COMMON SENSE PEST CONTROL QUARTERLY

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Protecting Raptors from Rodenticides

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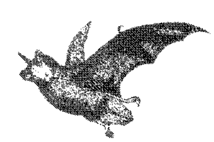


Protecting Raptors from Rodenticides

By William Quarles

Rats and mice have been pests throughout recorded history. They eat and contaminate food, and help transmit human diseases, including plague. Pest management as a profession started with rats and mice, and they are common elements in literature and in our cultural history. Who can forget *The Plague* by Albert Camus, or the *Pied Piper of Hamlein* folktale? (Corrigan 1997)

The best way to control rodents is by combining sanitation, exclusion, habitat management, and traps in an integrated control program. (See the second article in this issue.) This combination can work well for structures, but urban conditions can lead to rats breeding in sewers, vacant lots and other situations. Public health requires control, and often, resources to provide urban cleanup and integrated management are not available (Olkowski et al. 1991). As a last resort, poison baits have been used to reduce rat populations. Poison has also been used for voles, gophers, prairie dogs, ground squirrels and other such pests (Hygnstrom et al. 1994).

Primary and Secondary Poisoning

Rodenticides should be used as a last resort because children, pets, and wildlife can be accidentally killed or injured. Primary poisoning is a problem when a non-target animal directly eats a rat bait, secondary poisoning occurs when a predator or scavenger eats a rodent that is full of poison. The potential for non-target poisoning can vary with the active ingredient, with the formulation, and with the bait deployment methods (see below) (see Box A. Primary and Secondary Poisoning). The purpose of this article is to identify the most problematic rodenticides and suggest less harmful alternatives. Emphasis is on secondary poisoning of raptors.

Poisoning of People and Pets

Each year about 13,000-20,000 people in the U.S. are poisoned by rodenticides (See Table 1). Most of these are children under the age of five. About 78-83% of the exposures and 76-82% of the hospitalizations are due to second generation anticoagulants, primarily brodifacoum (see Box A). Less than 6% of the hospitalizations are due to acute toxicants such as bromethalin, vitamin D_3, and zinc phosphide. Less than 2% are due to the first generation anticoagulant, warfarin (Bronstein et al 2011; Watson et al. 2005).

About 95,000 pet poisonings due to rodenticides were reported to American Poison Control Centers in 2010. About 75% of the animals poisoned were dogs (Bronstein et al. 2011). A study done by the Humane Society shows that 74% of their pet poisoning cases are due to second generation anticoagulants, primarily brodifacoum. Less than 14% are due to acute toxicants such as bromethalin, vitamin D_3, and zinc phosphide. Only 2% are due to warfarin (Erickson and Urban 2004).

Poisonings of children and dogs have occurred probably because

Barn owl, *Tyto alba*

Photo courtesy Mike Atkinson

consumers have been able to buy rodenticides formulated as treated grain or loose bait. This kind of packaging makes poisons easily accessible to children. To reduce exposures, the EPA in 2011 required manufacturers to produce baits only in tamper resistant bait stations for the consumer market. Some companies have refused to comply (EPA 2008; EPA 2011).

Poisoning of Wildlife

As well as people and pets, a wide variety of wild bird and mammal species are being killed by rodenticides. Both primary and secondary poisoning has occurred. Foxes, raccoons, coyotes, opposums, squirrels, bobcats, wild pigs, deer, even mountain lions have been killed by

Table 1. Rodenticide Exposures of Humans in the U.S.

Rodenticide	Exposures 2004	Exposures 2010	Percent Exposures 2010	Number in Hospital 2010	Percent Hospitalizations 2010
1080	2	2	---	2	---
Antu	2	5	---		0
Bromethalin	643	554	4.2	185	5.0
Other	772	602	4.5	56	1.5
Second generation anticoagulants	16,054	10,227	78 (83 in 2004)	2,774	75.7 (82 in 2004)
Strychnine	121	57	---	30	0.8
Unknown	1396	1291	9.8	516	14.1
Vitamin D_3	6	13	---	2	0.05
Warfarin	337	269	2.0	73	1.9
Zinc phosphide	94	87	0.7	27	0.7
Total	19,427	13,107	100	3,665	100

Bronstein et al. 2011. Annual Poison Center Report 2010
Watson et al. 2005, Annual Poison Center Report 2004

Bald eagle, *Haliaeetus leucocephalus*

rodenticides (Stone et al. 1999; Hosea 2000; Eason et al. 2002).

Raptors in the U.S., Canada, France, Great Britain and elsewhere are dying from consuming rodents poisoned with second generation anticoagulants such as brodifacoum and bromadiolone. Owls, hawks, and eagles have been affected (Albert et al. 2010; Stone et al. 2003; Walker et al. 2008).

How do we Know Raptors are Being Poisoned?

Direct information on the poisoning problem has come from laboratory experiments where birds are fed poisoned rodents, and from field studies where birds are monitored by radio tags after rodent baits are deployed. Indirect evidence is coming from surveillance programs where dead birds are found and turned in to a government agency or a wildlife care clinic. Most of the problems are due to the second generation anticoagulant brodifacoum (Erickson and Urban 2004).

Secondary Poisoning in the Laboratory

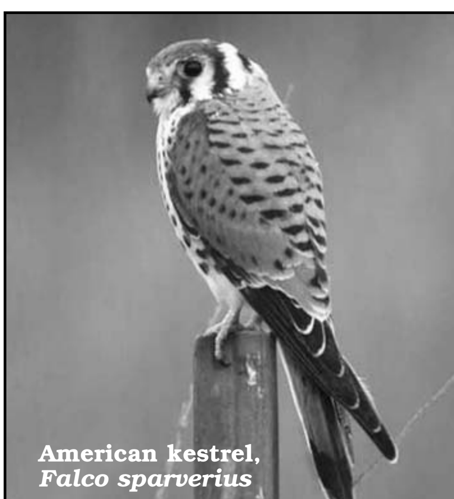
The secondary poisoning threat of brodifacoum has been known since its registration. In one experiment, 36 owls were fed rodents killed with 6 different anticoagulants. Dead rats containing brodifacoum killed 5 of 6 owls exposed (83%). Bromadiolone treated rats killed one of six owls (17%). Rats containing other anticoagulants such as diphacinone and chlorophacinone caused bleeding, but not death (Mendenhall and Pank 1980). In another experiment, when six barn owls were fed brodifacoum mice, four of them died (66%). Just three mice were enough to cause death (Newton et al. 1990).

