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Sign left by introduced and native predators feeding on Hutton's shearwaters *Puffinus huttoni*

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Abstract The identification of introduced and native predators is important for many conservation studies within New Zealand. Carcasses of Hutton's shearwaters were collected over three field seasons, and where predation was probable, the bodies were autopsied. Paired bites identified stoats as the principal predator of Hutton's shearwater, but also revealed that a feral cat was present within the colony. Stoats killed their prey with a bite to the back of the neck or head, and commenced feeding on the neck or head. Despite the limited number of cat-killed birds, cats appeared to feed on Hutton's shearwaters differently from stoats, starting on the breast muscles. Harriers and kea left sign that allowed birds killed or scavenged by these native birds to be distinguished from those killed by stoats or cats.

Keywords predator identification; feeding sign; stoats; *Mustela erminea*; cats; *Felis catus*; kea; *Nestor notabilis*; Australasian harrier; *Circus approximans*; Hutton's shearwater; *Puffinus huttoni*

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INTRODUCTION

The control of introduced predators is vital for the conservation of many bird species in New Zealand that are threatened by predation (e.g., Darby & Seddon 1990; McLennan et al. 1996; O'Donnell 1996; Wilson et al. 1998). Cost effective and biologically effective predator control requires targeting the specific predator species, as different predators are vulnerable to different control techniques. Thus, accurate predator identification is vital to allow conservation managers to target the most important predators of native species, rather than the predators presumed to be present in an area.

Documenting characteristic sign associated with particular predator species may help enable the key predators to be identified. Most attempts to analyse predation events have focused on nests, as these can readily be found and filmed (e.g., Moors 1983; Major 1991; Brown et al. 1998; Sanders & Maloney 2002). While observation of eggs and chicks attacked by predators provide important data on quantifying the sign left by predators and estimates of predation rates, relatively few predation events of adults are recorded (e.g., Brown et al. 1998). Consequently, alternative methods of obtaining descriptions of feeding sign on adult birds are required.

Few studies have been able to quantify the kill or feeding sign of introduced and native predators on adult native birds, because it is difficult to find freshly killed carcasses. Feeding trials offer an important method of identifying characteristic sign of introduced and native predators (Brown et al. 1996; Brown & Mudge 1999). However, this method is limited because few individuals can be kept captive, only non-native prey can be offered to predators, and there are ethical restrictions to the use of live prey to record kill-sign of predators. Identifying predators based on the inter-canine width of bite marks has been successfully used to identify predators of yellow-eyed penguins (*Megadyptes antipodensis*) and sooty shearwaters (*Puffinus griseus*) (Ratz 1997; Lyver 2000) and could offer a

useful technique in conjunction with characteristic feeding sign.

A 3-year study on Hutton's shearwaters (*Puffinus huttoni*) and introduced stoats (*Mustela erminea*) (Cuthbert 1999, 2001) presented an opportunity to quantify the kill sign and feeding pattern of stoats and other predators within the breeding colony. Carcasses of Hutton's shearwaters were found in all years of the study (Cuthbert 2001), and where predation was the probable cause of death, the carcass was autopsied and feeding sign quantified. The observed differences in feeding sign of different predators and the signs described in other predator studies are discussed.

METHODS

Study site and predators

The study was conducted over three breeding seasons (1996/97–1998/99) at the Kowhai valley colony (42°16′S, 173°36′W) of Hutton's shearwaters in the Seaward Kaikoura Mountains (1200–1800 m a.s.l.). Additional visits were made to the smaller Shearwater Stream colony (42°10′S, 173°44′W) in the 1997/98 and 1998/99 seasons, as well as short trips to the Kowhai valley colony during winter.

Stoats are the main predator within the remaining Hutton's shearwater colonies (Cuthbert & Davis 2002a), but other potential introduced predators include feral ferrets (*Mustela furo*) and feral cats (*Felis catus*). Introduced rats (*Rattus rattus* and *R. norvegicus*), weasels (*Mustela nivalis*), and hedgehogs (*Erinaceus europaeus*) have not been recorded in the area, and the high altitude location of the colonies is likely to exclude these species (King 1989; Innes 1990; Moors 1990). Neither rats nor weasels were trapped during two seasons of stoat trapping (Cuthbert & Sommer 2002), and hedgehogs were never seen despite many hours of nocturnal work.

