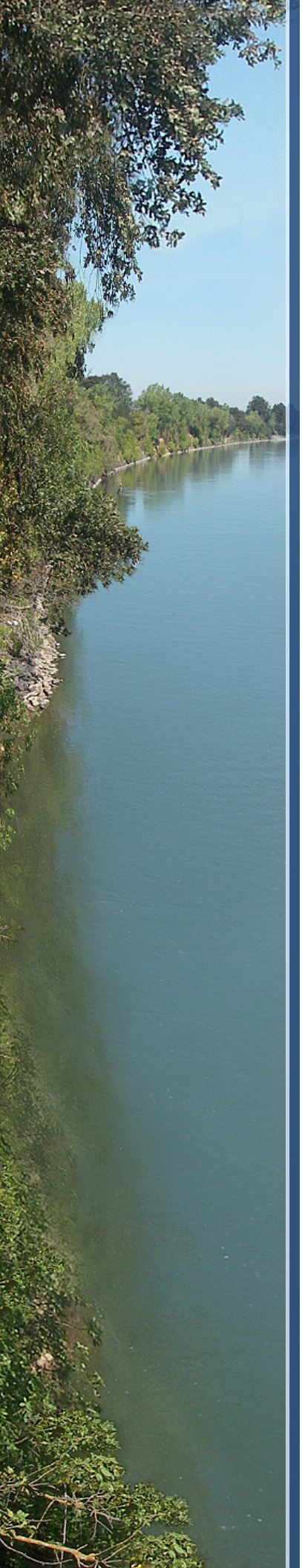
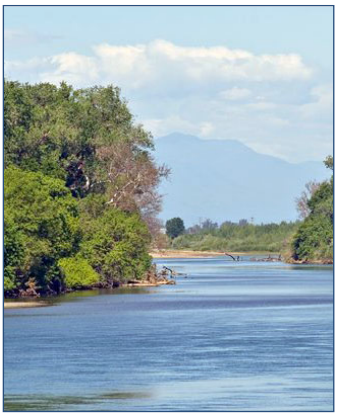


California Levee Vegetation Research Program

Influence of Adjacent Crop Type on Occurrence of California Ground Squirrels along Levees in the Sacramento Valley, California



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Sponsoring/Advisory Agencies of the California Levee Vegetation Research Program

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INTRODUCTION

Earthen levees improve human safety and prevent property damage during floods (Federal Emergency Management Agency 2005). In the Sacramento Valley of northern California, these levees are a crucial component of the flood management system of the Sacramento River and its tributaries (Fitzgerald and Marsh 1986). Levees are built with tightly compacted soil in order to withstand the pressure from the water body on one side of the embankment (Federal Emergency Management Agency 2005). For this reason, the soil-excavating activities of burrowing mammals are a significant threat to the structural integrity of levees (Federal Emergency Management Agency 2005, Bayoumi and Meguid 2011). California ground squirrels (*Otospermophilus beecheyi*) live on levees and exhibit the potential for especially destructive burrowing activity because of their elaborate and potentially long tunnel systems (Fitch 1948, Fitzgerald and Marsh 1986, Van Vuren and Ordeñana 2012). During a flood event, tunnels can act as a pipeline by channeling water internally as the water level rises, which can cause rapid erosion and levee failure (Fitzgerald and Marsh 1986, Bayoumi and Meguid 2011). Even after burrows have been abandoned, the damage to the levee remains and burrows can collapse over time, which might cause the levee to subside. Additionally, the loose soil deposited at burrow entrances erodes easily, thereby altering the levee profile (Federal Emergency Management Agency 2005, Bayoumi and Meguid 2011). Consequently, sections of levees damaged by burrowing activities of ground squirrels are more difficult to maintain and require more intensive monitoring and patrolling by maintenance crews to prevent levee failures (Fitzgerald and Marsh 1986).

