Increase the number of Whitaker's and robust skinks in captivity so that self-sustaining populations can be established for later release.

6. Protect populations on land outside Crown control.

Establish management partnerships on locations in private ownership to ensure that their natural values as key sites for threatened lizards are not compromised.

7. Manage the mainland population of Whitaker's skink at Pukerua Bay.

Establish a formally gazetted reserve at Pukerua Bay and institute management that will enhance the Whitaker's skink population.

8. Promote public interest and involvement in the recovery of Whitaker's skink and robust skink and in community restoration.

Keep the public informed of progress with habitat restoration, and lizard reintroductions, involve interested groups as appropriate and provide for long term public participation.

CRITICAL PATH

Priority	Year 1	Year 2	Year 3	Year 4	Year 5	Objective
1. Eradicate rodents	■	■		■		1
1. Translocation strategies	■	■	■		▒	2
1. Invertebrate recovery	■	■	■	▒	▒	3
2. Captive breeding		■	■	■	■	5
2. Protect populations	■	■	■			6
2. Manage Pukerua Bay		■	■	■	▒	7
2. Public promotion	■	■	▒	▒	▒	8
3. Causes of vulnerability			▒	▒	▒	4

KEY: Level of effort

■ High

▒ Low

8. RECOVERY STRATEGY: WORK PLAN

To meet each objective and the fulfil the recovery goals the following actions are required:

OBJECTIVE 1. ERADICATE RODENTS FROM LARGE ISLANDS

Explanation

Restoration of island biotic communities relies on efficient techniques for eradication of rodents. Successful cost-effective techniques have been developed for small islands, but these tend to be labour intensive (McFadden and Towns 1991). Mechanical techniques for air drops of rodenticide will need to be applied to islands of 100 ha or more if the options defined in this plan are to be met.

Plan

Aerial drops by helicopter using TALON 20P provided gratis by a chemical company began in September 1991 on Stanley Island (100 ha). If successful it may be extended to Red Mercury Island in 1992.

Outcomes

The eradication campaign against kiore (as well as rabbits) on Stanley and Red Mercury Islands will:

* Rehabilitate two populations of tuatara

* Release invertebrates from predation by kiore

* Provide two very large islands with considerable suitable habitat for Whitaker's and robust skinks.

Once eradications are completed the island will need to be checked regularly for at least two years to ensure that both pest species have been removed.

Kev Personnel

Ian McFadden - DOC, Science and Research, Auckland (eradication project leader)
Theo Stephens - DOC, Waikato Conservancy
Phil Thomson - DOC, Waikato Conservancy
David Towns - DOC, Science and Research, Auckland (liaison with sponsor)

OBJECTIVE 2. DETERMINE STRATEGIES FOR TRANSLOCATION AND MONITORING OF WHITAKER'S AND ROBUST SKINKS.

Explanation

Source populations of Whitaker's skinks may be too small to be used for frequent reintroductions. Success of newly established populations will therefore depend on location of suitable sites for release, ensuring that sufficient animals have been released to begin a viable populations, development of methods for monitoring new populations, and monitoring the effects of removal on the source populations.

Plan

Much of this information can be obtained on Korapuki Island where rats and rabbits have been eradicated for five years, suitable facilities to conduct this research have been established, and one release has already been conducted, Korapuki should be the focus of work for the next 2-3 years. Results from Korapuki would be used to predict changes that will occur on other islands, as well as indicate the ways in which lizards are likely to respond to new habitats.

The following tasks should be undertaken:

* Remove 25 robust skinks from Green Island for release onto Korapuki (year 1 or 2).

* Conduct a follow-up release of 25 Whitaker's skinks from Middle Island to complete the 50 proposed in 1988 (year 1 or 2).

* Review progress with existing approved research project on lizard translocation (year 2).

* Define release sites for lizards and release strategies for Double and Stanley Islands.

Evaluation

Successful establishment of Whitaker's skinks on Korapuki can only be confirmed from clear evidence of breeding in situ. Capture methods are biased towards adults (pitfall live traps). Because this species takes 3-4 years to reach maturity, young produced on the island cannot be expected to reach breeding age, and become susceptible to capture, until 1991-1992.

Outcome

Information from intensive study of released populations will enable guidelines to be established for releases and monitoring of other populations on other islands. Ideally new populations should be started from as few animals as is practical and monitoring should be conducted over time intervals that represent the minimum burden on staff time.

A new population of robust skinks should be established on Korapuki Island by year 2, and

of Whitaker's and/or robust skinks on Double Island by year 4. Plans for later releases on Stanley Island should be completed by year 5.

Key personnel

David Towns - DOC, Science and Research, Auckland (translocation research project leader).
Ian McFadden - DOC, Science and Research, Auckland.

OBJECTIVE 3. DETERMINE THE RATE AND FORM OF INVERTEBRATE RECOVERY FOLLOWING REMOVAL OF RATS, AND THEIR ROLE AS POTENTIAL FOOD SPECIES FOR REINTRODUCED LIZARDS.

Explanation

Success of reintroductions may ultimately depend on the extent and speed of recovery of invertebrate populations following rodent removal. It may be necessary to develop methods to enhance recovery of invertebrate populations. Changes in the abundance and density of resident invertebrates as potential food for released lizards should also be investigated following eradication of rats.

This information should also be linked with data required before releases of the endemic tusked weta are conducted.

Plan

A project that involves taking comparative litter invertebrate samples from Korapuki, Middle and Stanley Islands should be continued, with some additional material obtained from Double Island. Now that the invertebrates on Korapuki have been without a mammalian predator for five years, deficiencies in the invertebrate community should be identified and remedied as soon as possible. The remedies could involve restocking litter on Korapuki using sources from nearby islands (e.g. Green and Middle).

* Identify community structure of litter invertebrates on Korapuki Island and document changes that have occurred since 1988.

* If necessary obtain litter samples as "seed sources" for Korapuki litter communities.

Outcome

A litter invertebrate community on Korapuki Island that does not differ significantly from those on neighbouring naturally rat-free islands. Information that can be used to predict the rate of change in invertebrate populations at other locations.

