

**Habitat preference and distribution of the Northern California legless lizard
(*Anniella pulchra*) in Eastern Contra Costa County**

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ABSTRACT

Contra Costa County is the Northern most range of a California Department of Fish and Wildlife Special Species of Special Concern, the Northern California Legless Lizard (*Anniella pulchra*). Historically extensive habitat for this species was present in the Antioch Dune System which extended along the South bank of San Joaquin River for a distance of about 16 km from the towns of Antioch to Knightsen. Massive habitat destruction started in the late 1800s reducing this once prime legless habitat to a small fraction of the original dune system. For my senior thesis I decided to survey remaining parts of this and other areas of apparent suitable sandy habitat in Eastern Contra Costa County. My goal was to determine the current status of previously known populations in the region and if possible, find new populations. Using literature and museum records, field work was conducted between November 2018 and the end of April 2019. The primary method of surveys was the placement of cover boards that were placed in suitable sandy habitats and were checked at a later date. Lizards are now still very common at two previously known sites, the Antioch Dunes National Wildlife Refuge and the Silvery Legless Lizard Preserve. I compared present and past studies and found that possibly due to reduced predation pressure, incidences of tail loss and regeneration are amazingly lower now at the Antioch Dune site than they were almost 80 years ago.

KEYWORDS

Anniella, Antioch dunes, conservation, population distribution, predation

INTRODUCTION

Coastal sand dunes are small in number around the world but harbor unique endemic plants and animals while providing essential ecosystem services that we cannot live without (Everard et al. 2010). These services cannot be replaced and are home to many unique species, now under threat from human activities. Sand dunes provide important ecosystem services such as water regulation and purification, groundwater storage, and nitrogen fixation (Everard et al. 2010). When sand dunes are located near bodies of water such as the ocean or a river, they dissipate wave energy and are an important transition zone between water and land providing protection from land erosion and flood control (Everard et al. 2010). These sandy ecosystems provide habitat for endemic insects, vertebrates, and plant species with a diversity of ecological niches (Van Dam and Van Dam 2008). Sand dunes and their endemic flora and fauna are under threat because of agriculture, urban development, sand mining, and invasive grasses like *Bromus diandrus*, star thistle (*Centaurea solstitialis*) (Thomson et al 2005, Everard et al 2010).

The sand dunes of the San Joaquin Delta are a unique Californian ecosystem, being the only desert ecosystems in Northern California (Rentz 1997). These unique aeolian deposits of sand have been reduced in size over the last century because of agriculture expansion, sand mining and industry development. (Rentz 1997, Parham and Papenfuss 2009). Historically this dune system extended 16 km along the South bank of the San Joaquin River from Antioch to Knightsen with dunes up to 70 m high (Roof 1969). Only a few small fragments of this dune system remain (Jennings and Hayes 1994). Some species, now threatened, such as the Contra Costa Wallflower (*Erysimum capitatum*), the Antioch Dunes evening primrose (*Oenothera deltoides howellii*), and Lange's metalmark butterfly (*Apodemia mormo langei*) can only be found in these small declining sandy habitats (Thomson 2005, Stark et al. 2012). The Coast Horn Lizard (*Phrynosoma blainvillii*) used to inhabit sand dunes in the San Joaquin Delta but has been extirpated out to only a few populations on Mount Diablo, separating these lizards from other populations East and South of Contra Costa County. Currently the Northern California legless lizard (*Anniella pulchra*), a species that only lives in California sandy soils and dunes, is declining and in danger of disappearing at the northern most part of its range (Parham and Papenfuss 2009, Papenfuss and Parham 2013). The California Department of Fish and Wildlife (CDFW) has designated *Anniella pulchra* a

species of special concern (Thomson et al. 2016). All species of concern observations, including *A. pulchra*, are recorded in the California Natural Diversity Database (CNDDDB).

Anniella pulchra (Anniellidae), the Northern California Legless Lizard, is a unique lizard that has evolved to burrow and live in sandy soil. *Anniella* require moist sandy soil, or loam, with strong rooted and leafy vegetation to allow for their unique lifestyle and attract insect prey (Miller 1944). Rocky soils and areas with eroded or disturbed soils from human activities or intensive winds are not suitable for *Anniella* (Jennings and Hayes 1994). Plant cover from desert scrub, chaparral forests, pine-oak woodland, and streamside growths of sycamores, cottonwood, or oaks provide important microhabitat features (Stebbins 2003). *Anniella pulchra* is silvery or beige above, usually with a black dorsal line running along its body, and pale or bright yellow below. The scales are very smooth for burrowing, giving a shiny appearance (see Appendix A for a photo of a lizard caught at the Silvery Legless Lizard Preserve in the City of Oakley). Adult lizards are small with a short tail, usually between 15.2 and 23.5 cm in total length. (Behler and King 1979). *Anniella* is a sit and wait predator, feeding on insect larvae, beetles, termites, and spiders (Miller 1944). The range of this lizard is from Contra Costa County south to the tip of the Coast Ranges, in parts of the San Joaquin Valley and the western edge of the Sierra Nevada mountains (Thomson 2016).

