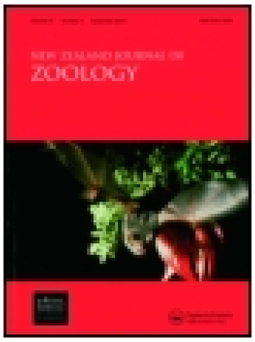

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Diet of house mice (*Mus musculus* L.) on coastal sand dunes, Otago, New Zealand

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Abstract The diet of feral house mice (*Mus musculus* L.) inhabiting a sand dune ecosystem near Dunedin, New Zealand, was determined from the contents of 102 stomachs, and quantified in relation to season, gender and reproductive status by fitting linear logistic regression models to frequency of occurrence data. Mice were omnivorous, although their diet was biased towards invertebrates. Overall, 86% of stomachs examined contained plant material, and 90% contained invertebrate remains. Lepidopteran larvae (66% of stomachs), Coleoptera (64%, mostly larvae), and Araneae (58%) were important dietary items. Plant material was largely unidentifiable (61%) but included leaves and seeds from three common grass species. Mouse diet varied seasonally, with lepidopteran larvae and coleopteran larvae eaten significantly more often in summer. Reproductive state also influenced diet, at least in summer, when reproductive females ate Araneae more often than non-reproductive females. Results emphasise the importance of invertebrates in the diet of feral house mice, and the need for more detailed research.

Keywords house mouse; *Mus musculus*; food habits; small mammal; invertebrates; lepidopteran larvae; sand dunes; Otago; New Zealand

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INTRODUCTION

The impacts of introduced feral house mice (*Mus musculus* L.) in New Zealand are little known. Mice have become well established since they were first noticed in the Bay of Islands around 1830 (Guthrie-Smith 1953), and are now widespread in New Zealand (Murphy & Pickard 1990). Invertebrates (mainly arthropods) are often eaten in large amounts by house mice inhabiting a range of habitats (Fitzgerald et al. 1996). The impact of house mice on local invertebrate populations may therefore be significant (Bull 1967; Ramsey 1978), but their importance as predators of endangered invertebrates in New Zealand has not been determined systematically.

New Zealand has over 300 000 ha of sand dune habitat (Taylor & Smith 1997) that harbours several specialised native invertebrate species (Patrick 1994). Less than 10 percent of this area is considered unmodified (Hunter & Blaschke 1986). Disturbed habitats often support high densities of mice in New Zealand (King et al. 1996), but there is little quantitative information on the diet of mice inhabiting dune ecosystems in New Zealand. This paper describes the diet of house mice in a coastal sand dune environment in relation to season, gender and reproductive status, as these factors are known to influence food selection in rodents (Myrcha et al. 1969; Badan 1986; Mutze et al. 1991).

STUDY AREA

This study was conducted on coastal sand dunes at Ocean View Recreational Reserve (45°56′S, 170°21′E), 15 km south of Dunedin, New Zealand. The reserve (about 15 ha) forms a narrow strip (150–300 m in width) that is characterised by small hollows and large areas of eroding, free-draining sand. Vegetation is dominated by marram grass (*Ammophila arenaria*), a vigorous sandbinder planted to promote dune stability. Pastoral grasses are widespread, along with tree lupin (*Lupinus* *arboreus*), bracken fern (*Pteridium esculentum*), pòhuehue (*Muehlenbeckia australis*) and gorse (*Ulex europaeus*). Native sand tussock (*Poa triodioides*), flax (*Phormium tenax*) and pìngao (*Desmoschoenus spiralis*) grow in clumps on the fore-dunes (dunes directly adjacent to the sea). Ocean View is subject to a variety of disturbances associated with public use (fire, dumping of clay and asphalt, and riding of horses and motor-cycles).

Ocean View has a maritime temperate climate. During sampling the house mice were exposed to a cold dry winter (June–August) alternating with a warm and wet summer (December–February). Ambient temperatures at ground level were higher on average in summer (summer 13.6°C; winter 4.8°C). Rainfall was doubled in summer (winter 110 mm; summer 254 mm) and frosts were frequent in June 1997. A detailed description of the study area, climate characteristics and flora present can be found in Miller (1999).

