THE VERTEBRATE PEST CONTROL RESEARCH ADVISORY COMMITTEE

Protecting California's Agriculture

INTRODUCTION

Each year ground squirrels, pocket gophers, voles, rats, birds, and other animals cause millions of dollars of damage to California agriculture. Farmers, park managers, foresters, and others, including homeowners, often use an integrated approach to deal with these important and sometimes devastating pest problems. An essential part of these management programs is the use of rodenticide baits such as anticoagulants, zinc phosphide, burrow fumigants such as gas cartridges, and bird control devices.

In the early 1900s, few rodenticide products were registered or available for agricultural use. The market was relatively small and private manufacturers were not generally involved in this pest management area. To address the serious vertebrate pest problems in the state, the California Department of Food and Agriculture (CDFA) was active in developing and ultimately registering rodenticides and avicides for use against agricultural pests. Today, CDFA maintains the registration of 10 vertebrate pesticides that are sold by 41 county agricultural commissioner offices. These materials, along with those registered by private manufacturers, are essential to help farmers, public health agents, and others deal with the many vertebrate pest problems throughout the state.

In the 1980s, changes in federal law established new scientific requirements for all new and existing pesticides. As a result, the U.S. Environmental Protection Agency (EPA) notified California that it must submit additional scientific data about the toxicology, use, and environmental fate of *zinc phosphide* and *anticoagulant* baits. Complex research projects, some costing well in excess of $100,000, were required. If EPA did not get this requested data, the rodenticides would be prohibited from use in agriculture, which would be a devastating consequence to the state. Without effective control measures, CDFA estimated that growers could suffer additional damage losses exceeding $1 billion annually. Clearly, CDFA was faced with a problem. Either spend millions of dollars to keep the materials necessary to protect California agriculture or lose these remaining pest management tools. The problem was even worse because several very effective rodent control materials including *Compound 1080* and the aboveground uses of *strychnine* had already been lost as a direct result of CDFA not having the financial resources to meet EPA's registration requirements.

In 1990, the California Legislature passed a bill to collect a surcharge for each pound of vertebrate pest control material sold, distributed, or applied by the county agricultural commissioners. The legislation specified that all money generated would be used to fund the research required to maintain current registrations, to improve existing rodenticides, and to find new materials and methods to solve vertebrate pest problems. The bill established an external advisory committee, the Vertebrate Pest Control Research Advisory Committee (VPCRAC), to set priorities for vertebrate pest research projects and to recommend to CDFA research projects that should be funded. In 1995, the surcharge program was extended for another five years.

The surcharge program has been extraordinarily effective. It has raised over $2.4 million to help meet the following objectives:

COSTS TO REGISTER A PESTICIDE

Registering pesticides for use against agricultural pests is expensive. Over a million dollars may be necessary for research and development before EPA and California Department of Pesticide Regulation (DPR) will approve the use of a new pesticide. Vertebrate pesticides have the same requirements as all others, but the market for them is relatively small, making these huge investments difficult for chemical companies to justify.

Even after a pesticide is registered, the costs continue to mount. An annual registration fee is required, but more importantly, EPA continues to ask registrants to supply new and expanded scientific data to maintain the registration.

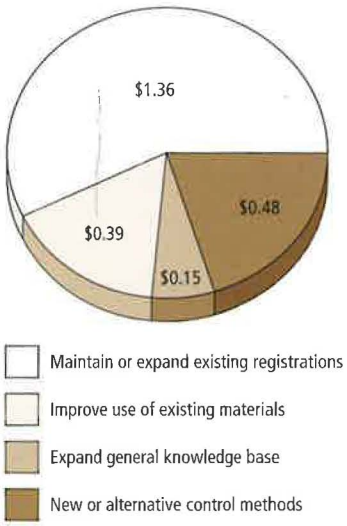
VPCRAC AFFILIATIONS

The California Vertebrate Pest Control Research Advisory Committee (VPCRAC) has representatives from the California Department of Food and Agriculture (CDFA), the County Agricultural Commissioners Association, the University of California, the California State University, the State Department of Health Services, and the general public. In addition, five representatives from the agricultural industry representing commodities affected by vertebrate pests are also on the committee.

- maintain current CDFA rodenticide registration
- improve the use of existing materials
- expand our knowledge about controlling vertebrate pests
- find alternative control materials and strategies

Since 1990 more than 45 research studies or projects have been funded by VPCRAC using surcharge funds. These have been conducted by scientists at locations throughout the country, including the U.S Department of Agriculture's National Wildlife Research Center (NWRC) in Fort Collins, Colorado; the University of California at Davis and Berkeley; private consultants; and EPA-approved testing laboratories. In addition, close cooperation with private chemical manufacturers, especially those that produce the technical-grade materials, continues to be an important aspect of the VPCRAC's work.

SURCHARGE EXPENDITURES 1990–1998
(Dollars in Millions)



California ground squirrels destroyed all the broccoli plants along the edge of this field.

During these early registration call-ins, EPA's most pressing data needs were on the *zinc phosphide* and *anticoagulant* rodent labels. In addition to these registration requirements, VPCRAC also placed high priority on discovering and evaluating alternative control methods, including feasibility studies for new toxicants, repellents, and other control methods, and studies on the understanding and use of existing materials for vertebrate pest control. The VPCRAC strongly supports integrated pest management approaches that use the most appropriate scientific techniques for specific pest problems.

Accomplishments

After almost 10 years of operation, the bait surcharge program has been extremely successful. It has

- maintained the 10 CDFA rodenticide registrations by developing and submitting the scientific data requested by EPA and other regulatory institutions
- researched improvements to existing rodenticides, especially *zinc phosphide*
- expanded our knowledge about rodenticides and other aspects of vertebrate pest control to help us better deal with these important pests

California ground squirrel damage to almond nuts.

- explored and found new ways to manage rodent and bird pests.

Getting a sense of the projects undertaken as well as how they can help solve California's rodent and bird problems is difficult. To help, we have summarized the major projects below.

The following icons identify the general type of research for each project:

maintaining or expanding existing registrations

expanding the general knowledge base

improving the use of existing materials

examining new or alternative control methods

We have also provided information to give you a better understanding of why some research is necessary and how it relates to operational vertebrate pest control programs.

Whenever an investment decision is made, good information on the costs and benefits of the proposal must be available. Investing in existing and new vertebrate pest control methods is no exception. A key element is understanding the economic impact of rodent

DATA MANAGEMENT

After operating for only a short time, VPCRAC recognized that it was generating a large amount of important information, making it more and more difficult to keep abreast of the findings and the status of each research project. To manage the research projects and to ensure that information, issues, and problems identified by researchers could be readily accessed, a computerized database was established to maintain information on each project.

and bird pests on California. Through VPCRAC-funded research, agricultural economists completed a study that estimated annual damage by rodents and birds at $95.9 million in California.

Economic Assessment

Assessing the Economic Damage of Nonpredator Vertebrate Pests

Vertebrate pest damage in California agriculture is significant, and it is particularly severe in alfalfa, fruit and nut crops, and artichokes. The animals causing damage include ground squirrels, pocket gophers, voles, rats, a variety of birds, and a few large mammals such as coyotes and feral pigs.

Using surveys, interviews, and computer models, researchers estimated the economic impact of vertebrate damage to selected California crops and rangeland. Their estimate is unique because it forms a picture of damage to 19 crops representing nearly 50% of California's $16 billion agricultural revenue in 1996–97. Since vertebrate pest damage varies considerably from year to year and across crops and regions, the researchers developed a model that separates impacts for each crop across the seven different production regions of the state. This analysis revealed that producer revenue losses are highest for alfalfa grown in northern California (19.4%), followed by pistachios and sugar beets in northern California (about 5% each) and artichokes on the central coast (3.5%).

