[1]Ecosystems Consultants, P.O. Box 6161, Dunedin, New Zealand.
[2]Department of Zoology, University of Otago, P.O. Box 56, Dunedin, New Zealand.

SHORT COMMUNICATION

DAILY ACTIVITY OF STOATS (*MUSTELA ERMINEA*), FERAL FERRETS (*MUSTELA FURO*) AND FERAL HOUSE CATS (*FELIS CATUS*) IN COASTAL GRASSLAND, OTAGO PENINSULA, NEW ZEALAND.

Summary: This radio-tracking study reports the daily activity rhythms in autumn and spring of 11 stoats (*Mustela erminea*) (9 male, 2 female), 20 ferrets (*M. furo*) (8 m, 12 f) and 11 feral house cats (*Felis catus*) (7 m, 4 f) resident on coastal grassland, Otago Peninsula, New Zealand. Activity rhythms differed markedly amongst individual stoats in autumn, but little amongst individual cats and ferrets in either season. Stoats were equally active day and night in autumn, but were more active at day than at night in spring. Cats showed moderate day activity, but were mainly active at night in both seasons. Ferrets showed low activity during daylight in autumn and were entirely nocturnal in spring. Overall, stoats were more active during daylight than cats or ferrets; and cats were more active during daylight than ferrets. Therefore, cats and especially stoats may pose the main predation threat to diurnal native species in New Zealand. Effective biological control of rabbits (*Oryctolagus cuniculus*) may effect the absolute abundance and daily activity of the predators, so is impossible to predict the overall impact of predation on diurnal and nocturnal native species.

Keywords: mustelids; stoats; ferrets; cats; daily activity rhythms; radio-tracking; coastal grassland.

Introduction

Several species of endemic wildlife are threatened by predation by introduced mammalian carnivores in New Zealand (King, 1990). Therefore, effective conservation management depends on effective control of the most important of the introduced predators (Brown, 1994; Moller, Ratz and Alterio, 1995). Diurnal predators eat more diurnal prey such as lizards than nocturnal predators (Baker, 1989; Alterio, 1994; Middlemiss, 1995). Consequently, a better understanding of the daily activity rhythms of introduced small mammalian carnivores may help identify which predators pose greatest risk to particular species of New Zealand wildlife.

The activity rhythms of small mammalian carnivores have been studied in the Northern Hemisphere (Erlinge, 1979; Debrot *et al.,* 1985; Robitaille and Baron, 1987; Weber, 1989), but only unpublished studies have reported on their activity patterns in New Zealand (Pierce, 1987; Baker, 1989; Murphy and Dowding, 1991; Middlemiss, 1995).

The aim of this paper was to investigate and compare daily activity rhythms in autumn and spring of stoats (*Mustela erminea* L.), feral ferrets (*M. furo* L.) and feral house cats (*Felis catus* L.) resident on two coastal grassland sites, Sandfly Bay (45°50'S, 170°36'E) and Boulder Beach (45°50'S, 170°33'E),

Otago Peninsula, South Island, New Zealand. These sites were chosen for study because they surround populations of yellow-eyed penguins (*Megadyptes antipodes* Hombron and Jacquinot), sooty shearwaters (*Puffinus griseus* Gmelin), little blue penguins (*Eudyptula minor* Forster) and jewelled geckos (*Naultinus gemmeus* McCann). Mustelids and/or cats have been identified as predators of these regionally threatened endemic species (Darby and Seddon, 1990; Alterio 1994; Moller *et al.*, 1995).

Methods

Live-trapping

Mustelids and feral cats were live-trapped in collapsible wire-mesh cages, Victor $1^{1/2}$" soft-catch traps (Pascoe, 1995) and Edgar traps (King and Edgar, 1977). Traps baited with rabbit (*Oryctolagus cuniculus* L.) meat were set at Boulder Beach in August 1992 and at Boulder Beach and Sandfly Bay in April 1995. Stoats (n=11), ferrets (n=20) and cats (n=11) were caught, radio-tagged (two-stage radio-transmitters with brass loop or whip aerials supplied by Sirtrack Ltd, Havelock North, New Zealand), ear-tagged, sexed and released.