MATERIALS AND METHODS

Trapping protocol & autopsy

Mice were trapped for five consecutive nights in July (winter) and 10 consecutive nights in December (summer) 1997. Three rodent trap-lines, two consisting of 40 trap stations and one of nine trap stations, were established at 15 m intervals adjacent to a small walking track running the length of the reserve. A single break-back trap (Ezeset Supreme, Australia) baited with a mixture of peanut butter and rolled oats was set at each trap station inside a plastic ice-cream container. Entry holes were cut into the containers which were placed upside down and stapled to the substrate to minimise disturbance. Traps were inspected daily and recorded as sprung, unsprung, baited or unbaited. Sprung traps were reset, rebaited if required, and noted as having been disturbed. For each captured individual, trap station, weight, gender and reproductive status (active, non-active) were recorded.

In the field, mice were placed individually into vials containing 70% alcohol before being measured and autopsied later each day in the laboratory. Standard morphological measurements were recorded (Jewell & Fullagar 1966) and the stomach was removed by cutting the oesophagus approximately 1 cm above the stomach and cutting at least 2 cm below the duodenum. Females were considered reproductively active if they had uterine scars or if they were pregnant and/or lactating. Males with macroscopic tubules present in the cauda epididymis were considered to be reproductively active (Laurie 1946).

Stomach content analysis

The stomach of each mouse was placed in a Petri dish containing a small amount of 70% alcohol and viewed under a binocular microscope. Contents were separated into three categories: invertebrate, plant or unidentifiable material. Invertebrate material was further classified as: Lepidoptera larvae, Coleoptera, Hemiptera, Orthoptera, Collembola, Diptera, Araneae and Annelida. The retention of leg appendages, spinnerets, head capsules, pedipalps, strongly sclerotised parts and distinctively sculptured or coloured body parts helped invertebrate identification. Generic descriptions and illustrations given by Commonwealth Scientific and Industrial Research Organisation (1991) and Dugdale (1996) were also helpful.

Plant material was divided further into seed, leaf and unidentifiable plant material. Seeds, where possible, were identified to species level using cellular patterns and hair formations on the seed coat and cuticles (Lambrechtsen 1975). Reference material collected from the field also proved valuable. Venation patterns and stems indicated the presence of leaf material in samples. The third category, unidentifiable plant material, consisted of the remaining plant fragments whose degree of mastication prevented positive identification. Unidentified invertebrate remains were grouped within the unidentified category.

Quantification of stomach contents

Dietary composition was quantified using the frequency of occurrence (FOO) method (Hansson 1970). Food items were recorded as being present or absent in each stomach. The frequency at which different food categories appeared in stomachs was calculated for each sample by expressing the number of stomachs in which an item appeared as a percentage of the total number of stomachs.

Statistical analysis

The effects of season, gender and reproductive status on the consumption of the different food categories was analysed by fitting logistic regression models to FOO data for each food category in the diet, using the procedure PROC LOGISTIC (SAS Institute Inc., 1989). A test for the significance of each variable is given by comparing the deviance statistics (–2 log likelihood) for appropriate models (further details in