An EPA review summarized laboratory experiments with brodifacoum in 2004. When 149 raptors or scavengers were fed brodifacoum poisoned prey in the laboratory, 42% of the birds died of secondary poisoning (Erickson and Urban 2004). So secondary poisoning of predatory birds and scavengers with brodifacoum has been well documented by laboratory experiments.

Raptors Show Increased Sensitivity

Part of the problem is that raptors are relatively sensitive to anticoagulants. Rattner et al. (2011) studied primary poisoning of American kestrels, *Falco sparverius*, with diphacinone in the laboratory. Kestrels were 20-30 times more sensitive (LD50 = 96.8mg/kg) to the lethal effects of diphacinone than the Northern bobwhite, *Colinus virginianus*; or mallards, *Anas platyrhynchos*; bird species often used in EPA tests for toxic pesticide effects.

But diphacinone is much less of a secondary poisoning problem than brodifacoum, and Rattner et al. (2011) calculated that secondary poisoning "risk associated with a single day exposure to diphacinone would be low" for hawks and owls. The risk is low because diphacinone is quickly eliminated, with a half life of 22 hours. However, hawks could show effects of sublethal exposure by as little as 3.5 g of liver from diphacinone poisoned rats (Rattner et al. 2011).



American kestrel, *Falco sparverius*

Photo courtesy University of Minnesota

Field Studies

There is also evidence of secondary poisoning of raptors from field studies. In one experiment brodifacoum scatter bait was used to control voles, *Microtus* spp. in apple orchards. Radio transmitters were attached to owls and hawks to monitor their progress. Problems occurred when raptors fed on voles in the treated orchards. If more than 20% of the foraging range had been treated with brodifacoum, minimum mortality of screech owls, *Otus asio*, was 58%. If less than 10% of the foraging area had been treated, mortality was 17%. Because of the severe impact, brodifacoum is not used for vole control in the U.S. (Hegdal and Colvin 1988).

Eastern screech owl, *Otus asio*

Photo courtesy Bob Jacksy

Secondary poisoning problems are greatest when the target rodent species is a common food source for the predator, and the poisoning occurs inside the predator's foraging range. In the experiment above, screech owls were affected, but barred owls, *Strix varia*, foraged mostly in woodlands and avoided the treated orchards (Hegdal and Colvin 1988).

Extended Exposures in the Food Chain

If baits are deployed for roof rats, predator species that do not eat roof rats should not be at risk.

Unfortunately, non-target rodents often consume rat baits. For instance, Brakes and Smith (2005) found that woodmice, field voles, and bank voles were being poisoned by rat bait boxes. Populations of these animals dropped, exposing their predators both to secondary poisoning and a reduced food supply.

Insectivorous birds have died after eating insects feeding on brodifacoum bait in bait stations (Hosea 2000). Secondary poisoning can also occur in humans when rodents are a food source, though this is not a problem in the U.S. (Fiedler 1990). Secondary poisoning of humans is possible when deer, wild pigs, and other game animals have been poisoned with anticoagulants. The poison is not destroyed by cooking (Eason et al. 2002; Stone et al. 1999).

Sublethal Effects

Raptors are dying from lethal exposures, but also sublethal amounts are making them more susceptible to disease and accidents (Lemus et al. 2011; Stone et al. 2003). According to Stone et al. (2003), "Sublethal hemorrhage may interfere with locomotion, predisposing animals to predation, accidental trauma, and reduced food intake." There is also the "possibility of toxic injury to the liver."

Synergistic effects between anticoagulants and disease have also been found in mammals. For instance, one study in Southern California showed that 90% of bobcats, *Lynx rufus*, in the area had been poisoned with anticoagulants. Anticoagulants correlated with incidence of lethal mange, and 100% of bobcats dead from mange had been exposed. Two mountain lions in the study area had also died from anticoagulants (Riley et al. 2007).

There can also be sublethal effects on reproduction in raptors. Nestling barn owls, *Tyto alba*, in test areas baited with brodifacoum weighed 13% less than those in untreated areas. Wingspans (15%) and tail lengths (18%) were also shorter. One nestling had malformed feathers, rendering it flightless (Naim et al. 2010). It is well known that anticoagulants cause birth defects in humans, so reproductive effects of secondary poisoning in raptors should be investigated further (Stevenson et al. 1980).

Persistence a Problem

Although first generation anticoagulants are eliminated fairly quickly, second generation products linger in the bloodstream, and the liver acts like a sponge. Large

Box A. Primary and Secondary Poisoning

There are two general kinds of rat poisons—acute poisons and chronic poisons (Meehan 1984). Until 1950, only acute poisons were available. With an acute poison, one encounter with the bait is enough to kill a rat. Various compounds such as arsenic, strychnine, red squill powder obtained from the lily, *Urginea maritima*, sodium monofluoroacetate (Compound 1080), vitamin D_3 (cholecalciferol; Terad3®), zinc phosphide (ZP Rodent Bait®; Ridall®), and bromethalin (Tom Cat®) have all been used (Meehan 1984; Erickson and Urban 2004).

There are three problems with acute baits. One, Norway rats, *Rattus norvegicus*; and roof rats, *Rattus rattus*, tend to view with suspicion any new item in their environment (neophobia). Two, if they consume a sublethal amount of an acute bait, they will avoid eating any more (bait shy). The other problem is that acute baits are extremely dangerous to pets and children, as one encounter can make them very sick or kill them (Meehan 1984). Non-target poisoning with acute baits is called primary poisoning, as the animal directly eats the bait (Erickson and Urban 2004).

Anticoagulants

The need to provide added safety for rat baits led to the invention of the anticoagulants. Early first generation anticoagulants include warfarin, chlorophacinone, and diphacinone. Most anticoagulants are chronic baits, and with many of the older first generation compounds, daily doses over several days are needed to kill a rat or a non-target animal. All the anticoagulants work in the same way; enzymatic synthesis of vitamin K is blocked. Vitamin K is essential for proper clotting of blood, and once vitamin K levels drop below a critical threshold, internal bleeding occurs and death follows.

The first-generation anticoagulants are much safer than acute poisons because several encounters are generally needed to produce a problem in a non-target species, and vitamin K is an antidote to anticoagulant poisoning (Hadler and Buckle 1992).

Secondary Poisoning

Although anticoagulants reduce the risk of primary poisoning, the risk of secondary poisoning increases. Secondary poisoning results when a predator or a scavenger eats a poisoned rodent. Both mammals and birds are affected by secondary exposures in laboratory tests (Littrell 1990; Mendenhall and Pank 1980). Effects of secondary poisoning from first generation anticoagulants are minimized because the poison is quickly eliminated by the rodent, and amounts do not accumulate (Hadler and Buckle 1992).