Radio-tracking

The activity patterns of the mustelids and cats were estimated from the proportions of active and inactive radio-fixes recorded at day (9.00 am to 6.00 pm) and at night (6.00 pm to 1.00 am) in spring (September to October 1992) and autumn (April to May 1995). Alterio (1994) found that radio-transmitters on predators denning (n=210) produced constant signals, whereas predators moving (n=102) produced highly erratic signals. Erlinge (1979) also used this method to estimate the daily activity of stoats in Sweden. Accordingly, an animal was scored as active when its radio-tag produced an erratic signal, and inactive when the signal was constant. The minimum interval for recording an animal's activity was one hour, but on most occasions only one or two radio-fixes were taken on an animal, at day or at night, in the 24 hour sampling period. Radio-fixes were made by remote radio-tracking using fixed-site five-element Tracking Towers and/or hand-held three-element Yagi antennae with Merlin 48 or Telonics TR4 receivers (radio-tracking equipment supplied by Sirtrack Ltd, Havelock North, New Zealand).

Data analysis

Contingency tables were constructed first by animal and then by activity (active, not active) for each predator species, sampling period (day, night) and season (spring, autumn) to test for heterogeneity. Chi-squared tests of independence were then calculated to test the null hypothesis that the proportion of radio-fixes that were active was the same within (males and females of the same species) and between species for each category (day, night and spring, autumn).

Results

Differences in activity between the individuals

Overall there were no significant differences in the proportions of active radio-fixes for different individuals of the same species within spring (χ^2 tests for heterogeneity: χ^2=1.45, d.f.=3, $P > 0.50$ for stoats; χ^2= 0.01, d.f.=5, $P > 0.99$ for ferrets; χ^2=3.30, d.f.=3, $P > 0.25$ for cats); or for ferrets within autumn (χ^2=12.1, d.f.=13, p > 0.50). However, cats and particularly stoats showed marked differences in their individual activity rhythms in autumn (χ^2=14.4, d.f.=6, $P < 0.025$ for cats; χ^2=43.3, d.f.=6, $P < 0.0001$ for stoats). The autumn result for cats was largely influenced by one individual which exhibited high activity at day and at night. Excluding this individual from analysis, the

remaining six cats exhibited similar day-night activity patterns (χ^2=1.82, d.f.=5, $P > 0.75$). Accordingly, we have combined data for individuals of the same species in our following analyses, but warn that the averages for stoats in autumn obscure a large degree of variation between individuals.

Differences in activity between the sexes

The only statistically significant difference in activity patterns found within the sexes of the same species was for stoats (Fig. 1). In autumn, female stoats were 77% more active at night than males. We caught no
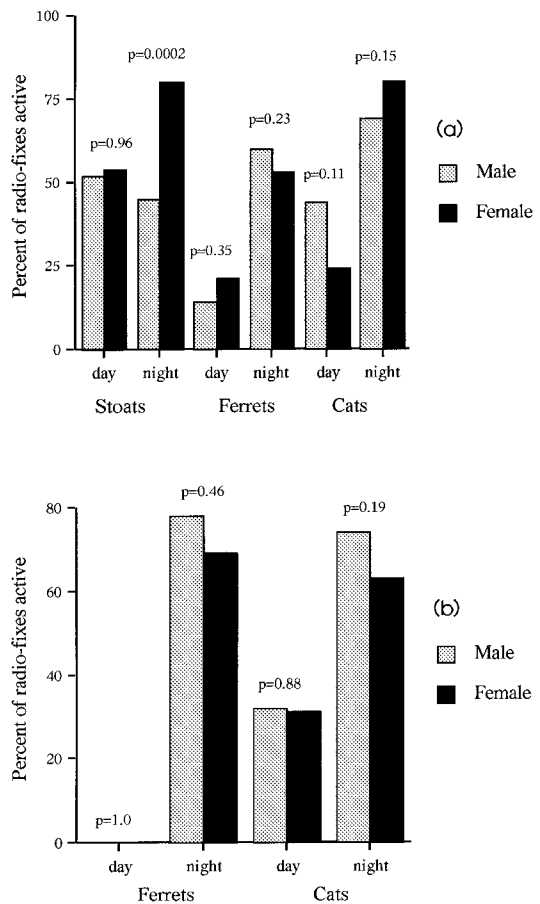