Anniella pulchra is a cryptic species, living in isolated populations with little gene flow between them. The range of this species significantly shrunk when DNA analysis revealed that this species in California is actually five because of extended population isolation (Papenfuss and Parham 2013). The current threats to this species are habitat loss, alteration, and fragmentation from urban and commercial development, plowing and agricultural expansion, bulldozing, introduced ice plants and non-native grasses (Bettleheim 2005). Other animals like cows and cats, both feral and domestic, contribute to their decline from grazing, trampling and predation (Stebbins 2003, ECCC HCP/NCCP 2006a). Besides loss of sand dune habitat from human expansion, invasive ice plants (*Carpobrotus edulis* and *Mesembryanthemum crystallinum*) have reduced soil moisture and the number of insects that inhabit the sand. They have no leaf litter and poor root structure, making the sand unsuitable for many herps, while outcompeting native plants that provide good microhabitats (Kuhn et al. 2005, Jennings and Hayes 1994). In Contra Costa County, there are scattered records of lizard accounts through Antioch, Oakley, Brentwood, and Stewartville (Bettleheim and Thayer 2006, CNDDDB). There are currently two preserves in Contra

Costa County that protect the legless lizard, Antioch Dunes National Wildlife Refuge (ADNWR) and the Silvery Legless Lizard Preserve (SLLP). Still, population estimates for this species in Contra Costa County are outdated (Papenfuss and Parham 2013, Bettelheim and Thayer 2006).

The preferred habitat of *Anniella pulchra*, like other *Anniella* species is sandy or loose loamy moist substrates that allow for burrowing and shedding (Thomson 2016, ECCC HCP/NCCP 2006a, Stebbins 2003). Lizard population densities have been reported associated with certain plant species that provide leaf litter and strong root structures attracting preferred prey and offering cover. Large lupines (*Lupinus arboreus*, *Lupinus chamissonis*, *Lupinus albifrons*), mock heather (*Ericameria ericoides*), and Coast Live Oak (*Quercus agrifolia*) are among the most common indicators for this species of *Anniella* (Kuhn 2005, Miller 1944). Some populations have been observed in irrigated gardens and in other urban areas if native bushy plant cover and sandy soil is present (Thomson 2016). This suggests that there is hope for lizards to be able to survive in moderately altered environments. However, locations and population density estimates for this lizard are scarce, geographically vague, or on land no longer suitable due to development. The key reason for lack of species evaluation is little sample data and comparison of prime habitat with dense populations (Jennings and Hayes 1994). This lizard is rarely observed above ground and requires extensive search efforts to be found (Param and Papenfuss 2009).

Due to the lack of current data on the distribution of these lizards in Contra Costa County, I decided to do a survey to updated information on legless lizards for my senior thesis. The goal of my research was to survey locations of documented *Anniella pulchra* populations at the northern most part of its range, specifically on East Bay Park District land which protects these species on their parkland. Past multi-year studies of *Anniella pulchra* have been conducted at Monterey Bay and parts of Contra Costa County giving us information on the behavior, soil and vegetation preference of this species (Kuhn et al. 2005, Miller 1944, Bettelheim and Thayer 2006). By conducting this research, new information about soil, vegetation preference, population densities and distribution can be obtained for Contra Costa County legless lizard populations. The results of this study will be provided to the East Bay Regional Parks District, the US Fish and Wildlife Service, California Department Fish and Wildlife, City of Oakley with information to update their conservation decisions for this species

METHODS

Study areas selection

To select study sites, I used VertNet, iNaturalist, and California Natural Diversity Database (CNDDDB) observations of *Anniella pulchra* cross-referenced with geospatial datasets of soil maps overlain on Google Earth (USDA 1977). Tammy Lim (East Bay Regional Parks) provided CNDDDB occurrence points, and GIS data of soil types and East Bay Regional Park property lines. I visited all of these sites from Nov 2018- Feb 2019 looking for the best areas that fit microhabitat preferences of *Anniella*. I was accompanied by Ted Papenfuss, a frequent collector and researcher of *Anniella*. If both of us agreed that the site was not suitable because of too much invasive grass, shade, or not good soil, the site was not checked for lizards. After these visits, I narrowed my study area to 5 sites, all areas that I believe could have populations of these lizards and land where permission to dig is allowed and easily accessible (Figure 1). Sites 1, 2, and 3, have previous CNDDDB siting's of *Anniella pulchra*.

