SHORT COMMUNICATION

Survival of PIT-tagged lesser short-tailed bats (*Mystacina tuberculata*) through a pest control operation using the toxin pindone in bait stations

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Abstract: Introduced mammalian predators are a major threat to New Zealand's wildlife, including bats. Controlling these predators using traps and poison baits can reduce their impact on bat populations. However, lesser short-tailed bats (*Mystacina tuberculata*) are potentially susceptible to toxins used for pest control in New Zealand forests because of their broad diet and habit of feeding on the ground. Therefore, the risk of secondary poisoning should always be assessed before new toxins are used in areas inhabited by lesser short-tailed bats. We measured survivorship of a sample of lesser short-tailed bats monitored before, during and after deployment of the first-generation anticoagulant toxin pindone in the Eglinton Valley, Fiordland, during late winter and summer 2009–2010. Pindone-laced cereal baits were deployed in bait stations from September to late December 2009 in an effort to control rats (*Rattus* spp.). Communal roosts of the one lesser short-tailed bat colony in the valley are located entirely within or immediately adjacent to the area poisoned. Minimum number alive was determined for the sampled bat population after monitoring the occupancy of colonial roosts by individually PIT-tagged bats through the study period. Survivorship of bats was high throughout the monitoring period, with 319 of 322 bats (99%) recorded in the pre-monitoring period (August) known to be alive in October 2009 and 312 of 322 bats (97%) known to still be alive in January 2010. We conclude that lesser short-tailed bats did not consume pindone baits and that their survival was probably enhanced by rat control in the study area.

Keywords: Mystacinidae; pest control; rats; transponders

Introduction

Introduced mammalian predators are a major threat to bird and bat populations in New Zealand (e.g. Elliott et al. 1996; O'Donnell et al. 1996; Dilks et al. 2003; Pryde et al. 2005, 2006; Innes et al. 2010; O'Donnell 2010). Observers have inferred that feral cats (*Felis catus*), rats (*Rattus* spp.), stoats (*Mustela erminea*) and brushtail possums (*Trichosurus vulpecula*) either prey upon or attempt to prey upon New Zealand bats (Daniel & Williams 1984; Daniel 1990; O'Donnell 2000, 2005; Lloyd 2005). Significant mortality of endangered long-tailed bats (*Chalinolobus tuberculatus*) and lesser short-tailed bats (*Mystacina tuberculata*) occurred in beech (*Nothofagus* spp.) forest in the Eglinton Valley, Fiordland, following irruptions of ship rats (*Rattus rattus*) that followed heavy mast fruiting of the beech trees (20–30% mortality in years when predator numbers are high) (Pryde et al. 2005; J. Sedgeley, Department of Conservation (DOC), Christchurch, pers. comm.). In addition to posing a direct threat from predation, introduced mammals are likely to reduce the food resources available to bats by consuming insects, flowers and fruit (e.g. Cowan & Waddington 1990; Miller & Miller 1995).

Control of introduced mammalian predators is likely to benefit bat populations. In order to both (1) reduce the threat of predation on bats, and (2) improve food resources available to bats, the Department of Conservation is undertaking, or has undertaken, mammalian pest control programmes in several areas where bats are found in New Zealand. These include Pureora, Waitaanga and Rangataua in the central North Island, the Oparara and Eglinton valleys in the South Island, and Codfish Island (Whenuahou) (Sedgeley & Anderson 2000; Lloyd & McQueen 2002; Pryde et al. 2005; G. Hill, DOC, Te Anau, J. Lyall, DOC, Hokitika, D. Smith, DOC, Te Kuiti, pers. comms.).

Animals are potentially susceptible to toxins used in pest control either through direct consumption or secondary poisoning via their natural food supplies (e.g. Eason & Spurr 1995; Dowding et al. 2006). Lesser short-tailed bats have a broad diet and a habit of feeding on the ground (Daniel 1976; Eason & Spurr 1995). They are primarily insectivorous, but also eat nectar, pollen and fruit (Daniel 1976; Arkins et al. 1999). Evidence from captive feeding trials suggests that it is unlikely that lesser short-tailed bats will directly consume the carrot or grain-based baits used in most pest poisoning operations (Lloyd 1994, 2005). However, they are potentially at risk from secondary poisoning by consuming arthropods that feed on toxic baits (Lloyd & McQueen 2000; Sherley et al. 2000; Lloyd & McQueen 2002; Craddock 2003). No harmful impacts were detected in lesser short-tailed bat populations that were monitored through two aerially broadcast poisoning operations using pollard (grain-based) baits, one on Codfish Island (Whenuahou) using the second-generation-toxin brodifacoum (Sedgeley & Anderson 2000) and one in Rangataua Forest in the central North Island using sodium monoflouroacetate (1080) (Lloyd & McQueen 2002).

