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ERADICATION OF NORWAY RATS *(RATTUS NORVEGICUS)* FROM HAWEA ISLAND, FIORDLAND, USING BRODIFACOUM

Summary: Norway rats were eradicated on bush-covered Hawea Island (9 ha) in Breaksea Sound, using the anticoagulant rodenticide "Talon 50 WB" (brodifacoum). The work was done as a conservation measure and to evaluate the feasibility and costs of eradicating rodents quickly from islands. The 50-100 rats present were eradicated in about two weeks by applying a simple strategy that took full account of the characteristics of the poison, the environment, and the behaviour of the target species. The technique used was designed to monitor its own progress, kill every rat as quickly as possible, continually detect the presence of surviving rats, limit the risk to non-target species, and overcome the many problems often associated with "getting the last rat".

Keywords: Norway rat; *Rattus norvegicus;* Rodentia; Fiordland; Hawea Island; Breaksea Sound; New Zealand; eradication; poisoning; brodifacoum.

Introduction

In eradication campaigns when few of the target species are left, the operations usually become protracted, costs become increasingly high for each animal killed, and field staff tend to lose motivation. Unfortunately, there is also a tendency for managers, or those providing finance, to stop the campaign before eradication is achieved, on the grounds of excessive costs without any certainty of success (Merton, 1978).

In 1976, Yaldwyn (1978) concluded a conference on the ecology and control of rodents in New Zealand by stating that the possibility of complete extermination of rodent populations from New Zealand offshore islands was "remote, or at least a very, very difficult thing indeed". By the early 1980s it was still widely held that no real breakthrough in this field was in sight (Atkinson, 1986).

Today the scene is very different. New, potent and highly palatable "second-generation" anticoagulant poisons have been developed to improve control of rats and mice, and to combat the genetic resistance to warfarin that has developed in many populations of rodents throughout the world (Greaves, 1985). Unlike warfarin and other earlier anticoagulants, second-generation anticoagulants kill after a single feeding and so dispense with the need for ingestion over several days. Rats will consume a lethal dose well before they begin to experience toxic effects (Redfern, Gill and Halder, 1976), and unlike many other acute or chronic poisons, sub-lethal doses are not known to cause bait aversion in Norway rats *(Rattus norvegicus).*

Since the early 19805, these new poisons have been used to eradicate Norway rats, ship rats *(R. rattus),* and kiore *(R. exulans)* from several New Zealand islands up to 22 ha in extent (Moors, 1985a; Taylor, 1984a; Towns, 1988). Following long-drawn-out campaigns against Norway rats on the Noises Islands, Moors (1985a) concluded that "the last few rats are certainly the most expensive and exacting to destroy, but they are also obviously the most vital if the campaign is to succeed". He also found that the greatest practical difficulty encountered was detecting the continued presence of rats at very low density (Moors, 1986).

Most recent commentators on methods of rat extermination have stressed the difficulty of getting the last rat, and the importance of using as many methods of killing rats as possible and never relying on one weapon alone (Moors, 1985a; Wace, 1986). Moors' (1985a) plan of campaign was to use sodium monofluoroacetate (1080) to try and obtain a rapid initial reduction in rat numbers, and then follow up with the anticoagulant brodifacoum "against those rats which had become shy of 1080, or had not been attracted to bait containing 1080".

Repeated control with poison or traps represents a major selective pressure on Norway rat populations (Barnett, 1975). One result is the very rapid development of genetical resistance to frequently used poisons (Howard, Marsh and Palmateer, 1973; Greaves, 1985). Another is an increase in the level of neophobia (sometimes called "new object reaction") among members of controlled populations (Shorten, 1954; Cowan, 1977). Neophobia is an inherited tendency - which can be reinforced by learning - for animals to avoid any new object or changed situation in the environment. Of course all new things will eventually become familiar - so the effect is always temporary (Barnett, 1975). Usually the avoidance of new bait stations lasts from one to ten days, but novel baits in familiar surroundings are often accepted in one or two days (Elton and Ranson, 1954). Another behavioural response is a learned aversion to a poison, type of bait, or bait station. Such "bait shyness" occurs in individuals that have previously suffered from sub-lethal poisoning, and its effects can be long lasting (Rzoska, 1953; Chitty, 1954).