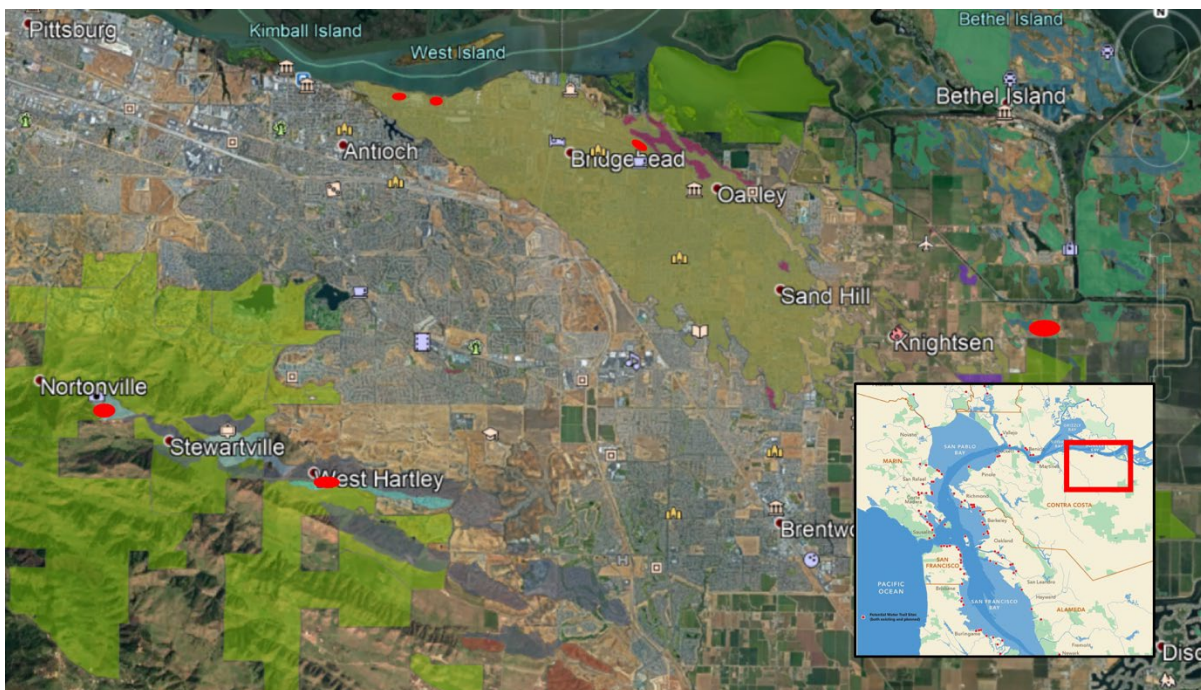


Figure 1. CC map and study areas. The red ovals correspond to each study area. The light green represents East Bay Park property. The other colors represent sand, loamy sand, and sandy loam soil types. From top to bottom the areas searched are 1. Two points, West (Stamm Unit) and East (Sardis Unit) sides of ADNWR, 2. Sliver Legless Lizard Preserve, 3. Undisturbed land of the Nunn Property, 4. sand near Chaparral loop trail in BDM, and 5. Sand at Deer Valley in West Hartley,

To improve chances of observing lizards, I placed cover boards at all of my sites, to add more cover and attract lizards and lizard prey. Many of my sites have little leaf litter present and cover boards act as a place to search while mimicking natural cover of legless lizards. Flat cardboard boxes or asphalt roof tiles were used to act as cover because of availability. Cardboard will form to the terrain after a rain making a more attractable home for legless lizards and prey, and asphalt roof tiles warm up in the sun attracting lizards closer up in colder weather. For sites with cows, asphalt roof shingles are used because cows are known to eat the cardboard (Jennings and Hayes 1994). The Nunn Property site had one giant mat coverboard and 10 corrugated metal roof panels that will not be counted in coverboard placement because they are there for another study. These cover boards will still be searched and incorporated into the results. To avoid biased for the different number of coverboards at each site and the size of each area, the time (in minutes) spent digging and looking under cover is recorded for each site. GPS Kit app was used to record the location of each coverboard and areas searched. Each coverboard was labeled with a number starting from 1.

