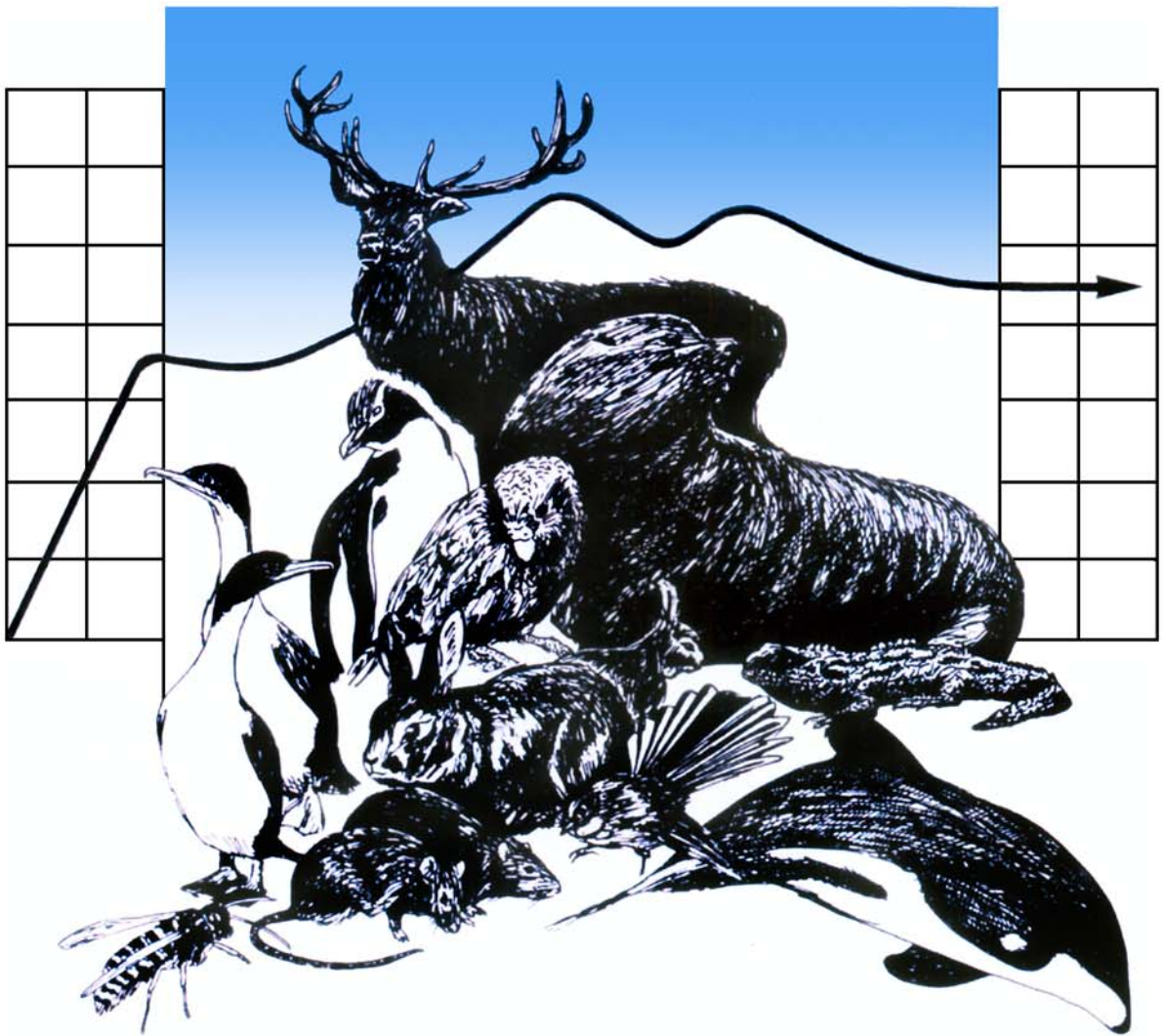# DEPARTMENT OF ZOOLOGY

WILDLIFE MANAGEMENT

A preliminary evaluation of mammalian predator trapping efficacy at Macraes Flat, Otago

Aparna Lal

A report submitted in partial fulfilment of the requirements for the
Postgraduate Diploma in Wildlife Management

University of Otago

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New Zealand

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ABSTRACT

Grand *(Oligosoma grande)* and Otago skink (*Oligosoma otagense*) populations, threatened largely by mammalian predation are restricted to the montane tussock grassland habitats of Macraes flat, Otago, New Zealand. In late 2005-2006, an experimental predator control programme aimed at enhancing skink survival was started at Macraes. This study represents a preliminary evaluation of trends in the first year of trapping and analyses the relative efficacy of the six trap types (Victor, DOC150, DOC250, Conibear, Timms, Fenns) and three bait types (rabbit, fish, egg) used. A total of 1384 target predators were caught over 202864 trap nights during the 2005-2006 trapping period, resulting in an overall trapping efficiency of one predator per 147 trap nights. Four predator species were caught in sufficient numbers to allow statistical comparisons. Hedgehogs ($n = 939$) and cats ($n = 217$) were the most abundant, followed by ferrets ($n = 154$) and lastly stoats ($n = 74$). All four species showed high initial capture rates from December 2005 to May 2006 followed by a general decline in capture rates through to winter, with distinct seasonal peaks in trapping success throughout the year. Chi-square analyses revealed significant differences in captures rates between two consecutive summers for both hedgehogs ($\chi^2 = 43.16$, df =1, p<0.001) and cats ($\chi^2 = 3.85$, df =1, p<0.05), with hedgehogs decreasing and cats increasing. Two way contingency table analyses indicated that all six trap types exhibited species specific differences in capture success ($\chi^2 = 266.52$, df =25, p<0.001). Victor traps caught proportionally more animals than any other trap type (0.51). Contingency table analyses also revealed that bait type affected species specific trap success ($\chi^2 = 364.6$, df =24, p<0.001). Rabbit meat caught proportionally more carnivores (0.65) while fish caught more omnivores (hedgehogs) (0.60). This study highlights the need for a balanced design, suitable data structure and knowledge of predator ecology when planning trapping programmes. It also emphasises the need for long-term trapping data to validate the observed trends. It is recommended that in order to accurately assess predator trapping efficacy the trapping data is supplemented by an independent estimate of predator abundance.

1. INTRODUCTION

1.1 Mammalian predators in New Zealand

Mammalian predators introduced to ecosystems outside their former range have been known to decimate endemic island biotas that evolved in their absence (Burbridge and Manly 2002). Biological invasions of terrestrial mammals occurring mostly as a consequence of human colonisation are currently cited as one of the primary drivers of global faunal declines (Brooke et al. 2007). Indeed, islands have received 80% of recorded bird and mammal introductions (Ebenhard 1988), with the result that 90% of documented extinctions of reptiles, amphibians and avifauna since the seventeenth century have been endemic island species (Case and Bolger 1991). Particularly susceptible are isolated islands like New Zealand, whose unique and indigenous flora and fauna are largely ecologically and behaviourally maladapted to terrestrial mammals (Atkinson 2001). Today, New Zealand has more species of successfully established introduced mammalian predators (11) than any other island archipelago (Towns et al. 1997). These invasive mammals are characterised by high fecundity, high dispersal and the capacity to rapidly colonise previously unoccupied areas (Alterio and Moller 2000). In the absence of natural enemies and environmental constraints, the successful establishment and spread of these introduced predators into vacant niches is inevitable (Shea and Chesson 2002).

Feral cats (*Felis catus*) mustelids (ferrets (*Mustela furo*), stoats (*M. erminea*) weasels *(M. nivalis)*), hedgehogs (*Erinaceus europaeus)* and three rat species (*Rattus rattus*, *Rattus norvegicus* and *Rattus exulans*) in particular have had a catastrophic effect on New Zealand's indigenous biodiversity (Norbury and Heyward 2008). Indeed, more than 40% of land bird species present before humans arrived are now extinct (Clout 1997), with remaining populations of many endemic bird species being restricted to predator-free offshore islands (Elliott et al. 2001) or predator proof 'mainland islands' (Saunders and Norton 2001). The collapse of some important ecosystem processes has also been attributed to mammalian predation. For example, Robertson et al. (1999) documented the pollination failure of native mistletoe (Loranthaceae) due to the

loss of key pollinators and dispersers to mammalian predators. By indirectly disrupting such mutualistic plant-animal interactions, introduced species can cause cascading trophic effects, possibly triggering ecological meltdowns (Traveset and Richardson 2006). Additionally, disease transmission and its subsequent impact on the country's livestock production has also been proposed as a possible negative effect of these exotic mammals (McDonald and Lariviere 2001). Given the magnitude and variety of these impacts, introduced mammals are recognised as significant environmental, ecological, agricultural and social pests in New Zealand (McDonald and Lariviere 2001, Moss and Sanders 2001). It is hardly surprising therefore, that conservation of threatened biota in New Zealand relies extensively on intensive predator management.