Renewed concern about the non-target effects of toxins

on lesser short-tailed bats was raised after the discovery of a number of bats found dead or dying during a pest control operation in Pureora Forest in 2008 (D. Smith, pers. comm.). This operation used the first-generation anticoagulant toxin diphacinone presented in a paste matrix. First-generation anticoagulants, which are less toxic and less persistent than some alternatives, are increasingly being used for pest control in New Zealand (Eason & Wickstrom 2001; Fisher et al. 2003; Gillies et al. 2006; Fairweather & Fisher 2009). However, diphacinone is used elsewhere for the control of bats (Schmidt & Badger 1979).

Pindone is a first-generation anticoagulant toxin commonly used in open country in New Zealand for controlling introduced rabbits (*Oryctolagus cuniculus*). It has been used less frequently in forests to control rats and brushtail possums (Eason & Jolly 1993; Fairweather & Fisher 2009). The toxicity of pindone to native New Zealand species has not been widely studied. While some birds, lizards and invertebrates have been found dead following pindone operations, it is unknown whether pindone has an impact at a population level (Fairweather & Fisher 2009; G. Sullivan, Environment Canterbury, Christchurch, pers. comm.). The effects of pindone on survival of native bats have not previously been monitored.

In spring 2009, pindone was used in the Eglinton Valley, Fiordland, to control numbers of ship rats following a moderate mast fruiting of beech (*Nothofagus* spp.) that was expected to trigger an irruption of rodents (Elliott et al. 1996; O'Donnell et al. 1996; Dilks et al. 2003; Pryde et al. 2005). The toxin was deployed in bait stations over 990 ha of forest inhabited by lesser short-tailed bats (O'Donnell et al. 1999; Christie 2003). In this paper, we report on survivorship of a sample of lesser short-tailed bats monitored before, during and after deployment of pindone and compare bat survival rates with previous estimates of survival from this population. We predicted that we would detect few or no negative impacts of use of the toxin because baits were carefully placed in bait stations in a form previously found not to be attractive to lesser short-tailed bats.

Methods

Study area

The study was conducted in the Eglinton Valley, Fiordland National Park, in the South Island, New Zealand (44°58' S, 168°00' E). The valley is a typical U-shaped glaciated valley with steep valley sides and a flat floor 0.5 to 2 km wide, containing an active shingle riverbed, at an altitude of 250–550 m above sea level. Large pockets of modified tussock grasslands dominate much of the valley floor, and are surrounded by mature mixed beech forest dominated by red beech (*Nothofagus fusca)* and silver beech (*N. menziesii*).

Bait stations

Philproof-Mini bait stations (Philproof Pest Control Products, Hamilton) were installed in three blocks covering 430 ha (496 stations; Block 1), 200 ha (200 stations; Block 2) and 360 ha (363 stations; Block 3). Bait stations were laid out in a grid pattern (100 × 100 m) in each block. They were filled with cereal baits (2-g cylindrical pellets (11 × 18 mm), dyed green, containing 0.5 g kg^{-1} pindone; Pest Management Services, Christchurch). The stations were first filled between 7 and 19 September 2009 then refilled five times at approximately fortnightly intervals until 17 December 2009. All stations were initially filled with 500 g of pindone pellets, and then topped up (if required) to the same level on subsequent visits. Most bait stations also had one to three Feratox pellets (encapsulated cyanide, Connovation, Auckland) placed in the bait stations at the same time as the pindone pellets, to kill possums and prevent them from consuming large amounts of pindone bait. Rats and mice (*Mus musculus*) do not generally eat the Feratox pellets but will readily consume the pindone cereal pellets (G. Hill, pers. comm.). We used the GPS locations of all colonial roosts of lesser short-tailed bats found during a radio-telemetric study over 12 summers to evaluate spatial overlap with the poison operation (1997–1998, 2000, 2002–2010; O'Donnell et al. 1999; Christie 2003; Sedgeley 2003; CFJOD unpubl. data). Every known colonial roost within the Eglinton Valley (n = 39) was within or immediately adjacent to either Block 2 or Block 3. The mean distance of roosts to the nearest bait station was 56.0 m (± 9.4 SEM; range = 8–306 m). The mean distance of the subset of communal roosts known to be used during the sampling for this study was 35.4 m (± 2.9 SEM; range = 19–45 m). Furthermore, the 100% Minimum Convex Polygon and 85% core foraging range of the colony overlapped all three blocks (O'Donnell et al. 1999; Christie 2003).