Site visits and data collection

To collect data about each study location, I photographed different habitats of each site, recorded information on dominant vegetation and sand dune type plants, and the soil type. I also recorded invertebrate species encountered under cover. General notes like temperature, date, time, and weather conditions were also recorded for consistency among searches. I searched for legless lizards by digging under coverboards and under leaf litter and bushes near sand plots using hand tools and hands digging to depths of about 15cm. Initial searches were conducted at least one month after coverboards were placed. Sites were surveyed after rains when the weather was warm and sunny. Lizards are more likely to be seen and closer to the surface on sunny days (Shaw 1953). All our surveys were conducted from late March to the end of April. Sites where no lizards were found were surveyed twice, waiting at least two weeks after the first survey to allow for soil disturbance to pass. At the request of the US Fish and Wildlife Service, because of sand dumping on the Stamm Unit of ADNWR, any lizards found there will be translocated to an area of stable dunes away from dumping area. Sand dredged from the San Joaquin River will be dumped on the

West side, Stamm Unit, of the Antioch dunes to help restore dune habitat (Louis Terrazas Wildlife Refuge Specialist, *personal communication*).

To record information on habitat preference for *A. pulchra*, I dug in the sand and recorded an approximate depth where every lizard was found. To get an estimate for lizard health and age, I recorded snout-vent length (SVL) and total body length for each lizard captured. Lizards were oriented on a gridded paper of known measurements and a photo was taken to record size. Using ImageJ, lizard length can be calculated (see Appendix B for more details on measurement technique). A study on growth by Miller, 1944 was used to estimate the age of all the lizards found. I took a photo of each lizard to serve as ID when resurveying as well as to note if the tail was regrown, to measure predation. *Anniella* readily drop their tails to survive a predation attack. When they grow their tail back it will always have a black tip at the end of the tail making it easy to determine if the original tail was ever lost (Miller 1944). The type of cover and species of nearby vegetation were recorded for all searches regardless of lizard observation. This was used to establish vegetation cover preference for habitats.

Data analysis methods

Three dot plots are created to analyze different details of size, age distribution, and predation differences across sites using Rcmdr. The first plot looked at overall size distribution for SVL so age classes could be assigned. Another plot looked at tail loss among all sites to look for correlation among age and tail loss. The third compared sizes across all the localities. A graph showing soil depth of each lizard was prepared using Rcmdr. A chi-squared test of significance was used to compare tail loss from my present study at Antioch Dunes to a previous study at the same site by Miller in 1940s.

RESULTS

Study areas

I placed 88 coverboards across 5 sites, 32 asphalt and 56 cardboard. The ADNWR has cover placed at two localities, all other sites have cover in one location. All 10 coverboards at the

Nunn Property site were eaten by cows and thus were useless. The corrugated sheet metal cover was also indented concave and disturbed by the cows on the property. Seven digs with about 3 minutes each and 20 cm of effort was done here to look for legless lizards. Little to no leaf litter is present at this site, digs were done where cover used to be and at high concentrations of surface sand.

Four different soil types occur at the sites: Dehli Sand, Briones loamy sand, Gaviota sandy loam, and Piper fine sandy loam. Dominant vegetation from trees to shrubs to grasses is different across the various sites, ADNWR and SLLP being the most similar (see Appendix C for photos of each study site). All of the sites where cover was placed had sandy soil and contained various potential *Anniella* invertebrate prey. The most frequently encountered were beetles, beetle larvae, termites, and ants (see Table 1).

Table 1. Study Areas: sand type, dominant vegetation, coverboard placement time, number of lizards found and frequent invertebrates encountered is summarized here