1.2 Predator management strategies in New Zealand

Eradication, exclusion and control are the three main strategies used to manage populations of introduced mammalian pests in New Zealand. While complete removal or eradication of predators on offshore islands has resulted in the resurgence of many translocated populations (Newman 1994, Elliott et al. 2001), the costs of eradication on the mainland usually outweigh the benefits given the threat of recolonisation (Bomford and O'Brien 1995). Also, since removal measures often need to be species specific (Simberloff 2001), eradication may not be a suitable option for removal of many species simultaneously. When the species/habitat to be protected is small, exclusion of exotics by means of a barrier (e.g. fence, moat) might prove effective (e.g. Karori Wildlife Sanctuary) (Saunders and Norton 2001). Yet in most cases, control of predator numbers by population reduction is often the preferred management option due to its relative logistical ease and feasibility (Baxter et al. 2008).

Trapping is one of the major tools used to control introduced populations of small mammal predators in New Zealand (Keedwell and Brown 2001). Compared to non selective methods like poisoning, trapping can deliberately exclude native species (Alterio 2000). It is also suitable when targeting a wide range of predators similar in size (Courchamp et al. 2003). Perhaps most important, is that unlike eradication and exclusion methods, trapping can be

flexible and adaptive without the comparatively large time, labour and financial investment.

1.3 Terrestrial reptiles in New Zealand

One of the most common trends in lizard island biogeography is the positive correlation between lizard abundance and negligible presence or complete absence of mammalian predators (Newman 1994, Towns et al. 2003, Hoare et al. 2007). Most island forms of terrestrial reptiles are characterised by low annual reproductive output, slow rate of sexual maturity, large size and low dispersal capability (Case and Bolger 1991). Such ecological traits seem to augment their vulnerability and diminish their chances of recovery when subjected to sustained mammal predation (Towns and Daugherty 1994, Berry and Gleeson 2005). Consequently, predation has been identified as a potent force shaping the distribution and abundance of native terrestrial reptilian fauna on islands (Case and Bolger 1991).

The ancient terrestrial reptilian fauna of New Zealand has been described as "the most diverse lizard fauna of any temperate archipelago on earth" (Towns and Daugherty 1994) and is noted for its high degree of endemism (Towns et al. 2003). It comprises the last extant members of the early Order Sphenodontida and around 60 species of lizards belonging to four endemic genera; Hoplodactylus and Naultinus (Family: Gekkonidae) and Cyclodina and Oligosoma (Family: Scincidae) (Towns et al. 2001). Unfortunately, many of these species have historically suffered severe range contractions, resulting in fragmented distributions (Towns and Daugherty 1994, Newman 1994). The considerable proportion of skinks recorded in predator scats (Cuthbert et al. 2000, Norbury 2001) together with the recovery of lizard populations on predator-free offshore islands (e.g. Newman 1994) suggest that predation by introduced mammals has significantly contributed to these declines. Consequently, both tuatara species, 24% of geckos and 50% of skink species have been recognised as high priorities for conservation management (Towns et al. 2001).

1.4 Macraes Flat, Otago

The largest remnant populations of the critically endangered Grand skink (*Oligosoma grande*) and Otago skink (*O. otagense*) are located in the rocky mid altitude montane grasslands of southern New Zealand (Berry and Gleeson 2005, Wilson et al. 2007). These lizards, which now occupy only 8% of their former range (Whitaker and Loh 1995), are actively managed at Macraes Flat (Macraes) by the Department of Conservation (DoC) (Reardon et al. 2006). However, despite almost 2400ha of prime skink habitat being protected (Whitaker and Houston 2002), it is thought that range contraction is an ongoing process (Berry and Gleeson 2005). Protection of these species in situ at Macraes is especially important given their habitat specificity (Whitaker and Loh 1995) and the unavailability of such habitat on offshore islands (Hoare et al. 2007).

Habitat modification and introduced predators seem to be working synergistically to adversely affect skink populations at Macraes. The recent conversion of land surrounding the tussock grasslands to pasture has contributed to an increase in rabbit numbers in the area (Reardon et al. 2006). Rabbits constitute primary prey for many introduced predators in New Zealand (Fitzgerald 1990, Lavers and Clapperton 1990). According to Norbury (2001), as predator numbers increase in response to an increase in primary prey, so does incidental predation on native lizards, a secondary prey item. It is therefore probable that the surrounding habitat is elevating predator abundance in the sanctuary due to overflow (Cross et al. 1998), reinforcing the importance of predator control at Macraes Flat.

In an attempt to quantify the effect of predators on Grand and Otago skink populations, in late 2005 DoC set up 19ha of mammal proof fencing together with an experimental trapping programme consisting of 60 km of trapline covering 1200ha (Reardon et al. 2006). This trapping regime currently consists of 12 trap-bait combinations using six trap types and three bait types (Reardon et al. 2006), with increased skink survival and growing skink populations being the ultimate management aim.

1.4.1 Study rationale

Adaptive management implies a scientific approach to conservation management that involves combining management, monitoring and research, the results of which feed back into future decision-making (Wilhere 2002). This system is aimed at maximizing the effectiveness of the management plan over time and is especially important in programmes where limited funds dictate best practice approaches (Fig 1). Therefore, in trapping regimes targeting effective control of mammalian predators, knowledge of the factors that influence trap efficacy is crucial Stephenson 1994, Baker et al. 2001, Nicolas and Colyn 2006).

PLAN: Developing a management plan and monitoring protocol based on objectives

IMPLEMENT: Applying management strategies

MONITOR: Using targeted studies

ANALYSE AND EVALUATE outcomes

ADAPT COMPONENTS as needed to meet primary objectives
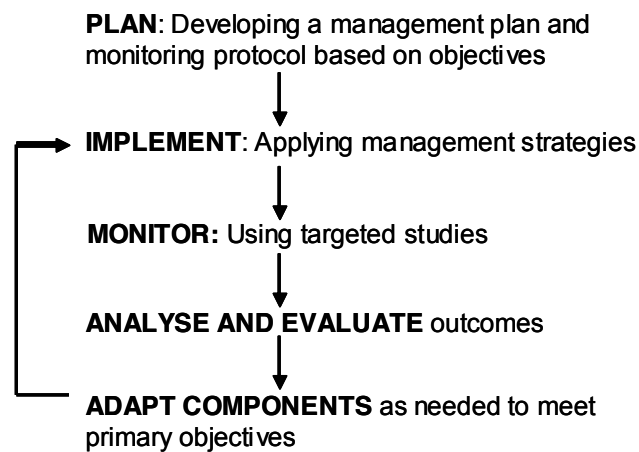
Fig 1. A schematic representation of the adaptive management cycle.

Biases in trapping may arise due to a number of different factors such as the type of trap or bait used, trap location, animal body size, weather conditions or seasons (Patric 1970, Lawrence 1992, Bryom 2002). Trap performance can also be related to several other factors including (among many others): social organisation between conspecifics (Baker et al. 2001), inter specific behavioural, ecological and numerical relationships (Middleliss 1995) and habitat features (Cameron et al. 2005). Synergistic interactions between factors have also been found to influence the effectiveness of trapping (Short et al. 2002). Therefore, evaluating overall trap success and identifying the potential causes of differential trapping efficacy for each species as well as qualitatively describing trap catch in

terms of species, sex and age of individuals caught will be key determinants when adapting existing predator monitoring and control strategies. As this programme was set up at the end of 2005, so far this study represents the initial analysis of trends present in the first year of trapping data.

1.5 Objectives

The primary aim of this study was to evaluate the initial experimental trapping protocol at Macraes by addressing the following objectives:

1. To evaluate overall trap success between the six trap types and three bait types employed.

2. To illustrate changes or biases in population structure of the trapped predator species over the trapping year (December 2005-December 2006).

3. To illustrate the trend in predator capture rates over the trapping period (December 2005-February 2007) and test whether capture rate for each species changed between two consecutive summers.

