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Franklin, Katie R.

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The Oahu Army Natural Resources Program Adaptive Rat Control Strategy: Protecting Endangered Hawaiian Species

Katie R. Franklin

Oahu Army Natural Resources Program, Pacific Cooperative Studies Unit, University of Hawaii at Manoa, Honolulu, Hawaii

ABSTRACT: Since 1995 the Oahu Army Natural Resources Program (OANRP) has managed over 60 federally endangered Hawaiian species, including plants, invertebrates, and one forest bird. An adaptive rodent control program is essential for the stabilization of many of these species. OANRP has utilized and experimented with various rodent control methods in remote settings on Oahu, including using small grids of bait stations containing rodenticide coupled with snap traps; deploying small grids of snap traps only; constructing predator-proof fence enclosures; and maintaining large-scale grids of snap traps for ecosystem-wide protection. In 2012, the program began to phase out the use of rodenticide in bait stations and transitioned to using kill-traps only, including the use of automatically self-resetting rat traps. To gauge the effectiveness of rat control methods, resources are monitored for changes in rat predation. Rat activity (both black rats and Polynesian rats) is also monitored with tracking tunnels inside and outside of management areas. This study discusses rat control and monitoring methods utilized by OANRP in the past and present. It also reviews investigations into the use of automatic rat traps, the transition to using kill-traps only instead of bait station grids, and highlight some strengths and weaknesses of various rat control methods. OANRP is working towards integrating multiple control methods for adaptive management in an effort to determine the most effective means to control rats in Army-managed areas on Oahu.

KEY WORDS: conservation, endangered species, Hawaii, Oahu, predator-proof fencing, rats, *Rattus exulans*, *Rattus rattus*, rodenticides, rodents, trapping grids, traps

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INTRODUCTION

The Oahu Army Natural Resources Program (OANRP) has managed since 1995 lands that are home to almost 80% of Oahu's endangered species. OANRP currently manages 47 endangered Hawaiian species including 43 endangered plant species, one endangered Oahu tree snail species (*Achatinella mustelina*), 2 species of fruit flies (*Drosophila montgomeryi* and *D. substenoptera*), and one species of endangered forest bird, the Oahu Elepaio (*Chasiempis sandwichensis ibidis*). Managed habitat for these species occurs across two mountain ranges (Koolau and Waianae ranges) on the island of Oahu, with habitat ranging from rare dry mesic forest to short stature rainforest. In compliance with the Federal Endangered Species Act and the Sikes Act, the goal of OANRP has been to effectively balance the requirements of the Army's training mission with its natural resource responsibilities. Through these efforts, the Army has become a major contributor to conservation on the island of Oahu.

Introduced rodents are worldwide pests and their impacts can be especially harmful in island ecosystems where species evolved without predation by mammals (Atkinson 1977, Athens et al. 2002, Athens 2009, Harris 2009). The first rodent species introduced to the Hawaiian Islands was the Polynesian rat (*Rattus exulans*), which was brought by the Polynesians around AD 1000 (Athens 2009). The house mouse (*Mus musculus*), the Norway rat (*R. norvegicus*), and the black or roof rat (*R. rattus*) were later introduced by European explorers in the late 1700s to mid-1800s (Atkinson 1977). All 4 rodent species are now found throughout terrestrial ecosystems in Hawaii (Shiels 2010) and are thought to have been

responsible for the endangerment and/or extinction of many Hawaiian species (Atkinson 1977, Stone 1985, Athens et al. 2002, Athens 2009).

