# **Feasibility Plan to Eradicate Common Mynas (*Acridotheres tristis*) from Mangaia Island, Cook Islands**

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## Summary


Common mynas (*Acridotheres tristis*) have been introduced (often as a biocontrol for insects) or colonised many islands in the Pacific. They are one cause of decline in some native bird species such as endemic kingfishers, and are a pest when they damage fruit and compete for food put out for domestic animals. The Taporoporoanga Ipukarea Society (TIS) of the Cook Islands proposes to eradicate mynas from Mangaia Island (5180 ha) to protect kingfishers and commissioned this study to determine whether this is feasible and what would need to be done to reduce the risks of failure or overcome constraints during such an attempt. The Pacific Invasives Initiative supported this study partly because of the potential biodiversity and societal benefits to Mangaia, but partly to act as a demonstration for the management of mynas on other islands.

The report concludes that eradication of mynas is justified and technically feasible. Three operational phases are likely to be required. The first is on initial knockdown that targets all mynas using toxic baits. The second phase would involve locating and killing survivors of the initial knockdown using a variety of control tools. The third phase requires ongoing surveillance (and reaction if required) until it is clear no mynas remain. The first phase would be conducted over about 2 months during winter. The second phase should be planned to end before the following winter, and the third phase will depend on whether this succeeds. The attempt would be novel at this scale, and so has an unresolved element of technical risk. These risks of failure or of adverse consequences are identified and ways suggested to minimise them. Constraints on the use of the preferred technique for the initial phase – the use of an avicide called DRC1339 – are identified as largely the risk to non-target domestic animals such as chickens, and these can be avoided. It is estimated that the costs to achieve eradication with appropriate levels of monitoring would be about NZ$100,000.

Two risks remain to be resolved. First, while the Mangaia Resource Council has approved the development of this feasibility plan and initial surveys of where mynas roost, they will need to give their final consent to proceed once they have seen the plan. There was general, although not unanimous, community support to get rid of the mynas expressed at preliminary meetings on the island.

Second, there is an unresolved risk from the lack of experience in bird control and in large-scale project eradication project management by the TIS. This can be resolved by including appropriate technical advisors in the project delivery team, along with TIS and local people. A cause of many past failures to eradicate pests from islands when even the best method fails to kill 100% in the initial control effort has been lack of commitment and a process to deal with survivors. Sustaining a presence on the island by TIS staff (they live in Rarotonga) may be difficult during this secondary phase of the operation.

# 1. Introduction

Mangaia Island (5180 ha) is the second largest island in the Cook Islands. It is located 200 km from Rarotonga and has a population of about 700 people. The island is a makatea (raised coral reef) but is interesting because the original volcano has remerged in the past and provided rich volcanic soils amid the fossil coral.

Common mynas were first introduced to Mangaia in the early 20$^{th}$ century but did not establish invasive populations until a major release of birds from Rarotonga, made in 1964 in response to the damage to coconuts by a stick insect (*Graeffea crouanii*).

Common mynas (*Acridotheres tristis*) and their cousins the jungle myna (*A. fuscus*) are native to India but have been introduced or subsequently invaded many countries (Long 1981; Lever 1987) including many islands in the Pacific (Appendix 1).

Despite earlier support for mynas as a means of biocontrol of insect pests and a perception that, at least in some cases, the birds may have controlled the insects, mynas today are generally seen throughout the Pacific at best as a nuisance and at worst as a serious pest. Common and jungle mynas continue to expand their range either naturally (Upolu to Savai'i) or by hitching rides on ships (Upolu to Fakaofo). The common myna is listed as one of the world's worst invasive species (IUCN 2000), and several island states with mynas have expressed a desire to eradicate or control them. However, this is easier said than done!

The Pacific Invasives Initiative (PII) received three proposals to eradicate mynas: one to eradicate a very recent introduction of a few birds on Fakaofo Atoll in the Tokelau Islands (the birds turned out to be jungle mynas), one to eradicate the recent arrivals of both species (?) on Savai'i Island in Samoa, and one to eradicate common mynas from Mangaia Island in the Cook Islands. It was decided to develop feasibility plans for the easiest case for Fakaofo (a small atoll with only a few birds) and for a difficult case (a large area and many birds) for Mangaia. Savai'i is more complicated because of the ongoing invasion from Upolu with water gaps of only a few kilometres between the two islands. Eradication on Upolu (111 400 ha) and Savai'I (182 100 hs) would be highly unlikely to be considered if the attempt on Mangaia did not proceed or did but failed.

The Taporoporoanga Ipukarea Society (TIS) of the Cook Islands proposed a project to the PII for Critical Ecosystem Partnership Fund (CEPF) funds to protect the tanga'eo, the threatened endemic Mangaian kingfisher (*Todiramphus* (*Halcyon) rufficollaris*) from the common myna on Mangaia Island. This project relates to the Cook Islands National Biodiversity Strategy and Action Plan and the priorities identified (ranked as medium) at a workshop held in Apia, Samoa, in 1999 (Sherley & Tiraa 1999, unpubl.).

The PII project development process requires (a) an analysis of the problem and the feasibility of the proposed solutions and (b) the development of a detailed project design if the project is assessed as being feasible. Together these plans underpin bids to the funding agencies to achieve the proximal goals – management of the pest – that would lead to the ultimate goals – protection of biodiversity and sustainable societies.

This report aims to complete the first of these planning functions: an assessment of the need for management action and the feasibility of eradication and consideration of the tactical (what methods are required and acceptable) options and their inherent risks and constraints. We foreshadow now that we think eradication is feasible but we will identify some unresolved risks that will have to be addressed either by preliminary trials (which would not necessarily need to be done on Mangaia) or during the initial phases of the operation. The second aim, the project design, is also provided in this report, but with some costs that are contingent upon the resolution of these risks and on the progress of the operation when some of the risks can only be resolved by the operations itself, e.g. the time taken to achieve various phases of the campaign.

## 2. Methods

The TIS visited Mangaia to consult with the Mangaia Resource Council in May 2006 to assess their views on mynas and their control. The Council is a group of traditional leaders, ministers of the local churches, and Government representatives who have responsibilities to assess and approve resource management issues on Mangaia. They were supportive of the process to conduct a feasibility study and facilitated the involvement of local students in roost surveys (see below), but of course had not seen the details of this report and indeed raised several of the issues addressed here.

