Observed responses of captive stoats (*Mustela erminea*) to nest boxes and metal collars used to protect kaka (*Nestor meridionalis*) nest cavities

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Abstract: Artificial barriers, such as nest boxes and metal collars, are sometimes used, with variable success, to exclude predators and/or competitors from tree nests of vulnerable bird species. This paper describes the observed response of captive stoats (*Mustela erminea*) to a nest box design and an aluminium sheet collar used to protect kaka (*Nestor meridionalis*) nest cavities. The nest box, a prototype for kaka, was manufactured from PVC pipe. Initial trials failed to exclude stoats until an overhanging roof was added. All subsequent trials successfully prevented access by stoats. Trials with a 590 mm wide aluminium collar were less successful, but this was mainly due to restrictions enforced by enclosure design: Stoats gained access above the collar via the enclosure walls and ceiling. In only one of twelve trials was a stoat able to climb past the collar itself. The conservation implications of these trials and directions for future research are discussed.

Keywords: kaka; metal collar; nest box; *Nestor meridionalis*; parrot; predation; stoat.

Introduction

Kaka (*Nestor meridionalis*) are medium sized parrots (45 cm) endemic to New Zealand. Populations of kaka on the mainland have been severely reduced by a combination of large-scale destruction of forest habitats and the introduction of a variety of competitors and predators (Wilson *et al*., 1998). The single largest threat to remaining mainland populations is thought to be predation by stoats (*Mustela erminea*). These predators are extremely agile and are able to reach kaka nest cavities without difficulty, killing adult females and young on the nest (Wilson *et al*., 1998). Disproportionate predation on females has resulted in many remnant kaka populations being highly skewed toward males thereby threatening their long-term viability (Greene and Fraser, 1998). Effective measures to exclude predators from kaka nests are clearly needed.

Use of nest boxes by a target species is dependent on a variety of factors which include the availability of suitable natural sites, number, type, design and construction of the nest boxes, use by nest cavity competitors and the ability of boxes to exclude natural and alien predators (Nycander *et al*., 1995; Christian *et al*., 1996; Major and Kendal, 1996; Hesse and Duffield, 2000). Potential competitors can be excluded by making slight changes to nest box design such as reducing the size of the entrance hole, altering the shape of the box, constructing baffles, exclusion barriers or entrance tunnels, or constructing nest boxes specifically for competing species (Gray, 1969; Wiley, 1985; Christian *et al*., 1996).

In recent years materials other than timber have been used for the construction of artificial nest sites particularly for threatened parrot species. This trend has been driven largely by the search for lighter and more versatile materials, and greater ease of construction and durability. The most popular of these materials has been PVC pipe of various diameters, capped at either end, with an appropriately-sized entrance hole and internal ladder to assist access (Wiley, 1985; Beissinger and Bucher, 1992; Munn, 1994; Nycander *et al*., 1995; Emison, 1996; Pedler, 1996; Garnett *et al*., 1999). The smooth external surface of these "pipe-nests" suggests that access may be difficult for climbing predators (such as stoats and rats), but there is no evidence to confirm this.

Passive barriers have been used in attempts to improve breeding success or protect species *in situ* (Hicks and Greenwood, 1989; Nycander *et al*., 1995; Garnett *et al*. 1999). Metal sheets or collars are wrapped about the base of trees below the nest or other objects (e.g. tree canopy or mistletoe) to be protected. Such barriers are relatively cheap, simple to construct, and widely used (Wilson *et al*., 1998). On Kangaroo Island, South Australia, the addition of corrugated iron collars to the nest trees of glossy black-cockatoos (*Calyptorhynchus lathami*) to exlude brushtail possums

(*Trichosurus vulpecula*) increased fledging success for nests from 22.6% to 42.2% (Garnett *et al*., 1999). Despite the widespread use of such barriers there is a surprising lack of information on recommended construction, materials, optimal placement and overall effectiveness.

The need to test barriers such as nest boxes and collars is long overdue, particularly where such methods (often untested) are promoted as an effective means of excluding predators. Trials of a prototype PVC nest box designed for kaka, and similar trials of metal collars as barriers to wild caught captive stoats, were therefore conducted and the effectiveness of both compared.

