

# Spatio-temporal patterns of introduced mice and invertebrates on Antipodes Island

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Received: 21 November 2011 / Revised: 10 February 2012 / Accepted: 13 February 2012 / Published online: 1 March 2012  
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**Abstract** House mice (*Mus musculus*) are a widespread introduced species with major but often overlooked impacts on ecosystems, proportionally greater when they are the only introduced mammal present. Studies conducted on the ecology of mice on Antipodes Island, where they are the only introduced mammal, are presented and compared to previous work over the past four decades. Mice live-trapped on grids were more abundant in dense coastal tussock (147 mice/ha) compared to inland plateau grasslands (59 mice/ha), with a significant effect of age, but not sex, on both capture probability and range size. Body-size of mice has not changed over four decades, providing no evidence of gigantism, which on other Southern Ocean islands has been speculated to increase the predation risk to birds. Over 2,405 invertebrates from fourteen Orders were identified from pitfall traps and litter samples across five sites. Differences in invertebrate communities and taxonomic units attributable to habitat and altitude were detected among sites in both pitfall and litter samples on Antipodes Island. Differences in invertebrate communities were detected from litter samples on a neighbouring mouse-free island, with significantly greater abundance of large Amphipods and Collembola, but fewer Spiders. These data on introduced mouse ecology and invertebrate distribution on Antipodes Island contribute to the body of knowledge on Southern Ocean islands.

**Keywords** Body-size · Density · House mouse · Invertebrates · Southern Ocean · Spatially explicit capture–recapture

## Introduction

House mice (*Mus musculus* and synonyms) are the most widespread introduced vertebrate in the world (Boursot et al. 1990), having dispersed commensally with humans for thousands of years (Auffray et al. 1990). On islands, introduced mice are one of a group of introduced mammal species which can have important negative effects on native biodiversity (Courchamp et al. 2003). Commonly, introduced mice on islands coexist with other introduced mammals such as cats (e.g. neighbouring Auckland Island; Harper 2010), but they can also be the sole mammal, either through historical accident or following the eradication of other introduced mammals (MacKay et al. 2007). On Southern Ocean islands in particular, mice have had a major impact on insular communities. Widespread impacts on invertebrate communities have been documented (Angel et al. 2009; St Clair 2011). More recently, their potential to impact avian communities has been demonstrated, particularly on Gough Island (Cuthbert and Hilton 2004; Wanless et al. 2007) and possibly Marion Island (Jones and Ryan 2010). Given these impacts, eradication of mice is a sensible conservation goal; however, mouse eradication can be challenging (MacKay et al. 2007), including potential issues with bait-uptake (Wanless et al. 2008; Cuthbert et al. 2011) and non-target poisoning (Wanless et al. 2009).

Mice were first reported in the castaway depot on the main Antipodes Island in the early twentieth century (Chilton 1909, p 600). The introduced species of mice on Antipodes Island have been shown to have a unique haplotype not found elsewhere in New Zealand, with affinities to Spain (Searle et al. 2009). This genetic evidence suggests mice did not arrive during castaway depot annual provisioning from mainland New Zealand as previously believed, but more

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likely with a foreign shipwreck such as the Spirit of the Dawn or President Felix Faure (Taylor 2006; personal communication 2011). Mice are now widespread across the entire island, but remain absent from the northern pair of Bollons and Archway Islands and presumably other offshore stacks. Mice could potentially be eradicated from Antipodes Island, but challenges include the isolation of the island, elevated failure risk with mouse eradications, and non-target impacts from primary or secondary poisoning on two species of island endemic parakeets (*Cyanoramphus unicolor* and *C. hochstetteri*), subantarctic skuas (*Catharacta lonnbergi*) and gulls (*Larus dominicus*).

The Antipodes Islands are isolated and only visited occasionally by scientists, where the visits are of a short duration and are strictly regulated. Previous unpublished research has been undertaken on the mice of Antipodes Island. During the University of Canterbury February–March 1969 expedition Rowley Taylor trapped and made observations on mice, noting in particular their association with *Carex* spp. seeding (Taylor 1969; Warham and Jones 1975; hereafter ‘Taylor’). During the Bountys, Antipodes And Snares (BAAS) expedition of November 1978 Phil Moors intensively studied the mice using live-capture grids (Moors unpubl.; hereafter ‘Moors’), and during the Department of Conservation Taiko search expedition November 1995, Angus McIntosh and John Marris studied the impact of mice on the invertebrate fauna on Antipodes Island and compared it to the mouse-free northern pair of Bollons and Archway Islands (Marris 2000; McIntosh 2001; hereafter ‘McIntosh’). The objective of this study was to repeat the methods of Taylor, Moors and McIntosh to provide a spatio-temporal comparison of mouse and invertebrate community relative abundance and mouse morphology from a rarely visited Southern Ocean island. An important purpose of this time series analysis was to test for an increase in rodent body-size, as has occurred on other Southern Ocean islands recently, and for any ongoing change in invertebrate communities. I also conduct the first reliable density estimates of mice on Antipodes Island.