California ground squirrels rely on vision and vocal communication with conspecifics to detect predators (Hanson and Coss 2001, Rabin et al. 2006). Hence, California ground squirrels prefer habitats characterized by structurally open vegetation with good visibility (Grinnell and Dixon 1918, Owings and Borchert 1975, Klitz 1982, Van Vuren and Ordeñana

2011), such as grassland and open oak woodland (Evans and Holdenried 1943, Fitch 1948). Although some levees in the Sacramento Valley support trees and shrubs, most levee vegetation is maintained as annual grassland typical of California's Mediterranean climate. Food availability might also influence ground squirrel habitat preferences on levees. California ground squirrels eat primarily the nuts, fruits, flowers, stems, and leaves of a variety of plants (Grinnell and Dixon 1918, Evans and Holdenried 1943, Fitch 1948). Although grasses and forbs growing on the levee itself provide food for ground squirrels, adjacent crops also can provide a rich source of food that may influence squirrel occurrence on levees (Daar et al. 1984, Fitzgerald and Marsh 1986, Marsh 1998). Several crops are grown adjacent to levees in the Sacramento Valley, including nut crops (e.g., walnuts and almonds), fruit crops (e.g., prunes, peaches, kiwi, and grapes), annual crops (e.g., corn, wheat, tomatoes, onions, and squash), alfalfa, and rice. Each of the crops also can be characterized by different cultural practices with respect to soil cultivation (e.g., tillage or no tillage) and irrigation (e.g., drip, sprinkler, or flood), which might affect the occurrence of ground squirrels in or adjacent to the crop (Marsh 1998). The objective of this study was to evaluate the influence of adjacent land-use types on the occurrence and abundance of California ground squirrels on levees in the Sacramento Valley. Across the agricultural landscape, some land-use types might be stronger attractants for ground squirrels than others. This knowledge can guide landscape-scale planning for ground squirrel management on levees.

METHODS

Study area

We conducted our study in the Sacramento Valley on portions of 15 levees along the Sacramento River, Feather River, and tributaries in Butte, Glenn, Solano, Sutter, Yolo, and Yuba counties (Figure 1). The levees of this study are managed by state and local agencies and special districts, including the California Department of Water Resources and five local

reclamation and levee districts. Most habitats on the levees were grasslands (e.g., ripgut brome, *Bromus diandrus*; Italian ryegrass, *Lolium multiflorum*, and wild oat, *Avena fatua)*. Habitats dominated by shrubs (e.g., blackberry, *Rubus* spp.; western poison oak, *Toxicodendron diversilobum*; and willow, *Salix* spp.) and trees (e.g., valley oak, *Quercus lobata*; western sycamore, *Platanus racemosa*; California black walnut, *Juglans californica*; Fremont's cottonwood, *Populus fremontii*; and willow, *Salix* spp.) were present but less common on levees. Adjacent to levees, the majority of land uses were agriculture, but in some places levees passed through wildlife refuges, including portions of the Upper Butte Basin Wildlife Area and Sutter National Wildlife Refuge, that were comprised predominantly of seasonal wetlands managed to benefit migratory waterfowl.

Data collection

Our sampling unit was a 50-meter segment of a levee, measured along the longitudinal axis of the levee. From 7 June through 9 September 2012, we surveyed 248 levee segments, with a mean of 15.5 segments per levee (range = 2-35). We employed a stratified-random approach in locating segments, with strata based on ground squirrel presence and vegetation on the levee. Using a database generated by W.D. Meyersohn (California Department of Water Resources, personal communication), we targeted those levees that had evidence of activity by California ground squirrels. Further, in order to remove the confounding influence of habitat on the levee, we confined our surveys to levees that supported only grassland vegetation, based on aerial photographs or visual inspection. Once we found a suitable levee, we located the first segment at a random distance from the start of the levee, ranging from 500 meters to 1000 meters, then located subsequent segments in succession at a random distance apart ranging 500-1000 meters. A distance of ≥500 meters facilitated independence among observations; the radius of activity for a California ground squirrel is typically ≤75 meters (Van Vuren et al. 1997). For each levee segment, we delineated the upstream and downstream boundaries using a

compass and flagging. The length of all segments was 50 meters, but width varied according the height and slope of the levee.

