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SHORT COMMUNICATION

SIGN LEFT BY BRUSHTAIL POSSUMS AFTER FEEDING ON BIRD EGGS AND CHICKS

Summary: Brushtail possums (*Trichosurus vulpecula*) were offered Japanese quail (*Coturnix japonica*) eggs and day-old domestic chickens (*Gallus gallus*) during a captive feeding trial. Differences in feeding sign left by possums of differing sex, age class, and hunger were slight or absent. Possum feeding trial remains were also compared with remains of North Island robin (*Petroica australis longipes*) and North Island tomtit (*Petroica macrocephala toitoi*) eggs and chicks preyed on by ship rats (*Rattus rattus*) at videoed nests. Eggs fed on by possums were frequently crushed or had crushed shell margins whereas eggs preyed on by ship rats often had jagged shell margins and separate small shell fragments. Possums that ate chickens mostly left partially eaten carcasses with torn flesh, of which 50% were at least partially skinned. Ship rats left partially eaten birds with chewed flesh and bones but did not skin carcases. Possums rarely spat out shell pellets but produced feather pellets on eight of 13 occasions. Egg shell remains left by possums were indistinguishable from those left by ship rats for 11% of 72 shell remains examined from the feeding trial. Characteristic sign should enable possums and ship rats to be differentiated as predators after most but not all predations.

Keywords: Brushtail possums; *Trichosurus vulpecula*; ship rats; feeding trials; predation; predator sign; conservation.

Introduction

Brushtail possums (*Trichosurus vulpecula* Kerr) have been identified as predators of adult birds, eggs and chicks. A captive possum caught and partially ate a house sparrow (*Passer domesticus* L.) (Morgan, 1981), and time-lapse video photography recorded wild possums eating kokako (*Callaeas cinerea wilsoni* Gmelin) eggs (Brown, Innes and Shorten, 1993) and chicks (Innes, Crook and Jansen, 1994). Anecdotal accounts implicated possums as predators of at least five other bird species, and feeding trials linked sign left at preyed-on kokako nests to possum feeding (Brown *et al.*, 1993).

Possum predation has direct and potentially enormous implications for protected species management on the New Zealand mainland because possums are ubiquitous and abundant (up to 25 ha^{-1} in some mixed hardwood forests; Coleman, Gillman and Green, 1980). Conservation managers need to know the significance of possums as predators in different forest communities if they are to develop effective control programmes to protect species at risk. However the impacts of possums on bird populations is unknown. Determining impacts of predators on bird populations relies on linking predator identity to predation events.

Predation at nests is virtually never observed (Major, 1991), therefore the sample size of evidence linking predator species to sign left after predation (i.e. egg shells and bird carcases) is small. Video photography is currently the most reliable means of identifying predators and linking predators to sign (Brown, 1994) but is expensive and time consuming, so that usually only a few predation events are detected. Characteristic sign (sign particular to one predator species) offers a potentially valuable and cheaper method of monitoring predation at a much larger number of nests but its worth as a diagnostic tool for guiding predator management has yet to be determined. Removal of evidence from the nest by parent birds, scavenging, and overlap in sign between predator species can confuse predator identity (Skutch, 1966; Baker, 1980; Angelstam, 1986; Storaas, 1988; Brown, 1994).

Variability in sign between and within predator species needs to be clearly determined. Feeding trials with captive animals offer an effective means of linking predator identity with sign. They also enable quantification of between-species and within-species (age, sex) variability in sign production and whether or not hunger alters the nature of the signs left. Accordingly the aims of this paper are to:

(1) Examine and describe the feeding sign of male and female, adult and sub-adult, fed and fasted possums when feeding on eggs and dead day-old chickens.
(2) Compare the sign left by captive possums with that of wild ship rats filmed feeding on birds and eggs.