The decline of Oahu Elepaio has been attributed partially to nest predation, particularly adult mortality of females killed by black rats (VanderWerf and Smith 2002, VanderWerf 2009). Black rats have also been implicated in declines of endemic Oahu tree snails (*Achatinella* spp.) and other species elsewhere in Hawaii (Hadfield et al. 1993, Hadfield and Saufler 2009). Direct evidence of damage caused by rodents has been observed for at least 15 of the 43 endangered plant species currently managed by OANRP. These include *Alectryon macrococcus* var. *macrococcus*, *Cenchrus agrimonioides* var. *agrimonioides*, *Cyanea acuminata*, *C. grimesiana* subsp. *obatae*, *C. longiflora*, *C. superba* subsp. *superba*, *Delissea waianaeensis*, *Euphorbia celastroides* var. *kaenana*, *Hesperomannia oahuensis*, *Labordia cyrtandrae*, *Schiedea nuttallii*, *S. obovata*, *Phyllostegia kaalaensis*, *Plantago princeps* var. *princeps*, and *Pritchardia kaalae*. An effective rodent control program, especially one that targets rats, is an essential element in a management plan for many vulnerable native Hawaiian species.

OANRP has experimented with various rodent control methods over the years. These have included using rodenticide in small-scale bait station grids in combination with traps; bait station grids without traps; small grids of snap traps; large-scale trapping grids; predator exclusion fences; and most recently, deploying new automatic self-resetting rat traps. Rat control, primarily for black rats (*R. rattus*) but also for Polynesian rats (*R. exulans*), is typically a continuous effort and

many sites are remote, steep, or require a helicopter to access. These factors make rat control there a significant and expensive endeavor. To gauge the effectiveness of rat control methods, rat activity is monitored inside and outside of control areas. OANRP also monitors ecosystem response to rat control when possible. The program continues to adapt and modify strategies in an effort to determine the most effective means to control rats in conservation areas important to the Army's program on Oahu.

OVERVIEW OF RAT CONTROL METHODS

Historical Rodent Control Methods

Small-scale Bait Station Grids with Rat Traps

Until recently, OANRP primarily controlled black rats and Polynesian rats through the use of HACCO Ramik® Mini Bars All-Weather Rat and Mouse Killer (rodenticide with 0.005% diphacinone; HACCO Inc., Randolph, WI) in bait stations coupled with Victor® snap traps (Victor Pest, Lititz, PA) in close proximity to the bait stations. Ramik® was the only registered rodenticide available for conservation purposes in natural areas in Hawaii. The dual method approach of using bait stations and snap traps together was thought to be more effective than one method by itself. This approach may be best suited for drier habitats, where the bait may persist for several weeks and remain more palatable to rats than in wetter habitats. Over the years, OANRP successfully protected some species, such as the endangered palm *P. kaalae*, using the dual method. Prior to rat control, there was no naturally occurring recruitment of *P. kaalae*; now there are carpets of seedlings and over 1,000 immature plants (Kawelo et al. 2012). The baiting grids were typically maintained at 2- to 6-week intervals.

The use of rodenticide bait, however, can be expensive, highly variable in efficacy, heavily regulated, and controversial. The bait was often moldy within a week, eaten by slugs within days, or untouched by rodents. In 2012, only 12.2% of the total bait deployed in Elepaio bird territories was reported "taken," which resulted in over \$4,500 worth of wasted bait. Unused bait was removed from the field and disposed of following label regulations. There has also been concern that rats often consume sub-lethal doses of bait and may be left unharmed to prey upon vulnerable resources (OANRP 2012). Furthermore, a portion of the bait that is reported as "taken" was lost to slugs, insects, and mold. There is no way to determine what percentage of bait is lost to these non-rodent factors, but it is suspected to be significant. Field crews continually reported this concern along with an overall concern with the efficacy of baits.

In consultation with the U.S. Fish and Wildlife Service, in 2012 OANRP decided to significantly reduce the use of Ramik® as a management tool due to the aforementioned issues. Hundreds of bait stations were removed from field sites and replaced by grids of rat traps. These changes were in compliance with the Army's initiative to reduce pesticide use by 55% since 1993. Thereafter, the Special Local Needs Label (SLN) for Ramik® expired on June 8, 2013. There is currently no other toxicant available for conservation use in Hawaii. The new Ramik® label will have stricter

stipulations and grid design requirements (C. Swift, USFWS, Honolulu, HI, pers. comm.), which will likely preclude the use of Ramik® at many sites because the grid design requirements may be impractical or impossible to meet.