Key personnel

Chris Green - DOC, Auckland (litter invertebrate project leader)
Phil Thomson - DOC, Waikato (tusked weta)

OBJECTIVE 4. DETERMINE CAUSES OF VULNERABILITY TO EXTINCTION

Explanation

As with a number of other rare lizard species, Whitaker's and robust skinks appear to be restricted in the range of habitats that they use. However, observed distributions of the species on small islands could be an artifact of availability or use of suboptimal microhabitats. Studies relating microhabitat use to physiological capabilities should therefore be undertaken. This is relevant to management of Whitaker's skink habitat at Pukerua Bay, as well as to ensuring that the correct conditions are identified for both species on restored islands.

Plan

A field study relating the laboratory results to habitat use in the wild should be conducted. This is not regarded as a high priority project and funding and key personnel have therefore not been identified.

OBJECTIVE 5. MAINTAIN CAPTIVE POPULATIONS OF BOTH SPECIES.

Explanation

Maintenance of populations of lizards in captivity can have three goals: as insurance against the loss of wild populations; as an advocacy tool that involves private individuals in a conservation project, and enable the public to view the animals; to provide animals that can later be released into the wild.

Unfortunately the cryptic habits of these lizards make them less than ideal subjects for public viewing unless the institutions involved are willing to invest in a nocturnal facility. Neither of the species is currently held in any facility where they can be viewed by the public.

With increasing efforts directed towards island restoration demands for lizards are likely to be higher than the source populations can support. Captive breeding specifically for release is therefore likely to be required (see Appendices 2, 4).

To date there has been minimal success with maintaining and breeding Whitaker's skinks in captivity. The causes for these difficulties will need to be identified.

Plan

A captive breeding programme is being undertaken for robust skinks by the New Zealand

Herpetological Society. This programme should be placed on a more formal basis with some co-ordinating role played by the Department of Conservation. The prospects of breeding sufficient animals for release into the wild at defined locations should be investigated and goals for the breeding populations should be defined.

A captive breeding programme should be developed for Whitaker's skink, with one northern and one southern population developed around the animals from Castle Island and Pukerua Bay respectively. The possibility of basing the southern population at the National Wildlife Centre needs investigation, especially in view of the potential to involve experienced breeders from the Wellington area.

To establish viable populations in captivity the following tasks are required:

* Removal of 5-10 Whitaker's skinks from Pukerua Bay (over a time frame to be determined) to expand the breeding group currently in captivity.

* Dependent on success of this breeding programme (after review at year 3), removal of up to 25 Whitaker's skinks from Castle Island to form the basis of a breeding population for later release.

* Removal of up to 25 robust skinks from Middle Island in year 3 for later release on Double Island, and/or to form the basis for stock to be released on Stanley Island.

* Identification of a breeding co-ordinator for the Whitaker's skink and robust skink breeding programmes.

Evaluation

Whether two populations of Whitaker's skinks should be established in captivity will depend on success with the group formed of Pukerua Bay animals. A well co-ordinated effort is expected to produce information that will lead to improved prospects for success with a northern population.

Similarly, whether robust skinks from the Mercury Islands are used to form a captive breeding group for later release should depend on the level of success with the existing groups of animals in captivity.

Key personnel

Martin Bell - DOC, National Wildlife Centre, Mt Bruce
David Butler - DOC, Threatened Species Unit, Wellington (Co-ordinator, captive breeding programmes)
Raewyn Empson - DOC, Wellington Conservancy
Bernard Goetz - Private breeder, Nelson
Dennis Keall - Private breeder, Wellington
Ian McFadden - DOC, Science and Research, Auckland (liaison with Auckland Zoo)
Phil Thomson - DOC, Waikato Conservancy
John West - Secretary, New Zealand Herpetological Society, Auckland.

OBJECTIVE 6. PROTECT POPULATIONS ON LAND OUTSIDE CROWN CONTROL.

Explanation

Two key populations of robust skink in Northland and Waikato are outside Department of Conservation control, as are some of the locations in which their recovery could be contemplated. Success with long-term recovery options will depend on locally targeted advocacy and development of management partnerships. This need is highest in Northland Conservancy.

Plan

l n Northland Conservancy maintain and increase dialogue with local Maori tribal authorities with a view to establishing management partnerships for Matapia and Moturoa Islands. In the latter group this should include plans to restore modified islands and/or to ensure that conservation values of Moturoa Island are not compromised by activities elsewhere.

In Waikato Conservancy establish a pathway for protection of the conservation values of Castle Island. Continue discussions with Ngati Hei over possible restoration in the Ohinau Islands.

Outcomes

Within two years obtain lasting agreements for protection of islands outside Crown control and approval for restoration programmes in Moturoa and Ohinau Islands. Greater understanding amongst tangata whenua of DOC's capabilities for species recovery and restoration. This should be achieved by encouraging their involvement in planning and implementation of restoration programmes.

Key personnel

Peter Anderson - DOC, Northland Conservancy
Te Aniwa Hona - DOC, Northland Conservancy
Richard Parrish - DOC, Northland Conservancy
Ray Pierce - DOC, Northland Conservancy
John Greenwood - DOC, Waikato Conservancy
Buddy Tuwhare - DOC, Waikato Conservancy
Theo Stephens - DOC, Waikato Conservancy

OBJECTIVE 7. MANAGE THE MAINLAND POPULATION OF WHITAKER'S SKINK AT PUKERUA BAY.

Explanation

Although the main known habitat for Whitaker's skink at Pukerua Bay is under DOC control, significant habitat occurs in an adjacent reserve and paper road administered by Porirua City Council. Livestock have been fenced out of both areas since 1987 and it is important to ensure that the resulting changes in habitat will benefit Whitaker's skink. Security of Whitaker's skink habitat will require establishment of joint administration agreements with Porirua City Council.

Plan

Effective management of the Pukerua Bay population will require completion of the following tasks:

* Management strategy for the reserve at Pukerua Bay.

* An administration agreement with Porirua City Council. A draft working plan to establish working relationships with Porirua City Council was prepared by Towns (1985b). This needs updating and expanding.

* A suitable reserve category needs to be determined and appropriate management options for the reserve needs to be defined.