Site	soil type	dominant vegetation	coverboards placed (#)	coverboard time (days)	lizards found	Prey and predators observed
ADNWR W	Dehli sand	Silvery Bush Lupine (<i>Lupinus albifrons</i>), Telegraphweed (<i>Heterotheca grandiflora</i>), Coast Live Oak (<i>Quercus agrifolia</i>), Vetch (<i>Vicia sp.</i>), Tall grass	16	37	5	California Harvester Ants, Argentine Ants, Giant Millipedes, Earwigs, Termites, Beetle larvae
ADNWR E	Dehli sand	Silvery Bush Lupine (<i>Lupinus albifrons</i>), California Croton (<i>Croton californicus</i>), Telegraphweed (<i>Heterotheca grandiflora</i>), Coast Live Oak (<i>Quercus agrifolia</i>), Vetch (<i>Vicia sp.</i>), Buckwheat	24	47	4	Giant Millipedes, Centipedes, Cockroaches, California Common Scorpions, Harvester Ants, Darkling Beetles, Ground Beetles,
SLLP	Dehli sand	Silvery Bush Lupine (<i>Lupinus albifrons</i>), Telegraphweed (<i>Heterotheca grandiflora</i>), Coast Live Oak (<i>Quercus agrifolia</i>), Vetch (<i>Vicia sp.</i>), Tall grass, Deerweed (<i>Acmispon glaber</i>)	10	45	8	Giant Millipedes, California Harvester Ants, Gopher Snakes
BDM	gaviota sandy loam	California Yerba santa (<i>Eriodictyon californicum</i>), Chamise (<i>Adenostoma fasciculatum</i>), Black sage (<i>Salvia mellifera</i>)	15	49	0	California Harvester Ants, Ground Beetles, Termites, Jerusalem Crickets
Deer Valley	briones loamy sand	short grasses, Miniature Lupine (<i>Lupinus bicolor</i>)	16	37	0	California Harvester Ants, Darkling Beetles, Beetle larvae, Jerusalem Crickets, Black Widows
Nunn	Piper fine sandy loam	Russian Thistle, various grasses	10	60+	0	Darkling Beetles, Earwigs

Lizard ecology and site association

Eighteen lizards at two sites were found during the first survey of all cover board localities on April 7th for ANDWR, and April 10th for SLLP. 5 lizards at ADNWR West, 4 at the East side. 9 lizards were found at SLLP. The SLLP has only 10 cover and is the smallest area of all the sites, but results suggest the highest density of lizards. All lizards were found under cover boards except two, both at SLLP. They were found under natural cover on February 24, 2019. One lizard was found under a Silvery Bush Lupine while moving sand to place a cover board, the other was under an old wooden fence board. One third of the lizards were seen at the surface of the soil under cover (see Figure 2). At the localities where lizards were found under cover, 4 were found in open areas, 9 under Coast Live Oak, and 5 under lupine bushes. There were 8 pieces of cover in open areas, 20 under oak trees, and 7 under lupine for the groupings of cover where lizards were found.

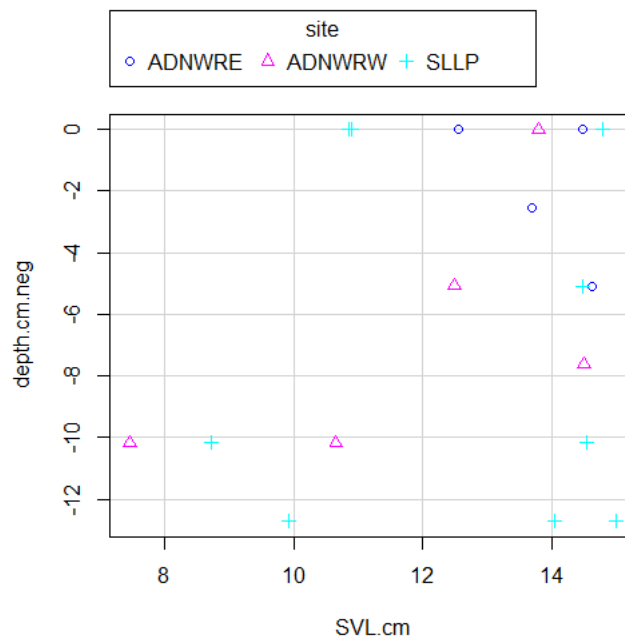


Figure 2. The relative depth \pm 2cm at which every lizard was found at each cover locality is shown above

The SVL ranged from 74.5 to 150.0 mm, with the largest found at SLLP (see Figure 3). The total length ranged from 109.0 to 232.7 mm, with the largest with an intact tail found at ADNWR East.

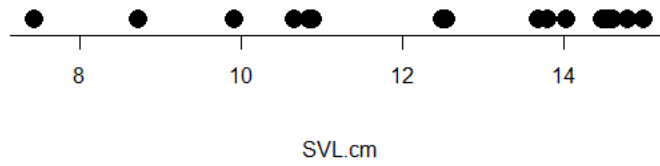


Figure 3. All 18 lizards captured and measured using imageJ. About half are adults and fully grown, as shown by the clumps in the 14 cm range

Five lizards had regrown tails, all being adult lizards (see Figure 4). Eight out of nine lizards at ADNWR had intact tails and the only lizard with a lost tail was found under a coverboard on the East side. Five out of nine at SLLP had intact tails. The average SVL of all 18 lizards collected is 126.4 mm, and 188.6 mm average total length. The average adult, > 120 mm, SVL for ADNWR is 137.4 mm and 145.7 mm for SLLP. Five adults were found at both sites (see Figure 5).

