EFFECT OF CATTLE GRAZING ON LIZARD DIVERSITY IN MANAGED CENTRAL CALIFORNIA GRASSLANDS

DAVID L. RIENSCHE, East Bay Regional Park District, 2950 Peralta Oaks Court, P.O. Box 5381, Oakland, CA 94605.

ABSTRACT: Management of vegetation in undeveloped lands, especially those at the interface with urban landscapes, is critical to the maintenance of plant and animal species diversity and public safety. Research can help develop vegetation management strategies to achieve fire safety goals, support ranching programs and provide suitable grassland habitat for special status and other wildlife species. I studied how the abundance of lizards was affected by grazing and how different levels of residual dry matter (RDM) are associated with lizard densities. Lizard density was significantly greater in grazed areas than ungrazed grasslands. Lizard population densities, on average, were 2.75 times higher in these managed grazed grasslands than in ungrazed grasslands. Lizard densities decreased with increased vegetation height and thatch density (RDM levels). Relatively low, moderately grazed, RDM levels, 2200 - 5530 kg/ha, appear to support the highest lizard population densities. In particular, adult Western fence lizard (*Sceloporus occidentalis*) populations averaged three times greater density in grazed areas than ungrazed grasslands. These results help managers understand some of the effects of grassland management on Central California lizard populations.

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Throughout history climatic variation, fires, burrowing rodents and native herbivores comprised natural disturbance factors influencing grassland ecology. Wildlife managers often attempt to simulate these ecological forces, fire or herbivory, to manipulate vegetation to meet management goals. For more than 50 years, the proper role of livestock in wildlife habitat management has sparked controversy. For example, Fitch (1948) and Howard et al. (1959) suggested that the California ground squirrel (*Spermophilus beecheyi*) competed with livestock for green forage. Those studies, conducted at the San Joaquin Experimental Range in Madera County, California, justified suppression of ground squirrel populations until Schitoskey and Woodmansee (1978) showed that cattle and ground squirrels feed on different plants during the green forage season (February, March and April).

Relationships between livestock grazing and wildlife populations are difficult to define because grazing intensity, time, and distribution often differs (Kirsch et al. 1978). Numerous studies on western rangelands have assessed the effects of livestock grazing and the resulting changes to plant species. Heavy livestock grazing reduces biomass and diversity of annual forbs and grasses, and changes shrub species composition (Brown and Schuster 1969, Laycock 1967, Potter and Krenetsky 1967, Ellison 1960, Byldenstein et al. 1957). In contrast, based on a 55-year study, species richness and diversity in shortgrass prairie were higher in moderately grazed plots than in ungrazed plots (Hart 2001). Likewise, plots in Nevada showed few changes in species composition, cover, density and production inside or outside herbivory exclosures over a 65-year period, indicating that recovery rates were similar under moderate grazing and on grazing exclusion sites (Courtois et al. 2004). Additionally, species richness and cover of native annual forbs at a site in California were higher in grazed sites, and this effect was concomitant with decreased vegetation height and litter depth (Hayes and Holl 2003).

Only a few studies have addressed effects of grazing on reptile populations. At a Mojave Desert site in Southern California, plots without heavy sheep grazing had twice the number of lizards and three times the plant biomass of grazed plots (Busack and Bury 1974). Pianka (1966) documented that vegetative communities with more plant structure supported more desert lizard species than those with less plant structure. Also, changes in vegetation structure due to overgrazing reduced overall lizard abundance and diversity in the Sonoran Desert scrub Jones (1981a). However, not all 23 species of lizards decreased in number, and heavy grazing may in fact increase the abundance of some species. Grazing can cause reduction in debris heaps, which offer important sources of food and cover for the western terrestrial garter snake (*Thamnophis elegans*) inhabiting high elevation riparian habitat, and may result in the species decline Szaro et al. (1985). In contrast, there is a general trend of greater abundance of small vertebrates with decreasing levels of residual dry matter in arid areas of the San Joaquin Valley of California (Germano et al. 2001). This study showed that heavy growth of non-native grasses in average and above-average rainfall years seemed to depress populations of a variety of lizards and rodents, including the endangered blunt-nosed leopard lizard (*Gambelia sila*), giant kangaroo rat (*Dipodomys ingens*), and the threatened San Joaquin antelope squirrel (*Ammospermophilus nelsoni*). The invasion of non-native grasses has been a significant cause for the decline of lizard species in brushland and dune habitats in the Great Plains (Scott 1996). Likewise, successive years of increasing plant biomass started to decrease blunt-nosed leopard lizard survival (Germano and Williams 2005). Thick herbaceous plant cover impeded the leopard lizard's ability to run, making it possible to capture adult lizards by hand, something they could never do when the ground was more open (Germano and Williams 2005). In Nebraska, the abundance of lesser earless lizards (*Holbrookia maculata*) was positively associated with cattle grazing and soil disturbance (Ballinger and Jones 1985, Ballinger and Watts 1995). Furthermore, the lesser earless lizard was more abundant on Gunnison's prairie dog (*Cynomys gunnisoni*) colonies than off, suggesting that the rodent burrows act as a refuge from predators (Davis and Theimer 2003).