Three native bird species, which kill or scavenge Hutton's shearwaters, are also found in the breeding colonies; the kea (*Nestor notabilis*), Australasian harrier (*Circus approximans*), and New Zealand falcon (*Falco novaezeelandicae*). While New Zealand falcons are known to take Hutton's shearwaters (Harrow 1976), they were only infrequently sighted at the elevation of the colonies, compared with lower altitudes in the Kaikoura Mountains (pers. obs.). Consequently, almost all raptor sign found in the colony is likely to be from harriers, which were observed there daily. The primarily diurnal foraging of harriers and the exclusively nocturnal behaviour of Hutton's shearwaters mean that almost all harrier feeding sign is likely to result from scavenging, although two harriers were flushed from a colony on a moonlit night.

Recovery of carcasses and autopsies

Bodies of Hutton's shearwaters were found by four main methods: along transects walked every 2 weeks through eight spatially distinct subcolonies, in 350 study burrows distributed in eight separate subcolonies, by radio-tracking stoats, and as miscellaneous bodies found in the course of other fieldwork (for a more detailed description of this sampling see Cuthbert & Davis 2002a,b; Cuthbert & Sommer 2002). Information on the location and position of each body was recorded, as well as any associated feeding sign. This information included the distance of the body to the nearest shearwater burrow, its position on top of, under or between tussocks (*Chionocloa* sp.), the presence or absence of plucked feathers, stoat scats or harrier feathers, and any sign of digging.

All bodies were collected and carefully dissected to locate and measure bites and injuries. Each autopsy followed a standard protocol in which all injuries and feeding sign were described with 35 categorical variables. After the initial inspection the carcass was skinned (if skin was present and the carcass was not too decayed) to search for bite marks and injuries that were not visible through feathers or coagulated blood. The minimum and maximum distances between all paired bites were measured to estimate the median inter-canine distance (Ratz 1997). When bite marks were clustered in a group, only bites that were out-lying by more than 21 mm from the group were measured to ensure measured bite marks were independent (Lyver 2000).

The feeding pattern of each species was determined from those carcasses where the predator or scavenger was either known or could be reliably determined. The species identity was considered to be "known" when predators or scavengers were directly observed feeding on the carcass, or when carcasses were recovered from radio-tracking stoats. The species identity was "reliably determined" if paired-bites unequivocally identified the predator as a stoat or cat. Carcasses that had bite marks in the range that overlapped between these two predator species (7–11 mm; Fig. 1) were excluded from the analysis. In order to quantify the feeding pattern of predators over time I classified all bodies into four

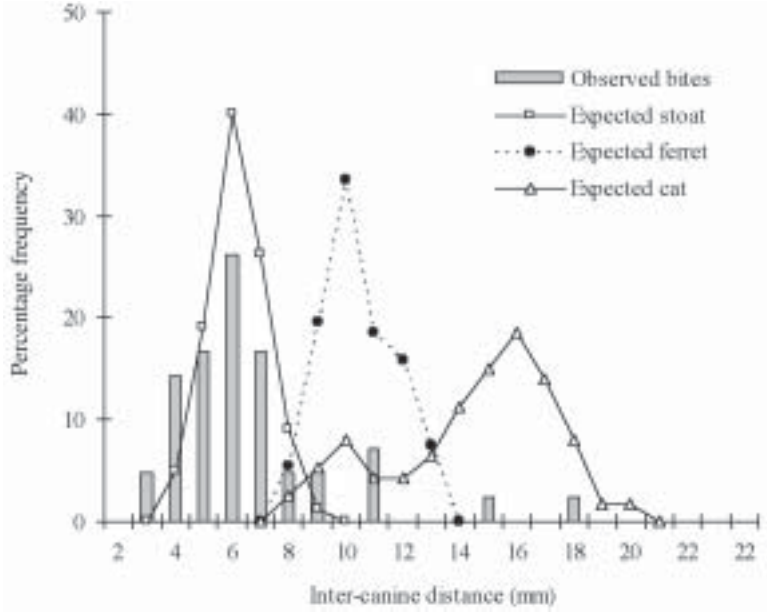


Fig. 1 Observed frequency of paired bite marks on Hutton's shearwater carcasses and expected frequency distribution of stoat, ferret, and cat inter-canine distances (after Ratz 1997).

different age-classes based on the amount of decay present or a maximum possible age (some burrows with incubating birds or chicks were checked every few days). These age classes were: 0–2 days old with fresh flesh, no sign of decay and no fly maggots present; 3–4 days old with fresh flesh and small amounts of decay in the abdomen and fly larvae <7 mm in length; 5–8 days old with some decaying flesh and maggots >7 mm in length; and carcasses 9–14 days old with the body consisting of dried skin and flesh and with maggot pupae.

