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OFFICE OF
PREVENTION, PESTICIDES AND TOXIC
SUBSTANCES

MEMORANDUM

SUBJECT: Analysis of Rodenticide Bait Use

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Attached is the revised version of BEAD's Analysis of Rodenticide Bait Use document. This final version incorporates comments and suggestions on a wide range of rodenticide bait use and rodent management issues received from stakeholders in early 2005.

Analysis of Rodenticide Bait Use

Executive Summary

This document presents an overview of the current use of nine rodenticide baits in the United States. Topics summarized include: the potential impact of rodents as disease vectors on human health; the damage caused by rodents to man-made structures and agriculture; a description of available market information, main use sites, target pests, and efficacy issues for these rodenticide baits; and alternative rodent control methods. The use profile for the nine rodenticides is summarized in Table 1 (P. 33).

The following major conclusions are put forward in this document:

$ In the United States, rodents pose a significant public health risk and cause economic damage to man-made structures and agriculture.

$ Because rodenticide baits are an essential component of an integrated pest management approach to rodent control, this document concludes that the availability of rodenticide baits is necessary for the successful management of rodent populations.

$ Since all nine rodenticide baits discussed in this document are currently registered for the control of commensal rodents in and around buildings, each of these can be seen as a potential alternative to each of the others in that use site situation.

Up-to-date data pertaining to amounts used, effectiveness, and prevalence of first generation anticoagulant resistance are not readily available.

I. Introduction

For the past several years, EPA has been assessing the risks posed by rodenticides. As part of its ongoing work to reassess the safety of older pesticides, EPA issued a Reregistration Eligibility Decision (RED) for the Rodenticide Cluster in 1998. In that RED, EPA noted concern about potential adverse effects to birds and nontarget mammals, and announced a plan to further evaluate the potential ecological risks before issuing final decisions about reregistration eligibility. In 1999 EPA initiated a comparative ecological assessment, in which the Agency compared and ranked nine rodenticide active ingredients in terms of potential severity of risk. The comparative ecological assessment concludes that there is adverse risk to nontarget organisms from all rodenticides, but certain compounds present more risk than others.

The statute under which EPA regulates pesticides, the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), requires consideration of benefits if adverse risks were assessed to be of concern. Thus, EPA must consider the benefits derived from the nine rodenticide products being evaluated before arriving at a decision regarding appropriate mitigation measures. The nine rodenticides included in the assessment are those addressed in the Rodenticide Cluster RED (brodifacoum, bromadiolone, bromethalin, chlorophacinone, diphacinone),[1] as well as zinc phosphide, warfarin, difethialone, and cholecalciferol.

The dual purpose for this document is, first, to summarize the available benefit/usage information in order to inform any risk management decisions, and, second, to request additional information not considered here (See Section X. Topics for Specific Public Comments.). EPA lacks complete usage information on rodenticide baits, particularly in the large homeowner market for rodenticides. Limited information is available concerning the professional applicator and agricultural markets. This document discusses the public health and other benefits associated with rodenticide products, briefly discusses efficacy, and concludes with a request for additional information on various aspects of rodenticide use and benefits. No attempt is made in this document to quantify the societal and environmental costs and benefits resulting from the use of rodenticide baits.

II. Impact of Rodents on Society

Background

Some rodents can be injurious to humans and their belongings. Both introduced and native species may be carriers or reservoirs for infectious diseases. Rodents may cause economic damage to crops; consume and contaminate stored food supplies; disturb soil through burrowing activities; damage houses, other types of buildings and man-made structures; and prey on native species, including birds that nest on oceanic islands. It is generally estimated that commensal rats cause between $0.5 and $1.0 billion of economic losses in the United States annually. This estimate is based on the assumption that there is one commensal rat per every two people in the country, at a time when the population of the United States numbered approximately 200 million, and that each rat consumes or damages between $1 and $10 worth of food and other materials, while contaminating 5 to 10 times more of it (Pratt et al., 1976). Commensal rats and mice have become adapted to live in close proximity to humans, thus having relatively easy access to almost unlimited food and shelter under certain conditions. Commensal rodents are introduced Old World rats and mice in the family Muridae: the brown, sewer, or Norway rat (*Rattus norvegicus*), the black or roof rat (*R. rattus*), and the house mouse (*Mus musculus*). It is estimated that a typical large city in the United States annually receives more than 10,000 complaints about commensal rodent problems and performs tens of thousands of rodent control inspections and baiting services (Illinois Department of Public Health, 2004). Some native rodents may also achieve a pest status comparable to commensal rodents and/or may be especially damaging to field and orchard crops or to turf. A high reproductive potential and mobility allows these rodents to rapidly fill available habitats and replace the individuals taken through available control methods.

[1] In addition to brodifacoum, bromadiolone, bromethalin, chlorophacinone, diphacinone, the 1998 Rodenticide Cluster RED also presented EPA=s reregistration decision for pival and its sodium salt, which were not supported and, therefore, determined to be ineligible for re-registration.

Rodenticide baits, along with a variety of habitat modification and other pest management techniques, are used to reduce the damage caused by native and introduced rodents, as well as other pest mammals. Rodenticide baits are especially useful for rapidly reducing rodent numbers in cases of major infestations. For commensal rodent control, rodenticide baits are best used within the context of an integrated pest management (IPM) approach that emphasizes measures such as sanitation, exclusion, habitat modification, trapping, coordination at the community level, public health education, and legal measures such as the enforcement of sanitation codes.

A. Impact of Rodents on Public Health

In the past, commensal rodents have been the main cause of rodent-related public health concerns in the United States. In recent years, however, white-footed mice and deer mice (*Peromyscus* spp.) have been implicated in the transmission of diseases such as hantavirus pulmonary syndrome, Lyme disease, and human granulocytic ehrlichiosis.

Disease transmission

Salmonellosis - Commensal rats and mice exposed to *Salmonella* bacteria in sewers or garbage may carry this pathogen in their gastrointestinal tract. Infected rats coming in contact with stored food, kitchenware, or food preparation surfaces may readily contaminate them with their droppings, which in turn could result in *Salmonella* food poisoning for humans exposed to the pathogens. Symptoms include nausea, diarrhea, and dehydration. This disease is rarely fatal (Blindauer, 1999).

Plague - In the Middle Ages, a plague pandemic transmitted to humans from infected rats by the bite of the oriental rat flea (*Xenopsylla cheopis*), was responsible for the death of about one third of Europe=s population. Plague is caused by the bacterium *Yersinia pestis* and exists in three forms, systemic, pneumonic and bubonic. Symptoms include chills, generalized pain, and swollen lymph nodes. Untreated, the fatality rate could exceed 50% (Dept. Environ. Health, San Diego Co., undated). However, at present this disease is uncommon in humans in the United States, and no major urban plague outbreak has occurred in the country since 1924 (Schwarz, 2003). Plague can be treated with available antibiotics. During the 1980s, human plague cases in the United States averaged about 18 per year, with a fatality rate of one in seven (CDC, 2003). A plague reservoir exists in some wild rodent populations in several Western states, principally the rock squirrel, (*Spermophilus variegatus*) in the southwestern states and the California ground squirrel (*S. beecheyi*) in the Pacific states. Townzen, *et al* (1996) describe the management of a sylvatic plague epizootic in campgrounds in California. The primary rodent vector in that case was the California ground squirrel. Closing campgrounds, trapping fleas and squirrels to index their numbers and detect plague-positive individuals, insecticide dust for flea control, and Zinc Phosphide bait for controlling ground squirrels were elements of the program undertaken to combat the epizootic. Other rodents also identified as potential reservoirs include other ground squirrel species, prairie dogs (*Cynomys* spp.), wood rats (*Neotoma* spp.), chipmunks, and perhaps even deer mice and voles (CDC, 2003; Schwartz, 2003). Although cases of plague involving commensal rats have not been reported since 1925 (Dept. Environ. Health, San Diego Co., undated), there is a latent risk that as urban areas expand, the disease could be transmitted to commensal rats.

Murine Typhus - This disease, caused by *Rickettsia typhi*, is transmitted to humans by rat fleas when feces of infected fleas are scratched or rubbed into a flea bite area and into the bloodstream. Human cases of murine typhus increased rapidly in the United States from 1916 to 1945, with 21,572 cases being reported in 38 states from 1941 through 1945 (Andrews and Link, 1947). In 1944, 5276 cases were reported in eight southern States (AL, GA, FL, LA, MS, NC, TX, and TN). In Alabama in 1932-1933, the human death rate from murine typhus was 4.5 per 1000 reported cases, but nearly one-third of the cases involving people who were at least 65 years of ended in a fatality (Andrews and Link, 1947). The incidence of murine typhus cases ultimately was greatly reduced through improved sanitation; insecticidal control of rat fleas; and lethal rodent control by use of rodenticide baits, chiefly anticoagulants after they became available (e.g., Beall, 1946; Wiley, 1946; Hill and Morlan, 1948; Morlan and Hines, 1951; Mohr and Smith, 1957), and fumigants. The 10% DDT dust used to control rat fleas also produced some debility and mortality in rats (Dent, *et al* 1949).

Since disease management efforts took hold in the middle of the last century, murine typhus fever is relatively uncommon in the United States Fewer than 50 cases are reported annually in the United States, mainly in California, Texas, and Hawaii (CDC, 2002). In some areas, such as southern California, the opossum (*Didelphis marsupialis*) can be a reservoir (Dept. Environ. Health, San Diego Co., undated). Several species of fleas have been implicated as vectors, including the rat flea (*X. cheopis*), the cat flea (on opossums) (*Ctenocephalides felis*), and the house mouse flea (*Leptopsylla segnis*). Although only a few cases are reported in Hawaii in typical years, in 2002 there were 47 cases recorded. Rodents suspected of being reservoirs in Hawaii include the Norway rat, the roof rat, the Polynesian rat (*Rattus exulans*) and the house mouse (CDC, 2002). Symptoms include fever, severe headache, general pain, and possibly a rash. It is rarely fatal at present (Blindauer, 1999).

Rat Bite Fever - Rat-bite fever is a bacterial disease caused by *Streptobacillus moniliformis* that can be acquired through the bite or scratch of a rodent or the ingestion of food or water contaminated with rat feces. Because cases are rarely reported in the United States, the true incidence of disease is unknown (CDC, 2003). Symptoms include influenza-like illness, rash, and arthritis, which may not be readily associated with a rat bite (Blindauer, 1999).