4. To assess the effects of trap type and bait type on trap success for each species.

2. METHODS

2.1 Study area

This study was part of the experimental management being carried out by the Grand and Otago Skink (GAOS) Recovery Programme at the Department of Conservation's 2400ha reserve situated near Macraes Flat, inland North Otago (45° 27′ S; 170° 26′ E) (Fig 2). Historic burning, grazing and sowing practices carried out in the area have resulted in highly modified present day vegetation in the reserve (Whitaker 1996). Tussock grassland species (*Chinochloa rigida, Poa cita*, *Festuca nova-zealandiae* and *C. rubra*) dominate, while inter-tussock vegetation consists of a mixture of native and exotic grasses, forbs and mosses (Wilson et al. 2007). Patches of shrubs (matagouri *Discaria toumatou*, mānuka *Leptospermum scoparium*, kānuka *Kunzea ericoides*, *Coprosoma* spp. and *Olearia* spp.) concentrated in stream gullies and rocky outcrops are also common (Tocher 2006). Apart from the Grand and Otago skink, the common lizard fauna in the area includes the common skink (*O. nigriplantare polychroma*), McCann's skink (*O. maccanni*), cryptic skink (O*. inconspicuum*) and the common gecko (*Hoplodactylus maculatus*) (Wilson et al. 2007).
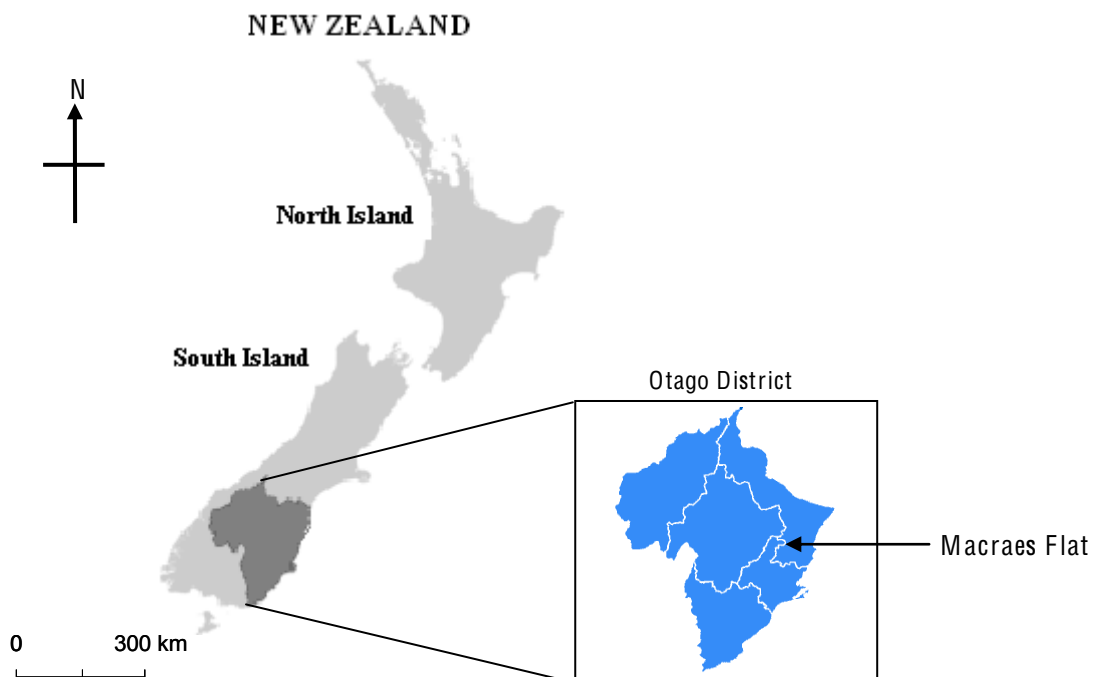

Fig 2. Map of New Zealand with the Macraes Flat study site marked (inset)

2.2. Trapping protocol

The trapping programme, initiated in October 2005, utilised a randomised block design with fourteen blocks protecting a core, middle and peripheral area of nearly 1500ha using approximately 60km of traplines (Fig 3). A random number table was used to establish the initial sequence of traps in the lines/blocks and to eliminate neighbour bias. This trapping protocol was designed to target cats, ferrets, stoats, weasels, hedgehogs, and possums.

Currently, there are 12 trap type -bait type combinations being used. The trap types being utilized are the Conibear 220, Victor soft jaw legholds, modified Timm's (with a widened keyhole entrance), DoC 250, DoC 150 (under wooden covers) and Fenn mk6 (under Philproof cover). The DoC 150's and Fenn mk6's are double sets (two traps under a cover with two entrances). The three bait types being used are hen's egg, un-skinned gutted rabbit or hare pieces and fish balls (made with fish flavoured cat food balled up in a mutton cloth).

The Victor soft-jaw leg-hold traps (live traps) are checked daily, with rebaiting as required. The other five trap types (kill traps) are checked weekly and are only reset on the scheduled rebait day and not if sprung opportunistically. If a trap cover is found to be partly open, or the trap has been kicked by stock or blown from its position it is placed back but it is not reset if sprung. On the scheduled rebait day, trapping results (e.g. sprung empty, bait taken, capture etc.) along with the species caught, sex, age, length and weight of the individual is recorded. For non- target animals, only the species is noted. All trap sets are located within about twenty metres of an all-terrain vehicle (ATV) track or road. Detailed methodology is given in Reardon et al. (2006).
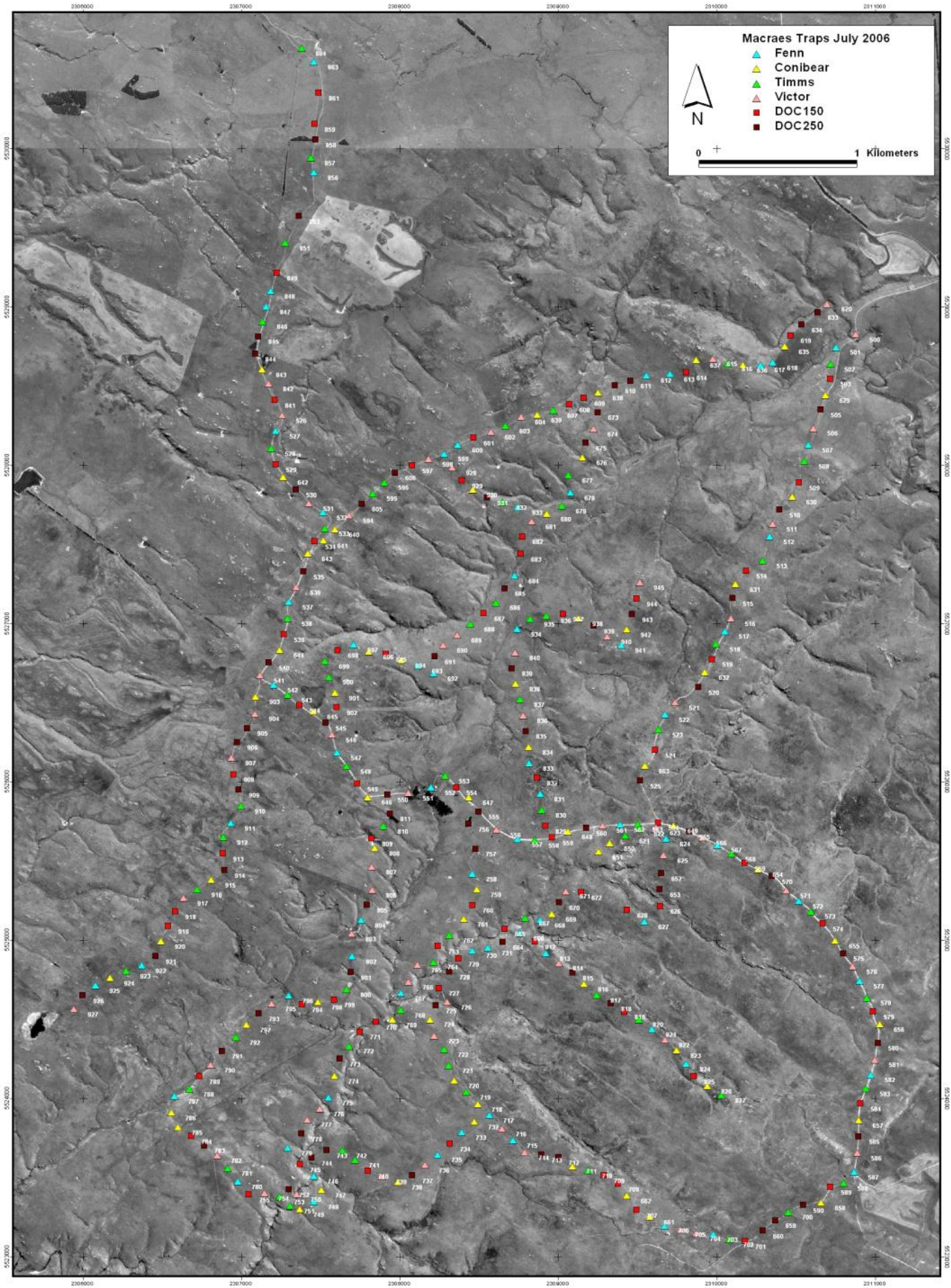
Fig 3. Trap layout at Macraes Flat showing the trap type and individual trap number

2.3 Data analysis

2.3.1 Descriptive

For each species, seasonal patterns in predator trapping data were illustrated by plotting the monthly total number of captures. This data was segregated by age (adults and juveniles) and sex (adult females and adult males). To examine trends in predator capture rate, the cumulative catch for each species was plotted over the entire trapping period for which data was available (December 2005-February 2007).

2.3.2 Analytical

According to the procedure outlined by Nelson and Clark (1973) and Cunningham and Moors (1996), total trap nights were corrected for sprung traps and total captures. Hereafter, these corrected values are referred to as 'trap-nights'. The period of each trap-night was 24 hrs (Michalski et al. 2007). Trap success (T) was calculated as the number of individuals caught per 100 trap-nights, i.e. $T = (N_m/N_{tn}) \times 100$ where N_m is the number of individuals of a particular species and N_{tn} is the number of trap nights (Nicolas and Colyn 2006). While logistic regression would have been more informative than the chosen non parametric analyses, especially when testing for interactions (e.g. Cameron et al. 2005), the unbalanced design and the unsuitable structure of the data rendered this approach unfeasible.

Trap type, bait type and season were recognised as key determinants of trap success for all four target species. For all four species combined, a two-way contingency table analysis was used to test whether trap type influenced the species' trap success (Anthony et al. 2005). To test whether trap type affected trap success of each species separately, non parametric chi-square analyses were used (Nicolas and Colyn 2006). In order to determine the efficiency of the different trap types for each species, data was collated across the different bait types.