Current Rodent Control Methods

Overview of Current Rat Control Program

All rodent control methods currently utilized by OANRP are either lethal (trapping) or are designed to exclude rodents from an area (fencing). Rodent control methods utilized by OANRP in 2013 included the use of small snap trap grids for localized rat control, large-scale snap trap grids, predator exclusion fences, and experimental grids of Goodnature® A24 automatic rat traps (Goodnature Limited, Wellington, New Zealand). Based on the Ramik® SLN label expiring and on positive results from rat trap-only grids, OANRP removed all remaining bait stations in 2013 and replaced them with rat traps arranged in small grids. The program does not anticipate returning to the use of bait stations in the near future.

Small-Scale Rat Trapping

Most rodent control sites that OANRP currently maintains are comprised of small grids of Victor® snap traps. These traps are the least expensive tool used by OANRP for rat control excluding labor costs. The total number of snap traps currently maintained by OANRP has more than doubled in the last 2 years due to phasing out the use of rodenticide bait stations and replacing them with snap traps. These grids protect rare plants, Oahu tree snails, and Oahu Elepaio from both black and Polynesian rats.

The majority of the small-scale snap trap grids are in Elepaio territories. OANRP currently manages 105 pairs of Elepaio with rat control across 4 management units (MUs); 69 pairs are protected by small-scale snap trap grids while the remaining pairs are protected by a large-scale trapping grid (discussed below). Rat control is only conducted during the Elepaio breeding season (December-June). During this time of year, female Elepaio are very vulnerable to rat predation, since females incubate eggs through the night. Rat control in Elepaio territories has been shown to increase fledgling success and increase female survival during the breeding season (VanderWerf and Smith 2002).

The 2013 Elepaio breeding season was the first season that rat control was conducted without the use of bait stations. Instead of small bait station grids, grids of 12 Victor® snap traps have been installed that are centered on the core area used for nesting. The traps are tied onto tree branches or onto logs and are typically baited with peanut butter every 2 weeks during the nesting season. Many territories are adjacent to one another; therefore, the small grids are somewhat continuous in some areas.

Overall, the small-scale trapping grids in Elepaio territories appear to be effective at reducing rodent populations to a level that allow for Elepaio nesting success at least as well as the former rodent control method. With nearly doubling the number of traps deployed in Elepaio territories in 2013 in compared to the

number of traps present in 2012 (372 and 192, respectively), the number of black rats and Polynesian rats killed in traps almost tripled between the 2 years, from 1,110 in 2012 to 3,145 in 2013. However, the number of rats killed from rodenticide bait stations in the past is unknown because the lethal dose for a rat varies widely for individual rats depending on factors such as age, size, sex, and species (C. Swift, pers. comm.). Slugs and insects are also responsible for a large amount of “bait take.” In general, the use of bait stations is a much more expensive rodent control method and the results are difficult to determine.

OANRP continues to use small trapping grids for localized rat control in 69 Elepaio territories, at 7 *A. mustelina* sites year-round, and at several populations of rare plants (seasonally or year-round).

Large-Scale Rat Trapping

OANRP maintains 3 large-scale trapping grids in 3 MUs in the Waianae mountain range. The grids are designed to target black and Polynesian rats, because rats pose the largest rodent threat to the species that OANRP protects (Mosher et al. 2010, Shiels 2010). They are modeled after the New Zealand Department of Conservation’s (DOC) current best practice for kill trapping rats (DOC 2005); however, they vary in design, size, maintenance protocols, trap type, bait type, and trap deployment. The overall goal for this method of rat control is to reduce rat activity within an MU to a level that benefits the native ecosystem as a whole. Each grid has unique characteristics and obstacles that raise questions and allow for testing and trialing in an effort to improve rat control efficacy. Because rat ecology is likely very different in Hawaii from that in New Zealand, OANRP strives to adapt DOC’s best practice guidelines to suit Hawaiian conditions. OANRP is continually testing new baits, trap types, and trap placement strategies to find the optimal strategy.