Methods

Two plywood and metal mesh enclosures (2070 mm x 1880 mm x 2400 mm) designed to contain stoats were purpose-built in a large shed (Fig. 1a) where a number of stoats were held in captivity (Massey University Animal Ethics Committee Approval No. 98-146). In one enclosure a prototype PVC pipe nest box for kaka (height = 1200 mm, external diameter = 400 mm) was bolted to a section of tree trunk (diameter = 190 mm) which in turn was fastened to the rear wall of the enclosure (Fig. 1b). Nest box specifications were derived from measurements of more than 30 natural nest cavities. Particular attention was paid to

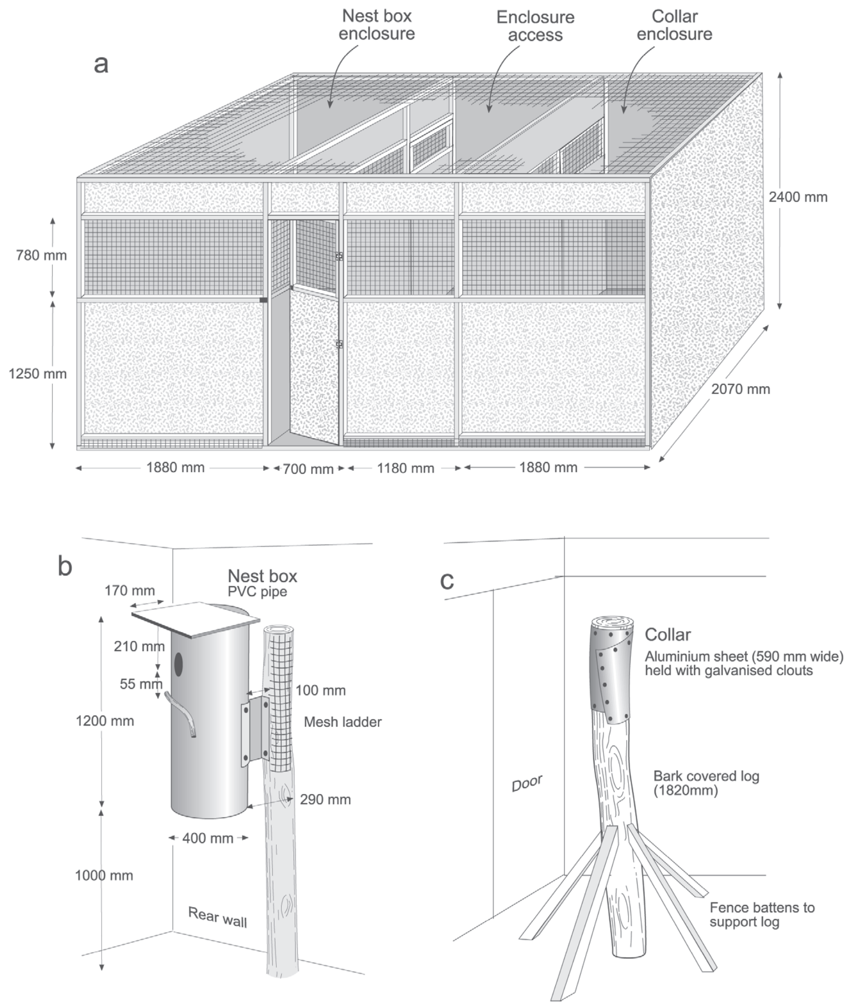

Figure 1. Dimensions and layout of trial enclosures. (a) Enclosures used for trials. (b) Nest box trial enclosure. (c) Metal collar trial enclosure.

measurements of internal diameter, depth of nest from the entrance hole and entrance dimensions.

In the other enclosure a section of tree trunk 1820 mm long (diameter = 220 mm) was fastened in an upright position to the centre of the floor using 1200 mm long fence battens for braces (Fig. 1c). The minimum distance between the top of these battens and the top of the trunk was 1060 mm. An aluminium collar 590 mm wide was attached to the top of this trunk with galvanised clouts ensuring that gaps between the trunk were minimised and overlaps were as smooth as possible.

The floor of both enclosures was covered in hay and a small den with nest material was provided as the shelter for the stoats during the trials. Fresh water was provided on a daily basis. A small video camera and infra-red light source was placed in the corner of each enclosure and connected to a 24-hour time lapse video recorder (Panasonic™ AG1070DCE). Two dead white mice (the usual diet of the captive stoats) were placed either within the nest box or on top of the tree trunk above the aluminium collar during each 24-hour trial. No other food was provided during each trial period and no other experiments were conducted on these animals over the trial period.