With the approval of the Resource Council, the TIS also employed a youth coordinator, who organised a survey of myna roosts (many birds flock to common roost sites during the non-breeding season in winter, and it was thought they might be targeted there for control). Mangaian senior school students were employed to find and record the GPS position of roosts.

The PII feasibility study team (John Parkes, Bill Nagle) along with TIS (Ian Karika, Ewan Cameron) and the Cook Islands Natural Heritage Trust (Gerald McCormack) visited the island from 10 to 21 June 2006. They were joined on 17–19 June by James Atherton of Conservation International, Apia, Samoa. The purpose of the feasibility trip was (a) to complete this assessment and to consult again with Mangaians on their level of engagement with the project, particularly on whether they wanted to eradicate the mynas, the social acceptability of potential control methods, and on general constraints on where acceptable methods might be used to avoid non-target animals or for human safety reasons, and (b) to explore the technical feasibility and methods for eradication.

Some preliminary non-toxic baiting trials using boiled rice were conducted during the visit to see if birds could be attracted to baited sites near villages and near roosts, and the best time of day to achieve this.

# 3. Impacts of Mynas

## 3.1 Impacts on native animals

There is much anecdotal evidence that mynas affect hole-nesting birds by competition for nest sites when these are scarce, by aggressive behaviour at nest sites (Rowe & Empson 1996), and from inter-specific territorial defense that is sometimes instigated by the mynas and sometimes by the other species (Pierce 2005). Mynas are also predators on other birds (Armstrong et al. 2000; Heather & Robertson 2000). However, the effect of these aggressive encounters on other animals at population levels, as well as the affects of direct competition for food, are unknown.

Mynas may also have direct impacts on the invertebrates they eat, but there is no information on these effects.

Few studies give objective measures of the effect of mynas on other birds. Common and jungle mynas were introduced to Tutuila Island in American Samoa in the mid-1980s and are now common in the settled and agricultural areas. Freifeld (1999) counted birds at 57 permanent stations between 1992 and 1996. At the 16 stations where mynas were counted (the two species were pooled) collared kingfishers (*Halcyon chloris*) were significantly more common at sites with fewest mynas (Fig. 1). The kingfisher occurred at all sites but there was no significant difference in the mean counts at sites with mynas ($\bar{x}$ = 0.524 ± 0.03) or without mynas ($\bar{x}$ = 0.636 ± 0.02) ($t$ = 2.00, $P$ = 0.15).

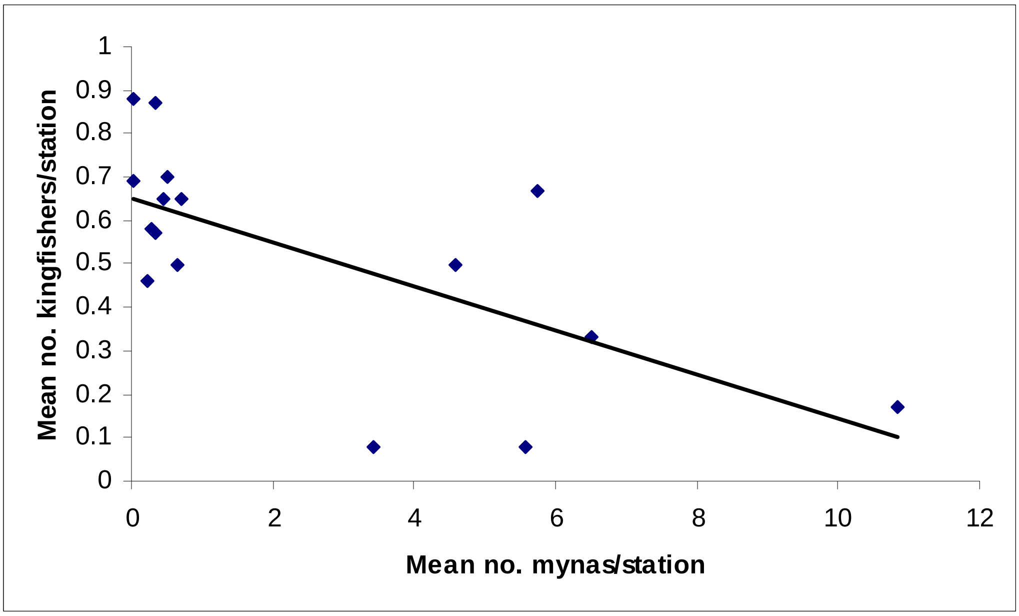


**Fig. 1** Relationship (linear regression) between myna and kingfisher abundance at sites with mynas on Tutuila Island, American Samoa (data from Freifeld 1999).

On Tahiti more mynas (and red-fronted bulbuls (*Pycnonotus cafer*)) were present in Tahitian flycatcher (*Pomarea nigra*) territories where the flycatchers failed to raise chicks than in territories where the flycatchers were successful (Blanvillain et al. 2003).

Mynas destroyed 23% of wedge-tailed shearwater (*Puffinis pacificus cuneatus*) eggs and chicks on Kauai Island, Hawaii (Byrd 1979), and are known to prey on the eggs and young of terns (*Sterna* spp.) and noddies (*Anous* spp.) in Fiji (quoted in Lever 1987).

On Mangaia Island mynas are very common (many thousands judging by the number of roost sites found (21) and the number of birds counted in a few roosts (see p.13)) while the local perception of the tanga'eo is that it is declining (e.g. Holyoak & Thibault (1984) and local residents' view reported in Rowe & Empson (1996). However, the various surveys of kingfisher numbers conducted since 1973 are too imprecise, even when similar methods are used, to provide any measure of a trend in numbers (Table 1).