Monitoring resource response to the trapping grids has occurred in a number of projects; thus far, all of these projects indicate a positive response overall. These include increased native invertebrate abundances (Krushelnicky 2011), reduced fruit predation on *Cyanea superba* subsp. *superba* (Pender et al. 2013), increased native seed rain (*Diospyros hillebrandii*), and common native seedlings (A. Shiels, Univ. of Hawaii, unpubl.), and the Oahu Elepaio pairs that are protected by one of the large grids have had increased fledging success in recent years (OANRP 2013).

Rat activity is monitored using footprint tracking tunnels at least once a quarter inside each grid. The tunnels are baited with peanut butter and set out for one night. Tracking tunnels rely on ink-pads and paper to record target species’ tracks, and by extrapolation, their relative abundance. The tracks are analyzed by taxa (e.g., rat, mouse, cat, or mongoose) and recorded as “present” or “absent;” no inference on the number of rodents of each species is made: they are used to compare relative abundances of rodents within similar habitat types, and are best when coupled with another sampling method, such as trap-catch data or resource response (Blackwell et al. 2002). Rat activity was also monitored quarterly using

tracking tunnels outside of the trapping grids for 2 years as a control for the rat activity data. Overall, the trapping grids were effective at reducing rat activity inside the grids relative to the control sites.

OANRP has experienced difficulties and conditions that are not shared in New Zealand. For example, bait consumption by slugs and other invertebrates is a major issue that is not experienced to the same degree in New Zealand. Additionally, it is possible that black rats in Hawaii spend more time in trees than black rats in New Zealand (D. Peters, DOC, New Zealand, pers. comm.). One question OANRP asked over the past year is whether or not rat control is improved by housing snap traps inside a protective box (typically placed on the ground) or whether uncovered snap traps mounted directly to trees are just as effective, if not more effective. DOC’s best practice includes housing Victor® traps inside wooden boxes placed on the ground in order to exclude non-target species; ensure the proper rodent orientation to result in a humane kill; prevent accidental triggering; protect the bait from weathering; and maintain the integrity of the trap (DOC 2005). But perhaps rats in Hawaii are more likely to encounter a trap in a tree, and slugs are less likely to remove the bait on a trap if it is off the ground. Recent trials in one trapping grid indicate that catch-rates may increase if traps are removed from the boxes and mounted off the ground in trees. OANRP is investigating this question further over the next year and will use the results to help inform a best practice guide for OANRP’s trapping grids.

Another question is whether Victor® traps are the most effective trap, or if there are other types of traps that may prove to be more effective. One trapping grid that OANRP currently maintains consists of metal Ka Mate™ snap traps (Ka Mate Traps Ltd, Nelson, New Zealand; Figure 1). The Ka Mate™ traps were deployed to evaluate that style of trap and compare the trapping efficacy to Victor® snap traps. Ka Mate™ traps are mounted onto trees or set on the ground without wooden boxes because they have less risk of being accidentally triggered. Preliminary data indicate that Ka Mate™ traps may be more effective at killing rats; more experimentation will occur in the future.

Figure 1. Ka Mate™ reverse-bait snap trap.

Additionally, OANRP will assess trapping data using GIS to discover geographical trends in relative abundance and identify areas in need of more traps or areas where traps can be removed. Essentially, the reason for the differences between the grids and the objective for conducting these trials is to synthesize the data in order to define OANRP’s best practice protocols for trapping

grids. Adaptive management is essential, and the best practice protocols will continue to evolve and employ varied methodologies.

Automatic Rat Traps

Recently, OANRP acquired a new tool from New Zealand for rat control: the Goodnature® A24 automatic self-resetting trap. A24 traps are powered by compressed carbon dioxide (CO₂) and can reset automatically up to 24 times before the CO₂ canister needs to be replaced. They are designed to be baited with a long-lasting attractant to increase maintenance intervals and thereby reduce labor costs. The traps also kill stoats (*Mustela erminea*, not found in Hawaii) and mongooses (*Herpestes javanicus*) (see Peters et al. 2014).

