A principles-based decision tree for future investigations of native New Zealand birds during aerial 1080 operations

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Abstract: Ongoing investigations into bird mortality caused by aerial 1080 poison operations to suppress pest populations will be required because the operational specifications continually change and improve. We summarise recent studies of bird deaths following 1080 operations and present six principles for use in prioritising future research into poison risk for bird populations. A decision tree and supporting flow diagram show how the need for new surveys can be evaluated using these principles. Iterative reporting of surveys and use of the six principles to prioritise new work will enable bird mortality risks to be continually updated in an evidence-base for conservation.

Keywords: baits; bird surveys; conservation; evidence-base; non-target mortality; sodium fluoroacetate

Introduction

In one New Zealand forest with no pest control, the biomass of herbivorous and predatory invasive mammals was estimated to be 42 times greater than the biomass of native birds (Brockie & Moeed 1986). To restore bird and above-ground invertebrate populations and reduce tree mortality in such forests, large-scale poison operations targeting brushtail possums (*Trichosurus vulpecula*) and ship rats (*Rattus rattus*) are carried out using air drops of baits containing sodium fluoracetate ('1080'; Innes et al. 1995; Morgan & Hickling 2000). Feral cats (*Felis catus*), stoats (*Mustela erminea*), and ferrets (*Mustela furo*) die by secondary poisoning if they prey on moribund rodents or scavenge fresh carcasses (Gillies & Pierce 1999; Murphy et al. 1999).

Concern that native birds may also die from primary or secondary poisoning during 1080 poison operations, negating any benefits of pest control, prompted conservation managers to commission field counts of certain native birds before and after poison baits were applied (Spurr & Powlesland 1997). In a variety of approaches, workers investigated changes in nest or territory occupancy, conspicuousness at listening stations, encounters with banded individuals, survival of individually banded or radio-tagged birds (Spurr & Powlesland 1997) and numbers of territorial males detected on transects (Westbrooke et al. 2003). A review and meta-analysis of the surveys of individually marked birds showed there is strong evidence that species of kiwi (*Apteryx* spp.), kākā (*Nestor meridionalis*) whio (*Hymenolaimus malacorhynchos*), and kōkako (*Callaeas cinerea*) have very low poisoning risk during such operations, but the risk of primary poisoning of other birds is less well defined (Veltman & Westbrooke 2011). It also revealed a failure to investigate some native birds known to be killed during 1080 poison operations, insufficient sample sizes and lack of experimental controls in many studies, and very few surveys of native birds under modern baiting practices (Veltman & Westbrooke 2011).

Whilst sowing rates (the weight of bait broadcast over one hectare of forest) of 1080 poison baits have been declining (Veltman & Pinder 2001; Veltman & Westbrooke 2011), the practice of 'prefeeding' with non-toxic baits to increase the consumption of poison baits by pests (Warburton et al. 2009) has become more frequent (Veltman & Westbrooke 2011). This kind of evolution of operational specifications will certainly continue, and no single list of data-deficient species will ensure conservation managers maintain up-to-date risk profiles for non-target species.

Methods

What is needed are guiding principles that can be applied as the baiting procedures change. We developed a decision tool based on six principles that, when rephrased as questions (Table 1), assist users to identify the bird populations requiring some precautionary investigation at sites that will be exposed to aerial 1080 poison baiting. A flow diagram illustrates how the decisions impact on each other (Fig. 1). To ensure an evidence-base grows for reviewing whether conservation managers are doing more good than harm (Pullin & Knight 2009) when aerial 1080 operations are done to control invasive mammals, we also report further studies of bird deaths to update Veltman & Westbrooke (2011).

Principles on which decision tree is based

Principle 1: Species lacking satisfactory investigation of individual fates during previous 1080 operations should be given first priority for monitoring.

Native birds that are likely to occur in forests, grasslands, and wetlands subject to aerial 1080 poison operations and that lack formal studies of individual fates are listed in Table 2. Veltman and Westbrooke (2011) reviewed surveys of individually

Table 1. Six-step decision tree for planning studies of native bird survival during aerial 1080 operations.

