) and 9 traps were small (7.62 x 8.89 x 22.86cm). On the two subsequent nights, 89 traps were large and 11 were small.

Olympia Quarry

Trapping was conducted three consecutive nights at the end of April 2017 using 58 folding Sherman traps on the first night and 111 on each following night. For the first night, 53 traps were large (7.62 x 9.525 x 30.48cm) and 5 traps were small (7.62 x 8.89 x 22.86cm). On the two subsequent nights, 89 traps were large and 22 were small.

All Sites

At each location, traps were set for three nights shortly before sunset, baited with oats and roasted sunflower seeds, and supplied with synthetic pillow filling for rodent bedding (Brown 2012). Traps were checked shortly after sunrise, and captured animals were identified to species, marked at the tail-base with a black lab marker, and released at the site of capture. Measurements were taken when necessary for identification (tail, ear, and foot length, weight,

and life stage). Feet were measured without claws, tails were measured without hair tuft, and ears were measured from the bottom notch to the outermost edge. After the first night of trapping, all animals were checked on subsequent mornings for pen markings on the tail to signify a recapture, and were marked if they were not recaptures.

Results

Historical Records and Intact Habitat

Historical records of *D. v. venustus* distribution indicate that their range has shrunk dramatically in the last century (Table 2), supporting the conclusions of previous studies (Bean 2003).

My review of sandhill distribution, combined with recent publications on remaining sandhill chaparral and with aerial images of vegetation and development indicate that much of the historic range is destroyed (e.g. by mining or development) or temporarily unsuitable (e.g. due to fire suppression or clearing of brush) (Table 2; Figure 1) (Lee 1994; Bean 2003; McGraw 2004). Sandhill habitat originally covered over 6000 acres in Santa Cruz County with 40% of that range permanently destroyed by 1994 due to mining and development for residential and commercial purposes (Lee 1994; McGraw 2005). Much of the remaining 60% of these sandhills exist in small, scattered patches and contain a range of specific habitat types that are not all suitable for kangaroo rats. When considering specifically the habitat type most closely associated with *D. v. venustus*, Silverleaf Manzanita Mixed Chaparral, habitat destruction is more severe. This habitat originally covered over 3500 acres and by 1994 had lost over 30% due to mining and development (Lee 1994; McGraw 2004, 2005).

My map of historical records and sandhills, when examined alongside Google Earth images, suggested that although much of the original kangaroo rat habitat has been destroyed or degraded, there are some remaining potential habitats that have not been surveyed recently, with a few sites never trapped for small mammals, such as the Ben Lomond Sandhill Preserve (Table 2; Figure 1).

Assessing Presence Absence at Three Potential Sites

Trapping efforts captured 91 small mammal individuals at Ben Lomond Sandhill Preserve, 52 small mammal individuals at the Bias Property, and 87 small mammal individuals at Olympia Quarry (Table 1). None of my surveys caught *D. v. venustus*, and no signs of their distinctive burrows or tracks were found (Roest 1984).

Discussion

The region surrounding Felton, California contains a number of sandhill sites that support Silverleaf Manzanita Mixed Chaparral habitat, many of which are currently protected by Santa Cruz County and several are managed for conservation (Bean 2003; McGraw 2004, 2005). This suggests sites may exist that support *D. v. venustus*, particularly those only a few miles from Henry Cowell State Park. This includes Olympia Quarry, Bias Property, and Ben Lomond Sandhill Preserve. My trapping effort failed to detect kangaroo rats at these sites that are 2-3 miles away from Henry Cowell (Table 1; Figure 1). This suggests other factors besides soil and vegetation type may be preventing the kangaroo rats from persisting and/or recolonizing sites outside of Henry Cowell. The Olympia Quarry survey did, however, capture two California pocket mice (*Chaetodipus californicus*) (Table 1), a relative of kangaroo rats—they are both in the Heteromyidae family—that also requires soft soil and seed-producing plants (Johnson 2001). Presence of a Heteromyid relative at Olympia Quarry with ecological needs similar to that of *D. v. venustus* may indicate potential for the site to become suitable for kangaroo rat recolonization.

Previous studies discussing the threats to *D. v. venustus* have suggested habitat destruction, domestic cat predation, vegetative succession due to fire-suppression, habitat fragmentation into small patches, and isolation of patches by increased distance as the top threats to kangaroo rats in Santa Cruz County (Bean 2003; McGraw 2004).

