Density, body size, and reproduction of feral house mice on Gough Island

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Received 2 May 1991; accepted 9 September 1991

Feral house mice *Mus musculus* have occurred on Gough Island, South Atlantic Ocean, for about 180 years. The population was sampled during the austral spring of 1990. Estimated density on a live-trapping grid in dense cover (woody plants, ferns, grass) near the coast was 224 mice/ha. Snap-trapping at high altitude, in open moorland and bog, indicated lower densities in exposed habitats. In overall size the mice were larger than *Mus musculus* from other localities, and larger than specimens collected on Gough Island during 1955–56. At the time of sampling 43% of adult females were pregnant or lactating and juveniles made up 14% of the trapped sample. The mean number of 9,2 foetuses per pregnant female suggests that litter size may be larger than those recorded in other feral mouse populations. Mice collected from high altitudes were smaller, and there were no juveniles in the sample. The inference is that breeding commences later at the cooler, high elevations.

Die huismuisbevolking *(Mus musculus)* op Gougheiland, in die Suid-Atlantiese Oseaan, is ongeveer 180 jaar gelede gevestig. 'n Bevolkingstudie van die muise is tydens die suidelike lente van 1990 onderneem. 'n Geskatte bevolkingsdigtheid van 224 muise/ha is verkry met vangste in vanghokke op 'n ruitpatroon in digte kus plantegroei (varings, grasse en houtagtige kruide). Vangste met valletjies in die oop grasveld en moerasplantegroei van hoogliggende gebiede het gedui op laer bevolkingsdigthede in hierdie blootgestelde habitatte. Die liggamsgrootte van die muise was groter as dié van *Mus musculus* van ander lokaliteite, en groter as die van eksemplare wat tydens 1955–1956 op Gougheiland versamel is. Voortplanting het voor die aanvang van hierdie studie begin: 43% van die volwasse wyfies was swanger of lakterend, en aan die kus het onvolwasse muise 14% van die vangste uitgemaak. Gemiddeld 9,2 fetusse per dragtige wyfie is aangeteken, wat daarop dui dat die werpselgrootte groter mag wees as in ander wilde huismuisbevolkings. Muise wat in hoogliggende gebiede versamel is, was kleiner, en daar was geen onvolwassenes in die steekproef nie. Die afleiding is dat voortplanting later geskied in die kouer, hoër gebiede.

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Feral house mice *Mus musculus* were first reported from Gough Island by a sealer, George Comer, in 1888 (Verill 1895). The mice had probably come ashore with the previous party of sealers who remained on the island during 1810–11, and were the first humans known to have lived there (Wace 1961). During 1955–56 scientists recorded mice from sea level to close to the mountain tops (Hill 1959). No ecological studies have previously been done on the mice of Gough Island, although Hill (1959) presented data on body and cranial measurements, and Breytenbach (1986) made preliminary estimates of mouse densities.

We visited Gough Island as invited members of the Thirteenth FitzPatrick Institute Expedition during October 1990, to estimate mouse density, establish population demography, and assess the impact of the alien mice on biota. In this article we report on mouse population density, body size, and reproduction. Impact on the island's biota will be dealt with elsewhere.

Study area

Gough Island (40°17′–40°22′S / 9°52′–10°01′W), a formally proclaimed British wildlife reserve which falls under the Administrator of Tristan da Cunha, is in the temperate zone of the South Atlantic Ocean. The island, with a planar area of 83 km^2, is mountainous, rising steeply from sea level to highlands between 760 and 910 m above sea level, dissected by steep-sided valleys. The climate is oceanic: mean monthly sea surface temperatures are between 10 and 15°C, and mean monthly air temperatures (at sea level) range between 9°C in July and 16°C in February (Bester 1981). Mean annual rainfall is *ca* 3100 mm at sea level, and about 50% higher at elevations above 600 m (Wace 1961). Westerly winds prevail.

The plateaux and valleys are covered with deep peat, whereas mountain ridges have a shallow covering of mineral soil. Wace (1961) recognized five vegetation communities: tussock grassland (*Poa flabellata* and *Spartina arundinacea*) on cliffs and seal wallows; *Phylica arborea* woodland and thickets amongst fern bush (*Histiopterus incisa* and *Blechnum palmiforme)* up to about 300 m; open vegetation of windswept moorland; peat bogs at high altitudes; and wet heath between the windswept moorland and *Phylica*-fern bush communities.

Twenty-two bird species breed on the island (Swales 1965). The only indigenous mammals are the sub-Antarctic fur seal *Arctocephalus tropicalis* and the southern elephant seal *Mirounga leonina*. Invertebrates have not been studied in detail: preliminary investigations indicate few species and low numbers (Holdgate 1965).

The South African government operates a meteorological station on the more sheltered, east coast. The seven people that live at the base station for a year at a time form the only human habitation on the island.

Materials and Methods

Population density of house mice was estimated from mark

and recapture live trapping on a grid set out in *Phylica*-fern bush woodland at South East Point, 30 m above sea level. Fifty folding, aluminium, Sherman live traps (230 × 76 × 90 mm) were set in the configuration 5 × 10, covering an area of 0,49 ha. Mean perpendicular distance between traps was 11,5 m. Traps were baited with a mixture of peanut butter and rolled oats between 17h00 and 18h00 and checked from 07h00 onwards the following morning. On the first two mornings all captured mice were marked by clipping toes on the hind feet only, using the 1,2,4,7 marking system, and released after sex and weight were noted. The third morning was regarded as the recapture session. The number of mice on the grid ± *SE* was calculated using Bailey's modified Petersen Estimate (Caughley 1977).