Secondary poisoning became a real problem with the development of second generation anticoagulants such as brodifacoum, bromadiolone, and others. These are more acutely toxic and are extremely persistent. One feeding on a second generation bait provides a lethal dose. But because a rat does not die right away, repeated feeding can occur, leading one rat to accumulate 20-40 lethal doses (Erickson and Urban 2004).

Since predators prefer to eat live rats, quick-acting acute poisons produce very few secondary poisonings. Rats die slowly from anticoagulant baiting, however, and the possibility of secondary poisoning increases with time. Poisoned rats tend to die in the open, and may be moving slowly and erratically just before death. Such rats make good targets for predators such as owls and foxes (Meehan 1984; Cox and Smith 1992).

amounts accumulate in the liver of rodents, and subsequently in the livers of predators. Repeated feedings allow an accumulation of toxins to lethal levels over time (Erickson and Urban 2004).

Second generation anticoagulants are also extremely persistent. For instance, after field populations of voles in France were baited with bromadiolone, 50-80% of surviving voles had detectable residues 135 days later. About 59% of the residue was concentrated in the livers. Longterm persistence in the pest population can lead to cumulative risk for predators (Sage et al. 2008). According to a review by Eason et al. (2002), sublethal amounts of brodifacoum and bromadiolone are likely to persist 6-12 months.

Surveillance Programs

Another source of information about secondary poisoning is government surveillance programs. Dead birds found in the environment are submitted to monitoring agencies. Birds are then analyzed for poison. For instance, anticoagulant rodenticides were found in the livers of 48% of 265 raptors collected in New York. Of those exposed, anticoagulants were related to their deaths in about 22% of the cases (Stone et al. 2003).

Also, 37% of 351 owls in Great Britain and 72% of 164 owls in Canada had detectable concentrations of anticoagulant rodenticides in their livers (Ratner et al. 2011). Concentrations in at least 21% of the Canadian owls were large enough to be life threatening (Albert et al. 2010).

Wildcare, an animal rehabilitation center in Marin County, CA is seeing poisoning in 58% of the bird and mammal patients. In Massachusetts, of 161 raptors admitted to a wildlife clinic, 86% had brodifacoum anticoagulant residues in their livers (Murray 2011).

Cases from surveillance programs are likely the tip of the iceberg, as many bird poisonings go unnoticed, since the corpses decay quickly in out of the way locations. Toxic carcasses are also eaten by scavengers or predatory mammals, and these animals are also poisoned (Eason et al. 2002).

Owls in Canada

When 164 owl carcasses in western Canada were analyzed for anticoagulants, 72% had residues of at least one anticoagulant in their livers. Frequency varied with species: barn owls (62%), *Tyto alba*; great horned owls (70%), *Bubo virginianus*; and barred owls (92%), *Strix varia*. Barred owls encountered poisoned rodents more often because they hunt mostly in urban and suburban sites (Albert et al. 2010).

Brodifacoum and bromadiolone were the most frequently detected anticoagulants at liver concentrations up to about 1 mg/kg. Levels of anticoagulants were high enough to cause bleeding in 92% of the cases. Anticoagulants were directly the cause of death in 3.6% of the cases, 6% had liver concentrations (>0.6 µg/g) known to correlate with death, and 15% had liver concentrations (>0.2 µg/g) likely to correlate with death (Newton et al. 1999). About 32% of the owls had liver concentrations (>0.1 µg/g) that some studies have associated with lethal risk in owls (Thomas et al. 2011; Newton et al. 1998).

Barred owl, *Strix varia*

Photo courtesy Joe Vincent

From these data, if dead owl samples were representative of the general owl population, at least 11% and up to 23% of the owl population in western Canada from 1988 to 2003 was at risk of death from anticoagulants especially brodifacoum and bromadiolone (Albert et al. 2010).

Another Canadian study used a statistical method to estimate that about 11% of the great horned owl population of Canada was at risk of being killed by second generation anticoagulants (Thomas et al. 2011).

Raptors in New York

When 265 dead raptors from 12 species were collected and analyzed in New York (1998-2001), anticoagulant residues were found in 49%. Brodifacoum was detected in 84% of the positive cases, and was considered the principal or probable cause of death in 27 of 28 deaths attributed to anticoagulants. Of raptors exposed, brodifacoum may have killed 21% of them. If the sample was representative of the raptor population, then very roughly at least 10% of New York raptors that died during this sampling period were likely killed by brodifacoum. (There was no systematic monitoring across the state. But the estimate is likely to be a lower limit because dead birds die in out of the way locations, and few are brought in by the public for analysis. Scavengers also feed on the corpses.)

Some species are more at risk due to food preferences and sensitivity to brodifacoum. Anticoagulants were found in 81% of great horned owls, *Bubo virginianus*, and 58% of red tailed hawks, *Buteo jamaicensis*. Brodifacoum was the principal or probable cause of death in about 21% of the great horned owls and about 27% of the red tailed hawks exposed to anticoagulants (Stone et al. 2003).

Bromadiolone was detected in 22% of the positive anticoagulant cases, but was likely involved in only two deaths. Chlorophacinone, diphacinone, and warfarin were detected in some cases, but led to no deaths (Stone et al. 2003).

Raptors in California and Massachusetts

California Department of Fish and Game collected 74 animals from

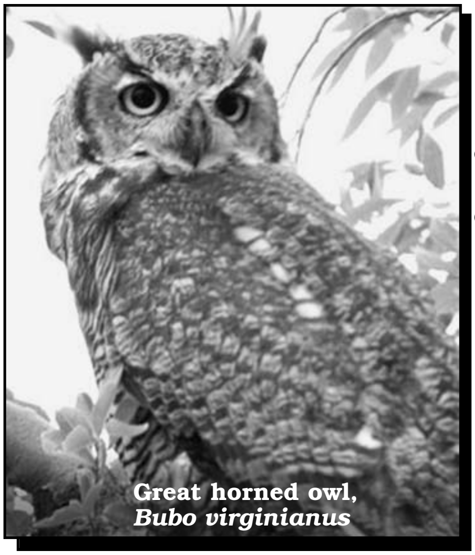


Photo courtesy George Jameson

Great horned owl, *Bubo virginianus*

1994-1999. Residues of anticoagulants were found in 74% of the mammals and 68% of the birds collected. About 61% of the mammals and 55% of the birds contained brodifacoum. About 19% of the birds were exposed to bromadiolone, 10% contained diphacinone, and 10% chlorophacinone. Most frequently exposed were coyote, *Canis latrans*; bobcats, *Lynx rufus*; golden eagles, and barn owls. About one-third of the birds exposed were owls, about 55% other predatory birds (Hosea 2000).