To test the effect of bait type on trap success for all four species combined and well as for each species separately, contingency table analyses were used (Woodman et al. 1996). However, due to unbalanced sample sizes, a few compromises had to be made when analysing this data. Just two bait types (rabbit meat and fish) were used in the analyses as egg was used in only three of the six trap types. Two trap types (Doc150 and DOC250) also had to be dropped as fish was not used in the former trap type and used sparingly in the latter (Table 1).

When testing for seasonal variations in captures within a species, chi-square analyses were used (Slade et al. 1993). Differences in the number of individuals captured of each species between two consecutive summers (December, January, February of 2005-06 and 2006-07) were also tested using a chi-square analysis (Slade et al. 1993). Only consecutive summers could be compared as complete data for other seasons in 2006-07 was not available. For the purposes of this study when analysing seasonal data, December, January, February were considered as summer, March, April, May as autumn, June, July, August as winter and September, October, November as spring. Additionally, for both adults and juveniles of each species, chi-square analyses were used to determine whether sex ratios (male:female) differed significantly from a 1:1 ratio (Laves and Loeb 2006).

All these non parametric tests were two-tailed as there was no *a priori* reason to suggest that any one trap, bait type, season or sex would be superior to any other. Unless otherwise indicated, a significance level of 0.05 was adopted for all the analyses. Except for the descriptive analysis of predator capture rates which used data from December 2005-February 2007, all other analyses used data from only the first year of trapping (December 2005-December 2006). All statistical analyses were carried out using Microsoft Excel and SPSS (v.16.0).

3. RESULTS

3.1 Overall trap success

Over the trapping period (December 2005-December 2006), a total of ten target mammalian species and five non-target species were captured using a combination of six trap types and three different bait types. Only four target species (Hedgehogs, Cats, Ferrets and Stoats) were trapped in sufficient quantity (greater than 50 captures over the trapping period) for further statistical analyses. We recorded 1384 predator captures for the four species over 202864 corrected trap nights with 939 hedgehogs (0.46 individuals per 100 corrected trap nights (ctn^{-1})), 217 cats (0.11 individual 100 ctn^{-1}), 154 ferrets (0.07 individual 100 ctn^{-1}), and 74 stoats (0.04 individual 100 ctn^{-1}). Hedgehogs and cats were the most abundant predators caught, accounting for approximately 68% and 16% of all captures respectively, while ferrets and stoats accounted for around 11% and 5% of total captures respectively. The overall trap success for the four species using all six trap types and three bait types was 0.68 individuals 100 ctn^{-1}, or 147 trap nights necessary to capture a target individual. Three hundred and seventy nine non target animals were caught; all of which were non-native avifauna. The total number of corrected trap nights, total captures for each of the four species, number of traps sprung empty and escapes with bait taken is given in Table 1.

Table 1. Comparison of capture frequency for each trap and bait type for each species over the trapping period (Dec 2005 - Dec 2006). Species specific capture frequencies are shown as total number of animals caught for each trap and bait type.

Trap type	Bait type	Hedgehog	Cat	Ferret	Stoat	Sprung/ Empty & Escapes	Bait taken	Corrected trap nights
Conibear	Rabbit	18	35	17	1	12	22	12890.5
	Fish	47	13	3	0	17	57	12044.5
	Egg	-	-	-	-	-	-	-
DOC150	Rabbit	37	8	8	13	59	1	27388
	Fish	-	-	-	-	-	-	-
	Egg	14	3	4	5	89	4	25064
DOC250	Rabbit	27	3	21	10	36	3	13478.5
	Fish	0	0	0	0	1	0	385
	Egg	12	0	3	6	35	1	12497.5
Fenn6	Rabbit	59	9	22	18	57	0	25312
	Fish	7	1	2	1	4	0	1064
	Egg	85	3	3	3	40	6	22296
Timms	Rabbit	9	38	6	2	31	1	14746.5
	Fish	69	15	4	4	43	42	12602
	Egg	-	-	-	-	-	-	-
Victor	Rabbit	232	47	35	9	116	133	11733
	Fish	323	42	26	2	63	47	11362.5
	Egg	-	-	-	-	-	-	-

3.2 Trends in trapping data

3.2.1 Predator catch rates

When cumulative catch over time was plotted for all the species, initial capture rates for all species were high from December to May, with the number of hedgehogs caught increasing most dramatically (Fig 4). The catch rate for stoats showed the slowest rate over this period. The number of hedgehogs clearly outnumbered the other species, followed by cats, ferrets and lastly stoats. The number of individuals caught for al four species seemed to stabilise over winter, with captures reaching a plateau. The catch rate for hedgehogs appears to have decreased after the first year, as the cumulative catch for the second summer (December - February 2006-07) was not as steep as that of the initial summer (December-February 2005-06) (Fig 4). The captures of ferrets and stoats did not show any apparent pattern over the two summers. Only the catch rate for cats showed a further increase in the second summer.
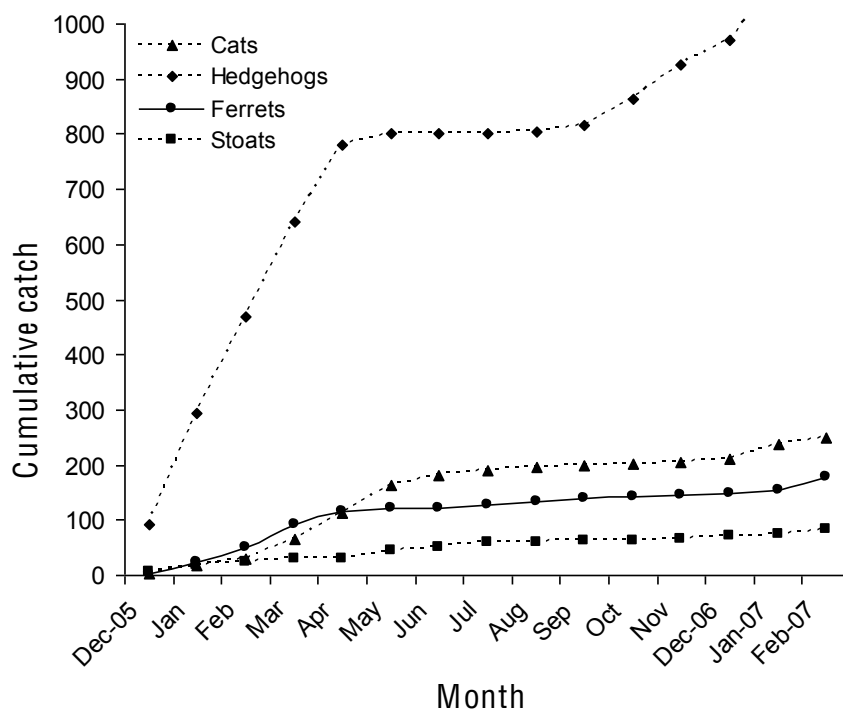
Fig 4. Cumulative predator catch over time for each of the four species (Dec 2005-Feb 2007)

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3.2.2. Comparison of captures between two summers

When testing for differences in the number of individuals caught between two consecutive summers (Dec 2005-Feb 2006) and (Dec 2006- Feb 2007), only cats and hedgehogs showed significant differences in the number of animals caught between the two summers (Table 2). In the second summer, there was a considerable drop in the number of hedgehogs trapped, representing a drop in the catch rate (Fig 4) and a significant increase in the number of cats caught, indicative of an increase in the catch rate for cats in the second summer (Fig 4). For ferrets and stoats, however, there was no significant difference in the number of captures between the two summers.

Table 2. Number of captures in each summer (2005-2006) and (2006-2007) for each species with the calculated chi-square (χ^2) values given

Species	Summer 2005-2006	Summer 2006-2007	χ^2
Cats	29	46	3.85*
Hedgehogs	470	289	43.16**
Ferrets	49	33	3.12
Stoats	23	20	0.2

**$p < 0.001$
 *$p < 0.05$

3.2.3 Age and Sex

An evident difference in trap response was found between the age of individuals trapped, with more adults being caught than juveniles for all the four species (Table 3). Adults represented a greater proportion (0.72) of the total catch than juveniles (0.28).

For ferrets and hedgehogs, apparent sex biases in adults were noted (Table 3). Adult sex ratios of both hedgehogs and ferrets were significantly biased towards males ($\chi^2 = 36.80$, df =1, p<0.001) and ($\chi^2 = 3.97$, df =1, p<0.05) respectively. However, for both cats and stoats, the number of adult males and females trapped were not significantly different ($\chi^2 = 0.79$, df =1, p>0.05) and ($\chi^2 = 3.16$, df =1, p>0.05) respectively.

The juvenile sex ratio varied between the four species (Table 3). For juvenile hedgehogs, the sex ratio was greatly biased towards males ($\chi^2 = 6.03$, df =1, p<0.05), while for cats ($\chi^2 = 9.22$, df =1, p<0.05) and ferrets ($\chi^2 = 6.25$, df =1, p<0.05) it was biased heavily towards females. The juvenile sex ratio for stoats could not be calculated due to low sample size.