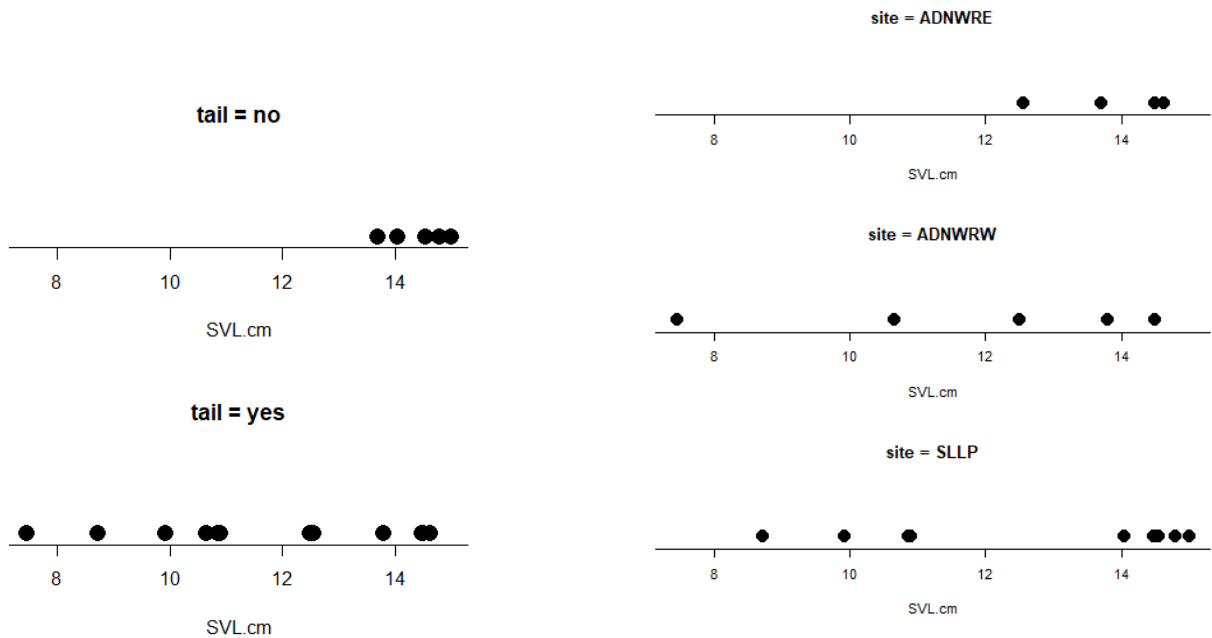


Figure 4. Tail loss among all lizards. Only adult lizards have a lost tail.

Figure 5. SVL of all lizards split by locality. As can be seen on average the adult lizards were bigger at SLLP.

DISCUSSION

Anniella pulchra were only seen at 2 out of the 4 sites where cover survived, Antioch Dunes National Wildlife Refuge and the Silvery Legless Lizard Preserve, despite two surveys at Black Diamond Mines and Deer Valley. Antioch Dunes and the legless lizard preserve are part of a large historic dune system that was originally 16 km long with dunes up to 70 m high along the South bank of the San Joaquin River (Roof 1969). Black Diamond Mines and Deer Valley have patchier areas of sandy soil and are not coastal habitat. The 18 lizards that were found suggest different population density and predation variation among the Dehli Sand sites, ADNWR and SLLP. There is only modest conservation protection for this species since is only listed by the state of California as a Species of Special Concern, rather than a higher level of protection such as State Threatened, State Endangered, Federally Threatened, or Federally Endangered. Several communities in Eastern Contra Costa County require developers to include a number of species in their environmental impact studies in order to receive permits for development. The permit fees are used for habitat purchase or improvement and *Anniella pulchra* is one of the species on their list.

These areas where lizards were found, ADNWR and SLLP, are fragments of large dune and sandy soil system about 16 kilometers long along the south bank of the San Joaquin River between Antioch and Brentwood. This presumed *Anniella* habitat is now fragmented due to extensive human modification over the last 150 years. Most of this once continued habitat has been fragmented by urbanization, agriculture, and extensive sand removal (Roof 1969). I found 18 lizards with only 50 coverboards at ADNWR and SLLP, and none at BDM at Deer Valley which totaled 28 coverboards. BDM and Deer Valley were even checked twice, but no lizards were found. This is likely because densities are low in the small areas of sandy soil and population fluctuations may be more severe due to conditions such as drought, that may cause population declines. Important indicator species such as lupine and Coast Live Oak are absent from these sites. Previous observations (Bettelheim and Thayer 2006, CNDDDB) have in last 50 years only observed *Anniella* in areas of Dehli and Piper sands in the Antioch in Oakley Area.