The work presented here is the first study to compare lizard populations within managed grasslands of Central California. The primary goal of this study was to compare how vegetation mass and structure affects lizard species densities under year-long grazed, seasonally grazed, and ungrazed situations. The second goal of this study was to systematically document different grassland RDM and their associated effects on adjacent lizard species densities. The third goal of this study was to compare grazing treatments on the density of Western fence lizard by size class, as this species was the most common lizard in the study area and represents a major food resource for the endangered Alameda whipsnake (*Masticophis lateralis euryxanthus*).

STUDY AREA

I studied lizard densities at Garin Regional Park in Hayward and Sunol Regional Wilderness near Sunol, California. Both properties are part of the East Bay Regional Park District, a two-county special district with about 38,850 ha in Alameda and Contra Costa Counties. I selected the precise coordinates of sampling sites with a random number table to reduce bias and increase statistical validity. All sites possessed similar topography, rainfall, and elevation to minimize the effects of natural environmental factors. I used a Global Positioning System (GPS) receiver to find sites on the ground.

Annual grassland is the predominant plant community at both locations. The vegetation is composed primarily of non-native annual grasses and herbs with scattered oak trees. Non-native grasses, which were introduced to California by early settlers, are the major component of the region's grassland flora. Common non-native grasses at the study sites included wild oats (*Avena fatua*), rye grass (*Lolium multiflorum*), annual bluegrass (*Poa annua*), foxtail barley (*Hordeum jubatum*), and ripgut brome (*Bromus diandrus*). Other introduced species included black mustard (*Brassica nigra*), poison hemlock (*Conium maculatum*), sweet fennel (*Foeniculum vulgare*), and wild radish (*Raphanus sativus*). These weedy species may be expanding their populations over time to dominate ungrazed sites.

METHODS

Lizard species richness at Garin Regional Park and Sunol Regional Wilderness is low with only the Western fence lizard, Western skink (*Eumeces skiltonianus*), California whiptail (*Aspidoscelis tigris mundus*) and Southern alligator lizard (*Elgaria multicarinata*) comprising the majority of the species in this area. I used 35 trapping arrays, each with multiple trapping sessions, throughout three summer seasons: 2002, 2003 and 2004. I characterized 14 year-long grazed sites by the existence of cattle trails and the presence of livestock year round. The seven sites I characterized as being seasonally grazed had cattle trails but cattle were only present December through June each year. The 14 ungrazed sites had not been grazed by livestock for > 15 years. At each lizard trap site, I collected daily air temperature, weather conditions, number of each lizard species captured, number of recaptured individuals, age, sex, snout to vent length (SVL) of each individual, and the identification of other trapped vertebrate species. I toe-clipped each lizard with a unique pattern for later identification (Tinkle 1967), and drew a colored numeral on the ventral surface of the body using a non-toxic felt marker. Each lizard was released at its point of capture after handling.

I also recorded the characteristics of each site and the RDM each field season. I measured RDM by collecting three samples at each trap array site. At each site, I clipped herbaceous vegetation 13 mm from the ground within 0.1 m^2 plots. Loose plant material that could be easily picked up was included in the sample. The dry samples were air dried and weighed using a gram scale (Davis 1976, Hormay 1942, Frost 1988, Heady 1994, NRC 1994, UCCE 1994).