With these problems in mind, our approach to practical rat eradication from islands has been to develop a strategy that will be closely adhered to throughout the campaign and require little, if any, additional input to get the last rat. We aim for a planned programme for each island that takes account of the behaviour and ecology of the target species and all aspects of the local environment. This programme should progressively kill rats in the shortest possible time, continually monitor its own progress, detect the presence of surviving rats, limit the risk to non-target species, and - most importantly - maintain the confidence of administrators and the morale of the campaign personnel. We consider that for each campaign the operators should select the single best method available and employ it with the aim of achieving a 100% kill in the shortest possible time. If this initial plan fails, then contingency techniques can be resorted to, but it will be easier to understand any problems if the effectiveness of each killing method is assessed separately.

The work reported here involved the eradication of a population of Norway rats from Hawea Island, Fiordland, using the anticoagulant rodenticide "Talon 50 WB" (ICI New Zealand Ltd), a wax briquette formulation containing brodifacoum. The need for this action became clear during biological surveys of islands in Doubtful, Breaksea and Dusky Sounds undertaken by Ecology Division and Fiordland National Park staff in the period 1974-84. These surveys disclosed that Norway rats were plentiful on Breaksea Island and also present on neighbouring Hawea Island, that rats had not yet reached adjacent Wairaki Island - only 300 m away, and that these three islands (Fig. 1) had high conservation potential (Thomas, 1985), being among the very few in Fiordland that remained free of stoats *Mustela erminea* (Taylor and Tilley, 1984). Other major objectives of the rat extermination campaign were to test our strategy and techniques for rat eradication on islands, and to evaluate the feasibility of using these

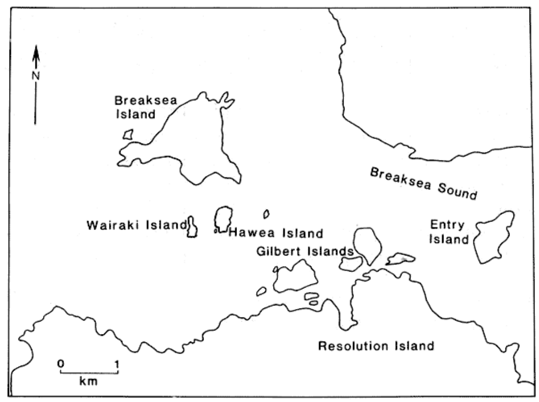

Figure 1: *Islands at the entrance of Breaksea Sound.*

to eradicate rats from the large (170 ha) and rugged Breaksea Island (Thomas and Taylor, 1988), where Norway rats have affected the population densities of many invertebrate groups (Bremner, Butcher and Patterson, 1984).

A concurrent study of the effects on Hawea Island's other biota from rat eradication (Taylor, Thomas and Taylor, 1986; Taylor and Thomas, 1986) is still underway and will be reported separately.

Study Area

Hawea Island (45° 35 'S, 166 ° 38 'E) is a 9 ha bush-clad island in the entrance of Breaksea Sound, Fiordland National Park. A small vegetated islet, "The Hump", lies less than 5 m off its southern shore (Fig. 2). Apart from a narrow zone of bare rock around the coast, both islands are covered with peaty soils which are deepest on the ridges and spurs, and less than 1 m deep in most other areas.

A vegetation survey in October 1986 showed that the forest was tallest (6-18 m) towards the centre of Hawea Island and was dominated by southern rata *(Metrosideros umbellata)* and kamahi *(Weinmannia racemosa),* with pigeonwood *(Hedycarya arborea),* stinkwood *(Coprosma foetidissima),* kotukutuku *(Fuchsia excorticata),* five-finger *(Pseudopanax colensoi),* miro *(Prumnopitys ferruginea)* and broadleaf *(Griselinia littoralis).* In less sheltered parts, where the canopy was lower, the main species were *Dracophyllym longifolium,* five-finger, southern rata, pigeonwood, mapou *(Myrsine australis),* kotukutuku, broadleaf, kamahi and stinkwood. The exposed coastal scrub fringe was mainly of *Dracophyllum,* *Hebe elliptica, Olearia oporina, O. reinoldii* and flax *(Phormium cookianum).*