It could be that these sand types have larger populations of lizards because of historically being part of a massive sand dune ecosystem. Even in these smaller fragments, densities remain high because of sandy soil, suitable vegetation, and habitat protection. These small fragments can support large densities because *Anniella* do not need large territories (Miller 1944). When revisiting SLLP 45 days after placing cover and discovering a legless lizard, the same lizard was

found in the same location under the cover in the sand. However, one CNDDDB observation suggests that populations are still present outside of Antioch and Oakley. In 2002 and 2004, two lizards were seen near my Deer Valley coverboard placements. I did not find any here likely because of smaller populations due to sand fragmentation, and because only a modest amount of cover was placed for a short period of time. This site and BDM, have potential and should not be abandoned.

Comparative Studies

A previous study was done at the Antioch Dunes site over a period of several years prior to 1944 (Miller 1944). This study found a total of 79 lizards of *A. pulchra* at the Northwest part of Antioch dunes by the San Joaquin River. The location of my study at ADNWR is presumed to be close to or at the location of where his surveys were done. Miller found that 69% of the 79 lizards at the Antioch Dunes to have black tips and lost their tails from predators. Only one lizard out of nine total observations, 11.1%, on what is now the ADNWR had a regenerated tail. Using a chi-squared test of significance, comparing 55/79 lizards to 1/9, this is a highly significant decrease in tail loss ($p=0.0023$). The substantial reduction of habitat since Miller in 1940s of the Antioch Dunes has resulted in a reduction of suitable habitat for this lizard, while at the same time a reduction in habitat and extirpation of even more predators. For example, a potential predator, the Glossy Snake (*Arizona elegans*) appears to have become extinct in Contra Costa County over the last 50 years (Crawford 1958). If you take into account the whole dune system and sandy substrates, it stretched from Antioch to Brentwood at the time of Miller's observations and included the dunes which are now the Oakley Preserve. If we include the tail loss data from both ADNWR and SLLP as part of historical Antioch Dunes, present tail loss is still extremely low, 5 out of 18 compared to 55 out of 79 that Miller found using a Chi-squared test ($p=0.0001$). Although a relatively small sample size, the level of predation at the SLLP may be greater than at ADNWR because of domestic cat predation from the adjacent suburbs.

Miller recorded size and growth of these lizards and created age and maturity classes based on size. Based on Miller's age and size class system, I compared my age distribution data with Kuhnz et al, a translocation study done in Moss Landing, California in 1997. This study found 3,582 lizards in 1.57 ha area in Moss Landing. The purpose of the study was a temporary

translocation, while invasive plants were removed from the habitat. Part of the study included recording size distribution of lizards found. Lizards are classified as one year old or younger with SVL less than 82 mm, 2nd year immature or subadults between 82 and 120 mm, and adults over 120 mm (Miller 1944). For comparisons of percent of each age class at the three different locations (Table 2). Adult lizards make up the majority of all three samples, suggesting that once the lizards reach adulthood they survive for some years.

Table 2. Age class distribution: percentage of total collected lizards of each age class from ADNWR, SLLP from my study, and Moss Landing from Kunhz is shown below.

Age class	ADNWR (N=9)	SLLP (N=9)	Moss Landing (N=3.582)
Young of the year	11.1%	0%	6.6%
Immature and subadults	11.1%	44.4%	35.8%
Adults	77.8%	55.6%	57.6%

The California Department of Fish and Wildlife lists *Anniella pulchra* as Species of Special Concern. This is a low level of protection that requires this species to be included in environmental evaluations but the state does not require any mitigation if the species is found. However, cities like the City of Oakley, can use this listing to add city protection to set aside land to create prime habitat for species. The city of Oakley required a developer to donate prime legless lizard habitat as a preserve before permits were issued approving development of a housing project. This preserve was originally managed by the East Bay Regional Park District in the 1970s, but was transferred to the City of Oakley in 2007 for administrative purposes (Jesse Dela Cruz park and landscape superintendent Oakley California, *personal communication*). Although, less than an acre, this preserve is in my opinion the most prime habitat for legless lizards in Contra Costa County. The Silver Legless Lizard Preserve has a denser community of Coast Live Oaks and Lupine compared to the Antioch Dunes, and I found 9 lizards under 10 coverboards during a single visit in less than an hour. This is an example of how local community protection can be used to preserve species that do not have higher level protection. Local community protection persisted because Oakley is a member of the East Contra Costa County Habitat Conservation Plan/ Natural Community Conservation Plan (ECCC HCP/NCCP 2006b). This organization provides potential developers in advance with any conservation issues that would need to be addressed before developing an area.

