## Title
Assessment and monitoring of California vole (Microtus californicus) feeding damage to a coastal redwood (Sequoia sempervirens) restoration project



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# Assessment and Monitoring of California Vole (*Microtus californicus*) Feeding Damage to a Coastal Redwood (*Sequoia sempervirens*) Restoration Project

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**ABSTRACT:** Throughout its range, coast redwood is subjected to vertebrate feeding damage at various life stages. Although some quantified information exists regarding feeding behavior by black bears and woodrats, only anecdotal evidence exists for most rodent feeding behavior, including California voles. This project adds to the base of knowledge regarding vole damage to sapling coast redwoods by describing and quantifying damage characteristics, and it establishes a protocol for field assessment and monitoring over time. It describes the distribution of vole feeding damage within a sample area, and it identifies cultural practices that potentially intensify feeding behaviors. An index is developed and provided to assay damage to saplings, in order to facilitate field assessments. A monitoring scheme is presented to evaluate sapling vigor and growth over time. Additionally, pruning of saplings is being assessed to evaluate the utility of this treatment in improving growth traits to damaged trees.

**KEY WORDS**: coast redwood, damage assessment, forestry, *Microtus californicus*, rodent damage, *Sequoia sempervirens*, silviculture, voles

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## INTRODUCTION

Coast redwood (*Sequoia sempervirens*) forests have been subjected to a myriad of management strategies over the past 100 years (O'Dell 1996), affecting forest composition and structure. These practices have included conversion of forestlands to non-forest uses including vineyards, orchards, and livestock grazing. The resulting consequences of this change affect the vertebrate fauna associated with sites. Consequently, the assemblage of microtine and other rodents in a forest-dominated site is different, once the site has been converted for intensive agriculture or rangeland. Typically, microtine species that occur in unconverted coastal redwood forests include red-backed voles (*Clethrionomys californicus*) and red tree voles (*Phenocomys longicaudus*). Once converted to non-forest grasslands, the most common microtine genus expected to occupy such Pacific coast sites is *Microtus*.

This transformation of the small mammal assemblage can be problematic in the event a landowner chooses to reverse past management decisions by restoring trees to the site. Planting seedlings on a site dominated by annual grasses and forbs places the trees at risk from feeding, since voles can achieve high population densities in a relatively short time. Additionally, the herbaceous cover can conceal feeding damage from field technicians who may not anticipate rodent damage. Once damaged, coast redwoods sprout vigorously, redirecting much of their metabolic energies to basal sprouts and taking on a shrub-like appearance. This slows their advancement to a tree form and subsequent commercial marketability.

The California vole (*Microtus californicus*) is widely recognized as a pest species in many crops and has been observed feeding and killing conifer seedlings in other coastal plantings (Clark 1984; G. Giusti, pers. observation). Most publications dealing with *Microtus* feeding damage in crops and trees offer solutions to minimize damage through population reduction strategies after damage has been noticed (Clark 1984, Jackson 1990, Askham 1992). There is little information regarding management strategies that may remedy *M. californicus* feeding damage to insure the viability of a plantation after damage has been detected.

Once damage is detected, a site manager is challenged with the need to maintain the vitality of the planting until the trees have reached harvest maturity. In the case of coast redwoods, this may span several decades. Since coast redwoods are unique among North American conifers because of their sprouting ability, a manager can opt to sever the damaged tree at the root crown and encourage sprouting, thereby losing years of accumulated growth, or he can choose other cultural practices (i.e., pruning) that may redirect tree growth to a limited number of sprouts. Though pruning has been evaluated to improve tree form and wood quality in pole-sized conifers (O'Hara 1989, 2002) the technique has not been appraised for its utility in restoring productivity in trees damaged by vertebrate feeding.