1. Has this species been studied during previous aerial 1080 operations? *Logic*: No formal studies of fates of individual birds exposed to aerial 1080 poison operations have been done for 31 native bird species occurring at sites subject to aerial 1080 baiting for pest control. See text, Principle 1.	Yes, go to 2 No, go to 5
2. Will operational specifications (bait type, 1080 concentration, sowing rate, use of prefeed, bait additives) differ from operations in which birds were previously studied? *Logic*: The risk of poisoning non-target animals may be related to the way the baits are made or distributed. See text, Principle 2.	Yes, go to 4 No, go to 3
3. Is this a population of kiwi, kākā, whio or kōkako? *Logic*: If specifications for the planned operation are the same as those of past operations in which these birds were studied, a survival/mortality study is not indicated (Table 3). See text, Principle 3.	Yes, stop No, go to 4
4. Was there evidence that birds died from direct or indirect poisoning? *Logic*: In cases where birds are known to be at risk of poisoning but have not been studied, or were studied but the way operations were done differs from current best practice, some investment in measuring bird survival is advisable. For other species, it would be useful to run more surveys in order to provide data for a meta-analysis in future.	Yes, go to 5 No, go to 6
5. Is the extinction threat ranking for this species either Nationally Critical or Nationally Endangered? *Logic*: Kiwi and kākā were covered in question 3 but for other Critical or Endangered bird species (see Miskelly et al. 2008, appendix 1), the risk of mortality may be estimated from observations of similar but non-threatened bird species (e.g. the risk to South Island brown teal or to grey duck may be assessed with information about grey teal or mallards). Where this cannot be done, it is advisable to test for bait palatability to potential non-targets or to remove birds for the duration of the 1080 exposure.	Yes, pause to reconsider No, go to 6
6. Can birds of this species be individually marked in some way? *Logic*: It is advisable to measure survival of individually marked birds and radio-tags are preferred. If it is not feasible to collect any corpses of marked birds for residue testing, or if birds cannot be marked or individually identified (e.g. parakeets have such short legs that bands cannot be seen), different strategies are required.	Yes, conduct survey of individuals No, consider sampling population

Table 2. Native bird species exposed to 1080 baits during aerial operations that have not been formally investigated for individual survival or mortality.

Threat status (Miskelly et al. 2008, fig. 1)	Carcasses reported (Spurr 2000)		No carcasses reported	
Nationally Critical			*Anas chlorotis* 'South Island'	South Island brown teal
			Anas superciliosa superciliosa	Grey duck
			Ardea modesta	White heron
			Cyanoramphus malherbi	Orange-fronted parakeet
Nationally Endangered			*Botaurus poiciloptilus*	Bittern
Nationally Vulnerable			*Eudyptes pachyrhynchus*	Fiordland crested penguin
			Falco novaeseelandiae	Falcon
			Mohoua ochrocephala	Mohua
			Xenicus gilviventris	Rock wren
At Risk/Declining	*Acanthisitta chloris*	South Island rifleman		
	Anthus novaeseelandiae	Pipit		
At Risk/Relict			*Cyanoramphus novaezelandiae*	Red-crowned parakeet
			Porzana pusilla affinis	Marsh crake
			Porzana tabuensis plumbea	Spotless crake
At Risk/Naturally Uncommon			*Eudynamys taitensis*	Long-tailed cuckoo
			Gallirallus philippensis assimilis	Banded rail
Not Threatened	*Mohoua albicilla*	Whitehead	*Anas gracilis*	Grey teal
	Gerygone igata	Grey warbler	*Anas rhynchotis variegata*	New Zealand shoveller
	Rhipidura fuliginosa	Fantail	*Ardea novaehollandiae*	White-faced heron
	Zosterops lateralis	Silvereye	*Todiramphus sanctus*	New Zealand kingfisher
	Anthornis melanura	Bellbird	*Chrysococcyx lucidus*	Shining cuckoo
	Prosthemadera novaeseelandiae	Tūī	*Mohua novaeseelandiae*	Brown creeper
	Larus dominicanus	Black-backed gull	*Tadorna variegta*	Paradise shelduck
	Porphyrio porphyrio	Pūkeko		
	Circus approximans	Australasian harrier		