Loss of sandhill habitat has been caused largely by residential development, sand mining operations, and commercial development (Lee 1994; McGraw 2004). The portion of the original range of *D. v. venustus* that stretched into the southern San Francisco Bay Area to Belmont has been permanently destroyed by urbanization, fragmentation, and fire suppression (Bean 2003). Much of the historic range in the Santa Cruz Mountains (the largest concentration centered around Felton and Mt. Hermon) has been partially destroyed and fragmented by development and mining (Lee 1994; Bean 2003; McGraw 2005). The original range of silverleaf manzanita in

Santa Cruz County was estimated to cover 1263 ha, with the majority of that range occurring on sandhills; by 1994, over 400 hectares were lost to residential development, quarrying, and commercial development (Lee 1994; Bean 2003). The sandhill regions most closely adjoining the Henry Cowell site were largely destroyed by conversion to mines or residences in the last half of the 20th century (Bean 2003). Additional manzanita habitat has been altered or destroyed by fire suppression and development in the decades since the survey conducted by Lee (1994). Wilder Ranch, for example, has become overgrown due to fire suppression, the only apparent change coinciding with the disappearance of *D. v. venustus* at the site (Bean 2003). Olympia Quarry was made unsuitable by clearing of all manzanita stands for mining operations. The resident *D. v. venustus* population likely depended on these stands for subsistence (Bean 2003). The closest neighboring mine to the Northeast of Henry Cowell, Kaiser Quarry, has been decommissioned and is currently being replanted in hopes of restoring the native vegetation community, as are many of the nearby mines. However, the deep layer of loose sand previously present at these sites has been irrevocably removed, making the sites less suitable for burrows of *D. v. venustus*. This may serve as a substantial obstacle for the spread and recolonization of *D. v. venustus* into these areas (McGraw 2004).

Increase in residential development near sandhills has led to an increase in the threat to *D. v. venustus* by domestic cat predation (Bean 2003). This possibility of threat from domestic cats is made more extreme by the possibility that the slow-moving nature of kangaroo rats makes them easy prey for cats (Roest 1984). Feral cat predation is also a threat to many kangaroo rat species, however it is believed there are no feral colonies in the Santa Cruz Mountains, only in the city of Santa Cruz (Luz de Wit, pers. Comm.). This could be due to predation by large predators such as bobcats and mountain lions (Crooks and Soulé 1999; Smith et al. 2016). With this in mind, the close proximity of many of the sandhill habitats to residential development with domestic cats may be contributing to local extinction of *D. v. venustus* at these sites (Bean 2003). In contrast, the sandhill habitat in Henry Cowell State Park is surrounded by a buffer of protected evergreen forest.

Santa Cruz County's silverleaf manzanita sandhill habitats have also been gradually degraded over the last century from succession caused by fire suppression (Lee 1994; Bean 2003; McGraw 2004; Kauffmann et al. 2015). Manzanita is a fire-adapted plant that has evolved adaptations to thrive in the fire regimes of California's long dry season. These fire regimes are

characterized by frequency intervals of 30-150+ years and high intensity burns that clear entire chaparral stands. To flourish in this environment, the endemic species *A. silvicola* evolved seeds that germinate only following fires, allowing a new stand to grow from the germinated seed bank and quickly fill the space made by the burn. In addition, manzanita has evolved seeds that appeal to seed-burying rodents, facilitating creation of a seed-bank in preparation for future burns (Kauffmann et al. 2015). In the 20th century, the California Fish and Wildlife service prevented most chaparral habitats from burning due to possible hazards to nearby human development. Continued expansion of development in the Santa Cruz Mountains after the 1950s brought fire suppression to an ever-increasing region of the Santa Cruz Mountains. This practice may have been one of the main factors that caused *D. v. venustus* to go locally extinct at Wilder Ranch State Park, as overgrowth has been the only major change to the site since they were found in 1990 by Axtell (Bean 2003). In the last couple of decades, the importance of wildfires for fire-adapted chaparral habitats has been recognized and the policy of prescribed burning has been set in place. This recently enacted practice is beneficial to the health and continuation of fire-adapted manzanita habitats that *D. v. venustus* depends on and may increase the likelihood of *D. v. venustus* expansion outside of Henry Cowell.