VPCRAC OUTREACH MEETINGS

In 1996, VPCRAC held a series of five meetings throughout California. Our goal was to help people become more familiar with the surcharge program and how it is helping to protect California agriculture. We also asked for and received input regarding significant vertebrate pest problems in the state. These important issues were identified by those attending the meetings:

- The public needs to be better educated about vertebrate pest problems and their solutions.
- More research is needed on repellents.
- More effective control measures other than toxicants are needed.
- There are no satisfactory controls for voles or Belding's ground squirrels.
- The effectiveness of currently registered materials such as *zinc phosphide* should be improved.
- *Compound 1080* should be registered in California or other materials that are just as effective should be developed.
- Rodenticide registrations for specific crops not currently covered should be broadened.
- VPCRAC should conduct risk/benefit studies for rodenticides.
- VPCRAC should also conduct studies to establish an economic damage threshold due to vertebrate pests.
- More research is needed to improve the design of the burrow builder to enable it to accept a variety of grain baits.

Broccoli damaged so extensively by California ground squirrels that no product is harvestable for market.

PARTNERING WITH INDUSTRY

CDFA, through VPCRAC support, has been instrumental in the formation and operation of the Zinc Phosphide Consortium. This is a partnership between private manufacturers and several public agencies that pooled resources to meet the EPA data call-in requirements for this important rodenticide. All members of the consortium benefit by sharing the costs of data generation and the administrative costs associated with registration. Ultimately, California farmers benefit by keeping this important rodenticide available for their use.

REGISTERING RODENTICIDES

Like all pesticides, EPA and DPR require certain kinds of tests, both laboratory and field, to prove that materials are safe and effective and that they do not pose unacceptable risks to the environment. The Food Quality Protection Act of 1996 requires EPA to consider the special sensitivity of infants and children to pesticides. When evaluating a pesticide for re-registration, EPA obtains and reviews a complete set of studies from the pesticide producer. Major tests required for most rodenticides include the following.

Human Health Assessment

- *Toxicity:* EPA requires studies on lab animals to determine acute effects via oral or inhalation exposure, dermal exposure, or eye irritation.
- *Dietary exposure:* If EPA determines that the rodenticide's use causes contact with food, a dietary risk assessment is undertaken to determine tolerances or maximum residues that will be allowed on that food or feed.
- *Occupational and residential exposure:* If EPA determines that there is a potential exposure to applicators or handlers due to inhalation or dermal contact, special protective requirements may be imposed. These precautions may include specific wearing apparel, chemical-resistant gloves, and a filtering respirator.
- *Human risk assessment:* EPA is concerned about the likelihood of risk of exposure to humans, especially children, resulting from continued use of rodenticides in residential settings. EPA calculates a margin of exposure (MOE) for each chemical and may require additional precautions if there is a risk from accidental exposure to residential users. If the chemical is classified for carcinogenicity, additional requirements are also imposed.

Environmental Assessment

- *Environmental fate:* Because EPA is concerned about how persistently a rodenticide remains in an active and stable state, they require studies to show degradation rates due to hydrolysis or contact with soil microorganisms. If there is concern that the chemical may contaminate groundwater or surface water by leaching, additional tests are required.
- *Ecological effects:* Concerned about primary and secondary toxicity to avian species, small mammals, mammalian predators, and aquatic organisms, EPA requires special studies on ecological effects, some of which must be performed under field conditions.
- *Environmental risk characterization:* If EPA determines that there are risks of secondary poisoning to nontarget species based on reviewed studies or incidents, it may request additional studies to obtain the necessary data to determine the degree of risk.

Risk Mitigation

When there is the likelihood of product exposure to humans, especially children, EPA now requires rodenticide producers to incorporate an indicator dye to help identify whether a child or pet has actually consumed the pesticide. In addition, these products will have to be formulated with a bittering agent to make them less palatable. After consultation with stakeholder groups, there may be additional means of significantly reducing exposure to children and pets. To monitor the effectiveness of these mitigation measures, EPA requires registrants to submit annual National Poison Control Center data for 1999 through 2009.

Additional Data

EPA has the authority to require additional generic studies to confirm its regulatory assessments and conclusions. These tests may vary with the particular rodenticide's characteristics and may include specific studies on efficacy; estimation of dermal or inhalation exposure at indoor or outdoor sites; leaching, adsorption, or desorption; hydrolysis; general metabolism; secondary poisoning to birds or mammals; avian reproduction for quail or duck; acute fish toxicity for bluegill sunfish or rainbow trout; acute aquatic invertebrate toxicity; whole-body residue for target species; storage stability; crop field trials; and more. Each of these studies must follow standard published protocols to ensure reliability.

Product Labeling

Although not a required test, EPA mandates that all end-use products must comply with their current pesticide labeling requirements and with any revised labeling for re-registration.

This litter illustrates the high reproductive rate of California ground squirrels.

For all the commodities considered in this study, the overall economic impacts range between $43 million and $156 million, with a mean estimated impact of $96 million. The models also predicted that approximately 400 jobs are lost annually because of vertebrate damage. These results represent a conservative estimate of the total impacts of vertebrate damage in California because only a small portion of all agricultural activity in the state was sampled.

Potential Vertebrate Pest Control Chemicals

Finding new rodenticides or repellents is an exciting but expensive avenue of research. The time from the discovery of a new chemical to its availability for public use may be many years. Costs are extensive and almost always reach many millions of dollars. Before investing in the development of new materials, VPCRAC commissioned a study to identify the most promising vertebrate pest control materials. This information helped focus our further efforts in developing new materials and in investing in those we already have.

In this 1995 study 40 vertebrate pest control chemicals or potential pesticides were examined. Past and current uses of all materials, along with a brief discussion as to whether they warrant further exploration, an expansion of their use, or a significant developmental undertaking, were identified.

The bare patch among these sugar beets was caused by California ground squirrels living in the field.

California ground squirrels often climb atop fence posts for a better view of the area.

Compounds with the highest priority ratings were *chlorophacinone, diphacinone, strychnine* (rodenticide), and *zinc phosphide.*

Most of the vertebrate pest problems in California are caused by rodents. Ground squirrels are probably the most significant rodent pest in agriculture. Two primary species, the California ground squirrel and the Belding's ground squirrel, were found to cause the most damage.

California Ground Squirrel

The three most important CDFA rodenticides for ground squirrels are *zinc phosphide* and the *anticoagulants diphacinone* and *chlorophacinone.* Each of these materials has been subject to additional data requirements from EPA to ensure continued registration. The VPCRAC has also funded work to help growers better understand and use these materials. Additionally, two other compounds, *bromethalin* and *cholecalciferol,* were investigated for potential control of ground squirrels.

Efficacy of *Zinc Phosphide* under Field Conditions

EPA required efficacy studies to maintain current registrations for *zinc phosphide* grain bait concentrations for both hand- and ground-based broadcast baiting for ground squirrels. The researchers found no significant difference in mor-

PARTNERING WITH INDUSTRY RESEARCH PRIORITIES

To prioritize our work, VPCRAC considered the data demands from EPA as well as the overall vertebrate pest management needs of the state. To help guide our research regarding specific pesticides, VPCRAC prioritized the research as follows:

- *chlorophacinone*
- *diphacinone*
- *strychnine (rodenticide)*
- *zinc phosphide*
- *strychnine (avicide)*
- *sodium fluoroacetate (1080)*
- *cholecalciferol*
- *Avitrol*
- *aluminum phosphide*
- *fenthion*
- *gas cartridges*
- *warfarin*

An almond branch was completely stripped of nuts by California ground squirrels.

MEASURING THE EFFECTIVENESS OF A RODENTICIDE

Often farmers use a pesticide and "know" from experience that it is effective. During rodenticide research, we must go beyond general observations and conclusively demonstrate the level of control obtained. When required by EPA, research must establish at least a 70% reduction in the test population.

To determine this, researchers use several methods. The most common method is measuring the change in the rodent population or activity from before to after the treatment. For ground squirrels, this is often done by counting the animals before and after the treatment. It can also be done by filling in burrow openings and measuring how many and how fast they are reopened. Trapping before and after a test can also establish the change in population size. Probably the most sophisticated method is the use of radio transmitters. After attaching them to the animals, researchers use them to follow the animals' activity and determine whether it survived or died as a result of the treatment.