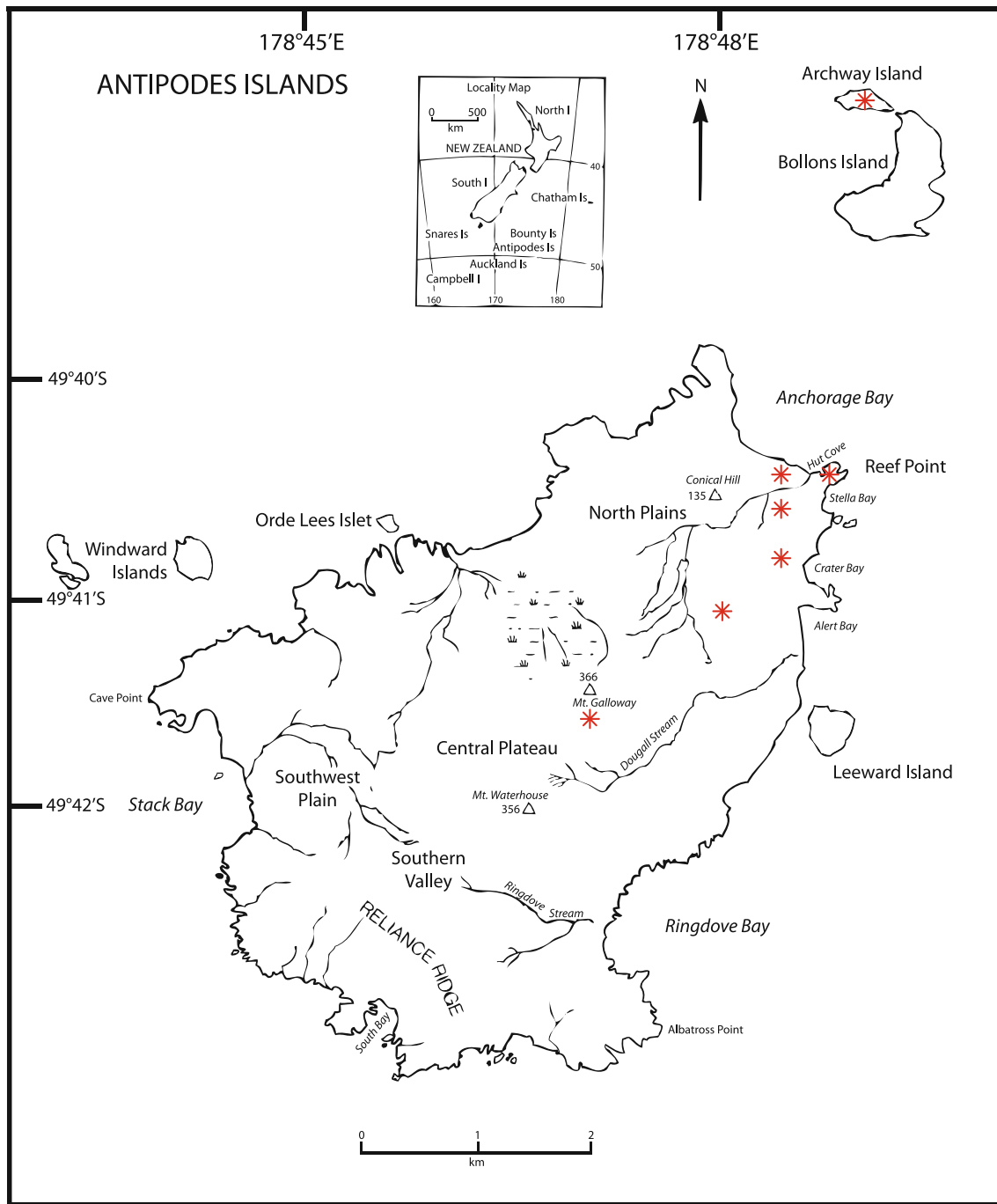
## Materials and methods

The Antipodes Islands group (2,097 ha; 49°41’S; 178°48’E) lie 872 km south-east of Bluff, New Zealand. The climate is characterised by strong south-westerly winds with frequent cloud, fog and rain, and cool temperatures (2–13°C) with little variation (Taylor 2006). The island group is an important and diverse breeding site for seabirds and two species of native parakeets (Warham and Bell 1979). Vegetation on the main Antipodes Island (2,025 ha) is entirely composed of tussock grassland (*Poa* and *Carex* spp.) interspersed with some shrubs (*Coprosma*