* An account of possible management options for the resident lizard community needs to be presented to reserve managers by the end of year 1.

Outcomes

By the end of year 2 a management strategy that defines the role of DOC, Porirua City Council and the public in the management of the Pukerua Bay site should be completed. It should include options for reserve management based on the results of an intensive study of the lizard community provided to Wellington Conservancy by end of year 1 (Towns in press).

Key personnel

Raewyn Empson - DOC, Wellington Conservancy
Richard Anderson - DOC, Wellington Conservancy
Porirua City Council
David Towns - DOC, Science and Research, Auckland.

OBJECTIVE 8. PROMOTE PUBLIC INTEREST AND INVOLVEMENT IN THE RECOVERY OF WHITAKER'S SKINK AND ROBUST SKINK AND IN COMMUNITY RESTORATION.

Explanation

Education of the public is seen as the primary outcome of effective advocacy. Contribution by the public to breeding programmes therefore has an advocacy role (Porter 1988), but this activity can only be undertaken by a few individuals. Much wider support for the recovery process would result from involving the public in habitat restoration (e.g. Objective 5).

It has been suggested that lizards do not generate much public enthusiasm and that there is often little public support for programmes advocating their conservation (e.g. Towns 1985b). In fact the experience at Pukerua Bay has demonstrated considerable local interest and pride in the presence of a nationally threatened species in the vicinity.

Plan

The interest in the Pukerua Bay site could be further developed by using local people as guardians of the reserve (Towns 1985b).

The proximity of Whitaker's skink to the greater Wellington area should also be exploited, particularly through the planned children's museum and science centre (Capital Discovery Place), due to open in 1992.

The most useful theme that could be developed nationally is to emphasise the role of Whitaker's and robust skinks in ecological restoration and by linking recovery of these species to that of the tuatara (see Cree 1990). The educational opportunities presented by this linkage could productively be exploited by the National Wildlife Centre at Mount Bruce.

Opportunities to involve the public directly or indirectly in restoration activities will be identified by Waikato Conservancy in the Conservation Action Plan for the Mercury Islands Ecological District (Thomson et al in prep).

Outcome

Public awareness and support for the recovery goal defined in this plan, as well as a wider appreciation of conservation issues in general.

Key personnel

Theo Stephens - DOC, Waikato Conservancy
Buddy Tuwhare - DOC, Waikato Conservancy
Richard Anderson - DOC, Wellington Conservancy
Peter Hapeta - DOC, Wellington Conservancy
Porirua City Council

9. RECOVERY STRATEGY: COSTS

Costs exclude DOC staff salaries but effort is given as person-day equivalents (bold).

Year	1	2	3	4	5

OBJECTIVE 1: Eradicate rodents[1]

Staff time	**60**	**112**	**60**	**30**	
Rat eradication	Stanley	Red Mercury			
Check Double Island rat free	1500	-	-	-	-
Check Stanley Island rat free	4000	2000	1500	-	-
Check Red Mercury rat free	-	3000	3000	2000	-

OBJECTIVE 2: Translocation strategies

Staff time	**15**	**25**	**25**	**25**	**15**
Translocation research[2]	4000	4000	3000	3000	3000
Obtain lizards from Green Is	-	3000	-	-	-
Obtain lizards for Stanley	-	-	3000	-	-
Check releases on Double	-	-	-	1000	-

OBJECTIVE 3: Invertebrate studies[3]

Staff time	**14**	**110**	**14**	**14**	**14**

OBJECTIVE 4: Determine causes of vulnerability [4]

OBJECTIVE 5: Maintain captive populations

Staff time	**20**	**20**	**20**	**10**	**5**
Establishment costs	-	5000	-	-	-
Lizards for Double Island and/or captivity	-	-	3000	-	-

OBJECTIVE 6: Protect populations [5]

Staff time: Pukerua Bay monitoring	**10**	**10**	**10**	**5**	**5**
Staff time: Negotiations	**10**	**10**	**10**	-	-

OBJECTIVE 7: Manage Pukerua Bay site[6]

Staff time	**10**	**30**	**20**	**10**	**10**
Vegetation: trials and plants	-	5000	1000	500	-
Management reports and plans[6]	500	-	500	-	500

NB: Travel costs identified under 2 subsidize other activities (1,3,and 5).

[1] Costs already identified in tuatara recovery plan and covered by sponsorship (estimated value $20-60 000). Costs are based on three monitoring trips in year one reducing to one by year three.

[2] Further costs to be identified following review in year 2, but currently based on shared costs with objective 1.

[3] Costs covered under objective 2, includes major data collation and write up in year 2.

[4] Opportunistic study that can be covered within other work programmes or as a university project

[5] Staff time but may require some consumables (e.g. pitfall traps)

[6] Includes time in year 2 for compiling reserve management strategy.

APPENDIX 1. BIOLOGY OF WHITAKER'S AND ROBUST SKINKS

Taxonomic Relationships

The genus *Cyclodina* Girard 1858 was re-established in the New Zealand literature by Hardy (1977) to include a group of species previously in *Leiolopisma,* but distinguished by having a discontinuous subocular row of scales, a body squarish in cross-section and shortened digits on the limbs. *Cyclodina* was regarded by Hardy as endemic to New Zealand, but its members showed close relationships to some from New Caledonia, especially *Marmorosphax euryotis*. Subsequently Cogger (1986) transferred a nocturnal skink found in the Lord Howe and Norfolk Island Groups, from *Leiolopisma* to *Cyclodina,* as *C. lichenigera*. Relationships of the New Zealand species have been re-examined by Vos (1988), but those between *C. lichenigera* and the New Zealand species remain unknown.

Within the New Zealand species, Whitaker's skink has close morphological similarity with the marbled skink *(C. oliveri)* and allies (Towns 1988a, see also Vos 1988), whereas the robust skink is most similar to McGregor's skink *(C. macgregori)* in size and morphology.