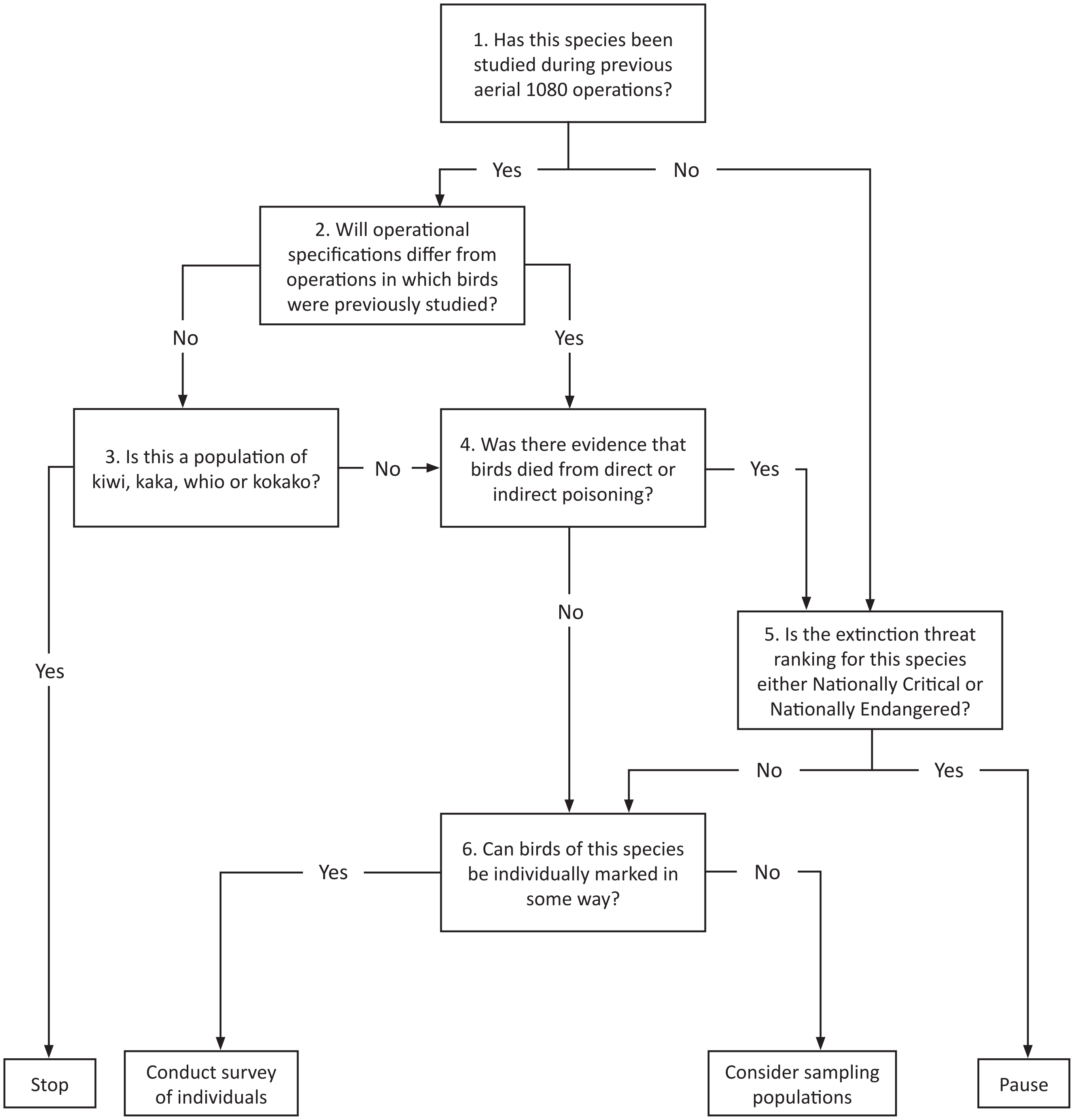

Figure 1. Six-step decision tree for planning studies of native bird survival during aerial 1080 operations.

banded or radio-tagged birds conducted between 1986 and 2009, and studies completed since then or not documented at that time are listed in Table 3.