spp.) and ferns (see Godley 1989 for a complete description). On the main island, six sites of differing vegetation and altitude were re-surveyed in January and February 2011, corresponding to previous locations selected by Taylor, Moors and McIntosh (Fig. 1). Sites were relocated to within 100 m from written descriptions and photographs. At these sites, vegetation is most dense (2 m height) around low-lying coastal areas such as Reef Point, Anchorage Bay and Hut Creek, in contrast to smaller, widely spaced, cushion plants (0.5 m height) in the inland elevated plateau areas such as North Plains and Mt Galloway. These vegetation communities have remained unchanged over the duration of studies reported here. In addition, a brief comparative visit (1 h), allowing only litter sampling, was made to the mouse-free northern pair of Bollons and Archway Islands before departure in February, which are similarly characterised by dense low-lying coastal tussock grassland (*Poa* and *Carex* spp.). The terrestrial arthropod fauna exhibits substantial endemism with general affinities to other Southern Ocean islands of New Zealand, and is likely to have been impacted in both abundance and composition by mice (Marris 2000).

Mouse population density was estimated using capture–recapture on a 7 × 7 grid of 49 Longworth live-traps at 10-m spacing for 7 nights at two intensively trapped sites (Reef Point and North Plains plateau). Traps were checked every morning, and at Reef Point all mice caught were ear-tagged for short-term individual identification. On the final night of trapping, all mice captured were euthanized for autopsy. As part of a simultaneous bait-marker study, all mice on the North Plains plateau grid were euthanized on first capture. During autopsy, all mice were weighed to the nearest 0.5 g (50 g Pesola Scale) and measured for body and total length to the nearest 1 mm (30 cm ruler). With additional autopsy data from Anchorage Bay (see later), data were used to compare body-size, sex and adult/juvenile ratios with 1978 autopsy summaries at three sites from Moors (Reef Point, Anchorage Bay and North Plains plateau) and 1969 data at one site from Taylor (Reef Point). Differences in body-size metrics (weight, head–body length and total length) were individually tested with analyses of variance for the model including fixed effects for site (Reef Point, North Plains and Anchorage Bay) and sex, a random effect for year of study (1969, 1978 or 2011), and a study–site interaction. Only adults were used in this analysis to prevent confounding from different adult/juvenile ratios among seasons.

Density,  $D$ , was estimated using maximum-likelihood spatially explicit capture–recapture (ML SECR) implemented in program *R* and package SECR (Borchers and Efford 2008). I assume a Poisson distribution of range centres (i.e. random) with a half-normal curve detection function parameterised by  $g_0$  (the probability of detection



**Fig. 1** Antipodes Islands (New Zealand inset). Asterisks are sampling sites

when trap and range centre coincide) and  $\sigma$  (the spatial scale of the detection function). Removals in the population (i.e. accidental deaths during trapping) are assigned known capture histories of 0 with probability equals 1 following death. A conditional likelihood is used to derive density, incorporating individual covariates of age and sex, and models are compared using an AIC framework. The ‘capture function’, which in many ways is related to an animal’s actual home-range (Borchers and Efford 2008), is

approximated by the 95% circular probability density area of capture as

$$A = \pi(2.45\sigma)^2$$

As part of a bait-marker study, all mice on the North Plains plateau grid were euthanized on first capture; however, I analyse both grids simultaneously and allow density,  $D$ , and probability of capture,  $g_0$ , to vary between grids as a function of site but necessarily assume mice have

a constant range size (i.e.  $\sigma$  is estimated from only the Reef Point grid). Other rodent studies using spatially explicit capture–recapture methods have shown that although  $D$  and  $g_0$  will differ among sites,  $\sigma$  remains remarkably constant (e.g. Russell et al. 2011). I assume a trapping buffer around the grid extending 40 m.