Trichinosis - Humans become infected with the nematode (an almost microscopic round worm) *Trichina spiralis* when ingesting improperly cooked infected pork. Nematode larvae parasitize the intestines and muscle tissue of humans. Pigs acquire the nematode by eating the carcasses of infected animals or grain food or garbage contaminated with feces from infected animals. Several wild and domestic mammals, including rats, cats, raccoons, and bears, may serve as reservoirs for the pathogen, but the role of rats as a important reservoir may have been overemphasized in the past (USDA APHIS, 1972). According to the CDC, trichinosis infection in humans, once a common disease, is now relatively rare in United States From 1991-1996, an annual average of 38 cases per year were reported (CDC, 2003). Symptoms include nausea, diarrhea, muscle aches, and may be fatal if the heart is involved (Blindauer, 1999).

Leptospirosis - This disease can be contracted by exposure to urine from infected commensal rats and mice. The causative organism, the spirochete bacterium *Leptospira icterohaemorrhagicae*, infect humans, dogs, and other domestic and wild animals by entering through mucous membranes or through cuts and scratches of the skin. Humans can become infected by handling contaminated items, from rodent bites, or from exposure to contaminated water. Symptoms due to infection may range from those associated with the common cold to kidney damage and liver failure (Blindauer, 1999).

Rickettsial Pox - This disease, caused by the obligate intracellular bacterium *Rickettsia akari*, can be transmitted to humans by the house mouse mite. Infection produces a chicken pox-like rash which is rarely fatal (Blindauer, 1999).

Tropical Rat Mite - In southern California and in the southern states, the tropical rat (*Ornithonyssus bacoti*) mite is a common ectoparasite of the roof rat. In rat-infested houses or buildings, this mite may also bite humans, causing irritation and dermatitis (Ebeling, 1975).

Hantavirus - A localized outbreak of hantavirus pulmonary syndrome resulting in several deaths occurred in 1993 in the area shared by Arizona, New Mexico, Colorado, and Utah, known as the Four Corners. The main virus host in this outbreak was the deer mouse (*Peromyscus maniculatus*). Since then, isolated cases have been reported in Louisiana, Florida, and New York involving the rice rat (*Oryzomys palustris*), the cotton rat (*Sigmodon hispidus*), and the white-footed mouse (*Peromyscus leucopus*) as reservoir hosts of several hantaviruses. The virus can be transmitted to humans through contact with accumulated urine and droppings from infected mice when tiny droplets of the material are stirred and become airborne (CDC, 1999). People may breathe in contaminated dust while cleaning or working in an infected area. Human exposure can also occur by introduction of the virus through the eyes, by ingesting contaminated food, or when bitten by an infected rodent. Symptoms include Afever, muscle ache, cough, rapid progression into severe lung disease@ and often death (NPCA, 1994). Deaths occur due to rapid filling of lungs with bodily fluids (Larson and Morgenthaler, 1994). According to Boren and Valdez (2003), the mortality rate for humans is approximately 43% for the U.S. and 51% for New Mexico, while Mills *et al.* (2002) report that as of June, 2002, a total of 318 cases had been identified in 31 states, with a fatality rate of 37%. Hantaviruses do not cause illness in host rodents.

Other Diseases - Additional diseases known to be transmitted directly or indirectly by commensal and wild rodents in the United States include the following: lymphocytic choriomeningitis, toxoplasmosis, Colorado tick fever, Rocky Mountain spotted fever, Lyme disease, relapsing fever, babesiosis, western equine encephalitis, California encephalitis, human granulocytic ehrlilchiosis, and cutaneous leishmaniasis, and *Yersinia pseudotuberculosis* (Blindauer, 1999).

Bites – Based on data collected from many city health departments, Scott (1965) and Clinton (1969) independently estimated that in the United States there were approximately 10 rat bite incidents per 100,000 city dwellers per year, or a total of 14,000 bite incidents per year for the then estimated 140 million city dwellers in the U.S. Most of the bites occurred where people lived under crowded conditions, in substandard housing, in areas with poor environmental sanitation, or in neighborhoods where rat-infested property was being eliminated. This estimate may still hold true for certain urban areas.

B. Impact of Rodents on Domestic Animal Health

Commensal rodents can also transmit diseases to domestic animals, such as leptospirosis and tapeworms to dogs and cats; brucellosis and foot-and-mouth disease to cattle; hog cholera and trichinosis to hogs; and salmonella, erysipelas, and fowl pox to poultry.

C. Impact of Rodents on Agriculture

Preharvest

Rodents such as voles, deer mice, Old World rats, ground squirrels, and gophers, may at times become agricultural pests by feeding on crops or by damaging farm structures and equipment by gnawing or through their burrowing activities.

Some species of voles (*Microtus* spp.) can damage or kill young trees and shrubs by feeding on the inner bark layer of the trunks near the base, both above and below ground. When voles gnaw completely around the trunk (girdling), the flow of water and nutrients is disrupted and the tree or shrub is killed. This type of damage is often more prevalent in fall and winter months, when their preferred food plants are not available (Fisher and Hygnstrom, 1997). Tree crops affected include avocado, apple, citrus, cherry, olive, and tree nuts. Voles also feed on flower bulbs, nursery stock, turf and other landscape plantings; on vegetables, including carrots, turnips, sweet potato, artichokes, celery, sugar beets, potatoes, tomato, and Brussel sprouts; and on various field and forage crops such as alfalfa, timothy hay, clover (Fisher and Hygnstrom, 1997; Salmon and Gorenzel, 2002; Montana Dept. Agr., 2001a). Lowe and Hudson (2004) report that in the state of Washington, yield and quality losses in timothy hay due to uncontrolled vole damage may cause a loss in net revenue of approximately 50%. In a letter submitted to EPA's docket, Kiess (2004) informs the Agency that in California, where over one million acres of alfalfa are grown, a vole infestation in 1999 caused a yield and price reduction to this crop of 11%, resulting in a $126 million loss to the industry.

Deer mice (*Peromyscus* spp.) can cause economic damage to Douglas fir and Ponderosa reforestation activities in the West and Northwest logging areas because of their ability to locate and collect broadcasted pine seeds, as well as naturally dispersed seeds. Deer mice can also dig up planted seeds, including melon and alfalfa seeds. High populations of deer mice have caused damage to almond, avocado, citrus, pomegranate, and sugar beets (Silberhorn, *et al.*, 2003).

Several species of pocket gophers (Geomyidae) feed on tubers and plants with succulent tap roots. Crops damaged include alfalfa, pastures, conifer plantations, row crops, and flower and vegetable gardens. Pocket gophers are a major problem wherever they occur in irrigated alfalfa. In Montana, for instance, yield losses in alfalfa may be up to 20-40%. In addition, pocket gopher mounds interfere with harvesting operations and damage harvest equipment. If gopher populations are moderate to dense, their mounds may cover 10-20% of the soil surface. It is estimated that the average pocket gopher can move 2,000 to 3,000 pounds of soil each year. (Montana Department of Agriculture, 2001b).

In Central Oregon, over 100,000 acres of hay are at risk of damage from voles, pocket gophers, ground squirrels, and woodchucks (Central Oregon Hay Growers' Association, 2004).

Ground squirrels can inflict significant damage to agriculture. In California, ground squirrels cause damage to a wide variety of field and orchard crops, including grain, fruits and nuts (almonds, apples, apricots, grapes, peaches, pistachios, prunes, oranges, strawberries, and walnuts), vegetables, and field crops (sugar beets, alfalfa, and cotton) (Silberhorn et al., 2003)

For instance, Schramm and Bullard (2004a) estimate that, uncontrolled, ground squirrels in California could theoretically cause a $7.5 million annual loss to the pistachio industry. This estimate assumes that: a) one ground squirrel consumes approximately 50 pounds of pistachio nuts per year; b) at infestation levels, ground squirrels average 20 per acre; c) 5,000 acres of pistachio orchards are affected; and d) the value of pistachios is $1.50 per pound. Ground squirrels and pocket gophers may cause extensive damage to irrigation systems by chewing through hoses and water lines; their tunnels and burrows can create hazardous conditions for machinery used to harvest pistachios; they cause direct damage by eating the pistachio nuts; and wounds inflicted upon tree trunks and roots can open avenues of infection by pathogenic fungi (*Aspergillus* spp.), which can destroy the trees.

In California, the main pest of carrots is the California ground squirrel, while minor rodent pests include the black tailed jackrabbit and pocket gophers. Large ground squirrel populations can denude 5-10 acres of carrot seedling tops. Since carrot cost of production is estimated at $2,000 per acre, the economic loss under such circumstances could be considerable (Schramm and Bullard, 2004b). Marsh (1998) estimates that the California ground squirrel may cause between $12 and $16 million in crop losses annually to California agriculture. When locally abundant, the burrowing activities of ground squirrels and prairie dogs in agricultural areas and pasturelands can also cause damage to farm equipment, pose a risk to livestock, and contribute to soil erosion.

In agricultural areas, commensal rats and mice can be significant field pests of crops such as sugarcane, citrus, and Macadamia nuts. They can also damage agricultural equipment, including farm machinery, irrigation pipes and hoses.

Post-harvest

Rodents often eat, damage, or contaminate (with urine, droppings, and hair) tons of stored food items, including grain, flour, cereals, sugar, vegetables, fruit, nuts, meat, animal feed, pet food, and any existing kind of stored edible material (Ebeling, 1975). The most damaging species in the U.S. are the commensal rodents and several species of voles. According to Hopf *et* *al.* (1976), cited by Brooks and Fiedler (1999), stored food losses to rodents in developing countries commonly range from 1% to 10%, but occasionally can be as high as 50%. Rodents typically contaminate far more stored grain than they consume. During a year, a single mouse will deposit several thousand pellets (droppings) and about one pint of urine (Hygnstrom, 1995). The amount of rodent filth in stored grain is regulated by FDA and USDA: two or more rodent pellets or equivalent quantity of other animal filth per 1000 grams of grain reduces its quality to AU.S. Sample Grade,@ which can only be used for livestock feed (Brown, 1994; Hygnstrom, 1995). While the numbers of rodent droppings found at any one time cannot be correlated with rodent population density, the rate of dropping accumulation can provide a relative census tool (Frantz and Davis, 1991). The appearance of fresh droppings is indicative of an active infestation. Although damage to stored food by rodents is not nearly as high in the U.S. as in developing countries, some losses do occur. The rodent damage to stored grain resulting from feeding and contamination was estimated at $8.4 million per year in Nebraska alone (Hygnstrom, 1995). Such levels occur although efforts to mitigate rodent damage commonly are employed in the United States

D. Structural/Industrial Rodent Damage

Rodents= incisors never stop growing and are regularly worn down by their own self-wearing action and by gnawing hard materials (Frantz and Davis, 1991). In houses and buildings, commensal rodents can gnaw through gas pipes, electric wiring and its insulation, and building insulation, thereby creating a fire risk. They can also damage electronic and computer equipment. White-footed and deer mice often enter cabins and other buildings, where they may build nests and raise their young, causing damage to furniture, clothing, books, paper files, and other belongings (Timm and Howard, 1994).

