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Managing California Ground Squirrels on Levees Using Habitat Modification

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ABSTRACT: Burrowing mammals such as ground squirrels are considered threats to levee integrity, and some authors have proposed that ground squirrel occurrence on levees might be reduced by habitat modification. We characterized the threat that California ground squirrels pose to levees by summarizing available information on burrow lengths and depths, and we reviewed available information about the efficacy of habitat modification to reduce squirrel occurrence on levees. Burrows of California ground squirrels averaged 8.2 m in length (range = 0.9-42.1 m) and 75 cm in greatest depth (range = 33-168 cm), indicating that most burrows are not long enough to transect most levees but nonetheless could contribute to "piping" of water through the levee and create voids that trigger collapses of levee soil. There is little evidence that managing for either short-stature grassland or shrubby vegetation on levees will reduce occurrence of ground squirrels, but further research is needed for both approaches. Managing for trees on levees likely will reduce the occurrence of ground squirrels, probably because tree-covered habitats create visual obstruction that is avoided by ground squirrels. The presence of nut and fruit crops adjacent to levees increases the occurrence of ground squirrels on the levee, probably because these crops provide a rich food resource.

KEY WORDS: burrow depth, burrow length, California ground squirrel, flood control, habitat modification, levee management, levee vegetation, *Otospermophilus beecheyi*

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INTRODUCTION

Levees are constructed to safeguard people and their property from the damage caused by floods. Earthen levees are built with tightly compacted soil that can withstand the pressure created by the body of water on one side of the embankment (Federal Emergency Management Agency 2005). Some species of mammals excavate underground burrows as part of their life history, and these soil-excavating activities can alter the internal and external geometry of earthen levees in ways that compromise levee function (Bayoumi and Meguid 2011). Consequently, burrowing mammals are considered threats to levee integrity, and their burrowing activities have been implicated as a cause of numerous levee failures (Dixon 1922, Fitzgerald and Marsh 1986, Federal Emergency Management Agency 2005, Bayoumi and Meguid 2011).

Burrowing activities by mammals involve tunnel formation and soil displacement; these two processes can impact levees in three ways. First, burrows can become conduits for water that causes "piping," the internal erosion of levee materials that can lead to rapid failure. Even burrows that only partially penetrate a levee can threaten levee integrity by reducing the extent of intact soil available to retard water seepage through the levee. Second, burrows create voids within the levee that can collapse over time, weakening the levee structure. Third, soil excavation and movement can promote erosion that alters the levee profile (Federal Emergency Management Agency 2005, Bayoumi and Meguid 2011).

The California ground squirrel (*Otospermophilus beecheyi*) is common on levees in California and is considered a threat to levee integrity because of its burrowing activities (Daar et al. 1984, Fitzgerald and Marsh 1986). Levee districts often manage California ground squirrels by control with rodenticides, coupled with grouting of burrows using a cement-bentonite mixture to repair the damage caused by burrow excavation. Some authors, however, have proposed that habitat modification on or adjacent to the levee might be an effective approach for managing ground squirrels on levees; because California ground squirrels favor open habitats where visibility is good and prefer nuts and seeds for food, managing for vegetation that obscures visibility and removes preferred food sources might reduce the occurrence of squirrels on levees (Klitz 1982, Daar et al. 1984, Fitzgerald and Marsh 1986).

The biology of the California ground squirrel is not well known. Numerous burrows of California ground squirrels have been excavated, with lengths ranging from 1-266 m and depths ranging from 0.3-8.5 m (Linsdale 1946, Berentsen and Salmon 2001) but these data have not been summarized to characterize the typical dimensions of California ground squirrel burrows. California ground squirrels eat the nuts, fruits, flowers, stems, and leaves of a variety of plants, and some authors have noted that the species is especially fond of agricultural crops, including nut, fruit, and grain crops (Grinnell and Dixon 1918, Evans and Holdenried 1943, Fitch 1948, Marsh 1998). California ground squirrels are thought to prefer open habitats, such as grassland and open oak woodland, with some indication of a preference for short-stature grasslands (Evans and Holdenried 1943, Fitch 1948, Daar et al. 1984, Fitzgerald and Marsh 1986, Marsh 1998). Our objective was to characterize the threat that California ground squirrel burrowing poses to levees by summarizing available information on burrow lengths and depths, and to review the evidence about the efficacy of habitat modification to reduce squirrel occurrence on levees.