In addition to general habitat loss, further fragmentation of sandhill habitat that is naturally patchy hinders the ability of the kangaroo rats to persist in these sites due to limited resources in small habitat patches and increased patch distance from the metapopulation's source population (Cain et al. 2014). The small patch size supports a smaller population, making the population more vulnerable to extinction from stochastic fluctuations, particularly for a species known to naturally undergo demographic fluctuations (Bean 2003). Increased patch distance decreases immigration rates, therefore decreasing the ability of a source population to rescue a declining small population with a new influx of immigrants. This effect is intensified for kangaroo rats due to their limited dispersal ranges with a maximum around 500 meters, depending on species (Jones 1989; Price et al. 1994). Both of these effects can break down normal metapopulation functioning of neighboring patches that normally prevents local extinctions (Bean 2003; Cain et al. 2014). This fragmentation and loss of metapopulation functioning can prevent locally extinct populations from being recolonized by a source population (i.e. Henry Cowell State Park), as may be the case with many of the current sites that seem suitable but do not support *D. v. venustus*, such as Olympia Quarry.

The table I compiled of historical records, Table 2, in combination with my map of records and sandhills (Figure 1), illustrates that the range of *Dipodomys venustus venustus* has contracted at a concerning rate. Although the trend of habitat loss is clear, lack of extensive on-the-ground surveys prevents accurate estimation of how much their distribution has shrunk—i.e. persisting only at Henry Cowell or at additional nearby sites. My results suggest they may be limited to Henry Cowell, supporting the conclusions reached by previous studies (Bean 2003; McGraw 2004; Biosearch Wildlife Surveys 2014). The *D. v. venustus* populations that previously occurred in much of Felton likely went locally extinct because of a combination of threats that include direct habitat destruction, domestic cat predation, fire suppression, patch size reduction, and increased patch distance. Once these populations went locally extinct, the lost metapopulation functioning likely prevented the sites from being recolonized once the habitats recovered. My table and map of historical records serve to aid in future conservation efforts for *D. v. venustus* by gathering the important literature and databases for the topic in one location. Additional surveys of *D. v. venustus* range and intact habitat are necessary to know their current state and the likelihood of their eventual recovery. Due to their limited dispersal ranges and the current fragmentation of potential habitats, they may not spread outside of Henry Cowell on their own, making translocations a possible necessity. Efforts in the past to translocate kangaroo rats have had little success (Biosearch Wildlife Surveys 1996), making any effort to translocate *D. v. venustus* difficult. Prior to any translocation efforts, further research into their habitat requirements and population dynamics is needed, or research into a similar subspecies or species that is not endangered.

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Tables

Table 1. Small mammal captures at all three sites for this study, by species. Capture data is in units of unique individuals captured and unique individuals captured per trap night.
Species keys: DI Ve= *Dipodomys venustus venustus*, CH Ca = *Chaetodipus californicus*, PE Ca = *Peromyscus californicus*, PE Tr = *Peromyscus truei*, NE Fu = *Neotoma fuscipes*

Site	DI Ve		CH Ca		PE Ca		PE Tr		NE Fu	
	indvs	indvs/effort	indvs	indvs/effort	indvs	indvs/effort	indvs	indvs/effort	indvs	indvs/effort
Zayante	0	0	0	0	85	0.283	5	0.017	1	0.003
Bias	0	0	0	0	47	0.164	5	0.017	0	0
Olympia	0	0	2	0.007	30	0.107	55	0.196	0	0
total	0	0	2	0.002	162	0.187	65	0.075	1	0.001

Table 2. Records of historical *Dipodomys venustus venustus* surveys and sightings