In most parts of the forest there was a thick understory of kiekie *(Freycinetia baueriana),* tree ferns *(Dicksonia squarrosa* and *Cyathea smithii),* haumakaroa *(Pseudopanax simplex),* mahoe *(Melicytus ramiflorus),* the above-mentioned canopy species, and other shrubs. The forest floor was covered by hen and chicken fern *(Asplenium bulbiferum),* other ferns, *Astelia fragrans,* flax, moss, liverworts and seedlings. In open areas the main plants were shore tussock *(Poa astonii), Anisotome lyallii, Carex appressa,* moss and lichens.

In 1985 and 1986 the common native forest birds on Hawea Island were the New Zealand pigeon *(Hemiphaga novaeseelandiae),* grey warbler *(Gerygone igata),* South Island fantail *(Rhipidura fuliginosa fuliginosa),* yellow-breasted tit *(Petroica macrocephala macrocephala),* bellbird *(Anthornis melanura)* and silvereye *(Zosterops lateralis).* New Zealand falcons *(Falco novaeseelandiae)* were regular visitors. Common introduced species were the hedgesparrow *(Prunella modularis),* blackbird *(Turdus merula),* song thrush *(Turdus philomelos)* and chaffinch *(Fringilla coelebs).* Breeding sea birds were southern blue penguin *(Eudyptula minor),* Fiordland crested penguin *(Eudyptes pachyrhynchus),* broad-billed prion *(Pachyptila vittata),* sooty shearwater *(Puffinus griseus),* and southern great skua *(Stercorarius parasiticus).*

Although the creviced rocky foreshore is a suitable habitat for Fiordland skinks *(Leiolopisma acrinasum),* none have been found on Hawea Island (Thomas, 1985). Similarly, large flax weevils *(Anagotus fairburni)* and stag beetles *(Dorcus helmsi)* appear to be absent, although the dried mandibles of a stag beetle were found on The Hump. Fiordland skinks and these large flightless insects are abundant only 300 m away, on adjacent Wairaki Island (Thomas and Taylor, 1988). Presumably, they were exterminated from Hawea Island by rats.

It is not known exactly when or how Norway rats reached Hawea Island, but they could well have been there for over 150 years. They first arrived at Dusky Sound, Fiordland, in May 1773 on Captain James Cook's *Resolution,* and most likely reached Breaksea and Hawea Islands during the intense period of sealing that followed Cook's reports (Thomas and Taylor, 1988). In modern times the risk of re-invasion seems slight. There are no regular anchorages or landing beaches at Hawea Island, visitors are few and no stores are landed there. The distance to the nearest mainland is about 900 m which is well in excess of a rat's swimming range in southern New Zealand waters (Taylor, 1984b).

Methods

The broad plan of campaign was to observe the rats and their environment on Hawea Island; to avoid any unnecessary actions that would induce food aversion or neophobia in the population; to eradicate the rats as quickly as possible using Talon poison; to continue monitoring with Talon and non-toxic baits to confirm eradication; and to investigate the potential for using the same methods to eradicate rats from Breaksea Island.

Presence, distribution and behaviour of rats

Observations on the presence, abundance and distribution of rats on Hawea Island before and during the poisoning included: recording rat sightings by day and night; detecting rat tracks on prepared surfaces of damp sand; counting rat burrows on three marked plots (Fig. 3) of 400 m^2 at the centre of the island, 175 m^2 near the south coast, and 675 m^2 on The Hump; searching for rat burrows, droppings and feeding sign; and kill-trapping. Twenty rat snap-traps were set under sheet metal covers and operated over three nights in both April 1984 and October 1985, and 73 similar sets were operated over five nights from 17 to 21 April 1986 during the latter part of the poisoning campaign. All traps were baited with fish-flavoured pet food. The results of the trapping are expressed as captures per 100 trap nights (C/l00 TN) after correcting for unavailable traps by the method of Nelson and Clark (1973).