Methods

The feeding trial was carried out between 8-20 June 1994 at the Landcare Research captive possum facility at Rangiora, New Zealand. Possums were caught in farmland, pine plantation and river edge habitats, near Darfield, New Zealand. They were held for at least six weeks to acclimatise to captivity prior to this feeding trial. Cages were 1 x 0.4 x 0.4 m and contained nest boxes measuring 0.35 x 0.2 x 0.2 m.

Forty individually caged possums (10 adult males, 10 sub-adult males, 10 adult females and 10 sub-adult females) were offered three Japanese quail (*Coturnix japonica* Temmick and Schlegel) eggs (34 x 26 mm) and two dead day-old domestic chickens (*Gallus gallus* L., 33-46 g), on two separate occasions each. Eggs and chickens were presented in metal trays (200 x 100 x 50 mm) on all occasions except in treatment one when eggs were presented to 24 of 40 possums in robin and tomtit nests. Freshly killed, frozen male day-old chickens obtained from South Chicks Limited, Ohoka, Christchurch, New Zealand were defrosted before being offered to possums.

Male possums with small testes were classed as sub-adult (Cowan, 1990). Females showing no sign of breeding (i.e. lactation, extended pouch, pouch young) and weighing less than 2.8 kg when caught were classed as sub-adult.

A "normal" captive possum diet (150-200 g of pellets with a pollard base, vitamins, molasses and meadow hay and half an apple daily and other fresh fruit or vegetables 2-3 times per week) was provided during 50% of treatments (see below). Fresh water was available at all times and in all treatments. Two days were allowed between treatments (Table 1).

The possums were divided into two groups, split evenly by age and sex (Table 1). On any one treatment day, one group was provided with only the test material ("Fasted") and the other group received normal rations as well as the test material ("Fed"). Those fasted in treatments 1 and 2 were fed in treatments 3 and 4 and vice versa. The test materials were given to the possums at 1600 hours of the treatment day. At 0800 hours on the following day all remains were removed and normal food supplies were replenished. Possums were weighed on the morning of the first treatment day and again on 20 June 1994, three days after the forth treatment day.

Sign left after feeding on eggs and chickens was recorded and comparisons were made between possums of different sex, age (adult versus sub-adult) and feeding regime (fed versus fasted). Damaged egg clutches, chickens removed from trays or eaten and pellets of shell or feather regurgitated by possums were recorded. Removal of chickens from trays and partially damaged clutches provided indices of interference.

Fisher's exact tests were used to compare outcomes (i.e. nest damaged, at least one of three eggs eaten or damaged, at least one whole egg remaining, chickens eaten and chickens removed from trays) in each group (i.e. male vs female, adult vs sub-adult, fed vs fasted, treatment 1 vs 3 and treatment 2 vs 4).

Casual observations of possum behaviour were made by walking around the possum housing facility for approximately one hour after possums were given eggs and chickens.

A sample of 72 individual shell pieces was collected from beneath possum cages after possums had fed on them during treatments 1 and 3. This sample may be biased towards larger shell pieces as no attempt was made to collect all the shell pieces and fragments present.

Egg and chick remains from this possum feeding trial were compared with others from videoed wild nests which had been preyed on by ship rats (Brown, 1994) to contrast sign left by the two predator species.

Approval for the feeding trial was obtained from the Otago University Committee of Ethics in the Care & Use of Laboratory Animals (Licence No. 26-94).

Results

Comparison of outcomes by sex, age, time and feeding regime

Males ate or damaged significantly more eggs than females, as did sub-adults compared to adults in treatment 1 but not 3 (Table 2). However, neither

Table 1: *Design of the possum feeding trial.*

Treatment	Date	Fed (50% of each age, sex class)	Fasted (50% of each age, sex class)	Prey item (no. per possum)
1	8 June 94	Possums 1-20	Possums 21-40	Eggs (3)
2	11 June 94	Possums 1-20	Possums 21-40	Chickens (2)
3	14 June 94	Possums 21-40	Possums 1-20	Eggs (3)
4	17 June 94	Possums 21-40	Possums 1-20	Chickens (2)

length of exposure nor denying normal food (fasted) significantly altered possum consumption of or damage to eggs and chicks.