OANRP began putting this new rat control technology to the test in October 2012. In partnership with Kalaupapa National Historical Park and in collaboration with the State of Hawaii Department of Land and Natural Resources, an experimental grid of 45 automatic traps (A24s) was installed around an outplanting site of *C. superba* subsp. *superba* in Pahole Natural Area Reserve (NAR) in the northern Waianae range. The traps were installed on lines 100 m apart and were placed 50 m apart on each line, extending roughly 200 m in all directions from the outplanting (12.6 hectares). This layout was in accordance with DOC's recommendation for trap placement at the time.

The objective of the project was to systematically collect data regarding trap performance, rat activity levels, and ecological response to the traps. The data from 2 neighboring MUs was compared: Kahanahaiki, where OANRP maintains a large-scale trapping grid consisting of 464 Victor® traps housed in wooden boxes across 25.9 hectares; and Kapuna, an MU with no rat control measures in place, to serve as a control. Data was collected until the project concluded in August 2013.

The results indicate that the grid of A24s was successful at reducing local rat abundances at Pahole but was not adequate to meet the management objective of having less than 20% of the *C. superba* subsp. *superba* fruit predated. Approximately 639 black and Polynesian rats were killed by A24s over the duration of the project, which equated to 1.5 times more rats per hectare than the large-scale trapping grid eliminated at Kahanahaiki over the same time period. Moreover, the Pahole A24 grid was maintained with roughly 35% of labor required for the Kahanahaiki trapping grid. Rat activity in tracking tunnels was reduced in Pahole over the duration of the project relative to rat activity at the control site (Kapuna). Predation levels on *C. superba* subsp. *superba* fruit did not meet the management objective at either Kahanahaiki or Pahole. However, relative to the results from a 2009 study by Pender et al. (2013), predation did not increase by the same magnitude in Pahole as it did in Kahanahaiki. The percent of total fruit predated at Kahanahaiki increased from 5% (2009) to 43% (2012), and at Pahole it increased from 60% (2009) to 73% (2012). If the addition of A24s had made no difference, theoretically, there would have been the same magnitude of change in predation at both sites.

A second trial to assess a high-density, small-scale

deployment of Goodnature® A24 traps was conducted from November 2013 to January 2014. The objective of this project was to meet the management goal of having less than 20% of *C. superba* subsp. *superba* fruit predated using small-scale, localized rat control using A24s. Twenty-two A24s were installed throughout the population of *C. superba* subsp. *superba* at Pahole NAR. The traps were placed no greater than 25 m from each other and were within 25 m from the edge of the *C. superba* subsp. *superba* population, an approximately 4-fold increase in traps per area as compared to the previous trial.

In sum, 129 trap activations were recorded. Overall, there was significantly more predation on *C. superba* subsp. *superba* fruit within the Kahanahaiki trapping grid than at Pahole. The management goal was met at Pahole but not at Kahanahaiki. All plants monitored at Kahanahaiki had some level of predation, whereas at Pahole only 39% were predated. The mean percent predation per tree at Pahole was 4% while at Kahanahaiki it was 47%. The high-density, small-scale use of A24s seemed to be effective at controlling black and Polynesian rats in Pahole to a level that adequately protected *C. superba* subsp. *superba* fruit.

Overall, OANRP has learned a great deal about these new traps over the past year. A24 automatic traps appear to be a more effective and humane way to conduct rat control. The high up-front cost of A24s may be an important consideration; however, data indicate that long-term rat control costs may significantly be reduced because the traps require less frequent maintenance than other rat control methods. Downsides to using A24s include the up-front cost of purchasing them, limited research indicating their effectiveness, finding a long-lasting attractant, and troubleshooting mechanical issues. Gas leaks in earlier models of A24s were common (38% of initial shipment of traps became faulty) and batteries inside counters died prematurely (19% faulty). However, Goodnature® has continued to modify and update their products based on new research and consumer reviews and has replaced all faulty products.