The behaviour of Norway rats towards bait stations, Talon bait, apples, and to other rats in the vicinity of these stations, were observed incidentally during the poisoning operations on Hawea Island. These aspects were also studied in more detail and with a variety of non-toxic baits (bacon, cheese, bread, shellfish) on Breaksea Island.

The poisoning campaign

Bird-proof bait stations (illustrated in Thomas and Taylor, 1988) were constructed from 100 mm diameter, yellow, non-perforated, plastic "Nova-coil" pipe. Their colour made them easy to find, even among thick ground vegetation. Stations were 400 mm long, had a tracking surface of damp sand at each end and a watertight, transparent lid in the centre for inserting and checking the baits. They were held firmly to the ground by two hoops of fencing wire.

In March 1986, 73 bait stations were distributed over Hawea Island at about 40 m intervals, using a network of tracks (Fig. 2) which had been cut and marked during this and a previous visit. To minimise neophobic avoidance by rats, the bait stations were left in position for three weeks before poison was laid on 10 April. During the poison operation each station was baited with two 15 g Talon poison baits, each containing 0.005% brodifacoum, placed loosely in the tunnels and not anchored in any way. The number of baits taken from each station was recorded, and the baits replenished daily from 11 to 22 April 1986. At the end of this period each station was left baited with four Talon baits.

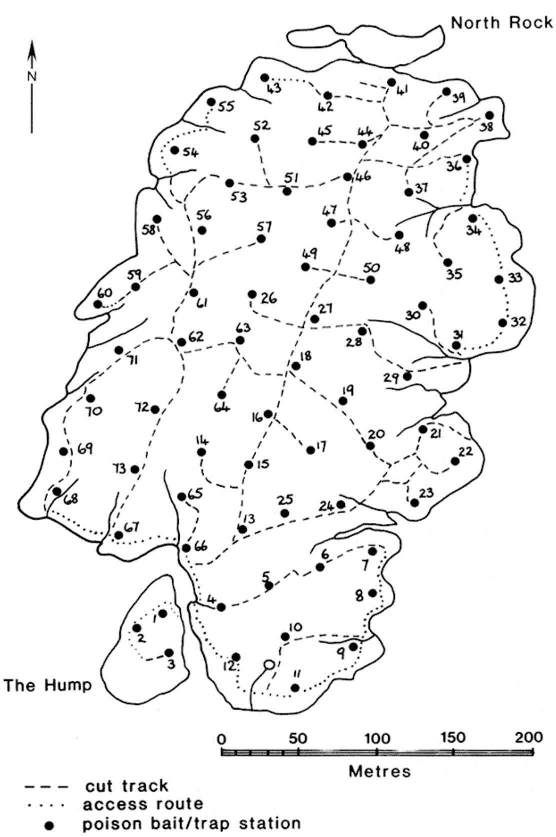

Figure 2: *Hawea Island, showing cut tracks and routes, and the distribution of poison-bait and rat-trapping stations (numbered).*

The eradication of rats from Hawea Island was determined by:

1) Checking all 73 bait stations for interference in June, July, August and October 1986, and in March and October 1987; old baits in each station were replaced with two fresh talon baits in July and October 1986, and March and October 1987.
2) Snap-trapping at each bait/trap station for a total of 2,139 trap nights, from 27 July to 27 August 1986.
3) Placing ripe eating apples on the ground near each of the 73 bait/trap stations for a total of 3,286 apple nights; from 27 July to 27 August 1986, from 24 to 29 October 1986, from 11 to 16 March 1987, and from 15 to 21 October 1987. Between 12 and 24 apples were similarly placed on Breaksea Island during each of these four visits to test their acceptability to Norway rats at those times. Apple is a favoured food of both Norway and ship rats (pers. obs.) and distinctive grooves left by the rodents' incisors show up clearly on its skin and flesh. Some birds and invertebrates will also feed on apples (particularly over-ripe ones), but their feeding signs are easily distinguished from that of rats.
4) Searching for fresh sign of rats in locations on Hawea Island previously favoured by them. Full details of time and expenditure were recorded during all operations.