We searched the landside slope of each levee segment for burrow entrances of California ground squirrels. We restricted our search to the landside slope because this is the levee slope that faces adjacent land uses. Land use on the waterside of the levee usually was restricted by the presence of the river, although in some instances crops were grown there. Visibility of burrow entrances can be affected by density and height of vegetation, which varied among segments. To avoid detection bias we systematically searched the landside slope of each segment using adjoining parallel transects 1.0-1.5 meters wide, aligned with the longitudinal axis of the levee. We slowly walked the center of each transect and visually scanned the ground surface for burrow entrances. Although other burrowing mammals were present on levee segments, such as Botta's pocket gopher (*Thomomys bottae*), we classified all burrows with a diameter of 6-15 centimeters as California ground squirrel burrows because no other mammals in our study area excavate burrows of this diameter (Van Vuren and Ordeñana 2011). Burrows of California ground squirrels typically exhibit a compacted soil pile downslope of the burrow entrance (Grinnell and Dixon 1918, Dobson 1979, Van Vuren and Ordeñana 2011), which aided in identification. We searched until all entrances of California ground squirrel burrows were located.

While standing on the crown of the levee at the mid-point of the segment, which provided a good view of the adjacent landscape, we visually estimated the percent cover of land uses within a 75-meter radius (representing the maximum radius of ground squirrel activity; Van Vuren et al. 1997) of the toe of the levee on the landside. The 75-meter distance was measured using a laser rangefinder (Nikon ProStaff 550). We employed five land-use classifications: 1) perennial nut crops (walnuts and almonds); 2) perennial fruit crops (prunes, peaches, grapes, and kiwis); 3) annual crops of grains, seeds, and vegetables (e.g., wheat, corn, sunflower, safflower, tomatoes, onions, and squash), which we combined as one classification to improve

sample size; 4) rice, which we distinguished from other grains because rice is flooded seasonally; and 5) grasslands, which were areas dominated by uncultivated grasses and forbs, often occurring in wildlife refuges adjacent to levees. Although alfalfa was common in our study area, we did not encounter this crop adjacent to any of our levee segments.

Data analysis

We used bivariate logistic regression to evaluate the association of California ground squirrel occurrence with the adjacent land-use type. For the logistic regression analysis, we assigned a score of 1 (present) if we identified one or more California ground squirrel burrows on the segment, or a score of 0 (absent) if we did not identify any ground squirrel burrows. We then modeled the probability of occurrence of ground squirrels on levees, with adjacent land-use type as the categorical predictor variable. Some segments were bordered by more than one land use. To avoid the confounding influences of multiple land uses on squirrel occurrence, we included only those segments bordered by one predominant land use, as indicated by >50% cover, and we classified the adjacent land use according to that predominant type. Three segments were excluded from this analysis, and all three were bordered by two land uses with equal cover (i.e., 50% each). Differences in the log odds-ratio estimates for each land-use type were evaluated relative to the log odds-ratios of the grasslands type, which we set as the reference group because it approximates the natural habitat of California ground squirrels (Grinnell and Dixon 1918, Evans and Holdenried 1943, Fitch 1948).

We used Kendall's rank correlation coefficient (τ) to assess associations between the abundance of ground squirrels on levees and the percent cover of each adjacent land use. We used the number of burrow entrances per segment as an index of abundance, an assumption that has been substantiated for California ground squirrels (Owings and Borchert 1975). Many segments lacked ground squirrel burrows, resulting in tied ranks, which are adjusted for by the Kendall's rank correlation method.

For all analyses, the significance level was set at 0.05. We used False Discovery Rate corrections (Benjamini and Hochberg 1995) to control for Type I errors associated with multiple simultaneous tests. All tests were performed in R version 2.15.1 (R Development Core Team 2012), using the base packages.