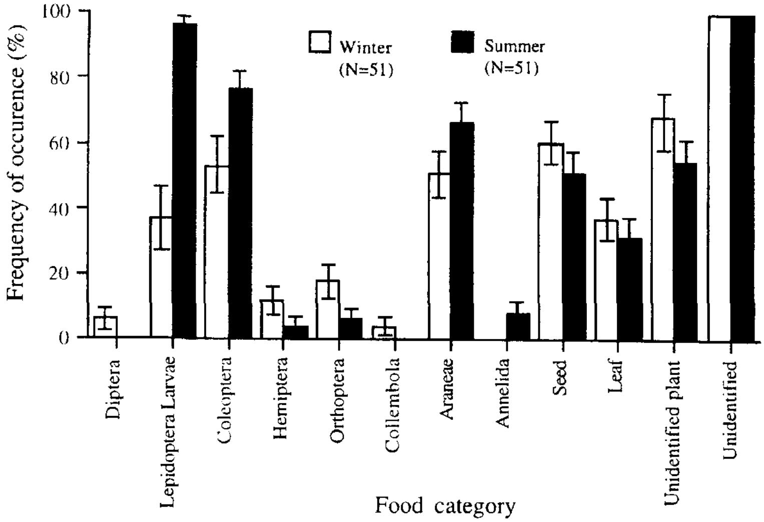

Fig. 1 Seasonal analyses of mouse diet at Ocean View. Results expressed as frequency of occurrence values. Error bars represent upper and lower 95 % binomial confidence intervals.

Table 1 Frequency of occurrence of food categories present in stomach contents of house mice collected from Ocean View. N = 102. Lower and upper binomial 95% confidence intervals given in parenthesis.

Food Category	Frequency of Occurrence (%) and 95% CI
Invertebrate	
Diptera	
Tethinidae (adult)	2.9 (0.61, 8.3)
Lepidoptera	
Noctuidae (larvae)	66.6 (56.6, 75.7)
Coleoptera (Total)	64.7 (54.6, 73.9)
Elateridae (larvae)	54.9 (44.7, 64.8)
Curculionidae (adult)	9.8 (4.8, 17.3)
Hemiptera	
Delphacidae	7.8 (3.4, 14.9)
Orthoptera	
Rhaphidophoridae	11.7 (6.2, 19.6)
Collembola	
Sminthuridae	1.9 (0.2, 6.9)
Araneae	
Spiders	58.8 (48.6, 68.5)
Annelida	
Earthworms	3.9 (1.1, 9.7)
Total Invertebrate	90.0 (81.2, 99.8)
Plant Material	
Seed (Total)	55.8 (45.7, 65.7)
Leaf	34.3 (25.2, 44.4)
Unidentified Plant	61.7 (51.6, 71.2)
Total Plant	86.6 (85.7, 96.2)
Unidentified	100 (96.4 , ∞)

Harraway 1995). The FOO data were too few to allow valid tests for interaction effects.

Sample sizes for some food categories (Diptera, Collembola and Annelida) and for reproductively active mice caught in winter were small, so chi square (χ^2) tests of independence were employed to test for any significant differences in occurrence of food items between reproductively active and non-active mice. In all tables, significant differences were assumed if $P < 0.05$. Empty stomachs were excluded from analyses.

RESULTS

Dietary composition

Mice were the only rodents trapped at Ocean View. The stomach contents of 102 mice were examined and analysed (excluding six stomachs found empty). Contents were well masticated, so identification was difficult for some food categories (Table 1). Nevertheless, identifiable invertebrate material was found in 90% and plant material in 86% of stomachs (Table 1). Insects were major dietary components, with lepidopteran larvae (family Noctuidae) (FOO 66%), Coleoptera (mostly larval forms, total FOO 64%), and Araneae (spiders) (FOO 58%) the most common (Table 1).

Other less common invertebrate food types identified are listed in Table 1. Unidentifiable plant material was common (FOO 61%). Leaves and seeds of three species (Yorkshire fog, kneed foxtail,