Whitaker's skink

Habitats and habits

Whitaker's skink may be seen by day basking at the entrance to seabird burrows (Macredie 1984, Southey 1985, Towns pers. obs.); it forages at night within the first few hours after sunset. The skinks appear to forage at the surface less commonly than robust skinks, instead moving about under leaf litter and within seabird burrow complexes (Southey 1985). They also apparently forage at Pukerua Bay within boulder banks that mimic seabird burrows in temperature and humidity regimes, appearing on the surface at irregular intervals during spring and summer (Towns 1985a).

At Pukerua Bay Whitaker's skink was the least commonly captured species, with only 79 captures of 56 individuals made over about 30 000 trap days (covering four summers), compared with 1524 captures of common skinks, 377 brown skinks, 675 copper skinks and 242 common geckos (each includes multiple recaptures). Whitaker's skink was also the most narrowly distributed species, being confined to the stable, deep rocky scree at the base of the hill slope. The species was captured most frequently where *Muehlenbeckia* cover was dense. Recapture rate (all summers lumped) was lowest for Whitaker's skink (25 %), compared with 49 % for brown skinks and 30-44 % for all other species. Capture rates for Whitaker's skinks were in addition strongly influenced by climatic conditions, and showed high within-season and between-season variability. Capture rates were highest in summer when nighttime air temperatures exceeded 15°C, but were depressed by high daytime surface temperatures. Most captures were in January and February (Towns in press).

Density

Whitaker's skinks occur at low densities on Middle Island, with numbers in different habitats ranging from 0.02-0.09/m2 (Southey 1985). Density estimates at Pukerua Bay were at the upper end of this range at 0.06/m^2, but these estimates were obtained where the lizards were at greatest abundance (Towns pers obs.).

Food requirements

Like most skinks, Whitaker's skink will ingest a wide range of invertebrates (Southey 1985), and also seem to be attracted to fish-based catfood when used as a bait for pitfall traps (Towns pers . obs.). At Pukerua Bay Whitaker's skinks were seen to eat large spiders, and on Korapuki Island maintained very good condition on a depleted invertebrate fauna of amphipods, isopods, spiders and millipedes. The association of this species with seabird burrows may mean that Whitaker's skink is to some extent a carrion feeder or feeds on material spilt by birds when feeding chicks.

Reproduction, productivity and growth rate

Mating of Whitaker's skinks occurs in spring and summer and young are born in autumn (Southey 1985). The number of young produced ranges from one to four, with most females probably producing two. There is some evidence that mature females may not reproduce annually (Southey 1985), but on Korapuki Island a high proportion of captured females have been pregnant (Towns pers. obs.). Males mature earlier (3 years) than females (4 years) (Southey 1985, Towns pers. obs.).

Robust skink

Habitats and habits

The robust skink is strongly nocturnal and has not been observed basking by day (Robb 1980, Southey 1985). During day-time it inhabits seabird burrows and root tangles or stays under logs, rocks or clumps of coastal vegetation such as *Dysphyma* (Robb 1980, Southey 1985). At night the skinks may be seen foraging on the surface under forest (Southey 1985). The robust skink is active throughout a larger part of the year than Whitaker's skink and seems to have a wider thermal tolerance (Southey 1985).

Density

Like Whitaker's skink, robust skinks do not occur at high density, with 0.03-0.08/m2 being reported by Southey (1985) on Middle Island.

Food

Robust skinks eat a wide variety of invertebrates. Any differences between this species and Whitaker's skinks can be accounted for by different sizes of the two lizard species.

Reproduction and growth

Mating of robust skinks appears to occur in summer and autumn (Southey 1985). Reproductive status of museum specimens examined by Southey indicates that females may not reproduce annually but has not been confirmed by populations in captivity. Up to five offspring can be produced (I. McFadden pers. comm.). Males take up to four years to reach maturity and females up to six years (Southey 1985).

Cutaneous water loss

Laboratory studies by Towns (1972) and Cree and Daugherty (1991) indicate that some *Cyclodina* skinks, including Whitaker's and robust skinks, are prone to high evaporative or cutaneous water loss. Cutaneous water loss rates recorded for Whitaker's and robust skinks are amongst the highest known for terrestrial reptiles. This characteristic helps explain their burrow and litter-inhabiting tendencies (high humidity environments), and also indicates why they are vulnerable to predation and habitat destruction (Cree and Daugherty 1991).

APPENDIX 2. METHODS FOR REINTRODUCTION OF *Cyclodina* SKINKS

The following notes are provided for guidance when translocation of *Cyclodina* skinks is being planned. Their use is based on the assumption that the planned translocation falls within DOC policy (see guidelines for transfer compiled by Protected Species Policy Division, see also Towns et al. 1990b) and has been worked through the checklist of questions provided by Atkinson (1990). The notes are directed towards options 2-4, but the possibility of additional locations becoming available should be recognised (see Table 2.1).

Introduction

Unlike birds, but like invertebrates, lizards may have limited mobility as well as physiological constraints that limit the kinds of location in which they are able to live. For example, individual Whitaker's skinks are highly site-specific (Southey 1985), and even animals translocated to Korapuki Island have shown only short-distance movements (< 20 m) from the release sites. There is also ample field evidence indicating that both robust and Whitaker's skinks have narrow thermal and moisture requirements. These characteristics need to be borne in mind when releases are planned and release sites are chosen. These notes elaborate on such considerations and add some others that should be addressed before a release is conducted.

Choice of population size at release

Theoretical population genetics, combined with an understanding of the ecological and behavioural requirements of the species, provides some guidance on the question of suitable population sizes to be used for release. For the Whitaker's skink programme, a starting population of 50 was used in designing computer simulations of possible release strategies (Towns et al in press). This minimum was derived from theoretical models, but these models were not developed in the context of establishing founder populations. A higher ideal figure of 80 was given by Griffith et al. (1989), in their review of the success of translocation programmes, whereas a lower figure of 40 is proposed by Craig and Veitch (1990) based on experience with New Zealand birds.

So far the Whitaker's skink release on Korapuki Island has consisted of a mass release of 25 and subsequent releases of only three of the remaining 25 proposed. Most authors agree that follow-up releases should be undertaken (e.g. Simberloff (1990). For *Cyclodina* skinks an initial release of at least 25 should either be followed by close monitoring to estimate breeding success and/or by subsequent releases of a further 25 spread over the time taken for adult females to reach maturity: four years for Whitaker's skink and six years for robust skink (Towns et al 1990b).