One stoat was released into each enclosure. Stoats were initially held in the enclosures for 48 hours. The first 24 hours were used as a training period during which wire mesh ladders provided access to the food. For the last 24-hour period the ladders were removed and all attempts to access food items recorded. It quickly became apparent that a training period was unnecessary and the remainder of the trials were conducted over a single 24-hour period. Following each trial the stoat was returned to its usual enclosure for a minimum period of seven days prior to participating in a further trial. Exposure to the nest box and collar enclosures was alternated as each animal was cycled through the two trials.

Nine stoats were selected for trials between 24 June 1999 and 24 September 1999. One of these animals died early in the trial period from unknown causes before its second exposure to the PVC nest box enclosure. Five stoats were exposed to the PVC nest box twice, one three times and three other animals (including the stoat that died) on only one occasion. The same nine stoats were also tested against the aluminium collars. Six of these animals were tested twice and the remaining three animals only once.

Videotapes were changed daily, labelled and stored for later viewing. The number of attempts to access food in a given period of activity and whether each stoat succeeded or failed in these attempts were systematically recorded. Detailed statistical analysis of the data (other than basic summary statistics) was considered inappropriate given the highly observational and descriptive nature of the study and the small effective sample size (n = maximum of 9 stoats).

Results

Nest box trials

Following the first three trials with two different stoats, it quickly became apparent that the initial nest box design was unable to prevent access. The stoats simply climbed the trunk (to which the nest box was attached), jumped onto the roof of the nest box (which was flush with the external circumference of the pipe), dropped onto the perch (265 mm below roof) and entered the nest box. Exits, usually with a mouse in their mouth, were achieved by reversing the process.

The nest box design was then modified by attaching a piece of PVC board on the top of the pipe so that it overlapped the entrance by 170 mm (Fig. 1b). None of the nine stoats in the subsequent 13 trials was able to gain access to the nest box.

The intensity of each stoat's efforts varied considerably over the 24-hour trial period. Much of the time (90% or more) was spent in dens (although some individuals were seen sleeping on the nest box roof), interspersed with short periods of intense activity. Figure 2 shows the effort (defined as the number of access attempts per minute for each period of activity over 24 hours) for each stoat. An access attempt was defined as a discrete lunge or jump at entrance or bait. The mean number of activity periods in which attempts were made to access food for each 24-hr trial for all nine stoats was 14.33 (S.D. = 7.97).

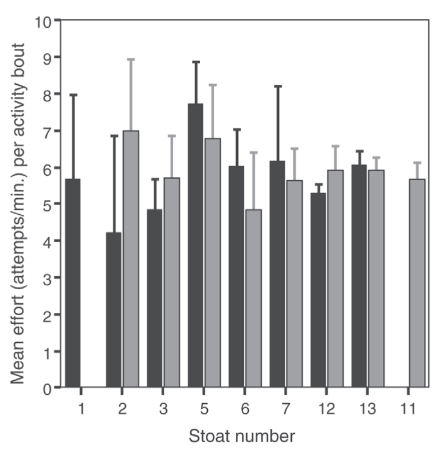

Figure 2. Effort (number of access attempts per minute for each period of activity) made to access food by each stoat in nest box and metal collar trials. Error bars show 95% confidence interval of mean. Solid bars represent 'collar effort' and shaded bars represent 'nest box effort'.

Almost all stoats climbed the trunk to access the roof. From here stoats repeatedly lunged toward the nest entrance from a variety of positions. Attempts were often so intense that they resulted in the stoat overbalancing and falling the 2.2 m to the floor. However, this did not dissuade them. Up to 33 access attempts and 10 falls were recorded in rapid succession within one 14-minute period of activity for one stoat. Other strategies to access the nest box included attempts to climb around the outside of the pipe, digging and chewing at the roof, climbing across the wire mesh ceiling of the enclosure and dropping onto the roof, or leaping horizontally from the walls of the enclosure toward the pipe — none of which succeeded.

Aluminium collar trials

Of the 15 trials conducted, three stoats were successful in gaining access to the mice on top of the trunk. Two animals in three separate trials were able to gain access by either dropping onto the trunk from the ceiling (580 mm) or by leaping from the walls (minimum of 775 mm). These animals were excluded from further analysis. In only one of these twelve trials was one of the eight remaining stoats seen to successfully jump up past the aluminium collar; this was from a batten part way up the tree trunk.

As for the nest box trials, stoats spent much of the time (about 95%) in their dens. The number of periods of activity in which attempts were made to gain access to food on top of the tree trunk was higher (mean number of activity periods for each 24-hr trial = 24.58, S.D. = 9.69) than that observed in the nest box enclosure, even though the intensity of efforts to gain access to the food per activity period (Fig. 2) was similar to that seen in the nest box enclosure.