The Antioch Dunes National Wildlife Refuge was established in 1980 to protect the Antioch Dunes Evening Primrose (*Oenothera deltoides howellii*), the Contra Costa Wallflower (*Erysimum capitatum*), and the Lange's Metalmark Butterfly (*Apodemia mormo langei*). Although not federally protected, the Northern California Legless Lizard (*Anniella pulchra*) is commonly found on the site. The Antioch Dunes protects these endangered plants and the endangered butterfly but also protects this lizard. The manager of the dunes gave me personal permission to conduct surveys at this habitat. The Refuge coordinated with the Army Corp of Engineers and the Port of Stockton to dump sand that is dredged out of the San Joaquin River, 600 yards from the Stamm Unit, on the preserve to restore habitat. So far since 2013, 68,000 cubic yards have been pumped into the site. Hundreds of Antioch Dunes Evening Primrose can be seen across the top of the newly created dune habitat. I was asked to translocate lizards at the Stamm unit to a part of the dunes where sand dumping will not occur. For the future protection of this lizard, translocation of lizards at the Stamm Unit will be continued.

Ted Papenfuss, and the East Bay Regional Parks will take over surveys and management of the cover board that were placed at the four sites. There are other sites in Contra Costa County, such as Morgan Territory Regional Preserve, Vasco Caves Regional Preserve, and Big Break Regional Shoreline which are likely to have populations of legless lizards. The South tip of Big Break Regional, which is extremely close to the SLLP, has sandy habitat which was connected to the Oakley Preserve site before a housing development was built between them. Vasco Caves and Morgan Territory both require the presence of a cultural curator to allow digging for lizards. These sites should still be surveyed because a lizard was observed by a park staff at Vasco Caves, and the parks are close to each other with suitable soil (USDA 1977). In conclusion this study provided current useful data on the present status of Northern California Legless Lizards (*Anniella pulchra*) in Eastern Contra Costa County. This information is being given to relevant governmental agencies including the East Bay Regional Park District, the City of Oakley, the California Department of Fish and Wildlife, and the US Fish and Wildlife Service.

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APPENDIX A: Adult *Anniella pulchra*



Figure A1. Adult *Anniella pulchra*. Ted Papenfuss holds an adult lizard just after capture on the Silvery Legless Lizard Preserve. During capture the tail was autotomized to increase chances of escaping “predation”. This lizard shows typical adult color patterns of beige above and yellow below with a lateral black stripe.

APPENDIX B: Lizard SVL and total length measurement



Figure B1. ImageJ screenshot of measurement technique. Lizards are oriented on a graph paper that has squares each one quarter inch. A segmented line can be drawn from head to vent or tail of the lizard. This allows for a great accuracy of lizard size. Photos are not taken until the lizard is flat on the paper and completely still.

APPENDIX C: Study Site Photos



Figure C1. Stamm Unit-ADNWR. Habitat where cover was placed consisted mostly of Coast Live Oak driplines. Previous sand dumpings on site can be seen in the back.



Figure C2. The Sardis Unit-ADNWR. This side of the dune has a large hill with Coast Live Oak and Lupine bushes. This side of ADNWR has Contra Costa Wallflower (*Erysimum capitatum*), yellow flowers, and has had no dune modification.



Figure C3. Silvery Legless Lizard Preserve. *Lupinus abilfrons*, one of the best indicator species for *Anniella* is shown here at the SLLP. This site had the highest concentration of Coast Live Oak and Silvery Bush Lupines. A lizard was seen under this cover board on a warm day on April 10th, 2019.



Figure C4. BDM habitat. No lizards were seen at this site but, the soil West of Chaparral Loop is incredibly sandy near these Black Sage (*Salvia mellifera*) and Yerba Santa (*Eriodictyon californicum*) plants. A coverboard can be seen on the far left of the photo at the edge of the grass.



Figure C5. Deer Valley habitat. Deer Valley had only small fragments of surface sand near the north edge of the park. No shrubs are present but soil texture and inveterbrates present suggest great habitat. Small plants such as Miniature Lupine (*Lupinus bicolor*).