MITIGATING RAT DEPREDATION IN NATIVE HAWAIIAN HABITATS

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ABSTRACT: This paper reviews methods for mitigating rat (*Rattus* spp.) depredation on the native Hawaiian flora and fauna; describes the process for obtaining clearance to use rodenticides in noncrop, outdoor areas; and outlines some major steps for conducting a rodent control program.

1994 TRANSACTIONS OF THE WESTERN SECTION OF THE WILDLIFE SOCIETY 30:15-20

Hawaii is the most isolated archipelago in the world, separated by more than 4,000 km from the nearest large land mass. This isolation has resulted in some stunning examples of adaptive radiation, such as among the Hawaiian honeycreepers (*Drepanidinae*). However, it has also led to an extreme vulnerability among the native biota to the predators, competitors, and diseases that Polynesian settlers, European discoverers, and more recent visitors introduced. Introduced animals prey on and compete with native species, transmit diseases, and degrade the habitat (Stone and Scott 1985). As a result, Hawaii's native flora and fauna suffer some of the highest extinction rates in the world. Of the historically known 71 taxa of endemic Hawaiian birds, 23 are now extinct; 31 of the remaining 48 are classified as either endangered or threatened (Anon. 1992). Recent fossil finds by Olson and James (1982) indicate that 40 additional species of birds became extinct between the arrival of the Polynesians and Western contact in 1778. The USFWS (Anon. 1992) classifies 173 taxa of Hawaiian plants as either threatened or endangered, and proposed an additional 33 for listing. The USFWS (Anon. 1992) also lists 41 species of tree snails as endangered. Rats are one of the alien species that have had a major impact on Hawaiian flora and fauna.

Three species of rats reside in Hawaii. Polynesian rats (*Rattus exulans*) were introduced by early Polynesian settlers about 1,500 years ago, and today are common in lowland forests, agricultural fields, and adjacent grassy and wooded gulches and waste areas (Tomich 1986:41). Norway rats (*R. norvegicus*) reached the Hawaiian islands shortly after the arrival of Captain James Cook in the 1770s and live mainly around farms, mills, sugarcane fields, landfills, and other areas with human activity (Tomich 1986:41). Roof rats (*R. rattus*) probably did not reach Hawaii until sometime after 1870 and occur in low- to mid-elevation gulches, sugarcane fields, macadamia orchards, and forests (Tomich 1986:38-40). This is the only species of rat in Hawaii that regularly climbs trees.

All three species of rats cause a myriad of economic, health, and ecological problems in Hawaii. These pests damage sugarcane, macadamia nuts, and other agricultural crops; they are vectors of bubonic plague, leptospirosis, and other diseases; and they have been implicated in the decline of threatened and endangered plants (Stone 1985), snails (Miller and Hadfield 1993), and birds (Kepler 1967, Buxbaum 1973, Atkinson 1977).

The Denver Wildlife Research Center (DWRC) of the U.S. Department of Agriculture's Animal and Plant Health Inspection Service is the major federal institution devoted to resolving problems caused by the interaction of wild animals and human society. In 1967 DWRC established a field station in Hawaii to investigate rat depredations to Hawaiian agricultural crops, and to develop biological and ecological data to effectively use new and existing control methods. This paper reviews methods for mitigating rat depredation on native Hawaiian flora and fauna; describes the process for obtaining clearance to use rodenticides in non-crop, outdoor areas; and outlines some major steps for conducting a rodent control program.

J. Brooks, G. Giusti, K. Fagerstone, M. Fall, A. Koehler, R. Marsh, R. Sugihara, and R. Timm constructively criticized earlier drafts of this manuscript.

CONTROL METHODS

Habitat Modification

Eliminating food or cover can reduce the carrying capacity of an area for rats. Some home gardeners and small farmers control rat populations in limited areas by removing prunings and other debris, or thinning the canopy of trees. Farmers in California maintain weed-free fence rows, dikes, levees, and drainage ditches to reduce rat damage to rice fields in the Sacramento Valley. However, habitat modification has only limited application for reducing rat populations over large areas, such as native forests in Hawaii.

Broad-scale chemical or mechanical removal of vegetation is neither practical nor ecologically acceptable in most native Hawaiian habitats (e.g., Sugihara et al. 1977). Major changes of the habitat are nonselective and may be detrimental to other components of the ecosystem besides the pest species (Allan 1942, Howard 1967). One should consider such nontarget effects carefully before inducing large-scale changes in the habitat to reduce rat populations.

Trapping

Trapping can be an effective, short-term nonchemical means of removing rats from limited areas such as gardens and small orchards. However, trapping is labor-intensive and usually impractical over large areas.

Barriers

Physical barriers such as fences or metal bands around tree trunks can exclude rats from limited areas. Researchers at the International Rice Research Institute in the Republic of the Philippines used a plastic fence and funnel traps to reduce rat invasion of experimental rice plots (Quick 1991). However, material, construction, and maintenance are impediments to cost-effective use of barriers for protecting large areas.