Ground squirrels and chipmunks may, when abundant, cause structural damage by burrowing under foundations, patios, retention walls, and other structures. Estimated annual damage by the California ground squirrel to structures such as levees, earthen dams, and roadbeds may amount to $8-12 million. The combined California ground squirrel damage to structures and agriculture (see above) represents estimated annual losses of $20-28 million in California (Marsh, 1998).

E. Rodent Predation on Island Species

Introduced commensal rats contribute to the endangerment and extinction of island plants and animals. When commensal rats or other rodents become established on oceanic islands, they typically prey on the eggs, chicks, and sometimes the adults of ground- and hole-nesting birds, reptiles, and other types of organisms. The victims often include rare and endangered species. Often there are few or no native predators on such islands, and the resident birds have not evolved defense mechanisms which enable them to cope with introduced predators such as rats. If uncontrolled, this type of predation can lead to the local extinction of the affected bird populations (e.g., National Park Service, 2000). Brodifacoum baits have often been used to eradicate rats from islands. Cholecalciferol and diphacinone baits have been tested as potential alternatives to brodifacoum use in oceanic islands (Donlan *et al.* 2003).

F. Other Types of Rodent Damage

Rodents also cause economic losses to poultry operations by consuming feed, by causing structural damage to poultry facilities, and by vectoring pathogens, such as *Salmonella enteriditis*. New York poultry farmers, for instance, consider rodents, along with flies, as serious pest problems that cause an economic loss to the poultry industry (Harrington *et al.* 1998). Pocket gophers often damage lawns, golf courses, parks, and other noncrop areas through their burrowing activities. In Colorado alone, about three million acres of private lands are reported to be damaged by prairie dogs and other rodents (State of Colorado Department of Agriculture, undated). Muskrats, nutria, and ground squirrels may damage levees, ditch banks, and culverts in agricultural areas.

III. Rodenticide Use in Rodent Control

Rodenticides are used, sometimes as part of community rodent-control programs, in situations where major commensal rodent infestations must be reduced rapidly. Rodenticide baits are also used to control rodents that have entered homes and other buildings or to eliminate rodents that remain after buildings have been rodent-proofed (CDC 1999). The impact of coordinated rodenticide bait use can be significant in urban areas. For instance, during 1969-1981 the Center for Disease Control and Prevention (CDC)'s Urban Rat Control Program funded rat control projects in over 100 communities in 31 states. As a result, by 1980 there were 36,000 rat-free city blocks in the communities covered by the program, with another 20,000 blocks in the process of becoming rat-free. CDC estimates that by 1980 seven million people lived in areas that were made rat-free through this program (Blindauer, 1999).

The use of rodenticide baits is one of several techniques available for controlling noxious rodents. There is limited information publicly available on the use of and market for rodent control chemicals in residential, commercial, and agricultural settings. EPA proprietary data that are available for residential and commercial use of rodenticide baits provide limited information on two broad markets for rodent control: the homeowner and the professional or pest control operator (PCO) markets. The private residential (Ahomeowner@) market includes products purchased by people to control rodents at home. The professional applicator market includes products purchased to control rodents in both residential and commercial settings.

The data available for agricultural rodenticide use are limited to general on-farm use and some specific field uses. A description of each market follows.

A. Homeowner Market for Rodent Control

Based on EPA proprietary data, the annual expenditures by homeowners on rodent control products are estimated to equal more than $90 million. The largest regional homeowner market is estimated to be the Southern United States (an estimated 35%-40% of the total market), followed by the Midwestern, Northeastern and Western United States. An estimated 90% of the market for the control of rodents is in the form of dry bait rodenticides, with other methods, such as glue boards, spring traps, and gas cartridges for burrowing rodents, making up the remaining 10% of the market.

D-Con7 brand baits are the most widely used rodenticide product in the homeowner market. The most widely used active ingredient in d-Con7 products is, at present, brodifacoum. Chlorophacinone, diphacinone, and other active ingredients also are available on the homeowner market.

B. Professional (Pest Control Operator) Market for Rodent Control in Residential and Commercial Settings

The estimated expenditures on rodent control products used by PCOs are more than $15 million annually (EPA proprietary data). The largest regional market for professional rodent control is the Southern United States (40% to 45% of the total market), followed by the Midwestern, Northeastern and Western United States. An estimated 75% to 80% of the professional market is rodenticide products, with the remaining 20% to 25% of the market including other methods of rodent control, such as glue boards and traps. An estimated 60% to 65% of professional rodent control is for house mice, 35% to 40% is for commensal rats, and 1% to 2% is for other rodents (e.g., pocket gophers, ground squirrels, etc.). An estimated 60% of the PCO work to control rodents is residential and 40% is commercial.

As much as 80% of the rodenticide sales to professional applicators are of products containing the active ingredients bromadiolone and brodifacoum. We estimate from available information that bromadiolone comprises 50% and brodifacoum 30% of the total professional market for rodenticides. The primary brand names for products containing bromadiolone are Contrac7 and Maki7. For brodifacoum, the primary brand names are Talon7 , Final7 and WeatherBlok7. Other rodenticide baits with estimated use by professional applicators include difethialone, diphacinone, chlorophacinone, zinc phosphide, bromethalin and cholecalciferol.

C. Rodent Control in Agriculture

EPA proprietary and USDA National Agricultural Statistics Service (NASS) data (1999) on rodent control in agriculture provide estimates of the use of rodenticide baits only. There is no information readily available on the extent of use of other methods, such as glue boards and traps, although it is assumed that these methods are used as well in agricultural settings. Based on the extent of use of these other methods in residential and commercial settings by homeowners and PCOs, it is assumed that the use of other methods in agricultural settings ranges from 10% to 25% of the total market for rodent control in these areas, with rodenticide baits accounting for the rest of the market.

According to the California Farm Bureau Federation (2005), which represents 37,000 farmers and ranchers in that state, zinc phosphide, chlorophacinone, and diphacinone are the primary rodenticides used in the state for controlling squirrels, deer mice, meadow mice, and other field rodents in cropland and rangeland.

According to EPA proprietary and USDA NASS data, the primary rodenticide used in the field for rodent control is zinc phosphide. No other rodenticide appears to be used in significant amounts in agricultural fields. An estimate of the total amount of zinc phosphide used is not available, however, the data suggest that approximately 30% of total zinc phosphide use is in agricultural fields. Zinc phosphide is also used in noncrop areas (see below), in residential areas and on turf. Of the 30% of total zinc phosphide used in agriculture, an estimated 10% is in sugar beet fields, 10% is in grain fields (e.g., wheat, barley, oats, etc.), and 10% is on rangeland (U.S. EPA, 1998). The regional distribution of this use is not known.

The largest proportion of on-farm zinc phosphide use is in general farm areas. An estimated 40% of total zinc phosphide use is in and around farm buildings and structures, roads, ditches, and other noncrop areas (e.g., drainage ditches, irrigation canals, riding areas, feedlots, fence rows, etc.). In addition to zinc phosphide, the available data (USDA-NASS, 1999) estimates (but does not quantify) the use of brodifacoum, bromadiolone, bromethalin, cholecalcifoerol, difethialone, diphacinone, and warfarin in and around building structures; and for brodifacoum, bromadiolone and warfarin in roads, ditches and other non-cropland areas. Brodifacoum, bromethalin, diphacinone, and warfarin are also used in grain storage facilities for rodent control.

IV. Summary of Rodent Management Methods

A. Management of Commensal Rodents in Urban and Suburban Settings

In addition to the use of poison baits, there are several control methods available and recommended for managing commensal rodent populations. These approaches aim at permanently denying them of access to food, water, and shelter. Denying rodents access to food, water, and shelter is called Asanitation@ (Bjornson and Wright, 1956). Denying rodents access to existing buildings is called Aexclusion@ (Frantz and Davis, 1991). Designing structures to deny or deter rodent entry are called "proofing" and "stoppage," respectively (Scott, 1982). Other types of habitat modification that may reduce the attractiveness of an area to rodents include changes to landscaping such as replacement of ground cover, such as English ivy with grass. To be successful in large, infested urban areas, these measures must be implemented on a community-wide basis. Most practical rodent control manuals, handbooks, and related literature include a section on nonchemical rodent management measures. Comprehensive reviews of this subject can be found in Frantz (1988) and Frantz and Davis (1991).

Access to indoor and outdoor food sources can be limited by using rodentproof refuse containers, keeping garbage containers and bins tightly sealed, increasing the frequency of garbage pickup, rapidly and completely cleaning food spills, ensuring that no food or water remains exposed overnight at home, storing dried foods in rodentproof containers or rodentproof pantries, and retrieving seeds spilled from bird feeders on a daily basis. Eliminating non-toxic food sources also may make rodents more inclined to accept toxic baits.

Nesting and hiding places can be limited by thinning the planting density or by removing all the plant ground cover that offers protection to rodents near buildings, using plants that do not provide rodent harborage or attract rodents, removing or mowing tall vegetation growing in vacant lots; removing wood, construction debris, or any other materials stacked against buildings; cleaning up and reducing clutter in basements and other rarely-used rooms.

Young commensal rats can squeeze through openings Ahigher or wider than 2 inch@ (Baker, *et al*, 1994). House mice can access openings about 3 inch by 12 inch (Frantz, 1988) or larger than 3 inch (Baker, *et al*, 1994). To prevent rodents from gaining entry, buildings can be Arat-proofed@ by sealing probable points of entry with heavy wire mesh or other appropriate materials. Potential points of entry may include air vents; openings around water and sewer pipes, electric lights, telephone wires, and TV cables; cracks around windows; doors and door frames, especially between lower edge and floor; holes in floors, walls, and ceilings; and any other type of opening that permits access to rodents. Trimming tree branches that overhang or touch homes or buildings keep roof rats, squirrels, and deer mice from using them to get access to homes.

Snap traps can be used to control rodents under low infestation levels, or where rodenticide use is too hazardous, or where the odor of dead rodents in inaccessible places would not be acceptable. Using snap traps correctly requires a good understanding of rodent habits. Glue boards are sticky material that trap rodents upon contact and work best with mice and immature rats. Glue traps are considered to be less humane than snap traps (Frantz and Padula, 1983). Naphthalene and paradichlorobenzene (PDB) may discourage rodents from entering an enclosed space that is not frequented by humans.