**Table 1** Estimated numbers of kingfishers on Mangaia Island in surveys conducted since 1973.

| Year | Estimate | Range | Method | Reference |
|---|---|---|---|---|
| 1973 | | 100–1000 | Guess | Holyoak (1980) |
| 1984 | | 100–300 | ? | Steadman (1985) |
| 1990 | < 200 | | ? | Steadman & Kirch (1990) |
| 1992 | 409 | 300–500 | 5-minute counts | Rowe & Empson (1996) |
| 1996 | 576 | 390–760 | Distance transects | Baker (1996) quoted in McCormack, unpubl. notes |

In 1992, using 5-minute bird counts, the population was estimated at between 250 and 450 birds (Rowe & Empson 1996). In 1996, using distance-transect methods, the population was estimated at 580 ± 180 (80% CL) birds (Baker 1996 quoted in McCormack unpubl. notes). A resurvey of one habitat type in 1997 showed no significant change in numbers; 218 in 1996 and 175 in 1997. Clearly these surveys have little power to detect trends in numbers, but the distance-transect methods are probably the most accurate, although imprecise.

Diagnosing the cause of any real or potential decline in Managian kingfishers is not simple – mynas and rats would be the prime suspects, but other less-obvious and less-manageable causes cannot be ruled out. Most management experiments that have shown increases in native birds after myna control are confounded by concurrent control or eradication of rodents (e.g. on Moturoa Island in New Zealand; Tindall 1996).

## 3.2 Mynas as vectors of weeds and diseases

Mynas are also the likely agent in the spread of several exotic weeds on Mangaia. Red passionfruit, chillies, and pawpaw are all eaten by mynas and are spreading through the island. The passionfruit is an invasive weed. Elsewhere, mynas spread the serious invasive weed *Lantana* spp. (Lever 1987).

Mynas are known vectors of avian malaria in Hawai'i.

### 3.3 Impacts on people

Mynas are basically a nuisance to people. They invade houses in search of food, they nest in eaves of houses and thus contaminate the water supply, they nest in telecommunications systems, and they compete for food put out for pigs and chickens – flocks of 20+ birds were seen at some pig sties during feeding time and these birds must be taking a significant proportion of the food put out for pigs.

For some people, mynas are more than just a nuisance as they can restrict options for growing crops such as pawpaws and tomatoes for commercial sale in local markets (Fig. 2). The cost of this is unknown but was raised as an important issue at the island meeting held on Mangaia.

**Fig. 2** Myna damage to pawpaws, Mangaia. June 2006 (Photo: Bill Nagle).

## 4. Feasibility of Eradication

### 4.1 Lessons from past attempts

Common mynas have been eradicated at very small scales, but other attempts at even modest scales at places with higher numbers of birds have failed (Table 2). Thus there is no proven ‘recipe’ for success we can follow.

**Table 2** Attempts at eradicating common mynas from islands.

| Island | Area (ha) | Method | Outcome | Reference |
|---|---|---|---|---|
| Cousin | 27 | Nest trapping and shooting | Eradicated: 4 shot, 1 trapped | Millett et al. (2004) |
| Aride | 63 | Shooting | Eradicated: 16 shot | Lucking & Ayrton (1994, unpubl.) |
| Denis | 143 | DRC1339 and shooting | Failed: stopped when nuts invaded | Millett et al. (2004) |
| Fregate | 219 | Shooting | Failed: 1015 shot | Feare et al. (1994); Millett et al. (2004) |
| Nuku Hiva | | ? | Introduced in 1971 but 'killed shortly afterwards' | Lever (1987) |

To be feasible, eradication must be both technically possible and socially acceptable. However, it is important to ask these questions in the right order. People may well want to eradicate a pest, but if it is not technically possible this wish is unrealistic and may preclude other positive options to manage the problem (e.g. see Parkes 1989). Conversely, although a project might be technically possible, unless key decision-makers want to eradicate the pest, it is unlikely to proceed.

## 4.2 Feasibility planning

Eradicating invasive alien species requires: a social agreement that action of an appropriate sort is required, the tactics and tools to achieve the goal, the logistics and trained people to do it, and a system to know when to stop and declare success, change the strategy to sustained control, or give up. However, pests are not inert and present some biological rules that all have to be met before eradication is feasible, even if everyone wants to do it.

One aim of PII projects is to generate awareness of invasive species impacts among Pacific Island communities, management agencies and other stakeholders, and to gain support for their management. Therefore, even if technically feasible, this project will need to fulfil all or some of these aims. These issues are discussed in section 6.

### Biological rules that must be met

To achieve eradication three conditions must be met (Hone et al. in press):

- There must be no immigration (accidental or intentional) of birds that breed.
- There should be no net adverse effects on other species or communities being conserved. In practice this means no unacceptable or unmanageable downside from either the control methods themselves or as an ecological consequence of removing the mynas.
- In source populations the average long-term rate of removal must be greater than the annual intrinsic rate of increase. In practice this means that all mynas must be at risk and killed faster than they can replace their losses – the quicker it's done, the cheaper it will be.

Bomford & O'Brien (1995) noted some extra rules that, although not obligatory, should be met to increase the chance of success:

- Animals should be detectable at low densities. In practice this requires that there is 100% probability that any surviving myna is detectable. This is usually not possible so some analysis of the risk of being wrong (and falsely declaring success) needs to be built into the plan.

- Benefits should outweigh the costs. In practice this is difficult to measure for biodiversity values – how much are kingfishers worth compared with the costs of eradication?
- The goal and methods should be socially acceptable. In practice Mangaians must want to get rid of the mynas and must approve the methods used to do so.

**Probability of immigration**

The probability of immigration of new mynas, should the current population be eradicated, is unknown, but is probably low and certainly manageable (see section 8.5). Mynas are known to hitch rides on ships so it is possible that new birds might arrive with regular shipping from Rarotonga. Of course this might already have happened and the immigrants just absorbed into the population without being noted. For example, it is claimed that there were still a few mynas on Mangaia just before the 1964 introduction and that these were survivors of the 1906 liberation. It is more likely that they were more recent immigrants as it seems unlikely that the earlier introduction would have persisted for half a century without becoming invasive and remaining obvious.

This is a wider issue than just for Mangaia and the options to manage it are to be proactive at the source and either eradicate the birds (not likely for Rarotonga) or ensure there are none on board when the ship leaves, or to be reactive and make sure any new birds that arrive are killed before they can disperse and establish, or a bit of both. The optimal action depends on the frequency of immigration events, the costs of the remedial action, and the costs of failure (e.g. see Fraser et al. 2003).