The differences between sex, age and fed/fasted groups were slight or absent with only two significant results by sex and age in treatment 1 (Table 2). When results are pooled by combining treatments 1 with 3 and 2 with 4, the most frequent outcomes were partially eaten or damaged clutches and damaged nests (Table 3). Shell pellets (Brown *et al.*, 1993) were produced from only 5% of 80 egg clutches (Table 3). Chickens were moved from trays on 31% of 79 occasions and chickens were at least partially eaten on 18% of 79 occasions. Possums produced feather pellets (Fig. 1a) on eight of 13 occasions when chickens were eaten and one occasion when the chicken was not eaten but feathers were removed. Egg shell pellets were produced on three of 72 occasions when egg clutches were eaten or damaged (Table 3).

Feeding observations and sign left

Captive possums frequently fed on eggs while sitting on their nest boxes or elsewhere in the cage away from nests and metal trays. Most possums held the

Table 2: *Comparisons of sign left by male (m) and female (f), adult (a) and sub-adult (s), fed (f) and fasted (h) possums after feeding on eggs and birds. Sex, Age and Fasted data are expressed as percentages. The * indicates* P *<0.05 (Fisher's exact test). All other comparisons were non-significant. n=20 for each group except for* [1] *n=12 and* [2] *n=19.*

Outcome	Treatment	No. showing outcome (%)	Sex %		Age %		Fasted %	
			m	f	a	s	f	h
Nest damaged	1	17/24 (71)	92[1]	50[1]	58[1]	83[1]	67[1]	75[1]
At least one of three eggs eaten or damaged	1	35/40 (88)	100	75*	75	100*	90	85
At least one of three eggs eaten or damaged	3	37/40 (92)	95	90	85	100	95	90
At least one whole egg remaining	1	4/40 (10)	10	10	15	5	15	5
At least one whole egg remaining	3	9/40 (23)	15	30	25	20	10	35
Chickens at least partially eaten	2	5/39 (15)	15	11[2]	11[2]	15	15	16[2]
Chickens at least partially eaten	4	8/40 (20)	25	15	15	25	20	20
Chickens removed from trays	2	14/39 (36)	45	26[2]	21[2]	50	25	47[2]
Chickens removed from trays	4	13/40 (26)	35	20	30	25	35	20
Shell pellets produced	1	1/40 (3)	0	5	0	5	5	0
Shell pellets produced	3	3/40 (8)	10	5	5	10	10	5
Feather pellets produced	2	3/39 (8)	5	11[2]	0[2]	15	15	0[2]
Feather pellets produced	4	6/40 (15)	10	20	10	20	5	25

Table 3: *Frequency of possum (this feeding trial; Brown,* et al., *1993) and ship rat sign (Brown, 1994) after feeding on eggs and birds. The * indicates that parent bird removal of sign and/or rearrangement of nest lining (n=10) probably influenced the frequency of occurrence of outcomes.*

Outcome	Possum (This feeding trial)	Possum (Video evidence; Brown *et al.*, 1993)	Ship rat (Video evidence; Brown 1994)
Nest damaged	17/24	0/2	0/15
Lining disrupted	0/24	2/2	9/12*
Shell fragments	Infrequent	2/2	9/9
Shell pieces (>33% of shell remains)	40/72	2/2	7/9*
Shell pellets	3/72	2/2	0/9
Birds eaten, no remains	1/14	-	1/3*
Partially eaten bird	13/14	-	2/3
Some viscera eaten	11/14	-	2/3
Brain eaten	9/14	-	2/3
Feather pellets	9/15	-	0/3
Gnawed bones & flesh	0/14	-	2/3
Rat faeces	-	-	1/12

egg in one paw while licking out the contents before dropping the shell. Crushed shell and/or shell margins were found in 89% of 72 individual shell remains examined. Shell pieces (where > 33% of shell material was left, either estimated by volume or mass) had crushed shell margins and/or a crushed shell structure on 85% of 40 occasions (Fig. 1b). Some (15%) of 40 shell pieces examined were not crushed (Fig. 2a) and were similar in appearance to shell pieces left by ship rats (Fig. 2b).