The more common and conspicuous of bird species listed on Table 2 can be detected during transect or point counts using a variety of methods. Several reports of counts conducted before and after aerial 1080 poison operations using defensible designs and statistical power sufficient to detect a change have found little difference in abundance (Westbrooke et al. 2003; Greene et al. 2013). As a result of these reports, any assessment of environmental effects prior to an operation is likely to find the non-target poisoning risk low for species like fantails (*Rhipidura fuliginosa*) and silvereyes (*Zosterops lateralis*).

If a bird species has not been investigated satisfactorily, decision-makers are directed to next consider the extinction threat ranking of the species (Table 1: Question 5). In those cases where survival has been formally investigated, decision-makers are directed to consider the operational conditions under which measurements were made (Table 1, Question 2).

Table 3. Studies of the fates of individual birds not reported in Veltman & Westbrooke (2011). Column labels as in Veltman & Westbrooke (2011). [a] signifies same operation. * The pooled upper confidence bound for *Hymenolaimus malacorhynchos* (see table 2 of Veltman & Westbrooke 2011) is now 3.0%, given no mortality in four surveys comprising 98 birds in total.

Species	Year	Site	Operational specifications						Bird survey				Upper-bound (as percentage) of 95% confidence interval	Information source
			Month	Prefed	Bait	Mass (g)	1080 (g kg^{-1})	Sow rate (kg ha^{-1})	Treatment		Non-treatment			
									Sample size	No. died	Sample size	No. died		
*Hymenolaimus malacorhynchos**	2006	Tongariro Forest Central North I	9	Y	W7	12	0.8	4	28	0	0	0	10.1	A. Beath pers. comm.
*Hymenolaimus malacorhynchos**	2007	Pukepoto-Mangatepopo Central North I	9	Y	W7	12	1.5	3 & 5	34	0	0	0	8.4	N. Poutu pers. comm.
Nestor meridionalis	2010[a]	Waitutu Forest Southland	10	Y	RS5	12	1.5	2	15	0	0	0	18.1	Greene et al. 2013
Ninox novaeseelandiae	2010[a]	Waitutu Forest Southland	10	Y	RS5	12	1.5	2	11	0	0	0	23.8	Greene et al. 2013
Bowdleria punctata punctata	2010	Ianthe Forest, West Coast	7	Y	RS5	12	1.5	2	43	3	0	0	19.1	Van Klink et al. 2013

Principle 2: If proposed poison-baiting methods have changed from those investigated previously, assessment of the need for remeasurement is warranted.

As sowing rates reduced and prefeeding with non-toxic baits was widely adopted (Veltman & Pinder 2001; Veltman & Westbrooke 2011), the risks of birds swallowing baits or contaminated insects may have changed, in directions we cannot predict. On the one hand, fewer baits must reduce the likelihood of birds encountering them, but conversely, birds may familiarise themselves with non-toxic baits and be killed when the toxic baits are distributed (Veltman & Westbrooke 2011).

Changes in baiting methods have generally not been accompanied by remeasurements of risks for native birds (Veltman & Westbrooke 2011). This means that investigations may be warranted, even if the native bird population of concern has previously been studied.

Principle 3: Additional expenditure on surveys is not required for well-studied taxa when funding is scarce.

A meta-analysis of surveys of kiwi, kākā, kōkako and whio in aerial 1080 poison operations using carrot or cereal baits found the risk of by-kill to be very small (Veltman & Westbrooke 2011). One more survey of kākā and two additional surveys of whio have been reported since then (Table 3). The set of all surveys for these taxa includes operations with carrot and cereal baits, and some with prefeeding. The revised confidence intervals are consistent with a very small risk that individuals of these species will die from poisoning (Table 3). If Question 3 on Table 1 is answered in the affirmative, resources should be put into measuring other species. If there is little additional cost involved, for example where there is an existing marked population, then reporting may still be warranted.

Principle 4: Birds known to be vulnerable to 1080 poisoning and not well-studied should be resurveyed as a precautionary measure.

In cases where birds are known to be at risk of poisoning but have not been adequately studied, or were studied but the way operations were done differs from the proposed work, some investment in measuring bird survival is advisable.