Most attempts involved climbing the trunk to the base of the aluminium collar via the supporting braces. Once in this position the stoats held onto the trunk with their rear feet using their flattened tails as a means of support while they scrabbled about with their front legs trying to get some purchase on the aluminium. Often several positions would be tried around the base of the collar before the animal either retreated down the supporting braces or leapt at the top of the collar. Such leaps usually propelled the stoats 75% the height of the collar (approximately 440 mm or 1.6–1.7 times the body length of a stoat) and resulted in the stoats falling 1.23 m to the ground. Falls did not deter stoats from repeating the process.

The single successful jump past the collar was achieved by the stoat jumping particularly high from the top of one of the battens supporting the trunk. Once the animal was able to get its front claws on the upper edge of the collar it was an easy process to haul itself onto the top of the trunk. This feat was not repeated by this stoat during a subsequent trial.

Discussion

Artificial nest sites, such as nest boxes, are often used in attempts to assist species recovery (especially of secondary cavity nesting birds, such as parrots) where the availability of natural sites is thought to be low and competition (both intra- and interspecific) for access is high (Beggs *et al.*, 1984; Wiley, 1985; Hicks and Greenwood, 1989; Munn, 1992; Jones and Duffy, 1992; Emison, 1996; Garnett *et al.*, 1999). Success varies considerably, however, ranging from significant increases in reproductive rate (Beissinger and Bucher, 1992; Bock and Fleck, 1995; Nycander *et al.*, 1995; Garnett *et al.*, 1999) to little or no change in population status (Beggs *et al.*, 1984; Hicks and Greenwood, 1989; Low, 1994; Christian *et al.*, 1996; Hesse and Duffield, 2000).

Although not a field test, these trials could be regarded as a worst case scenario in a natural situation, given the extremely persistent and energetic attempts made by the stoats to reach the only source of food. The experimental design of the trials allowed design flaws in the construction and/or positioning of these barriers to be detected and rectified almost immediately under controlled conditions. Very minor modifications, such as the addition of a roof extension overlapping the entrance of the nest box, had a major impact and proved critical in preventing access by stoats to the nest boxes being tested. Although the number of active periods for stoats in the two enclosures were variable, this probably only reflects the stronger olfactory and/ or visual cues available to stoats attempting to reach mice placed above the metal collar. Likewise, the similarities in the intensity of activity during these periods in both enclosures are probably just a function of the energetic constraints under which stoats are able to operate.

Nest box effectiveness

Nest boxes will only be effective if they exclude predators, are recognised as attractive breeding sites, and exclude or at least effectively control competitors. Nest boxes also have to be durable, relatively cheap to build and maintain, able to be monitored on a regular basis and be provided in sufficient numbers to enable population recovery.

If there are many natural cavities in a given area but their utilisation is low, nest boxes must be provided in high enough numbers in order to maximise their chances of use (Beggs *et al.*, 1994; Hicks and Greenwood, 1989; Jones and Duffy, 1992). Under this scenario, accessible natural nests protected by metal collars will be far more effective and efficient than artificial cavities in preventing predation.

The probability of nest box utilisation will be highest in areas that have few natural cavities. Suitable areas for nest boxes of the design used in these trials may include suburban parks and reserves where kaka are known to have a regular presence (e.g. the Auckland Isthmus), and islands or "mainland islands" with few trees of suitable cavity forming size which are regularly visited by kaka (e.g. Tiritiri-Matangi and Tuhua Island). Nest boxes are also suitable for provision to populations of released captive-reared birds that have previously been exposed to them (e.g. Mount Bruce).

Preliminary observations of the acceptability of PVC pipe nest boxes to kaka and their effectiveness in preventing access to potential predators are encouraging. Several nest boxes (with an overhanging roof) have been erected within the forested reserve bordering the Mount Bruce Wildlife Centre in an attempt to increase the productivity of a reintroduced kaka population. All seven nests in nest boxes have so far successfully fledged young in the absence of additional pest control (K. Barlow, Department of Conservation, Wellington, N.Z., *pers. comm.*). It is hoped that the result is indicative of the potential benefits of artificial nest sites both at Mount Bruce in the future and their deployment at other suitable sites.