Results

Presence, distribution and behaviour of rats

Eleven Norway rats (20/100TN) were trapped near the south coast of Hawea Island in April 1984, and eight (14/100TN) in October 1985. On later visits, evidence of rats was found over the entire island, including The Hump. In March and April 1986, rats were commonly encountered on Hawea by day and by night, most often in the taller forest at the southern end. In general, rats on Hawea Island were most common in areas with miro trees, areas where ferns and other low plants covered more than 25% of the ground, and areas close to an extensive intertidal zone. Rat burrow density was measured as four per 100 m^2 on The Hump, seven per 100 m^2 at the centre of the island, and 34 per 100 m^2 near the south coast. The distribution of rats on the island was also indicated by the amount of bait removed from each station; most bait was taken from the south end of Hawea Island and the least from The Hump (Fig. 3).

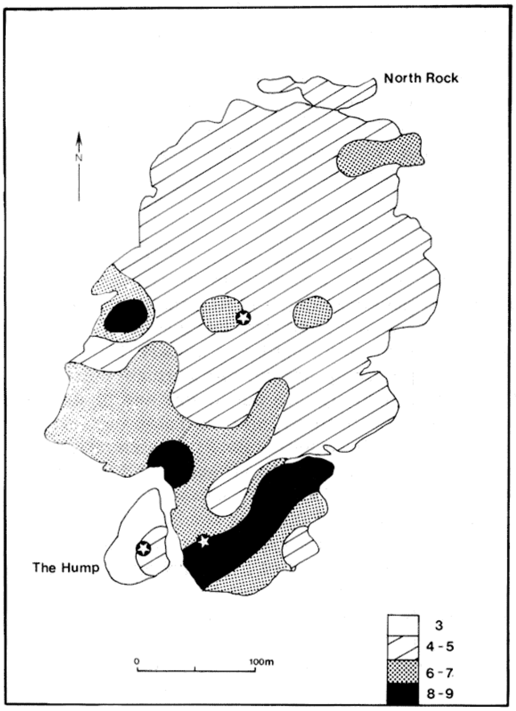

Figure 3: *Hawea Island, showing the number of nights over which poison was taken by rats on different parts of the island, and the position of plots (stars) on which rat burrows were counted.*

Rat tracks were found on the sand surfaces of 13 (18%) of the 73 unbaited tunnels left on Hawea Island for three weeks between March and April 1986. During the poisoning campaign on Hawea the rats almost always removed entire Talon baits from the stations, and it seems from direct observations and from lack of residue that fewer than 4% of baits were eaten *in situ*. Despite this behaviour, only six baits or part baits, of a total of 734 poison baits removed by rats on Hawea Island, were found on the surface - and it is certain that all others were taken into rat burrows before being eaten or stored. During later tests on Breaksea Island, Norway rats were observed readily entering the Nova-coil tunnels soon after the tunnels were positioned and baited. Talon baits were invariably carried away whole, and rats commonly returned to the bait stations for the second bait within 30 seconds of removing and cacheing the first. One large male rat continued to return as long as the tunnel was re-baited, and took a total of five Talon baits within approximately 3 minutes. On several later occasions, when the observer visited and touched the bait station but did not re-bait it, the rat almost immediately returned and entered the tunnel.

Large rats carried off whole apples in their mouths. Smaller rats occasionally rolled apples away, sometimes to burrow entrances, but usually they took very large bites and carried off that portion before quickly returning for further bites. Large pieces of bread, cheese and bacon were similarly carried off. Only small crumbs of food were eaten *in situ,* whether in a bait station or in the open.

Large male rats aggressively defended the baited tunnels from the rest of the population. Although smaller rats were obviously attracted to the smell of the baits, they appeared reluctant to approach closer than about 2-3 m while a large rat was nearby. Some large males were seen to chase smaller rats away for periods of up to two hours, biting any they managed to catch. Finally, when the dominant animals had apparently had their fill and left, smaller rats (sometimes several at one time) cautiously approached to feed, and similarly carried off the larger items. One group of three small rats moved around a particular circuit several times, returning to the tunnel every 15-20 minutes apparently to check for competitors, before they finally carried off the baits.

