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POTENTIAL OF VEGETATION MANAGEMENT FOR GROUND SQUIRREL CONTROL

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ABSTRACT: Manipulation or alteration of habitat vegetation is used frequently with integrated pest management of certain vertebrate pest species. However, it has been less than satisfactory with ground squirrel species in many situations. Special plantings of tall grasses and broadleaf species were experimentally explored in an effort to make levee habitat less suitable for the California ground squirrel in the Sacramento Valley. The experimental plantings failed to achieve that objective for a variety of apparent or suspected reasons and, in fact, in some grass plots the number of ground squirrels increased over what was present prior to planting. Other problems associated with these experimental plantings, including aggressive tendencies of some species, are discussed.

INTRODUCTION

Management or control of the California ground squirrel (Spermophilus beecheyi) is accomplished by a number of techniques including habitat modification, exclusion, burrow fumigation, and the use of toxic baits, repellents, and traps. They all have their place in integrated pest management. Habitat modification as a ground squirrel management approach takes many forms. It is known that frequent plowing or cultivation tends to eliminate a high percentage of ground squirrels and is amply demonstrated when rangeland or wildland is cultivated and repeatedly planted in cotton, cereals, or row crops (Dixon 1922). After several years, few ground squirrels inhabit the fields except where there are rock outcroppings or standing oak trees that provide locations for undisturbed burrow systems. The cereal fields, however, may have numerous squirrels living along the fence surrounding the field and feeding on the cereal crop (Tomich 1962).

In addition to cultivation, habitat modification by eliminating good burrowing cover, such as fallen oaks, tree stumps, and piles of rubble like broken concrete slabs, may in some situations reduce ground squirrel numbers, as does the plowing and disking close to fence lines.

Ground squirrels, like jackrabbits (Lepus californicus), are frequently more numerous in open-type habitats whereas meadow mice (Microtus spp.), cotton rats (Sigmodon hispidus), and Norway rats (Rattus norvegicus) prefer denser vegetative cover. This has led some to believe that ground squirrel populations can be reduced or eliminated if tall, dense vegetation can be established where squirrels now exist. Linsdale (1946) is often cited as a basis for this belief (Klitz 1982). Linsdale observed that the ground squirrels in some of his plots disappeared when the grasses became tall and theorized that this was a cause-and-effect relationship. Tomich (1962) indicated, however, that of all environmental factors, excessive rainfall seems to be the one that adversely affects ground squirrels the most. Since excessive rainfall generally produces more lush (i.e., taller and denser) growth of our annual grasses, the cause-and-effect relationship of any single factor concerning changes in ground squirrel populations may be an oversimplification of the ground squirrel's requirements. This was also recognized by Linsdale (1946) who stated: "Too rigid a classification of elements in the natural history of an animal only tends to obscure the complexity of its life."

To date no attempts to increase the vegetative cover of an area have been successful in the permanent reduction of ground squirrel populations while still retaining the land for its original purpose. Although rangeland may be permitted to return to brushland, which is unfavorable ground squirrel habitat, that land is no longer suitable for grazing. Some of our freeway rights-of-way provide good examples of squirrels surviving well in relatively dense vegetation, especially if that vegetation represents narrow strips of habitat where the ground squirrel can take advantage of the edge effect.

Some years ago the Department of Water Resources' (DWR) Division of Flood Management explored the possibility of vegetation alteration and enhancement as a means of reducing or eliminating ground squirrels from levees. The Department of Fish and Game (DFG) had hopes that this would also improve the habitat for other wildlife. This paper discusses some of the ramifications.

The California ground squirrel is an adaptable and prolific species living in a variety of habitats. Agricultural areas, rangeland, urban areas, industrial sites, and rights-of-way are a few of the areas occupied by this species. The ground squirrel's ability to thrive under diverse environmental conditions is one of several characteristics that makes it a pest and presents special control problems to vertebrate pest control specialists (Longhurst 1961).