Choice of population structure

To estimate productivity required for successful release of Whitaker's skinks Towns et al (in press) developed a computer model which predicts rates of increase, changes in sex ratios and demography, given set mortality rates, sex ratios and productivity. The model requires some idea of growth rate and life expectancy, derived from data on the Pukerua Bay population (Towns 1985a). These data indicate that males mature at three years of age and

females at four, and studies of museum material suggest a probable litter size of 3-5 (Southey 1985). Taking the conservative option that females produce every second year, litter size per year is set at two.

Given those constraints, mortality of released adults can be set and a combination of "recipes" can be applied. With similar release regimes (30 adults in year 1, 10 adults per year for three further years), the model predicts that any regime involving a juvenile mortality > 60 % is likely to fail. This is despite maximum predicted longevity being 28 years at a 10 % adult mortality rate. Even moderate juvenile mortality (50 %) would lead to extinction if coupled with 20% adult mortality. If mortality can be reduced to 20% throughout the age classes (including newly released adults), the population will increase rapidly. Such a mortality rate would lead to a maximum life expectancy in any one cohort of 18 years. This life expectancy is reasonable in view of the Pukerua Bay data, where the minimum age of some animals is 7 years. It is also supported by known age recaptures in other New Zealand lizard species of similar size, some of which reach at least 17 years of age in wild populations (Anastasiadis and Whitaker 1987).

To achieve maximum productivity in the year of release the released population should be biased towards pregnant females, with the remainder of the population being males and 2-3 yr juveniles likely to become sexually mature in the following breeding season.

Choice of suitable sites for introduction

The only means by which a low mortality can be achieved, interactions with other species minimised and interactions between males and females of Whitaker's skink maximised is to insulate the released animals from all undefined or unmeasurable influences. A forested area on Korapuki Island, which closely resembled the microclimatic conditions and topography of the source locations, but which was occupied by few other lizard species, was therefore chosen for the release. Release sites can only approximate the conditions of the source area, and the final choice of most suitable microhabitat needs to be left to the released animals. For this reason it can be useful to release into an habitat interface, where by short distance movements released animals can occupy new environments. For example extensive areas of flax on Korapuki are not present on the source island (Middle Island), but lizards released on Korapuki in mahoe are now periodically occupying the flax areas nearby.

Aspect may also be important, and for Whitaker's skink, which sometimes basks, a warm, northwest-facing slope was chosen. Robust skinks, which do not bask in the open, may be released into more heavily vegetated areas.

Choices of suitable sites as a source for removal

For birds good reasons can be advanced to base translocations on existing flocks or socially integrated groups (e.g. Craig and Veitch 1990). This is not normally an important consideration for lizards. Instead, more may be gained in the long term by using animals from a wide area of the source population, by having multiple capture points. There are two reasons for this:

(a) It minimises the risk of the new population being established by a single family group, and eventually failing because of inbreeding depression.

(b) It maximises the extent to which individual variation in habitat use is incorporated into the new populations. Some microhabitats will be more suited to the learned requirements of particular individuals. Since the new microhabitats cannot exactly duplicate original ones, it is prudent to combine genetic variability with variability in habitat preference (see also Vrijenhoek 1989).

Choices for restoration of whole communities

Where restoration of entire reptile communities is proposed (e.g. Towns et al. 1990b, Towns and Atkinson 1991), the relatively slow growth rates of some species, and site specificity of others, can be used to advantage. There is no reason why several species cannot be reintroduced simultaneously as long as:

(a) They are known to co-exist elsewhere;

(b) Each species is released some distance from all others (100-200 m);

(c) Sites are chosen that are occupied by a low density of resident lizards with similar habitat requirements. For example, the forested areas of Korapuki Island still support a low lizard biomass five years after the rat eradication campaign because the resident lizards are still expanding into available coastal habitats (Towns 1991).

On small islands, such as Korapuki, introductions of species such as tuatara could threaten the rare lizards if the tuatara are introduced too early or in too close proximity. On larger islands, such as Stanley Island tuatara reintroductions are likely to take many decades before the animals are likely to have any impact on resident lizards. Lizard reintroductions should therefore be conducted early in the restoration process.

Species such as the tusked weta, which could be managed on the same islands as rare reptiles, have a far higher potential productivity than do lizards and a relatively short life cycle of less than five years (G. Sherley pers. comm. 1990). These species would also benefit from reintroduction early in the restoration process. By careful analysis of suitable sites and timing of reintroductions an array of compatible species could be established simultaneously on islands freed of rats.

Choice of models for Mercury Islands

Restoration of reptile communities in the Mercury Islands is likely to be influenced by:

(a) The small size of source populations;

(b) The need to maximise productivity of some key lizard species;

(c) The pending plans to eradicate kiore from islands where tuatara. populations are under threat.

For Whitaker's skink the source population can only be Middle Island. Over the short-term removal of about 50 lizards should have a negligible effect on the parent population (Towns, submission to Hauraki Gulf Maritime Park Board). However the prospects now exist to reintroduce the species to four islands over the next 10 years, which, if based on a minimum of 50 per release, could deplete the Middle Island population. On the other hand, Whitaker's skink is difficult to keep and has a low productivity in captivity. A solution may be to lower

the size of the released population to about 30, allow at least two years to elapse between each release and to define an end point beyond which further removal from Middle Island would stop and any further releases be based on a newly established source population.

There are fewer difficulties for robust skinks, for which breeding populations exist in captivity. However, none of the breeding populations originated from the Mercury Islands. They should therefore form the basis of new populations centred near the island of origin. In the Mercury Islands robust skinks occur on both Middle and Green Islands, and should be used for different host islands - the Green Island population for Korapuki and the Middle Island population for Double. Later release strategies could be developed as other locations become available in the island group.

The need to maximise productivity means that at some locations, such as Korapuki (and probably Double) it would be unwise to add the top predator - tuatara in the short term (if at all). Elsewhere, such as on Stanley and Red Mercury, there is a prospect of greatly increasing the area occupied by rare lizards while tuatara populations are in the process of recovering.