RESULTS

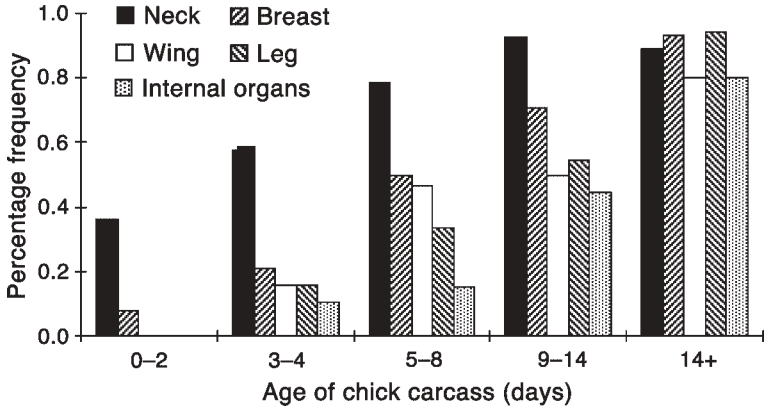
Bite marks and kill-sign

A total of 86 bodies (59 adults and 27 chicks) were found with clearly defined paired bites (n = 110 bites). The plotted frequency distribution of paired bites fitted the expected distribution of inter-canine distances measured from skulls of stoats (Fig. 1). The analysis also revealed two paired-bites that could only have come from a cat, and three paired bites within the cat and ferret range (Fig. 1). Of the 86 carcasses found with paired-bites in the stoat range, 60 were intact enough to examine the distribution of bites over the whole body (i.e., damage to the carcass was minimal). From this subsample, 56 carcasses (93.3%) had bites to the back of the head and neck. A further 17 paired bites were found on the breast (7), upper back (6), wing (2), legs (1), and rump (1). These bite marks may have resulted from initial attempts to seize the bird, or from moving the body after it had been killed. On two occasions a stoat was observed carrying a dead chick. The chicks were both gripped on the upper back, and examination of these two bodies found paired bite marks in this region, as well as killing bites to the head and neck.

Feeding pattern of introduced predators

A total of 154 carcasses could be classified with near certainty as stoat kills. Stoats first ate flesh from the neck, and 83.3% of feeding started in this region (Fig. 2). Flesh was then taken from the breast, legs, and upper wings, as indicated by the pattern of injuries with increasing carcass age (Fig. 2). The feeding patterns observed on chicks and adults were similar (Fig. 2): on both, feeding started in the neck area before progressing to other body parts. The muscles around the wing were less frequently taken from chicks (Fig. 2), presumably because these muscles are mostly undeveloped until chicks are close to fledging.

Five carcasses were identified from paired bites as having been killed and fed on by cats. In three of these five cases, feeding had started on the breast muscle, but (in contrast to stoats) the muscles of the neck were untouched. Additionally, two cat-killed birds were found in which the keel and sternum had



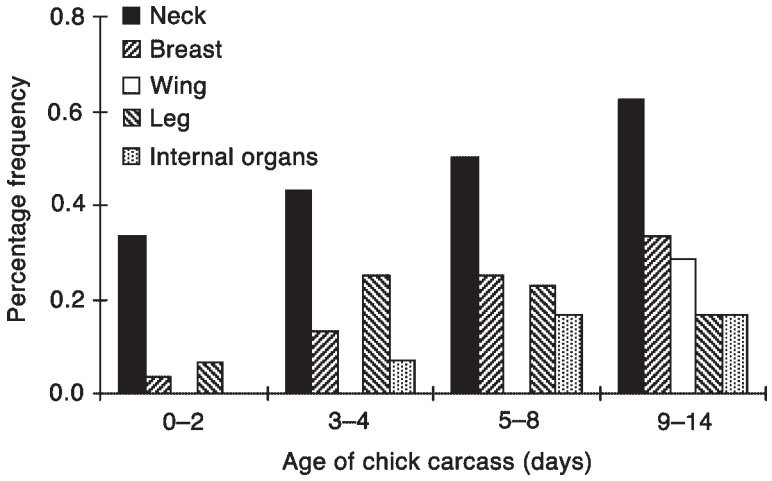


Fig. 2 Feeding pattern of stoats on adult ($n = 87$) and chick ($n = 67$) Hutton's shearwater carcasses of increasing age (chick carcasses older than 14 days were not autopsied as decay obscured the original feeding sign).

been chewed through to open the thoracic cavity, a pattern never observed for stoat-killed birds (Table 1).