Levees maintained by the Division of Flood Management frequently transect agricultural areas. Certain agricultural crops, especially cereals and forage crops, provide a surplus of food for the ground squirrels. The absence of cultivation or soil disturbance to the levee slopes, and the protection from flooding due to irrigation or winter rainy conditions make these levees extremely suitable habitat for ground squirrels. Many urban environments, including landscape plantings and home gardens, parks, cemeteries, and golf courses replace native forage or agricultural crops as habitat for ground squirrels.

THE SIGNIFICANCE OF GROUND SQUIRREL CONTROL TO LEVEE MANAGEMENT

The California Department of Water Resources' Division of Flood Management maintains 300 miles of project levee and associated rights-of-way, including access roads, maintenance and patrolling roads, and access ramps, in the north Central Valley of California. The Sacramento River Flood Control Project was constructed in the early 1900s to provide protection to the surrounding areas from flooding by the Sacramento River and its tributaries. This flood control project depends on a network of levees, channels, weirs, and bypasses to safely carry floodwaters in times of flood emergency. Without this system, virtually all of the Sacramento Valley would be subject to flooding during the winter rainy season. The success of the system to contain huge volumes of floodwater is dependent on the integrity of all components. The structural stability of levees is paramount in protecting agriculture, industry, and residents of the Sacramento Valley and the Sacramento-San Joaquin Delta from flooding. This flood management system is of incalculable value to the economy of Northern California.

Serious widespread flooding of Northern California, including the Central Valley, in February 1986 caused damage estimated to be in excess of $400 million. While the February 1986 flooding was geographically widespread, flood control systems generally performed their intended function, limiting serious flooding to relatively small areas where levees failed or were unprotected by flood control systems. This flooding, while very serious, is only a small fraction of what might have happened without the benefit of an effective flood-control system.

Ground squirrel burrows located within a levee section present a threat to levee safety and the safe functioning of any flood control system. Ground squirrels burrow into the levees' earthen structure, often excavating many cubic yards of soil for their burrow systems, and may actually burrow complately through the levee section. According to Storer (1942), the burrows average about 4.3 inches in diameter and may be 5 to 34 feet in length. The burrows on flat land are generally 30 to 48 inches below the surface, yet in one reported case a burrow system was found 28 feet below ground (Linsdale 1946). A record burrow system had a total length for all tunnels of 741 feet with 33 openings (Linsdale 1946). The role of burrowing rodents and soil erosion has long been recognized (Day 1931).

Levees depend on a stable mass of soil to retain floodwaters. Squirrel burrows can act like a pipeline carrying floodwaters into or completely through the levee, resulting in a possible levee break. Erosion, seepage, sloughing and subsidence are more frequent occurrences. Additionally, loose soil from burrow excavations is highly erodable, causing degradation of the levee section.

Levee sections with ground squirrel populations, or known to have been previously subjected to squirrel burrowings, must be more closely monitored during flood patrolling and often require more intensive flood fighting to prevent further structural damage and circumvent instabilities that could result in levee failure. Once squirrels dig to some depth or distance into the levee, that damage to the structural integrity remains even though the squirrels are removed and their burrow entrances cave in and are no longer apparent. The burrow cavity remains or eventually fills in with loose, sloughed soil, but since it is not compacted, it is easily penetrated by water.

GROUND SQUIRREL CONTROL ON RIGHTS-OF-WAY

In agriculture, ground squirrel control, like other types of pest control, is usually based on an economic tolerance level or a projection of potential damage. When the economic value of ground squirrel damage exceeds or will exceed the cost of control, control programs are implemented. In a levee or right-of-way situation, the actual or potential cost of ground squirrel damage may be difficult to accurately project. However, because of the potential consequences of ground squirrel burrows, the tolerance level for ground squirrels on levees is zero. Every ground squirrel that burrows into a levee lessens that levee's structural stability, potentially resulting in levee failure. In essence, on levees ground squirrels must be removed or eliminated at any reasonable cost; the principle of economic tolerance does not come into play. Every ground squirrel burrow has the potential to result in levee failure and consequently substantial potential for the loss of lives and property. In California's Central Valley this could be potentially catastrophic in scope.