Of 161 raptors collected in a Massachusetts wildlife clinic from 2006-2010, 85% tested positive for brodifacoum. Species included red-tailed hawks, *Buteo jamaicensis*; barred owls, *Strix varia*, eastern screech owls, *Megascops asio*, and great horned owls, *Bubo virginianus*. At least 6% of the birds had died from poisoning (Murray 2011).

Raptors in Europe and the UK

In Demark, a total of 430 raptors from 11 species were analyzed for anticoagulants. Frequency of anticoagulant liver residues varied with species, but residues were found in 84-100% of the bird species analyzed. Amounts also varied by species, but about 13-37% of residues in the livers were large enough to have caused poisoning symptoms or death (Christensen et al. 2012).

In Britain, 20% of the tawny owl, *Strix aluco*, population had been exposed to second generation anticoagulants over a five year observation period (Walker et al. 2008). Over a 15 year period, 28% of dead barn owls, *Tyto alba*, contained residues of these anticoagulants. About 48% of the owls had died from auto accidents and 31% from starvation. The residues increased over the years, and 40% of the birds were positive for the anticoagulants at the end of the experiment in 1998 (Newton and Wylie 2002).

When 401 wild or domestic animals were examined in Spain, about 39% had been exposed to anticoagulants, either through primary or secondary poisoning. Of those exposed, 90% had died from the poison. About 62% of dead raptors and 38% of carnivorous mammals had died from the poison. Widespread exposure occurred through treated grain spread on the soil surface (Sanchez-Barbudo et al. 2012).

Raptors in New Zealand

Brodifacoum and second generation anticoagulants are widely used in New Zealand. Aerial applications are used to clear islands of rats. With island applications, 80-90% of some bird species were killed by a combination of primary and secondary poisoning. On one island, about 21% of the native owl morepork, *Ninox* sp., were presumably killed by secondary poisoning.

Photo courtesy Patricia Velte

Red tailed hawk, *Buteo jamaicensis*

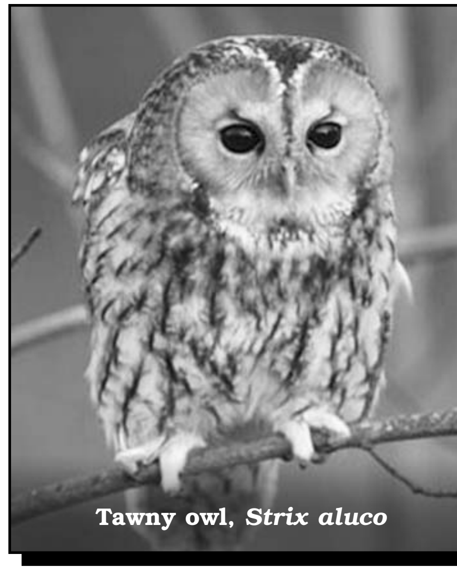


Photo courtesy Mark Payne-Gill

Tawny owl, *Strix aluco*

On the mainland in areas where brodifacoum is used, 63% of dead birds have residues in their livers. Mammals are also at risk, as 60% of wild pigs, 33% of deer, 80% of wildcats, and 85% of stoats sampled have residues in their livers. Deer poisoning is likely primary poisoning from feeding directly on the bait (Eason et al. 2002).

Where are Rodenticides Used?

Rodenticides are used in urban situations to reduce rat populations. They are used in agricultural situations to remove gophers and voles from crops, and in wildlife situations to reduce populations of prairie dogs, and ground squirrels. But second generation anticoagulants are registered only for structural pest control in the U.S. First generation chlorophacinone and diphacinone baits are used for voles, gophers, and ground squirrels (Erickson and Urban 2004; Hygnstrom et al. 1994).

Declining Raptor Populations

Secondary poisoning effects on bird and mammal populations are localized to the treated area. Birds or mammals must be feeding on the treated rodents to get poisoned. In the case of brodifacoum, one rat can contain 30-40 times a lethal dose (Erickson and Urban 2004).

But if large areas are treated, predator populations in large areas can be affected. Owls in western Canada are declining (Albert et al. 2010). Kestrels and some owl species are declining in the U.S. (Smallwood et al. 2009).

Various published studies cited above have found these species are often exposed to secondary rodenticide poisoning (Stone et al. 2003; Hosea 2000; Albert et al. 2010). Predatory birds such as kestrels are more sensitive to anticoagulants than grain eaters such as bobwhites or mallards (Rattner et al. 2011). Rodenticides are likely one factor in areawide population decline.

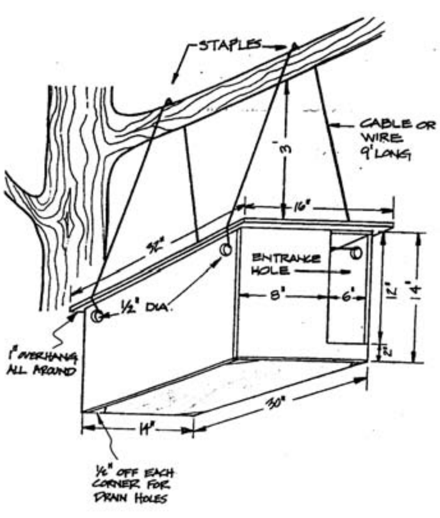
Raptors are the Solution

Raptors should be encouraged as part of an integrated rodent control program. In Malaysia on 188 oil palm plantations where barn owl boxes were built, there was a decline in rat numbers and damage (Basri et al. 1996). Barn owl boxes on a rice plantation reduced rat damage from about 6.5% to 2.5% (Mohamad and Goh 1991). Another experiment showed that barn owl boxes were most effective when rodent numbers were low (Chia et al. 1995). Barn owl boxes and blueprints for their construction are available on the Internet.

New EPA Regulations

From the information above, it is clear that second generation anticoagulants, and especially brodifacoum, are the major cause of accidental poisonings in humans and pets. They are also causing secondary poisoning of wildlife and especially raptors. The EPA reviewed problems with rodenticides in 2008. As a result, second generation anticoagulants were banned in the consumer market, and bait stations were required for all rodenticides sold in this market. The rules were implemented in June 2011. Many companies have complied, but three companies are fighting the new regulations (EPA 2008; EPA 2011).

The new EPA regulations do not affect the professional market and applications on farms. Although second generation anticoagulants are not registered for agricultural pests such as gophers and voles, farmers are allowed to use them for rat and mouse control in and around structures (EPA 2011).