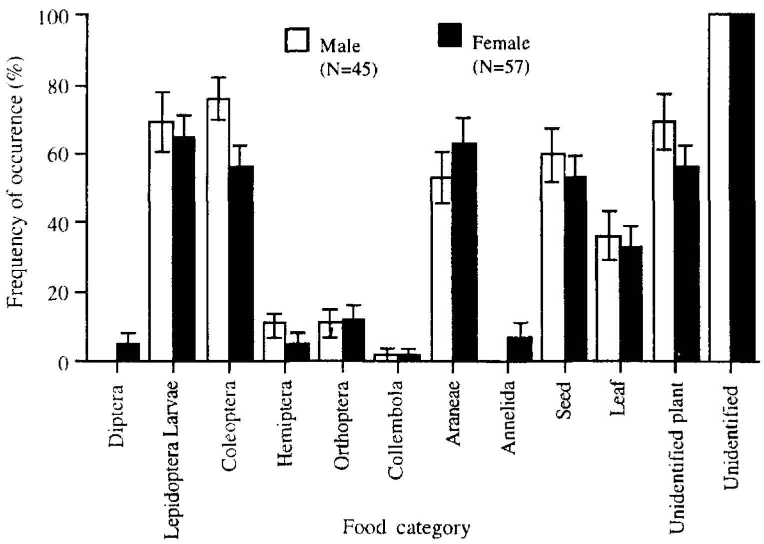

Fig. 2 Diets of male and female mice at Ocean View. Results expressed as frequency of occurrence values. Error bars represent upper and lower 95% binomial confidence intervals.

Table 2 Calculated *P*-values from logistic linear regression models summarising the individual and combined effects of season, gender and reproductive status on the occurrence of food categories identified in mouse stomachs (N = 102). Regression models that analysed more than one variable at a time are presented with the controlled variable given last (e.g., the 'season/gender' model tests for season effects while controlling for any possible confounding gender effects).

	Model type						
Food category	Season	Gender	Repro stat	Season/ gender	Gender/ season	Season/ repro stat	Repro stat/ season
Lepidoptera	0.0001	0.6718	0.001	0.0001	0.701	0.0001	0.361
Coleoptera	0.007	0.071	0.140	0.007	0.0688	0.024	0.975
Hemiptera	0.133	0.277	0.216	0.125	0.259	0.314	0.597
Orthoptera	0.060	0.854	0.248	0.072	0.882	0.135	0.860
Araneae	0.107	0.317	0.0004	0.1005	0.295	0.810	0.0016
Seed	0.318	0.456	0.567	0.310	0.442	0.413	0.964
Leaf	0.531	0.815	0.772	0.528	0.805	0.577	0.956
Unident. Plant	0.152	0.186	0.344	0.142	0.173	0.274	0.825

marram grass) belonging to the family Gramineae were identified (Table 1). Seeds and unidentified plant material occurred less frequently compared with lepidopteran larvae, Coleoptera and Araneae (Table 1). No vertebrate remains (bones, feathers, scales or flesh) were found, but mouse hair was present in most stomachs, presumably from grooming.

Influences on mouse diet

The diet of mice varied seasonally. Plant material was more frequent (although not statistically significant) in winter. In contrast, lepidopteran larvae (χ^2 = 45.6, df = 1, $P < 0.01$) and Coleoptera (χ^2 = 7.2, df = 1, $P < 0.01$) were eaten significantly more often in summer (Fig. 1; Table 2). These differences remained even after variation due to gender and reproductive status effects were accounted for (Table 2). There was little difference between the diets of males and females (Fig. 2), and FOO data were similar across genders for all identifiable food categories (Fig. 2; Table 2).

The reproductive status of house mice influenced the consumption of Araneae (Table 2). Remains of Araneae were found in more stomachs from reproductively active mice of both sexes than mice in non-reproductive condition in summer (Fig. 3). This difference was significant in females (χ^2 = 8.239, df = 1, $P < 0.01$) (Fig. 3b). Plant remains were found more frequently in in winter, reflecting an increase