B. Management of Rodents in Agriculture

Rodenticide baits are widely used to control pest rodents in agricultural fields, rangeland, and pastureland. Bait can be broadcasted or placed selectively in specific locations. Although the use of poison baits is, in most cases, the fastest and most economical way of reducing pest rodent populations in these areas, several non-chemical rodent management methods exist that can be used in conjunction with available chemical control tools, in what amounts to an IPM approach. Some of these methods are summarized below.

$ Habitat modification: Keeping the orchard floor closely-mowed and maintaining weed-free strips under trees eliminates cover and reduces the chances of build-up of vole populations in orchards. Voles and other small rodents need alternative food sources and protection from predators if their populations are to grow. Depriving them from these resources is an effective way of inhibiting vole population growth. Because voles tend to avoid open spaces, the installation of a 4-foot diameter circle around the base of young trees and vines is recommended. Similarly, keeping weed-free strips around fields, gardens, and other areas to be protected tend to discourage voles from crossing the buffer to get to the food source (Salmon and Gorenzel, 2002).

$ Exclusion: Placing guards made of materials such as galvanized hardware cloth or woven wire tree around tree trunks can prevent tree girdling by voles. Voles can also be discouraged from entering small flower beds or gardens by installing woven wire or hardware cloth fences around them.

$ Flooding: Periodic flooding and soil tillage practices discourage gophers and other burrowing rodents from becoming established in croplands (Montana Dept. Agr., 2001b).

$ Sanitation: Promptly eliminating fallen fruit in orchards is one way of reducing a preferred food source for rodents such as voles, especially when poisoned baits are to be used.

$ Trapping: On a small-scale basis, voles, white-footed mice, squirrels, and other rodents can be trapped using one of several traps available in the market. Trapping is also used to identify rodents and monitor their populations.

$ Fumigants: Ignitable gas cartridges and aluminum phosphide tablets can be used to fumigate ground squirrel and gopher burrows. These materials are placed in burrows, which are then sealed with soil. Efficacy of fumigants is reduced in dry, porous soil, since much of the gas escapes to the surface. Gophers also routinely plug sections of their burrows, thus providing a barrier that prevent the gas from dispersing throughout the system.

$ Predation: In the field, rodents are a major food source for a wide range of predators such as hawks, owls, and other birds of prey; coyotes and foxes; weasels, badgers, and other mustelids; and snakes. Life expectancy for the smaller rodents seldom exceeds one year. Thus, where predators are present, predation contributes to the natural mortality of rodents, although by itself, predation is seldom sufficient to keep rodents below damaging levels.

$ Integrated Pest Management: As for other pest organisms, applying a combination of control methods suitable for a given target rodent species, the degree of infestation, and the site affected, rather than relying on a single pest control approach, is generally a more effective way to manage rodent pests.

V. Rodenticide Bait Profiles

Rodenticide baits are used extensively to manage rodents that feed on, contaminate, or cause various types of damage to a wide range of crops and farm infrastructure and equipment. There are currently six anticoagulant rodenticides registered for use in the United States. These are: warfarin, chlorophacinone, diphacinone, brodifacoum, bromadiolone, and difethialone. The first three, often described as Afirst-generation anticoagulants,@ generally require multiple feedings over several days to cause the death of a target rodent. Anticoagulants inhibit the formation of prothrombin, a key protein in the blood clotting process, thus leading to capillary damage, internal bleeding, and eventually to death.

Resistance to first generation anticoagulant rodenticides in commensal rodents is known to be widespread in United States. Norway rat populations in which resistance exceeded 5%, as indicated by samples submitted for testing, has been documented for 16 U.S. cities (Frantz and Padula, 1980). However, it may be possible to counteract this type of resistance with baiting schemes that alternate periods of baiting with warfarin, or other first generation anticoagulants, with periods of no anticoagulant exposure (Frantz and Padula, 1980; Frantz and Madigan, 1998).

Brodifacoum, bromadiolone, and difethialone are considered to be Asecond-generation anticoagulants.@ The expression Asecond-generation anticoagulant@ was coined to describe anticoagulant compounds that were believed to be effective against rodents that are resistant to the first-generation anticoagulants (Marsh, *et al*, 1980). Second-generation anticoagulants sometimes are also called Asingle-feeding anticoagulants@ because rodents exposed to them may ingest a lethal quantity of the poison in a single night=s feeding. As the toxic symptoms of anticoagulant rodenticides do not take full effect for several days, however, rodents exposed to second-generation anticoagulant baits may continue to feed relatively normally on them for 3 or 4 days and accumulate a Asuper-lethal dose.@

Anticoagulant rodenticide baits are used primarily to control commensal rats and mice and are mixed with grain products and other ingredients to make ready-to-use bait in meal, pelleted, or wax-block form. Meal and pelleted anticoagulant baits are intended for use in dry areas in and around buildings. Pelleted and meal formulations may be marketed in small plastic or paper bags (placepacks) which contain them at the site of placement until an animal breaks into the bag to feed on bait. Wax-block baits may be used where meal and pelleted baits are used and also may be used in sewers if the label of the specific product provides for such use. All placements of baits used to control commensal rodents in structural situations must be in tamper-resistant bait or stations if such placements otherwise would be accessible to children under six years-of-age, as well as to domestic animals and/or nontarget wildlife. Some commercial bait stations are designed especially to hold paraffinized bait blocks.

This assessment also considers rodenticides that are not anticoagulants. These compounds are zinc phosphide, cholecalciferol, and bromethalin. Zinc phosphide is an acute poison that may kill a target rodent as the result of a single bout of feeding. Zinc phosphide has a garlic-like smell that may attract some rodents and, reportedly, repel many nontarget species. Zinc phosphide=s natural emetic action may, in some cases, serve to protect some nontarget species from toxicosis after they have eaten bait containing this active ingredient (Cornell University, 2001). Exposure of target rodents to untreated grain (prebaiting) is generally recommended to increase bait acceptance and is required for some use patterns. Bromethalin induces anorexia after a toxic, and usually fatal, amount has been consumed. Death ensues within one to several days after consumption. Cholecalciferol may require several feedings for death to occur.

Although all nine rodenticides briefly discussed above are registered for commensal rodent control, only zinc phosphide, chlorophacinone, diphacinone, and warfarin are registered for control of small native mammals, including Afield@ rodents such as voles, deer mice, ground squirrels, pocket gophers, prairie dogs, and kangaroo rats; jack rabbits; and moles. Target species claims vary according to chemical and label. Depending on application directions and use restrictions, baits used to control native rodents in agricultural and nonagricultural lands can be broadcasted or applied by hand in selected areas.

A. Warfarin and its Sodium Salt

Warfarin, the first anticoagulant rodenticide to be developed, was first registered in 1950. Warfarin was named after the foundation that developed it, the Wisconsin Alumni Research Foundation (WARF) (Link, 1959). EPA issued a Registration Standard for Warfarin in 1981 (EPA, 1981) and issued the Warfarin RED in 1991. Activities associated with those reregistration efforts brought the Warfarin products that remained registered up to the standards of the times and led to the cancellation of many other Warfarin products. Although resistance to warfarin and other first generation anticoagulants has been detected in rats and mice in Europe since the late 1950s, current reliable estimates of its prevalence in the United States are not available.

Warfarin is formulated predominantly as dry (meal, pelleted, or paraffinized) baits. All but one of these baits are 0.025% active ingredient, with the exception being a 0.054% warfarin bait registered only for control of house mice. Other registered end-use products containing warfarin include 0.3% and 0.5% active ingredient concentrates for preparing baits. The sole remaining registered formulation of sodium salt of warfarin (0.54% active ingredient) is designed to be diluted with water to make liquid baits.

Warfarin is federally registered mainly for control of Norway rats, roof rats, and house mice in and around homes, agricultural buildings, and commercial and industrial sites, including food and feed handling establishments. Warfarin is also registered for deer mouse and white-footed mouse control in and around homes, agricultural and industrial buildings and similar structure; in parks, woodlots, yards and lots surrounding residential buildings and noncrop areas near agricultural buildings. Finally, there is a recent warfarin registration for the control of several species of moles (eastern, starnose, hairy-tailed, coast, broad-footed, Townsend) on lawns, turf areas, golf courses, and other non-food grassy areas. The warfarin bait registered for mole control must be applied directly into their underground tunnels.

B. Chlorophacinone

Chlorophacinone is a first-generation anticoagulant that was first registered in 1971. Chlorophacinone may kill some rodents after a single night=s feeding, but multiple feedings are needed in most cases. Death in rodents occurs within three to ten days.

Chlorophacinone is formulated as tracking powder, loose-grain bait, paraffinized pellets, bait in ready-to-use placepacks, and paraffin blocks. Bait formulations contain 0.005% active ingredient. Baits are applied as often as needed for controlling commensal rodents. Most field uses have a limited number of applications. Both restricted use and unclassified[2] products are registered.

Most of the unclassified products are ready-to-use baits registered for structural use to control commensal rodents. Application rates for placepacks and paraffinized blocks are similar to those for loose baits, but application amounts typically are expressed in terms of the numbers of placepacks, blocks, or pieces of blocks to deploy at each placement location. There also is one 0.005% chlorophacinone bait registered to control pocket gophers and another registered to control moles. These unclassified products must be applied directly into the underground burrow systems of pocket gophers and moles, respectively.

The restricted-use products containing chlorophacinone include 0.2% a.i. tracking powders that are federally registered for indoor use to control commensal rodents and some 0.005% and 0.01% a.i. baits registered under Section 24(c) of FIFRA to control various types of field rodents. At the time of product reregistration, all chlorophacinone products registered for above-ground uses to control field rodents will be classified as Restricted Use Pesticides.

Chlorophacinone is federally registered for control of commensal rodents in and around homes; industrial, commercial, or agricultural buildings and structures; and inside sewers. There also are 24(c) Aspecial local needs@ (SLN) registrations authorizing use of chlorophacinone baits in 19 states for control of numerous small mammals in a variety of agricultural and non-agricultural field sites. Chlorophacinone is registered for control of eastern moles (*Scalopus aquaticus*), star-nosed moles (*Condylura cristata*), or moles (*Scapanus* spp.) in lawns, golf courses, and other turf areas; and pocket gophers in lawns, golf courses, range land, and noncrop areas. It is also registered to control various types of voles (*Microtus* spp.) in dormant and non-bearing orchards; California voles in artichoke fields; and ground squirrels around farm buildings, in orchards, alfalfa, rangelands, pastures, and noncrop areas. Other target mammals claimed on SLN labels for chlorophacinone baits are deer mice (*Peromyscus maniculatus*), wood rats (*Neotoma*), chipmunks (*Eutamias* spp.), prairie dogs (*Cynomys* spp.), muskrats (*Ondatra zibethica*), nutria (*Myocastor coypus*), and jackrabbits (*Lepus* spp.). Field use sites listed on labels include orchards, forests, groves, nurseries, tree plantations, inside transport vehicles, commercial transportation facilities, and food processing, handling and storage areas and facilities.