Repellents

Nonlethal repellents are an attractive idea that has found few practical applications for rodents. Researchers have successfully protected crops in small areas (Sullivan et al. 1988, Nolte et al. 1993), and the DWRC Hawaii Field Station is currently conducting both laboratory and field studies to evaluate synthetic predator odors for repelling rats and protecting crops. However, large-scale efficacy of repellents has yet to be demonstrated.

Reproductive Inhibitors

Reproductive inhibitors such as chemosterilants and immunocontraceptives are appealing as a humane and nonlethal means of regulating rodent populations (Marsh 1988). DWRC is evaluating immunocontraceptives that induce rats to produce antibodies against their own reproductive systems. However, effective sterilants and delivery systems have yet to be developed for field use.

Biological control

Biological control has proven to be a difficult and usually ineffective method of controlling vertebrate pests (Howard 1967). Attempts have been made to increase predation on rodent pests by introducing predators (Sullivan and Sullivan 1980), modifying the habitat (Muñoz and Murúa 1990), or providing artificial perches (Hall et al. 1981, Askham 1990). Numerous studies have demonstrated the importance of rodent pests in the diet of selected predators (e.g., Lenton 1980, Duckett 1981). However, the author is not aware of any evidence that such measures actually reduce pest populations to economically or ecologically acceptable levels.

Mongooses (*Herpestes auropunctatus*) were introduced into Hawaii during the 1880s to control rat damage to sugarcane, and today thrive on all the main Hawaiian islands except Kauai. Mongooses survive in some areas on a diet composed mainly of rats (Baldwin et al. 1952, Kami 1964), but they also prey on the eggs and young of native birds such as the nene (*Nesochen sandvicensis*), or Hawaiian goose (Baker and Russell 1979). In the late 1950s, barn owls (*Tyto alba*) were also introduced into Hawaii to control rat populations in sugarcane fields (Tomich 1962). Today, these two predators are ubiquitous throughout most of the state, yet rats thrive.

Rodenticides

Toxicants offer a practical means of managing rats on large areas (Moors et al. 1992). Commercial rodenticides are easy to use, are relatively inexpensive, and can be applied over large areas. However, effectiveness and safety vary among products, species, and situations. Although environmental risks accompany the use of any toxicant, methods exist to minimize potential hazards. Careful choice of toxicants, use of protective bait stations, training of field personnel in proper techniques, and careful monitoring can enhance the selectivity of baiting programs and minimize undesirable side effects. Several types of rodenticides are currently marketed in the United States.

Cholecalciferol. — Cholecalciferol, or vitamin D_3, is a natural vitamin that is necessary for normal growth and important in the prevention of rickets in humans, but in excessive amounts causes calcification of internal organs (Vanderveen and Vanderveen 1985). It is sold as a rodenticide under the trade names of Quintox® and Rampage®. This rodenticide is registered for rock squirrels (*Spermophilus variegatus*) in New Mexico for plague control, and has potential for controlling a number of other field rodents (Tobin et al. 1993). Marshall (1984) concluded that cholecalciferol has low potential for secondary poisoning of predators and scavengers.

Bromethalin. — Bromethalin is another rodenticide for indoor or structural use but currently with no clearances for field use. It is a highly potent, single-feeding toxicant that is sold under the trade name Vengeance®. Bromethalin interferes with cellular respiration (Jackson et al. 1982).

Zinc phosphide. — Zinc phosphide is a broad spectrum toxicant used extensively as a field rodenticide in the United States since the 1940s. This toxicant is relatively inexpensive, does not build up in animal tissues, and breaks down rapidly in the environment (Hood 1972, Marsh 1987). The active ingredient reacts with acids in the stomach, producing toxic phosphine gas. Bait shyness may lead to variable or inconsistent results (Marsh 1987).

Anticoagulants. — Since the introduction of warfarin in the 1950s, anticoagulants have increasingly been used to control damage by voles, squirrels, rats, field mice, and other rodents in a variety of situations (Hadler and Buckle 1992, Jackson and Ashton 1992). Anticoagulants reduce blood clotting by interfering with the production of vitamin K. Delayed toxicosis circumvents bait shyness, a major problem with most acute, or fast-acting, rodenticides. However, prolonged use may lead to genetic resistance in some populations (Hadler and Buckle 1992). Potential secondary poisoning of predators and scavengers is another concern (Hegdal and Colvin 1988, Mendenhall and Pank 1980, Townsend et al. 1984). In the United States, diphacinone (e.g., Eaton's All Weather Bait Block®, Ramik®) and chlorophacinone (e.g., RoZol®) are the anticoagulants most often used in field situations. Bromadiolone (e.g., Maki®) and brodifacoum (e.g., Talon®) are more potent second generation anticoagulants that are available for use in and around buildings.

REGULATION OF RODENTICIDE USE

Most rodenticide products registered for use in the United States are for indoor or structural use, such as around homes, warehouses, feed lots, sewers, and other areas associated with human activity. Forty-two rodenticides are registered in Hawaii for indoor or structural use, compared to only four products for field use. The indoor/structural market is the most profitable, and thus provides the largest incentive for investment capital. Most field uses not only are less profitable, but also require considerably more data to obtain U.S. Environmental Protection Agency (EPA) registration. Additional tests to determine such things as environmental fate, wildlife hazards, and aquatic toxicity are required for field registration and use (Fagerstone et al. 1990).