Dimensions of a barn owl box

Courtesy USDA

Resources

American Bird Conservancy, PO Box 249, The Plains, VA 20198; 202-234-7181, www.abcbirds.org

Golden Gate Audubon, 2530 San Pablo Ave, Ste G, Berkeley, CA 94702; 510-843-9912, www-goldengateaudubon.org

Golden Gate Raptor Observatory, Bdlg 1064, Ft. Cronkhite, Sausalito, CA 94965; 415-331-0730, www.ggro.org

Hungry Owl Project, 179 The Alameda, San Anselmo, CA 94960; 415-454-4587, www.hungryowlproject.org

Raptors are the Solution, www.raptorsarethesolution.org

Rodenticide Free Project, PO Box 892. Bolinas, CA 94924; 415-786-8467, www.rodenticide-freeproject.org

Wildcare, 76 Albert Park Lane, San Rafael, CA 94901; 415-456-7283, www.wildcareb-yarea.org

Best Methods for Rodents

The best way to control rodents is with an IPM program featuring several different methods. Habitat management, sanitation, and exclusion can be combined with trapping. (see the next article) Rodenticides should be used as a last resort because accidental poisonings can occur, and dead rodents can lead to odors in structures and production of other pests such as flies (Olkowski et al. 1991).

If a rodent bait is necessary, first generation materials such as warfarin, diphacinone, or chlorophacinone should be used. Where rodents are known to be resistant to warfarin, acute baits such as bromethalin or vitamin D_3 may be needed. All baits used by consumers should be contained within a tamper resistant bait station.

Conclusion

Thousands of children in the U.S. are exposed to rodenticides each year. About 76% of the hospitalizations are due to brodifacoum and second generation anticoagulants. About 74% of pet poisonings are primarily due to brodifacoum. In areas where brodifacoum is used, at least 11% of the raptors may be at lethal risk from secondary poisoning. First generation anticoagulants such as warfarin, chlorophacinone, and diphacinone are causing sublethal effects, but are rarely determined to be a direct cause of death in raptors, and cause only a small percentage of human poisonings. To reduce exposures, all manufacturers should follow EPA regulations that eliminate second generation anticoagulants and mandate tamper resistant bait stations for the consumer market.

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Managing Rats and Minimizing Rodenticides

By William Quarles

Rodents most often encountered as structural pests include the Norway rat, *Rattus norvegicus*; the roof rat, *Rattus rattus*; and the house mouse, *Mus musculus*. The Norway rat, considered the most important pest rat in the U.S., is also known as the brown, wharf, house, grey, or sewer rat. (Albino forms of the Norway rat are used for scientific research.) It occurs in every state and is widely distributed around the world. The roof rat, also known as the ship or black rat, occurs mainly in the coastal U.S., including the Pacific Coast states, the Gulf states, and the Southeast and some Middle Atlantic states. The house mouse is found throughout the U.S. (Marsh 1994; Corrigan 1997).

Both Norway rats and roof rats are omnivores, and will feed on almost anything. Unlike mice, rats require water daily, and prefer to nest where water is available. In general, Norway rats build their nests in underground burrows or in ground level areas in buildings. Roof rats prefer living in elevated areas and build nests in trees, vine-covered fences, and roofs, attics, and walls, although they will nest at ground level if arboreal habitat is limited. Roof rats often enter buildings from the roof or via overhead utility lines, which they use to travel from area to area. They are often found living on the second floor of buildings, whereas Norway rats are more likely to occupy the first or basement floor (Meehan 1984). Mice prefer to nest inside dwellings—wall voids, cabinets, furniture, and appliances are favorite targets (Olkowski et al. 1991).

How to Identify a Rat

The Norway rat and the roof rat differ from other rats and mice in that their tails are noticeably scaly. The Norway rat's tail is shorter than its head and body length, the roof rat's tail is longer than the head and body. Including the tail in the measurement, both rats grow to an overall length of about 16 inches (40 cm) at adulthood. The Norway rat is a larger, heavier rat, but has smaller eyes and a blunter snout than the roof rat (Ingles 1965; Meehan 1984). House mice are much smaller than rats. Their bodies and tails are each about 3.5 inches (9 cm) long, and they can gain entrance through holes as small as a dime. Mice can be distinguished from immature rats by their large ears, and their heads and feet are smaller relative to their body size (Olkowski et al. 1991).

Norway rats, *Rattus norvegicus*, have short tails and stout bodies.

Roof rats, *Rattus rattus*, have long tails and slender bodies.

If rats are not seen, the species involved can be deduced from their excrement. Norway rat droppings are larger and more ovoid than roof rat droppings, which tend to be longer and more cylindrical (Weber 1982). Each pest has a different biology and management methods must take this into account. Due to space limitations, rodent biology will not be covered here. The reader is referred to other sources (Olkowski et al. 1991; Corrigan 1997; Simon and Quarles 2004). Presented here is an IPM blueprint that can lead to effective rat management and reduction of rodenticides.

An IPM Approach

The best approach to rat management is a combination of monitoring, exclusion, habitat management and sanitation to prevent infestations. Once an infestation occurs, exclusion efforts should be intensified, and resident rats should be removed by traps. In some cases, a rodenticide may be necessary (Frantz and Davis 1991).

Until rat problems are under control, any attractive food, even closed packages of crackers or candy, can be temporarily stored in the refrigerator. Since hungry rats will eat nearly anything, even bars of soap may have to be refrigerated.

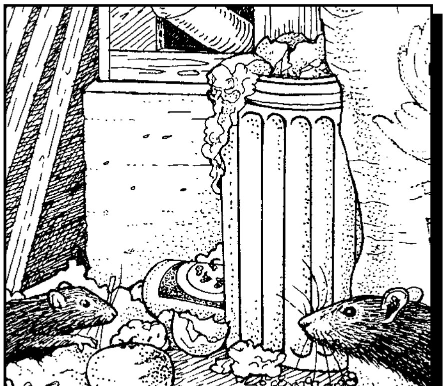
Large bags of flour, grain, dry pet or livestock food that are stored in basements or sheds should be placed on open-wire metal shelving that offers little rat harborage and is elevated at least 18 inches (45.7 cm) from the floor (Olkowski et al. 1991; Timm 1994).

Outdoor Garbage Management

Proper disposal of organic garbage is essential to keep rats at bay. Organic wastes should be separated from metal, glass and plastic. In some locations, green recycling cans are provided for organic waste. Check every evening to make sure there is no garbage lying on the ground around the cans, and lids are securely in place. Outdoor cans with holes or lids that do not fit tightly should be replaced or repaired. Where rat problems are compounded by raccoons or dogs tipping over garbage cans, spring-type or stretchy fasteners can be used to keep lids tightly closed (Olkowski et al. 1991; Timm 1994).