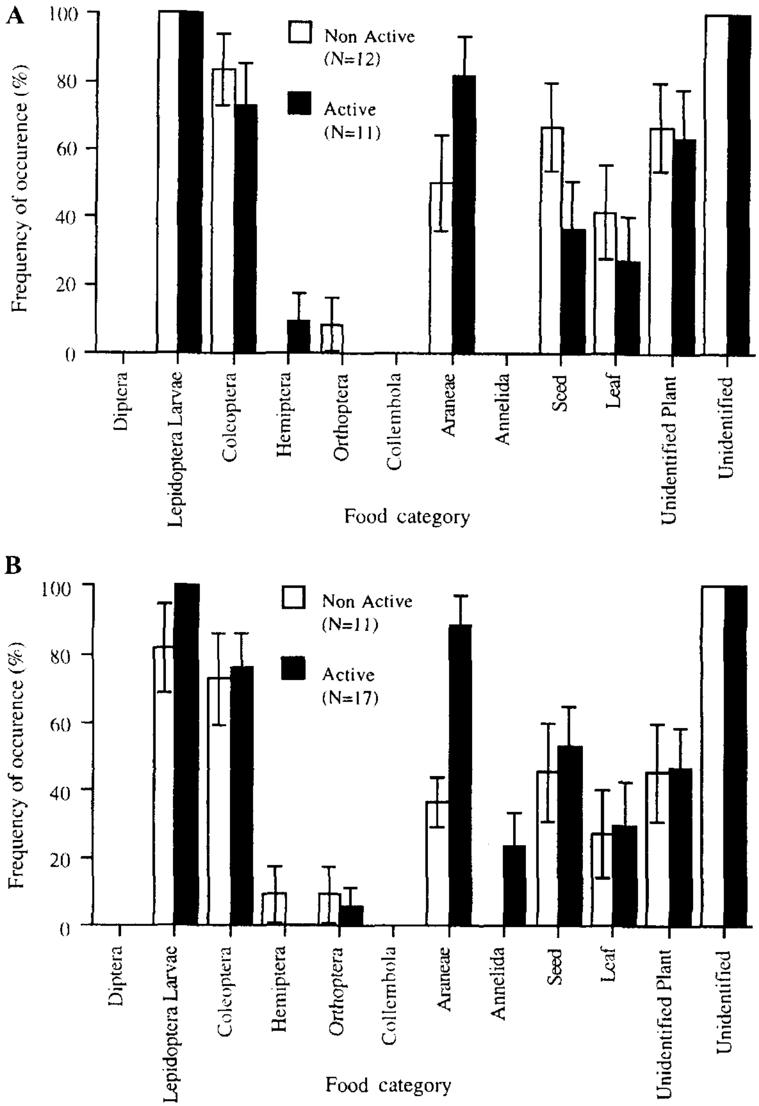

Fig. 3 Effect of reproductive status on diet of mice trapped in summer (December 1997) at Ocean View. Results expressed as frequency of occurrence for males A, and females B. Error bars represent upper and lower 95% binomial confidence intervals.

in consumption of plant material by house mice during this period (Fig. 1). These differences, were not, however, statistically significant (Table 2).

DISCUSSION

The results of this study can be used to infer which food items are most likely to be targeted by house mice. House mice on the dune habitat were omnivorous, although their diet was strongly biased towards insects, and moth larvae were a major dietary component. These findings concur with results obtained both overseas (Watts & Braithwaite 1978; Gleeson & van Rensburg 1982; Chown & Smith 1993) and in New Zealand (Pickard 1984; Badan 1986; Fitzgerald et al. 1996). In New Zealand beech forests (*Nothofagus* spp.), lepidopteran larvae are a significant food resource contributing to periodic high populations of mice (Fitzgerald et al. 1996).

Mouse diet varied with season. Lepidopteran larvae and Coleoptera were consumed significantly more often in summer and similar trends have been described in other populations of house mice (Whitaker 1966; Badan 1979; Pickard 1984; Copson 1986). Seasonal changes in food quality and availability affect prey selection by most invertebrate-eating mammals, and undoubtedly influenced predation by mice on moth and beetle larvae during this study. Increased summer predation on insect larvae may reflect active selection of nutritious foods by breeding individuals whose energy demands are comparatively higher than those of non-breeding individuals. This may also apply to Araneae, at least in summer, when reproductive female mice ate Araneae more often than non-reproductive females.