The chance of deliberate reintroduction of mynas to Mangaia should the present population be eradicated is likely to depend on the response of the stick insect to the absence of mynas and of people to that event should it occur (see below).

**Adverse effects of eradication**

The only potential adverse flow-on effect of the removal of mynas (as opposed to effects of the methods used to do so) would appear to be the possibility that the coconut stick insect would irrupt and cause unacceptable damage to coconuts. This issue was raised by one participant at the community meeting.

The stick insect has been of ‘sporadic importance’ in the Pacific (Paine 1968; Kamath 1979) and are currently a severe problem on Taveuni and in parts of Vanua Levu in Fiji – despite the presence of mynas on both these islands. Attempts at biocontrol using parasites appear to have had variable success (O’Connor et al. 1955; Paine 1968). The wasp, *Paranastatus verticalis* parasitises stick insect eggs and can kill up to 80% of the eggs (Waterhouse & Norris 1987), but it appears that natural populations of the wasp are too low to limit stick insect irruptions and mass-rearing and release of the wasps may be required for sustained control of the pest. A trial to test this method in Fiji has been proposed to the FAO.

Mechanical control of the hatched nymphs as they ascend palm trunks can ameliorate damage (O’Connor et al. 1955) – presumably for a limited number of key palms.

If damage to coconuts from stick insects is an issue with Mangaians, it could be tested by excluding mynas from a sample of coconut trees, using bird netting, and seeing if the insects did increase to unacceptable levels in comparison with a non-netted set of trees.

### Can all mynas be put at risk?

Mynas are intelligent, social and mobile birds – all characters that present both problems (they can learn to avoid control) and opportunities (they may flock to roosts or be attracted to feeding sites) in an attempt to place them all at risk.

The optimal aim would be to kill all mynas during a single operation (which might require a single control event or repeated control events over a set time frame of perhaps days but more likely many weeks (= primary control). However, it may be that it is impossible to kill 100% of mynas in a single operation and that survivors will have to be detected and killed by ongoing or new control methods (= secondary control).

There are two (not necessarily exclusive) control strategies that might separately or together put 100% of mynas at risk – essentially ‘we can go to the mynas’ and kill them at or near their roost sites or with widespread application of control, or ‘the mynas can come to us’ where we might attract them to feeding and baiting sites independent of their roosts. We now spend some time exploring the advantages and disadvantages of these two options with respect to the chances that either will get 100% of the birds and the non-target and social constraints inherent in each.

*1. Roost sites:* A survey of Mangaia carried out by local students in May and June 2006 identified 21 roost sites. These locations have been recorded using GPS and are held by the TIS.

Mynas appear to group together into small flocks during late afternoon, especially around pig sties when the pigs are fed in the late afternoon. They then appear to group in trees in the vicinity of the roosts, with much calling and social behaviour until they fly off to their roosts generally c. 20 minutes before nightfall. We counted 120 mynas flying into one roost where the main flight path was visible.

We also watched roosts from about 30 minutes before dawn until about 0700 hours. Birds were awake and calling before dawn and then as the day lightened they flew out in pairs or small groups and rapidly dispersed away from the roost. They often flew off some distance and perched in trees until about 0745 hours before beginning to feed on the ground in pairs on the inland roads but with up to 20 birds at some sites in the villages.

Two questions arise – do all mynas go to roost sites and can all (or most) mynas at all roost sites be killed? If the answer to either question is no, then either widespread baiting or the ‘bring the mynas to us’ strategies would be the preferred options for primary control.

Do all mynas go to roost sites?

It appears that not all mynas use the roosts at least on some nights. Pre-dawn activity was noticed at places away from the known roost sites (G. McCormack, pers. comm.). We do not know what proportion of birds do not go to roost sites on any night or if some never go to roosts. A referee for this report suggested that some adult birds remained and roosted in their territories even outside the breeding season. We also do not know if non-territorial birds continue to use roost sites during the breeding season.

There is some evidence that the removal of food reduces the size of roosts in urban areas (Yap et al. 2002). Thus it is possible that feeding near roosts might bring more birds to the roost.

Can all mynas at all roost sites be killed?

Application of poisons in sticky gels to roost or nest sites is used to control pest birds such as rooks in New Zealand (Dave Hunter, Target Pest, Christchurch, pers. comm.). We do not think it would be possible to do this from the ground beneath the roost sites as many are in inaccessible places along the internal makatea cliffs (Fig. 3) – which also rules out shooting the birds at night with the aid of a spotlight or night-vision scope. Shooting would also induce wariness, and (as noted by a referee) mynas will become active at night if disturbed. An option would be to spray the toxic gel from above from a small helicopter, but we did note that non-target birds (kingfishers, tropic birds (*Phaethon lepturus* and *P. rubicaudata*), white terns (*Gygis alba*) and the Cook islands reed warbler (*Acrocephalus kerearako*) were present in or near some roosts and so would be at risk from such a tactic.

Baiting with boiled rice on roads near the roosts did not attract birds dispersing in the morning, and their behaviour suggests that this would not be improved with more baiting or with call birds or taped feeding calls.

Baiting with boiled rice near roosts in the evening did attract birds flying in to their roosts. At one large roost only a few birds fed on the bait (laid c. 150 m away from the roost) but the bait was laid late in the afternoon when many birds were already in the roost. Second and third trials laid the bait closer to the roost in mid-afternoon before any birds were at the roost. These were more successful with up to 50 birds being counted feeding at the baited site at any one time.

**Fig. 3** Internal cliffs of the makatea on Mangaia (Photo: John Parkes)..

*2. Other sites to which mynas can be attracted:* It is clear that most mynas are seen around settled areas, presumably because of the food supplied by human activities, at pig sties, and along the road edges. No birds were seen on the ground within forested areas on the makatea or in the interior (although a few mynas were heard in the canopy in the makatea). Thus one option is to lure all/most mynas to relatively few sites, near roots or pig stys with extensive (perhaps several weeks) pre-baiting and poison them there (see section 6.2).