BURROW DIMENSIONS

To characterize the length and depth of California ground squirrel burrows, we reviewed the literature for measures of burrows that were representative of nest burrows of adults of each species. Hence, we excluded burrows of juveniles, burrows considered to be auxiliary burrows used for temporary refuge, and burrows likely to represent bias such as those reported as the longest or deepest burrow encountered. We considered length to be the aggregate length of all tunnels in the burrow system. Depth was the greatest depth of the burrow system beneath the ground surface. We used measures of length and depth reported by the authors, or we measured these distances from scale drawings of the burrows.

We obtained measures of length for 29 burrows and measures of depth for 28 burrows (Grinnell and Dixon 1918, Edge 1934, Ryckman 1971, Berentsen and Salmon 2001, J. T. Wilcox pers. comm.). Mean burrow length was 8.2 m (range = 0.9-42.1 m), but the distribution was skewed (Figure 1); the median length was 4.9 m, and 76% of burrows were less than 10 m long. Burrow depth was more normally distributed than burrow length (Figure 2), with a mean of 75 cm, median of 70 cm, and range of 33-168 cm. These values are in general agreement with the characterization by Tracy Storer (Linsdale 1946) that burrows of California ground squirrels are typically 1.5 to 10.4 m long and 76 to 122 cm deep. Burrow configuration varied considerably. Some burrows consisted of a short, nearly straight tunnel, one or two entrances, and a nest chamber, whereas others consisted of a complex of tunnels extending in various directions and with multiple entrances (Ryckman 1971). Values of typical length and depth do not represent the maximum burrowing potential for California ground squirrels. The longest burrow system for California ground squirrels was unearthed in San Luis Obispo County, CA; it totaled 226 m in aggregate length, had 33 entrances, displaced a total volume of 2.8 m^3, and was inhabited by 6 adult females and 5 adult males (Linsdale 1946). The deepest burrow system was unearthed in Fresno County, CA, and extended 8.5 m below the surface (Linsdale 1946).

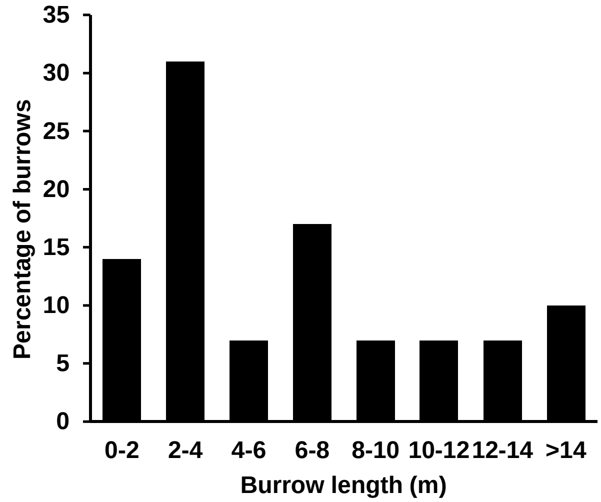

Figure 1. Frequency distribution of lengths of 29 burrows of California ground squirrels. Burrows exceeding 14 m were 23.8, 28.5, and 42.1 m in length.