Possums infrequently left small shell fragments (<3 mm x <3 mm) that were not connected to other shell remains by shell membrane. One possum was seen to eat both egg shell and contents. This animal left only two small fragments of shell. Some eggs had holes with inwardly turned shell fragments as though something had been pushed through the shell but otherwise the clutch of eggs was untouched.

Three possums produced shell "pellets" (Brown *et al.* 1993) by crushing egg shell in their palate before spitting it out. Some shell pellets were of tightly compressed shell fragments held by the egg membrane while others were of a looser infolded nature.

Nine possums produced feather pellets (Fig. 1a). Pellets were distinctive (on average 15 x 5 mm in size) but some variation in shape did occur, from string-like to arrowhead. A possum was observed moving feather material around in its mouth prior to spitting it out as a pellet.

Most (93%) of possums that fed on chickens left chicken remains. One possum was observed to eat one and a half chickens (feather, bone, flesh, skin and viscera) without discarding any remains other than the uneaten half chicken. In a second case only

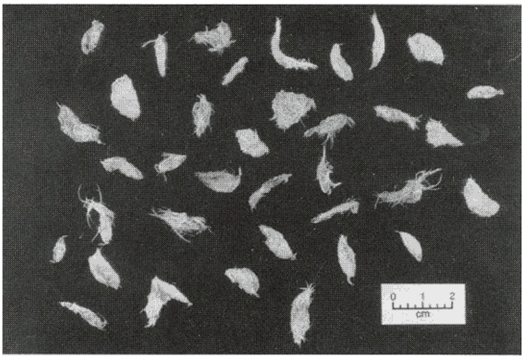

Figure. 1a: *Feather pellets left by possums after feeding on day-old domestic chickens. Note the variation in shape from string-like to arrowhead-like.*

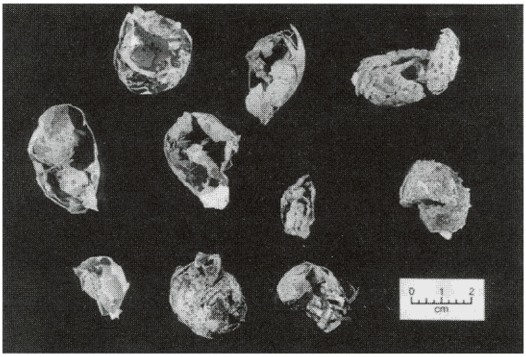

Figure. 1b: *Japanese quail eggs after being fed-on by possums. Note the crushed nature of their shell margins and shell structure.*

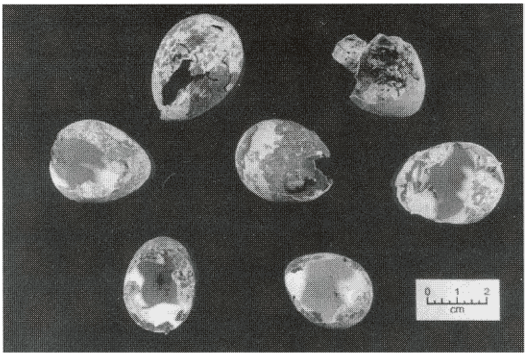

Figure. 2a: *Japanese quail eggs after being fed-on by possums. Note that some are partially crushed while others are very similar to large shell pieces left by ship rats in Fig. 2b.*

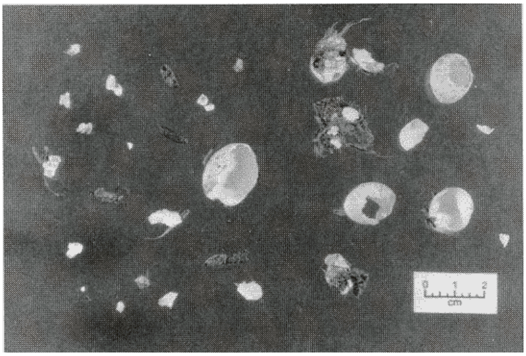

Figure 2b: *North Island Robin (*Petroica australis longipes*) and North Island Tomtit (*Petroica macrocephala toitoi*) eggs after videoed ship rat predation. Note shell pieces with jagged margins and small shell fragments.*

one leg remained uneaten and in a third case no viscera, body or feathers were left.