The questions raised by vole damage and tree recovery are pertinent to other scenarios involving vertebrate feeding damage to coast redwoods (black bears *Ursus americanus*; and woodrats, *Neotoma fuscipes*). This project was designed to evaluate field assessment assays of damaged trees and post-damage manipulations in a way that might be broadly applicable to other north coast plantations of redwoods suffering from feeding damage, regardless of the species involved. Specifically, the objectives of this project are to:

- establish impact to tree growth from (vole) feeding damaged based on percentage of damage;
- assess cultural strategies (pre-planting site preparation) that may promote vertebrate feeding behaviors; and
- evaluate benefits of post-damage treatments (pruning).

## PROJECT SITE DESCRIPTION

The project site is located in Mendocino County, California, approximately 11 km east of the Pacific Ocean along State Highway 20. The site is typical for this part of the redwood region, with steep slopes of Franciscan series soils, dominated by coast redwood with associates of tanoak (*Lithocarpus densiflorus*), California bay-laurel (*Umbelleria californica*), and Douglas fir (*Pseudotsuga menziesii*). The site previously had been converted from a tree-dominated site to a grass-dominant mix to accommodate livestock grazing; the current land managers estimate that site conversion occurred nearly 100 years ago, and it has been maintained in continuous grazing since conversion. The site is dominated by annual and perennial grasses and forbs planted to accommodate livestock foraging.

Prior to conifer planting, the site was terraced in a manner similar to site preparation for a vineyard. Each terrace center was spaced at 3.3 m. On the downslope side of each bench, the displaced soil from terracing was accumulated in a parallel "berm", a ridge of soil ≅0.3 m above grade, running the length of the terrace. This cultural practice is not common in forestry plantings and was arbitrarily chosen by the landowner. Trees were planted in a grid fashion in the center of each terrace, at a spacing of 2.6 m × 3.33 m (8 × 10 ft). Trees were planted in winter 1994 and were in their ninth growing season when evaluated in 2003.

*Microtus* occupied the elevated locations created by terracing the soil along the bench edge. Their presence was readily visible from both open burrow entrances and obvious runways meandering through the grass and forbs. Prior to damage evaluation, the site was treated with commercially formulated 2% zinc phosphide rodent bait. One application of the bait was applied within runways and near burrow entrances. The owner opted not to re-engineer the berms to grade because of financial constraints. The decision not to alter the site conditions may necessitate future baiting, if voles should re-occupy the site.

## METHODOLOGY

Trees were selected for evaluation by simply walking into the stand, tossing a stick into the air, and using the point were the stick fell to the ground as the corner of the sampling grid. The sample size was 100 trees in a 10 × 10 grid. (The project will be expanded in 2004 to include more replications).

Trees diameters were measured using a 20-cm caliper (Figure 1). Tree heights were measured using a 7-m telescoping tree pole. Damaged tree diameters were measured on the main boles at a point immediately above the highest point of feeding damage where the bark was intact. Non-damaged tree diameters were measured approximately 10 cm from the ground. Tree heights were measured from the ground to the height of the tallest terminal leader (Figure 2).

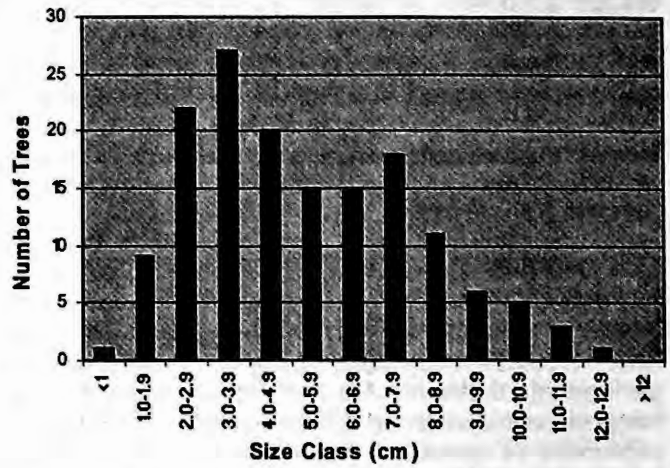


**Figure 1. Diameter class distribution of 100 saplings sampled for *Microtus* feeding damage on coast redwood (*Sequoia sempervirens*), Mendocino County, California. Mean diameter = 5.1 cm.**

The trees within the sample were then divided into a randomized block (using a random numbers table) to delineate treatments (pruning) vs. controls (Figure 3). Of those trees within the sample grid, 49 were pruned and 51 were retained as controls. The pruning needed to be done in a manner that simulated a commercial approach to stand recovery, if it was to be considered a viable option in future managerial decisions.