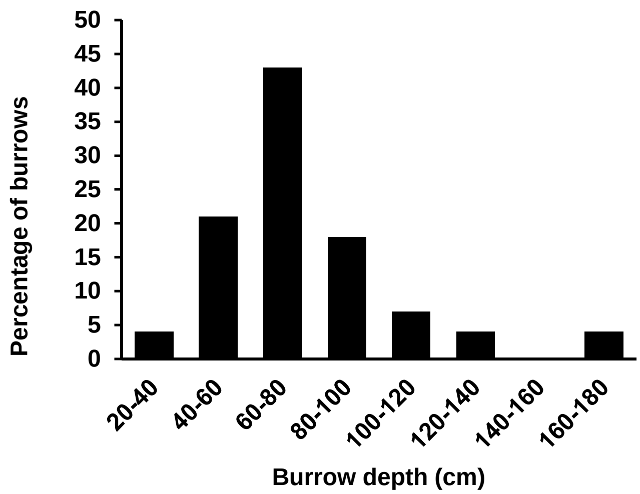

Figure 2. Frequency distribution of greatest depths of 28 burrows of California ground squirrels.

GRASSLAND VEGETATION

California ground squirrels appear to be more numerous in grasslands that are heavily grazed (Linsdale 1946, Marsh 1998). Grassland vegetation on levees is often managed with treatments such as grazing, mowing, or herbicides, which potentially increases suitability for ground squirrels. Hence, managing for taller-stature vegetation, such as tall grasses and low-growing shrubs, might reduce the occurrence of California ground squirrels on levees (Klitz 1982, Daar et al. 1984). This possibility was evaluated by planting a levee reach with a tall-stature species of bunchgrass and counting California ground squirrel burrows for three years in planted areas and in adjacent portions of the levee that supported lower-stature annual grassland vegetation (Fitzgerald and Marsh 1986). The results were inconclusive, although apparently there was some evidence that tall, dense vegetation might have the potential to reduce the occurrence of ground squirrels (Fitzgerald and Marsh 1986).

WOODY VEGETATION

Manipulating woody vegetation might have a greater potential than herbaceous vegetation in influencing the occurrence of California ground squirrels. The species is considered a resident of grasslands and open oak woodlands (Owings et al. 1977, Fehmi et al. 2005), is thought to prefer open habitats with good visibility (Klitz 1982, Marsh 1998, Fehmi et al. 2005), and is believed to be rare or absent in areas of heavy tree or brush growth (Evans and Holdenried 1943). California ground squirrels sometimes excavate burrows beneath the canopies of oak trees, but this might be because of the availability of acorns as food (Fitch 1948, Owings and Borchert 1975).

The effect of woody vegetation on the occurrence of California ground squirrels was evaluated by Ordeñana et al. (2012), who characterized the vegetation on 166 levee segments, each 50 m long, and compared the presence and number of ground squirrel burrows on the segment with type of vegetation cover. Ground squirrel occurrence and abundance showed a strong, negative relationship with tree canopy cover and the leaf litter associated with trees, probably because ground squirrels avoid tree-covered areas due to visual obstruction; California ground squirrels detect predators visually (Ordeñana et al. 2012). Shrub cover did not have a negative effect on ground squirrels, and there was some evidence of a positive effect but only on the water side of the levee, perhaps because shrubs there such as blackberry (*Rubus* spp.) provide a food source (Ordeñana et al. 2012). The effect of shrubs on ground squirrel occurrence might depend not only on whether the shrubs provide a food source, but also on the physical configuration of the shrub; some types of shrubs might be avoided because they impede a squirrel detecting a predator by obstructing vision, whereas others might be preferred because they interfere with a predator detecting or attacking the squirrel (Schooley et al. 1996, Sharpe and Van Horne 1998). In addition to ground squirrel occurrence on levees, vegetation influenced where the burrow was excavated on the levee slope. Analysis of vegetation within 5 m of each burrow entrance revealed that California ground squirrels strongly avoided excavating their burrows near trees and preferred barren areas (Ordeñana et al. 2012). There was some evidence that ground squirrels preferred excavating their burrows near shrubs, again illustrating the variable effect that shrubs might have on habitat quality for California ground squirrels (Ordeñana et al. 2012).