Relative abundances of mice and invertebrates were investigated by trapping mice and sampling the invertebrate community at five sites (Reef Point, Anchorage Bay, Hut Creek, North Plains crater and Mt Galloway) to repeat the studies of McIntosh. Mice were trapped on a  $3 \times 4$  grid of 12 Longworth live-traps at 5-m spacing for 3 nights (36 trap nights). Corrected captures (removing half a night per sprung trap) per 100 trap nights were then calculated. Additional trapping at some sites then took place for further samples. Surface invertebrates most at risk from mice were sampled at each site with ten pitfall traps (80 mm diameter and 90 mm depth) located greater than 10 m apart buried with their rim flush with the surface and covered with a green plastic lid and filled to approximately 2 cm depth with a 50/50 mix of glycol and water, with a drop of detergent added. After 10 days, the contents were removed and identified to taxonomic unit (Class or Order). Litter was collected from eight randomly placed  $30 \times 30$  cm quadrats at each site. The quadrat was placed over the nearest accumulation of litter, and all dead plant material down to the soil was removed from inside it. Litter was sieved (10 mm) to remove coarse material and then sorted on a white tray. All macroinvertebrates (>1 mm in length) detected were removed and identified to taxonomic unit (Class or Order). As a measure of effort, approximately 15–30 min was spent sorting each litter sample. Multivariate (using Pillai's trace) and univariate analyses of variance were used to test for invertebrate community and taxonomic unit differences, respectively, among sites on Antipodes Island and between Antipodes and Archway Islands. Count data for number of individuals were  $\log_{10} + 1$  transformed to remove right skew, and for multivariate analysis data were then standardised by subtracting means and dividing by standard deviations. Only taxonomic units with sufficient data were used for univariate comparisons.

## Results

A total of 195 mice were trapped at six sites on the island, 120 of these on the two intensive live-capture trapping grids at Reef Point and North Plains plateau (Table 1). A total of 122 adult mice of both sexes from Reef Point, North Plains crater and plateau, and Anchorage Bay were autopsied for morphological analysis. Representative specimens are lodged at the National Museum of New Zealand (LM2439 and LM2478).

### Introduced mice

Although Moors classified mice by age-classes based on tooth-wear, I use a less labour-intensive clear bimodal body length division at 72 mm between adults and juveniles to distinguish maturity, falling at approximately the same age-class division used by Moors. Morphological summaries are given only for adult mice to prevent confounding from differing adult/juvenile ratios among seasons (Table 2). Sex was the only factor that significantly influenced total length ( $F_{1,295} = 10.3$ ,  $P < 0.01$ ) and weight ( $F_{1,347} = 11.7$ ,  $P < 0.01$ ) of mice (Fig. 2). From autopsy data at Reef Point and North Plains, where mice were exhaustively trapped to exclude the effects of trap dominance by age, juveniles made up 32 and 16% of the population, respectively, compared to 2 and 0% by Moors.

Spatially explicit capture–recapture models were constructed, including age and sex as covariates on  $g_0$  and  $\sigma$ , and allowing  $g_0$  to vary with site. The model where  $g_0$  and  $\sigma$  varied with age only had greatest weight (47%) followed by the same model including a site effect on  $g_0$  (27%). Results are presented for the strongest supported model where age was the only covariate. Density was estimated separately for adults and juveniles at each site (Table 3). Adult mice had significantly larger ranges as estimated from  $\sigma$ , but significantly lower  $g_0$  (Table 4).

The relative trapping rate of mice in February 2011 (first 36 trap nights at all five relative trapping sites) was half that of November 1995. At Reef Point, two mice released at the end of mark–recapture were caught three nights later in the relative abundance line, at distances of 45 and 70 m.

