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SHORT COMMUNICATION

TRAPPABILITY AND DENSITIES OF STOATS (*MUSTELA ERMINEA*) AND SHIP RATS (*RATTUS RATTUS*) IN A SOUTH ISLAND *NOTHOFAGUS* FOREST, NEW ZEALAND

Summary: Stoat (*Mustela erminea*) density was estimated by live-trapping in a South Island *Nothofagus* forest, New Zealand, at 8-9 (Jan/Feb 1996) and 15-16 (Aug/Sep 1996) month intervals after significant beech seedfall in autumn 1995. Absolute densities were 4.2 stoats km^{-2} (2.9-7.7 stoats km^{-2}, 95% confidence intervals) in Jan/Feb 1996 and 2.5 stoats km^{-2} (2.1-3.5 stoats km^{-2}) in Aug/Sep 1996. Trappability of stoats increased in the latter sampling period, probably because mice (*Mus musculus*) had become extremely scarce. Accordingly, trapping rates of stoats may vary temporally and spatially with food supply rather than only with absolute abundance. Ship rats (*Rattus rattus*) capture rates doubled between Jan/Feb 1996 and Aug/Sep 1996, but rapidly declined shortly afterwards. Trappability of ship rats also increased in the latter sampling period. These factors must be considered when planning methods of indexing relative densities of stoats and rats.

Keywords: *Mustela erminea*; stoat; ship rat; house mouse; absolute density; live-trapping; trappability; beech forest; conservation.

Introduction

Trapping and footprint tunnel tracking rates are commonly used methods of indexing the relative abundance of small mammals in New Zealand (King and Edgar, 1977; Innes *et al*., 1995; Brown *et al*., 1996). Very few data exist on the absolute abundance of stoats (*Mustela erminea* L.) because they usually live at low density (King, 1990a) and are often difficult to trap (King, 1989), and no attempts have yet been made to calibrate tracking tunnel indices of relative abundance of stoats with estimates of actual density.

Southern beech (*Nothofagus* spp.) trees produce heavy crops of seed (mast years) at 3-11 year intervals, but in other years set insignificant crops (Wardle, 1984). Fluctuations in trap success suggest that stoats become very numerous in the summer and autumn following heavy seedfall, but remain at low abundance in the intervening times (King, 1983; Murphy and Dowding, 1995).

The heavy predation suffered by yellowheads (*Mohoua ochrocephala* Gmelin) following heavy seedfall years has been attributed to increased stoat predation (O'Donnell, Dilks and Elliott, 1996). O'Donnell *et al*. (1996) and Elliott (1996) suggest that the viability of populations of yellowheads and yellow-crowned parakeets (*Cyanoramphus auriceps* Kuhl) in South Island *Nothofagus* forest are critically dependent on stoat density. Control of stoats is currently very expensive, so estimating "ecological damage thresholds" (Moller, 1989) using measures of density of stoats could help determine when control is necessary. Accordingly, the aim of this study was to estimate the absolute density of stoats in a South Island *Nothofagus* forest, New Zealand, at 8-9 and 15-16 months after heavy seedfall. Changes in absolute abundance from the first to second period were compared with stoat trapping rates and the trappability of individual marked stoats to determine whether trapping rates are a reliable index of relative abundance.

Ship rats (*Rattus rattus* L.) may also become very numerous in *Nothofagus* forest following significant seedfall (King and Moller, 1997) and ship rats are important predators of small native passerine forest birds (Brown, 1997). Accordingly, this study also measured a relative index (capture rate) of ship rat abundance during the sampling periods.