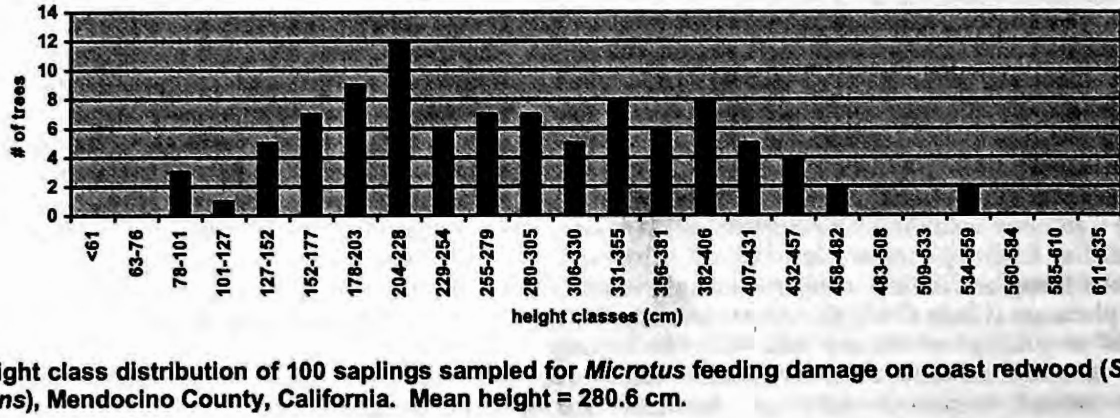


**Figure 2. Height class distribution of 100 saplings sampled for *Microtus* feeding damage on coast redwood (*Sequoia sempervirens*), Mendocino County, California. Mean height = 280.6 cm.**

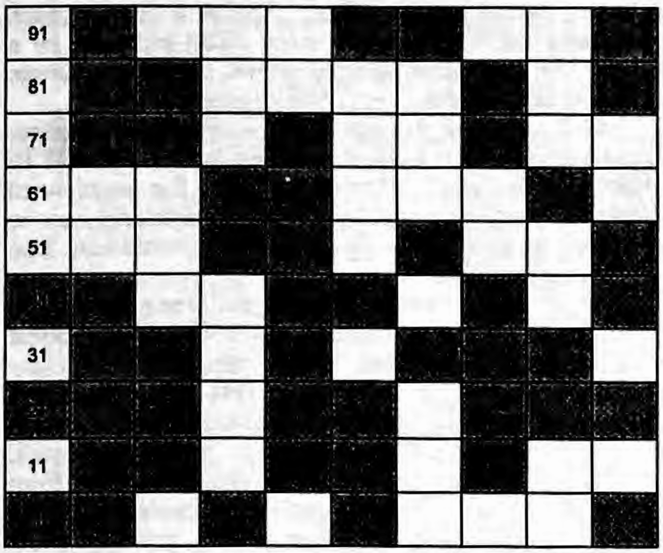


**Figure 3. Randomized treatment design for control vs. pruning; 49 were pruned (shaded) and 51 were retained as unpruned controls.**

In order to establish a managerial approach to pruning, discussions between the stand manager and myself were necessary to establish pruning protocols and a reasonable amount of time for pruning (per tree) under commercial constrictions, given the high number of trees in the plantation. The agreed-upon guidelines included a desire to re-establish a "tree form" in damaged trees and a need to conduct the pruning in a timely and safe manner. In order to satisfy the first condition of re-establishing tree form, it was agreed to remove all but the 2 or 3 dominant sprouts that had minimal feeding damage. We agreed that time spend pruning (per tree) should be ≤6 minutes. This would allow a field worker to prune a minimum of 10 trees/hour.