RESULTS

We counted a total of 250 burrows of California ground squirrels among 248 levee segments, with a range of 0-18 burrows per levee segment. Most burrows appeared to be active, with tracks and other signs of activity such as discarded walnut shells present at the entrance, and on some segments ground squirrels were observed. Ground squirrel burrows occurred on 23% of segments surveyed, but occurrence differed according to land-use type, with the highest occurrence adjacent to perennial fruit crops and the lowest adjacent to grasslands (Table 1). The odds of ground squirrels occurring adjacent to rice, annual crops, fruit crops, and nut crops were all greater than the odds of ground squirrels occurring adjacent to grasslands, but the difference was statistically significant only for fruit and nut crops, and approached statistical significance for annual crops (Table 2). The odds of ground squirrels occurring adjacent to perennial nut crops and perennial fruit crops were 8.40 times greater and 6.11 times greater, respectively, than the odds of ground squirrels occurring adjacent to grasslands. Kendall's correlation analysis showed a significant positive relationship between the number of burrows and the percent cover of perennial nut crops. Conversely, there was a significant negative relationship between the number of burrows and percent cover of grasslands (Table 3).

DISCUSSION

A landscape perspective is important in managing damage done by wildlife, especially in those situations where the home range of the wildlife species extends beyond the location of

damage because of the availability of resources nearby (Van Vuren and Smallwood 1996, Conover 2002, Martin et al. 2011). For California ground squirrels in the Sacramento Valley, levees and adjacent land uses might provide a juxtaposition of important resources. Levees might provide good sites for excavating burrows because levees are elevated above the surrounding landscape, which provides sites that have enhanced visibility for detecting predators and that are not subject to seasonal flooding or irrigation. Levees might also provide a food resource in the form of grassland vegetation, but that food varies seasonally because of the summer drought typical of California's Mediterranean climate, as well as levee maintenance practices such as mowing, burning, or spraying herbicides. Adjacent land uses, depending on the crop and cultural practices, might provide an important food resource that either supplements or complements that available on the levee (Klitz 1982).

We found that levee segments next to perennial nut crops exhibited the highest probability of occurrence of ground squirrels, and that the percent cover of adjacent nut crops was positively related to squirrel abundance. Walnuts and almonds, the two nut crops that we encountered, are highly preferred by California ground squirrels (Grinnell and Dixon 1918), can be stored in caches, and become available in the dry summer and fall seasons when foods produced by grasses and forbs are less abundant (Fitch 1948). Levee segments next to perennial fruit crops also exhibited a high probability of occurrence by ground squirrels. Peaches and prunes were the most common fruit crops we encountered, and both are preferred by California ground squirrels (Grinnell and Dixon 1918). The fleshy part of fruits provides a food source as they ripen during the summer, and for some fruits, including peaches and prunes, the pit provides a food source that can be cached for later use (Grinnell and Dixon 1918, Marsh 1998).

We found a positive association between ground squirrel occurrence and the presence of annual crops adjacent to the levee, probably because some annual crops, especially grains of all types, provide a valuable food source for California ground squirrels (Marsh 1998).

However, the association fell short of statistical significance, perhaps because the food value of annual crops for ground squirrels varies among crops, and also because annual crops are cultivated. The annual crops we encountered were comprised of grains and vegetables. California ground squirrels strongly prefer a variety of grain crops, which are eaten throughout the growing season and also can be cached for later consumption (Marsh 1998). California ground squirrels also eat the leaves, flowers, and fruits of some vegetable crops (Marsh 1998), but these foods are available only during the growing season and cannot be cached. Further, frequent cultivation and irrigation of annual crops prevents ground squirrels from establishing burrows in the field (Fitzgerald and Marsh 1986, Marsh 1998), and also might deny squirrels access to crop residue left after harvest. We found no significant association between rice and California ground squirrel occurrence. Rice is a grain that might provide a valuable food source, but access by squirrels likely is precluded because rice fields are flooded during the growing season. Further, rice fields are more intensively tilled (pre- and post-harvest) than other annual crops, and sometimes burned or flooded during the winter to accelerate residual straw decomposition.