Reducing Landscape Habitat

Both Norway and roof rats can harbor in dense vegetation, which provides them both habitat and food. Keep woody shrubs and ground covers adjacent to buildings pruned to expose the lower 18 inches (45.7 cm) of trunk. This facilitates inspection for burrows and discourages rat harborage by exposing the area to light (Frantz 1988). Large leaf Algerian ivy, *Hedera canariensis,* is a favorite hiding place for rats, particularly when grown in dense monocultures and allowed to cover fences and trees. Roof rats also feed on the ivy berries. If you have this plant in your landscape, it should be trimmed to a height of at least 30 cm (11.8 in), or replaced with English ivy, *Hedera helix* (Frantz and Davis 1991).



Garbage cans should be tightly closed.

Avoid planting large areas of uniform ground cover that allows rats to run for long distances unseen. Break up existing dense plantings with exposed pathways, stretches of lawn or very low ground cover. Rats do not like to move across areas where they can be easily seen.

Fallen fruit, nuts and similar foods may be feeding rats around buildings. They should be shoveled, raked or swept up and put into rat-proof garbage containers or green recycling cans. Trees such as date palms offer both food and harborage for roof rats. These trees should be thinned, the low-hanging branches pruned off, and a rat guard attached around each trunk. Rat guards on trees should be checked annually and released as necessary to prevent girdling (Frantz and Davis 1991; Olkowski et al. 1991). Rats will also feed on cat, dog, and horse feces, so these must be picked up daily around infested areas.

A gap of at least one meter (3 ft) should be maintained between buildings and adjacent trees and shrubs so that branches do not enable rats to jump to and from roofs or ledges (Frantz and Davis 1991). Debris heaps, woodpiles or construction debris near buildings should also be removed. Power lines running into the upper portions of buildings and trees that are brushing up against the structure give rodents access to the roof (Marsh 1994).

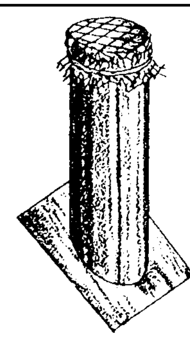
Rat-Proofing Buildings

Exclusion of rodents by rat-proofing a building is very important. Entry points into buildings should be thoroughly rat-proofed by plugging holes larger than 1/2 inch (1.3 cm) in diameter, installing guards to prevent rats from moving along pipes and wires, screening drains in basement and shower room floors, and placing barriers between and within walls to prevent rodent travel. Wooden doors should have metal kickplates at the bottom to discourage rodents from gnawing their way inside along the bottom corners of the door (Scott 1991; Timm 1994). Rodent-proofing against roof rats usually requires more time to find entry points than for Norway rats because of their greater climbing ability (Marsh 1994).

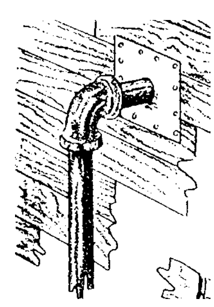
Storage rooms should be reorganized to eliminate as much clutter as possible to facilitate inspection and reduce rat harborage. Broken sewer pipes should be repaired as rats can dig into them and swim up the trap in a toilet to enter a building. Toilet bowl drains can be rat-proofed by feeding the pipe from the toilet bowl into a pipe section of larger diameter (Frantz and Davis 1991).

The Better Rat Trap

When rats are present inside the house, trapping should be the primary approach used in an IPM program (Hedges 1995). There are a number of advantages to traps compared to poisons. Traps provide physical evidence of capture, and there is less risk to non-target organisms. They are also usually quicker in ridding your house of rats. When poison is used, there is the possibility that rats may die in wall voids and subfloors, where it is difficult to find and remove them. These carcasses cause unpleasant odors and attract flies, carpet beetles, and other pests.



Roof vents should be screened.



Entry points around plumbing should be secured.

Traps should be placed in attics, basements, or locked storage rooms where children and pets or other non-target animals will not have access to them. If this is impossible, traps can be placed in tamper resistant bait stations.

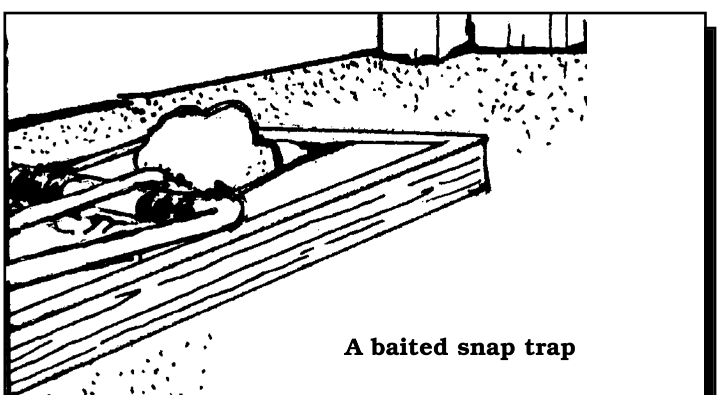
Rats are extremely wary of new objects in their environment. Traps, baits and bait stations may be avoided for several days after initial placement. Even after this period, rats will be very cautious in approaching them. If a rat nibbles on a bit of poison bait that later makes it sick without killing it, the rat will avoid similar baits or bait stations in the future, and, if it is a female, will teach its young to do the same. Thus, it is difficult to make a substantial long-term reduction in a rat population through trapping and baiting alone (Olkowski et al. 1991; Timm 1994).

Kinds of Traps

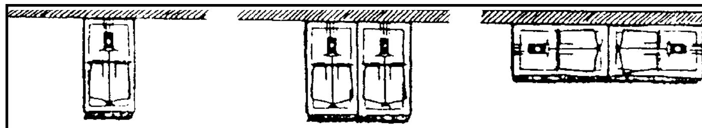
There are three types of traps—snap traps, live traps and glue boards. Live traps are not generally recommended for rat removal. Sometimes, pest control professionals use them so that the rat can be checked for ectoparasites or disease. Glue boards may not be effective for rats, and when used for mice can produce inhumane results. Snap traps are probably the best to use in a rat infestation, although they may require some care, time, and persistence (Hedges 1995; Corrigan 1997). These traps capture and instantly kill single rats, and can be placed on floors for Norway rats or nailed to beams for roof rats. When handling traps, gloves should always be worn for protection from diseases. Care should be taken because snap traps have very strong springs, and accidental release may damage an exposed hand or foot. Always keep them out of the reach of children and pets (Olkowski et al. 1991).