C. Diphacinone and its Sodium Salt

Background Information - Diphacinone is a first-generation anticoagulant rodenticide first registered in 1960. As with chlorophacinone, diphacinone may kill some rodents after a single night=s feeding, but multiple feedings will occur and may be needed to cause death.

Diphacinone is federally registered for control of commensal rodents in and around

[2] The U.S. EPA does not normally classify products for general use; products that are not restricted remain unclassified. See 40 CFR 152.160(a).

homes, industrial and agricultural buildings and similar man-made structures; in sewers; in wet or damp areas including river banks, irrigation ditches, gullies, railroad tracks, loading areas, along fences, under granaries, garbage dumps, and landfills. Diphacinone is also federally registered for control of pocket gophers (*Thomomys bottae, T. talpoides, T. mazama, T. townsendi, T. bulbivorus, T. monticola, and Geomys bursarius*) in rangeland, grain fields, forage crops, hay and alfalfa crops, vegetable crops, forest, nurseries, and noncrop areas, including parks and around homes.

Twenty-two states currently have at least one 24(c) special local needs diphacinone registration for field uses. Uses of these products include control of voles, mainly *Microtus* spp., in dormant bearing and/or non-bearing tree fruit orchards in New Hampshire, Ohio, Pennsylvania, Virginia, Washington, West Virginia; control of voles in orchards, Christmas tree farms, commercial nurseries, and tree plantations in North Carolina; control of ground squirrels (*Spermophilus* spp.) and muskrats in noncrop areas, control of jack rabbits (*Lepus californicus*) in noncrop areas bordering agricultural fields and at airports, control of California voles (*Microtus californicus*) and montane voles (*M. montanus*) in orchards and groves, and control of wood rats (*Neotoma* spp.) in/around cabins and plantations of citrus trees and conifers in California; control of ground squirrels (*Spermophilus* spp.) in levee or ditch banks, around farm buildings, along fence lines, in orchards, in or near crops, and in noncrop areas in Washington (State); control of voles around small grain crops in Washington and Idaho; control of cotton rats (*Sigmodon hispidus*), rice rats (*Oryzomys palustris*) and Florida water rats (*Neofiber alleni*) in noncrop areas adjacent to sugar cane and sweet corn fields in Florida; control of mongoose in Hawaii and the Virgin Islands for protection of numerous species of ground nesting birds, including endangered bird species; control of rats and mice around the perimeter of planted fields and nurseries in Florida; control of commensal rats in forests, offshore islands and other noncrop outdoor areas in Hawaii and the Virgin Islands; control of commensal rats for conservation purposes on islands in the Alaska Maritime National Wildlife Refuge; and control of deer mice, jackrabbits, chipmunks, muskrats, woodrats, voles.

The only remaining registered products containing sodium salt of diphacinone as the active ingredient (at 0.106%) are registered only for mixing liquid baits to be used to control commensal rodents in and around homes, industrial and agricultural buildings, and similar man-made structures.

D. Brodifacoum

Brodifacoum, first registered in 1979, is a second-generation anticoagulant and the most widely used by homeowners in urban areas at present. A single night=s feeding may be sufficient to kill a target rodent within a three to ten days, but rodents often feed and behave normally for 2-3 days after their first exposure to the bait.

Brodifacoum is formulated as meal baits, paraffinized pellets, and paraffin bait blocks. All end use formulations contain 0.005% active ingredient. Baits may be applied as often as necessary. All registered brodifacoum products are unclassified.

Brodifacoum is currently registered for use only against commensal rats and mice in and around homes, agricultural buildings, commercial buildings, public buildings, and industrial buildings, inside transport vehicles, in and around related port or terminal buildings, in alleys, and in sewers.

At times, Brodifacoum has been used under ' 18 emergency exemptions from the requirements of FIFRA in Federal conservation programs to control rodents on oceanic islands. However, Brodifacoum does not have a Section 3 registration for that purpose.

E. Bromadiolone

Bromadiolone is a second-generation anticoagulant which first was registered in 1980. Bromadiolone is formulated as meal baits, paraffinized pellets, and paraffin bait blocks. All formulations contain 0.005% a.i. Some pelleted baits and meal baits are sold in placepacks.

Bromadiolone is registered for control of commensal rats and mice in and around buildings, inside transport vehicles, in alleys, and in sewers in urban areas. It is limited to indoor use in homes and agricultural buildings in non-urban areas.

F. Difethialone

Difethialone is a second generation anticoagulant rodenticide that was first registered in 1995. Difethialone is registered for the control of Norway rats, roof rats, and house mice in and around homes and industrial, commercial, and public buildings in urban areas; in transport and cargo vehicles (ships, trains, aircraft) and in and around related port or terminal buildings. In non-urban areas, difethialone may only be used inside of homes and agricultural buildings.

G. Zinc Phosphide

Zinc phosphide was registered in the United States in 1947, the first year of the Federal pesticide registration program under FIFRA. Prior to that time, zinc phosphide was used as a rodenticide in the United States and was used in that capacity in Italy as early as 1911. Once ingested, zinc phosphide reacts with moisture in the gastrointestinal tract to liberate phosphine gas, which is the lethal agent.

Zinc phosphide is the rodenticide most commonly used in agriculture. It is available in ready-to-use dry baits (whole-grains and pellets) and in the form of a dry concentrate to be used by applicators to prepare toxic baits. A 10% zinc phosphide tracking powder is registered to control house mice. All zinc phosphide end-use products are classified as Restricted Use Pesticides except those that containing 2% active-ingredient or less and are limited to use in and around buildings or to manual, subterranean applications to the burrow systems of pocket gophers or moles.

Depending upon the specific use pattern and label, zinc phosphide baits may be applied manually, by ground or aerial bait broadcasting equipment, or by use of other specialized equipment such as trail builders or burrow builders. As zinc phosphide baits often are not readily accepted by target rodents, labels often advise that bait-acceptance tests be conducted prior to baiting operations. Depending upon the specific use pattern, labels may recommend or require prebaiting the entire infested area with rodenticide-free grain of the type to be used in the toxic bait to accustom target rodents to feeding on that particular grain.

Zinc phosphide is registered for control of commensal rats and mice, white-footed mice (*Peromyscus leucopus*), and voles in and around homes and industrial, commercial, agricultural, and public buildings. It is also federally registered for use against a wide range of small mammals, mainly rodents, such as the following: meadow voles in alfalfa and timothy hayfields; muskrats and nutria in areas where they damage levees, irrigation ditch banks, or water impoundments, or where they might feed on rice, soybean, milo, corn, or damage turf; pocket gophers in rangeland and Christmas tree plantations; pocket gophers and moles in grain fields, forage crops, hay and alfalfa crops, and vegetable crops, forest areas, parks, nurseries, lawns, golf courses, homes, and other noncrop areas; voles, white-footed and deer mice, and jumping mice (*Zapus* spp.) in grape vineyards; voles and white-footed mice in berry production areas; voles in sugar beets; voles and deer mice in noncrop areas, including right-of-ways, lawns, parks, nurseries, and golf courses; voles and white-footed mice in pastures, ornamentals, orchards, vineyards, rangelands, forests, reforestation areas, lawns, golf courses, parks, nurseries, and highway medians; roof rats in macadamia nut orchards; deer mice and voles in orchards, groves, nursery stock (ornamental and non-bearing fruit trees), and conifer and hardwood seeding plantations; prairie dogs and ground squirrels in rangeland and reforestation seedlings and plantings; kangaroo rats (*Dipodomys* spp.) in rangeland, pastures, and noncrop areas; rats (Polynesian, Norway, roof, rice, Florida water, cotton) in sugarcane fields; California ground squirrel and voles in noncrop rights-of-way; voles; ground squirrels in dormant orchards or vineyards, ornamentals, cemeteries, golf courses, nurseries, canals and ditch banks, rangelands, pastures, lawn and turf grasses, and along fence rows; prairie dogs on rangelands, pastures, and reforestation seedlings and plantings in the western United States; woodrats in rangelands, pastures, noncrop right-of-ways, dormant orchards, tree farms, and rural agricultural buildings.

H. Cholecalciferol

Cholecalciferol, also known as Vitamin D_3, was first registered in 1984. Cholecalciferol triggers the mobilization of calcium from the bone matrix into blood plasma, resulting in death from hypercalcemia in 3-4 days after ingestion of a lethal dose. Cholecalciferol is not an anticoagulant. Cholecalciferol is formulated into baits containing 0.075% active ingredient.

Cholecalciferol is registered for the control of Norway rats, roof rats, and house mice in and around homes; industrial and commercial buildings; and similar man-made structures, inside transport and cargo vehicles (ships, trains, aircraft), and in related port or terminal buildings.

I. Bromethalin

Bromethalin is a diphenylamine rodenticide that acts, after one or more feedings, by blocking nerve impulse transmission, causing paralysis of the central nervous system and respiratory arrest in 2-4 days. Bromethalin was initially registered in 1982.

Bromethalin is formulated into various types of rodenticide baits, including paraffinized blocks, meal baits, and pelleted baits. Most formulated products contain 0.01% active ingredient. Some bromethalin baits are sold in placepacks. Two products consist of nine 0.01% bromethalin bait in a ready-to-use bait station. These bait stations have not been shown to be tamper-resistant.

Bromethalin is registered for control of commensal rats and mice in and around homes, industrial and agricultural buildings, and similar man-made structures; in alleys, in transport vehicles (ships, trains, and aircraft), and in and around related port or terminal buildings.

VI. Efficacy Considerations

The rodenticide active ingredients discussed in this document were subjected to the product performance (efficacy) data requirements that were in effect at the time that they were registered. Those requirements have changed over time, with the most significant developments being the amendments to the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) passed 1972 and 1978, the development of the Product Performance portion (Subdivision G) of the *Pesticide Assessment Guidelines* (Schneider and Hitch, 1982), and the promulgation of the regulations published in 40 CFR ' 158.640.

The 1972 amendments to FIFRA required EPA to formalize its data and testing requirements through publication of relevant guidelines, instituted data compensation requirements, and required EPA to Aregister and reclassify pesticides registered@ under FIFRA prior to the effective date of Aregulations promulgated@ to provide for Aregistration and reclassification of pesticides under the provisions of@ FIFRA, as amended. This Aregistration and reclassification@ activity later came to be known as Areregistration@.