Possums skinned birds (removed skin and feathers) on 50% of occasions. The skin and feathers were either eaten or left connected to the carcase. Possums were observed pulling flesh, viscera and skin from dead chickens rather than chewing the chickens, resulting in torn flesh without tooth marks, though a scallop-shaped flap of flesh (presumably produced by the possum's front incisors) was noted in one case. Bones were cleanly broken with no evidence of teeth marks. Further detailed descriptions of remains are in Table 4.

Change in weight over the trial duration

No significant difference was found between capture weights and weights obtained at the start of the trial (Paired t-test, $P = 0.105$). However a significant increase in mean weight (37%) occurred from the start to the finish of the feeding trial (Wilcoxon signed-rank, $P = 0.0004$). Twenty-seven possums gained weight, ten lost weight and three showed no change.

Discussion

The reliability of feeding trials

This feeding trial was carried out with only 40 possums in a captive setting. Predation rates and sign of wild possums are probably affected by numerous factors such as habitat type and quality, possum density and behaviour, prey behaviour, season and climate. Genetic variation and learned experiences also probably influence predatory behaviour and sign of individual possums.

Observations of how sign is produced can be easily made during feeding trials. For example, during this trial possums were observed for the first time moving feather remains around in their mouths before spitting out feather pellets.

Comparisons between sign left by wild possums and those in feeding trials are needed if results from feeding trials are to be validated. However only six reports of direct observations of possum visits to wild nests have been published (Brown *et al*., 1993; Innes *et al*., 1994), all with North Island kokako whose eggs (34-42 x 25-29 mm) are similar in size to those of Japanese quail (34 x 26 mm). These few available videoed events are largely consistent with results from this trial. Captive possums frequently left crushed egg shell after feeding on eggs, while on the three occasions when wild possums were videoed feeding on eggs (Brown *et al*., 1993; J. Innes *unpubl. data*) they left crushed infolded shell pellets. Two other recorded visits by wild possums to kokako nests did not result in predation (Innes *et al*., 1994). The female kokako successfully fended off a possum in one case and in the second the possum did not molest kokako chicks after the female left the nest. In a third case, a possum chewed the head and wings of a 9-day old chick during a three-minute visit to the nest. The chick died 4-5 days later. The possum was filmed at the nest again after the chick died but it did not scavenge the chick. Captive possums also showed a variety of responses to day-old chickens. Some left chickens untouched; others moved chickens without feeding on them and others fed on chickens.

Despite their potential weaknesses, feeding trials provide a valuable means of obtaining data of sign quickly when observations of natural events are

Table 4: *Description of body parts remaining and missing from dead day-old chickens (two per possum) after they were fed on by captive possums. The numbers in brackets (1&2) refer to separate chickens.*