ADJACENT CROPS

California ground squirrels feed on a variety of agricultural crops (Grinnell and Dixon 1918, Marsh 1998), and levees that transect agricultural lands might create a juxtaposition of two resources important to California ground squirrels: an elevated burrow site on the levee with good visibility and safety from flooding, and a rich food source in the adjacent agricultural field (Daar et al. 1984, Fitzgerald and Marsh 1986). This possibility was evaluated by McGrann et al. (2014), who characterized the land use adjacent to 248 levee segments (each 50 m long) that supported only grassland vegetation, and compared the presence and number of ground squirrel burrows on these grassland segments with land use in the adjacent field. Results revealed that both the occurrence and abundance of ground squirrel burrows were much greater on levee segments adjacent to nut orchards such as walnuts and almonds; fruit crops also had a strong positive influence on occurrence of ground squirrel burrows on nearby levees (McGrann et al. 2014). Surprisingly, the study found that levees adjacent to any agricultural crop, including grains and vegetables in addition to nut and fruit orchards, had a greater likelihood of ground squirrel occurrence than did levees adjacent to grassland vegetation, which is considered the natural habitat of California ground squirrels. One explanation is that most adjacent grasslands encountered in this study were relatively tall in stature, which would provide some support for the hypothesis that vegetation height influences suitability for ground squirrels in grasslands; another explanation is that ground squirrels benefit from food sources provided by a wide variety of agricultural crops (McGrann et al. 2014).

DISCUSSION

Our findings indicate that although California ground squirrels have the potential to burrow entirely through a levee, most burrows are much shorter than the length needed to do so. Further, burrow length is measured in terms of aggregate length of all passages in the system, and burrow systems of ground squirrels may be tortuous, include dead-end branches, and incorporate numerous entrances, all of which can contribute to length without necessarily increasing the likelihood of transecting a levee. Nonetheless, the burrow of one California ground squirrel can be long enough to perforate a levee, or shorter burrows on opposite sides of a levee can be sufficiently proximate to nearly perforate a levee, thereby increasing the risk of "piping." Moreover, tortuosity in burrow configuration, as well as multiple burrows in close proximity, can lead to localized voids that are prone to collapse.

Results compiled from other species of ground squirrels suggest factors that might influence burrow dimensions on levees. There is some evidence that ground squirrel burrows are longer in softer soils (Van Vuren and Ordeñana 2012). Some levees were constructed from uncompacted material dredged from the river bottom, and these levees might provide more favorable substrates for efficient excavation of longer burrows than compacted levees. There is also some evidence that burrow systems are progressively lengthened with time (Berentsen and Salmon 2001, Van Vuren and Ordeñana 2012), suggesting that the longer a population of squirrels inhabits a levee, the greater the likelihood that continued excavation will result in burrow enlargement.

There is currently little evidence that managing for tall-stature grasslands on levees will reduce the occurrence of California ground squirrels, but the possibility has not been adequately researched and the potential remains. Similarly, there is little evidence that managing for shrubby vegetation on levees will reduce ground squirrel occurrence. Research is needed on what shrub species might reduce habitat suitability on the levee by impeding visibility to squirrels, but which do not also provide them a food source or protection from predator attack. In contrast to grasslands and shrubs, managing for trees on levees shows promise for reducing both the occurrence and abundance of California ground squirrels. However, vegetation management on levees involves consideration of multiple factors in addition to the likelihood of ground squirrel occurrence, such as ease of levee inspection during maintenance and flood fighting; effects of plant roots on levee integrity; and wildlife and recreational values of vegetation.

Managing crops adjacent to the levee is problematic because these areas usually are not under the jurisdiction of the levee management agency (Fitzgerald and Marsh 1986). Further, nut and fruit crops are long-lived and require a major expense to plant and bring into production, hence conversion to a different crop might be cost-prohibitive. Nonetheless, as orchards senesce and are replaced, opportunities might arise to work with local landowners to establish crops close to the levee that are less likely to attract ground squirrels. Moreover, knowledge of the effect of adjacent crops on ground squirrel occurrence on the levee can allow levee managers to prioritize those reaches most at risk from infestation by ground squirrels, for inspection during routine maintenance or for monitoring during a flood event.

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