Both cats and stoats often skinned the bird, peeling the intact skin with attached feathers away from the body. Neither stoats nor cats chewed through or snapped large radial bones (e.g., femur, tibiotarsus, and humerus), and these injuries were found only on kea-killed or harrier-scavenged birds (Table 1). The only exceptions were four shearwater bodies cached by stoats over the winter. Checks at the colony during winter found that stoats had revisited the caches, and had broken and consumed large radial bones as well as the webbing of the feet and metatarsal bones (a pattern not observed when these carcasses were first autopsied).

Feeding pattern of native predators

Altogether, 42 bodies were known to be killed by kea or scavenged by harriers. The 24 harrier carcasses were typically found on a flat patch of ground or on top of a tussock, and were surrounded by large quantities of plucked feathers. Carcasses that had been fed on by harriers showed signs of plucked skin, heavily "notched" keel bones, or consisted of only the sternum and wings. None of the birds known to be killed by stoats, cats or keas showed any of these signs (Table 1).

The principal sign of kea predation was the presence of digging and 83% of chick carcasses were found in, alongside, or downhill of a burrow with fresh sign of attempts to enlarge the entrance or dig into the nesting chamber. In contrast to stoats and

Table 1 Frequency of occurrence of characteristic injuries or feeding sign of stoats, cats, Australasian harrier, and kea, feeding upon Hutton's shearwaters.

Injury or feeding sign	Stoat %	Cat %	Harrier %	Kea %
Flesh only consumed from neck, rest of body intact	83	0	0	4
Puncture wounds to the back of the head and neck	65	0	0	0
Skin peeled away from body with feathers attached	25	80	0	0
Hole chewed through sternum	0	40	0	0
Flesh consumed from breast or back, neck intact	0	60	0	12
Bare plucked skin or plucked feathers around body	0	0	89	0
Notched keel-bone/triangular gashes in sternum	0	0	33	0
Wings and sternum only part of body remaining	0	0	39	0
Humerus, femur or other large radial bones broken	2*	20	100	38.9
Fat consumed from body flesh intact	2	0	0	46
Neck and breast intact, injuries to back, legs or wings	0	0	0	31
Body found within, alongside or below fresh digging at a burrow	0	0	0	83
Total sample of bodies with known cause of death (no.)	154	5	18	24

*The only exception to this were carcasses cached and revisited by stoats over winter (see Results).

cats, kea do not appear to eat the carcass in any systematic fashion, but attack all body areas with equal frequency. Kea would often consume only the fat from the chick's carcass (47% of cases), leaving the underlying muscles and internal organs intact. Such a feeding pattern was very infrequently found in stoat-killed birds (Table 1).

DISCUSSION

The results of this study confirm that stoats are the main predator of Hutton's shearwaters (Cuthbert & Davis 2002a). The frequency distribution of paired bite marks confirms both the role of stoats and the usefulness of this predator identification technique (Ratz 1997; Lyver 2000). Paired bite marks also revealed the presence of at least one feral cat within the Kowhai valley colony. No cat has previously been reported there, but this record is definite, since cat-scats and five cat-killed bodies were found during the same 2 weeks. There was no indication that cats were present in the Kowhai valley colony at any other stage of the three breeding seasons, nor were cat-scats found at Shearwater Stream. The measurements of three of the five cat bite-marks overlapped with the range expected for feral ferrets. I interpreted these three bites as being probably from a cat, as they were found within the same 2-week period as the two definite cat bites, and because ferrets are easily trapped (Cross et al. 1998) and no ferrets were caught during two seasons of stoat trapping (Cuthbert & Sommer 2002). The variation in the size of cat-bite marks recorded is likely to result from differences in inter-canine distances of the upper and lower jaw (Fig. 1; Ratz 1997), rather than indicating the presence of more than one cat in the colony.

Over 90% of paired-bites in the stoat range were found on the back of the head or neck, confirming that the killing bite of stoats is most often delivered to this region (Hewson 1971; King 1990). In most cases stoats began feeding on the neck of the bird (Hewson 1971), usually around the location of the killing bite. Feeding by stoats then progressed to the muscles of the breast, legs, and upper wings, suggesting that stoats eat their prey in a systematic manner.