Taking a census of rodent populations to determine the effect of a rodenticide is time-consuming and often must be done several weeks before and after the test treatment. The results are important, however, to maintain and support the registration as well as to allow growers and others to better understand the high costs and extended time periods needed to complete what might otherwise appear to be a relatively minor test.

tality between the two bait concentrations or application methods. Prebaiting was used in this study. Mortality averaged over 90%, which is excellent. These studies have been used to support the continued use of *zinc phosphide* for California ground squirrel control.

EPA required 10 tests that ultimately cost more than $520,000 in order to maintain the *zinc phosphide* label for ground squirrels. While the EPA data requirements are always subject to change, VPCRAC has so far met the requests and the labels have been maintained.

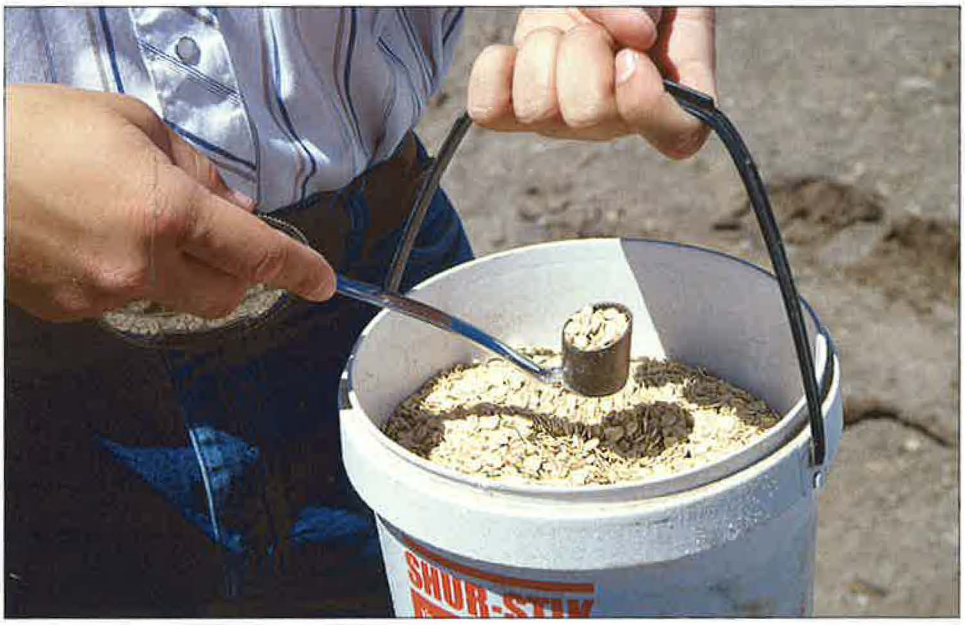
While *zinc phosphide* is an important rodenticide bait for ground squirrel control, its use has somewhat diminished because some have found its effectiveness to be inconsistent. Clearly, more research is needed to better understand this material.

"Best Management Practices" Protocol for *Zinc Phosphide*

Concerned with the variability of field trial results related to the use of *zinc phosphide*, scientists are developing a comprehensive set of guidelines for using this material, based on knowledge of past control efforts, the efficacy trials required by EPA, and the published literature about squirrels and *zinc phosphide*. The guidelines take into account procedures such as prebait acceptance tests, prebaiting techniques, and calibration of baiting equipment, as well as a thorough understanding of squirrel biology. Preliminary testing of these strategies occurred during summer 1998 in trials conducted in San Joaquin and San Luis Obispo Counties. These early studies demonstrated excellent control ranging from 89% to 100%. When this study is completed, these strategies will help growers identify whether and when to use *zinc phosphide* and which procedures to use to obtain excellent control.

Anticoagulants are by far the most common rodenticide used for ground squirrel control in California. Although

Prebaiting for ground squirrel control using clean oat groats and a spoon that delivers a tablespoon of grain.



BAIT ANALYSIS

In all field studies, baits are first analyzed for the level of active ingredient to determine if they are within certified limits before being applied. A posttreatment analysis is often performed to determine bait stability when exposed to field conditions inside or outside of a bait station.

PREBAITING

Research has shown that rodents' acceptance of some types of toxic bait (and therefore the control) can be improved by prebaiting. Prebaiting is the application of nontoxic, or "clean," bait on the area that will be treated later with a toxic bait. The same material must be used for prebaiting that will be used to carry the toxic bait. Prebaiting introduces the bait material to the target animals and conditions them to eat the toxic bait.

Prebaiting is used with *zinc phosphide*, most commonly for California ground squirrel control (*zinc phosphide* on oat groats is a common formulation used for ground squirrels). Prebaiting would consist of applying "clean" oat groats on the area and then treating the same area 2 or 3 days later with the *zinc phosphide*. Prebaiting may increase control by 20% or more.

A T-style bait station made of PVC pipe dispenses bait to ground squirrels.

these materials have been used for many years, complete data on their laboratory and field effectiveness were not always available. Continued registration and use practices of these materials were in jeopardy unless CDFA met the data requirements of EPA.

Efficacy of *Anticoagulants* in Field Tests

Four studies were required by EPA in order to maintain the current registrations of 0.005% and 0.01% concentrations of *diphacinone* and *chlorophacinone* in treated grain for spot-baiting and bait station use against the California ground squirrel. A secondary objective was to evaluate the potential nontarget hazards from these baits. Test sites were located in Madera County on oak rangelands. Plots varied in size from 11 to 20 acres.

These comprehensive field tests have demonstrated that *anticoagulants* at either concentration achieve acceptable levels of ground squirrel control when applied either by spot-baiting or in bait stations. No secondary hazards to nontarget species were found. These tests were submitted to EPA and have been important in allowing the registrations for these two *anticoagulants* to continue.

While *anticoagulant* baits are extremely effective for ground squirrel control, they are relatively expensive because baits must be broadcast three or four times or distributed in a bait station. VPCRAC is exploring ways to lower the costs and improve the efficacy of anticoagulants.

Anticoagulant Baiting Strategies

Laboratory and field tests are underway to evaluate the effect of several anticoagulant bait application strategies. Through these tests, researchers discovered that fewer applications of *diphacinone* may be as effective as the number currently recommended. While these tests are not finished, preliminary results indicate that we may be able to reduce the costs of baiting by over 30%.

Experienced pest control operators know that relying on only one pesticide can lead to problems and eventually give poor or no control. Exploring new materials for ground squirrel control is an important function of VPCRAC. Two experimental materials, *bromethalin* and *cholecalciferol*, show promise for ground squirrel control and have been researched both in the laboratory and field.

Bait stations prevent nontarget species, such as deer, from gaining access to the anticoagulant bait.

APPLICATION TECHNIQUES MAKE A DIFFERENCE

When controlling the California ground squirrel, applicators often design their baiting strategy to take advantage of the rodent's life cycle and feeding behavior.

Broadcast baiting takes advantage of the active foraging nature of the ground squirrel during the spring and summer when the animals are out of their burrows for most of the day. The bait is distributed evenly over the terrain where burrows are present using a ground-based mechanical spreader.

Spot-baiting is the placing of a small quantity (such as 1 tablespoon) of bait in the 2 to 3 square feet directly around the squirrel's active burrow. The advantages of this technique is that less material may be used and its placement can be very specific. It is especially useful when treating relatively small areas.

Bait stations provide a continued source of bait for squirrels. They are especially useful if there is a concern about larger nontarget species coming into contact with the bait. Bait boxes can be constructed out of many materials, including exterior plywood and PVC plastic pipe. Stations are placed near active burrows and secured so they can't be turned over. Bait stations also keep bait from becoming wet and moldy.

ANTICOAGULANT BAITS

Anticoagulants work by interfering with an animal's blood clotting mechanism. Bait stations are often used to apply anticoagulants because to be effective, the animal must eat the bait in multiple feedings over several days. The current CDFA label for broadcast treatment suggests treating every other day for three applications. However, little scientific data exists on which to accurately design the most appropriate baiting strategy that is effective and at the same time cost sensitive and environmentally sound. VPCRAC research is addressing this question. While it is too early to change our baiting recommendations, this research has demonstrated good control of ground squirrels with less bait material and fewer applications than are currently recommended.