To capture lizards, I used drift fences in combination with pitfall traps, following a design by Jones (1981a, b). Each trap array had three drift fences (7.3 m) and four buckets (substituting 15 l for recommended 19 l) comprised each trap array. I sheltered traps from direct sunlight using 13-mm thick plywood. A trap-cover locking system was attached to the drift fence system to prevent predation in the pitfall traps over night. In addition, I placed a small, damp, nontoxic sponge in the bottom of each trap to reduce the risk of amphibian mortality, and I drilled 6-8 holes in the sides of the traps to allow water drainage. I checked temperatures in these covered pitfall traps during the mid afternoon heat to make sure that the critical thermal maximum (44–45 °C) for the Western fence lizard would not be exceeded. Also, I placed "Safe-houses" modified from the design by Padgett-Flohr and Jennings (2001) in the bottom of each pitfall trap to reduce the risk of harm to nocturnal mammals. During the sampling period, I checked traps once every 24 hours; the traps were opened at 0730 and were checked the following morning. The sampling periods consisted of a maximum of three consecutive days in June, July, and August for three field seasons (2002, 2003, and 2004). I tightly covered all bucket traps between sampling periods and removed the buckets at the conclusion of the study.

Lizard density was calculated as the number of lizards caught within 24 hours in one array approximately 1000 m^2 (one lizard array night). In addition, 25 out of the 616 lizards were recaptures among all 35 trap arrays during this three year study. Lizards caught more than once were not included more than once in the density estimate. Densities were calculated for lizard species on grazed, seasonal grazed and ungrazed study sites. The test for statistically significant differences between managed grassland conditions was based on the Mann-Whitney *U*-test at the 95% confidence level. I compared the relationships between RDM and lizard density using the Kendall's coefficient of ranked correlation. In addition, I compared lizard size classes among the three grazing treatments, using the Kruskal-Wallis test, at the 95% confidence level.

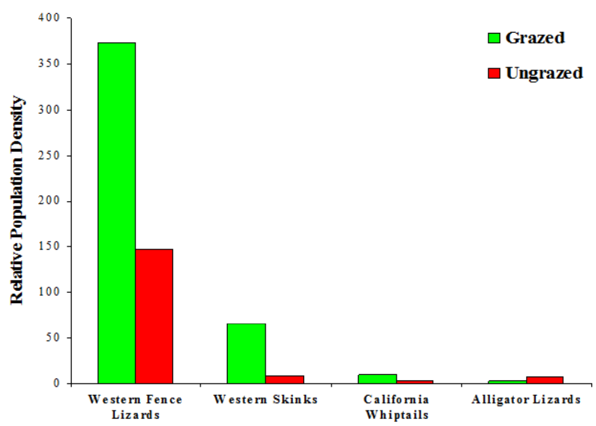

Figure 1. The densities of lizard species in grazed managed grasslands versus ungrazed managed grasslands. Western fence lizards and western skinks exhibit a significant difference in abundance (Mann-Whitney U-test, n = 616 lizards among 35 sites, tied p < 0.001) and may be 3 x more abundant in grazed versus ungrazed regions.

RESULTS

The number of Western fence lizards and Western skinks differed in grazed managed grasslands, as compared to ungrazed managed grasslands (Fig. 1). These two species were three times denser in these two moderately grazed regions than ungrazed sites. California alligator lizards were significantly denser in ungrazed managed grasslands compared to grazed areas (Fig. 1). The density of California whiptails were not significantly different between grazed and ungrazed sites (Fig. 1). In addition, there was a significant inverse relationship between density of lizards and RDM levels over a range of 389 – 34,650 kg/ha ($t > 3.3$, $P < 0.05$, $R^2 = 0.12$; Fig. 2). The Kruskal-Wallis test revealed a highly significant difference for male (df = 2, tied p < 0.001; Figure 3) and female (df = 2, tied p < 0.001; Figure 3) Western fence lizard size class abundance and their use of the three grazing treatments. The Kruskal-Wallis test showed no statistically significant nor nearly significant difference for juvenile Western fence lizards in their use of the three grazing treatments (df = 2, tied p = 0.36; Figure 3).