The poisoning campaign

The nightly take of poison bait over the period of the April 1986 visit is shown in Fig. 4. Eighty-three percent of the amount available was taken by rats on the first night, and 100% on the second and third nights. Bait take remained above 75% for a total of five nights before dropping to 25% on the sixth night, and then quickly tailing off. After the seventh night of poisoning, no more rats were seen on Hawea Island by day or night. Seventy-three snap-traps set adjacent to the bait stations during the last five nights of the 12-night operation failed to catch any rats, and showed no sign of rat interference. No Talon bait was taken on the twelfth night of poisoning. However, a check of all bait stations on 3 June showed that two more baits had disappeared. These were both from one bait station in an area with many rats, which had previously had more poison taken from it than had any other station.

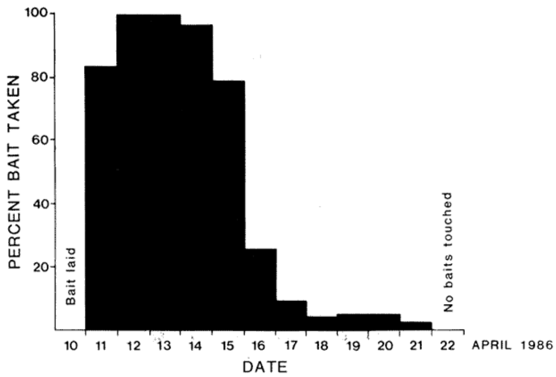

Figure 4: *The percentage of "Talon 50 WB" baits taken each* 24 *hours on Hawea Island during the first 13 days of the poisoning campaign. Note: A total of* 146 *baits was available each day.*

Eradication of the rats from Hawea Island was confirmed as follows:

1) Although Talon baits were continually available in the 73 bait stations, none were touched by rats in a total of 36,866 bait-station nights between June 1986 and October 1987.
2) No rats were caught, or traps interferred with by rats, during 2,139 snap-trap nights between April and July 1986.
3) No apples were touched by rats during a total of 3,286 apple nights in July, August and October 1986, and in March and October 1987. Eighty-eight percent of apples placed on Breaksea Island during these same visits were eaten by rats either within a few hours, or during the first four nights after being put out - giving an overall take of 70 per 100 apple nights.
4) No fresh sign of rats has been found on any of ten visits to Hawea Island between April 1986 and April 1988.

Costs

The campaign involved a total of 154 person-days (PD) by paid and volunteer workers. This included time spent in planning and organising (23 PD), travelling (51 PD), surveying and tracking (29 PD), constructing bait stations (8 PD), poisoning (27 PD), checking results on two follow-up visits (3 PD), and analysing data and writing two preliminary reports (13 PD). The total cost in salaries and wages was about $30,200.

Major material costs were less than $700 at 1986 values, and comprised the cost of 32.5 kg of Talon poison, 50 m of Nova-coil pipe, 80 rat snap-traps and associated materials, and apples for detecting the presence of rats.

In addition there were travel and servicing costs associated with moving personnel and gear to and from Fiordland (c. $7,300), and the support provided by Fiordland National Park's MV *Renown* and her crew (c. $27,000).

Discussion

It seems certain that all rats living on Hawea Island were killed within a period of about two weeks during the April 1986 poisoning, and that the two talon baits found missing on 3 June were taken soon after the twelfth night of poisoning by an already dying rat.

When poisoning started, rats were abundant. They were commonly seen during day and night, there were many fresh burrows, and the Talon baits were taken promptly from most tunnels. A comparison of the numbers kill-trapped on Hawea Island (20 and 14/100 TN in April 1984 and October 1985 respectively), with kill-trapping results and population densities based on live trapping on three other islands ÖMotuhoropapa Island (9.1/100 TN and 2.6-4.2 rats/ha; Moors, 1985b), Whale Island (6.9 and 23.6/100 TN and 5-10 rats/ha; Bettesworth, 1972), and Campbell Island (14.6/100 TN and 10 rats/ha; Taylor, 1986) - indicates that the Hawea population may have been in the order of 6-11 rats/ha, i.e., a total population of around 50-100 rats.

Our observations of Norway rats at bait stations on Hawea and Breaksea Islands showed that Talon was extremely attractive and palatable to them. Their behaviour of removing and cacheing baits (Calhoun, 1962), and chasing away subordinate rats, means that not all rats will have ready access to the bait during the first few days of a poisoning operation.