We regularly baited one strip of road verge near Oneroa village but only appeared to attract the local birds (a group of c. 20) to the bait (Fig. 4).

**Fig. 4** Local group of mynas attracted to pawpaw, coconut, and boiled rice baits, Babe's motel, Mangaia (Photo: Bill Nagle).

# 5. Control Options

## 5.1 Review of options

Pierce (2005) has reviewed the techniques available to control mynas – basically poisoning, shooting, netting and trapping. He recommended the toxin DRC-1339 (Starlicide®) over other registered toxins such as alpha-chloralose, shooting and some traps under specific circumstances.

## 5.2 Primary control – poisoned baits

It appears that only the use of poisoned baits is capable of killing a high proportion of mynas in a limited time.

Spurr & Eason (1999) reviewed over 15 registered and unregistered (and illegal) avicides and concluded that the surfactant PA-15 (Tergitol®), which is used as a wetting agent, when sprayed on birds that then die of hypothermia probably presented least non-target risk but is inhumane, while alpha-chloralose was humane but neither it nor PA-15 might be effective in warm climates. Alpha-chloralose apparently induces taste-aversion in mynas when used at effective concentrations in the tropics (C. Feare, pers. comm.). Birds poisoned with alpha-chloralose and another toxin, 4-aminopyridine (Avitrol®), also present symptoms that may reduce the acceptance of baits by the rest of the target flock – an important constraint when dealing with a smart social bird such as the myna.

**Toxin of choice**

On balance, the toxin of choice appears to be DRC1339 (Starlicide®).

Use of pesticides in the Cook Islands is regulated under the Pesticides Act 1987. Unless used for scientific trials or evaluation, all pesticides must be registered and a permit to import must be obtained before the toxin can be imported.

DRC1339 is not registered in the Cook Islands (N. Ngatoko, Dept of Agriculture, Rarotonga, pers. comm.). A process to register it and gain permits to import the toxin will need to be initiated if the eradication project is to proceed.

DRC1339 is registered for use against birds in New Zealand (Agricultural Chemicals Board 1977) and the USA, and is being registered in Australia (J. Dawes, Postat Ltd, pers. comm.).

The active ingredient, 3-chloro-p-toluidine hydrochloride, is a pale yellow soluble powder (Timm 1983) that is relatively unstable and easily degrades to non-toxic compounds – so that baits lose their efficacy after 3 days in the field (Lilleboe 1996). It is highly toxic to most birds and freshwater invertebrates, but only moderately toxic to mammals and freshwater fish. There are no data for mynas but for starlings the $LD_{50}$ is around 4 mg/kg: for Norway rats the $LD_{50}$ is 1500 mg/kg. A myna weighs 126 g for males and 114 g for females (Telecky 1989). The usual way to use the toxin is to mix non-toxic bait with about 10% of baits that each contain a lethal dose. Generally, a 2.5-g sachet of DRC-1339 is mixed with 1 kg of bait (B. Simmons, pers. comm.). The toxin can be surface coated on boiled rice, and it helps to add a little icing sugar to the mix to mask any taste – the toxin is bitter to mammals although birds are not supposed to be able to taste it. An alternative method is to use 130 ml of a 7.5% solution of DRC-1339 on 1 kg of bait (New Zealand Food Safety Authority 2002).

The toxin is readily absorbed through the gut into the blood and is metabolised in the bird's liver within 3–24 hours (Ramey et al. 1994). Only 10% of the DRC1339 remained in starlings dosed with a large dose of 100 mg/kg after 30 minutes (Cunningham et al. 1981), and the metabolites are excreted if the bird is still alive so the toxin does not accumulate in the body to any extent. This means there is low risk of secondary poisoning of predators or scavengers that eat poisoned mynas. For mynas (and starlings) birds usually die in a coma within 48 hours after eating a lethal dose, and often at their night roosts (Millett et al. 2004).

Symptoms include listlessness, inactivity and slightly increased breathlessness. Death is non-violent and without spasms, which is important if birds learn to avoid baits that have made their fellows ill, and appears humane (DeCino et al. 1966).

Oral toxicity to humans is probably low, but as little is known about its effects on the skin or when inhaled, people using the toxin should wear gloves, overalls and a face mask, especially when preparing bait. An education campaign in the schools and with parents would be needed to ensure children are aware of the baiting.

DRC-1339 can be purchased from Animal Control Products, 408 Heads Rd, Wanganui, New Zealand, at a cost of $9.80 for a 2.5-g sachet.

Note: Pestat, a spin-off company from the Australian Pest Animal Cooperative Research Centre, is registering Starlicide in Australia (Lapidge et al. 2005) and may be interested in contributing to the Mangaia operation as a demonstration site.

**Baits of choice**

Mynas are omnivorous and will readily eat fruit (pawpaws) and grains such as boiled rice or bread. Cooked rice (perhaps lured with pawpaw) would seem to be the simplest and cheapest bait to use although more favoured (or at least more familiar) food such as pawpaw might be used to attract mynas to baiting sites or as a secondary bait if some do not eat rice.

*Constraints on use:* Non-target issues on Mangaia appear to be domestic (and feral) chickens, pigs and dogs. All are likely to eat toxic baits if they are exposed to them and the chickens, at least, are likely to be killed unless excluded from the baits by fencing or raised feeding tables. The $LD_{50}$ for chickens is 6 mg/kg. However, mynas appear to prefer to feed on the ground so it would be best to locate bait stations at places where pigs and chickens are absent or uncommon. However, some deaths of chickens (particularly feral birds) is likely despite careful use of baits. Compensation for affected owners should be planned.

## 5.3 Secondary control of survivors

Assuming some birds are not killed by the initial control method, there are a variety of ways they can be found and killed. The best method may depend on whether the secondary control phase is begun while the birds are still flocking in communal roosts or have become territorial during the breeding season – assumed to be spring to late summer.