A damage index was developed to facilitate evaluation of feeding damage per tree. The index simply associated a numerical classification with each tree, based on the percentage of the bole that was damaged by vole feeding (Table 1). The index should facilitate future mathematical evaluations by allowing "categories" of damaged trees to be compared.

**Table 1. Level of damage measured as a % of girdling to the bole.**

| % of Girdling | Rating Index |
|---|---|
| <25 | 1 |
| 25-50 | 2 |
| 50-75 | 3 |
| 75-100 | 4 |
| 100 | 5 |

## RESULTS

*Microtus* feeding damage was sporadically dispersed throughout the sample grid (Figure 4) but was heavily influenced by the presence and proximity of raised "berms" associated with the benched terraces. Damage was concentrated in areas of high *Microtus* activity associated with the raised soil. It was obvious that the raised soil created optimal habitat particularly during the wet season when much of the site was saturated with moisture.

Of the trees sampled, 44% had incurred *Microtus* feeding damage. There was no clear association between feeding and tree diameter or height class. Of the damaged trees, 59% had sustained ≤50% damage. A total of 33% of the damaged trees sustained levels of damage above 50%, while 8% were completely girdled, resulting in the death of the dominant, terminal leader (Figure 5). Using the damage index, in most cases it was possible to assess damage per tree in <15 seconds, thus providing an accurate and quick assay for field applications.

Pruning was applied to 49 trees. In most but not all cases, pruning took <6 minutes per tree. However, in some of the heavily damaged trees with multiple basal sprouts, it was not possible to accomplish the desired level of pruning in the predetermined time allotment.

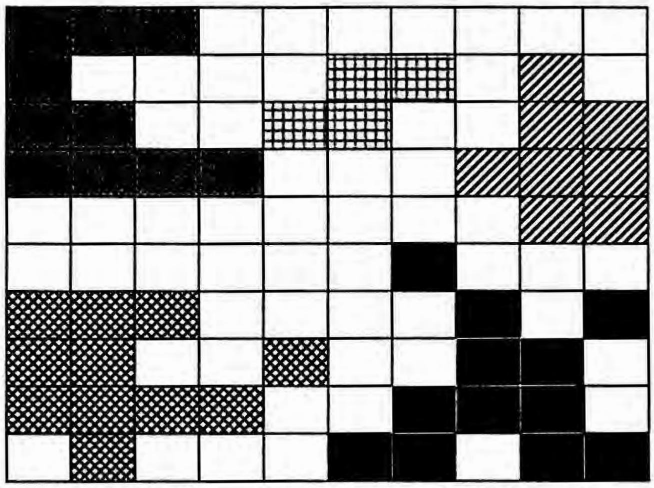

**Figure 4. Distribution of vole-damaged redwood sampling within the sample. Shaded blocks designate damage trees; unique shading indicates separate concentrations of vole activity. Percent damaged = 44%.**

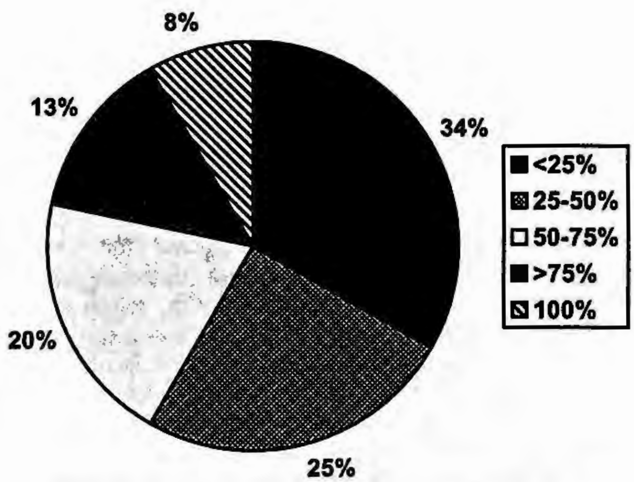


**Figure 5. Level of damage sustained on individual trees sampled.**

## DISCUSSION

Vertebrate feeding damage on coast redwoods has been reported sporadically in the literature for the past half-century (Glover 1955, Giusti and Schmidt 1988, Giusti 1999). Anecdotal reports of feeding by rodents on redwoods exist; however, many of these have not been evaluated for their relative importance to the success of redwood plantings and restoration projects. Virtually no quantified information exists from feeding damage to coast redwood by California voles, and most literature that evaluated tree-vole interactions does not provide alternatives for post-damage decision matrices (Askham 1992).