Figure 1: *Comparison of the activity of male and female stoats, ferrets and cats inhabiting coastal grassland, Otago Peninsula, New Zealand in (a) autumn and (b) spring. The* P *values test the null hypothesis that the proportions of radio-fixes that were active was the same during day and night between males and females of the same species.*

female stoats in spring to test whether this difference was repeated. Since differences are slight, except for stoats in autumn, we have combined data for both sexes of the same species in our following analyses.

Daily activity of stoats, ferrets and cats

Stoat and cats were diurnal in both seasons, but ferrets were diurnal only in autumn (Table 1; Fig. 2). Stoats showed equal day-night activity in autumn, but were mainly diurnal in spring. Feral cats and ferrets were mainly nocturnal in both seasons (Table 1; Fig. 2).

Differences in activity between the seasons

The activity rhythms did not vary significantly with season for feral house cats, but varied for the mustelids (Table 2). Overall, activity at night was higher for stoats in autumn than in spring, whereas the reverse pattern was exhibited by ferrets. Similarly, diurnal activity was lower for stoats, but higher for ferrets, in autumn compared with spring.

Differences in activity between the species

Stoats were more active by day than cats or ferrets in both seasons, and cats were also more active by day than ferrets (Table 3). Stoats and ferrets were equally active by night in autumn, but ferrets were more active by night than stoats in spring. Feral house cats were more active than stoats by night in both seasons, but were only more active by night than ferrets in autumn.
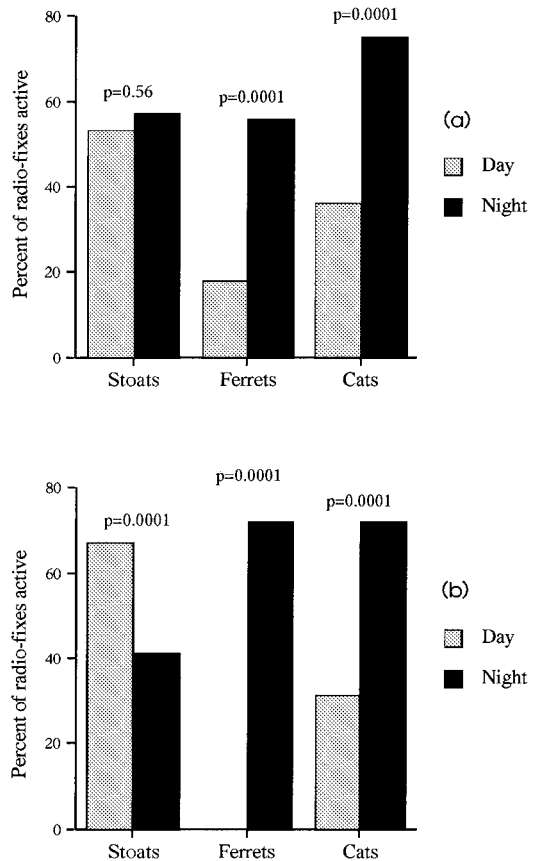

Figure 2: *Comparison of the day and night activity patterns of stoats, feral ferrets and feral house cats inhabiting coastal grassland, Otago Peninsula, New Zealand in (a) autumn and (b) spring. The* P *values test the null hypothesis that the proportions of radio-fixes that were active was the same between day and night for each species within each season.*