California ground squirrels used in laboratory studies must be trapped live in the wild.

Efficacy Of *Bromethalin* Using Pelleted and Grain Baits under Lab Conditions

Bromethalin is a unique compound that is presently used for rat and mouse control on farms and in urban situations. Because it has the potential of being an effective alternative to existing ground squirrel baits, laboratory trials were undertaken to determine the appropriate concentration of *bromethalin* on pellets that would result in the control of California ground squirrels. The results showed that bromethalin can control California ground squirrels, with mortality exceeding the EPA 70% standard in several tests. The optimal concentration of bromethalin was calculated to be 0.07%. There was also some suggestion that the squirrels were sensitive to the time of year in accepting the bait, which could be important for any subsequent field studies.

Efficacy of *Bromethalin* under Field Conditions

To examine the potential of *bromethalin* under field conditions, a field efficacy study was conducted using two concentrations (0.01% and 0.10%) of *bromethalin*-treated oat groats in bait stations. A secondary objective of the study was to evaluate the potential nontarget hazards. The study was located in Tulare County in the oak-grass woodland zone of the Sierra Nevada foothills. Test baits were applied in bait stations to plots that ranged in size from 11 to 14 acres. Bait was given an exposure period of 19 to 20 days. Under the conditions of this test, the efficacy of *bromethalin*-treated oat groats when used in a standard bait station remains inconclusive. However, it was established that the lower concentration was as effective as the higher concentration. Further field tests will be necessary to determine if this material will be effective in controlling ground squirrels.

This standard box-type bait station placed on the ground is easily accessed by kangaroo rats (top). Infrared night photography shows that kangaroo rats cannot reach an elevated station (bottom).

Efficacy of *Cholecalciferol* under Lab Conditions

Cholecalciferol (vitamin D_3) is toxic when consumed in large doses because it causes calcification of the blood vessels. It offers the possibility of being a new control material for California ground squirrels. A laboratory feeding

SQUIRREL PHYSIOLOGY MAY DETERMINE BAITING STRATEGIES

A study of blood clotting response time in squirrels following one application of *diphacinone* is underway. The information collected will provide a second way of determining the optimal interval between bait applications. This could help to identify the ideal time for subsequent applications of bait. It may even show that only two applications of *anticoagulants* are required for effective ground squirrel control.

WHY LABORATORY AND FIELD TEST RESULTS OFTEN DIFFER

When comparing laboratory and field tests, we often see significant differences in the results. In the laboratory, scientists control the environment, including the temperature, light, food, and water. Test animals are usually individually caged, so contact between animals, including intimidation and fighting, is minimized. These controls influence the behavior of the test animals and their stress during the experiments. In the field, weather, other animals, and food availability all play important roles in determining how animals respond to a test program. This is a primary reason why we test materials both in the laboratory and in the field where more natural conditions prevail.

This elevated bait station allows anticoagulants to be used for ground squirrel control while protecting kangaroo rats (top). A modified-T bait station also denies kangaroo rats access to bait (bottom).

trial was initiated to determine the minimum *cholecalciferol* concentration in bait necessary for good squirrel control. The laboratory tests obtained 90% mortality, demonstrating a good potential for ground squirrel control in the field.

Several endangered species of kangaroo rats live in the same habitat as the California ground squirrel. Attention has been focused on learning more about the habits and behavior of these nontarget species so control programs can be designed to minimize the impact on these animals.

Ecology and Behavior of Endangered Kangaroo Rats

An extensive literature review was conducted on kangaroo rats with emphasis on their biology and behavior as it might relate to squirrel control programs. From these findings, we have been able to keep more ground squirrel control options available in areas where these endangered kangaroo rat species are present.

PROTECTING KANGAROO RATS

The federal government has listed the Stephen's (*Dipodomys stephensi*), the San Bernardino (*D. merriami parvus*) the giant (*D. ingens*), the Fresno (*D. nitratoides exilis*), and Tipton's (*D. n. nitratoides*) kangaroo rats as endangered. To protect small populations of endangered kangaroo rats, it is necessary to minimize other hazards, including those associated with using rodenticides to control the California ground squirrel. It is necessary to have a good basic understanding of kangaroo rat ecology and behavior in areas where such control is being contemplated.

The following factors should be considered when controlling California ground squirrels in areas where kangaroo rats also live:

- The range and habitats of kangaroo rats overlap extensively with those of California ground squirrels.
- In many areas, kangaroo rat colonies inhabit raised areas such as berms and margins of crops.
- Kangaroo rats feed on seeds that they locate through their highly developed sense of smell. Any grain supplied in a bait station or any grain used in spot-baiting is likely to be very attractive to them.
- Kangaroo rats are very curious and will readily explore new objects in their environment, such as bait boxes.
- Kangaroo rats are nocturnal. They are at low risk of poisoning from bait that is spilled on the ground during the day as long as the bait is picked up before dusk.
- Kangaroo rats are not climbing animals, although there is anecdotal evidence to suggest that they can climb or jump if necessary to escape predation or to reach favored food resources.
- Seed in caches created by ground squirrels may be readily eaten by kangaroo rats. If baiting occurs in fall when ground squirrels are caching seed, ground squirrels may move poison bait from bait boxes designed to exclude kangaroo rats to caches where it becomes accessible to them.
- Kangaroo rat burrows are easily distinguished from California ground squirrel burrows by size and form compared to the much larger ground squirrel burrows. Kangaroo rat burrow systems are typically found on slightly elevated land, often in association with shrubs or other vegetation.
- Although kangaroo rats have developed physical and behavioral adaptations to avoid predators, the impact of predators on their populations may be severe.

Their excellent climbing ability allows California ground squirrels to enter a modified-T bait station.

Opportunities for Using Elevated Bait Stations

As a direct result of the literature review on kangaroo rats, laboratory and field studies were conducted. Two elevated bait station designs intended to exclude kangaroo rats, while allowing access by California ground squirrels, were tested. Data loggers and remote cameras were used to demonstrate that kangaroo rats could not gain entrance into the bait stations. Since ground squirrels have no problems climbing into the stations, these designs are effective in protecting kangaroo rats.

VPCRAC-funded investigations have shown that behavioral differences between kangaroo rats and ground squirrels make it possible to mitigate potential hazards to the endangered species. For example, differences in burrow size and other burrow characteristics enable *fumigants* to be selectively directed to ground squirrels. Most importantly, research showed that the use of elevated bait stations and careful timing of baiting minimizes hazards to kangaroo rats during a ground squirrel baiting program.

Belding's Ground Squirrel

During the past five years several studies have been funded by VPCRAC to investigate Belding's ground squirrel, a very serious pest of alfalfa and grain

ENDANGERED SPECIES AND RODENTICIDES

The biggest threat to endangered and threatened species is the loss of suitable habitat. However, when an endangered animal eats the same food as pest rodents, a potential for poisoning exists when controlling the pest. This situation may occur when ground squirrels are controlled in the range of endangered kangaroo rats. One solution is to minimize the kangaroo rat's exposure to the ground squirrel bait. VPCRAC-funded research resulted in new and improved bait stations that elevate the bait to a point where kangaroo rats cannot climb into the station and feed on the bait. Ground squirrels have no problem with this climb. This new, field-proven design has been accepted for use in areas where kangaroo rats are present.

production in northeastern California. The loss in the early 1990s of two rodenticides, *Compound 1080* and *strychnine*, for the control of Belding's ground squirrel left growers with very few and, in some situations, no effective control materials. Because of this, VPCRAC has supported research on bait additives, formulation approaches, and baiting techniques to improve the control of Belding's ground squirrel.

Belding's ground squirrel is a serious pest to growers in northeastern California.