The 1978 amendments authorized conditional registration of pesticide products, expanded on the subject of reregistration, and granted discretionary authority to the EPA administrator to Awaive data requirements pertaining to efficacy.@ EPA thus initiated a policy of waiving efficacy data requirements for all pesticidal claims except those pertaining to control of pests considered to be of significance to public health. The efficacy waiver policy was expanded in 1982 to include essentially all pesticidal claims. The policy soon was changed back to one of routinely requiring efficacy data to support claims for controlling pests of significance to public health and emphasizing that the waiver policy only applied to the efficacy data requirement. Registrants were expected to test pesticide products to verify that they were efficacious. The efficacy data submission requirements and policies are summarized in 40 CFR ' 158.640.

Of the claims being made for the rodenticides discussed in this document, the following rodent types have been considered to be of significance to public health: Norway rats, roof rats, house mice, deer or white footed mice (*Peromyscus* spp., except for endangered subspecies), ground squirrels (*Spermophilus* spp.), and prairie dogs (*Cynomys* spp., except for the endangered Utah prairie dog, *C. parvidens*). Applicable efficacy data must be submitted or cited to support claims for controlling these species. Distinctions are not drawn between urban and rural, domestic and industrial, or structural and agricultural use sites because rodent-vectored diseases may be spread to humans in any of these locations. There is a public health aspect to virtually all efforts to control these species.

As indicated in 40 CFR '158.640, EPA reserves the right to require that efficacy data be submitted Aon a case-by-case basis for any pesticide product.@ For the rodenticides discussed here, that authority has been considered in a few cases in which the claims being evaluated seemed unlikely for the product formulation involved.

Four of the nine rodenticides discussed in this document were registered prior to passage of the 1972 amendments. In order of the date of initial registration, those compounds are: zinc phosphide, warfarin, diphacinone, and chlorophacinone. In addition to the efficacy data that may have been required for registration, baits containing these active ingredients -- especially zinc phosphide and warfarin B were tested rather extensively for effectiveness against commensal rodents under actual use conditions by university, municipal, and public health personnel (e.g., Emlen and Stokes, 1947; Hayes and Gaines, 1950). Additional uses of these four compounds that were accepted under Section 3 of FIFRA after passage of the 1972 amendments were subject to prevailing data requirements and, if efficacy data submission requirements applied, were thoroughly researched (Tietjen, 1976; Tietjen, 1979; Tietjen and Matschke, 1981).

The other 5 rodenticides considered here (brodifacoum, bromadiolone, bromethalin, cholecalciferol, and difethialone) were not registered until after passage of the 1978 amendments. These 5 compounds were extensively tested for efficacy according to procedures similar to those described in Subdivision G of the *Pesticide Assessment Guidelines* with respect to claims for controlling commensal rodents. Such testing entailed laboratory assessments of toxicity to target species, laboratory Achoice@ feeding trials to assess palatability and lethality of candidate bait formulations, and regional field testing. Although Bromethalin was initially registered in 1982, during the time of the expanded efficacy waiver, its laboratory and field testing regimens were largely completed before that policy went into effect.

Research has shown that seemingly small changes to bait composition can have drastic adverse effects upon palatability to commensal rodents. Therefore, specific bait formulations claimed to control commensal rodents are required to be screened for efficacy. Most commensal rodenticide bait formulations registered since the 1972 amendments have been screened for effectiveness against Norway rats and house mice, if both species are claimed on product labels. A few such products registered during the period of the expanded efficacy waiver (mid 1982 to early 1984) were not screened for efficacy prior to registration, but will be if they are to be reregistered. Warfarin baits registered prior to the 1972 amendment were screened for efficacy prior to their being reregistered in the early 1990's. Registered commensal rodenticide baits must be screened for efficacy again if they are reformulated.

Cholecalciferol and difethialone were registered after November 1, 1984 and, therefore, are not subject to reregistration requirements. Prior to registration, however, these active ingredients were thoroughly tested for efficacy against commensal rodents in laboratory and field trials. All registered commensal rodenticide bait formulations containing these compounds have been screened for efficacy.

For registered baits products containing the compounds currently undergoing registration (zinc phosphide, diphacinone, chlorophacinone, brodifacoum, bromadiolone, and difethialone), new efficacy data generally will be needed for reregistration only if their registrants: (1) seek to modify existing bait formulations; (2) desire to make claims of effectiveness which go beyond simple claims for controlling the target species claimed on the products= labels, or (3) have not yet supported some claims for which submission of efficacy data is required.

Although the methods for screening rodenticide baits for efficacy in laboratory tests vary somewhat according to the type of product and the nature of the claim being investigated, the product performance criteria are similar across the nine compounds being considered in this document. In controlled laboratory tests with fresh Adry@ or liquid baits claimed to control commensal rodents, at least 90% of the rodents exposed to the rodenticide must die for the bait to be considered to be efficacious. For multiple-feeding anticoagulants (e.g., warfarin, diphacinone, and chlorophacinone), there also is a requirement that fresh baits be accepted as 33% or more of total intake in a choice test involving EPA=s standard challenge diet for dry baits or water for liquid baits. Slightly lower criteria (80% mortality and 25% acceptance) apply when experimentally Aweathered@ anticoagulant baits are evaluated for suitability for use in wet or damp areas (e.g., sewers) or are claimed to be Aweather-resistant.@

The performance criteria in field tests are similar across active ingredients used in rodenticide baits. EPA accepts field efficacy studies of rodenticide baits if appropriate procedures were employed in the research and if rodent activity indices indicate that at least 70% control of the baited population was obtained. All the rodenticide compounds discussed here have been tested according to essentially similar criteria and are considered by EPA to be useful for controlling commensal rodents.

Three of the nine compounds under discussion are registered for use to control Afield@ rodents of public health significance (e.g., ground squirrels, prairie dogs, *Peromyscus* spp.). These compounds are: zinc phosphide, diphacinone, and chlorophacinone. Zinc phosphide bait products labeled for controlling these species and other field rodents (e.g., *Microtus* spp. voles; *Geomys* and *Thomomys* spp. pocket gophers; non-endangered kangaroo rats, *Dipodomys* spp. etc.) typically are registered under Section 3 of FIFRA. Most diphacinone and chlorophacinone products labeled for field rodent uses are available only in certain States under Aspecial local needs@ registrations issued according to the provisions of Section 24(c) of FIFRA. Reregistration of field uses for these three compounds will entail submitting or citing relevant data, including efficacy data regarding claims for controlling pests that are of significance to public-health claims. Some information of that nature that has been reviewed to date is tacitly considered in this assessment. New efficacy studies may be needed if there are any public-health claims that are not fully supported by existing data.

Although rodenticide compounds registered for similar uses have been required to meet essentially the same performance criteria, the field tests that have been reported to EPA to fulfill efficacy data requirements for these chemicals were run at different sites, at different times, and often by different personnel. That these and other factors may affect study outcomes should be kept in mind when comparing results from such tests.

Relatively few field efficacy trials have been conducted specifically to compare the performance of various rodenticide baits under United States field conditions. Generally, such trials were conducted under conditions in which control of the target species had proven to be difficult. For example, Tickes, *et al* (1982) ran comparative efficacy trials with valley pocket gophers using three compounds that are registered for that purpose, but reported that none of the six bait formulations tested appeared to control that organism well. Some of the comparative studies that have been reported have primarily involved use of compounds which are not included in this evaluation and/or are no longer are registered (e.g., Albert and Record, 1979; Emlen and Stokes, 1947).

Ashton, *et al* (1983) conducted comparative efficacy trials for several currently registered rodenticide baits containing warfarin, bromethalin, brodifacoum, or bromadiolone. Baits were evaluated for efficacy against house mice and Norway rats. As those trials were performed at sites where resistance to warfarin (see below) had been detected, the test results obtained for warfarin were likely lower than typical results would have been with populations of non-warfarin resistant rodents. Frantz and Madigan (1998) report that a significant number of rats that had previously been found to be resistant to warfarin, according to WHO testing protocol, died after been exposed again to warfarin a second time, suggesting that warfarin may prove to be effective against resistant rats by modifying the baiting schedules.

VII. Factors Affecting Rodenticide Bait Selection

Although the nine rodenticide compounds considered here have been required to meet similar criteria in efficacy trials, several additional factors must be considered when assessing the degree to which compounds registered for similar uses may serve as alternatives to one another. These factors are identified and briefly discussed below.

Registered Uses - Rodenticide baits may only be used at the use sites that are indicated on their labels and may not be applied by application methods that are prohibited by label text (e.g., ADo not broadcast bait@, AApply this product only by the methods prescribed on this label@, AThis product must be applied directly into pocket gophers= underground burrow systems@, etc.). While all of the nine rodenticides considered here are registered for controlling commensal rodents, zinc phosphide is the only one that has been accepted under Section 3 of FIFRA for broad usage to control field rodents and is the only one for which tolerances have been issued to allow for food and feed uses. These circumstances leave users with no toxic-bait alternative to zinc phosphide for many uses. In certain states, baits containing Chlorophacinone or Diphacinone are available under Section 24(c), Aspecial local needs,@ registrations for control of field rodents.

Classification - Not all rodenticide baits are available to all prospective users. Products labeled as ARestricted Use Pesticides@ may only be purchased by certified applicators and may only be used by such applicators or by persons under their direct supervision. Such products include zinc phosphide baits registered for above-ground uses to control field rodents. All above-ground uses of any of the other eight compounds to control field rodents will likely be classified as restricted use pesticides at the time of reregistration.

Speed of Kill - How fast a compound kills a given target species may affect the choice of the toxicant. Of the nine rodenticides considered, zinc phosphide and bromethalin come closest to being true Aacute@ rodenticides, with individual rodents generally feeding on the bait for only one day and dying within one or two days after feeding occurs. With cholecalciferol baits, significant feeding usually occurs on more than one day with death ensuing several days later.

Anticoagulants generally take at least four days from the onset of feeding until rodents begin to die. It may take two weeks or more for some individuals to die. Although second-generation anticoagulants also have been touted as Asingle-feeding@ anticoagulants, that expression is misleading. It has been shown that although the amount of bait containing bromadiolone, brodifacoum, or difethialone eaten in one 24-hour period can be sufficient to cause the deaths of rodents, the animals generally continue to feed normally for two or three more days. Thus, free-ranging rodents exposed to a palatable second-generation anticoagulant bait would be expected to eat nearly as much of it as they would if exposed to a palatable first-generation anticoagulant bait, thereby accumulating a Asuper-lethal dose.@

Perceived risks to nontarget species - The extent of the applicator=s knowledge and concern about nontarget effects would likely play a part in the selection of a toxicant. If, for example, bait applications are to be primarily used in indoor locations to which children or nontarget animals, such as pets and livestock, do not have access, an applicator might feel more comfortable in using a second-generation anticoagulant than if outdoor placements were needed in areas frequented by birds or nontarget mammals.