Levee segments adjacent to grasslands had the lowest probability of occurrence of ground squirrels among all land-use types, and abundance of ground squirrels was negatively related to the percent cover of grasslands. These results might seem surprising, because grasslands are considered a natural habitat of California ground squirrels (Grinnell and Dixon 1918, Evans and Holdenried 1943, Fitch 1948). However, grasslands vary in their suitability for California ground squirrels, with short-stature vegetation being preferred (Kiltz 1982, Marsh 1998). Most of the grasslands we encountered were tall in stature (>30 centimeters). Perhaps more important, the development of agriculture in general is thought to have resulted in increased numbers of California ground squirrels because of the increased food abundance, as well as food availability during seasons when natural foods are scarce (Marsh 1998). Hence, a

wide variety of crops adjacent to levees may provide better quality habitat for ground squirrels than do grasslands.

MANAGEMENT IMPLICATIONS

California ground squirrels are considered serious threats to levee integrity (Fitzgerald and Marsh 1986, Bayoumi and Meguid 2011). Management approaches for controlling ground squirrels, either direct control via rodenticides or indirect control via vegetation management and filling burrows with cement grout, have focused on the levee itself (Daar et al. 1982, Klitz 1982, Fitzgerald and Marsh 1986, Van Vuren and Ordeñana 2011). Our results add to those of an increasing number of studies that show that managers might benefit by looking beyond the entity at risk and considering a landscape perspective (e.g., Pagano and Madison 1982, Godfrey 1987, Linz et al. 1995, Brown et al. 1998, Horskins et al. 1998, Gray 2004).

Our results can be of use to levee managers in two ways, risk assessment and landscape management. California ground squirrels are most likely to occur on levees adjacent to nut and fruit crops, allowing 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. Opportunities for landscape management are limited because lands adjacent to the levee typically are not under the control of a levee maintaining/reclamation district (Fitzgerald and Marsh 1986). Further, nut and fruit crops are long-lived perennials that entail a considerable capital expense to bring into production, hence conversion to a different crop might be cost-prohibitive. Nonetheless, as orchards senesce and come due for replacement, opportunities might emerge to work with local landowners to establish crops close to the levee (i.e., within 75 meters; Van Vuren et al. 1997) that are less likely to attract ground squirrels. Both the levee maintaining/reclamation district and the adjacent landowner benefit from a levee that retains its integrity.

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Table 1. Distribution of California ground squirrel occurrences on levee segments according to adjacent land-use type in the Sacramento Valley, California, 2012, based on those segments (N = 245) bordered by one predominant land-use type.

	Grasslands	Rice	Annual crops	Perennial fruit crops	Perennial nut crops
Total segments	35	48	39	37	86
Squirrels present	2	8	8	10	29
Percent occurrence	6	17	21	27	34

Table 2. Bivariate logistic regression model of the effect of adjacent land-use type on the occurrence of California ground squirrels among 245 levee segments in the Sacramento Valley, California, 2012. The intercept represents grasslands, which was selected as the reference group; the odds ratio gives the likelihood of occurrence of ground squirrels for each adjacent land-use type in comparison with grasslands. Also presented are the regression coefficient and its associated standard error (SE), *z*-statistic (*z*), and probability (*P*).

Land use type	Odds ratio	Coefficient	SE	z value	*P*
Intercept	0.061	-2.803	0.728	-3.850	<0.001
Rice	3.300	1.194	0.825	1.448	0.148
Annual crops	4.258	1.449	0.829	1.747	0.081
Perennial fruit crop	6.111	1.810	0.817	2.216	0.027
Perennial nut crop	8.395	2.128	0.763	2.788	0.005

Table 3. Correlation analysis of the association between percent cover of adjacent land-use type and the number of burrows of California ground squirrels on 248 levee segments in the Sacramento Valley, California, 2012, showing Kendall's rank correlation (τ) and probability value (P).