Survivorship of bats

We calculated a simple measure of survivorship – minimum number alive (MNA; O'Donnell 2009) – before, during and after the toxin was deployed in bait stations, to assess any potential effects of use of the toxin. MNA was determined by monitoring the occupancy of colonial roosts by individually marked bats through the study period. Bats were monitored during three periods: (1) from 17 August to 13 September 2009 (pre-toxin deployment), (2) from 12 to 19 October 2009 (bait stations kept filled with baits containing toxin), and (3) from 7 January to 3 February 2010 (post-toxin deployment). We assumed that the 6-day overlap between the end of the pre-monitoring period for bats and deployment of the toxin (7–19 Sept.) would not influence results of this study because time to death of most mammals after first exposure to pindone is 10–14 days (Sharp & Saunders 2004).

We located colonial roosts by radio-tracking bats. Lesser short-tailed bats occupy 20–30 roost trees in the Eglinton Valley, which they move among regularly (O'Donnell et al. 1999; Sedgeley 2003). Free-ranging bats were captured in mist nets set at ground level in the centre of the bats' roosting area at the beginning of the pre- and post-toxin monitoring periods. Eight bats were fitted with 0.7-g transmitters (BD2A, Holohil Systems, Carp, Ontario). The mass of each transmitter was <5% of the average mass of an individual bat. Transmitters were attached between bats' scapulae, using a latex-based contact adhesive (F2®, Ados Chemical Co.), after the fur had been trimmed. Age and sex of the radio-tagged bats was recorded. Roosts were located during the day by using a TR4 receiver (Telonics, Mesa, Arizona) and three-element hand-held Yagi antennae (Sirtrack, Havelock North) to radio-track the bats. Once the general vicinity of the tracked bats was determined, the precise locations of roosting cavities in trees were identified audibly or by climbing trees and using a TR4 receiver to locate roost cavities. All roost cavities and the ground beneath roosts were checked for sick or dead bats.

As well as those bats tagged with radio transmitters, 588 lesser short-tailed bats were also marked with Passive Integrated Transponder (PIT) tags between 2006 and 2009 (J Sedgeley & CFJOD unpubl. data). The PIT tags (ISO FDX-B

11 × 2.1-mm glass-encased transponder; Allflex Australia Pty) were inserted subcutaneously between the bats' scapulae by trained personnel using Henkijet applicators.

The identities of individual tagged bats inhabiting roost cavities were recorded during the study using radio frequency identification (RFID) data loggers and antennae at the roost entrances. Circular antennae were fixed around the roost entrances and attached via cables to data loggers and a battery on the ground. When a PIT tag passed close to an antenna it used the energy of the electromagnetic field to broadcast its individual code in the chip to a receiver, where it was processed. The precise time and date that a tag triggered the reader were recorded in a text file. Data loggers were downloaded regularly and the identity of tagged bats recorded in a database. Numbers of bats emerging from roost trees were also recorded on flash memory cards by mini portable security recorders attached to infrared-sensitive video cameras mounted at the roost cavity entrances.

Results

Pre-toxin deployment monitoring

The three lesser short-tailed bats (2 adult males, 1 adult female) fitted with radio transmitters were radio-tracked between 17 and 26 August 2009 (10 days). Ten roost sites were found, of which only one was a colonial roost; all others were solitary. The roost sites of the radio-tagged bats were not located every day. On some days the bats were not located at all, and on others they were found at high altitude on the valley-sides. The colony was monitored from 22 August until 13 September. We were uncertain about the precise number of bats using the colonial roost, mainly because there was constant traffic in and out of the roost through the night. The minimum number of bats arriving at the roost was 459 individuals. A total of 3052 registrations of 322 tagged bats were recorded, representing a range of ages and both sexes (Table 1).

Post-toxin deployment monitoring

Five adult bats were radio tracked (2 males, 12–19 October, 3 lactating females, 6–21 January). In October, they led us to three roost sites, one of which was colonial. The single colonial roost was occupied throughout the monitoring period (6 days). We were unable to video both entrances of this roost. However, a total of 1019 registrations of 313 tagged bats were recorded, representing a range of ages and both sexes. In January, the bats led us to 10 roosts, of which six were colonial and the maximum exit count recorded was 909 individuals. Data loggers were successfully set up at two roosts and from a total of 10 692 registrations, 312 tagged bats were recorded, including six tagged bats that were not recorded in the October session. Therefore 319 of 322 bats (99%) recorded in the pre-monitoring period (August) were known to be alive in October and 312 of 322 bats (97%) were known to still be alive in January (Table 1). No carcasses were found during this study, either in roost cavities or on the ground below them.