Resistance - Resistance to first-generation anticoagulants has been detected in commensal rodent populations in many places throughout the world including some localities in the United States (Frantz and Padula, 1980; Frantz and Madigan, 1998). Efficacy data submitted to the Agency for brodifacoum indicate that baits containing that second-generation anticoagulant at 0.005% active ingredient are likely to be effective against Norway rats and house mice of United States origin that are resistant to warfarin and other first generation anticoagulants. Data submitted to the Agency suggest that bromadiolone baits at 0.005% a.i. are likely to control warfarin-resistant Norway rats of United States origin and that 0.0025% difethialone baits that are registered for controlling house mice are likely to control warfarin-resistant house mice of United States origin. The expression Awarfarin-resistant@ is used here because the test subjects ultimately killed by the second-generation anticoagulants mentioned initially were screened for resistance to warfarin. Resistance to other rodenticides has been recorded in other parts of the world as well. For instance, in Velen, Germany, 20% of rats trapped on livestock farms were found to be resistant to bromadiolone, according to a blood-clotting response (BCR) test (Endepols *et al*., 2003).

Some success in controlling United States rodent populations resistant to warfarin has been reported in field trials involving second-generation anticoagulants and bromethalin (Ashton, *et al*, 1983). Anticoagulant-resistant rodents likely would be susceptible to any rodenticide that is not an anticoagulant. Resistant rats may also become again susceptible to warfarin if the baiting schedule is adjusted cyclically so that each warfarin baiting is followed by a period of at least 30 days, during which exposure to anticoagulants baits is suspended (Frantz and Padula, 1980; Frantz and Madigan, 1998). Alternating anticoagulant use with use of alternative control methods, including a toxicant with a different mode of action, would be expected to lessen the selective pressure favoring anticoagulant-resistant individuals. Frantz and Madigan (1998) suggested that a non-chemical strategy should be considered in areas where resistant rodents exist and that habitat modifications, especially limiting alternate food sources, might enhance the effectiveness of cyclical applications of first-generation anticoagulants in such areas by increasing the amount of bait consumed. Frantz and Madigan (1998) and Baroch (2004) present data which suggest that, if used cyclically and in conjunction with sanitation, Warfarin itself may eventually control resistant populations.

Conditioned Food Aversion (Bait Shyness) - Animals that become ill after ingesting a new food with a novel taste often avoid that food taste subsequently. When the new food is a toxic rodenticide bait, rodents obtaining sublethal oral doses may avoid both the bait base material and the toxicant in the bait base in the future, perhaps for the rest of their lives. Such acquired bait shyness can greatly diminish the effectiveness of rodent control programs and is most pronounced with quick-acting poisons that have salient flavors. Most such compounds no longer are registered in the United States. Among the rodenticides considered here, bait shyness is often a significant problem with zinc phosphide. With small target rodents such as voles (*Microtus* spp.), bait shyness to zinc phosphide can be mitigated appreciably by formulating baits to an active ingredient strength such that a single ingested bait particle is fatal to the rodent (Eadie, 1950). For larger species, prebaiting target mammals by exposing them to untreated bait grain several days before the toxic bait is applied may result in good control (Tietjen, 1976).

Due, at least in part, to the delayed toxic action of anticoagulants and cholecalciferol, bait shyness does not develop with these rodenticides. Bromethalin produces anorexia as an early symptom of exposure, but animals that recover do not seem to avoid the same bait subsequently.

Weather - Changes in ambient weather conditions can alter the behavior of rodents and may effect the amount of time that some species spend foraging above ground. Wet weather can also affect exposed baits directly by changing their integrity (especially with some types of pelleted baits) and by altering their toxic properties. Wet zinc phosphide baits Aprematurely@ liberate phosphine gas, reducing the toxicity of each particle and affecting palatability.

Structural Use Considerations - All rodenticide baits under discussion currently are registered for use to control commensal rodents in and around buildings. Consequently, each of these compounds potentially is a viable alternative to each of the others in that use situation, except perhaps at sites where a high incidence of resistance to first-generation anticoagulants has been detected. Absent resistance problems, selection among active ingredients by professional applicators is likely to be based upon past experience, safety, cost, and possibly product promotions from manufacturers and/or distributors. In structural situations, most incidents for primary exposure are reported for young children (under 6 years of age) and for nontarget species, such as dogs, cats, and livestock, although primary exposures of wildlife may also occur. By following label directions regarding bait stations and proper use of tamper-resistant bait stations, professional users can minimize incidents of primary exposures to nontarget species. As secondary exposures are not affected by the use of bait stations and may occur even if all bait placements are located indoors, professional users may consider the likelihood of secondary exposures of avian and mammalian predators and scavengers when selecting among rodenticides.

A large proportion of rodenticide use by non-professional applicators (i.e., homeowners) occurs in structural situations, chiefly in and around their homes. Selection among rodenticide products by consumers depends to a large extent on local availability. The labels on rodenticide baits that consumers purchase are similar to the labels on baits used by professional applicators, but tamper-resistant bait stations are seldom offered at locations where consumers buy rodenticides. Some ready-to-use bait station products (bait stations loaded with bait) are offered for sale at retail outlets, but none of those stations has been demonstrated to be tamper-resistant. Ready-to-use bait stations that are made of cardboard are not tamper-resistant.

Field Uses - Most field uses of rodenticide bait are, or are soon to be, limited to labels of products that are classified as "Restricted Use Pesticides". Consequently, most applications to control field rodents or commensal rodents in field situations are to be made by certified applicators or by those under their direct supervision. Such applicators are expected to have access to training materials and equipment appropriate for the types of applications that they intend to make. Broadly, such types of applications include: above-ground treatments made manually or by aerial or ground broadcast equipment or by trail-builders; and below-ground applications made by hand, by hand-operated probes, or by machine-drawn burrow builders. Manual, above-ground treatments include "spot" placements of small amounts of bait in discrete locations, scattering bait over small areas near active burrows or runways, and placing larger amounts of bait in bait stations.

All above-ground placements are available to nontarget species to some extent. For spot, scattering, and trail-builder applications, some mitigation of primary nontarget exposure is realized by confining treatments to places where target species are likely to be the first animals to encounter baits. Bait stations used in the control of field rodents often are designed to exclude nontarget animals that are larger than the target species. In some cases, special designs have been developed which exploit behavioral traits and limitations of species of small nontarget mammals that are to be protected and allow control of larger rodents with little risk to those smaller species (e.g., Erickson *, et al*, 1990; Whisson, 1998)

With broadcast applications, spatial dilution of bait and its settling into vegetation may make it somewhat more likely to be encountered by the olfactory-guided foraging strategies of rodents than by visually guided granivorous birds.

For all above ground uses, proper timing of application in terms of season and time of day increases the likelihood of uptake by target species and thereby limits the amount of bait remaining for nontarget species.

Currently, for zinc phosphide, and following product reregistration for chlorophacinone and diphacinone, the field rodenticide uses available to nonprofessional applicators will be limited to manual, below-ground applications to control moles and/or pocket gophers. If label directions for such products are followed, primary nontarget exposures to such baits would be limited to species that entered the burrow systems of the target species. The likelihood that consumers would follow such directions may be greater for the mole and pocket gopher baits than for baits used to control commensal rodents because it is not necessary to obtain additional equipment to treat mole and gopher burrows and because there is little hope for successful control of moles and pocket gophers unless bait is applied directly to their burrow systems.

Quarantine Uses - When there is a need to ensure that no target pests survive, the selection of a rodenticide or combination of rodenticides is likely to favor the most highly toxic compounds. Whether there is a need to control a vector or an invasive rodent, a short-term increase in local risk factors might be offset by the long-term benefits of arresting the disease or preventing the invasive species from establishing itself.

Conservation Uses - If an invasive rodent species has become established, rodenticide baits may be incorporated in management or eradication programs intended to benefit native species. Such programs may be feasible on islands of small to moderate size to protect colonies of ground- and hole-nesting birds. If eradication is judged to be feasible, one season=s use of a highly toxic rodenticide could eliminate the invasive rodent population to the subsequent benefit of the native species. Applying baits after migratory species have left the area may simultaneously promote acceptance of bait by food-stressed rodents while minimizing adverse impacts on native species. Some adverse impacts of island baiting programs on native species have been documented (e.g., Howald, *et al*, 1999). Recognizing the potential adverse impacts of baiting programs and planning appropriate mitigation actions are essential steps in designing strategies for managing or eradicating rodents for conservation purposes (e.g., National Park Service, 2000).

VIII. Alternative Methods of Rodent Control

A. Chemical Alternatives

Fumigants (gas cartridges, aluminum phosphide, magnesium phosphide, Vargon, acrolein, all available as Special Local Need registrations only]) - Some types of rodents can be controlled by application of fumigant products to their burrow systems. Such applications potentially will kill target species and any other animals in the burrows. However, burrow treatments with some fumigants have been less than fully effective for organisms such as pocket gophers and moles, which have complicated burrow systems and may also have behavioral defenses against certain types of fumigants. Apparently for these reasons, gas cartridges do not appear to be effective against pocket gophers (e.g., Matschke, *et al* 1995).

The usefulness of burrow fumigants is further limited by prohibitions on treatments of burrows that are close to buildings and the need for soil moisture to be adequate to retain toxic gases. Especially under dry conditions, using gas cartridges may present a fire hazard. Aluminum phosphide, magnesium phosphide, and acrolein are Restricted Use Pesticides for which applicator certification and specialized training are required. Special equipment is needed to apply acrolein and Vargon to burrows. Burrow fumigations are time-consuming and labor-intensive, with repeat treatments often being needed. Consequently, burrow fumigations may be too costly to conduct except when controlling small infestations, "mopping up" survivors from a toxic baiting program, or protecting extremely valuable resources.

Structural fumigation aimed at controlling insect pests may also control exposed rodents. Benefits realized in this regard usually are in addition to the invertebrate control which was the primary treatment objective.

Repellents (e.g., Dr. T=s., Ro$Pel, Naphthalene) - There are few products registered in the United States as rodent repellents. Such products generally are claimed to be area repellents or feeding deterrents. Evidence supporting either type of claim is limited. Denatonium compounds have been claimed to act as feeding deterrents to certain types of rodents as well as other mammals. At lower concentrations (e.g., 0.001%), however, denatonium benzoate is used in rodenticide baits and is claimed not to deter feeding by commensal rodents (Kaukeinen and Buckle, 1992).

Area repellents containing materials such as naphthalene or paradichlorobenzene are irritating to humans and are not appropriate for use in occupied buildings unless the products themselves are in sealed containers, in which case they would be useless as rodent repellents.