BELDING'S GROUND SQUIRREL

Although Belding's ground squirrel is smaller than the California ground squirrel, it can be even more destructive to some crops. This squirrel is common in alfalfa fields throughout much of northeastern California. Left uncontrolled, they can completely destroy an alfalfa crop. Finding effective means of managing these pests continues to be a high priority.

Comparing Spot-Baiting and Bait Stations Using *Chlorophacinone*

Field studies were required by EPA for *chlorophacinone* grain baits applied by spot-baiting and in bait stations to control Belding's ground squirrel. They have been initiated in an irrigated alfalfa field in Siskiyou County. Their purpose is to evaluate bait station and hand-applied spot-baiting methods for this bait. The data will be used to maintain the registration for these materials.

Belding's ground squirrels, especially those found in the northeastern part of the state, are difficult to control with bait

A researcher is spot-baiting with chlorophacinone *near the Belding's ground squirrel burrows marked with flags (below). A researcher examines a sparse alfalfa stand caused by Belding's ground squirrel (bottom).*

A constant supply of anticoagulant *bait must be available.*

because they tend to eat only fresh green plants. Normal grain baits are not effective. Cabbage treated with *Compound 1080* or *strychnine* was effective in the past but these rodenticides were lost before the surcharge program began.

Zinc Phosphide-Treated Cabbage in Laboratory Trials

A two-year study focused on finding a more effective way of using *zinc phosphide* for baiting Belding's ground squirrels. Several approaches using *zinc phosphide*-treated cabbage bait were evaluated. After intensive testing, *zinc phosphide*-treated cabbage bait achieved about 67% mortality. This bait would need further development before it could be used in the field.

Chlorophacinone-Treated Cabbage

A series of studies focused on the field efficacy of 0.005% *chlorophacinone*-treated cabbage bait to control Belding's ground squirrel. Another objective of the study was to determine the poten-

Researchers applying chlorophacinone-treated cabbage bait in a field infested with Belding's ground squirrels (top). Radiotelemetry helps determine animal movements and assess the effectiveness of a control program (bottom).

Chlorophacinone is hand-mixed with cabbage to find a more attractive bait for Belding's ground squirrel.

tial hazard to nontarget wildlife posed by spot-baiting applications. The study site was in Modoc County and the bait was applied during late winter.

In spite of very good bait acceptance, the efficacy of *chlorophacinone*-treated cabbage could not be established from these tests, in part due to poor weather and the wide-ranging movements of squirrels. No secondary poisoning of predators or scavengers was found.

CHRONIC OR ACUTE BAITS?

There are two general types of rodenticide baits: chronic and acute. Chronic baits, such as the *anticoagulants*, are effective in multiple feedings over a period of days. Usually, one feeding of a first-generation anticoagulant will not give effective control. Acute baits, on the other hand, are effective in only one feeding. *Zinc phosphide* is the most common acute rodenticide used for rodent control in California.

Rats and Mice

Rats and mice are serious pests. These rodents can destroy or foul large quantities of food grains and spread disease to humans and livestock. They cause significant damage to agricultural crops such as rice, grains, and citrus. They are also major pests in many urban and suburban areas. EPA has required that efficacy tests be undertaken to support registration of rodenticides for these pests.

Following passage of the surcharge legislation, VPCRAC recommended funding for several EPA-required laboratory trials that were focused on developing a basic understanding of how various chemicals (toxicants) affect the biology of specific species. In support of re-registrations of baits containing *zinc phosphide* and the *anticoagulants*, several bioassay and lab feeding trials were conducted and are summarized here. EPA often requires that pesticide tests be done using rats as a standard test animal so that the results for one chemical can be compared to those for other chemicals.

ROOF RATS—A SUBURBAN PEST

Roof rats in home gardens and freeway landscaping are a growing problem, especially in southern California. These pests live in dense vegetation such as ivy and pampas grass and feed on fruits and other plants common in southern California.

Zinc phosphide Feeding Trials

Studies were conducted on *zinc phosphide* to help determine potential chromosomal effects on animals. These included

- *zinc phosphide* feeding trial to determine the no-observed effect level (NOEL) for 91-day oral feeding of technical-grade *zinc phosphide* in rats
- the mutagenic potential of technical-grade *zinc phosphide* (three studies found no mutagenic effects on laboratory mice).

Rats are standard test animals for many laboratory tests.

DO WE NEED DIFFERENT TYPES OF BAIT?

Unlike many other pesticides, rodenticides must usually be eaten by the pest animal to be effective. Each species, and even the same species in different areas, prefers different food. We need different types of baits, sometimes formulated with different materials, to address the target animals' food preferences. One of the most powerful examples of this is the Belding's ground squirrel in northeastern California. This squirrel seems to prefer green foods, not grains. To accommodate this preference, fresh cabbage is chopped and mixed with the rodenticide, making a locally effective bait.

A laboratory worker at the National Wildlife Research Center in Colorado is conducting feeding trials on rats and mice.

Zinc phosphide (Grain Baits) Feeding Trial

Laboratory studies were also designed to furnish the efficacy data required by EPA for 1% and 2% *zinc phosphide* grain baits. Mortality exceeded 90% for both concentrations. These studies with lab rats have permitted the continued registration of both formulations of *zinc phosphide* on grain baits.

Efficacy of *Chlorophacinone* and *Diphacinone* Grain Bait for Rats

Laboratory studies were conducted to furnish the efficacy data required by EPA for the continued registration of 0.005% *chlorophacinone* and 0.005% *diphacinone* grain baits. Most of the study rats refused to eat the *chlorophacinone*-treated grain bait, and consequently only 15 of 40 animals died (37.5% mortality). Based on the results of the lab data it appears that something in the bait reduced bait acceptance. Similar poor bait consumption occurred with the *diphacinone*-treated material.

DIFFERENT BAITS FOR DIFFERENT ENVIRONMENTS

In general, rodents are sensitive to the quality of the food they eat. Rodents often detect that materials used to control them contain poison, and their enthusiasm for eating the bait is somewhat diminished. Because it can cause spoilage, moisture also plays a role in bait acceptance. To allow treatment in different areas, baits come in grain, wax block, and pelleted forms. The wax block is especially effective in moist environments.

To reduce the risk of hantavirus from mice trapped in the wild, researchers establish breeding colonies of disease-free deer mice.

Evaluating *Anticoagulant* Wax Baits for Rats

Studies are underway to determine the efficacy of the 0.005% concentration of *anticoagulants* such as *chlorophacinone* and *diphacinone* prepared in a wax bait for rats. These formulations are currently registered but EPA has required further testing to maintain their use.

RODENTS CAN DETECT TRACE MATERIALS IN THEIR FOOD

Most rodents are very sensitive to trace materials in their food. For example, mice can completely reject an otherwise preferred food if it is contaminated with as little as 50 parts per million of certain pesticides. This has implications for the development, manufacture, and use of rodenticides. VPCRAC-funded research demonstrates that mice and pocket gophers rejected certain *anticoagulant* baits, and we believe that a contaminate in the bait may have caused this rejection. Current research is addressing this question with the hope of identifying any contaminants or other materials that are affecting consumption of the rodent bait.

Evaluating *Anticoagulant* Grain Baits for House Mice

Laboratory studies were conducted to determine the efficiency of *chlorophacinone*- and *diphacinone*-treated grain baits on house mice. Unlike the previously mentioned rat studies, the house mice readily accepted the *chlorophacinone*- or *diphacinone-treated* grain baits, resulting in 95% mortality. These findings supported the continued registration of these *anticoagulants*.

Evaluating *Anticoagulant* Wax Blocks for House Mice

In keeping with VPCRAC's high priority to maintain current registrations for *anticoagulants*, this project focused on evaluating 0.005% *chlorophacinone* and *diphacinone* in wax blocks. The range of mortality was 40% to 90%, but it was generally lower than the same toxicants on grain baits. It also appeared that female house mice were less susceptible than males.

Deer mice are used in feeding trials to test bait efficacy.

PRIMARY VERSUS SECONDARY HAZARDS

Rodent control, when conducted following label instructions, is safe to applicators as well as the environment. Great care is taken to minimize the potential danger of a baiting program to nontarget wildlife (wildlife other than the pest being controlled). Two types of hazards must be considered.