Discussion

Large numbers of lesser short-tailed bats were detected at the colonial roosts monitored after deployment of the pindone baits in the Eglinton Valley. Furthermore, at least 97% of individually tagged bats recorded immediately prior to deployment of pindone baits were still alive 5 months after deployment. These results imply that use of pindone had little or no negative effect on survivorship of lesser short-tailed bats in the Eglinton Valley. This result was not unexpected, because of the low persistence of pindone in the environment (Fairweather & Fisher 2009) and the use of bait stations to deploy the toxin, but was reassuring in the light of the loss of lesser short-tailed bats following the diphacinone operation in Pureora in 2008 (D. Smith, pers. comm.). Losses of lesser short-tailed bats following the Pureora operation were unlikely to be typical because the bait matrix used there was a paste that was presented in bait bags stapled to tree trunks close to the ground rather than concealed in bait stations. Previous work has shown that cereal baits, which are more typically used for mammal pest control and similar to those used in this operation, generally appear to be unattractive to bats (Lloyd 1994; Sedgeley & Anderson 2000), despite there being instances where bats in captivity have shown interest in them (Beath et al. 2004). Following the bat deaths at Pureora in 2008, the Department of Conservation has changed the compulsory performance standards around using anticoagulant-laced paste

Table 1. Minimum number of PIT-tagged lesser short-tailed bats (*Mystacina tuberculata*) alive in the Eglinton Valley, Fiordland, 2009–2010. Juveniles are defined as bats born and tagged during the previous summer (i.e. January 2009).

Age–Sex class	September 2009 (pre-toxin)	October 2009 (6 weeks post-toxin)	January 2010 (5 months post-toxin)
Adult male	95	93	90
Adult female	157	156	154
Juvenile male	18	18	18
Juvenile female	24	24	24
Unknown-aged female	16	16	14
Unknown-aged male	10	10	10
Unknown age and sex	2	2	2
Totals	322	319 (99%)[1]	312 (97%)

[1]includes 6 bats alive but not recovered until January

baits so that they cannot be used in areas where bats are present (M. Crowell, DOC, Christchurch, pers. comm.).

The survival rates in our study appear to be among the highest so far recorded for bats generally. We have two previous estimates of MNA based on annual recapture rates of lesser short-tailed bats in the Eglinton Valley. Forty percent of PIT-tagged bats alive prior to a rat population irruption in 2006 were recorded the following summer (2007), and 76% of PIT-tagged bats were recorded after a non-predator year in 2008 (J Sedgeley & CFJOD unpubl. data). The second estimate appears more typical of bats based on the relatively few studies of survival available (Tuttle & Stevenson 1982; Vardon & Tidemann 2000; Hoyle et al. 2001; Sendor & Simon 2003; O'Shea et al. 2004; Pryde et al. 2005, 2006). Based on an estimate of 75% annual survival, we would expect a monthly mortality rate of c. 2% of bats (although this may vary across months), with an expected MNA of 284 tagged bats (of the 322 recorded prior to deployment of the toxin) at the end of the study. More optimistic estimates of survival (80% and 85%) yield MNA estimates of 297 and 299 bats respectively, all lower than the MNA of 312 bats that we recorded by the beginning of February. We conclude that the recapture rate we observed between August 2009 and January 2010 was higher than expected and potentially reflected the successful rat control operation (G. Hill pers. comm.).

Furthermore, the MNA of 97% that we recorded is likely to be an underestimate of the actual number alive. Tagged bats may have been missed in subsequent monitoring sessions either because they did not enter the colonies we monitored during the sampling period or because the antennae did not register bats that visited the roosts only briefly. For example, two tagged bats caught in mist nets in January were not logged at the colonial roosts. Earlier field trials indicated that tags are not always detected (J. Sedgeley, pers. comm.).

Toxins play an essential role in controlling introduced predators in New Zealand forests, and predator control will be required for the foreseeable future to ensure the survival of New Zealand bats (Molloy 1995; O'Donnell 2010). Monitoring the use of new toxins for control of mammalian pests in forests containing lesser short-tailed bats should be standard practice to ensure that no negative impacts accrue to the bats themselves.

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