B. Non-Chemical Alternatives

Exclusion and Rodentproofing - Rodent-resistant and rodentproof modifications to existing or new constructions (collectively called Astoppage@) can greatly reduce the likelihood that rodents will enter buildings and are an important element of successful structural rodent management operations. However, not all building designs allow for complete rodent proofing, considering that young commensal rats can enter holes 2" (13 mm) in diameter and house mice can enter even narrower openings (Frantz, 1988; Baker, *et al*, 1994). Even with conventional rodent proofing, rats can occasionally enter buildings by coming up through the plumbing that drains toilets. Business and farm operations which require doors to be kept open for extended periods of time, especially at night, cannot be completely rodentproofed. Exclusion is useful as a first approach, or as an accompanying IPM measure to existing infestations when rodenticides must also be applied. Exclusion reduces the ability of commensal rodents to survive because their food, water, and shelter resources are diminished or eliminated.

Habitat Modification - Properties can be made less attractive to commensal rodents by rather simple procedures such as improving sanitation, thereby reducing sources of harborage, food, and water (Timm, 1994a; 1994b). These approaches are helpful in deterring colonization by rodents and, as directed on existing labels for commensal rodenticides. These interventions should accompany or precede baiting or trapping programs.

Trapping - Trapping is useful for verifying the species responsible for a rodent infestation and may be sufficient to control small infestations, especially at the time of colonization (e.g., late summer invasions of homes by house mice). For larger infestations, rodent removal by trapping alone can be an extremely labor-intensive and costly (Boddicker, 1983). However, some management programs for commensal rats, such as the IPM program implemented by the San Francisco Department of the Environment, have found trapping to be a viable and often preferable rodent management technique (Blumenfeld, 2004). Where toxic baits cannot be used for reasons of safety, trapping may be the only removal method that can be implemented. Lethal and non-lethal traps of various types may be used to control various types of rodents and moles. Traps may be especially useful for controlling small infestations of house mice, *Peromyscus* spp. mice, pocket gophers, woodchucks, and Norway rats. Appropriate trap placement is important to success, and trap prebaiting may enhance the rate of capture of neophobic species (e.g., Timm, 1994a; 1994b).

The use of lethal traps may not always be acceptable to everyone, as the following comment submitted to the Agency by Thill (2004) indicates: "In many instances residents cannot tolerate trapping, cannot afford private pest control services, and for one reason or another, (are) not able to do certain exclusion work, or other associated rodent control work. In many instances the foul odor of a decaying rat is much more tolerable than the handling of a dead rat in a trap. The use of rodenticide can be a very valuable tool in these cases, but still needs to be used in conjunction with other control methods in order to achieve adequate control."

However, the City of San Francisco's IPM project has found that for some infestations, such as in restaurants, quick control is essential for public health reasons, and this can be achieved by trapping. Furthermore, in addition to a quick reduction of the rat population, using traps avoids the problem of dying or dead rats in public areas or inside walls where decomposing bodies will cause long-lasting putrid odors (Blumenfeld, 2004).

Lethal traps may pose a risk to small nontarget animals, and can cause injury to applicators and other on-site personnel. Placing lethal traps within locked rooms or in the rodent areas of properly applied tamper-resistant bait stations or other suitable objects can mitigate the risks posed to some nontarget species.

Live-trapping requires users to deal with captured animals. This circumstance often allows for the release of captured nontarget animals but presents to the trapper the problem of deciding the fate of target animals and may increase the opportunity for transfer of certain disease to humans (e.g., CDC, 2004). With repeating-type mouse traps, multiple house mice may be caught in a single trap (Timm, 1994a). With traps, there is some danger of targeted animals becoming trap-shy through their own experiences (i.e., near misses).

Electrical or electronic rodent traps have been marketed at times. These traps generally have been able to trap rodents, with some traps also killing them. Due to high unit costs, it is doubtful that such traps have had much usage.

Shooting - Some control of diurnal rodents such as prairie dogs and ground squirrels can be effected through shooting. The method has been described as selective, but not very efficient for controlling colonial species (e.g., Hyngstrom and Virchow, 1994; Marsh, 1994). For woodchucks, shooting can be used to manage local populations (Bollengier, 1994). However, shooting can only be employed where and when State laws and local ordinances permit the activity. Prohibitions on hunting near buildings or in parks and the Agame@ status of the pest are some of the factors affected by laws and ordinances.

Pest Control Devices - Under FIFRA, pest control devices are regulated to some extent, but there is no requirement that the products themselves be registered before they are marketed. Some pest control devices marketed for rodent control are discussed below.

Glue boards - Glue boards are sticky traps which have been marketed in ready-to-use condition or with the glue offered separately, enabling the user to apply it to a suitable surface for capturing rodents. The issues with glue boards are much like those discussed above for traps, except for logistical and humaneness problems since the glue restrains but does not kill the rodent, often leading to prolonged struggling in awkward positions (Frantz and Padula, 1983). Humans may be injured when picking up glue boards holding rodents that only appear to be dead. Neophobic responses to glue boards have been reported for house mice (Corrigan, 1998).

Burrow collapsers - Products that collapse rodent burrow systems are relatively new. One type of such a device ignites a mixture of propane and oxygen in underground burrow systems, causing an explosion which reportedly kills organisms living in the burrow. Compression and the collapsing of the tunnels are believed to effect rodent control, with the leveled burrow system subsequently being less inviting to immigrant rodents than the intact system would have been. The utility of this type of product would be limited to burrowing species.

Issues of safety to humans, property, environment are largely unstudied for this type of product. Appropriate personal protective equipment (PPE) should be worn when using a burrow collapsing device. Nontarget animals living in treated burrow systems also would be expected to be killed. The abrupt shifting of soil along the course of the treated burrow system could cause damage to nearby buildings, roads, fencing, utility poles, or other structures.

Electromagnetic Devices - Since the mid 1970's, various devices have been claimed to be able to control various types of pests, including rodents, through creation of electromagnetic fields. EPA collected and evaluated many such units that were available in the 1970's and concluded that the principle of controlling pests via low levels of electromagnetism is flawed (EPA, 1979). Consequently, electromagnetic devices are considered to be unlikely to exert rodent control effects on their own; and claims that they enhance the effectiveness of conventional rodent control techniques such as traps and toxic baits are regarded as highly unlikely.

Ultrasonic devices - Although many types of rodents can perceive ultrasonic stimuli and communicate via ultrasonic vocalizations, tests of ultrasound generators as rodent control agents have suggested little promise for them. Even though rodents may appear to perceive and may initially react to ultrasonic noise, they seem to adapt to it. Ultrasound rapidly attenuates over distance, is extremely directional, and is Ashadowed@ by objects. Consequently, commensal rodents appear to be able to coexist with ultrasonic signals by staying largely behind and under cover, which is typical behavior for these animals. EPA studied units available in the 1970's and early 1980s and concluded that they were not likely to be of significant value in rodent control.

C. Integrated Pest Management

Since first articulated by Stern et al. (1959), as "integrated control," there have been many attempts to redefine the integrated pest management (IPM) concept. As it applies to urban pests, including rodents, Frantz (1996) defines IPM as "the coordinated use of pest and environmental information with available pest suppression methods to prevent unacceptable levels of pest damage by the most economical means and with the least possible hazard to people, property, and the environment." As currently practiced, rodent IPM could be described as the use of complementary non-chemical and chemical rodent control techniques in a safe, cost effective, and least environmentally disruptive manner, to prevent rodents from adversely affecting the welfare and interests of humans. Frantz and Davis (1991) provide a comprehensive review of the principles and application of the IPM approach to rodent control, drawing from observations and experiences in the U.S. and several Asian countries.

Management of rodent pests, whether field or commensal species, is best achieved through a combination of viable methods (i.e., IPM) , with the approaches selected being adapted to conditions prevailing at the site when the program is initiated. For example, Timm (1994) presents a flow chart outlining the factors and control options that an applicator might consider in dealing with an infestation of house mice. If there are no rodents present, rodentproofing and habitat modification should be implemented to increase the likelihood that rodents will not take up residence on the premises. Planning to incorporate rodent stoppage into building designs, seeing to it that stoppage is effected during construction, and diligently maintaining stoppage and sanitation on the premises may prevent rodent infestations from occurring at a site (Frantz and Davis, 1991).

Several New York City agencies are currently implementing coordinated rat control programs that include lot cleaning, cracking down on illegal garbage dumping, making regular inspections, and exterminating rats. The New York Department of Parks, for instance, uses an IPM approach, emphasizing prevention and exclusion methods that include frequent garbage collection, use of rodent-resistant closed containers, pruning of overgrown areas to reduce outside shelter, and masonry work to reduce rodent harborage inside structures. Rat populations are monitored to determine if the use of rodenticide baits is needed. This initiative was built on an IPM pilot project funded by the CDC for implementation in a 48-block portion of Bushwick, Brooklyn, which had a long history of rodent infestations (Frieden, 2003).

The Contra Costa Mosquito and Vector Control District implements an IPM program for rodents that involves community education, interagency cooperation, and baiting programs (Thill, 2004). This program's community awareness and education component uses a wide range of outreach and information dissemination approaches to educate the community residents about appropriate rodent management techniques. This component is complemented by two baiting program, one of which targets Norway rats in sewer systems and the other commensal rodents in creeks, canals, waterfronts, parks, and other public areas. A non-toxic bait is often used to detect rat activity and determine where to best use toxic baits.

The City of San Francisco currently implements an IPM program for rats, based on an IPM ordinance adopted in 1996 that commits the City to selecting the least hazardous, effective rodent management methods in City properties (Blumenfeld, 2004). This program emphasizes the use of non-chemical methods, such as trapping, while still using rodenticide baits as needed. The program has found that for some infestations, such as in restaurants, quick control is essential for public health reasons, and this can be achieved by trapping, whereas baiting is better suited for use in certain locations, such as sewers.

IX. Matrix of Use Sites

Table 1. summarizes the use patterns of the nine rodenticides discussed here. The names of the rodenticides are listed on the first column. The second column shows a common classification scheme for these chemicals based on mode of action and developmental history. The next two columns indicate that all nine rodenticides are registered for commensal rodent control, whereas only four of these, warfarin, chlorophacinone, diphacinone, and zinc phosphide are registered for non-commensal rodent control. Of these, zinc phosphide has by far the most uses in terms of number of target species and use sites. The fifth column shows the ranking of the four rodenticides that pose the greatest overall risk to birds and nontarget mammals, based on EPA=s 2004 ecological risk assessment for the nine rodenticides discussed in this document. The sixth column includes some of the limited usage data publicly available at present. The seventh and last column attempts to categorize common use patterns in relation to the areas where these rodenticides are most commonly used.