Table 1: *Comparison of the autumn and spring day and night activity patterns of stoats, feral ferrets and feral house cats inhabiting coastal grassland, Otago Peninsula, New Zealand. The number of different males radio-tracked is given as the first number, and the number of females is given as the second number within the round brackets. The total number of radio-fixes for males is given as the first number and for females as the second number in the square brackets.*

| Species | Percent radio-fixes that were active | | | |
| | Autumn | | Spring | |
	Day	Night	Day	Night
Stoat	**53%**	**57%**	**67%**	**41%**
	(5, 2)	(5,2)	(4,0)	(4,0)
	[67,41]	[90,46]	[101,0]	[136,0]
Ferret	**18%**	**56%**	**0%**	**72%**
	(5, 9)	(5,9)	(3,3)	(3,3)
	[72, 107]	[148,216]	[16,97]	[55,91]
Cat	**36%**	**75%**	**31%**	**72%**
	(4, 3)	(4,3)	(3,1)	(3,1)
	[50, 33]	[75,73]	[82,86]	145,49]

Table 2: *Results of χ^2 tests of independence testing whether the proportions of radio-fixes that were active for each predator species during day and night varied between autumn and spring.*

Species	Day Autumn-Spring	Night Autumn-Spring
Stoat	χ^2=4.01	χ^2=6.49
	d.f.=1	d.f.=1
	P=0.04	**P=0.01**
Ferret	χ^2=20.9	χ^2=10.3
	d.f.=1	d.f.=1
	P=0.0001	**P=0.001**
Cat	χ^2=0.27	χ^2=0.49
	d.f.=1	d.f.=1
	P=0.60	**P=0.57**

Table 3: *Results of χ^2 tests of independence testing whether proportions of radio-fixes that were active in autumn and in spring varied between predator species by day and by night.*

Species	Autumn		Spring	
	Day	Night	Day	Night
Stoat-Ferret	χ^2=36.7	χ^2=0.03	χ^2=108	χ^2=25.9
	d.f.=1	d.f.=1	d.f.=1	d.f.=1
	P=0.0001	**P=0.87**	**P=0.0001**	**P=0.0001**
Stoat-Cat	χ^2=4.59	χ^2=9.14	χ^2=25.4	χ^2=29.5
	d.f.=1	d.f.=1	d.f.=1	d.f.=1
	P=0.03	**P=0.002**	**P=0.0001**	**P=0.0001**
Cat-Ferret	χ^2=9.49	χ^2=15.2	χ^2=39.6	χ^2=0.005
	d.f.=1	d.f.=1	d.f.=1	d.f.=1
	P=0.002	**P=0.0001**	**P=0.0001**	**P=0.95**

Discussion

Variation in predator activity patterns

Activity rhythms varied markedly amongst individual stoats in autumn, but little amongst individual ferrets and cats in either season. Ranking the predators, stoats showed high, cats moderate and ferrets low day activity, whereas all the predators showed high night activity. This result is replicated by observations of small mammalian carnivores elsewhere in New Zealand. In South Island tussock grasslands ferrets were almost entirely nocturnal whereas feral house cats showed moderate day activity, but were mainly active at night (Pierce, 1987; Baker, 1989; Middlemiss, 1995); and stoats showed high levels of activity at day and at night in South Island beech forest (Murphy and Dowding, 1991). If the activity patterns observed here and by the above researchers are repeated elsewhere in New Zealand, stoat may pose the main threat to diurnal native wildlife whereas the larger predators may pose the main threat to nocturnal native wildlife.

Activity patterns did not vary between of sexes of the larger carnivores in either season, but we found that male stoats had higher levels of activity at day than females in autumn. Similarly, male stoats were more diurnal than females in Switzerland and in Sweden during early spring (Erlinge, 1979; Debrot *et al*., 1985), perhaps reflecting intraspecific differences in breeding behaviour (Erlinge and Sandell, 1986; Sandell, 1986). However, our result was outside the stoat breeding season and therefore must be otherwise simulated. For example, stoat activity is influenced by prey abundance (King, 1989) and differences in stoat diet between the sexes have been reported in New Zealand (King and Moody, 1982; Alterio, 1994). Accordingly, the increased daytime activity of males might also relate

to food preferences and availability. However, in view of the marked differences in the individual stoat activity patterns in autumn, further investigation of the day-night activity by male and female stoats is warranted.