Choices in relation to other *Cyclodina* species

When defining recovery goals it is necessary to maintain sufficient flexibility to avoid conflicts with recovery options for related species. There may be up to six *Cyclodina* skinks that are rare or restricted in distribution (not all are described). In the light of possible future strategies, the present exercise has included a review of all rare *Cyclodina* skinks, identification of locations from which animals can be obtained for new populations, and consideration of the geographic areas into which they could go. A summary of possibilities is provided in Table 1.

Restrictions on which translocations will proceed will be set by previously established priorities, financial constraints and limits on the number of animals that can be removed from source populations. The recovery options defined in the present recovery plan identify where priorities should be placed for Whitaker's and robust skinks, but a similar exercise has yet to be undertaken for other species.

The most cost-effective approach to restoration that involves re-establishing lizard communities will be to plan, implement and monitor reintroductions of as many species as possible to the same location (island) over a relatively restricted timeframe rather than to attempt piecemeal translocations over several years. This approach would require co-ordination of complementary goals (such as recovery plans) for different groups of organisms at the same place.

Appendix Table 2.1. Summary of possible translocation strategies for *Cyclodina* skinks that are rare or restricted in distribution.

Species	Source	Host areas
Robust skink	Matapia, Moturoa	Northland islands as far south as but not including Cavallis
	Mercury Islands	Hauraki Gulf, other Mercury Islands, but not Aldermen
	Castle Island	Ohinau Islands
	to be determined	Mana Island
McGregor's skink	Cavalli Islands	other Cavalli islands
	Mana Island	islands in the Wellington area
	Sail and Bream Islands	Hen and Chickens Islands, Hauraki Gulf excluding those for Whitaker's skink
Marbled skink (common species)	Poor Knights	endemic to the area and should not be moved
	Hen and Chickens, Little and Great Barrier, Mercury Islands, Ohinau Islands, Aldermen	islands to be restored in close proximity to source, but not Mokohinau Islands
Marbled skink (Mokohinau species)	Stack H (Mokohinau Islands)	Mokohinau Islands now cleared of rats
Whitaker's skink	Middle Island	Mercury Islands but with later consideration of more northern locations
	Castle Island	Ohinau Islands
	Pukerua Bay	Islands in Wellington area if and when available
	to be determined	Bare Island

APPENDIX 3. STATUS AND BIOLOGICAL FEATURES OF ISLAND SITES OF WHITAKER' S AND ROBUST SKINKS

Location (Group): Matapia (Motupia)

Area: 2 ha
History: Robust skinks discovered by Anderson in 1986
Tenure: Maori Land
Vegetation: Lack of woody vegetation, low scrub of taupata *(Coprosma repens),* and *Cyperus ustulatus*, open areas covered by iceplant *(Dysphyma australe)*.
Birds: Black winged petrels.
Coexisting species of reptiles: Pacific gecko *(Hoplodactylus pacificus)*, *H. aff pacificus* (new species?), shore skink *(Leiolopisma smithi)*, robust skink.
Mammals: important northern hauling out site for fur seals *(Arctocephalus forsteri)*.
Security and long-term prospects: No management agreements or reserve status, believed owned by Te Aupouria tribe, difficult of access, birding?
References: Anderson (1986).

Location (Group): Moturoa Island (Moturoa Group)

Area: 9.5 ha
History: Long been identified as having high wildlife values, one of earliest known locations of robust skinks
Tenure: Maori Land
Vegetation: Taupata-Hymenanthera scrub, extensive iceplant.
Birds: Dense burrows, confirmed/probable breeding of at least five species of burrowing seabirds.
Coexisting species of reptiles: Pacific gecko, Suter's skink *(Leiolopisma suteri),* shore skink, ornate skink *(Cyclodina ornata)*, robust skink.
Security and long-term prospects: Threatened by activities on adjacent Whale Island and associated risk of rodent invasions, birding.
References: Adams (1971); Farley (1977); Hitchmough (1977); Miller (Undated (ca 1985)); Wright (1977).

Location (Group): Middle Island (Mercury Islands)

Area: 13 ha
History: Gifted to Crown by Ngati Karau, Ngati Whengaunga and Ngati Hako in 1971 and administered by Hauraki Gulf Maritime Park Board until 1990, when passed to Department of Conservation. Long identified as having high conservation values, site of intensive ecological study of robust, Whitaker's and marbled skinks (Southey 1985), and site of interisland comparisons by Whitaker (1973, 1978) and Towns (in press).
Tenure: Crown, Nature Reserve
Vegetation: Unique milktree forest, wharangi-mahoe forest and karo-taupata scrub.
Birds: At least 7 species of seabirds, dominated by diving petrels.
Coexisting species of reptiles: Tuatara, Whitaker's skink, robust skink, marbled skink,

copper skink *(Cyclodina aenea),* Suter's skink, shore skink, moko skink *(Leiolopisma moco),* Duvaucel's gecko *(Hoplodactylus duvaucelii),* Pacific gecko and common gecko *(H. maculatus).*

Other notable species: Endemic tusked weta

Security and long-term prospects: Fairly difficult of access, therefore relatively secure, but vulnerable to escape of rodents.

References: Atkinson (1964); Cameron (1990); McIntyre (1989); Southey (1985); Towns (in press); Whitaker (1973, 1978).

Location (Group): Green Island (Mercury Group)

Area: 4 ha

History: Gifted to Crown by Ngati Karau, Ngati Whengaunga and Ngati Hako in 1971 and administered by Hauraki Gulf Maritime Park Board until 1990, when passed to Department of Conservation. Long identified as having high conservation values, site of inter-island comparisons by Whitaker (1973, 1978).

Tenure: Crown, Nature Reserve

Vegetation: Wharangi-mahoe forest and karo-taupata scrub.

Birds: At least 7 species of seabirds, dominated by diving petrels.

Coexisting species of reptiles: Tuatara, robust skink, marbled skink, Suter's skink, shore skink, moko skink, Duvaucel's gecko, Pacific gecko and common gecko.