Methods

Stoats were studied at five sites (A, B, C, D and E) in a West Coast beech (*Nothofagus fusca* Hook, *N. menziesii* Hook) forest (42°13'S, 172°15'E), 5 km SE of Maruia, South Island, New Zealand (Fig. 1). Edgar traps (King and Edgar, 1977) placed at 150 m intervals on circular traplines and baited with lagomorph meat were used to live-capture stoats

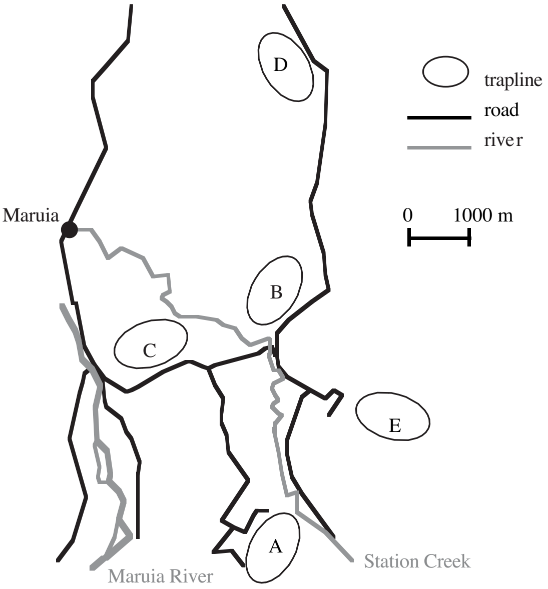

Figure 1: *Traplines at Sites A and B in January/February 1996 and at Sites C, D and E in August/September 1996 in* Nothofagus *forest, Station Creek, South Island, New Zealand.*

(Table 1). All mustelids caught were sexed, ear-tagged, radio-tagged and released. Any rodents trapped at Sites A and B in Jan/Feb 1996 and at Sites C and E in Aug/Sep 1996 were marked and released. Rodents trapped at Site D were not marked so they were not included in the following analysis.

Capture rates were determined by the total number of new individuals caught per 100 "effective trap nights" (etn) following Nelson and Clark (1973). 95% binomial confidence intervals were calculated using Mainland, Herrera and Sutcliffe (1956). Individuals were counted on first capture and thereafter subsequent captures were treated as sprung traps.

Population estimates were calculated for the stoat populations in each period by program CAPTURE, assuming closure over the duration of trapping (14 days and 11 days for Jan/Feb 1996 and Aug/Sep 1996, respectively; omitting days when not all areas were trapped) and using the jackknife model, which is robust to individual variation in capture probability (method of Otis *et al.*, 1978). The population estimates were divided by the effective trapping area to give absolute densities of stoats for each period.

The effective trapping areas were estimated by adding a boundary strip (Dice, 1938) to the "core" areas trapped (Table 2). The boundary strip was determined by adding the radius of a circle the size of an average stoat home range. Home range

Table 1: *Summary of stoat, weasel and ship rat trapping data at Sites A and B in Jan/Feb 1996 and at Sites C, D & E in Aug/Sep 1996 in a South Island* Nothofagus *forest, New Zealand. 95% binominal confidence intervals (ci) were fitted from Mainland, Herrera and Sutcliffe (1956). M=males, F=females. *Traps were closed for several days during the trapping period because of weather conditions. **Rodents trapped at Site D were not marked.*

	Site A	Site B	Total	Site C	Site D	Site E	Total
Trapping period	26 Jan - 12 Feb 1996	27 Jan - 12 Feb 1996		14 Aug - 1 Sept 1996*	16 Aug - 31 Sept 1996*	16 Aug - 3 Sept 1996*	
Total no. of nights traps were open	17	16		14	11	13	
Total no. of Edgar traps	25	25	50	26	27	27	80
Total no. of effective trap nights (etn)	409	379	788	333	258	323	914
Total no. of individual stoats trapped	11 (M10, F1)	5 (M4, F1)	16 (M14, F2)	10 (M3, F7)	13 (M8, F5)	9 (M8, F1)	32 (M19, F13)
Total no. of captures	13	6	19	24	23	20	67
Stoats/100 etn (95% ci)	2.7 (1.4-4.9)	1.3 (0.5-3.8)	2.1 (1.2-3.2)	3.0 (1.6-6.0)	5.0 (2.8-8.7)	2.8 (1.4-5.6)	3.5 (2.3-5.3)
Total no. of individual weasels trapped	1	0	1	3	0	0	3
Total no. of captures	1	0	1	7	0	0	7
Weasels/100 etn (95% ci)	0.2 (0.007-1.5)	0	0.1 (0.004-0.8)	0.9 (0.2-2.9)	0	0	0.3 (0.06-0.8)
Total no. of individual ship rats trapped	8	7	15	11	?**	18	29
Total no. of captures	10	10	20	22	?**	49	71
Ship rats/100 etn (95% ci)	1.9 (0.9-4.2)	1.8 (0.8-3.8)	1.9 (1.2-3.2)	3.3 (1.8-6.5)	?**	5.6 (3.2-8.6)	4.4 (3.0-6.4)