DISCUSSION

Wildlife habitat in the San Francisco Bay area has changed dramatically in the past three centuries. As Brown and McDonald (1995) point out, though, we can not go back to pre-European times, and therefore, we need to find a way to manage communities now dominated by exotic plant species. Diverse audiences are interested in the management of vegetation where undeveloped lands meet the urban expanse of homes and other buildings. Multiple perspectives are held on how best to manage this unique boundary commonly referred to as the urban-wildland intermix. Prevention of dangerous wildfires and potential loss of life and

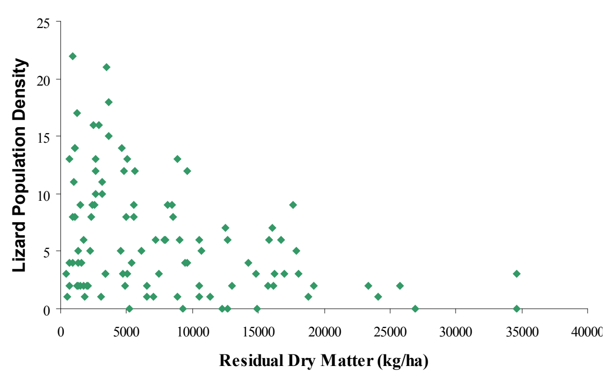

Figure 2. The Kendall's coefficient of ranked correlation revealed a statistically significant inverse relationship between lizard density (lizards/array/24 h) and residual dry matter (RDM) levels over a range of 389 – 34,650 kg/HA (Tied p < 0.001 for 35 traps).

property is something that most people agree on. Local research is needed to help shape vegetation management strategies so that resource agencies can achieve acceptable fire safety goals, prevent weed invasion, and provide habitat for the region's diverse flora and fauna. Cattle grazing, even if light, is one method that can decrease grassland fire intensity and might help reduce non-native grasses.

Pianka (1966) reported that structural richness of various vegetative communities was important in determining lizard species richness. In theory, communities with greater structural diversity (plant heights, and possibly RDM) would support greater abundance and diversity of lizard species. In Sonoran Desert scrub communities, cattle reduce short plants by totally consuming perennial grass and severely reducing the composition of palatable shrubs, leading to reduced lizard numbers (Jones 1981a,b). In contrast, I found that adult male and female Western fence lizards are more abundant in grazed grasslands compared to ungrazed grasslands. It is possible that adult fence lizards are selecting these open, moderately disturbed areas to improve their reproductive success. In a three-year study in the northern Arizona ponderosa pine forest, the reproductive success and hatching abundance of the sagebrush lizard (*Sceloporus gracious*) were consistently highest in the most open cover (meadow) and stand (savannah) types, and lowest in forest cover types, especially high density ponderosa forests (Germaine and Germaine 2003). Andrews and Wright (1994) and Overall (1994) have suggested that habitat favorability

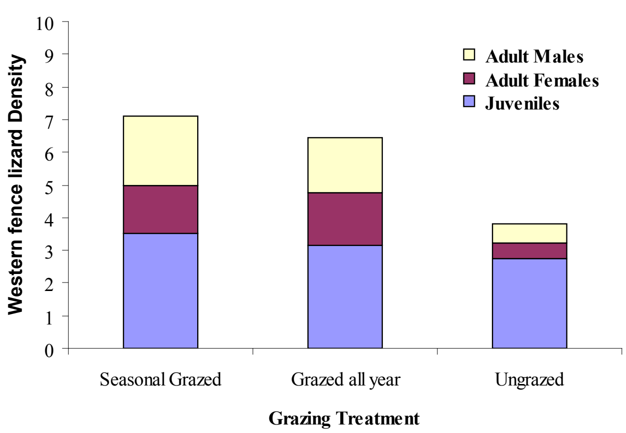

Figure 3. The Kruskal-Wallis test revealed a highly significant difference for adult male (df = 2, tied $p < 0.001$) and adult female (df = 2, tied $p < 0.001$) Western fence lizard density (lizards/array/24 h) and their use of the three grazing treatments. Adult Western fence lizard populations average three times greater density in grazed grasslands compared to ungrazed grasslands.

for reptile species often is strongly dependent on the site's favorability for the species' egg stage. Courtship displays also might be more effective in more open areas.

For many lizard species, horizontal vegetation structure (leaf, log, and limb debris) determines species composition more often than that of vertical vegetation structure (Pianka 1966, Jones 1981a, b). This trend results primarily from the lizards' foraging and thermoregulation needs (Brattstrom, 1965). Jones (1981a) demonstrated that grazing–induced vegetative structural changes reduced overall lizard abundance and diversity in the Western Arizona desert scrub, although not all lizards were adversely affected, and that heavy grazing in fact favored lizards that foraged while sitting on trees and downed tree limbs.