Table 3. Sex, size and male: female ratio for adults and juveniles of all four species trapped using all trap types and bait types

| Species | Number by sex and age | | | | | |
	Adult male	Adult female	Male: Female	Juvenile male	Juvenile female	Male: Female
Cats	68	58	**1:0.85**	26	53	**1:2.03***
Hedgehogs	332	193	**1:0.58**[**]	132	95	**1:0.71***
Ferrets	66	45	**1:0.68***	3	13	**1:4.33***
Stoats	38	24	**1:0.63**	0	1	-

**p<0.001
*p<0.05

3.2.4. Seasonal patterns

All four species showed significant seasonal variations in captures (Table 4, Fig 5). However, clear seasonal patterns were only exhibited by cats, hedgehogs and ferrets (Fig 6). Cats were caught most frequently between March and June; hedgehogs clearly showed a capture minima in winter with maxima in both February and October. Ferrets showed a similar response to hedgehogs, while stoat captures did not seem to exhibit an apparent seasonal pattern, although mean number of captures was higher in summer and autumn than in winter and spring. Season seemed to have an evident significant effect on sex and age of the animals caught (Fig 5). Unfortunately, this interaction could not be tested statistically.

Table 4. Seasonal frequency of captures for each species with the calculated χ^2 values given

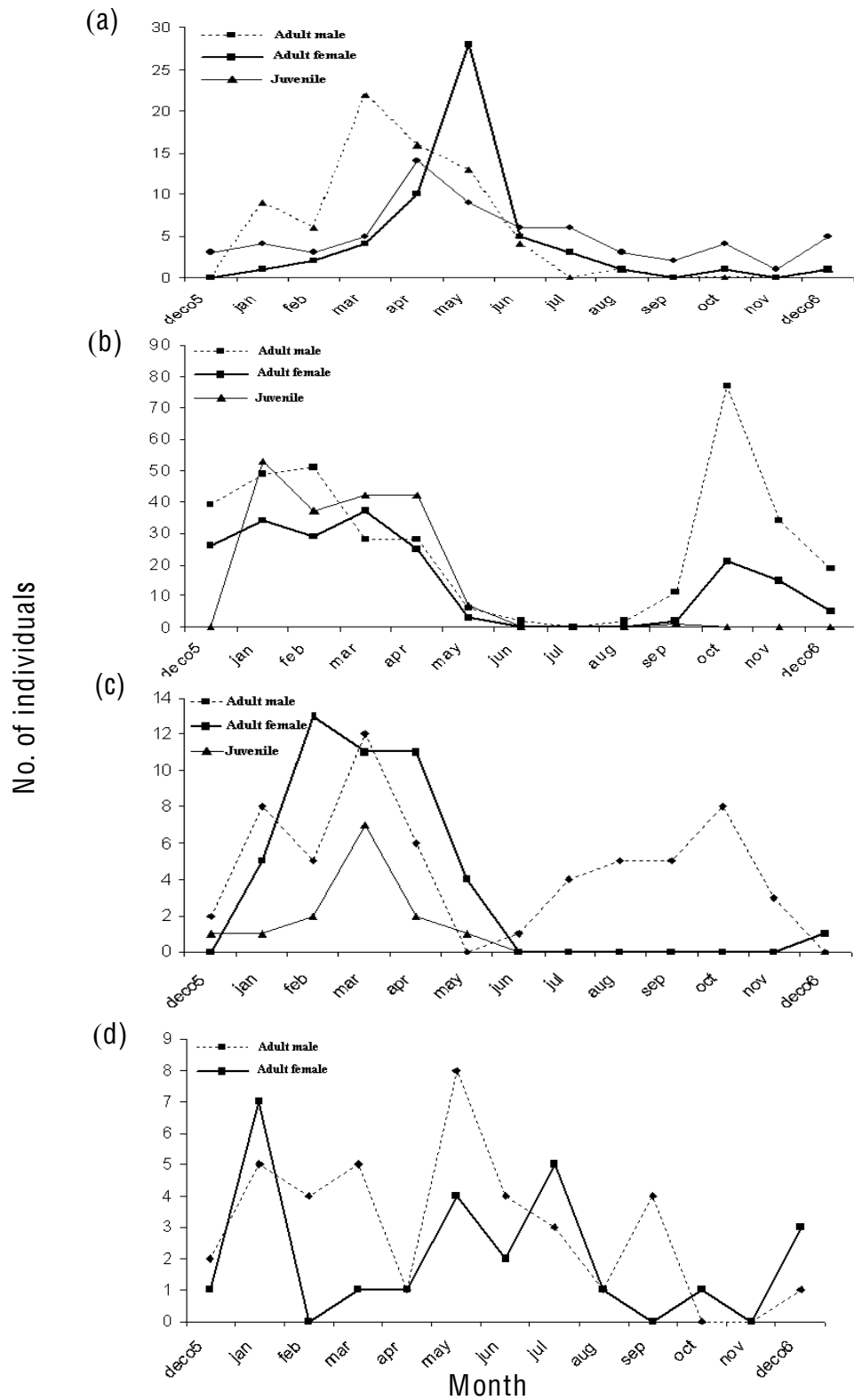| Species	Summer	Season Autumn	Winter	Spring	χ^2
Cats	28	121	29	8	165.18**
Hedgehogs	318	218	4	161	295.2**
Ferrets	37	54	10	16	41.66**
Stoats	19	21	16	5	10.01*

**$p < 0.001$
*$p < 0.05$

Fig 5. Number of adult males, adult females and juveniles trapped over December 2005-December 2006. (a) Cats (b) Hedgehogs (c) Ferrets (d) Stoats

3.3 Trap type

After standardisation for trapping effort (Stephenson 1994), Victor traps caught a greater number of animals consistently more than any other trap type and accounted for 51.7% ($n = 716$) of total trap catch. A highly significant Chi-square ($\chi^2 = 266.52$, df =25, p<0.001) revealed that the four species were not caught equally by all trap types. To determine if trap success was influenced by trap type, trap success was analysed separately for each species. There was a significant difference in trapping success between the different trap types. For hedgehogs ($\chi^2 = 1729.38$, df =5, p<0.001), cats ($\chi^2 = 211.06$, df =5, p<0.001) and ferrets ($\chi^2 = 87.66$, df =5, p<0.001) Victors were the best, while DOC150, DOC250 and DOC150 caught the least number of individuals respectively (Fig 6). For stoats ($\chi^2 = 15.83$, df =5, p<0.05), the value was just significant, with DOC250 having the highest trap success and Conibear's having the worst (Fig 6).

3.3 Bait type

A highly significant chi-square ($\chi^2 = 364.6$, df =24, p<0.001) showed that bait type affected species specific trap success. After standardisation for trapping effort, rabbit meat caught proportionally more carnivores (0.65) while fish caught more hedgehogs (0.60) (Fig 6). When evaluated individually for each species, bait type was shown to be a significant factor affecting species trap success for all four species; hedgehogs ($\chi^2 = 3401.86$, df =3, p<0.001), cats ($\chi^2 = 88.97$, df =3, p<0.001), ferrets ($\chi^2 = 80.93$, df =3, p<0.001) and stoats ($\chi^2 = 25.26$, df =3, p<0.001).
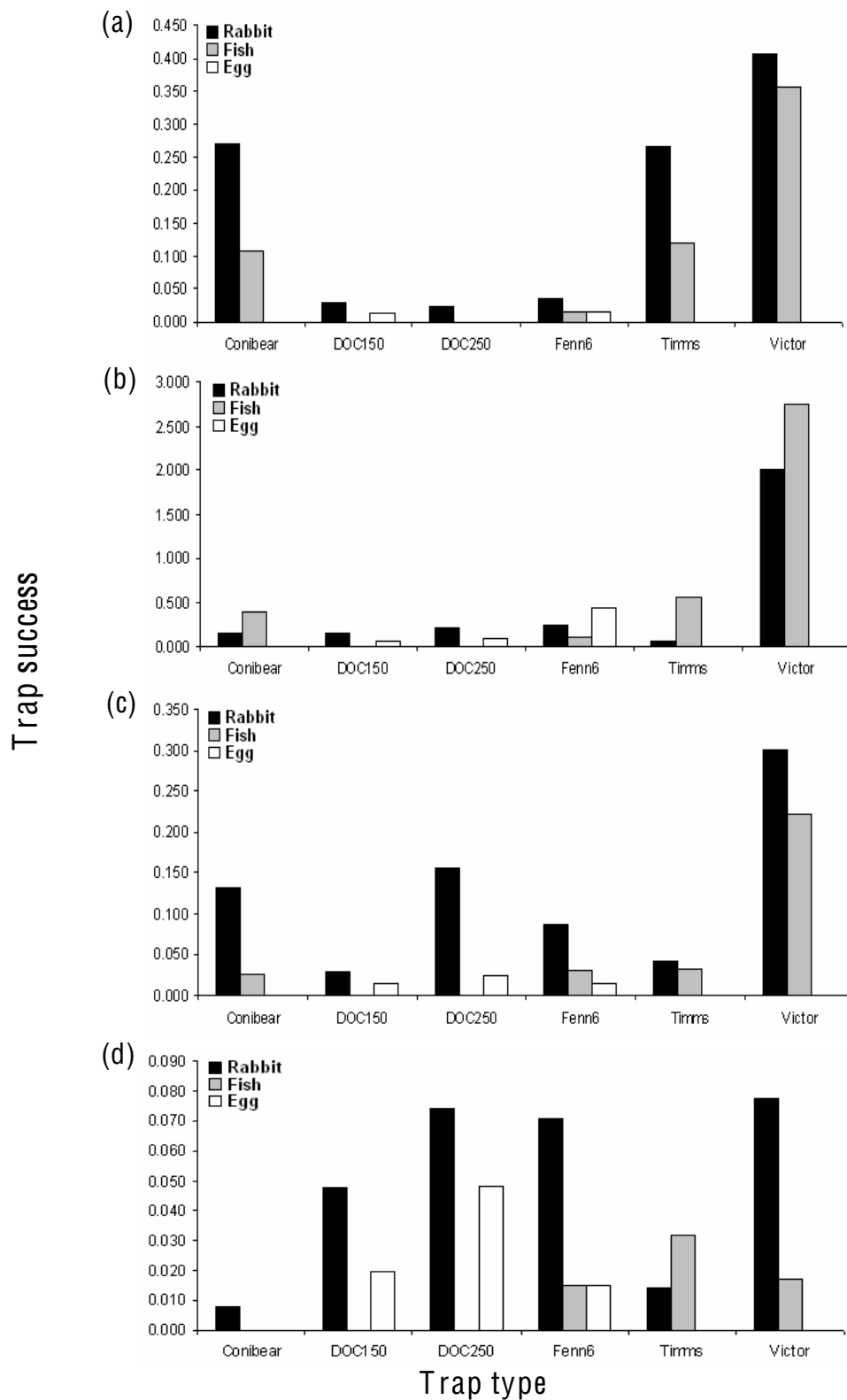
Fig 6. Comparisons of trap success of various trap and bait types for each species over the trapping period (Dec 2005- Dec 2006). Trap success is calculated 100 ctn^{-1}. (a) Cats (b) Hedgehogs (c) Ferrets (d) Stoats