In dune habitats, mice may affect the regeneration of native sand-binding species planted on fore-dunes (pìngao and sand tussock) by consuming their seeds (P. Pope, Dunedin City Council, pers. comm.), and seed was identified in more than half the stomachs examined. Damage to and destruction of soil seed banks, fallen seed and young shrubs by mice has been noted previously in New Zealand. Mice may also have affected the natural regeneration of indigenous kauri (*Agathis australis*) and rimu (*Dacrydium cupressimum*) (Wodzicki 1963; Beveridge 1964; Badan 1979). The impact of mice upon native fore-dune vegetation may be considerable, especially in winter (June–August) as many plants shed their seeds then and an associated increase in mouse consumption of seeds (and plant material in general) was noted.

Mice have been implicated in the decline of invertebrate populations in New Zealand (Bull 1967; Ramsey 1978; Newman 1994; Brignall-Theyer 1998). Endemic Lepidoptera may be at risk, because marram grass and pòhuehue provide suitable habitat for a wide diversity of endemic lepidoptera (Patrick 1994), and both predominate at Ocean View. Furthermore, the nocturnal feeding habits of some endemic moths (*Agrotis innominata*, Patrick & Green 1991) may render them susceptible to mouse predation. Other potential endemic prey for mice may include noctuid moths (*Tmetolophota phaula* & *Persectania aversa*) and the katipo spider (*Lactrodectus katipo*), all of which are found on sand dunes nearby (Patrick & Green 1991).

CONCLUSION

The results of this study emphasise the importance of invertebrates in the diet of feral house mice, and the need for more detailed research into the largely ignored impacts of house mice on endemic invertebrate populations in New Zealand.

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REFERENCES

Badan, D. 1979: The ecology of mice (*Mus musculus* L.) in two forests near Auckland. Unpublished MSc thesis, University of Auckland, New Zealand.

Badan, D. 1986: Diet of the house mouse (*Mus musculus* L.) in two pine and a kauri forest. *New Zealand Journal of Ecology 9*: 137–141.

Beveridge, A. E. 1964: Dispersal and destruction of seed in Central North Island podocarp forests. *Proceedings of The New Zealand Ecological Society 11*: 48–55.

Brignall-Theyer, M. E. 1998: Potential vertebrate predators of the Cromwell chafer beetle, *Prodontria lewisi*. Unpublished MSc thesis, University of Otago, Dunedin, New Zealand.

Bull, R. M. 1967: A study of the large New Zealand weevil, *Lyperobius huttoni* Pascoe, 1876 (Coleoptera: Curculionidae, Molytinae). Unpublished MSc thesis, Victoria University, Wellington, New Zealand.

Chown, S. L.; Smith, V. R. 1993: Climate change and the short-term impact of feral house mice at the sub-Antarctic Prince Edward Islands. *Oecologia 96*: 508–516.

Copson, G. R. 1986: The diet of the introduced rodents *Mus musculus* L. and *Rattus rattus* L. on Subantarctic Macquarie Island. *Australian Wildlife Research 13*: 441–445.

Commonwealth Scientific and Industrial Research Organisation. 1991: The insects of Australia. Volumes 1 & 2. Second edition. Victoria, Australia, Melbourne University Press.

Dugdale, J. S. 1996: Natural history and identification of litter-feeding lepidoptera larvae (Insecta) in beech forest, Orongorongo Valley, New Zealand, with especial reference to the diet of mice (*Mus musculus*). *Journal of the Royal Society of New Zealand 26*: 251–274.

Fitzgerald, B. M.; Daniel, M. J.; Fitzgerald, A. E.; Karl, B. J.; Meads, M. J.; Notman, P. R. 1996: Factors affecting the numbers of house mice (*Mus musculus*) in hard beech (*Nothofagus truncata*) forest. *Journal of the Royal Society of New Zealand 26*: 237–249.

Gleeson, J. P.; van Rensburg, P. J. J. 1982: Feeding ecology of the house mouse (*Mus musculus*) on Marion Island. *South African Journal of Antarctic Research 12*: 34–39.

Guthrie-Smith, H. 1953: Tutira; The story of a New Zealand sheep station. Third edition. Edinburgh and London. W. Blackwood & Sons. Pp. xxxi + 444.

Hansson, L. 1970: Methods of morphological diet microanalysis in rodents. *Oikos 21*: 255–266.