Date	Description of sign
11.6.94	(1) Body mostly skinned (feathers remain around cloaca, lower breast & top of legs), head severed, some flesh removed and hanging off tibia. Head missing-beak, eyes, 1/2 brain case and brain. (2) One leg-most of flesh & feet gone. Stomach remained.
11.6.94	Backbone, heart & two partially eaten ribs. Lower body-some flesh removed from both tibia, one tarsus & foot gone. Beak & 1/8 of the brain case, eyes, brain & flesh removed. Piece of bone, flesh removed. Lower bill with feathers attached. Lower body-skinned. Lower body-mostly skinned, one wing gone. One leg & portion of mid body. Wing tip. One leg-tibia & tarsus. Note: Possum had access to four chickens.
11.6.94	(1) Body wet all over as if sucked/licked, hole in body near cloaca. (2) One leg partially eaten, one wing partially eaten, head & neck partially skinned, hole near anus, some viscera eaten. Five feather pellets.
11.6.94	(1) Flesh on neck eaten, flesh of one leg partially eaten, viscera eaten and breast skinned. (2) Flesh of neck & one leg partially eaten.
11.6.94	(1) Legs & lower body skinned, some flesh eaten. (2) Neck, back & one leg skinned & some flesh eaten. Ten feather pellets.
11.6.94	(1) One leg & viscera eaten, including that in upper chest cavity. (2) Head separate, leg bones some flesh remaining connected to, rib cage & one wing remaining. Twenty feather pellets.
17.6.94	(1) Foot & lower third of tarsus remaining. (2) Lower body skinned, some feathers still attached, head and viscera eaten, flesh eaten from tibia & tarsus on one leg.
17.6.94	One tarsus and foot-skin still attached, remaining.
17.6.94	Both chickens eaten with no remains.
17.6.94	(1) Flesh & feather removed from head, most of the skull & brain gone, tarsus bone-flesh & foot missing, second leg gone-bone broken near top of tibia. Three feather pellets.
17.6.94	(1) Head almost severed at neck, toes of left foot gone, tarsus and flesh missing on right leg, some skin removed at top of abdomen below neck. Eleven feather pellets.
17.6.94	(1) Lower abdomen opened at belly, some viscera gone, right leg severed. (2) Head severed, skull opened & brain gone, tip of wing gone, right leg almost severed, belly & viscera eaten. Four feather pellets.
17.6.94	(1) Head gone, right leg severed & viscera gone. Three feather pellets.
17.6.94	(1) Skinned body, some feathers remained on lower back near cloaca, head severed and partially skinned, flesh removed from right tibia. (2) Head severed & partially skinned, neck skinned, one wing removed & second wing skinned, both tibia & upper abdomen skinned. Forty four feather pellets.

rare and very costly to obtain. However, the frequency with which eggs and chickens are eaten in feeding trials may not accurately reflect the wild situation, whereas feeding behaviour and the nature of the sign left after feeding are less likely to differ from that of wild possums. The sample size of sign left by possums after feeding on eggs and chicks has been dramatically increased by this trial and the results obtained should assist conservation biologists to better distinguish between possum and ship rat predation. However further comparisons of sign from feeding trials and "natural" predation events are needed if sign is to be used to identify predators reliably.

Comparisons by sex, age, time and different feeding regimes

The only two significant differences in sign detected between age and sex groups occurred in only one trial. Since over 30 tests have been made at least two marginally significant results such as this might be detected just by chance. Accordingly we dismiss the two results as "type two" errors of hypothesis testing (Sokal and Rohlf, 1981). Some males, females, adults and sub-adults consumed eggs and chickens and no difference was found between sex and age classes in the nature of the sign left behind. A high percentage (90%) of egg clutches was at least partially damaged. Damage or removal of even one egg in a clutch will result in abandonment by female robins and tomtits (Butler and Merton, 1992; KPB *pers obs.*). Accordingly possum encounters with some nests may result in nest failure even if possums do not prey on them.

The proportion of chicks removed and eaten suggest that many possums will eat birds if they encounter them. No trends were found between possums provided with food and those denied food which may indicate that a "significant" level of hunger was not induced. This possibility is further supported by a significant overall increase in weight during the trial. The possums may have been on an upward weight change anyway, through becoming increasingly accustomed to captivity. Alternatively, possums may have been hungry but this did not result in a change of "predatory" behaviours.

Comparison of possum and ship rat sign

The combined evidence from this feeding trial and from video sequences of wild possums at birds nests (Brown *et al*., 1993) found that shell pellets, crushed shell pieces and margins, feather pellets, skinned chickens, torn flesh and cleanly broken bones were left by possums after feeding on eggs and chicks. Evidence from video sequences of ship rats at birds' nests (Brown, 1994) found that jagged shell margins from which small shell fragments have been removed, gnawed flesh and bones and ship rat faeces were left by ship rats after feeding on eggs and chicks.