4. DISCUSSION

Worldwide, the hypothesis of equal trappability of small mammals has been frequently refuted and differential trap success has long since been recognised (Nicolas and Colyn 2006). New Zealand's mammalian predators are notoriously difficult to capture (Clapperton 2001, Barlow and Norbury 2001), resulting in the development of a vast range of trapping methods, baits and trap types in order to improve trapping efficacy (Dilks et al. 1996, Alterio and Moller 2000). Inherent trap biases together with differential trap success due to species specific behaviour and environmental variation could lead to under trapping of certain species or cohorts and over sampling of others (Stephenson 1994, Baker et al. 2001, Nicolas and Colyn 2006). These biases may result in key predators not being controlled or indirectly cause shifts in predator community structure. Changes in predator community structure have important implications for prey species (Gerht and Prange 2006) and trophic cascades as a result of such shifts have been documented (Terborgh et al. 2001). Also, when trapping is relied on to provide demographic data on predator populations (e.g. Kay et al. 2000) such biases could potentially confound estimates of predator population structure. Under these circumstances, trapping effectiveness and efficiency may be assessed inaccurately, making successful predator management unlikely.

In this study, six different trap types (Victor, Conibear, DOC150, DOC250, Timms and Fenn) and three bait types (rabbit meat, fish, eggs) were used to capture mammalian predators at Macraes. It was found that trap type, bait type and season significantly influenced predator capture rates. Trends in trapping data also revealed apparent sex and age biases. Since optimal management strategies are often governed by limited resources (Baxter et al. 2008), understanding how these factors influence predator abundances is important for long-term monitoring and control. This is especially true when survival of protected populations is largely dependent on accurate evaluation and elucidation of trapping data.

4.1 Overall trap success

When compared to similar studies done in different habitat types in New Zealand, the proportion of predators caught was similar to those documented by Keedwell and Brown (2001) and Cameron et al. (2005) in the Waitaki Basin and Baker (1989) in Macraes Flat. Cameron et al. (2005) trapped predators in spring and early summer over 71333 trap nights between 1998 and 2000, with traps being placed at sites more likely to catch predators. Keedwell and Brown (2001) conducted their study during the spring and summer of 1997 over 101650 trap nights. While differences in trapping intensity render it difficult to compare overall trapping success, comparison of the proportions of predators caught between studies provides useful information on predator communities.

Table 5. Comparison of overall predator trap success and the proportion of predators caught between different habitat types in New Zealand.

Study	Habitat	Overall trap success	Proportion of predators caught			
			Hedgehogs	Cats	Ferrets	Stoats
King et al. 1996	Forested	0.449	-	0.135	0.118	0.577
Cameron et al. 2005	Braided river	1.324	0.668	0.137	0.166	0.027
Keedwell and Brown 2001	Arid montane grasslands and river habitats	1.633	0.642	0.117	0.197	0.041
Baker 1989	Montane tussock grasslands	-	0.607	0.208	0.179	0.005
This study	Montane tussock grasslands	0.700	0.660	0.151	0.107	0.050

The proportion of hedgehogs and stoats caught at Macraes were very similar to those caught at the Waitaki Basin (Table 5), with these species recording the highest and lowest trap success respectively in all three studies. Conversely, the number of hedgehogs caught in the forests of Pureora Forest Park was not considered to be a threat to native kokako (*Callaeus cinerea wilsoni*), while stoats represented more than half of the trap catch (King et al. 1996) (Table 5). Different vegetation types have been documented to profoundly affect small mammal habitat use (Jorgensen 2002). Additionally, the configuration of habitats within the landscape may also influence predator population dynamics (Schneider 2001). Albeit the absence of braided river habitats, the vegetation and habitat mosaic of the Waitaki Basin is similar to the semi-arid montane grasslands of Macraes. Also similar are the predator communities at these sites. It is therefore, reasonable to presume that similar vegetation and landscape characteristics driving predator dynamics within the Waitaki basin may also be in part driving predator dynamics within Macraes.

Comparison of mammalian trapping success between different landscapes and studies allows the development of large scale distribution patterns and predictive models which can serve to direct trapping programmes in the future (Quinlan et al. 2004). This broader approach is especially important when planning control strategies for predators not restricted to the vicinity of the sampled area (Caro et al. 2001) and areas where spill-over predation could cause the decline of protected populations in adjoining habitats (Oksanen et al.1992). Generally, landscape level data has been found to better predict small mammal habitat use patterns compared to locality specific data (Jorgensen 2002). Thus, while predator control strategies may be designed to meet site specific objectives, comparing across programmes could lead to the establishment of common causal agents for observed patterns and allow the development of more effective control strategies.

Human altered landscapes may also affect mammalian populations, with animal abundances driven by land-use practices (Schneider 2001). In particular, pastoral land has been noted to sustain and enhance predator populations due to the increased availability of prey in these systems (Smith and Quin 1996). Both

Macraes and the Waitaki Basin are surrounded by intensively managed pastoral land (Keedwell and Brown 2001, Reardon et al. 2006). Maximising trapping efficacy may involve determining the influence of both vegetation within the park and surrounding land use on predator populations. Moreover, determining whether observed differences in trap success are because of specific habitats (e.g. forests versus grassland) or due to changes in small mammal assemblage over time as a result of stochastic or environmental variation may be better elucidated by larger scale studies (Quinlan et al. 2004). Therefore, integrating research from similar trapping programmes while accounting for site specific attributes may result in more cost-effective and efficient trapping protocols.

4.2 Trends in trapping data

4.2.1 Predator catch rates and variation between two consecutive summers

All four species showed high capture rates from December to May followed by a general decline in capture rates through to winter. High initial capture rates suggest that the trapping methodology was effective at catching animals within the study area during this time. According to Moore et al. (2003) high capture rates at the onset of a trapping programme indicate the relative ease of catching animals unaccustomed to traps. The leveling off of capture rates in winter could imply sufficient suppression of predator populations by trapping due to removal of all animals present in the area (Moore et al. 2003). However, Harding et al. (2001) cautions against such conclusions being drawn from short-term data as there is often a lag phase before predator populations respond to removal trapping. Species behaviour (e.g. winter hibernation in hedgehogs) could also result in the observed patterns (Moss and Sanders 2001). Also, variations in mammalian capture rates have been attributed to fluctuations in population abundances (Kozakiewicz 1976). According to Thomson et al. (2000) when population densities in the buffer zone (area surrounding the core trapping area) are high an effective dispersal source is maintained. Therefore, movement from high density (untrapped) areas into low density (trapped) areas could result in high capture rates at certain times of the year (Kozakiewicz and Jurasińska 1989) (see section 4.2.2).

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Variations in capture rates between two consecutive summers were seen for both hedgehogs and cats. Hedgehog capture rates in the second summer (2006-2007) decreased considerably, suggesting that trapping may have successfully reduced hedgehog numbers (e.g. Moore et al. 2003). However, this pattern could also be due to the development of trap avoidance in animals (trap-shyness) (Verts and Carraway 1986). On average, trap-shy animals are known to stay in the trapping area longer than residents (Norbury 2001), thereby possibly posing a greater threat to the species being protected. Therefore, establishing capture probability of animals needs to be recognized as a priority issue.