On levees, rights-of-way, and for some other nonagricultural situations, the control of burrowing rodents may be only one fraction of a maintenance program designed to ensure safety and/or structural stability. Such areas are sometimes managed as multiple-use areas for grazing, recreation, or wildlife habitat (U.S. Department of the Army 1977).

An important constraint faced by levee and right-of-way managers is the limited easement or area of responsibility. Unfortunately, ground squirrels do not respect easement boundaries and frequently migrate or disperse from adjacent highly populated areas into areas less populated (Dobson 1979). Levee managers may not have the authority or financial resources to treat these sources of squirrel reinvasion outside their areas of responsibility, and may not be able to enlist the cooperation of the adjacent property owners in jointly exercising squirrel control programs. In other words, in some areas, regardless of initial success, ground squirrel control will be an ongoing program because of reinvasion.

VEGETATION ALTERATION AND ENHANCEMENT

Over the last 15 years, the Department of Water Resources has experimented with habitat modification through the planting of selected plant species as a method of control for the California ground squirrel. These experimental plantings have been based on the premise that traditional maintenance practices create a "disturbed state" similar to grazing that is favorable for the ground squirrel. Therefore, the planting and retention of selected species--assuming that cover is the controlling factor for population density--would result in a decrease in ground squirrel populations (Olkowski et al. 1978).

Through close evaluation of past projects, it has been determined that on man-made levee environments the planting or retention of tall, dense vegetative cover has not proved a successful method of ground squirrel control. In this type of environment, cover does not appear to be a significant limiting factor as long as there is an unlimited food supply (Fitch 1948) and raised ground for protection from flooding (Phillips 1936). In some areas tall, dense vegetative cover may suppress or discourage ground squirrels from inhabiting a given location. However, with every ground squirrel burrow a potential threat to levee integrity, suppression is not sufficient to meet levee safety needs. As the predictability of satisfactory results cannot be assured, such an approach to squirrel management is not adequate to meet levee maintenance standards.

One might assume that the use of habitat modification to suppress ground squirrel populations would be a valuable addition to an integrated pest management program. Retaining vegetation on levee slopes not only makes ground squirrel infestations and their damage difficult to detect, but other types of structural or safety problems as well. The retention of vegetation on levee slopes conflicts with other maintenance practices necessary for levee safety and reduces the effectiveness of most other ground squirrel control methods. For example, burrow fumigation, a relatively safe form of chemical squirrel control, becomes a much less effective component of integrated pest management because of restricted access, inability to locate all burrow openings and the increased risk of fire when gas cartridges are used.

Where tall dense vegetation is planted or retained, even detailed foot searches of the levees may not detect all the squirrel burrows or other forms of structural damage. Even if the results were the same as when the vegetation is removed, few maintaining agencies can afford this labor-intensive approach to locating problem areas, especially when such funds could be better utilized in resolving the problems.

Past experiences have demonstrated to the Department that modifying the levee vegetation for any purpose without extensive research and planning can have costly negative results. Aggressive introduced plant species have required eradication efforts, and ground squirrel control has become less effective and more labor-intensive. A summary of some of these past habitat modification plantings is provided in Table 1. Many past revegetation experiments have used plant species without adequate knowledge or concern for their ecological significance or growth characteristics. Plant identification, characteristics, and comments of experimental plantings are provided in Table 2. Some of the species planted, including Agropyron trichophorum (Luna pubescent wheat grass) and Festuca spp. (fescue), failed to survive or thrive, while others, primarily Phalaris tuberosa (perla grass), have exhibited aggressive invasive characteristics (King 1984). P. tuberosa, a perennial bunchgrass that grows up to 8 ft tall and produces a large seed head, has become well established on levee slopes as a result of the experimental plantings, and a major weed pest requiring repeated costly control efforts. The dense clusters of stems associated with bunchgrass species are a major concern of maintenance crews, for in times of food emergency it prohibits laying of protective canvas or plastic on saturated levee slopes. Ground squirrels have a high affinity for burrowing at the base of the plant, apparently making use of its extensive root system to provide support for their burrows (Owings and Borchert 1975). This species' perennial growth characteristic prohibits the periodic removal of vegetation for a complete structural inspection, and the large seed head is a highly desirable food source for ground squirrels. Experience has shown that P. tuberosa takes 2 to 3 years to become well established and vigorous, and 3 to 5 years before it becomes invasive and begins to spread from the initial planted area. In fact, several experimental plantings of this species were initially considered failures, only to result in a subsequent aggressive stand.