Security and long-term prospects: Fairly difficult of access, therefore relatively secure, but vulnerable to escape of rodents.

References: Atkinson (1964); Thoreson (1967); Whitaker (1973, 1978).

Location (Group): Castle Island

Area: 3 ha

History: Presence of robust skink known since 1972 and Whitaker's skink since 1980.

Tenure: DOC Stewardship, no reserve status; Customary Maori land

Vegetation: Pohutukawa forest

Birds: Dominated by small, burrowing seabirds including fluttering shearwater, allied shearwater and diving petrel.

Coexisting species of reptiles: Common gecko, Pacific gecko, moko skink, robust skink, Whitaker's skink.

Security and long-term prospects: No management agreements or reserve status, difficult of access.

References: Macredie (1984).

APPENDIX 4. ASSESSMENT OF POSSIBLE FUTURE SITES FOR WHITAKER'S AND ROBUST SKINKS

This list includes islands from which potential mammalian predators have been eradicated, or for which funds for eradication campaigns have been obtained.

Location (Group): Motuopao Island (North Cape).

Area: 30 ha
History: Previously occupied as a lighthouse station that has since ceased operation. Inhabited by kiore until 1990, when they were eradicated by DoC staff.
Vegetation: Widespread buffalo grass apparently hampering revegetation of native shrubs and trees.
Birds: Several species of burrowing seabirds, including diving petrel and black-winged petrel.
Coexisting species of reptiles: Shore skink, moko skink and copper skink. A 1.7 ha stack off the main island free of rats has Suter's skink, shore skink and Pacific gecko.
Tenure: Crown, currently designated as Nature Reserve. Under claim by Rununga O Muriwhenua. Has potential for management partnership.
Security and long-term prospects: Very high potential for restoration of lizard and invertebrate communities. Priority species - robust skink. At present at risk from illegal landings. High fire risk.
Other compatible species: Matapia gecko *(Hoplodactylus* aff. *pacficus.)*
Incompatible species: Tuatara (at least until lizard populations well established), insectivorous/carnivorous birds that may utilize lizards in the diet (e.g. robin, saddleback).
Current management: at present being managed for resident flax snails *(Placostylus a. ambagiosus)*. Potential impact of robust skinks on juvenile flax snails should be considered. Transfers could await development of large snail populations on the island.

Location (Group): Korapuki Island (Mercury Islands).

Area: 18 ha
History: Highly modified island previously occupied by kiore and rabbits. Kiore removed by DoC staff in 1986 and rabbits in 1987. Invertebrate fauna highly depleted. Whitaker's skink reintroduced in 1988.
Vegetation: Early reports of rough grass cover, by 1985 had regenerated to pohutukawa, mahoe and flax. Following removal of rats and rabbits coastal broadleaf species now regenerating naturally.
Birds: Eight species of burrowing seabirds, including diving petrel and fluttering shearwater.
Coexisting species of lizards: Duvaucel's gecko, common gecko, copper skink, moko skink, shore skink, Whitaker's skink (reintroduced).
Tenure: Crown, Nature Reserve.
Security and long-term prospects: Easy access, one escape of ship rats documented in 1988. Prospects for comprehensive restoration of lizard and invertebrate communities.
Other compatible species: Tusked weta, other local flightless invertebrates, Suter's skink,

Pacific gecko, robust skink, marbled skink (all species recorded within the island group).

Incompatible species: Tuatara (at least until lizard populations well established), insectivorous/carnivorous birds that may eat lizards (e.g. robin, saddleback).

Location (Group): Double Island (Mercury Islands).

Area: 32.5 ha

History: Relatively little modified island occupied by kiore until their removal in 1989.

Vegetation: Pohutukawa - mahoe and mature lowland coastal forest.

Birds: At least 7 species of seabirds, including Pycroft's petrel.

Coexisting species: Duvaucel's gecko, common gecko, copper skink, moko skink, Suter's skink, shore skink.

Tenure: Crown, Nature Reserve

Security and long-term prospects: Moderately difficult access. Prospects for comprehensive restoration of lizard and invertebrate communities. Priority species - Whitaker's skink, robust skink.

Other compatible species: Tusked weta, other local flightless invertebrates, Pacific gecko, marbled skink (species recorded within the island group).

Incompatible species: Tuatara (at least until lizard populations well established), insectivorous/carnivorous birds that may utilize lizards in the diet (e.g. robin, saddleback).

Location (Group): Stanley Island (Mercury Islands)

Area: 100 ha

History: Severely modified and inhabited by kiore and rabbits until 1991. Saddleback introduced in 1977. Relict near extinct population of tuatara discovered in early 1980s.

Vegetation: Pohutukawa and mahoe but remnant coastal broadleaf forest.

Birds: Probably up to 8 species of burrowing seabirds including Pycroft's petrel.

Coexisting species of lizards: Duvaucel's gecko, common gecko, copper skink, moko skink, shore skink.

Tenure: Crown, Nature Reserve

Security and long-term prospects: Easy access. Very high potential for restoration of invertebrate and reptile communities and rehabilitation of tuatara. Priority species - Whitaker's skink and robust skink.

Other compatible species: Pacific gecko, marbled skink, Suter's skink (all species recorded within the island group). Tuatara should be compatible with these because the island is very large and tuatara numbers very low (<20).

Incompatible species: Large insectivorous/carnivorous birds

Location (Group): Bare Island

Area: 13.5 ha

History: Norway rats eradicated by DOC in 1990.

Vegetation: Mostly flax but occasional patches of coastal shrubs.

Birds: Little blue penguins and sooty shearwaters.

Coexisting species of lizards: at least one gecko and two species of skink (identity uncertain).
Tenure: Maori Land.
Security and long-term prospects: Reasonable access in good weather. High potential for reptile and invertebrate species. Priority species: Whitaker's skink.
Other compatible species: To be investigated.
Incompatible species. Predatory birds.
Future action: Need assessment for potential as site for Pukerua Bay population of Whitaker's skink. Available habitats more suitable for this species than for robust skink, although both benefit from well developed forest cover (lacking at present).