Increasingly strict regulations and rising costs impede the development and registration of rodenticides for field use (Ruttan et al. 1981). The Federal Insecticide, Fungicide, and Rodenticide Act of 1947 (FIFRA) and subsequent amendments regulate the registration and use of pesticides in the United States. The EPA registers new pesticides and ensures that they do not pose unreasonable risks to human health or the environment when used according to label directions. A myriad of studies are required to demonstrate efficacy and safety, but also increase the cost of new registrations. Almost 50 chemical, toxicological, and environmental studies costing as much as $800,000 may be required for registration of a technical product (K. Fagerstone, pers. comm.). Additional studies usually are required of the end product to evaluate product chemistry, human health and nontarget hazards. Minor use pesticides such as agricultural rodenticides usually do not provide the economic incentive for such an investment. Nonetheless, FIFRA provides several avenues for pursuing registrations.

Section 3 of FIFRA describes the normal registration route. A Section 3 registration allows use and/or distribution throughout the United States, but only after the product is registered or authorized for use by state governments. A minimum of 57 tests costing about $670,000 are required for registering a pesticide for a terrestrial nonfood use (Fagerstone et al. 1990). Studies involve product chemistry, human health hazards, genotoxic effects, avian and aquatic organisms toxicity, nontarget plant hazards, and environmental fate. Registration costs and data requirements for food uses are even more costly than those for nonfood uses.

Section 18 of FIFRA authorizes the EPA to exempt State and Federal agencies from provision of the Act when emergency conditions exist, such as for economic, quarantine, or public health reasons or because there is a significant risk to threatened or endangered species. EPA recently issued a Section 18 emergency exemption to allow the use of bromethalin and brodifacoum to control rat depredations on eggs and hatchlings of seabirds and marine turtles on Rose Atoll. Section 18 registrations are temporary solutions to emergency situations. Registrants granted exemptions under this provision of FIFRA are required to make significant progress toward Section 3 or Section 24(c) registrations.

Section 24(c) of FIFRA allows states to regulate the sale of Federally registered pesticides in the state, but only if and to the extent the regulation does not permit any sale or use prohibited by FIFRA. Thus, states can request additional uses of Federally registered products to meet special local needs (SLN's). Section 24(c) registrations involve both first and third party requests. First party 24(c)'s are those requested by the primary registrant of the product. Third party 24(c)'s are those requested by someone other than the company holding the basic registration, usually a governmental agency or agricultural organization. A third party 24(c) must be approved for that use by the basic registrant. Data required for 24(c) registrations include information to support the new use pattern, and often efficacy and residue information. A state must also substantiate to EPA the reason and justification for the issuance of the 24(c). The EPA has a statutory 90-day period to reject the 24(c) registration.

DISCUSSION

The spread of rats to oceanic islands throughout the world and the subsequent demise of island flora and fauna are well documented and have been reviewed by Atkinson (1985, 1989), Buckle and Fenn (1992), and Moors et al. (1992). Introduced *Rattus* have had a particularly devastating impact on insular avian populations. Rat predation on eggs and young has impacted bird populations on Midway Atoll (Fisher and Baldwin 1946, Grant et al. 1981), Danish islands (Møller 1983), New Zealand forests (J. Innes, in press), Hawaii (Kepler 1967), and numerous other oceanic islands (Atkinson 1985, 1989; Moors et al. 1992). Threatened and endangered plants (Stone 1985) and invertebrates (Miller and Hatfield 1993) are also susceptible to rat predation. The plight of threatened and endangered plant and animal species in Hawaii is sufficiently grave that action should be taken to reduce rat predation.

Of all the current approaches to rat control, toxic rodenticides seem to hold the most promise for mitigating rat depredation in native Hawaiian habitats. It is the most cost-effective and only practical means of killing rats in large numbers or in isolated places (Moors et al. 1992). Rodenticides have been used to reduce rat predation on birds on Midway Atoll (Fisher and Baldwin 1946), Danish islands (Møller 1983), and Kure Atoll (Woodward 1972), and a remote anchorage on Stewart Island (Hickson et al. 1986). Managers in New Zealand have used rodenticides to eradicate rats from forested, rugged Breaksea Island (170 ha) (Taylor and Thomas 1993), 30-ha Motuopao Island (McKenzie 1993), 100-ha Stanley Island (Thompson 1993), and 143-ha Moutohora Island (Jansen 1993).

Buckle and Fenn (1992) outline some major steps for conducting a successful rodent control program. These include defining the problem so that clear objectives can be established. Where eradication is not feasible, a more modest goal of removal from a limited area or for a restricted period, such as during the avian breeding season, may suffice. Managers should select, based on the best available information, the most appropriate rodenticide for the task and situation, and experimentally explore its field efficacy and evaluate potential hazards. Most successful attempts to reduce rat depredation on islands have involved the use of anticoagulant rodenticides. Managers should recognize the economic expense and regulatory complexities of registering rodenticides for field use, and pursue the appropriate registration or sequence of registrations by generating the data required by EPA.

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