Land use Type	τ	P
Grasslands	-0.169	0.004
Rice	-0.062	0.382
Annual crops	-0.062	0.382
Perennial fruit Crops	0.025	0.673
Perennial nut Crops	0.196	0.002
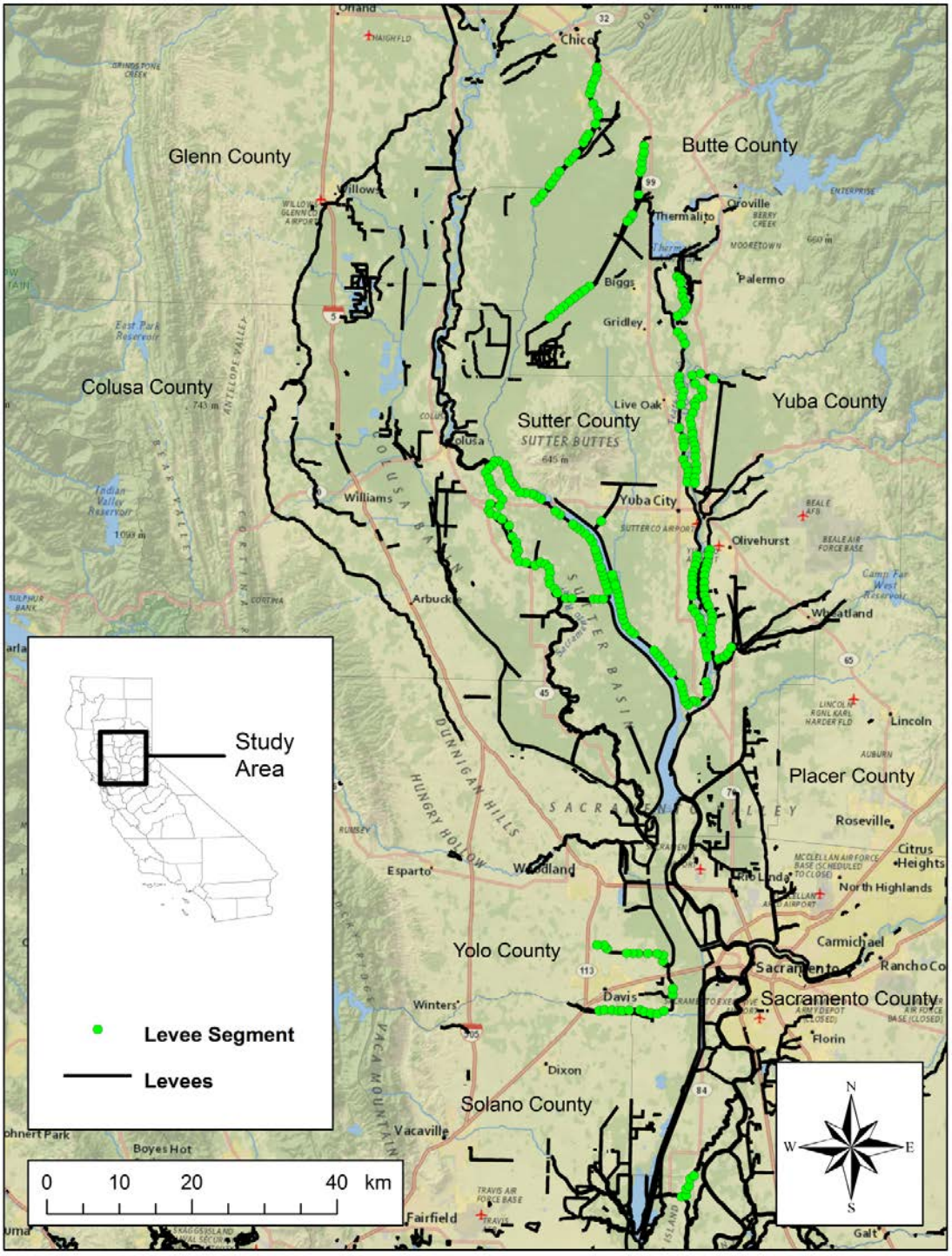
Figure 1. Locations of 248 levee segments surveyed for occurrence of California ground squirrels in the Sacramento Valley, California.