Giusti and Schmidt (1988) lamented the lack of information available to satisfy managerial questions regarding the viability of maintaining redwood stands heavily impacted by black bear feeding. The continued lack of field-tested data is hampering the recovery of many stands in the north coastal California that are slated for transformation from even-aged to uneven-aged stands for restorative purposes (Dan Porter, Save the Redwood League, pers. commun.). In most cases of vertebrate damage, it is widely apparent that certain managerial activities may induce feeding damage behaviors in forest plantations (Maser 1967, Mason 1987, Jackson 1990, Zeedyk 1957); however, post-damage strategies to insure the viability of the planting or restoration efforts are sorely lacking.

Voles provide a unique opportunity to test a variety of field techniques to evaluate and possibly remedy vertebrate feeding impacts to coast redwoods, since they often occur in high population densities, cause highly visible and distinguishable damage, and impact relatively small trees that are easily measured and monitored. Thus, a researcher can evaluate post-damage responses from young trees that are growing at an accelerated pace, and can collect tree growth data more readily than from trees that may be several decades old. Furthermore, they provide an opportunity to develop and test damage assessment protocols that can be applied to other vertebrate-redwood conflicts.

The fundamental question that confronts all forest managers addressing vertebrate pest damage is the degree to which a tree can sustain damage, still maintain good form, and continue to grow and develop wood fiber. There does not exist a sound decision matrix to assist forest managers in determining how an individual tree responds to various levels of damage, and what alternatives are available that might mitigate the impact over time.

By collecting individual criteria on trees within the sampled grid, growth can be monitored and compared over time between damaged and undamaged trees. Comparison of individual tree growth, using the tree damage index, should provide insights about the response of individual trees to the various levels of damage. If the null hypothesis proves to be correct (that there is no difference in growth rate between damaged vs. undamaged trees), then the obvious managerial response is to do nothing. However, if the null hypothesis is proved wrong, then treatment (e.g., pruning) can be evaluated to determine if it can minimize the long-term effect of partial basal girdling. Applying this approach and using the tree damage index could prove to be a useful tool for other species whose feeding behavior results in basal girdling (e.g., black bears).

The monitoring strategy for this project includes re-measurement of all trees at a minimum of 1, 5, and 10 years post-damage. However, given the accelerated growth of the young stand, monitoring protocols may be amended to annual site visits to assess treatments in a more timely manner.

The decision to terrace the site and create benches of soil above grade obviously improved the habitat conditions for voles and concentrated them in close proximity to the young trees. This site preparation strategy, in combination with the low hanging branches characteristic of growth patterns in young redwoods, created an optimum situation for voles to venture from their burrows and feed relatively undetected under the canopy of the saplings. Clark (1984) provided clear explanations of how similar pre-planting treatments can influence California vole densities and feeding patterns in field crops, while Askham (1992) and Black et al. (1974) provided similar accounts in forested situations.

If vole populations rebound and once again begin to feed heavily on the young trees, it may be necessary to re-apply a commercial rodenticide and to re-visit the need to contour the benches so as to eliminate the berms that are providing suitable habitat.

This project potentially can provide insight how to mitigate vertebrate damage to coast redwood by initiating post-damage treatments. The project will be expanded in the coming years to increase the degrees of freedom to insure the treatments will stand statistical scrutiny. In the meantime, in the absence of a sound body of field tested information, questions continue to be raised by forest managers challenged with addressing vertebrate feeding damage in coast redwood plantations.

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