Table 2: *Summary of minimum density estimates of stoats at Sites A and B in Jan/Feb 1996 and at Sites C, D & E in Aug/Sep 1996 in a South Island* Nothofagus *forest, New Zealand.*

	Site A	Site B	Total	Site C	Site D	Site E	Total
Core area trapped, ha	112	112	224	121	130	130	381
Effective trapping area for stoats, ha	381	381	762	523	543	543	1609
Effective trapping area for male stoats, ha	409	409	818	672	695	695	2062
Effective trapping area for female stoats, ha	357	357	714	428	446	446	1320
Minimum density of stoats, ind. km^{-2}	2.9	1.3	2.1 (*s.e.*=0.8)	1.9	2.4	1.7	2.0 (*s.e.*=0.2)
Minimum density of male stoats, ind. km^{-2}	2.4	1.0	1.7	0.5	1.2	1.2	0.9
Minimum density of female stoats, ind. km^{-2}	0.3	0.3	0.3	1.6	1.1	0.2	1.0

estimates were based on radio-tracking studies by Murphy and Dowding (1995) and by Alterio (1998) in South Island *Nothofagus* forest that approximated the post-seedfall phases and seasons sampled in this study. This gave radii of 505 m (544 m for males, 469 m for females) and 670 m (843 m for males, 547 m for females) in Jan/Feb 1996 and in Aug/Sep 1996, respectively. When added to the radii of the core areas trapped, our average effective trapping areas were estimated at 762 and 1609 ha for each period, respectively (Table 2).

No formal measurements of seedfall at the present study sites are available, but widespread heavy seeding of beech was noted in autumn 1995 in our general study area (Glenn Stewart, Lincoln University, N.Z., *pers. comm.*). Similarly, heavy seedfall was noted in the Catlins and Rowallan forests, Takitimu and Blue Mountains, Eglinton, Dart, Landsborough, Poulter, Hurunui, Hawdon and Buller Valleys in autumn 1995 (C. O'Donnell, Department of Conservation, Christchurch, N.Z.; G. Lowe, Department of Conservation, Dunedin, N.Z.; G. Ure, Department of Conservation, St Arnaud, N.Z.; P. Dilks, Department of Conservation, Christchurch, N.Z.; S. Philipson, Department of Conservation, Arthurs Pass, N.Z.; and Glenn Stewart, Lincoln University, N.Z., *pers. comms.*). Beech seeding is generally consistent over wide areas (Wardle, 1984) so it can be reliably inferred that our Jan/Feb and Aug/Sep 1996 study periods were approximately 8-9 and 15-16 months after the previous seedfall.

Results

The difference in capture rates between the two sampling periods was not formally significant (χ^2=3.34, d.f.=1, *P*=0.068), but the trend was for higher numbers of stoats to be caught in the latter sampling period (Table 1). Similarly, fewer captures per individual marked stoat were recorded in Jan/Feb than in Aug/Sep (Mann-Whitney U, d.f.=1, *P*=0.009; Table 3). There was no difference in the average number of captures per individual marked stoat between the sexes (Mann-Whitney U, d.f.=1, *P*=0.50; Table 3).

Fewer ship rats were trapped in Jan/Feb than in Aug/Sep (χ^2=7.68, d.f.=1, *P*=0.006; Table 1), but the average number of captures per individual marked ship rat was also higher in the latter sampling period (Mann-Whitney U, d.f.=1, *P*=0.02).

Few weasels (*M. nivalis* Erxleben) were caught in either sampling period and all were males (Table 1).