Spurr (2000) tabulated 19 native bird species that were found dead after aerial 1080 poison operations conducted between 1958 and c.1999. There have been no formal investigations of individual survival or mortality for 11 species on that list (Veltman & Westbrooke 2011). Carcasses have never been reported for a further 20 species that occupy forests, wetlands or grasslands that may be subject to aerial 1080 baiting (Table 2).

Principle 5: Risks should be assessed or reassessed for other species ranked Nationally Critical and Nationally Endangered.

Priority needs to be given to species where the population is particularly vulnerable to any possible additional mortality from 1080, using the New Zealand Threat Classification System (Miskelly et al. 2008; Townsend et al. 2008) and other information available. In this section, we review what is known for the birds that have a threat classification of 'Nationally Critical' or 'Nationally Endangered' as well as those that have been classified as 'Nationally Vulnerable' (Table 2) and could be using habitats treated with 1080.

The individual fates of South Island brown teal (*Anas chlorotis* 'South Island') and grey duck (*Anas superciliosa superciliosa*) have never been studied during aerial 1080 poison operations. However, we note that 1080 is rapidly dissolved in water (Eason et al. 2011) and the ubiquitous mallard (*Anas platyrhynchos*), which also dabbles in shallow water for invertebrates and seeds (Heather & Robertson 2005), has never been reported dead after aerial 1080 operations. White herons (*Ardea modesta*) primarily eat aquatic prey but do sometimes eat mice (Heather & Robertson 2005). The lack of carcasses and this foraging behaviour probably explain why further study of poisoning risk has not been done for white herons.

Orange-fronted parakeets (*Cyanoramphus malherbi*) cannot be easily identified in the field from leg bands. Estimation of risk for this species may need to be based on comparisons of call frequencies between treated and untreated areas of forest or perhaps on supplementary evidence from the somewhat similar and more common yellow-crowned parakeet (*Cyanoramphus auriceps*) (see Principle 6). Aerial 1080 operations were done in 2006, 2008, and 2009 at three South Island valleys where orange-fronted parakeet populations occur. After each operation, 19–30 transects were walked by observers and no parakeet carcasses were found (J. van Hal, pers. comm.).

Bittern (*Botaurus poiciloptilus*) may encounter baits or rodents that have consumed baits. Bitterns have been recorded as feeding on rodents (Marchant & Higgins 1990). The locations of 10 male bitterns were determined by observers from booming calls at South Taupo wetland near Turangi, before an aerial application of 1080 poison in carrot baits. Afterwards, one bird was no longer calling in the treatment area and four out of nine birds under observation in the non-treatment area were not heard again (Speedy 2005, unpubl. report). As bitterns in the study were neither colour-banded nor fitted with transmitters, their individual fates could not be reliably linked to the distribution of poisonous baits.

Fiordland crested penguins (*Eudyptes pachyrhynchus*) are at sea from mid-March to mid-June but nest in colonies in coastal forest of South Westland and Fiordland (Heather & Robertson 2005), which potentially exposes them to poison baits. All foraging by this 'Nationally Vulnerable' species is done in the marine environment, but we are unaware of any observational work to check for penguin corpses or whether Fiordland crested penguins peck or swallow (non-toxic) baits when they encounter them.

The New Zealand falcon (*Falco novaeseelandiae*) rarely feeds on carrion and the only carcass submitted for toxicological testing (2008, Landcare Research) did not contain 1080 residues. Informal monitoring of territory occupancy found no evidence of bird disappearances at Pureora Forest Park (Spurr & Powlesland 1997) but three falcons seen regularly were absent after an aerial 1080 operation in December 2007 near Whanganui National Park (J. Campbell, pers. comm.). One falcon carcass was recovered following three rabbit control operations in open grasslands near Mount Cook National Park, involving ground application of pindone and aerial distribution of 1080 in both carrot and cereal baits. It had decomposed too much for residue testing (Donoghue 2009, unpubl. report).

Although the presence and protection of remnant mohua populations is often one of the drivers for aerial distribution of 1080 baits in South Island beech forests (O'Donnell & Hoare 2012; G. Elliott, pers. comm.) the fate of individual mohua following such operations remains unknown. No transmitters are yet available that are small enough for use over a period of months and birds are territorial only from

November to December. Whilst populations of mohua are regularly exposed to 1080 baits, no mohua corpses have ever been recovered following aerial 1080 operations (G. Elliott, pers. comm.). The evidence that is available (i.e. longer term population counts from a number of sites; G. Elliott, pers. comm.) suggests the direct impacts of 1080 bait distribution over many years are either negligible or highly beneficial (e.g. O'Donnell & Hoare 2012).