**Table 1** Trapping data for mice on Antipodes Island

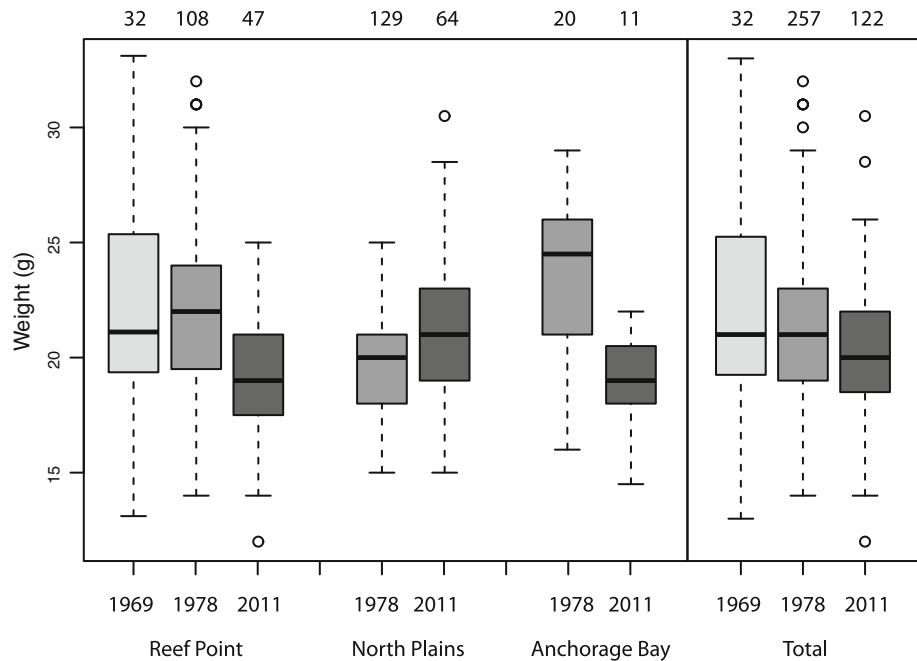
Site	Grid	Trap nights	Adults	Juveniles	Autopsy
Anchorage Bay	Relative	60	11	10	21
Reef Pt	Relative	48	9	0	9
Reef Pt	Recapture	343	56	24	60
Hut Creek	Relative	36	4	0	4
North Plains–Crater	Relative	170	27	9	36
North Plains–Plateau	Recapture	343	37	3	40
Mt Galloway	Relative	36	5	0	5

**Table 2** Mean (range) weight, body and total length of adult male and female mice on Antipodes Island in 1969 (Taylor), 1978 (Moors) and 2011 (this study)

Year	Sex	<i>n</i>	Weight (g)	<i>n</i>	Body (mm)	<i>n</i>	Total (mm)	<i>n</i>
1969	M	14	21.6 (17.5–27)	14	84.3 (79.0–91.0)	14	170.7 (159.0–181.0)	12
	F	18	22.7 (13.0–33.0)	18	85.9 (73.0–97.0)	18	171.3 (155.0–180.0)	15
1978	M	126	22.0 (14.0–31.0)	125	83.9 (73.0–96.0)	108	172.1 (149.0–186.0)	85
	F	131	20.2 (14.0–32.0)	128	82.0 (73.0–95.0)	95	167.8 (148.0–194.0)	72
2011	M	68	20.7 (12.0–28.5)	68	85.4 (74.0–96.0)	68	171.6 (154.0–195.0)	65
	F	54	19.7 (14.5–30.5)	54	85.3 (76.0–100.0)	54	169.8 (158.0–191.0)	53

Data are pooled across sites

**Fig. 2** Weights of adult mice (body length >72 mm) at three sites and overall on Antipodes Island in 1969 (Taylor), 1978 (Moors) and 2011 (this study). Bar lengths correspond to 75th and 25th percentiles, dark lines within bars medians, and whiskers 1.5 times the interquartile range. Sample sizes are above



**Invertebrate communities**

On the main Antipodes Island, 1,574 invertebrates were identified from 47 pitfall traps and 831 invertebrates were identified from 40 litter samples (Table 5). One pitfall trap was lost to parakeet disturbance and two to surface flooding. Species from fourteen taxonomic units were identified (Amphipoda, Araneae, Chilopoda, Coleoptera, Collembola, Diptera, Gastropoda, Hemiptera, Hymenoptera, Isopoda, Lepidoptera, Oligochaeta, Pseudoscorpionida and Siphonaptera) but were only abundant (>50 individuals in either all pitfall or litter samples) for seven (Araneae, Coleoptera, Diptera, Gastropoda, Isopoda, Oligochaeta and

Pseudoscorpionida) (Fig. 3). Representative specimens are lodged at the Auckland War Memorial Museum.

There was no evidence against the assumption of homogeneity of variances in total number of individuals per pitfall trap among sites ( $F_{4,42} = 0.32, P = 0.86$ ). There was evidence in pitfall traps of invertebrate community structuring among sites ( $Pseudo-F_{48,136} = 2.31, P < 0.01$ ), and for the five most common taxonomic units (Araneae, Coleoptera, Diptera, Isopoda, and Pseudoscorpionida), evidence for differences in abundance among sites was found for Araneae ( $F_{4,42} = 3.83, P < 0.01$ ), Diptera ( $F_{4,42} = 3.63, P = 0.01$ ), Isopoda ( $F_{4,42} = 9.48, P < 0.01$ ) and Pseudoscorpionida ( $F_{4,42} = 11.13, P < 0.01$ ).