Few new stoats were caught in the last six nights of trapping, except at Site A (Fig. 2a, b) so at the remaining study sites most of the trappable stoats were probably caught. Minimum densities were 2.1 (S.E.=0.8) and 2.0 (S.E.=0.2) stoats km^{-2} in Jan/Feb and in Aug/Sep respectively (Table 2). However, there were few captures at some sites and the proportion of captures of marked stoats in the last six nights varied considerably between the two

Table 3: *Frequency of live-captures of 16 (M14, F2) and 32 (M19, F13) stoats caught in Jan/Feb 1996 and in Aug/Sep 1996 respectively, in a South Island* Nothofagus *forest, New Zealand.*

Sampling period	Number of live-captures: 1	2	3	4	5	Total
Jan/Feb 1996						
Males	12	2	0	0	0	14
Females	1	1	0	0	0	2
Totals	13	3	0	0	0	16
Aug/Sep 1996						
Males	5	6	5	2	1	19
Females	8	3	1	0	1	13
Totals	13	9	6	2	2	32

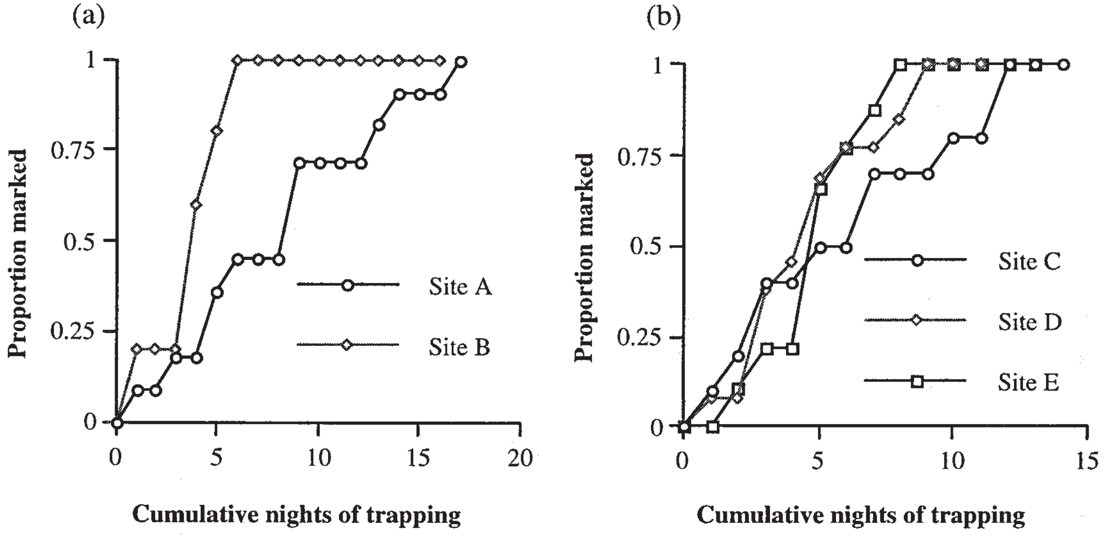

Figure 2: *Proportion of stoats marked against cumulative number of trap nights in a South Island Nothofagus forest, New Zealand at (a) Sites A* (n=*11) and B* (n=*5) and (b) Sites C* (n=*10), D* (n=*13) and E* (n=*9) between 8-9 and 15-16 months after heavy seedfall respectively.*

sampling periods (Table 2). Overall, a lower proportion of captured stoats were marked in the Jan/Feb period than in Aug/Sep. The absolute density estimates varied from 4.2 stoats km^{-2} (2.9-7.7 stoats km^{-2}, 95% confidence intervals) in Jan/Feb to 2.5 stoats km^{-2} (2.1-3.5 stoats km^{-2}, 95% confidence intervals) in Aug/Sep.