Location (Group): Mana Island

Area: 217 ha
History: Previously farmed, extensively modified, and occupied by mice. Mice eradicated in 1988-89. Evidence of locally extinct robust skinks found during midden analyses.
Vegetation: Regenerating scrub and rank pasture with a small area of coastal kanuka/milktree forest. Extensive planting of seral vegetation underway.
Birds: Little blue penguins and sooty shearwaters.
Coexisting species of lizards: Common gecko, gold-striped gecko *(Hoplodactylus chrysosireticus),* McGregor's skink *(Cyclodina macgregori),* copper skink, common skink *(Leiolopisma nigriplantare polychroma).*
Tenure: Crown, DoC Scientific Reserve.
Security and long-term prospects: High potential for restoration of reptile and invertebrate species.
Priority species: Robust skink.
Other compatible species: To be investigated, but potential for tuatara reintroductions after establishment of lizard populations.
Incompatible species: some large birds such as weka (e.g. Atkinson 1990).
Future action: Needs assessment for potential as site for a southern population of robust skink. The species would benefit from well developed forest cover (lacking at present), but eventual release of captive-bred robust skinks could be planned for this location subject to assessment of potential conflict with other objectives (e.g. management of bird populations, recovery of McGregor's skink). If successful would recreate a lizard assemblage with species composition no longer found elsewhere.

APPENDIX 5: IMPACT ASSESSMENT.

Introduction

Successful achievement of recovery targets will depend on the eradication of kiore from some islands additional to those from which eradication is completed or underway. The targets rely also on removal of rabbits from Stanley Island. Most concern over meeting these targets is likely to centre on kiore and the following assessment has focused on this species. Comments are also provided on the potential impact of releases of Whitaker's and robust skinks on resident lizard species.

Distribution of kiore

Kiore are not native to New Zealand (contrary to Barnett 1985), but were introduced to the country with the arrival of Polynesians about 1000 yr BP (Davidson 1984). Kiore are distributed throughout South-East Asia, the Indo-Malayan area, the Pacific islands and some islands of the Indian Ocean (Atkinson and Moller 1990), making the species one of the world's more widely distributed rats (Wodzicki and Taylor 1984).

Kiore were used as food by Maori, and there have been suggestions that these rats were intentionally introduced to islands by Maori as food. However, analysis of distribution of kiore relative to island habitation patterns led Atkinson (1986) to conclude that their dispersal in pre-European times was accidental rather than purposeful. There is usually an assumption that present kiore distribution patterns resulted from pre-European activities, but kiore have been dispersed between islands as recently as 1977 (McCallum 1986). Additional post-European distributions of kiore could have occurred.

As of 1986 kiore occurred on at least 33 islands around northern New Zealand (north of East Cape) (Atkinson 1986), and many additional islands around Cook Strait, on Stewart and some of its satellite islands (including Codfish Island) and on the South Island in Fiordland (see also Atkinson 1978). So far kiore have been eradicated /probably eradicated from five small northern islands: Rurima (6 ha), Korapuki (18 ha), Double (32.5 ha), Motuopao (30 ha) and Stanley (100 ha). These eradications were conducted between 1984 and 1991.

Effects of kiore on lizards

The reasons for incompatibility between kiore and some lizards are not clear, but there is widespread agreement that some species are particularly vulnerable to the presence of kiore - either kiore on their own or coupled with habitat disturbance (e.g. Whitaker 1978, Towns et al . 1985, McCallum 1986, Craig 1986, Towns 1991). Amongst the most vulnerable lizards are the large ground-dwelling species in *Cyclodina* (Whitaker 1978, Towns et al . 1985, Towns in press). The recovery plan for two of these *Cyclodina* species, Whitaker's skink and robust skink, requires eradication of kiore from at least two islands within five years (Stanley and Red Mercury), and may require eradication of kiore from a few additional islands in the longer term. The effect of these operations on the total kiore population will be negligible.

Impact of proposed eradications on total kiore population

Following the eradications already completed, kiore remain on 29 islands in northern New Zealand. Some of these islands are very large, including Mayor (1311 ha), Raoul (3000 ha), Little Barrier (3083 ha) and Great Barrier (27 761 ha). The combined area of islands occupied by kiore in northern New Zealand up to 1986 was about 38 000 ha, and in southern New Zealand (including Kapiti Island, but excluding Fiordland), was 180 000 ha. The reduction of area occupied resulting from previous eradications is 0.2 % of the area occupied on the northern islands. This recovery plan if implemented to include all long term options could result in the removal of kiore from up to 4 additional islands, some of which are also proposed in the tuatara recovery plan (Cree 1990). The total area involved could reach 450 ha (including eradications already conducted), and a reduction of northern islands occupied by kiore from 33 to 25 (total). This would reduce the area occupied by kiore by 1 % in northern New Zealand and by 0.2% of the national range, although other proposals could further reduce this range (e.g. Cree 1990). A statement by the Department about long-term effects on kiore of all management projects would encourage greater understanding of the need for some eradication campaigns (e.g. Jones 1992).

Impact of releases of skinks on resident lizards

All proposed releases are within the existing range of Whitaker's and robust skinks, and in some cases are supported by midden material that indicates that the lizards were there in the past (e.g. robust skinks on Maria Island). Both Whitaker's and robust skinks are forest inhabiting species now missing from most islands with introduced rodents (e.g. Towns in press). Where rodents are absent these species coexist with many resident species of lizards. With the exception of Mana Island, none of the proposed reintroductions would create combinations of species unknown in the wild.

Conclusion

Whitaker's skink and the robust skink once probably occupied much of lowland coastal southern North Island, and most of northern North Island (see Worthy 1987b). As a result of predation by introduced mammals, including kiore, the range of each species of skink has been reduced from several million ha to less than 50 ha. Proposed eradications of kiore in northern New Zealand will have a negligible impact on the total kiore population, but a highly significant reduction in vulnerability of the Whitaker's and robust skink as well as restoration of lizard and invertebrate communities that have become restricted in area.

Because Whitaker's and robust skinks are forest-inhabiting species, their reintroduction to islands freed of rodents will have little impact on resident lizards, many of which tend to be concentrated in coastal open areas.

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