In 1978 the Department of Water Resources, in cooperation with the Department of Fish and Game, planted 1000 ft of the landside of the south levee of the Tisdale Bypass with P. tuberosa in an attempt to improve wildlife habitat and discourage ground squirrel activity. As a measurement of the effects on ground squirrels of this habitat modification counts were made of active squirrel burrows annually in 1979, 1980, and 1981. Counts were made in the planted area and in adjacent areas with naturally occurring vegetation and are provided in Table 3. An important consideration is that the 1979 and 1980 counts by DFG staff were made with vegetation present on the levee slope. The 1981 count by DWR staff was made after an accidental levee burn removed all vegetation. No other pest control methods were used during this time.

It is uncertain whether the entire increase from 12 to 295 active burrows counted in 1981 in the experimental planting was a 1-year increase in the actual ground squirrel population, or whether the accidental burn allowed for a thorough inspection which was not possible in the 1979 and 1980 counts because of vegetative growth.

While it is difficult to draw specific conclusions on these limited data, it is obvious that ground squirrel populations were not depressed in the planted area. Since 1982, traditional vertebrate pest control methods, including burrow fumigation with gas cartridges and the use of toxic baits, have been implemented to control this unacceptably high density of ground squirrels.

Experimental plantings with broadleaf species, such as Atriplex semipaccata (Australian saltbush) and Vicia dasycarpa (wollypod vetch), also impact levee maintenance programs. Generally levee slopes are managed to encourage grass species. Tall, dense or armored weeds primarily in the Brassica and

Table 1. Summary of past habitat modification plantings

Location	Year planted	Plant types	Project goal	Preparation & maintenance	Estimated planting costs	Comments
Garcia Bend Sacramento River	1972	Grasses shrubs	Weed and rodent control study	Fertilizer and irrigation	------	Inadequate water, weed invasion
Tisdale Bypass South Levee	1978 1980	Grasses Ground-cover	Wildlife habitat rodent control	Harrow, hand seeded fall planting projected eradication cost	$5,000 $2,500	Perla grass: Aggressive growth, very tall, ground squirrels harvest seed heads. Other species: Poor survival.
Tisdale Bypass North Levee	1980	Grasses	Wildlife habitat rodent control	Harrow, hand seeded fall planting projected eradication cost	$2,500 $7,500	Perla grass: Aggressive growth, very tall, ground squirrels harvest seed heads. Other species: Poor survival.
Maintenance Area 4 Sacramento River	1980 1981	Ground-cover & shrubs	Rodent control	Disking, herbicides, hand weeding	$2,500	Inadequate water, weeds, poor germination and survival. Russian thistle invaded planted area.
East Yolo Bypass	1981	Ground-cover grasses	Rodent control	Disking, herbicides	$1,500	Inadequate water, weeds, poor germination, fire, Black mustard invaded planted area.
Cache Creek South Levee	1981	Ground-cover grasses	Rodent control	Disking, herbicides	$1,500	Inadequate water, poor germination, fire
Willow Slough South Levee	1980	Ground-cover grasses	Rodent control	Harrow, hand seeded	------	Poor germination and survival.

Table 2. Summary of experimental plant species used in habitat modification plantings.