Discussion

Variation in stoat trappability

Methods of estimating relative abundance of small mammals based on trapping data assume equal probability of catching all animals at all times. In this study, marked stoats were re-trapped more often in the latter sampling period, probably because mice (*Mus musculus* L.) were very scarce (Brown, Alterio and Moller, 1998). Similarly, King and McMillan (1982) noted that the trappability of individual stoats varied in several South Island *Nothofagus* forests during a post-seedfall summer peak. If stoats are less trappable at high prey density just after seedfall, the difference in stoat density between post-seedfall peaks and other periods will have been underestimated. Accordingly, the summer peak in stoats are probably relatively greater than recorded by King (1983), by Murphy and Dowding (1995) and by this study. Calibration of relative indices of stoat abundance (trapping and tracking tunnel rates) are urgently needed to provide reliable guidance to conservation management in beech forests. This study predicts that calibration curves will be fundamentally different in periods of high mouse and rat abundance just after seedfall compared with later when rodents are scarce and stoats are driven by hunger to enter traps or baited tracking tunnels.

Variation in rodent abundance in *Nothofagus* forest

Rodent capture rates fluctuate widely in *Nothofagus* forest in relation to infrequent and irregular seedfalls (King, 1983; King and Moller, 1997). For example, mouse tracking tunnel rates of 97% per 3 nights were recorded in February 1996 at Sites A and B (Alterio, Brown and Moller, 1997), but by August 1996, mice had almost disappeared from Sites C, D and E (Brown *et al.*, 1998). In contrast, twice as many ship rats were trapped in Aug/Sep 1996 compared with Jan/Feb 1996. However, tunnel tracking indices suggested that the rat population crashed shortly afterwards (Brown *et al.*, 1998). Similarly, relatively high numbers of ship rats were recorded in South Island *Nothofagus* forest following mast years after mice had become scarce (King, 1983; King and Moller, 1997). Ship rats usually returned to very low abundance 1-2 years after significant seedfall (King and Moller, 1997).

Estimates of mustelid density in *Nothofagus* forest

In the present study, minimum densities of 2.1 and 2.0 stoats km^{-2} were estimated at 8-9 and 15-16 month intervals after significant seedfall respectively. However, a lower proportion of the captured stoats were marked in Jan/Feb than in Aug/Sep 1996, so comparison of the minimum number alive obscures the fact that the density estimate was less well enumerated in the first period. Accordingly, the population estimates calculated by program CAPTURE (jackknife model is robust to individual differences in trappability) are the more reliable indicators of change in actual abundance. Median estimates suggest density declined to almost half of the Jan/Feb levels by Aug/Sep 1996 (i.e. from 4.2 to 2.5 stoats km^{-2}). Minimum densities of 5.6 and 1.3 stoats km^{-2} were recorded in another South Island *Nothofagus* forest at 5-12 and 17-24 month intervals after significant seedfall respectively (calculated from live-trapping and home range data in Murphy and Dowding, 1994; 1995). However, Murphy and Dowding (1994; 1995) live-trapped for stoats over a much longer period, so they probably marked a greater proportion of residents, but also immigrants, emigrants and transients than in this study. The majority of marked stoats stayed on or near the trapped areas during this study (Alterio *et al.*, 1997; Alterio, *unpubl. data*), so few stoats were transients or dispersing.

Few weasels have been caught in New Zealand *Nothofagus* forests in either seedfall or non-seedfall years (King, 1990b; this study) so it is uncertain whether weasels respond to increased food supply following a mast year, as do stoats (King, 1983; Murphy and Dowding, 1995).

Implications for conservation

Stoats are implicated in the decline of several species of native birds in South Island beech forest (Elliott, 1996; O'Donnell *et al.*, 1996). However, ship rats may also become very numerous in South Island *Nothofagus* forest at this time (King and Moller, 1997) and they have been identified as a major predator of small forest birds in a North Island mixed broadleaf/podocarp forest (Brown, 1997). Mice may also prey on eggs and the role of weasels in killing adult and young birds is unknown. Accordingly, predator control operations should target all these predators to minimise predation risks to native wildlife, at least until the relative impacts of each species has been discerned. This preliminary study suggests that changes in capture rates may greatly underestimate the true fluctuations in stoat abundance following seedfall. Modelling predation impacts on endangered birds and the costs and benefits of different control strategies from relative predator population indices might therefore be misleading. Long-term intensive live-trapping of mustelid and rodent populations through beech seedfall events would be valuable and are overdue.

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