- More of the same but focused to where survivors are seen. This may not work if the survivors have become ‘wise’ to the baits and toxin. If this appears to be the case, a new bait (perhaps pawpaw) might be tried.
- Nest box traps or snares. Mynas can be trapped using artificial nest boxes. The best method appears to be by snaring birds with loops of fine fishing line as they enter the nest box (J. Millett (pers. comm.).
- Shooting. This can be effective for isolated birds (where safety to people is not an issue). It is important not to teach other mynas the danger of armed people. A silenced .22 air rifle and a trained shooter have proved effective.
- Traps. There are a variety of cage traps available to catch mynas (e.g. the ‘Mynamagnet’ trap designed at Australian National University). Trials have proved traps barely effective in controlling mynas (C. Tidemann, Australian National University, unpubl. data), but they may be useful to catch survivors if all else fails.
- There are limited options to change the toxin if survivors become averse to DRC1339. Alpha-chloralose might be tried but this toxin proved ineffective (as an eradication tool) on Fregate Island (Orueta & Ramos 2001).

It is **essential** that any secondary control that may be required is seen as an integral part of the eradication plan and not left as an afterthought to be done by islanders in their spare time.

Basically, the longer the eradication takes the higher the risk of failure as the foods or determination wane. Plan to kill 100% in the initial knockdown, i.e. give it a chance to succeed in one hit. If, as likely, this leaves survivors, plan to kill them within a year. Then ongoing action may or may not be required, and the plan needs to at least cover this contingency. If success is not achieved within some set time (I suggest 2 years) the operation should be reviewed and either halted or changed to a sustained control strategy.

## 6. An Eradication Strategy

The island is too large to mimic a typical rodent eradication and apply the control method (e.g. aerial baits or bait stations) across the entire area in a one-method, one-hit operation; and with human settlement probably not a socially acceptable practice. Thus a phased strategy will be required with operational monitoring of milestones being used to move from one phase to the next (Table 3). This strategy will form the basis of the project design, with estimated costs. We assume here that approval has been given by the Mangaia Resource Council to proceed and the funds are available.

**Table 3** Phased strategy and key indicators for progress in myna eradication. We assume funding would not be approved before 2007 and so the initial control would not begin until winter of 2007.

| Phase | Function | Key milestones | Timeframe (a guess) | Estimated cost |
|---|---|---|---|---|
| Preparation and training | Reduce uncertainty | Measure detection probability | During 2006 | $15,000 |
| | | Operational plan produced and equipment, baits, etc in place | Before winter 2007 | $25,000 |
| | | Project manager appointed and local staff trained | Before winter 2007 | $10,000 |
| Initial knockdown | Kill up to 100% of the population | 1. Pre-baiting: numbers of birds attracted to sites reached stable maxima, and enough sites to attract all birds | 1. Beginning of winter 2007 – 3 weeks | $10,000 |
| | | 2. Toxic baiting: | See section 6.2 | $10,000 |
| Detection of survivors and | Find survivors | Surveys of whole island | See section 6.3 | $10,000 |
| Secondary control | Kill 100% of survivors | All known birds killed | | $15,000 |
| Surveillance | Sets stop rules | Assess probability that no sightings in surveys = no mynas | See section 6.4 | $ 5,000 |

These costings are based on a wage rate for the island team of 10 people paid $6 per hour and a project manager at $1,000/week. Hire or purchase of motor bikes at $2,000 each and a 4-wheel-drive vehicle at $150/day.

## 6.1 Preparation and training

### Measuring detection probability

A major problem in all eradication campaigns is determining when to stop and declare success – how confident can you be that the absence of sightings or sign of the pest truly equals no pests?

The key parameter that is required to measure this is called the detection probability – the probability that if a myna is present that it would be detected by whatever survey system or detection devices are likely to be used at the end of the eradication campaign. This can be measured while there are still some birds on the island simply by marking individual birds (say 10 caught over the whole island) and measuring the probability that each is detected.

A workplan to determine detection probabilities will be developed if the feasibility plan is approved and an eradication operation planned. There are some issues to be resolved to do this using naïve mynas – the assumption that survivors of poisoning do not become less detectable by changing their behaviour is unlikely to be true. Thus, use of birds caught during the secondary control phase might be best – if more expensive.

### Capacity issues

The Taporoporoanga Ipukarea Society is the main environmental NGO in the Cook Islands and is based on Rarotonga. Its mission is to undertake projects that support the implementation of the Cook Islands National Biodiversity Strategy Action Plan. Over the last 10 years, TIS has assisted in the control of rats to protect the kakerori on Rarotonga, and been involved with the Save Suwarrow Island campaign to ban marine farming in that uninhabited island's pristine lagoon, and with rat eradication on small islands in the Cook Islands. The TIS has no full-time staff and a membership of <100 people, mostly from Rarotonga.

The ability of the TIS to provide project leadership on Mangaia is uncertain. Mr Ian Karika of TIS undoubtedly has the skills to do so. He has been involved with conservation projects and although from Rarotonga has ariki family connections on Mangaia and of course speaks Maori. What is uncertain is his ability to commit full time to the operation, especially as the secondary phase can have no set deadline for completion.

Conversely, appointing an expert eradication project leader, say from New Zealand, would also be risky as without the mana that person may find it difficult to maintain the commitment of Mangaians.

There appear to be no particular constraints on establishing the necessary infrastructure on Mangaia – accommodation of off-island staff, vehicles, office space, a toxin storage and preparation area, etc are all available.

The best solution appears to be a dual project management team with both Mr Karika to bring his local knowledge of the people and their concerns to the project, and an experienced eradication project manager to maintain the process. The two would not always have to be present at all times and so would allow for some flexibility.

### Community engagement

Commitment of the Resource Council and people of Mangaia may be forthcoming to start the operation, as indicated to date by the community meetings. Most people spoke strongly against mynas while only two arguments were raised against killing them – one a theological argument that people had no right to kill what God had placed on the island, and the other a practical argument that mynas were keeping the stick insects controlled. However, maintaining that approval throughout the project, especially once people are inconvenienced by operational requirements, will require sympathetic management with both ad hoc consultations with people where the control impinges on their activities, and regular updates of the campaign at community meetings.

Mangaians will of course also be directly employed in the project, and the whole island may play a crucial role in the secondary phase by reporting sightings of surviving birds.

If the eradication is successful and benefits are obvious it may lead more people to consider how they might manage other exotic pests on the island. Better management of semi-feral pigs and sustained control of rats are potential future projects, but as they would require ongoing commitment they can only be done by residents.