Mustelid activity also varied seasonally. Stoats had higher daylight activity in spring compared with autumn whereas ferrets showed the reverse pattern. Similarly, nocturnal activity was lower for stoats, but higher for ferrets in spring compared with autumn. Replication in several years is required before this can be ascribed to a regular seasonal switch in New Zealand, but it does fit the seasonal patterns observed overseas (Erlinge, 1979; Debrot *et al*., 1985). This seasonal shift in mustelid activity may reflect intraspecific differences in breeding behaviour (Erlinge and Sandell, 1986; Sandell, 1986), food resources (Konecny, 1987; King, 1989) or predator-predator interactions (Moller, Norbury and King, 1996). For example, stoats visited different areas from ferrets within ungrazed coastal grassland habitats in our study area (Moller *et al*., 1996), perhaps because of competition and/or predation inference by the larger carnivores. Experimental removal of the larger predators, or manipulation of their prey would be needed to discern the relative importance of each putative effect on activity patterns.

Feral house cats showed no difference in activity patterns between seasons. Konecny (1987) also found cats maintained similar activity patterns throughout the year in the Galapagos Islands. In contrast, feral house cats became increasingly diurnal in winter in the semi-arid grassland habitats of the Mackenzie Basin, New Zealand (Pierce, 1987) when their staple prey, young rabbits were particularly scarce. Accordingly, local variation in prey numbers and/or prey manipulations such as rabbit control may trigger shifts in predator activity patterns and consequently increase the predation pressure on some native species, but decrease the predation pressure on others.

Activity patterns and conservation impacts

Predator activity rhythms are likely to be one determinant of the relative predation risk on endemic biota from the different introduced mammalian carnivores. Baker (1989) and Middlemiss (1995) concluded that cats were potentially the most important mammalian predator of giant skinks (*Leiolopisma otagense* McCann and *L. grande* Gray) because of their comparatively high diurnal activity. Activity patterns of predators during spring are particularly relevant when considering predation of chicks of endemic birds. The guarding patterns of

the adults may also be important, assuming that the parents can deter predators. For example, adult yellow-eyed penguins which react aggressively to some predators in some situations (Moller *et al*., 1995), leave their chicks unguarded during the day in early summer (Darby and Seddon, 1990), making them particularly vulnerable to stoat predation.

All the predators studied here showed high levels of activity at night, so nocturnal insects and lizards are potentially vulnerable to being eaten. Similarly, adult birds are vulnerable to attack while roosting or guarding young. For example, many adult sooty shearwaters are killed at night on the South Island mainland when returning to breeding burrows (Hamilton and Moller, 1995).

The Department of Conservation advocated retiring land from domestic grazing stock to restore populations of giant skinks, jewelled geckos and yellow-eyed penguins on the South Island mainland (Department of Conservation, 1991; 1995). However, retiring coastal grassland from grazing domestic stock attracts small mammalian carnivores (Alterio, Moller and Ratz, in press) and promotes stoat abundance (Moller *et al*., 1995). Similarly, stoats and weasels (*M. nivalis* Erxleben) also prefer areas of dense ground cover in North Island forest (King *et al*., 1996). Modifying the environment in ways that favour stoats (and perhaps weasels) may result in increased predation of some diurnal native wildlife such as lizards (Alterio, 1994) and yellow-eyed penguin chicks (Alterio, 1994; Moller *et al*., 1995).

Predation impacts on populations of endemic wildlife may sometimes be the work of individual predators that come to specialise on attacking a particular prey species or type. Diet studies in New Zealand have found that some cats and ferrets have consumed unusually high numbers of skinks (Baker, 1989; Middlemiss, 1995; Pascoe, 1995) or weta (Baker, 1989; Alterio, 1994; Pascoe, 1995). If such predators consistently use large numbers of a particular prey species or type, they may consequently apply severe localised predation pressure on some native wildlife populations (Ratz *et al*., 1992) and the success of control efforts may hinge on removing these "rogue" predators from an area. The marked individual differences in diurnal activity found amongst stoats and one of the cats here may be one determinant of this rogue animal phenomenon.