- *Primary hazard* results when nontarget wildlife somehow find and eat bait intended for the pest. The elevated bait station is a good example of a technique that reduces a primary hazard when using a rodenticide.
- *Secondary hazard* results when nontarget wildlife eat rodents whose bodies contain certain amounts of rodenticide. VPCRAC has funded research on *anticoagulant* baiting strategies that reduce secondary hazards by reducing the amount of bait needed, therefore reducing the amount of toxic chemical in any pest carcass.

Evaluating *Anticoagulant* Grain Baits for Deer Mice

This study is being conducted to support the continued registration of *chlorophacinone* and *diphacinone* for deer mice control. Due to the threat of hantavirus in wild populations of deer mice, it is safer and more efficient to raise a test population from a hantavirus-free breeding colony. This population has been established and the bait tests are underway.

VOLES

Voles are small, short-tailed rodents commonly found in open fields. They feed on grasses, roots, and stems. They are often seen during the day moving from their nests to their feeding ground using well-worn runways. Populations of voles fluctuate or cycle. In the high years, their numbers can reach 2,000 or more per acre.

During the past five years VPCRAC has approved funding for several studies to develop efficacy data and plant residue information on various rodenticides that are important for the control of voles in alfalfa fields. In addition, two studies focused on the hazards of the rodenticides to nontarget species. These studies successfully addressed EPA's concerns, so these baits will be registered to reduce damage by voles in alfalfa.

Efficacy of *Zinc Phosphide* When Tested in Field Enclosures

CDFA sought to expand the existing special local need *zinc phosphide* registration to include California voles and montane voles in alfalfa crops. Adhering to the label directions of prebaiting followed by a single broadcast application of 2% *zinc phosphide* (5–10 lb/acre), the vole population was reduced by 96%. These results far exceeded the EPA requirement of at least 70% control for efficacy studies. This study supports the expanded registration of *zinc phosphide* bait.

Hazards of *Zinc Phosphide* to Ring-Necked Pheasants and California Quail

This study was conducted to determine the potential nontarget hazards to ring-necked pheasants and California quail when using *zinc phosphide* grain bait.

Pen-raised pheasants and quail were randomly placed into 0.5-acre enclosures. All birds were wing-clipped to restrict their movements to the 18-inch-high alfalfa within the enclosures. They were provided water and game bird flight conditioner as an alternative food. About half of the pheasants and quail were also equipped for radiotelemetry, and their locations and movements were monitored twice daily. After an acclimation period, the enclosures were prebaited and then baited with *zinc phosphide*.

In the baited areas, 62% of the pheasants died, but none of the quail died. Researchers did note that the birds in this study were pen raised, restricted to the alfalfa, and fed on grain. These factors are quite different than what would be encountered in the field. The researchers recommended additional tests with wild, free-ranging pheasants to better identify the risks of using *zinc phosphide* bait. This worst-case scenario showed that the present California registration should not have a negative impact on quail populations, and that another field study with wild pheasants was warranted.

Field Testing *Zinc Phosphide* to Determine Hazards to Wild Pheasants

Based on the findings of the previous enclosure study, the investigator designed a follow-up experiment to assess the potential hazard of *zinc phosphide* to wild, free-ranging pheasants after a standard vole control program in alfalfa.

Ring-necked pheasants are used to study nontarget hazards of zinc phosphide *used for vole control in alfalfa.*

A mounted mechanical spreader broadcasts anticoagulant bait.

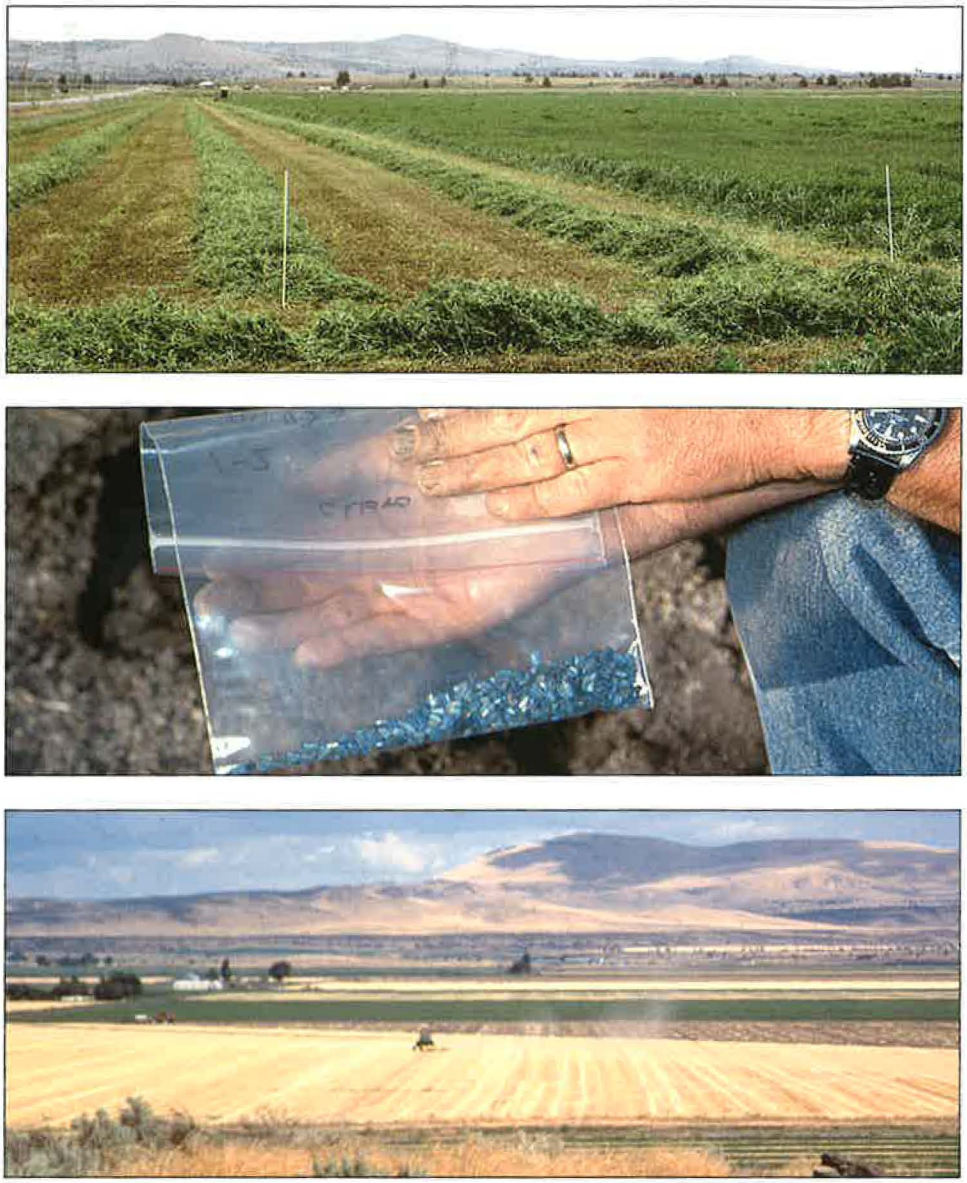
The study was conducted in Sutter County with the support of the California Department of Fish and Game. In this study wild pheasants were trapped and radio-tagged. After release, the pheasants generally avoided the postharvest treated alfalfa fields and were not affected or killed by the *zinc phosphide* treatment. Since these were wild, free-ranging birds, the researcher believes these results provide a more accurate and realistic demonstration of the degree of nontarget hazards when using this bait. The data support the use of *zinc phosphide* baits for voles after the last seasonal cutting of alfalfa.

Determining *Zinc Phosphide* Residue Levels on Alfalfa

Existing *zinc phosphide* bait registrations do not allow for direct application in alfalfa. This field study was conducted to determine the residue of *zinc phosphide* when broadcast at a 2% concentration on crimped oat groats.