A rat trap called the Rat Zapper® provides an alternative to a snap trap as long as infestations are limited. The trap uses 4 AA batteries to power an electric shock unit. It is a covered trap and can be used outside as well as inside. A bit of dry pet food is used to lure a rodent inside the trap. The shape of the rodent triggers a lethal electroshock. A red light goes on that signals the trap is in use. The rodent slides easily out of the trap into a plastic sack or a garbage can. According to company literature, it is safe for children and non-target organisms. It is difficult for children or pets to trigger it; the electroshock causes a reflex withdrawal of a hand or a paw, and current transfer is limited because it is battery operated (AgriZap 2012). Woodstream also sells an electric trap for mice (see Resources).

Setting and Placing Traps



A baited snap trap



Set traps with triggers toward the wall or set two traps in parallel with triggers in opposite directions.

Traps should be set along walls or other runways leading to the holes. Other good trap locations include: near droppings, gnaw marks or other signs of rat damage; under and behind objects likely to harbor rats; in dark corners; along rafters or other protected areas where rats are likely to travel. Note that traps or baits placed on the ground or floor may catch very few roof rats unless they are positioned at the very points that rats traverse from above down to a food source (Marsh 1994).

A sufficient number of traps must be used in order to be effective. Depending on the size of the infestation, a house may require a dozen traps. In an active corner of a room, 5 to 10 traps should be set. Three traps set in a row ensures that a rat trying to jump over the traps will be caught. If rat activity in an area is unknown, traps should be set 10 to 20 feet apart (3.0 to 6.0 m) along possible runways (Timm 1994).

Traps must be checked daily and fresh bait added as needed. Moving traps after three or four days is advised if there is no sign of activity.

If there are many rats in the house and most of the rats have been trapped, it can be hard to catch the last few because they may be trap-shy. In such cases, the traps can be removed for a week, then set in new locations using the pre-baiting method described below.

Insecticides should not be sprayed on the traps and they should not be stored with insecticides, rodenticides or application equipment. These smells can make the rats avoid the traps when they are next used (Corrigan 1997; Olkowski et al. 1991).

Food Baits

Traps should be baited if food for rats is limited. If there is plenty of food around, the traps will be more effective without bait. Alternatively, an extremely attractive food bait can be used. Baits can be tied to the trigger using string or dental floss to ensure that the rat will spring the trap when investigating the bait. Suggested baits for Norway rats are pieces of hot dog, bacon, liver, peanut butter or nut meats. Suggested baits for roof rats are nuts, dried fruits, or fresh fruits such as bananas or apples. Other baits include fruit, marshmallows, raisins, or peanut butter mixed with rolled oats. If rats are feeding on other foodstuffs present, these items can be tried as baits. Cereal (like oatmeal) can be sprinkled around the traps to make them more attractive (Timm 1994; Marsh 1994).

Pre-baiting Traps

If baited traps are initially unsuccessful, place baited but unset traps out for one to three days so rats become accustomed to them. Traps should be checked to see if the bait is being eaten—if not, another bait should be tried. Once bait is being eaten, the traps should be rebaited and this time set (Timm 1994).

Biological Control

Predators and diseases can produce substantial reductions in rat populations, but the effect is usually temporary (Frantz and Davis 1991). Snakes, owls and other birds of prey, coyotes, dogs and cats are natural enemies of rats. It should be noted that beneficial predators can be killed by consuming poisoned rats. In addition, rats may cache (hide) food that may or may not be eaten, taking the poison bait to a place where other animals can find it, or to other locations the label does not allow. Thus, trapping is preferred over baiting for rat suppression activities (Hedges 1995).

When to Bait

Pesticides must be used properly in accordance with their label directions. Protective gear should always be worn during pesticide applications. Outdoors, poison baits should be used only when trapping is not effective; in emergency situations where there are very high numbers of rats; and to prevent rats from migrating to neighboring areas when a building is being rat-proofed or demolished. Poisons are also justified where rat populations are carrying plague (Zinsser 1935; McNeill 1976; Weber 1982; Craven et al. 1993).

Use Bait Stations

When used, poison baits must be placed in high profile, tamper-resistant bait stations that lock (see Resources). Bait stations are useful because they protect the bait from moisture and dust; provide a protected place for rats to feed, making them feel more secure; keep other animals and children away from the poison; allow placement of bait in locations where it would otherwise be difficult; help prevent accidental spilling of bait; and allow easy inspection of bait to see if rodents are feeding on it. Waxy bait blocks that can be anchored to the bait station are the best formulation (Timm 1994; Corrigan 1997).

Which Rat Baits?

When possible, warfarin (Kaput®), chlorophacinone (Rozol®)or other first-generation anticoagulants are preferred. They present less hazard to humans and pets than second-generation anticoagulants (Frantz 2004). First generation anticoagulants also present fewer problems for wildlife, including raptors, as secondary poisoning problems are minimized (Erickson and Urban 2004).

Where rodent resistance to warfarin seems sure, an acute bait such as bromethalin (Tom Cat®) or vitamin D_3 (Terad3®) may be necessary. Research results up to now show that secondary poisoning of raptors, pets,

Box A. Monitoring and Locating Rats

The first step in a rat management program is finding areas of infestation. Try to identify as many of the areas as possible that provide rodents harborage, food, water and access to the building. Check doorways for gaps or holes and note windows without screens or glass. Look for other openings in the house such as holes, vents without screens, holes around pipe and electrical wire entry points. Entry points can be openings as small as 1/2 inch (1.2 cm) in diameter in walls, around pipe entries, sewer outlets, and under doors. Unscreened sewer outlets and even toilets can give rats access to buildings. Inspect all planters, woodpiles, vegetation.

Look for water leaks and rooms where water condenses on the walls. Rodents like to follow edges; inspect these areas for feces, rub marks, urine or other indications of activity. [Note: Rub marks are grease spots resulting from repeated contact of a rat with a surface.] After checking the main floor of the house, particularly the kitchen, continue into the basement and attic to look for holes, nests, feces, and rub marks. As noted earlier, Norway rats tend to seek harborage on lower levels and roof rats on higher levels of a building.

Always be on the lookout for piles of trash, clutter, or other debris. Nests are often composed of things like shredded paper, pieces of plastic, and bits of fabric gathered together into a 5 inch (12.7 cm) diameter mass for mice and 8 to 12 inch (20.3 to 30.5 cm) diameter for rats. If you find clothing or paper that looks torn or shredded but doesn't look like a nest, you will most likely find the nest nearby.

Check for leaks and any standing water such as irrigation or drainage ditches, stagnant pools, ornamental ponds, and fountains. On the roof, check air conditioning units that might provide water and harborage for rats (Corrigan 1997; Olkowski et al. 1991; Timm 1994).