Possums feeding on eggs can produce similar sign to rodents (Brown *et al*., 1993). Both ship rats and possums can leave small shell fragments in disrupted nest lining, despite earlier suggestions that such evidence was diagnostic of rat predation (Moors, 1978). One videoed possum (Brown *et al*., 1993) was observed using its paws and muzzle to displace nest lining, presumably in search of spilled egg contents, in a similar manner to videoed ship rats (Brown, 1994). However, all possums videoed at kokako nests left shell pellets or very infolded shell pieces which ship rats are not known to produce. Captive possums left few small shell fragments and few shell pellets though they frequently, but not always, left crushed shell remains and curved shell pieces with crushed margins. A possible explanation for the contrast between video evidence and these feeding trial results is that possum behaviour differs in captivity from the wild. Alternatively, differences in egg shell structure (between kokako and Japanese quail, in this case) such as shell thickness and strength of shell membrane may influence the frequency of small shell fragment and shell pellet production.

In previous feeding trials (Brown *et al*., 1993), a possum ate the egg of a domestic chicken without producing a shell pellet but shell pellets were produced by the same possum when offered four starling (*Sturnus vulgaris* L.) eggs. If wild possums feeding on forest bird eggs produce shell pellets consistently this might provide a definitive means of distinguishing between ship rat and possum predation of eggs. As most nests are preyed on at the egg stage (Moors, 1983; Brown, 1994; Clout *et al*., 1995) further knowledge on the production of shell pellets is useful. Therefore, feeding trials in which captive possums are offered a variety of egg types would provide a worthwhile test of the importance of varying shell structure to shell pellet production and provide confidence about the frequency at which possums produce shell pellets after feeding on different eggs.

Captive possums damaged 71% of 24 nests, while two videoed possums disrupted kokako nest lining but did not damage nest structures and a third possum did not disrupt the kokako nest lining. Captive possums tore most nests apart so that only a clump of nest material remained but ship rats are not known to destroy nests in the wild. The destruction of nests by possums has not been observed in the wild and may be an artefact of the captive situation. A comprehensive study of robin predation at nests carried out at Kowhai Bush, Kaikoura (Flack and Lloyd, 1978) reported "a small number" of nests from a sample size of 521 which were "totally destroyed". Possums were described as "present but uncommon" (Moors, 1979). Further studies of forest bird predation at nests are required to determine the importance of nest destruction to forest bird populations when possums are at high density.

Both ship rats and possums are capable of leaving partially eaten birds. However ship rats frequently leave gnawed bone and/or flesh after feeding on robins and tomtits (Brown, 1994) while captive possums were observed to tear off pieces of flesh and cleanly break bones when feeding on chickens. Possums also skinned chickens (this trial) and left feather pellets (this trial; Brown *et al*., 1993). Such evidence may provide an important means of distinguishing between possum and ship rat predation but can only be applied to a few predation events because most nests are lost at the egg stage in unprotected forest communities.

In summary, this research found that possums and ship rats mostly leave different sign after feeding on eggs and birds which strongly suggests that sign can be used as a valuable tool for determining the significance of possums and ship rats as predators. Still further research is required to quantify overlap in sign between possums and ship rats in the wild and to determine the frequency at which characteristic sign is produced at natural predation events. The nature of sign left by stoats (*Mustela erminea* L.), ferrets (*Mustela furo* L.), weasels (*Mustela nivalis* Erxleben), cats (*Felis catus* L.), morepork (*Ninox novaeseelandiae* Gmelin) and kahu (*Circus approximans* Peale) is little known and may overlap with possum and ship rat sign. Reliable knowledge on the significance of different predators is dependent on video photography supported by larger samples of characteristic sign. If mainland forest communities are to be managed with the goals of maintaining and enhancing present avifauna densities and diversity then it is essential that the relative importance of possums and other predators are measured.

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