One site in San Joaquin County and another in Siskiyou County were treated using a cyclone-type spreader on an all-terrain vehicle. Alfalfa samples were collected and analyzed using a procedure capable of detecting extremely small amounts of *zinc phosphide* (less than 5 parts per billion).

As expected, substantial concentrations of *zinc phosphide* were detected on alfalfa samples collected immediately following application and in plots receiving twice the normal rate. However, insignificant amounts of *zinc phosphide* residue (less than 45 parts per billion) were found in the alfalfa 25 days after application. This residue data provide a tolerance level to support registration allowing both mechanical ground and aerial applications. The results confirm that the chance of livestock being affected by eating baited alfalfa is small.



Harvested alfalfa samples are collected from the test plots for residue analysis (top). Carefully measured amounts of chlorophacinone-treated grain bait (center) are applied on plots of potato fields in the Tulelake region of northeastern California (bottom) to test for residues.

PESTICIDE RESIDUES

Before a pesticide can be applied to food or feed crops, EPA must ensure that the use poses an acceptable risk to humans or livestock that consume the crop. To do this, a two-tiered process is used. First, a tolerance for the chemical is established. This is the amount of the chemical that will be allowed in the food or feed when it is consumed.

Once the tolerance is established, residue data from each crop where the material is to be used must be obtained. The data show how much chemical is left in the crop at harvest when the pesticide is used according to label instructions. Only if the residue is at or below the established tolerance will the material be registered for use in the crop.

Researchers use hand-held spreaders to broadcast chlorophacinone *bait on potato plants; a paper barrier keeps bait confined to the test plots.*

Anticoagulant **Residue Studies in Alfalfa and Potatoes**

The purpose of these studies was to determine the potential residue levels of *anticoagulants* when used to control voles in alfalfa and potatoes. In these studies, 0.01% concentrations of *chlorophacinone* and *diphacinone* oat baits were applied to fields in Modoc, Siskiyou, and San Joaquin Counties. Plant samples were collected for residue analysis after the applications. No *anticoagulant* residues were detected in any of the samples.

Pocket Gopher

Statewide, pocket gophers damage may equal or surpass the economic loss caused by ground squirrels. These two animals rank as the most serious agricultural vertebrate pests in California.

During the past five years VPCRAC has funded several studies to determine the efficacy of three chemical compounds and two baiting techniques for controlling valley pocket gophers. Pocket gophers are a particularly troublesome rodent pest in alfalfa fields.

Efficacy of *Cholecalciferol* on Valley Pocket Gophers

This study investigated whether *cholecalciferol* has potential as a new field rodenticide for pocket gophers. It is currently registered in California for house mice and rats but not for pocket gophers. In the laboratory, valley pocket gophers were fed four concentrations of *cholecalciferol*-treated oat groats. Data obtained from these preliminary trials indicated that *cholecalciferol* could achieve 100% mortality and has potential as a field rodenticide for pocket gopher control. This study justified subsequent field research.

Cholecalciferol **Baiting Using the Mechanical Burrow Builder**

In a follow-up study, a burrow builder was used to place the *cholecalciferol* bait beneath the ground. The study was delayed for more than two years because of weather conditions affecting either

Pocket gophers rarely venture from the underground burrow system in which they live (above right). Underground pocket gopher tunnels are located by probing through the soil with a pointed metal rod (right). The pocket gopher is a serious pest in many crops (below).

A burrow builder creates an artificial burrow and drops in the bait.

the soil or plant development.

It was finally conducted in early 1998 in Tulare County. The site was a large flood-irrigated alfalfa field on sandy soil. After bait application it rained, and the sand cap that covered the artificial burrows collapsed, covering most of the bait in the burrows with sandy soil. The researchers have concluded that these factors are the likely cause of the bait not being effective.

Questions still remain on the efficacy of *cholecalciferol* as an alternative control compound for valley pocket gophers. This study points out the difficulties of field research, especially the lack of control of many factors, including weather.

Hand-Baiting with *Anticoagulants*

Hand-baiting can also be used to effectively control pocket gophers. It has the advantage over other control methods of not requiring ideal soil conditions. An experimental use permit was obtained to study and test 0.005% and 0.01% *chlorophacinone* and *diphacinone* pocket gopher grain baits applied by hand-baiting.

The Siskiyou County site was located in a field where overhead sprinklers are used and pocket gophers are normally distributed evenly.

The unusually low population reduction was thought to be caused by the blue dye used as a marker for the *anticoagulant* on the grain bait. The blue dye may have acted as a repellent to the pocket gopher.

For use on large acreages, the burrow builder can be towed by a tractor (top). A measured amount of diphacinone *is poured into gophers' underground tunnel through a funnel (above). Pocket gophers are radio-collared before release to help assess the hand-baiting (above right).*

Seasonal Uptake of Oat Groat Bait

In order to determine if gophers showed any seasonal preference for grain baits, a study was conducted in alfalfa fields baited with nonpoisonous oat groats containing a blue marker dye. At the conclusion of the baiting, valley pocket gophers were trapped in the alfalfa fields and almost half were marked with blue dye. Similar plots were also established in orchards, and 88% of the gophers trapped were marked with blue dye.

This long-term seasonal feeding study is now extending into 1999 with new plots established in walnut orchards in Tulare County. All of the plots were baited with the dyed oat groats.

GETTING BAIT TO THE ANIMAL

Since most rodenticides must be eaten by the rodent, we must often develop ingenious ways to get the bait to the animal. This is especially true for pocket gophers, since almost all of their feeding occurs under ground. To address this, a bait probe can be used to find their underground tunnels and make a small passageway to insert the bait. Another method is to use an artificial burrow builder. This machine makes an artificial burrow and automatically drops in the bait. Pocket gophers, being very curious, explore these artificial burrows and find the bait.

Red flags mark the location of pocket gopher burrows in an alfalfa field hand-baited with anticoagulants.

American crows cause significant damage in almond and pistachio orchards.

Afterwards, gophers in the plots were trapped and examined for bait consumption. The data are being analyzed and the final report is being drafted.

It is still too early to offer any final conclusions about *anticoagulants* and their effectiveness in pocket gopher control.

Birds

Birds can cause significant losses to agriculture. They also cause esthetic, nuisance, and public health problems resulting from their roosting behavior. At this time there are very few pesticides registered and used in California for bird control. Because of the tremendous damage caused by birds, several projects have been funded to address these issues.

Taped Calls for Crow Control in Almonds

Every year, American crows damage almond and pistachio orchards, causing considerable economic loss. During the summer of 1997, researchers broadcast a crow distress call as a new technique to reduce damage in almond orchards in the Sacramento Valley.

In most cases, crows responded to the taped call by leaving the orchards entirely. Damage in the orchards ranged from a low of $46 per acre to a high of $1,015 per acre. Despite high losses at some orchards, the damage was significantly below that expected if the call had not been used. The results highlighted the serious damage crows cause and suggested that improved hardware and expanded treatment from dawn till dusk could significantly reduce crow damage.

In 1998, improved broadcast units were deployed. Units were installed soon after the appearance of early flocks to discourage the birds from developing a feeding habit. The results, compared with 1997, showed a large reduction in crow numbers and damage. Losses ranged from $22 per acre to $138 per acre. This research has resulted in a new control technique for growers.

Potential Repellents for Bird Control in Lettuce

Lettuce is an important economic crop in California. In 1996 approximately 148,000 acres were planted with a value of $735 million. Annual losses to the crop due to bird damage at the early emergence stage have been estimated at $4.6 million.

Crows peck through the husk and shell to remove the almond.

ALARM CALLS: WHY DO THEY WORK?

Many species of animals communicate to other individuals of their own kind. An animal's language, which may range from body postures and movements to vocalizations, is used to communicate about social rank, courtship, territory, food sources, predators, and other subjects. An animal's survival depends on its ability to understand what is being communicated and respond appropriately.