The Western fence lizard, a sit-and-wait species who forages while on rock outcrops, log piles, and down trees, appears to be favored by moderate grazing. Abundance of fence lizards increased with lower RDM levels and moderate grazing. The Western skink, which searches for invertebrate prey beneath dense grass and leaf litter, also appears to be favored by moderate grazing. Kie and Loft (1990) predicted that livestock might improve habitat values for Western fence lizards, side-blotched lizards (*Uta stansburiana*), and Western pond turtles (*Actinemys marmorata*) by providing a mix of grasses and forbs in a herbaceous assemblage.

As stated earlier, much of California has been invaded by exotic plant species during the past 100 to 300 years. Large grazing native mammals probably have been depleted for even longer periods. It is generally believed that livestock and early settlers introduced non-native grasses in California. Germano et al. (2001) suggested that these introduced grasses and forbs create impenetrable thickets for small ground-dwelling native vertebrates, such as the giant kangaroo rat (*Dipodomys ingens*), San Joaquin kangaroo rats (*Dipodomys nitratoides*), San Joaquin antelope squirrels (*Ammospermophilus nelsoni*), and the blunt-nosed leopard lizards (*Gambelia sila*). Their research shows that these desert-dwelling threatened and endangered species are negatively affected by thick herbaceous cover. In some years, moderate to heavy grazing by livestock might be the best way to decrease the dense cover created by exotic annual grasses in order to prevent the further declines of these threatened and endangered species (Germano et al. 2001). These authors argued that these native desert-dwelling species are adapted morphologically, behaviorally, and physiologically to inhabit relatively open habitats and therefore are ill-equipped to live in dense grass.

Impacts of habitat alterations are not just limited to species inhabiting California's San Joaquin Valley. For example, Ballinger and Watts (1995) reported declines in abundance of the Lesser earless lizard and the Eastern fence lizard (*Sceloporus undulatus*) in the Sand Hills region of Nebraska when cattle grazing was stopped and the associated vegetation was allowed to increase, resulting in a denser grass community on the short-grass prairie. Absence of a natural disturbance factor such as fire has demonstrated that lizard populations can decline (Greenberg et al. 1994). Norbury and Norbury (1996) reported that little or no grazing in semiarid, exotic-dominated short-tussock grasslands in New Zealand can be detrimental to some native species. Also, Jaggi and Baur (1999) suggest that overgrowing vegetation (brushes and trees) may degrade the habitat quality for the asp viper (*Vipera aspis*), a threatened species in the northern Swiss Jura Mountains, which may lead to the local extinction of this snake and probably other reptiles as well. The results of a two-year study in northwest Spain by Galan (2004) showed that the lacertid lizard (*Podarcis bocagei*) population declined, largely due to a rapid decline in habitat favorability when dense vegetation colonized the site. Research in southeastern Australia on the broad-headed snake (*Hoplocephalus bungaroides*), a rock-dwelling nocturnal serpent, suggested that thermally suitable retreat sites are limiting resources, and that local increases in vegetation density might contribute to the decline of this endangered species (Pringle et al. 2003). The vegetation and soil disturbances created by black-tailed prairie dog (*Cynomys ludovicianus*) colonies in the short-grass prairie biome of western Kansas was reported by Kretzer and Cully (2001) to enhance landscape heterogeneity and contributes to greater reptile and amphibian diversity.

The effects of the livestock industry on wildlife are complex, and the analyses made by this research are limited to some degree. The critical time of year for wildlife in central California's annual grasslands depends on the wildlife species of specific interest. My findings suggest that the seasonal, managed consumption of grasses by moderate cattle densities in Central California's annual grasslands tends to create favorable conditions for the Western fence lizard and Western skink. While my research has emphasized the importance of cattle grazing on the lizard species evaluated during typical to heavy rainfall, it is obvious that other resource management issues must also be considered. They may include, but are not limited to, wildland fire management, pest management, providing opportunities for the "consumptive use of renewable wildlife resources," watershed quality, aesthetics, and the protection of special status species under the Endangered Species Act or other state or federal agency designation. The implementation of a grazing management plan to enhance wildlife needs an interdisciplinary approach, which includes knowledge of plant community dynamics and the habitat requirements of affected wildlife species (Vavra 2005). A grassland mosaic that includes all succession stages may be necessary to maximize wildlife species diversity and abundance. Patches of different habitats and management strategies across the landscape may be optimal. Hopefully others will contribute towards this effort, helping to develop an ecosystem perspective towards the management of Central California grasslands.

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