Effects of biological control on predator activity

Alterio (1994) found that rabbits were the staple prey of small mammalian carnivores living around South Island yellow-eyed penguin breeding areas,

and that use of rabbits increased in rank order of increasing predator size. Thus, reduction of rabbits would have greatest effect on the larger predators. Changes in predator guild may be expected. This is consistent with spatial correlations around South Island yellow-eyed penguin breeding areas. For example, stoats dominate in the southerly yellow-eyed penguin breeding areas whereas cats and ferrets dominate in the northerly breeding areas where rabbit abundance is higher (Bruce, 1991; Moller *et al*., 1995). Accordingly, widespread biological control of rabbits by Rabbit Calicivirus Disease which is currently under urgent consideration for New Zealand, could trigger the replacement of ferrets and cats by stoats in grassland habitats (Pierce, 1987). The high levels of daytime activity of stoats demonstrated here emphasises that this putative shift in predator guilds may increase predation pressure on diurnal species, but alternatively may reduce predation pressure on nocturnal species. Similarly, removal of rabbits, the main prey of cats and ferrets, might also trigger increased diurnal activity of these larger predators with consequent increased conservation risk to day active endemic species. However, potential changes in predator activity and diet may be partly or wholly counteracted by an overall decline in predator abundance following successful biological control of rabbits. Therefore, it is impossible to predict whether the introduction of Rabbit Calicivirus Disease will be of net benefit or harm to threatened wildlife species.

Acknowledgements

References

Alterio, N. 1994 (unpublished). *Diet and movements of carnivores and the distribution of their prey in grassland around Yellow-eyed penguin* (Megadyptes antipodes) *breeding colonies*. M.Sc. Thesis, University of Otago, Dunedin, N.Z. 120 pp.

Alterio, N.; Moller, H.; Ratz, H. in press. Movements and habitat use of feral house cats

Felis catus, stoats *Mustela erminea* and ferrets *Mustela furo* in grassland surrounding Yellow-eyed penguin *Megadyptes antipodes* breeding areas in spring. *Biological Conservation*.

Baker, G. 1989 (unpublished). *Aspects of mammalian predator ecology co-inhabiting giant skink habitat*. M.Sc. Thesis, University of Otago, Dunedin, N.Z. 97 pp.

Brown, K.P. 1994 (unpublished). *Predation at North Island robin* (Petroica australis longipes) *and North Island tomtit* (Petroica macrocephala toitoi) *nests*. M.Sc. Thesis, University of Otago, Dunedin, N.Z. 154 pp.

Bruce, L. 1991 (unpublished). *Lagomorph abundance and distribution around Yellow-eyed penguin* (Megadyptes antipodes) *breeding colonies on the Otago coast of New Zealand*. Wildlife Management Report Number 12, University of Otago, Dunedin, N.Z. 34 pp.

Darby, J.T.; Seddon, P.J. 1990. Breeding biology of yellow-eyed penguins (*Megadyptes antipodes*). *In*: Davis, L.S.; Darby, J.T. (Editors), *Penguin Biology,* pp. 45-62. Academic Press, San Diego, U.S.A. 467 pp.

Debrot, S.; Weber, J.M.; Marchesi, P.; Mermod, C. 1985. The day and night activity pattern of the stoat (*Mustela erminea L.*). *Mammalia 49*: 13-17.

Department of Conservation. 1991 (unpublished). *Species Conservation Strategy: Yellow-eyed penguin* (Megadyptes antipodes). Department of Conservation, Wellington, N.Z. 44 pp.

Department of Conservation. 1995. *Otago and grand skink recovery plan* (Leiolopisma otagense, Leiolopisma grande). Threatened Species Recovery Plan No. 14, Department of Conservation, Wellington, N.Z. 40 pp.

Erlinge, S. 1979. Movements and daily activity pattern of radio-tracked male stoats, *Mustela erminea*. *In*: Amlaner C.J. Jr.; Macdonald D.W. (Editors), *A handbook on biotelemetry and radio-tracking,* pp. 703-710. Pergamon Press, Oxford, U.K. 804 pp.