Effectiveness of metal collars

Given the failure of the collar to prevent access on one occasion, some doubt about their effectiveness is justified. Such concerns should, however, be tempered by knowledge of faults in the way the collar was set up within the enclosure. Space restrictions resulted in an enclosure for these tests that was, in retrospect, too small and constructed of materials that aided some stoats in circumventing the collar. Significant improvements to tests of collar efficacy could be made by increasing the overall enclosure dimensions, increasing the height of the collar above the supporting battens (or eliminating battens entirely), and ensuring that the tree trunk extends some distance above the top of the collar and is well below the enclosure's ceiling. Positioning the collar at a greater height above the ground may also significantly increase the risk of falling thereby reducing the intensity with which stoats attempt to pass the collar.

Metal collars will only work under a fairly limited set of conditions. Collars need to be as vertical as possible and with as few as possible seams, joins, nail heads or gaps between collar and trunk. The surface of the collar must be kept as smooth as possible. Gaps between the trunk and collar should be packed with wire mesh (or similar immovable and impenetrable materials) to prevent access. Increasing the width of collars could further increase their effectiveness by presenting a more formidable obstacle. If more than one metal sheet is required to increase the width, the base of the top band must overlap the top of the bottom band. Once in place a regular maintenance programme is also required to ensure that collars are still positioned correctly. As trees get older and larger it may be necessary to replace the metal collars to prevent attachment points from ripping out. Collars may also have to be cleaned periodically to maintain a consistently slippery surface over time.

If the canopy of the tree in which the nest cavity is located touches or is close to other trees, a second collar above the hole will be required. This strategy, however, is only likely to work if the cavity is in a trunk sufficiently distant from any major structural forks or branches that would enable a stoat or other animal such as a possum to jump directly to the entrance of the nest cavity, a limitation reinforced by the results of this study. Similarly, attaching collars to trunks or branches leaning at an angle or just below the cavity to be protected is likely to be ineffective, particularly if upper branches touch neighbouring trees.

Implications

Locating natural cavities to protect with collars is usually time consuming and, therefore, expensive. Nevertheless, natural cavities can be protected for significant periods of time for relatively little cost (e.g. Garnett *et al*., 1999). For this reason the addition of metal collars to suitable natural kaka (and other species) nest cavities within mainland habitats is strongly recommended. In addition, collars can be used in conjunction with traditional wooden nest boxes. Wooden nest boxes, although inherently more accessible to predators, are much cheaper and more easily constructed than the PVC nest boxes. However, considerable care would be required in choosing an appropriate site for such boxes to maximise the effectiveness of the collar(s).

There is a need to further develop alternative passive barriers for preventing access to natural cavities particularly those in trunks and branches that are rough, on angles, and with interlocking branches with neighbouring trees. Similarly, species such as mistletoes that are a challenge to defend against browsers also need to be effectively protected. This is particularly important on islands, where introduced climbing predators (e.g. rats, mustelids, snakes) have been implicated in significant declines of cavity nesting bird species (Evans, 1991; Gnam and Rockwell, 1991; Christian *et al*., 1996; Towns *et al*., 1997; Robinet *et al*., 1998). Unfortunately there have been few attempts to intentionally incorporate appropriate design features and construction materials to exclude such predators. Most nest boxes are often just that — box-like edifices of varying dimensions manufactured from rough-sawn planks of timber.

Although the results from our trials of preventing stoat access to PVC nest boxes and past aluminium collars are encouraging, they can only be applied to a limited set of conditions. Further trials need to be conducted with other potential nest predators of kaka (particularly possums) and other nest box and collar materials. These experiments could also be expanded to include other hole-nesting species such as kakariki (*Cyanoramphus* spp.) and mohua (*Mohoua ochrocephala*) that are also threatened by similar pests within mainland habitats. Modifications to PVC nest boxes and aluminium collars, particularly for other potential predators, are likely to be relatively minor (alterations of pipe diameter, nest box height, height and width of collar, etc.). However, any modified boxes will also need to be assessed for their acceptability to the target species and whether young are able to fledge successfully from them.

If the threat from nest predators can be removed, the next and arguably most significant challenge will be the exclusion of potential competitors for both natural and artificial nest sites. Starlings (*Sturnus vulgaris*), mynahs (*Acridotheres tristis*), eastern rosellas (*Platycercus eximius*) and even honeybees are likely to be competitors for cavities wherever they are common. Although such competitors could be locally controlled by live capture or culling, such measures are likely to be ongoing and expensive, particularly if large areas are involved. One-off modifications to natural or artificial nest sites, such as nest boxes and collars, will be more cost effective and viable over the long term. Simply reducing the size of the nest entrance may prove effective if potential competitors are significantly larger than the species to be protected (e.g. eastern rosellas and yellow-crowned parakeets, *C. auriceps*). The real test will be the successful application of these techniques in a practical field situation.

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