Rock wrens (*Xenicus gilviventris*) generally inhabit areas of alpine scrub and boulder fields above the treeline. This limits their exposure to 1080 because operations are rarely done in high altitude habitats. However, in winter months rock wrens are known to descend into areas of subalpine forest, which potentially exposes them to toxic baits (R. Hay, pers. comm.). We are unaware of any observational studies that have examined the impact of aerial 1080 application on rock wrens nor are we aware of the recovery of any corpses following 1080 operations.

Principle 6: Individual fates can only be reliably studied in species that can be individually marked.

To be statistically confident that the risk of mortality from poisoning is less than 3%, we need 100 observations of individual birds surviving through aerial 1080 poison operations (i.e. no mortality is observed for 100 birds). The sample can be accumulated from several surveys. A single survey should aim for a minimum of 15 individuals colour-banded or fitted with radio transmitters or having very singular plumage. Smaller sample sizes would provide very limited precision and make only modest contributions when pooled with other studies. Corpses must be retrieved, because the analytical aim is to estimate the risk of being killed by 1080. Birds die of natural causes and when operations are delayed by bad weather that also kills birds we might wrongly deduce that these animals were poisoned (Greene et al. 2013). The use of individually marked birds and retrieval of corpses of marked birds obviates the need for non-treatment sites (experimental controls), provided any mortality is clearly attributable to causes other than 1080.

If birds cannot be individually identified or if there is a danger of not collecting corpses for residue testing, an alternative approach is required that depends on detecting a change in population size after the poison operation. This is likely to require substantial effort. In this situation, there must be one or more well-matched non-treatment sites. The sample effort will depend on the precision required in estimating the magnitude of any change in population size (Choquenot & Ruscoe 1999). Methods for estimating abundance include counts, distance sampling, transect sampling, five-minute call counts, territory mapping, playback responses, and nest survival. Many of these are described online (DOC 2013).

Discussion

The principles applied here emphasise the need to investigate previously unstudied species with higher extinction-threat rankings before studying species known to die after 1080 operations but rated at a lower risk of extinction. Thus conservation planners are advised to pause for reflection when a 'Nationally Critical' or 'Nationally Endangered' bird species is found at a site and no previous studies are available for assessing the by-kill risk. It is not advisable to expose nationally critical or endangered birds to aerial 1080 baiting, unless evidence from trials or other sources shows the birds do not consume non-toxic baits. For example, South Island brown teal, grey duck and white heron forage in ways that seem unlikely to expose them to primary poisoning (Heather & Robertson 2005) and an argument could be made from studies of ecological analogues that there is little likelihood of poisoning these birds. Orange-fronted parakeets have a very restricted mainland distribution, being confined to beech forests (*Nothofagus* spp.) in the Hawdon, Poulter, and Hurunui valleys of North Canterbury (J. van Hal, pers. comm.). Aerial 1080 operations are used to control outbreaks of rodents and mustelids in these forests, and it is reported that nesting success of the parakeets is higher as a result (G. Elliott, pers. comm.).

There is one study of bittern, which is a nationally endangered species, involving a small number of unmarked birds. Based on the principles explained here, accumulating samples of radio-tagged bitterns from future aerial 1080 operations is advised.

In proposing this framework for decision-making by managers of sites where aerial 1080 operations are planned, we aim to ensure monitoring effort is focused where data are deficient and assumptions of no risk would lead to serious consequences if found to be wrong. At the same time, we recognise that the risk profile for birds will change continually as operational patterns are improved or altered, so no single list of species will be useful for very long. A recent demonstration that distributing baits in clusters can achieve pest mortalities similar to those obtained by conventional sowing (Nugent & Morriss 2013) is an example of how operations may change in future. We have also updated here further studies of individually marked birds studied in aerial 1080 operations, in pursuit of demonstrable evidence-based evaluation (Pullin & Knight 2009) of the ecological risks and benefits of using 1080.

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