In contrast to hedgehogs, cats showed an increase in capture rates in the second summer. This could be a result of increased immigration into the trapping area due to initial removal of territorial residents (Kozakiewicz and Jurasińska 1989). In fact, it has been suggested that compared to non destructive sampling of predator populations, removal trapping stimulates rapid reinvasion and dispersal in mammalian predators (Keedwell and Brown 2001). On the other hand, expansion of home range size by some animals to include the area vacated through removal trapping could also result in increased trapping success (Verts and Carraway 1986). For both ferrets and stoats however, no evident patterns in capture rates were documented between the two summers. It is possible that for such prolific species one year is too small a time frame in which to measure actual changes in population size (Swihart and Slade 1990). Also, small sample sizes such as those obtained for stoats may have obscured trends in capture rates.

Assumptions such as equal capture probability over the entire trapping period (Cameron et al. 2005) are implicit in these comparisons and have not been validated. However, the patterns observed here allow preliminary trends to be identified and investigated further. Indeed, mammalian capture rates are regularly used to compare the efficacy of different trapping methodologies (O'Brien et al. 2006), to determine trappability of marked individuals (Viera et al. 2004) and assess management impacts on animal populations (Ganzhorn 2003).

4.2.2 Age, Sex and Seasonal patterns

Distinct seasonal peaks in the trapping success of different sexes and cohorts for hedgehogs, cats and ferrets were apparent, indicating that annual trapping data may be biased towards certain ages or sexes in certain seasons. Seasonal variations in trapping success could be due to species specific breeding behaviour (King et al. 1996, Clapperton 2001), biology (Moss and Sanders 2001) and prey availability (Barlow and Norbury 2001). Effective evaluation of predator control strategies therefore, requires careful consideration of predator ecology. In light of such information, trapping provides a valuable insight into the demographics of predator populations over time which could potentially be used to target specific cohorts or sexes in the future.

The documented seasonal patterns for adults and juveniles of each species are discussed below:

Cats- The capture rate for adults and juveniles showed distinct autumn peaks (March-May), with seasonal patterns at Macraes similar to those recorded by King et al. (1996) in Pureora National Park and Tocher (2006). Late summer and autumn is generally the non breeding season for rabbits (Bell 1977) and as cats seem to prefer baby rabbits (Jones 1977), a peak in trap success at this time could be due to the reduced availability of their favored prey (Molsher 2001). Removal of individuals could also cause a release from density dependant limitation due to established territories, resulting in heightened trapping success as more predators are allowed into the area (Tocher 2006). Also, removal of territorial residents/adults could result in increased immigration of transients/juveniles from the surrounding areas (Keedwell and Brown 2001, Baker et al. 2001).

Hedgehogs- Trap success for hedgehogs was highest in summer/autumn and late spring with minimum success over winter. Seasonal variations in hedgehog capture rates are common (King et al 1996, Moss and Sanders 2001), with capture rates dropping by an order of magnitude in winter (King et al. 1996). This is probably due to winter hibernation shown by hedgehogs from mid-April to early-September (Moss and Sanders 2001). Additionally, long range dispersal

of animals in spring and summer (Moss and Sanders 2001) may have influenced these trends, causing an increase in trapping success.

Ferrets- Trap success of adult males, females and juveniles was highest between January and May, with an additional peak for adult males in September-October. Similar to cats, higher trap success for adult ferrets may represent the inability of transient juveniles to enter territories held by resident adults (Baker et al. 2001). Courting behaviour in ferrets has been observed in August-September Clapperton (2001), with a resulting increase in home range size for breeding males (Medina-Vogel 1998). This sudden expansion in range size could potentially explain the corresponding rise in trap success for adult males in September-October, as their chances of encountering a trap may be higher. Also, pregnant and lactating females have been recorded from September-October onwards (Clapperton 2001). Reduced movements by adult females at this time as suggested by Barlow and Norbury (2001) would presumably lower the opportunity for females to encounter traps, therefore resulting in a slump in trap success as seen in this study.

Trap success for juvenile ferrets was highest between March and April. Dispersal of juvenile ferrets from their natal home ranges has been recorded between February and March by Clapperton (2001), while Moller et al. (1996) documented high trap success for newly dispersed ferrets between January and May. Increased dispersal combined with the naivety of newly emerged juveniles could result in higher juvenile trap success.

Stoats- In contrast to the other species, stoats did not seem to exhibit any clear seasonal patterns, with fluctuating capture rates throughout the year. It is likely that the absence of any clear pattern in stoat capture rates may be due to low sample size. However, the immigration of transients into the area at any time of the year (King 1980), coupled with the breeding behaviour of stoats (King 1990) could help explain the observed trends. Female stoats mature rapidly (2-3 weeks of age) and are mated in the natal den, meaning that for 10-11 months of the year, they carry fertilized ovum (King 1990). Consequently, population growth is largely independent of the presence of breeding males in the area

(Choquenot et al. 2001). However, seasonal variation in stoat captures has been documented, with females better represented in December as compared to the rest of the year (King 1980).

Inferences regarding population structure and dynamics based on trapping data should be cautious, as it is presumed that the trapped sample represents the true unbiased underlying age and sex distribution of the target species (Caughley 1994). Unfortunately, stochastic variations in sex and age ratios depending on female mortality following breeding and differential rates of male and female mortality of dispersed juveniles are not accounted for in such trapping data. Indeed, previous studies on the effectiveness and selectivity of mammal trapping techniques have noted clear seasonal patterns in trapping data, as well as biases in the age and sex classes trapped (Stephenson 1994, Kay et al. 2000, Baker et al. 2001).

In summary, these biases represent opportunities for refining existing trapping protocols with knowledge of predator ecology. It is clear that trapping efficiency could be increased with knowledge of the reproductive cycle of the target species. Barlow and Norbury (2001) recommend that ferret control operations should be intensified in autumn because this is when ferret densities are highest. Trapping at this time would cause reductions additive to natural losses and potentially prevent recruitment for at least six months by removing part of the early reproduction.

The ecology of the species being protected is equally important when planning predator control operations. Autumn peaks in cats (this study) correspond to the birthing season in Grand and Otago skinks (Tocher 2006), a period when both adult females and newly emerged skinks are vulnerable to predation (Martin and Lopez 1995, Shine 2003). By intensifying trapping at certain times of the year it may be possible therefore, to achieve both minimal predator abundance and maximal skink protection. In order for trapping to be used to effectively suppress predator populations at Macraes, it is essential to establish whether the observed population trends persist through time and space. As increased skink survival is largely dependent on successful predator control, it

is recommended that for now, intensity of trapping should be maintained throughout the year until clear patterns in trapping success are identified and validated. Generally, however, the patterns of trap bias observed in this study are consistent with other similar studies done on small mammal populations, and are comparable with other capture methods.

4.3 Trap type

Victor traps consistently seemed to be the most effective (higher trap success across most species) in capturing predators. A significantly larger proportion of hedgehogs, cats and ferrets were caught in Victors, while DOC250 caught the largest proportion of stoats. Victors have been documented to efficiently capture a wide range of small mammals in various parts of the world (Warburton 1992, Linhart and Dasch 1992, Morriss et al. 2000, Short et al. 2002). For example, while trapping cats in Western Australia Short et al. (2002) found Victors to be the most efficient as well as the most cost effective, a finding reiterated by Drickamer and Mikesic (1993). Linhart and Dasch (1992) documented similar results while trapping coyotes in the United States, with Victors consistently reporting lower escape rates. Fewer associated welfare concerns (Drickamer and Mikesic 1993) as well as relative ease of use (Baker 1989) make them the favourite in many trapping programmes.

The observed results however, could also be due to a number of factors that were not accounted for in this study. For example, all the traps except Victors were covered with tunnels, while Victors (leg hold traps) were just staked to the ground, with the jaws obscured from plain view. It is possible that better concealment in the surrounding habitat could have resulted in a higher capture rate (e.g. Michalski et al. 2007). Also, O'Farrell (1994) documented a preference for open traps as compared to those enclosed in boxes/tunnels by some small mammals. Victors were also re-baited the most frequently, possibly making them more alluring due to fresh bait (Pierce et al. 2007). Trapping success could also have been overestimated due to the daily checking of victors as compared to the weekly checking of the other trap types (Reardon et al. 2006) and a more sensitive trigger mechanism (Wiener and Smith 1972). However, given the low overall trap success (1 animal per 147 days), this result is unlikely to be overly

inflated. Despite these probable limitations, Victors successfully captured the widest range of predators present in the trapping area.

4.4 Bait Type

Several studies that have observationally and experimentally tested a variety of visual, olfactory and auditory cues when developing bait types have reported inconsistent results across species, regions and habitats (e.g. Slade et al. 1993, Weihong et al. 1999). In Peru Woodman et al. (1996) found that baits with different odours, visual appearances and nutrient content did not influence the trappability of small mammals. In contrast, in Southeastern Brazil Michalski et al. (2007) reported a preference for live bait by small mammalian carnivores with omnivores preferring dead bait. Likewise, this study found that bait type had an evident influence on predator capture rates, with rabbit meat capturing proportionally more carnivores and fish catching proportionally more omnivores (hedgehogs).