Our need to control animal damage has given rise to *biosonics,* which is the use of an animal's natural vocalizations to influence the behavior of that pest species. *Biosonics* depends on animals reacting to particular calls in a predictable manner. Most often, alarm or distress calls are used to make an animal leave an area. *Biosonics* has been most successful with flocking birds in nonagricultural situations. Distress calls have been used to disperse crows and starlings from night roosts and gulls from airports, marinas, and outdoor restaurants. Recent research funded by the surcharge program on crows in almonds has shown that *biosonics* also has a place in reducing agricultural damage by certain pests.

In late 1995, researchers began to evaluate several potential repellents to reduce damage to lettuce seed and seedlings caused by horned larks. Laboratory tests determined that *methyl anthranilate* and *methiocarb* significantly reduced consumption of lettuce seedlings by horned larks. These two materials were field-tested in early 1997 in small plots in lettuce fields in the San Joaquin Valley. The compounds were sprayed onto lettuce seedlings.

The results were inconclusive due to the low number of horned larks on the study plots.

A second exploratory field trial examined the effectiveness of *methiocarb* and *Flight Control* (an *anthraquinone* product) for repellence on newly sprouted lettuce seedlings using horned larks in portable aviaries. The two *repellents* significantly reduced horned lark damage. The researchers are recommending additional field testing based on the promising results from this small-scale field aviary test.

Trapping As an Alternative Control Method for Birds

Growers often attempt to shoot or frighten depredating birds, but past surveys have shown a general dissatisfaction with these techniques. The discontent with scaring techniques and the loss of the toxicant *strychnine* has created the need to review the status of alternate existing control methods. The purpose of this study was to examine the status of trapping to control bird damage. A nationwide survey was conducted in 1996 with over 460 questionnaires mailed to practitioners involved with wildlife damage control. The responses showed that bird trapping is commonly used by a broad segment of wildlife damage control practitioners.

BIRD DAMAGE TO SEEDLINGS

California, the leading farm state in the United States, produces a wide variety of vegetables that are sometimes called "truck crops." Growers have long complained about bird damage to the seedlings of these crops, which include lettuce, broccoli, carrots, beans, peas, spinach, melons, onions, peppers, and flowers. Other crops damaged in the seedling stage include sugar beets and alfalfa. After the loss of strychnine in the early 1990s, there has been no effective lethal control method to protect crops from certain bird species.

The horned lark and the crowned sparrows are the major bird pests of seedling crops. The horned lark is often found in flocks that favor open habitats with few trees or shrubs, such as grasslands and croplands in the early stages of crop growth. Damage by horned larks typically begins when the seedlings first sprout. The larks nip off parts of the seedlings or pull entire plants from the soil. If the plants are slow growing, damage may extend over a long period. If plant growth is rapid, damage will be of short duration and usually end when the plants reach a height of 3 to 4 inches. Horned lark damage is usually first noticed as bare spots in the middle or center of a field.

Horned larks removed all of the lettuce seedlings in the bare patches of this San Joaquin Valley field.

The markings of the male horned lark are distinctive.

Rock doves, commonly called pigeons, can eat livestock feed and transmit disease in feedlots and dairies (top). Flocks of European starlings are the primary avian pest in vineyards (bottom).

Bird trapping is important for control of starlings and pigeons in noncrop sites such as around buildings in urban areas and for the control of starlings and house finches in certain California crops such as grapes. The respondents felt bird trapping will continue to be used at the same or increased levels in the future. The researchers concluded that bird trapping could be improved and that several new trap designs and strategies merit additional research.

Conclusions and Future Work

VPCRAC has been instrumental in funding high-priority research to support registrations and re-registrations of important compounds that are effective in controlling vertebrate pests. As a direct positive result of these studies, registrations for *zinc phosphide* and *anticoagulants* for field rodent control continue today. Studies have also looked at the economic impacts of damage so that regulators at the federal, state, and county levels can better assess the need to continue registration of various materials and application methods.

In keeping with the enabling legislation, several studies have examined alternatives to chemicals and have sought safer methods of chemical delivery so that hazards to nontarget species are minimized. For example, trapping or intimidating various species of pest birds offers growers an alternative to using chemical avicides.

The Endangered Species Act has spurred the public's interest in finding effective methods of vertebrate pest control that are highly selective to the pest and do not pose risks to other wildlife, especially those species listed by federal and state authorities as threatened or endangered. Several species of kangaroo rats are endangered and have been the focus of studies to find safer methods of delivering rodenticides that are effective on ground squirrels where they share the same range with kangaroo rats. The surcharge program provides support to help cover the costs of required investigations and to address our need to better understand the relationship between vertebrate pest control and endangered species.

During 1996 VPCRAC held outreach meetings around the state to solicit input regarding future research priorities. In response, several priority projects were undertaken and are continuing at this time. Livestock interests around the state have specifically expressed their desire for research oriented toward the re-registration of *sodium fluoroacetate*

GETTING THE WORD OUT

Many of the VPCRAC research projects focus on meeting EPA registration requirements. As such, the results lead to re-registration and continued use of control materials. Some projects, however, identify new or different ways to manage vertebrate pests. A number of papers have been published in scientific journals and conference proceedings as a result of VPCRAC research. In addition, this information is presented at local meetings with growers, pest control operators, farm advisors, and others who manage vertebrate pests.

SCIENTIFIC JOURNALS

Some people may wonder why we encourage researchers to publish their results in scientific journals. Publishing is important because it lets other scientists know about the work, often stimulating them to think about the problems and help contribute to the solutions.

EPA'S RE-REGISTRATION ELIGIBILITY DECISIONS (REDs)

In evaluating pesticides for re-registration, EPA reviews a complete set of studies from pesticide producers that describe the human health and environmental effects of each pesticide. To implement provisions of the Food Quality Protection Act (FQPA) of 1996, EPA considers the special sensitivity of infants and children to pesticides, as well as aggregate exposure of the public to pesticide residues from all sources and the cumulative effects of pesticides and other compounds with common mechanisms of toxicity. The agency develops mitigation measures or regulatory controls needed to effectively reduce each pesticide's risks. EPA then re-registers pesticides that meet the FQPA safety standard, allowing pesticides to be used that do not pose unreasonable risks to human health or the environment. When a pesticide is eligible for re-registration, EPA explains the basis for its decision in a RED document.

(Compound 1080) for the control of ground squirrels on rangeland. A feasibility study is underway to evaluate the potential cost to the state of California of pursuing re-registration of Compound 1080 and the potential economic benefit from its use. However, a voter-approved proposition (No. 4, Nov. 1998) specifically bans any use of *Compound 1080* in California.

Concern has been expressed by many within the agricultural, academic, and government communities that the surcharge program will "sunset" at the end of 1999. Much has been accomplished but many unanswered questions still remain. Our hope is this report gives you a better sense of the surcharge program and why it is essential to California's agriculture.

ACKNOWLEDGMENTS

The authors wish to thank all who reviewed the manuscript and offered their comments.

Chemical compounds have been italicized to help readers scan through the various projects. No endorsement of these compounds is to be implied by VPCRAC, CDFA, the University of California, or any other federal or state agency involved with the research.

The authors are:

Terrell P. Salmon
Wildlife Specialist
Department of Wildlife,
Fish and Conservation Biology
University of California, Davis

W. Paul Gorenzel
Staff Research Associate
Department of Wildlife,
Fish and Conservation Biology
University of California, Davis

Peter C. Passof
Forest Advisor Emeritus
University of California Cooperative
Extension, Mendocino County

For additional copies of this publication, contact:

Terrell P. Salmon
Wildlife Specialist
Department of Wildlife,
Fish and Conservation Biology
University of California
Davis, CA 95616
(530) 752-2263
tpsalmon@ucdavis.edu

or your local county Agricultural Commissioner office

Front cover: California alfalfa fields, like this one being harvested, have been used for several surcharge-funded studies on ground squirrels, voles, and pocket gophers. Back cover: Sunflowers are vulnerable to damage by blackbirds and house finches.

Photography by John Cummings, Jack Kelly Clark, Paul Gorenzel, Geraldine McCann, Gerald Miller, Suzanne Paisley, Terrell Salmon, Desley Whisson, and courtesy of Genesis Laboratory.