**Table 3** Estimates of adult, juvenile and total mouse density at each site

	Mean	SE	LCL	UCL	ESA
Reef Point					
Adult	83	17.37	56	125	0.68
Juvenile	64	18.28	37	111	0.38
Total	147	25.21	105	205	0.55
North Plains					
Adult	55	12.72	36	86	0.68
Juvenile	5	2.66	2	14	0.68
Total	60	13.37	39	92	0.68

SE standard error, LCL and UCL lower and upper 95% confidence limits, respectively, ESA effective sampling area (hectares)

**Table 4** Estimates of adult and juvenile  $g_0$  and  $\sigma$ 

	Mean	SE	LCL	UCL	HR
$g_0$					
Adult	0.03	0.01	0.02	0.06	–
Juvenile	0.21	0.05	0.13	0.31	–
$\sigma$					
Adult	13.16	2.22	9.48	18.26	0.33
Juvenile	3.75	0.63	2.70	5.20	0.03

SE standard error, LCL and UCL lower and upper 95% confidence limits, respectively, HR 95% home-range probability density (hectares)

No difference in abundance was found among sites for Coleoptera. There was no evidence against the assumption of homogeneity of variances in total number of individuals per litter sample among sites ( $F_{4,35} = 1.06$ ,  $P = 0.39$ ). There was evidence in litter samples of invertebrate community structuring among sites ( $Pseudo-F_{44,112} = 2.34$ ,  $P < 0.01$ ), and for the five most common taxonomic units (Araneae, Coleoptera, Gastropoda, Isopoda and Oligochaeta), evidence for differences in abundance among sites was found for Coleoptera ( $F_{4,35} = 4.19$ ,  $P < 0.01$ ), Isopoda ( $F_{4,35} = 3.39$ ,  $P = 0.02$ ) and Oligochaeta ( $F_{4,35} = 6.83$ ,  $P < 0.01$ ). No difference in abundance was found among sites for Araneae or Gastropoda.

Over 175 invertebrates were identified from 8 litter samples on Archway Island (Table 5). The largest biomass comprised medium-sized amphipods (3 mm), of which not all could be counted due to decomposition during storage prior to sorting, so a minimum number present estimate up to ten was made (otherwise recorded as 10+). Litter samples from Archway Island were compared with those from Reef Point where coastal tussock habitat was similar. There was weak evidence of differences in invertebrate communities between the main Antipodes Island and Archway Island ( $Pseudo-F_{11,4} = 5.96$ ,  $P = 0.05$ ), but with

evidence for differences in abundance in Amphipoda ( $F_{1,14} = 82.74$ ,  $P < 0.01$ ) and Collembola ( $P < 0.05$ ) which were significantly more abundant, and Araneae which were significantly less abundant ( $F_{1,14} = 12.73$ ,  $P < 0.01$ ), on mouse-free Archway Island. Two beetle species not found on the main Antipodes Island were also detected (*Loxomerus brevis* and *Oopterus clivinoides*), although this was not reflected in overall Coleoptera abundance.