### Operational plan

An operational plan (who does what, when, how) and who is accountable, etc will need to be developed if the project is approved for funding. Infrastructure (hire of a vehicle, motor scooters, baits, toxins, a safe storage for the toxins and place to mix it, etc) will need to be in place.

### Staff and training

A project manager and perhaps 5–10 local staff will need to be appointed and trained. I would advise contracting a bird-control expert from New Zealand for one week to assist with this.

## 6.2 Initial knockdown phase

The aim in this phase should be to put all mynas at risk – whether all are killed remains to be seen.

### Non-toxic pre-feeding

Beginning in winter of 2007, all suitable sites where mynas feed (i.e. near roosts and at suitable places along roads or near villages and piggeries) should be pre-fed every afternoon (or perhaps every second afternoon) with boiled rice. Cut pawpaws might be used to attract birds to the rice but be withdrawn once the birds get used to feeding at the site. Ideally, enough bait should be laid out so that it is all gone each day.

The exact timing of this pre-feeding will need to be flexible and left to the judgement of the operational manager. I would guess it might take 3 weeks to ensure maximum numbers of birds visit the sites (essentially we want all birds on the island to know where pre-feed is available).

The number of sites might need to be adapted to need, i.e. extra sites can be added if birds are seen that do not apparently go to pre-feed places. Conversely, sites may be abandoned if few birds use them or if non-target animals are a problem. If the site is good for mynas but bad for non-targets, fencing or raised table feeders should be considered.

**Toxic baiting**

Once it is clear that birds are regularly visiting and feeding at the sites, the non-toxic bait should be substituted with toxic bait. I would attempt to poison all the pre-feed sites on the same day. The toxic baiting should be repeated every day at each site until no birds are seen to be feeding at the sites. I estimate this will take up to 3 weeks.

If many mynas are still left but not visiting the baiting sites, new sites should be selected and the pre-baiting – toxic baiting process repeated.

**With luck that will be the end of the mynas!**

## 6.3 Secondary phase

More likely some birds will survive and the next task will be to find these birds and kill them. Finding birds may not be difficult (with some determined effort) but killing them seems the most uncertain part of the campaign. Finding survivors can be done both by active searching by the control team and by setting up a 'hotline' reporting system for islanders to report any birds they see during their normal activities.

The most efficient way is to kill any survivors as they are detected. Options are to shoot them. However, this may not be practical if the birds are in settled areas or very wary and mynas very rapidly become gun-shy and even recognise individuals who have shot at them. Spot poisoning or trapping at the places any birds are seen may work and should be tried next.

If these methods fail to eradicate the last birds by the start of the breeding season then setting out artificial nest boxes is the best method. In New Zealand, nesting mynas had territories ranging in size from 0.7 to 2.3 ha (Wilson 1973) suggesting either that a large number of nest boxes would have to be used to get coverage of the island or (more likely) that nest boxes should be located in places where surviving birds are seen. J. Millett (pers. comm.) recommends using nest boxes of c. 30-cm sides with a 5-cm hole and hinged lid. Sets of fishing line snares are set inside the entrance to the box and are reported to catch both sexes. Trap doors are not effective, although painting the edge of the hole with DRC1339 gel might work, assuming kingfishers do not use nest boxes.

## 6.4 Stop rules and surveillance phase

Providing detection probabilities have been measured a priori, then the absence of any sightings during post-control surveys can be interpreted with a known degree of confidence. Of course detection of a myna means eradication has not been achieved.

The cheaper alternative (and riskier) strategy is assume that zero sightings post-control equals eradication and wait until any failure becomes obvious by weight of myna numbers.

Given the costs to attempt eradication and the problems a drawn-out secondary phase would pose, I would recommend the first option. Detection probabilities assessed on Mangaia would be applicable on other islands where eradication might be attempted.

### 6.5 Operational monitoring

PII projects are intended to demonstrate pest and weed management. In this case, the project managers should record simple daily information on the number and location of bait sites, the frequency and timing of pre-feeds and toxic baiting, the number of dead and live birds located and their location, the costs, and the effort expended during each phase of the operation.

## 7. Measuring Benefits and Consequences

### 7.1 Benefits to biodiversity

Given the lack of good baseline data on myna impacts, e.g. on productivity of kingfishers, it is unclear what should be done to monitor biodiversity benefits of any successful eradication. It would be very expensive to obtain precise estimates of kingfisher numbers before and after myna eradication. It could be done using mark-recapture and territory mapping methods, but the simpler methods used in the studies reported in Table 1 are too imprecise to be of any use.

### 7.2 Social benefits

Eradication of mynas would allow local gardeners, who are restricted in the sort of crops they can grow for home use and for sale in the local markets, to expand their food sources and diversify their incomes.

### 7.3 Adverse consequences of success

The only adverse effect of eradicating mynas might be to increase damage to coconut fronds from stick insects. This is a moot point as the insects apparently irrupt on islands with (e.g. Vanua Levu) and without (e.g. pre-1964 Mangaia) mynas, so their efficacy as a biocontrol is in doubt.

If trials to exclude mynas or the actual eradication do show unacceptable effects (i.e. irruptions of stick insects) there are two positive options: reintroduce the mynas (not an option I would recommend) or introduce the parasitic wasp as a biocontrol being suggested for use in Fiji.

## 8. Conclusions and Recommendations

### 8.1 Is eradication of mynas justified?

Although the evidence is weak and largely by extrapolation from other islands, eradication of mynas can be justified to protect kingfishers. The evidence shows some impacts although whether these are enough to drive ongoing declines in kingfisher numbers is unclear. The precautionary principle should apply.

Eradication of mynas from Mangaia is justified as a demonstration project for other islands – where their impacts might be more severe.

Ideally a study that measured the trends in kingfisher numbers **and** diagnosed the causes of any deline should be undertaken **if** myna eradication was to be attempted on this ground alone. This would not be a trivial task as the methods used to date (Table 1) have no power to detect change. An expensive bonding study would be required to detect changes in population sizes. Diagnosing causes of kingfisher nesting failure is more practical using standard video nest monitoring methods (e.g. see Innes et al. 1994, 2004).