OANRP considers the utility of A24s to be the greatest at remote sites that require helicopter access or are otherwise difficult to access. Several small-scale grids have recently been deployed in multiple MUs, and OANRP has plans to continue to install grids of A24s at some of the most remote sites. OANRP is also considering replacing the large-scale grid of Victor® traps at Kahanahaiki with Goodnature® A24s as part of long-term trial. Gaining a new tool for rat control in Hawaii is especially valuable because there are limited options available.

Predator-Proof Fencing

Predator-proof fencing is a relatively recent technology that was developed in New Zealand to exclude vertebrate pest species from an area of high conservation value. It has proven to be a particularly valuable tool in aiding the reintroduction of threatened species (Long and Robley 2004).

Oahu tree snails (*Achatinella* spp.) have experienced major declines in population and distribution over the last

century due to predation by non-native pests and habitat loss. Their habitat on Oahu is now restricted to upper elevations in both mountain ranges (USFWS 1992), often in remote areas on steep terrain with limited access. Management efforts aimed to stabilize select remaining populations have typically had limited success, and determining the success of predator control measures has proven difficult; the snails are very cryptic and sedentary, making them very difficult to detect in dense vegetation. They also have very low fecundity and it takes many years for a population to recover, even with effective threat abatement. The benefit of constructing a predator-proof enclosure for Oahu tree snails is achieving complete predator removal in remaining snail habitats without continually maintaining a trapping grid or monitoring the efficacy of rodent control methods. In addition, snails can occur at high densities allowing for a small enclosure to protect large populations.

In collaboration with Xcluder® Ltd. (Rotorua, New Zealand), the U.S. Fish and Wildlife Service, and the University of Hawaii Tree Snail Laboratory, OANRP has completed the construction of 3 predator-excluding fences in Oahu tree snail habitat. The Xcluder® 10-pest™ fence is designed to exclude small vertebrate pests in New Zealand and has been effectively working in the field for many years at sites across New Zealand. The 10-pest™ design was modified for OANRP to exclude both the vertebrate and invertebrate predators of Oahu tree snails. These predators include rats (*Rattus* spp.), the rosy wolf snail (*Euglandina rosea*), and Jackson's chameleons (*Chamaeleo jacksonii* subsp. *xantholophus*) (Hadfield and Mountain 1980, Hadfield et al. 1993, Holland et al. 2010). Two of the enclosures are located in mesic forest in the Waianae mountain range and one enclosure is located in wet forest of the Koolau mountain range. The perimeters of the 3 enclosures range from approximately 100 m to 160 m. The cost of construction, including labor and helicopter time, for each ranged from approximately \$200-\$300 per foot (\$660-\$980 per meter), depending on site specific details and logistics. They also require on-going maintenance and routine inspection for breeches. To date, approximately 1500 *A. mustelina* snails have been reintroduced or translocated into one of the enclosures and future reintroductions are planned.

SUMMARY

Adaptive management can be defined as a process in which natural resource managers learn from past management actions to improve management in the future while achieving the best short-term outcome based on current knowledge (Allan and Stankey 2009). After 17 years of conducting rodent control in natural areas on Oahu, OANRP has experienced many obstacles and some successes with various strategies across a diverse landscape. The program continues to adapt to changing conditions and gain new knowledge in order to achieve long-term goals. Technologies from New Zealand have been added to OANRP's rodent control program in recent years, including the use of large-scale kill-trap grids, automatic rat traps, and predator-proof fencing. In addition, the use of rodenticide bait stations has recently been

abandoned, despite indications of success for some species, in favor of simpler and more cost-effective kill-trap grids.

Aldo Leopold once said, "To keep every cog and wheel is the first precaution of intelligent tinkering" (Leopold 1972). OANRP is continually researching, assessing, and "intelligently tinkering" with multiple rat control methods to determine the most effective, efficient, and adaptive long-term management strategies for the protection of endangered Hawaiian flora and fauna.

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