Year	Locations	Presence	Evidence	Reference	Trap-nights
2017	Ben Lomond Preserve	No	trapped	This effort	300
2017	Bias Property	No	trapped	This effort	287
2016	Henry Cowell (across Graham Hill)	Yes	photos	Elliot Schoenig, anectodal	N/A
2003	Santa Cruz	Unsuitable	developed over	Google Earth images	N/A
2003	Stanford	Unsuitable	developed over	Bean 2003	N/A
2003	Redwood City	Unsuitable	developed over	Bean 2003	N/A
2003	Belmont	Unsuitable	developed over	Bean 2003	N/A
2003	Kaiser Quarry	Unsuitable	mined	Bean 2003	N/A
2001 & 2002; 2011	Henry Cowell State Park	Yes	photos, genetic analysis; photos	Bean 2003; Franco 2012	4400; 2800
2001; 2017	Olympia Quarry	No	trapped; trapped	Bean 2003; this effort	400; 280
1999 & 2001	Wilder Ranch State Park	No	trapped	Bean 2003	400
1992; 2001; 2014	Bonny Doon Ecoreserve	No	trapped; trapped; trapped	Biosearch 1992, unpublished survey; Bean 2003; Biosearch 2014, unpublished report	150; 400; 150
ca 1990	Wilder Ranch State Park	Yes	unknown	Axtell 1990, unpublished thesis	888
1984	Quail Hollow	No	unknown	Roest 1984	
1984	Crown Rd	No	trapped	Roest 1984	300
1984; 1996	Kaiser Quarry	Yes	tracks, trapped; unknown, in Bean 2003 & McGraw 2004	Roest 1984; Biosearch 1996b, unpublished report	120; unkown
1984	Lockhart Gulch Rd	Yes	tracks, did not trap	Roest 1984	N/A
1984	Olympia Quarry	Yes	photos, measurements	Roest 1984	737
1961; 1984; ca 1993; 1996	Henry Cowell State Park	Yes	specimens[1]measured; genetic analysis; measured, specimens[1]	CAS; Roest 1984; Best et. al 1996; Biosearch 1996a, unpublished report, at CAS	unknown; 285; unknown; 2800
1941	Henry Cowell South	Yes	specimens[2]	CAS	unknown
1940	Bean Creek Rd	Yes	specimens[3]	MVZ, Rudd 1948	unknown
1940; 1942	Berglund Ranch	Yes	specimens[4]	MVZ, Hawbecker 1940	unknown
1940	Mt Hermon Rd.	Yes	specimens[5]	MVZ, Rudd 1948	unknown
1940; 1961	Zayante Rd	Yes	specimens[6]	MVZ, Rudd 1948; CAS	unknown
1938	Stanford	Yes	specimens[7]	MVZ	unknown
1937; 1939	J Enos Ranch	Yes	specimens[8]	MVZ, Hawbecker 1940	unknown
1936	Bear Creek Rd	Yes	specimens[9]	MVZ, Rudd 1948	unknown
1934	Mt. Hermon	Yes	specimens[10]	MVZ	unknown
1933	Redwood City	Yes	specimens[11]	CAS	unknown
1931; 1937; ca 1957; 1984	Bonny Doon Ecoreserve	Yes	specimens[12]; anecdotal; tracks, did not trap	MVZ; Davilla 1980; Roest 1984	unknown; N/A
1930; 1931; 1935; 1941; 1960; 1961	Rodeo (Doyle) Gulch	Yes	specimens[13]	MVZ; CAS	unknown
1908	Belmont	Yes	specimens[14]	Grinnell 1922, Stone 1904 (Acad. of Nat. Sci. of Phila.)	unknown
1907; 1922; 1941	Jasper Ridge Biological Reserve	Yes	specimens[15]	CAS; four in collection Nat. Hist. Mus. of Stanford Univ, Grinnell 1922 ; CAS	unknown
1893; 1908; 1940	Santa Cruz	Yes	specimens[16]	Grinnell 1922, Poole & Schantz 1942, US Biol. Survey; MVZ; MSB	unknown
1868; 1938	Saratoga	Yes	specimens[17]	Grinnell 1922, Gray et al. 1868; MVZ	unknown

Table 2. Footnotes

specimen vouchers:
[1] CAS 12651-12652; CAS # unknown [2] CAS 8579 [3] MVZ 98027 [4] MVZ 98031-98032; 97959-97966 [5] MVZ 108396-108397 [6] MVZ 98028-98029; CAS 12610-12611 [7] MVZ 3678 [8] MVZ 98033, 101054; 98034-98036 [9] MVZ 108389-108391 [10] MVZ 112040 [11] CAS 7521 [12] MVZ 47700-47708; 78303-78307 [13] MVZ 46777-46785; 47695-47698; 68776; 95284-95285; CAS 12563-12566; 12609 [14] CAS-SU # unknown [15] CAS 20785-20788; four in CAS-SU CAS 19324 [16] US Biol. Survey 51852; MVZ 3485-3488; 112041-112044; MSB 189220-189221 [17] MVZ 83475-83481

MVZ= Museum of Vertebrate Zoology at Berkeley
CAS= California Academy of Sciences, Mammal Collection
CAS-SU=former Stanford University Mammal Collection, now part of CAS
MSB= Museum of Southwestern Biology, Mammal Collection

Newly referenced papers: (Stone 1904); (Poole and Schantz 1942); (Gray et al. 1868); (Rudd 1948)