Monitoring Tools and Techniques

All potential rat habitats and areas of activity such as attics, basements, garbage cans, and stored materials should be thoroughly inspected. It may be useful to do this at night, when the rats are most active. For nighttime inspections, use a powerful flashlight with a red filter, which is less likely to scare rats away from view.

If holes are found, they should be temporarily closed with soil, aluminum foil, sawdust or crumpled paper, and inspected 24 hours later to see whether they have been reopened or if the paper has been moved or chewed. If so, it can be assumed that the hole is actively being used by one or more rats.

If necessary, talcum powder can be sprinkled near suspected harborage or entry points to gain further information. Rat footprints and rattail drag lines across the powder confirm an infestation. A piece of white paper or cardboard can be temporarily placed in dark or hard-to-reach areas, and inspected for fecal pellets or other signs of rat activity. Rat signs, including droppings and sawdust from gnawed wood should be swept up. If new droppings or other clues are found a couple of days later, an active infestation is confirmed (Olkowski et al. 1991; Timm 1994).

Photo courtesy Bell Labs

Rat baits should be secured in bait stations.

and wildlife is less of a problem with these materials. Because there are no convenient antidotes to acute baits such as these, they should always be used in tamper resistant bait stations, or in areas where children and pets will not encounter them (Erickson and Urban 2004; EPA 2008; EPA 2011; Meehan 1984).

Baiting Procedures

When baiting, leave a prominent warning label on the bait station box, and posted in the immediate area of baiting. Place bait stations where rats have been found to be most active. In the case of roof rats, secure bait stations above the ground in areas such as attics, roofs or trees, or at the base of trees or other heavily vegetated structures such as fences overgrown with ivy. Space bait stations 15 to 50 feet apart (4.6 to 15.2 m), and leave them in place for a few days to determine if the bait is being taken. Rats may take a week to begin consuming the bait. If after a week none of the bait has been consumed, move the station to a new location.

Once it is observed that the bait is being taken, the stations should be left in place for a week or more since the rats are now accustomed to them. Bait stations should be checked and rebaited regularly—rats seldom feed on bait that is spoiled. The correct amount of bait should be used—too little can make the rats bait-shy or be ineffective; however too much will cause rats to avoid the bait or cache it. When the baiting program is over, all bait stations should be collected and stored (Timm 1994).

Conclusions

When rat infestations are discovered, there are five steps in an IPM program for controlling them: 1) improve sanitation and garbage management practices; 2) ratproof buildings and alter landscape plantings and other features that provide rat access and harborage; 3) use traps to reduce the existing rat population; 4) if trapping is not effective, supplement with poison baits placed in tamper-proof bait stations and checked frequently; 5) continue monitoring periodically to ensure that rats are not recolonizing.

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Resources

Bait Stations— Bell Laboratories Inc., 3699 Kinsman Blvd., Madison, WI 53704; 608/241-0202, Fax 608/241-9631; www.belllabs.com. JT Eaton & Company, Inc., 1393 E. Highland Rd., Twinsburg, OH 44087; 800/321-3421, 330/425-7801, Fax 330/425-8353; www.jteaton.com. Lipha Tech, 3600 W. Elm St. , Milwaukee, WI 53209; 888/331-7900, 414/351-1476, Fax 414/247-8166; www.liphatech.com

Bromethalin (0.01%) (Tom Cat®)— Bell Labs, see above

Chlorophacinone (0.005%)(Rozol®)— Liphatech, see above

Diphacinone (0.005%)(Ditrac®)— Bell Labs, see above

Rat and Mouse Traps (Victor®)— Woodstream Corp., 69 N. Locust St., Lititz, PA 17543-0327; 800/800-1819, 717/626-2125, Fax 717/626-1912; www.woodstream-pro.com

Rat Zapper, Agrizap, www.agrizap.com

Vitamin D_3 (Terad3®)—Bell Labs, see above

Warfarin (0.025%)(Kaput® Blocks)— Scimetrics, PO Box 1045, Wellington, CO 80549; 866/442-3467, 970/482-1330, www.kaput-products.com

*A more complete list of products can be found in the *IPM Practitioner's 2012 Directory of Least-Toxic Pest Control Products*, BIRC, PO Box 7414, Berkeley, CA 94707; www.birc.org

Bio-Integral Resource Center (BIRC) is now on Facebook and Twitter

For BIRC members and others who favor social media, BIRC is now on Facebook and Twitter. A convenient way to find us is to go to the BIRC website, www.birc.org. There are links there to Facebook and Twitter social media pages. We also established a crowdfunding appeal on CauseVox to help raise money for this issue of the *Quarterly*. BIRC thanks Maggie Ruffo of the Hungry Owl Project and Jennifer Bates of BIRC for donations toward production of this *Quarterly*. We also thank BIRC members who responded to our annual appeal. Our publications are dependent on donations and member support.

Six Million Voters in California Want Genetically Engineered Food Labeled

California voters in November had a chance to mandate labeling of genetically engineered food. A yes vote on Proposition 37 meant labeling would be required. An early vote count on November 9 showed the measure was defeated 4,326,770 (47%) yes and 4,884,961 (53%) no. A final tally on the California Secretary of State Website in January 2013 that included absentee and provisional ballots showed 6,088,714 (48.6%) yes and 6,442,371 (51.4%) no.

The election was swayed by negative advertising funded by food and chemical corporations. Early polls had Proposition 37 winning before the advertising barrage started. Despite $46 million in negative advertising, the measure lost by only 353,657 votes. The $46 million in advertising represents almost $7 for every no vote, and about $131 for each deciding vote.

The labeling measure generally won in most of the urban California counties, such as those in the San Francisco Bay Area and Los Angeles, and it generally lost in rural and agricultural counties.

The fight for Genetically Modified Organism (GMO) labels is not over. The vote in California is a preview of a national effort. With nearly half of voters politically committed to GMO labels, it is just a matter of time until GMO labels are a reality.

Dear BIRC Members

Decreased income due to the recession has forced us to delay publication dates, and to reduce the number of issues of the Quarterly that we produce each year. This Special Issue of *Common Sense Pest Control Quarterly* will be the only Quarterly produced for 2011.

For the calendar year 2011, Quarterly Members have also received three Special Issues of the *IPM Practitioner*—the Products Directory, Genetically Engineered Crops, and Honey Bee Death and Decline.

We are slowly recovering from the economic downturn. We appreciate your support, and hope you will continue as BIRC members.

Thank you,
William Quarles, Ph.D.
BIRC Executive Director

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Please renew your membership and help support BIRC. THANK YOU

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