From the limited sample of birds (five) identified from paired-bites to have been killed by a cat, it was nonetheless clear that the cat's pattern of eating was different from that of stoats. Cats did not preferentially start feeding on the neck, but from the larger pectoral muscles. Cats, like stoats, skinned the bird, peeling the intact skin with attached feathers away from the body. Possibly this is a common feature of mammalian predators as possums are also reported to skin their prey (Brown et al. 1996), and this pattern was not found in any known kea-killed or harrier-scavenged birds, nor is it reported for moreporks (*Ninox novaeseelandiae*; Brown & Mudge 1999).

The most common features of harrier scavenging were the presence of plucked feathers or skin, the

location of the carcass on top of a tussock or on bare open ground, and notches left on the keel or sternum of carcasses that frequently consisted of only the sternum and wings. Similar patterns have been observed for other birds of prey, and these sign appear characteristic of raptor predation or scavenging (Small et al. 1991; Hartman et al. 1997; Redpath & Thirgood 1997). Harriers were not found to pluck the primaries of Hutton's shearwaters, as has been observed for moreporks (Brown & Mudge 1999). Possibly this action is more likely when raptors feed on smaller birds than prey the size of Hutton's shearwaters.

This study confirms that kea are a predator of Hutton's shearwater chicks and eggs, and actively dig into the nesting chamber and kill the chick by biting and crushing the skull (pers. obs.). Other than digging, there was no specific kill or feeding sign typical of kea, although they showed a tendency to consume only fat more frequently than other predators.

CONCLUSIONS

A combination of direct observations, radio-telemetry, measuring of bite marks and recording feeding pattern and field sign were used to identify and quantify the role of different predators on Hutton's shearwaters (Cuthbert 2001; Cuthbert & Davis 2002a). For shearwaters recovered on frequently walked transects and down study burrows, the criteria of Table 2 identified the assumed original cause of death in around 50% of cases (54.2% of adults and 44.9% of chicks; Cuthbert & Davis 2002a). Scavenging by harriers was responsible for 94% of the cases where the original cause of death could not be determined, presumably because they consumed and obscured the feeding sign of the original predator. Paired bites alone were able to identify the cause of death in only 15% of cases. The major disadvantage of this technique as a tool for predator identification is the need to recover bodies that are still fresh and where the original kill sign has not been consumed.

Table 2 Injuries and sign used to classify the cause of death of adult Hutton's shearwaters found on transects (from Cuthbert 2001 and Cuthbert & Davis 2002a).

Classification	Sign	Injuries
Accident	Beneath bluff	Broken bill, broken wing
Trapped	Stuck in entrance or burrow	Intact body
Starvation		Intact body, mass of adult or chick <99% confidence intervals of healthy birds
Stoat	Down burrow	Paired punctures <9.5 mm apart[1]
	Between or under tussocks	Puncture/bite to back of head/neck[2,3]
	Chewed feathers[4]	Flesh consumed from neck and/or upper breast only[2,5]
	Stoat scats present	Skin peeled away from flesh[5]
Cat		Paired punctures between 9.5–21 mm apart[1]
		Flesh removed from breast or back with neck intact[5]
		Thoracic cavity entered by hole chewed through keel/sternum[5]
		Skin peeled away from flesh[5]
Kea	Digging close to body	Broken large bones[5]
		Fat consumed but flesh intact[5]
		Injuries to back, breast, wing, or legs but neck intact[5]
Harrier	Body found on top of tussock or rock	Feather plucked from skin
	Large numbers of plucked feathers[4,6]	Notched keel bone[5,7]
	Harrier feathers present	Just wings and sternum present[6]

[1]Lyver (2000); [2]Hewson (1971); [3]Hudson & Newborn (1995); [4]Small et al. (1991); [5]this study; [6]Hartman et al. (1997); [7]Redpath & Thirgood (1997).

While this study was restricted to quantifying the feeding and predation on Hutton's shearwaters, the criteria of Table 2, and other kill and feeding sign recorded here, may be of use for identifying predators of similar sized (c. 300–400 g) seabirds, shorebirds, and landbirds in New Zealand. The observed feeding behaviour of stoats may be common to all mustelids, so kills with mustelid like sign should not be attributed to stoats in areas where other mustelid species are present. The differences between the feeding behaviour of cats and of stoats, should be further quantified and confirmed through feeding trials.

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