Erlinge, S.; Sandell, M. 1986. Seasonal changes in the social organization of male stoats, *Mustela erminea*: an effect of shifts between two decisive resources. *Oikos 47*: 57-62.

Hamilton, S.; Moller, H. 1995. Can PVA models using computer packages offer useful conservation advice? Sooty Shearwaters in New Zealand as a case study. *Biological Conservation 73*: 107-117.

King, C.M. 1989. *The natural history of weasels and stoats*. Christopher Helm, London, U.K. 253 pp.

King, C.M. 1990. Stoat. *In:* King C.M. (Editor), *The handbook of New Zealand mammals*, pp. 288-312. Oxford University Press, Auckland, N.Z. 600 pp.

King, C.M.; Edgar, R.L. 1977. Techniques for trapping and tracking stoats (*Mustela erminea*); a review, and a new system. *New Zealand Journal of Zoology 4***:** 193-212.

King, C.M.; Moody, J.E. 1982. The biology of the stoat (*Mustela erminea*) in the National Parks of New Zealand. *New Zealand Journal of Zoology 9*: 49-139.

King, C.M.; Innes, J.G.; Flux, M.; Kimberley, M.O.; Leathwick, J.R.; Williams, D. S. 1996. Distribution and abundance of small mammals in relation to habitat in Pureora Forest Park. *New Zealand Journal of Ecology 20:* 215-240.

Konecny, M.J. 1987. Home range and activity patterns of feral house cats in the Galapagos Islands. *Oikos 50*: 17-23.

Middlemiss, A. 1995 (unpublished). *Predation of giant* (Leiolopisma otagense, Leiolopisma grande) *and common skinks by feral house cats* (Felis catus) *and ferrets* (Mustela furo) *in the tussock grassland of Otago, New Zealand*. M.Sc. Thesis, University of Otago, Dunedin, N.Z. 120 pp.

Moller, H.; Ratz, H.; Alterio, N. 1995 (unpublished). *Protection of yellow-eyed penguins* (Megadyptes antipodes) *from predators*. A report to World Wide Fund for Nature. New Wildlife Management Report No. 65, University of Otago, Dunedin, N.Z. 56 pp.

Moller, H.; Norbury, G.; King, C. M. 1996. Ecological and behavioural constraints to effective control of ferrets (*Mustela furo*). *In: Ferrets as vectors of tuberculosis and threats to conservation*. Miscellaneous Series 36, pp. 54-68, Royal Society of New Zealand, Wellington, N.Z. 101 pp.

Murphy, E.; Dowding, J. 1991 (unpublished). *Ecology and behaviour of stoats in a South Island beech forest*. A report for Science & Research Division, Department of Conservation, Wellington, N.Z. 14 pp.

Pascoe, A. 1995 (unpublished). *The effects of vegetation removal on rabbits* (Oryctolagus cuniculus) M.Sc. Thesis, University of Otago, Dunedin, N.Z. 118 pp.

Pierce, R.J. 1987 (unpublished). *Predators in the Mackenzie Basin: Their diet, population dynamics, and impacts in relation to the abundance and availability of their main prey (rabbits)*. Draft report for the Wildlife Service, Wellington, N.Z. 110 pp.

Ratz, H.; Moller, H.; Alterio, N.; Dymond, S.; Fechney, T.; and Wass, R. 1992 (unpublished). *Protection of Yellow-eyed penguins from*

predation; first year research report. Wildlife Management Report, No. 25, University of Otago, Dunedin, N.Z. 27 pp.

Robitaille, J.F.; Baron, G. 1987. Seasonal changes in the activity budget of captive ermine, *Mustela erminea* L. *Canadian Journal of Zoology 65*: 2864-2871.

Sandell, M. 1986. Movement patterns of male stoats *Mustela erminea* during the mating season: differences in relation to social status. *Oikos 47*: 63-70.

Weber, D. 1989. Observations of activity, movements and ranges of polecats (*Mustela-putorius* L.). *Revue Suisse de Zoologie 96*: 841-862.