## Discussion

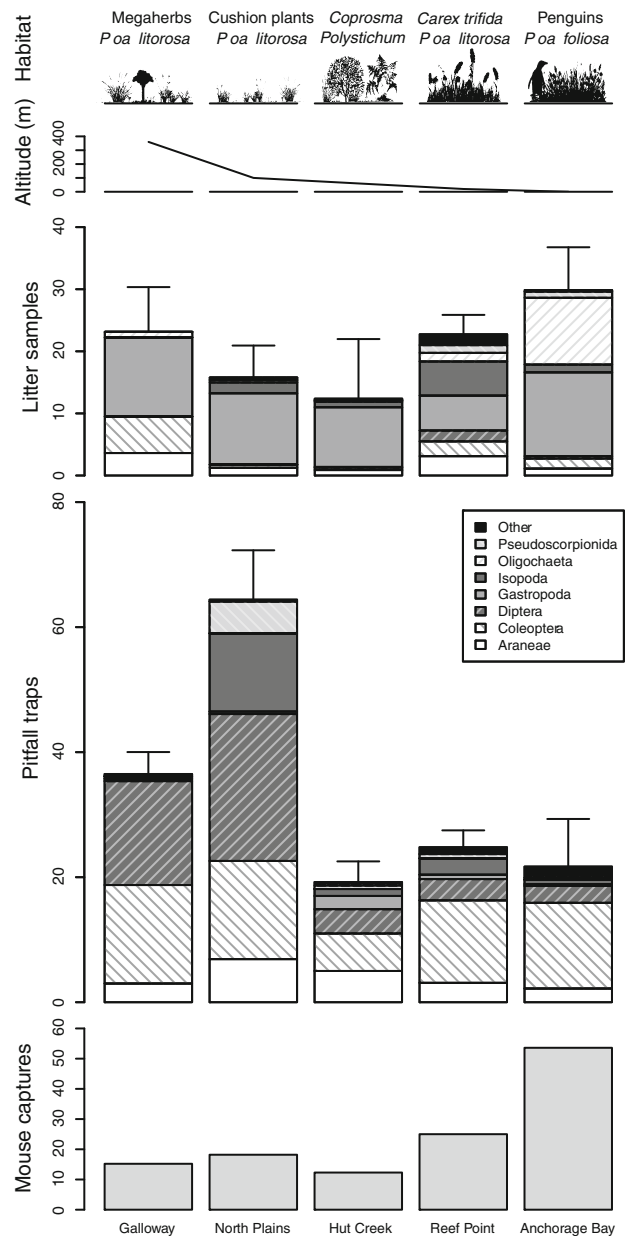
Introduced mice have been extensively studied on other Southern Ocean islands (Angel et al. 2009 and references therein; Berry et al. 1978b and related work), providing comparative data over a similar timeframe as the past four decades presented here. Comparisons between invaded and uninvaded islands within the same archipelago are particularly powerful for identifying the impacts of introduced mice (Angel et al. 2009). House mice have remained abundant across the entire main Antipodes Island over the past four decades (Taylor 1969), at high densities similar to Marion Island (Matthewson et al. 1994; Ferreira et al. 2006). Total density and the proportion of juveniles in the population were both highest in the dense coastal vegetation, putatively a result of the seeding *Carex* spp. and *Poa* spp. which drive mouse reproduction over summer (Taylor 1969). On neighbouring Auckland Island, mice are also most abundant in dense tussock (Harper 2010). Whereas I found many juveniles, Moors found almost no juveniles during his sampling in November, but many females were pregnant (Murphy and Pickard 1990), indicative of a clear seasonal irruption of mice over summer, as found on other Southern Ocean islands. McIntosh found increased trapping rates of mice in late spring than I found in late summer. Antipodes Island mice were in the upper range for body weight (excluding reports of exceptional gigantism) but lower range for body-size compared to mice from islands in other extreme latitudes of both hemispheres (Berry and Peters 1975). There was no obvious pattern in morphology across time or sites, in contrast to some other studies of mice introduced to islands (Berry et al. 1978a; Pergams and Ashley 2001). Mice on Antipodes Island had very similar body-size to those on neighbouring Auckland Island, where they coexist with introduced cats (Harper 2010).

Within the main Antipodes Island, the impact of mice is likely widespread and consistent across sites, concurrent with their distribution across the entire island. Differences in invertebrate communities and taxonomic units among sites were generally attributable to habitat and altitude. Compared to McIntosh who sampled in late spring, in late

**Table 5** Invertebrates counts from pitfall traps and litter samples

Site	Trap	n	Total																																						
			Order													Individuals																									
			Amphipoda			Araneae			Chilopoda			Coleoptera			Diptera			Gastropoda			Hemiptera			Hymenoptera			Isopoda			Lepidoptera			Oligochaeta			Pseudoscorpionida			Siphonaptera		
Anchorage Bay	Pitfall	10	1	1	22	1	1	137	27	3	3	15	0	0	7	0	0	0	0	0	0	3	1	217	10																
Reef Pt	Pitfall	10	0	2	31	2	132	34	7	7	2	0	0	26	0	0	0	0	0	0	7	7	248	9																	
Hut Creek	Pitfall	9	0	45	1	54	35	19	1	1	1	0	0	10	0	0	0	0	0	0	5	3	173	9																	
North Plains	Pitfall	10	0	69	1	157	235	4	4	1	1	0	0	125	1	0	0	0	0	0	51	0	644	9																	
Mt Galloway	Pitfall	8	0	24	0	126	133	3	3	0	0	1	1	3	1	0	0	0	0	0	0	1	292	8																	
Anchorage Bay	Litter	8	0	9	1	13	3	108	3	108	1	0	0	10	0	0	86	8	0	0	8	0	239	9																	
Reef Pt	Litter	8	1	25	1	19	14	45	14	45	9	0	0	44	3	11	10	10	0	0	10	0	182	11																	
Hut Creek	Litter	8	0	7	3	3	1	77	1	77	0	0	0	7	0	2	0	0	0	0	0	0	99	7																	
North Plains	Litter	8	0	10	4	4	0	92	0	92	0	0	0	14	0	3	3	3	0	0	3	0	126	6																	
Mt Galloway	Litter	8	0	29	47	47	0	102	0	102	0	0	0	0	0	7	7	0	0	0	0	0	185	4																	
Archway I.	Litter	8	68+	1	9	9	0	26	0	26	0	0	52	0	17	2	2	0	0	0	0	0	175	6																	