Species & common name	Plant type	Growth characteristics	Comments
Atriplex spp. Saltbush	Perennial Broadleaf	To 12 inches tall forms dense mat	Survives adverse soil conditions
Bacharis pilularis Dwarf Coyote Brush	Perennial Broadleaf	8-24 inches tall forms mat	Survives adverse soil conditions
Cistus salvitolius Sageleaf Rockrose	Perennial Shrub	To 24 inches tall forms mat	Poor germination and survival
Grevillea noellii Grevillea	Perennial Shrub	To 48 inches tall 4-5 feet wide	Poor germination and survival
Helianthemum nummularium Sunrose	Perennial Shrublet	6-8 inches tall forms mat	Poor germination and survival
Lavendula dentata French Lavender	Perennial Shrub	To 3 feet tall	Poor germination and survival
Salvia clevelandii Cleveland Sage	Perennial Shrub	To 4 feet tall	Poor germination and survival
Salvia sonomensis Sonoma Sage	Perennial Shrub	To 4 feet tall	Poor germination and survival
Teucrium chamaedrys Germander	Perennial Subshrub	To 12 inches tall	Attractive to bees
Agropyron trichophorum Luna pubescent Wheatgrass	Perennial Grass	36 to 48 inches bunchgrass	Preferred shady or moister locations
Lolium rigidum Wimmera 62 Ryegrass	Winter annual Grass	To 4 feet	
Phalaris tuberosa Perla Koleagrass	Perennial Grass	To 8 feet bunchgrass	Aggressive growth after est. similar to Johnson grass Very tall
Vicia dasycarpa Wollypod Vetch	Winter annual Broadleaf	To 24 inches	Attractive forage for ground squirrels
Festuca spp. Fescue	Winter annual Grass	8 to 24 inches	-
Lonicera spp. Honeysuckle	Perennial Shrub	2 to 6 feet tall	Cannot compete successfully with weedy species

Table 3. Number of ground squirrel burrows counted in three consecutive years ($\bar{x}$ holes per 1000 ft). In 1981 only active burrows 4 inches in diameter or larger were counted. Criteria for the 1979 and 1980 DFG counts are unavailable.

Year	L.S. experimental planting	L.S. natural vegetation	W.S. natural vegetation
1979	3	17	16
1980	12	20	0
1981	295	65	2.3

L.S. = landside, W.S. = waterside

Compositae families are considered undesirable in maintenance programs and frequently are suppressed with broadleaf selective herbicides. The experimental plantings required disking to prepare the seedbed, and hence the soil disturbance gave rise to many broadleaf weeds that presented additional problems. Two of the past experimental planting sites developed serious broadleaf weed problems, i.e., Russian thistle and black mustard, as a result of soil disturbance associated with the planting (King 1984). When broadleaf plants are introduced as the intended species, methods other than herbicides must be used to control the undesirable broadleaf weeds, usually at a substantially higher cost.

Further, with any experimental planting for the purpose of habitat modification or other nontraditional squirrel control technique, it is difficult to justify the risk of depending on a technique that is unproven to achieve the desired results. Adjacent property owners may be concerned over the lack of traditional squirrel control efforts. Experimental plants and resulting weeds may create new problems such as harborage or sources of insect pests, vertebrate pests such as meadow mice, and agricultural weeds.

SUMMARY

After considerable effort with a variety of plant species, the planting in these particular experiments on the Sacramento River Flood Control Project levees failed to significantly reduce ground squirrel populations and, in fact, in some situations appeared to substantially increase their numbers. The traditional methods of ground squirrel control, i.e., burrow fumigants and toxic baits, could not be abandoned or even substantially reduced. Dense plantings of certain species made finding and controlling ground squirrels more difficult and expensive. Aggressive plant species eventually had to be controlled at considerable additional expense. Levee maintenance generally became more difficult with increased potential of structural failure. Present evidence suggests that the planting of nonindigenious species on levees in an attempt to make the levee habitat unsuitable for ground squirrels is not a sound approach to their management where zero or near-zero ground squirrels can be tolerated.

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