Harraway, J. 1995: Regression Methods Applied. Dunedin, New Zealand. University of Otago Press. Pp. 148–173.

Hunter, G. G.; Blaschke, P. M. 1986: The New Zealand Land Resource Inventory Vegetation Cover Classification. *Water and Soil Miscellaneous Publication No. 101*. Wellington, New Zealand. National Water and Soil Conservation Authority.

Jewell, P. A.; Fullagar, P. J. 1966: Body measurements of small mammals: sources of error and anatomical changes. *Journal of Zoology, London 150*: 501–509.

King, C. M.; Innes, J. G.; Flux, M.; Kimberley, M. O. 1996: Population biology of small mammals in Pureora Forest Park: 2. The feral house mouse (*Mus musculus*). *New Zealand Journal of Ecology 20*: 253–269.

Lambrechtsen, N. C. 1975: What grass is that ? A guide to the identification of some introduced grasses in New Zealand. Second Edition. Information Series No 87. New Zealand Department of Vegetative Characters. Scientific & Industrial Research.

Laurie, E. M. O. 1946: The reproduction of the house mouse (*Mus musculus*) living in different environments. *Proceedings of the Royal Society of London 13*: 248–281.

Miller, A. P. 1999: Ecological energetics of feral house mice (*Mus musculus*) inhabiting coastal sand dunes. Unpublished MSc thesis, University of Otago, Dunedin, New Zealand.

Murphy, E. C.; Pickard, C. R. 1990: House mouse. *In*: King, C. M. *ed*. The handbook of New Zealand mammals. Auckland, Oxford University Press. Pp. 225–245.

Mutze, G. J.; Green, B.; Newgrain, K. 1991: Water flux and energy use in wild house mice (*Mus domesticus*) and the impact of seasonal aridity on breeding and population levels. *Oecologia 88*: 529–538.

Myrcha, A.; Ryszkowski, L.; Walkowa, W. 1969: Bioenergetics of pregnancy and lactation in white mouse. *Acta Theriologica 15*: 161–166.

Newman, D. G. 1994: Effects of a mouse, *Mus musculus*, eradication programme and habitat change on lizard populations of Mana Island, New Zealand, with special reference to McGregor's skink, *Cyclodina macgregori*. *New Zealand Journal of Zoology 21*: 443–456.

Patrick, B. H. 1994: Lepidoptera of Kaitorete Spit, Canterbury. *New Zealand Entomologist 17*: 52–63.

Patrick, B. H.; Green, K. J. 1991: Notes on *Agrotis innominata* Hudson (Lepidoptera: Noctuidae). *New Zealand Entomologist 14*: 32–36.

Pickard, C. R. 1984: The population ecology of the house mouse (*Mus musculus*) on Mana Island. Unpublished MSc thesis, Victoria University, Wellington, New Zealand.

Ramsey, G. W. 1978: A review of the effect of rodents on the New Zealand invertebrate fauna. *In*: Dingwall, P. R.; Atkinson, I. A. E.; Hay, C. *ed*. The ecology and control of rodents in New Zealand nature reserves. *Department of Lands & Survey Information Series No 4*. Pp. 89–95.

SAS Institute Inc. 1989: SAS/STAT User Guide. Version 6. Fourth Edition. North Carolina, Cary.

Taylor, R.; Smith, I. 1997: The state of our land. *In*: Ministry for the environment. The state of New Zealand's environment. Wellington, New Zealand. G. P. Publications.

Watts, C. H. S.; Braithwaite, R. W. 1978: The diet of *Rattus lutreolus* and five other rodents in Southern Victoria. *Australian Wildlife Research 5*: 47–57.

Whitaker, J. O. 1966: Food of *Mus musculus*, *Peromyscus maniculatus bairdi* and *Peromyscus leucopus* in Vigo County, Indiana. *Journal of Mammalogy 47*: 473–486.

Wodzicki, K. A. 1963: Introduced mammals in New Zealand forests. *Acta Biologica Cracoviensia – Series Zoologia 6*: 111–134.