Each 15 g Talon bait contains 0.005% brodifacoum, and it has been estimated that at this concentration the LD_{50},. for Norway rats weighing 250 g is 1.3 g of bait (Dubock and Kaukeinen, 1978). One bait, therefore, is sufficient to kill several rats. However, since rats die several days after they have consumed a lethal dose of brodifacoum, each rat poisoned on Hawea would almost certainly have eaten several baits. Norway rats can die within 4 days of consuming large doses of brodifacoum, whereas those that have ingested little more than a lethal dose may live for up to 12 days (Dubock and Kaukeinen, 1978). As a consequence, it would be expected that dominant individuals would eat a surfeit of bait and die in the first 3-4 days. Less dominant rats should then successively gain access to bait, whether in bait stations or in caches down burrows, and be poisoned over the following two or three weeks, until all are killed.

The 100 mm diameter bait stations were an ideal size for Norway rats. As expected, their yellow colour seemed not to concern the rats, which are colour blind. In fact, rats are thought to prefer yellows and greens - which would appear to them as light grey - to many other colours (Brooks and Rowe, 1987).

The approximate 40 m spacing between bait stations used on Hawea Island followed Moors (1985a), and was based on the average distance between successive captures found for marked Norway rats on Motuhoropapa Island - 113 m for males and 49 m for females. However, the mean range-length was about 200 m for five male and 108 m for three female rats trapped at least twice on forested Motuhoropapa Island (Moors, 1985b), and about 232 m for three male and 141 m for five female Norway rats similarly studied in forest on Stewart Island (Hickson, Moller and Garrick, 1986). For several species of rodents, including house mice *(Mus musculus),* ship rats, and Norway rats (Fitzgerald, Karl and Moller, 1981; Innes and Skipworth, 1983; Taylor, 1986), it has been shown that surviving animals quickly expand their home ranges once their neighbours are removed. These studies, of home range and swift invasion response, suggest that the spacing of bait stations on Hawea Island was unnecessarily close.

The possibility of accidental exposure of non-target species to primary or secondary poisoning was closely monitored during the poisoning campaign, but no such deaths were identified. Insects are not known to be directly affected from feeding on Talon. Bird species vary widely in their susceptibility to brodifacoum, and a secondary hazard can also exist to insectivorous birds and raptors feeding on prey that has consumed poison bait (Godfrey, 1985). There was no evidence that birds were interfering with the poison inside the bait stations, and the rats scattered very little about outside. On Hawea Island, some baits that were left in the tunnels for long periods showed evidence of being chewed by insects, probably wetas, cockroaches and ants.

Despite careful searches, no poisoned rats were found on the surface of Hawea Island, and it appears that most died in their burrows or under thick cover. Our snap-trap results near the end of the Hawea poisoning operation suggest that the last surviving rats, all of which would already have eaten Talon, were habituated to the poison baits but were avoiding fish-flavoured baits on newly-positioned snap-traps set near each bait station. It seems likely that dying rats could become dependent on Talon, from bait stations or from caches in burrows, for food. If so, they would spend little time in the open, and thus reduce the risk of secondary poisoning to other species. The main avian predators at risk on Hawea Island were southern great skuas and New Zealand falcons, both of which may have preyed on live but poisoned rats. However, comparable numbers of both species were seen in the vicinity of Hawea Island before and after the poisoning, and there was no evidence of adverse effects.

The major advances of the Hawea Island operation' over most previous rat control or eradication exercises in New Zealand were:

1) Eradication was achieved in one continuous short operation - not in irregular bursts.
2) The poison used had no history of inducing food aversion in rats eating a sub-lethal dose.
3) Only one poisoning technique was used, and its effectiveness could therefore be fully evaluated.
4) All poison bait was presented in standard amounts at fixed points, and checked and replaced daily - this not only allowed accurate data to be gathered on the amount of poison taken by rats, and for the progress of the campaign to be continuously monitored, but also for the rats to learn where food was regularly available. .
5) The bait stations used were bird proof and with an entrance of sufficient diameter to be readily accepted by Norway rats.
6) The Talon baits, each containing well in excess of a lethal dose, could be readily removed by rats to eat in a secure place of their own choice. This will have increased the chance of a lethal dose being consumed quickly. With oats, wheat or similar baits, rodents are forced to frequently visit, or stay in, the bait stations while they feed on poison.
7) An excellent method was devised for detecting the presence of rats, by laying out whole apples. This simple technique is an important advance in helping to decide if rats have reached an island, or if eradication has been achieved.
8) The possibility of neophobia causing some rats to avoid Talon baits was countered by setting out the bait stations three weeks prior to poisoning, and keeping Talon constantly available to rats at the same sites for over two years.

9) No special effort, or perseverance, was needed to get the last rat.
10) Only 154 person-days were required to complete the eradication campaign and to confirm its success, at a total cost of about $65,000.

There is no simple way to predict the costs of eradication campaigns on other offshore islands, especially those outside of Fiordland, by extrapolation from the Hawea Island operation. Some work was developmental and will not need repetition. Cost/area relationships will be roughly linear for materials, but the cost of transport, accommodation, and wages will rapidly decrease per unit area with increasing island size. These items will also vary immensely according to circumstances, such as the location, topography, and vegetative cover of the island, and facilities already available.

We consider that the "pulse baiting" technique, of replacing poison baits every five to seven days (Dubock, 1979) or the "minimal baiting" system (Richards and Huson, 1985) usually recommended for economy and safety when controlling rodent populations with second-generation anticoagulants, are not appropriate when attempting eradication of rats from an island. In these circumstances the main priorities are to kill every rat, and to guard against any possibility of encouraging the development of bait shyness, poison resistance, or neophobia in the population.

We detected little evidence of neophobia in this population of Norway rats which has possibly been isolated from the selective pressures of human control for over 150 years. Moors (1985a, 1986) claimed that Norway rats are more wary of man-made objects, such as traps and bait stations, than are ship rats or kiore. However, we know of no evidence supporting this generalisation from uninhabited islands or remote parts of New Zealand. A lack of severe neophobia could well be a common characteristic of long-isolated populations of commensal rats (Mitchell, Kirschbaum and Perry, 1975; Cowan, 1977). Therefore, we suggest that the best chance of eradicating any species of rat from New Zealand's island reserves is when the job, once started, is completed quickly before the population is affected by the human-induced phobias that have frustrated many control operations elsewhere.

Behavioural research has shown that Norway rats rely on their peers in deciding where and what to eat. When given a choice of feeding locations they prefer sites that conspecifics are exploiting (Shorten, 1954; Barnett, 1975; Galef and Heiber, 1976). When given a choice of diet, rats that have smelled a particular food on another rat's breath prefer it, even to other more familiar foods. Similarly, rats that have acquired an aversion to a food will eat it again after exposure to conspecifics that have recently fed on it (Galef, 1987; Galef, Mischinger and Malenfant, 1987). It seems sensible, therefore, to take advantage of this knowledge and keep poison baits continually available at regular sites during eradication campaigns against Norway rat populations using second-generation anticoagulants. Thus at any moment during the course of a campaign, a large proportion of the living population will have consumed some poison and will be influencing the remaining population to eat it, even though temporarily they may be chasing some less dominant individuals away. It is likely that other species of rats and house mice are also susceptible to similar "peer pressure" (Galef and Clark, 1971; Galef and Heiber, 1976; Bean, Galef and Mason, 1988).

We therefore recommend that whenever possible all poison baits be checked and replaced daily, during rodent eradication campaigns using anticoagulant poison. For each island being poisoned, a knowledge of the fauna likely to be at risk, appropriately designed bait stations, and the shortest possible poisoning campaign are important safeguards against primary or secondary poisoning of non-target species. Any extra financial costs, through more bait being taken by the rats, will be more than offset by the lower cost of a much shorter and more predictable operation.

The rodent extermination strategy and techniques, as developed on Hawea Island and described in this paper, were applied with only slight modifications on Breaksea Island in May/June 1988. We are currently part way through the planned campaign, but five visits to the island since July 1988 have failed to detect any sign of surviving rats.

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