Collembola were separately identified and are not included



**Fig. 3** Relative abundances of mice and mean number of macroinvertebrates per trap/sample, at five locations on Antipodes Island (following McIntosh 2001). Mouse abundance is corrected captures per 100 trap nights. The error bars indicate 1 SE for the mean number of total macroinvertebrates per trap/sample

summer I found more invertebrates in pitfall traps and twice as many in litter samples, although the latter is possibly related to search effort. I found similar relative numbers of Araneae and Coleoptera to McIntosh in each method, but not the same habitat trends, although like McIntosh I found the highest number of Coleoptera in litter samples at Mt Galloway. I found no larvae of Lepidoptera and Diptera, but instead many adult Diptera. McIntosh did not include Gastropoda in his results, but they were also highly represented as found here (A. McIntosh unpubl.

data). At extreme latitudes, invertebrates are the most consistent and dominant component of mouse diets (Angel et al. 2009; St Clair 2011). Although the invertebrate community in coastal tussock grassland was very similar between Antipodes Island and Archway Island, I found significantly increased abundance of large macroinvertebrates, such as Amphipoda and Collembola, on mouse-free Archway Island, as previously reported (Marris 2000). Although I did not record them, Orthoptera (an undescribed weta species) are also exclusively reported from Bollons Island but not the main Antipodes Island (Marris 2000). Indirect effects of mice on invertebrates may also occur (Marris 2000; Towns et al. 2009), such as Araneae which were more abundant in litter samples on Antipodes Island. More complex trends at the species level for invertebrates are likely, for example like McIntosh and Marris (2000) I also found unique Coleoptera species on Archway Island. Such differences in species composition may be indicative of mouse impacts not otherwise reflected in abundance differences, but were not specifically investigated further.

Both pitfall trapping and litter sampling tended to detect differences in the same taxonomic units, but within taxonomic units, the site-specific pattern of those differences varied between methods. Although litter sampling detected community-level differences, as a coarse method, real differences due to season or long-term trends can be masked by ephemeral effects such as weather, operator or clustering in invertebrate distribution. In future invertebrate sampling methods should be paired and systematically located to determine within site variation. Pitfall sampling alone may be suitable as an invertebrate monitoring tool on Antipodes Island given its relative simplicity.

Range size of adult mice on Antipodes Island was very similar to other islands, with similar occasional large movements (Lidicker 1966; Berry 1968; Cuthbert et al. 2011; Russell et al. 2011). Monitoring lines for mice should be separated by at least 200 m to remain independent (Harper 2010). In contrast, juvenile mice had concerning small home ranges. Any eradication operation should target mice during winter, when reproduction rates and hence the presence of juveniles are low to zero. For additional confidence, studies on mouse biology could be repeated in winter (e.g. Harper 2010) and include studies of bait consumption by mice and non-target species.

**Acknowledgments** The author thanks Phil Moors and Rowley Taylor for providing unpublished data and discussion; Angus McIntosh and John Marris for discussion; Pete McClelland and Gilly Adam of DOC for logistical support; Henk Haazen and the crew of Tiama for transport; and Paul Sagar and David Thompson of NIWA for support, and the seabird (Erica Sommer, Dave Boyle and Mark Fraser) and geology (James Scott, Ian Turnbull) teams on the island for their assistance. Many thanks to Stephen Thorpe for taxonomic identification, sorting and photography of invertebrate samples. This research was conducted under DOC entry (SO-29716-LND 1011/35)

and research (SO-29140-FAU 1011/20) permits, and University of Auckland Animal Ethics Committee approval (R845), and thanks to Pete McClelland, Keith Broome and a number of anonymous reviewers for critical comments on earlier versions of the manuscript.

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