The differential effectiveness of different bait types could be related to seasonal fluctuations in prey availability, with animals preferring certain baits when food is scarce (Fitch 1954). Given that rabbits are included in the dietary preferences of both cats and mustelids (Fitzgerald 1990, Lavers and Clapperton 1990, Murphy and Dowding 1995), it is reasonable to assume that they would be attracted to rabbit meat, particularly in times of food shortage. Indeed, Lawrence (1992) found that animals are attracted to bait which mirror their natural prey choices. Rabbit meat has been recorded as an effective bait for trapping small carnivores in Australia and New Zealand (Short et al. 2002, Montague 2002, Pierce et al. 2007). Hedgehogs, on the other hand, while predominantly insectivores, have been documented to be more opportunistic in their dietary choices, consuming locally available and abundant food (Jones et al. 2005). In fact, modification of foraging behavior to exploit locally available rich food sources has been seen in hedgehogs (Cassini and Krebs, 1994).

Since bait efficacy is also measured in part by its palatability, longevity, ease of availability and use, and cost (Fitch 1954, Dilks et al. 1996, Short et al. 2002), ultimately, choice of bait type should ensure that accessibility to bait is

relatively economical and logistically viable. More importantly, however, is that effective control of these predators depends on control operations targeting the right species, thus maximizing the benefit to the species being protected. These results suggest that potential preferences for certain bait types need to be evaluated in light of which predator species represent the greatest risk to survival of skink populations at Macraes.

4.5 Management implications and future directions

The primary management goal of this trapping programme is to reduce predator numbers, and consequently predation, ultimately enhancing Grand and Otago skink survival at Macraes (Reardon et al. 2006). Since these mammalian predators significantly threaten the existence of the Grand and Otago skinks (Baker 1989, Middlemiss 1995), qualitatively documenting their propensity to be trapped signifies a first step towards recovery of threatened skink populations. This study provides important baseline data on the range and nature of predators present at Macraes and has important implications for existing predator control practices.

Outlined below are the implications and the recommendations resulting from this study:

4.5.1 Trapping design

This study has significant implications for the design of predator trapping protocols. The unbalanced nature of the trapping design due to unequal effort across factors (trap type, bait type, trap location, and season) rendered any analysis of trapping success attributable to interactions between factors incoherent and was recognized as the biggest drawback of this study. As a result, it was difficult to test whether the observed patterns in trapping success occurred by chance or due to real preferences. While logistic regression was the obvious choice for data analysis, it could not be performed due to the unbalanced nature of the data. Also, the structure of the dataset was not suitable for logistic regression (Niven, *pers comm*). More than likely, factors such as trap type, bait type and season may be having a synergistic influence on trap success. For instance, Short et al. (2002) found that effect of bait on cat trapping success was

dependant on season, rabbit (prey) availability and the age of the individual, with rabbit meat being most effective against inexperienced young adults. Consequently, the use of logistic regression in this study might have resulted in outcomes quite different to those obtained by these preliminary chi-square tests, since logistic analyses specifically measure interactions between factors and the magnitude of such associations. This recommendation is very similar to that put forward by Cameron et al. (2005), who state that a balanced design is a fundamental component of any successful adaptive trapping protocol.

4.5.2 Predator removal

Stoat abundances and movements can be affected by interference competition from larger predators (King et al. 2001), with stoat numbers potentially increasing after the removal of cats and ferrets at Macraes (Tocher 2006). Terborgh et al. (1999) state that the removal of top predators releases populations of mesopredators (secondary predators), with simultaneous declines in prey species. For example, coyote presence has been documented to increase the nesting success of song sparrows by limiting raccoon, skink and opossum populations (Crooks and Soule´ 1999). It is possible, that by removing cats and ferrets from the study area, stoat populations could increase, with unknown but intuitively adverse consequences for skinks. It is suggested that assessing the potential for such a scenario is important for economically justifiable and effective predator management.

It might also be worthwhile to investigate the stomach contents of some trapped animals in order to quantify actual dietary choices of predators, particularly at different times of the year. This might lead to establishing the triggers for prey switching at Macraes, a phenomenon known to negatively affect skink populations (Norbury 2001). Diet studies could also be used to ascertain the time of year when greatest protection for skinks is needed (e.g. Risbey et al. 1999) and quantify which predator species pose the greatest threat to skink populations at Macraes (e.g. Jones et al. 2005).

Recolonisation of, and immigration into, the areas subjected to predator control may be influencing the patterns documented in this study. Rate of

recolonisation and direction of immigration have been recognized as important precursors of trapping success (Kozakiewicz and Jurasińska 1989). Therefore, while temporal prediction of predation due to changes in prey availability, predator reproduction and season etc. using conventional theoretical approaches is valuable, spatial prediction of predation risk using GIS based techniques would also be very useful. Such spatial modeling would allow large scale comparisons of predation risk across different landscapes, while also looking at the variation in risk within a particular site (e.g. Kliskey et al. 2000). There are two important advantages of such a method. First, directional flow of predators could potentially be determined and reasons for this directional flow addressed (e.g. high prey availability, ease of access, high population density). Consequently, rate of recolonisation and immigration could also be established. This is especially relevant to Macraes where the surrounding pastoral land is capable of building up and sustaining a viable predator source.

Second, areas with predator populations governed by causal factors similar to Macraes as well as areas with similar long-term effects of changes in predator abundance could be identified. Predator management strategies are likely to be similar in scope in these areas, although specific actions will be different. Collaborative management may help eliminate redundancy in research and ultimately reduce overall project costs. The potential for integrated research is therefore a key issue to be examined in the future.

4.5.3 Trapping efficacy

Lastly, this study highlights an evident significant difference in trappability of predators, biased towards a particular subset of species, age and sex classes in the community with a number of factors affecting their capture rates. Spatial and temporal variation in habitat use by mammals may be due to fluctuating nutritional requirements, species specific ecology and reproductive biology. Given these circumstances, estimates of predator abundance and population structure derived solely from trapping may not be a robust estimate of trapping efficacy (Baker et al. 2001). Increased trap avoidance in animals can also cause bias in population estimates (Lawrence 1992, Cross et al. 1998). For example, while trapping cats on Little Barrier Island, Veitch (2001) took an average of 500 nights to trap a cat, but the last five cats took an average of 6500

nights each to be caught. The development of such trap shy animals could have catastrophic consequences for the protected species, as a drop in capture rate could be mistakenly interpreted as increased effectiveness of the trapping programme. Therefore, it is imperative to establish an estimate of predator abundance independent of trapping data. Such estimates provide valuable insights into the structure and abundance of the untrapped population, and allow the actual efficacy of a predator trapping programme to be determined.

5. CONCLUSIONS

The proportion of predators caught with this trapping programme appears to be comparable to those recorded in similar habitats elsewhere in New Zealand. This potentially allows for integrated research with similar areas, leading to establishing and evaluating the primary drivers of predator numbers rather than the existing temporary control of abundances. All the species targeted by this trapping protocol were caught, with high initial capture rates for the four chosen species. This indicates a successful start to the trapping programme. However, the absence of independent estimates of population abundance did not allow actual success of this management strategy to be determined. Seasonal differences in capture rates as well as age and sex biases in the data suggest that species' life-history traits may be one of the deciding factors influencing trap success. Bait type and trap type also significantly affected predator trap success. Victor traps appeared to be the most successful at capturing all four species. Rabbit meat seemed to capture more carnivores, while fish caught proportionally more omnivores. While the structure of the data precluded any interactions between season, predator ecology, bait type and trap type from being tested, patterns indicate interactions are likely and need to be examined.

It is evident that longer term data is required to validate the trends documented here as well as create more focused research aimed at enhancing trapping efficacy. While a robust scientific experimental design may be logistically and financially unfeasible, increased trapping effectiveness can only be achieved using rigorous scientific techniques. Also, a more holistic view of predator population abundances and movements at Macraes may be achieved by analysing all the components of this experimental strategy together rather than in isolation.

6. ACKNOWLEDGEMENTS

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Appendix 1. Monthly compilation of raw trapping data (January 2006)

	Hedgehog	Cat	Ferret	Stoat	Weasel	Norway rat	Rabbit	Hare	Mouse	Possum	Pig	Ship rat	Harrier	Starling	Gull	Blackbird	Magpie	Sparrow	Falcon	Sheep	Skink	Other	Sprung/Empty & Escapes	Bait taken	Trap nights minus SE/ESC, BT & NT	Total trap nights including SE/ESC, BT & NT
Conibear																										
Rabbit	4	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	964	972
Fish	12	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	7	872	882
DOC150																										
Rabbit	16	0	1	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	1998	2004
Egg	1	0	0	0	0	0	2	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	18	0	1925	1944
DOC250																										
Rabbit	8	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1078	1080
Fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	30
Egg	2	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	914	930
Fenn6																										
Rabbit	13	2	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	1880	1886
Fish	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	178	180
Egg	16	1	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	1698	1702
Timms																										
Rabbit	2	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1031	1032
Fish	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	848	852
Victor																										

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Rabbit	44	2	5	4	1	1	1	0	0	0	0	0	27	0	0	0	0	0	0	0	0	0	7	12	865	913
Fish	68	2	5	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	10	1	870	882