Eradication of mynas is justified because of their adverse effects on peoples' livelihoods, although if this was the only reason a sustained control option might be considered – especially for more-settled islands such as Rarotonga or Upolu where the constraints on eradication are more acute.

### 8.2 Is eradication feasible?

So far as I can judge, eradication is feasible on an island such as Mangaia. Given it has not been achieved at this scale before, there remains a reasonable risk of failure.

### 8.3 What needs to be resolved before beginning an attempt?

(a) Approval of the Resource Council of Mangaia that mynas should be eradicated and that the methods indicated in this report are acceptable.

(b) If the role of mynas as a biocontrol of stick insects is an issue with Mangaians, a simple experiment as suggested in this report, is recommended.

(c) Formation of a suitable project management system. There are risks that have to be traded off between having an entirely professional outside team of eradication experts and an entirely local Mangaian team. The first is unsatisfactory because it would not have local support or build capacity, the second is unsatisfactory because it would not provide the necessary skills. A hybrid solution will need to be negotiated.

(d) Acceptance by the project team that the attempt should be made within the timeframe indicated in this report, i.e. within one year.

(e) Measurement of detection probabilities is advisable partly to support this project but partly to provide information for future attempts elsewhere.

(f) Appropriate permits to use DRC1339 and training of operational staff are in place.

### 8.4 What would it cost?

Final costs will need to be developed in an operational plan, but a rough estimate is $100,000 assuming some limited research input (to assess detection probabilities) and that 100% of the birds are not killed in the initial control operation.

### 8.5 Border control

It appears that Mangaia is too far from Rarotonga for mynas to reinvade without human help, but there is a risk that they could hitch rides on the ships that visit Mangaia from Rarotonga. This risk appears to be low as mynas have not colonised other islands in the Cook Islands visited by the boat – unless deliberately released (Appendix 1).

Transport of mynas on ships is a wider issue in the Pacific and requires a separate study to assess its prevalence.

### 8.6 Information campaign

If the myna eradication proceeds, a campaign to keep Mangaians informed of actions and progress will need to be developed by the operational manager. If the eradication succeeds, the results and now it was achieved should be widely disseminated.

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**Appendix 1 Current known distribution of common mynas in the Pacific. Unless stated the information is taken from the ISSG database (M. Browne, pers. comm.).**

| Country | Island | Area (ha) | Notes | References |
|---|---|---:|---|---|
| Cook Islands | Rarotonga | 6 700 | Introduced from Tahiti before 1920 | Holyoak & Thibault (1984) |
| | Mangaia | 5 180 | Introduced from Rarotonga in 1950s | McCormack (1993) |
| | Aitutaki | 1 800 | Introduced 1916 | McCormack (1993) |
| | Atiu | 2 800 | Introduced 1915 | McCormack (1993) |
| | Manuae | 600 | Common 1973 | Holyoak & Thibault (1984) |
| | Ma'uke | 1 800 | Introduced 1916 | |
| American Samoa | Tutuila | 13 700 | Introduced (via airplane) in mid-1980s | Freifeld (1999) |
| | Manu'a | | Spread from Tutuila | Watling (2004) |
| USA | Palmyra | 130 | Introduced in 1940s | |
| | Midway | 800 | | |
| | Oahu | 157 500 | | |
| | Hawai'i | 1 045 800 | | |
| | Kauai | 143 200 | | |
| | Molokai | 67 600 | | |
| | Lanai | 36 100 | | |
| | Maui | 188 800 | | |
| | Kure Atoll | 85 | | |
| Samoa | Upolu | 111 400 | First seen in 1988 | Watling (2004) |
| | Savai'i | 182 100 | ? or jungle mynas | |
| Fiji | Vanua Levu | 558 710 | | Watling (2004) |
| | Viti Levu | 1 038 800 | | Watling (2004) |
| | Taveuni | 43 500 | | Watling (2004) |
| | Ovalau | | | Watling (2004) |
| | Wakaya | | | Watling (2004) |
| | Yasawa group | | | Watling (2004) |
| | Mamanuca group | | | Watling (2004) |
| | Vatulele | | | |
| | Lakeba | | | |
| | Cicia (Lau group) | | | Watling (2004) |
| | Mago (Lau group) | | | Watling (2004) |
| Vanuatu | Tanna | 38 850 | | |
| | Efate | 90 000 | | |
| | Epi | 44 500 | | |
| | Paama | | | |
| | Malo | | | |
| | Aore | | | |
| | Espiritu Santo | 395 600 | | |

| Country | Island | Area (ha) | Notes | References |
|---|---|---|---|---|
| Solomons | Russell Islands | | | Lever (1987) |
| | Guadalcanal | 535 300 | | Lever (1987) |
| | Olu Malau | | | Lever (1987) |
| French Polynesia | Tahiti | 104 200 | Introduced before 1920 | Bruner (1972) |
| | Moorea | 13 200 | | |
| | Raiatea | | Common in 1972 | Holyoak & Thibault (1984) |
| | Tahaa | 9 840 | Common in 1972 | Holyoak & Thibault (1984) |
| | Huahine | 7 400 | Common in 1972 | Holyoak & Thibault (1984) |
| | Hiva Oa | | Introduced in 1918 | Holyoak & Thibault (1984) |
| | Hao | | Introduced in 1971 | Holyoak & Thibault (1984) |
| | Mururoa | | Introduced in 1971 | Holyoak & Thibault (1984) |
| | Mopelia | | Common in 1973 | Holyoak & Thibault (1984) |
| | Tubuai | 4 920 | Common in 1921 | Holyoak & Thibault (1984) |
| | Rapa | | | ISSG database |
| | Rurutu | | Present in 1921 | ISSG database |
| | Bellinghausen | | Introduced ? 1980s | Lever (1987) |
| | Scilly | | Few in 1973 | |
| | | | | |
| New Caledonia | New Caledonia | 1 691 200 | | Lever (1987) |
| Kiribati | Line Islands? | | | |
| Wallis/Futuna | Uvea | 6 000 | Two birds present in 1999 | Sherley & Tiraa (1999) |