Figures

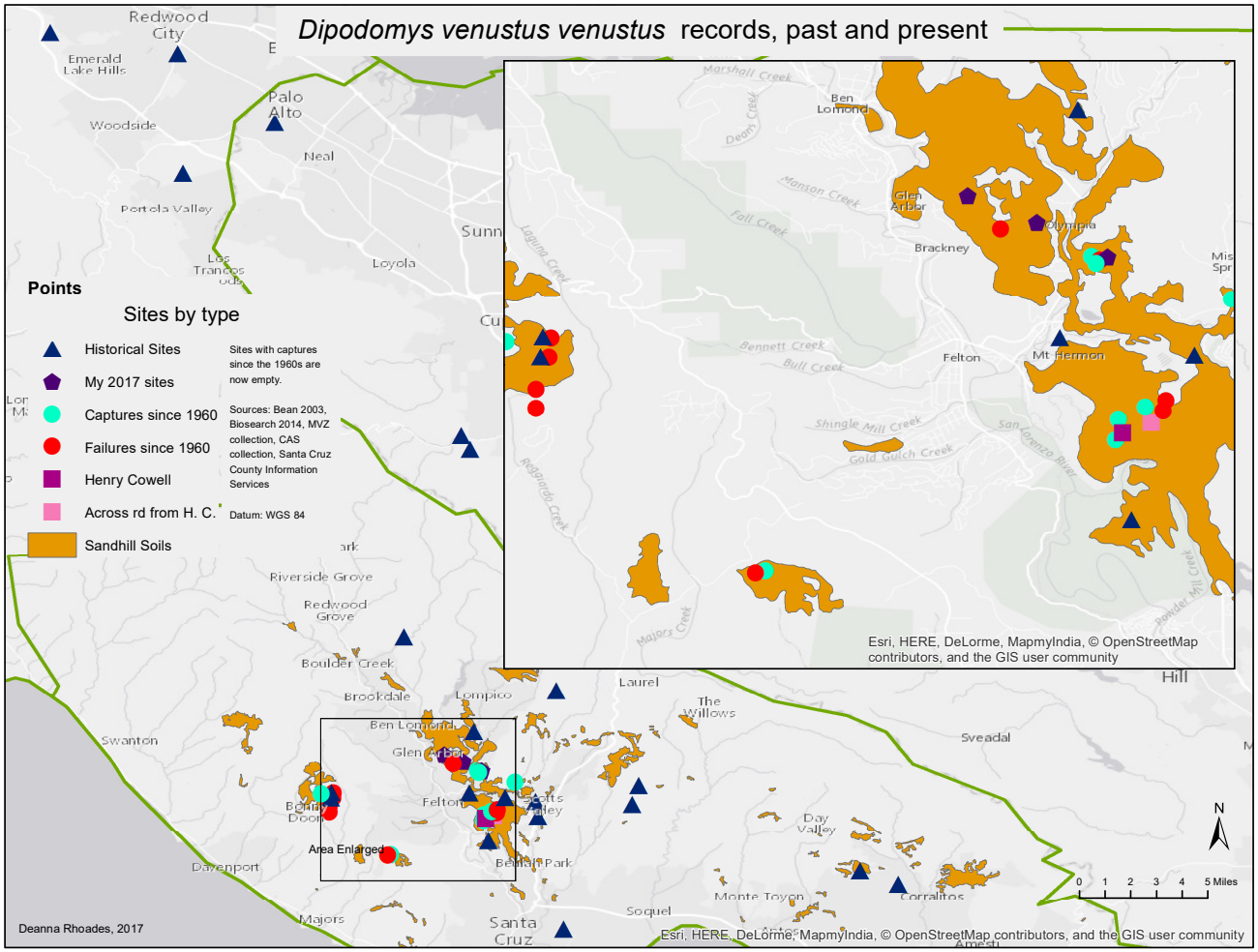

Figure 1. Sites that historically supported D. v. venustus. Legend key: 1) "historical sites" had records before the 1960s, 2) "my 2017 sites" are locations trapped in this study, 3) "captures since 1960" were surveys since 1960 that caught *D. v. venustus*, 4) "failures since 1960" were surveys since 1960 that failed to catch or detect *D. v. venustus*, 5) "Henry Cowell" is the Northernmost sandhill in Henry Cowell State Park, the only site still known to support *D. v. venustus*, 6) "Across rd from H. C." is the unexpected sighting by Elliot Schoenig in 2017 across Graham Hill Rd. from Henry Cowell. All sites with successful trapping since 1960 are thought to now be empty.