Museum Special mouse traps, baited with the peanut butter and oats mixture, were used to collect mice from which morphometric data, information on reproductive state, and stomach contents could be obtained, as well as entire specimens which were frozen and brought back to South Africa for the preparation of study skins and skulls at the Durban Natural Science Museum. In addition relative abundance in different parts of the island could be compared by converting trapping success figures to relative catch densities, based on Poisson distribution (Caughley 1977). Snap trapping was done on the grid for two consecutive nights, three days after live trapping had been concluded (Table 1). Trap lines (traps *ca* 10 m apart) were also set for two consecutive nights at other localities in grassland and *Phylica* woodland north and south of the base station, and in open peat bog and moorland vegetation on Tafelkop at 540 m. Smaller numbers of snap traps (10) were set for one and two nights respectively at The Glen in tussock grassland and fern thickets, at sea level, and in open vegetation at Waterfall Camp (675 m) – see Table 1. Five mice were caught in a bucket at Goneydale (425 m) in wet heathland beside a stream.

The following external measurements were taken from undamaged trapped mice: mass to the nearest g; length of head and body, tail, hind foot (with claw), and ear to the nearest mm. Males were recorded as having abdominal or scrotal testes, and testis length was measured to the nearest mm. Females were recorded as imperforate, perforate, lactating, or pregnant. If pregnant the number of foetuses and foetus crown-rump length were recorded. Mean values of measurements are given ± *SD* of the sample.

Results

Density and relative abundance

Trap success (captures as percentage of traps set) for the three nights that live trapping was done, was 70, 90 and 94%. Seventy-one mice were marked. In the recapture session, 30 marked mice and 17 unmarked mice were caught. From these figures the number of mice on the 0,49-ha grid was estimated at 110 (*SE* 11,6) individuals. Estimated mouse density in the *Phylica*-fern bush woodland was therefore 224/ha (*SE* 23,6).

Snap trapping on the grid and at other localities in *Phylica* woodland and tussock grassland yielded similar relative capture densities (Table 1). In the high altitude peat bog and moorland on Tafelkop the relative capture density was about a quarter of those at low altitudes.

External measurements

There were no significant differences between the measurements of males and females, therefore data have

Table 1 Summary of snap trapping of *Mus musculus* on Gough Island. See 'Material and Methods' for additional detail on localities. Trapping success figures are converted to relative density based on Poisson distribution, where f = frequency of capture per trap, $1-f$ = proportion of traps catching no mice, and e^{-x} = estimated relative density of catches per trap, i.e. the number of animals that would have been caught per trap if traps were capable of multiple captures (Caughley 1977)

	Traps set	Trap nights	Captures	Trapping success f	$1-f$	Relative density e^{-x}
Low altitudes						
Grid	49	98	62	0,63	0,37	0,99
South of Base A	41	82	45	0,55	0,45	0,80
South of Base B	20	40	25	0,63	0,37	0,99
North of Base	45	90	56	0,62	0,38	0,97
The Glen	10	10	6	0,60	0,40	0,92
High altitudes						
Tafelkop	47	94	20	0,21	0,79	0,24
Waterfall Camp	10	20	11	0,55	0,45	0,80
Totals						
Low altitudes	165	320	194	0,61	0,39	0,94
High altitudes	57	114	31	0,27	0,73	0,31
Overall	222	434	225	0,52	0,48	0,73

Table 2 External measurements of *Mus musculus* trapped on Gough Island. The term 'adult' refers to perforate females or males with scrotal testes. 'High altitude' refers to localities above 400 m. Mass is expressed in grams and linear measurements of the other parameters in millimetres

Sample	Measurement	Mean	*SD*	*n*	*CV*	Range
Total sample	Mass	31	8,7	158	28	8–52
	Head & body	102	11,1	158	11	65–121
	Tail	95	9,3	157	10	65–110
	Hind foot	19,2	0,8	157	4	17–20
	Ear	14,5	0,8	158	6	12–16
All adults	Mass	34	5,7	136	17	22–52
	Head & body	105	6,6	136	6	88–121
	Tail	98	5,6	135	6	85–110
	Hind foot	19,2	0,7	136	4	17–20
	Ear	14,6	0,6	136	4	13–16
Low altitude adults	Mass	35	5,1	105	15	26–52
	Head & body	107	5,9	105	6	91–121
	Tail	99	5,0	104	5	89–110
	Hind foot	19,1	0,8	105	4	17–20
	Ear	14,6	0,6	105	4	13–16
High altitude adults	Mass	29	4,6	31	16	22–41
	Head & body	101	7,0	31	7	88–116
	Tail	94	5,5	31	6	85–104
	Hind foot	19,4	0,7	31	4	18–20
	Ear	14,7	0,6	31	4	14–16

been combined. In Table 2 data summaries are presented for (i) all mice measured, including immature and juvenile specimens, (ii) adults, i.e. perforate females or males with scrotal testes, (iii) adults from low-altitude localities with dense vegetation, and (iv) adults from high-altitude (above 400 m) localities. The mass of entire pregnant females was included in all calculations. If pregnant females are omitted from the data, the mean mass for each of the four samples is (i) 30 ± 8,3 g, n = 139; (ii) 33 ± 5,1 g, n = 117; (iii) 34 ± 4,4 g, n = 88; (iv) 29 ± 4,6 g, n = 29.

High-altitude adults were significantly smaller in mass (t = 5,07), head and body length (t = 4,74), and tail length (t = 4,78), than were low-altitude adults (p < 0,001), but did not differ significantly in the length of hind foot or ear.

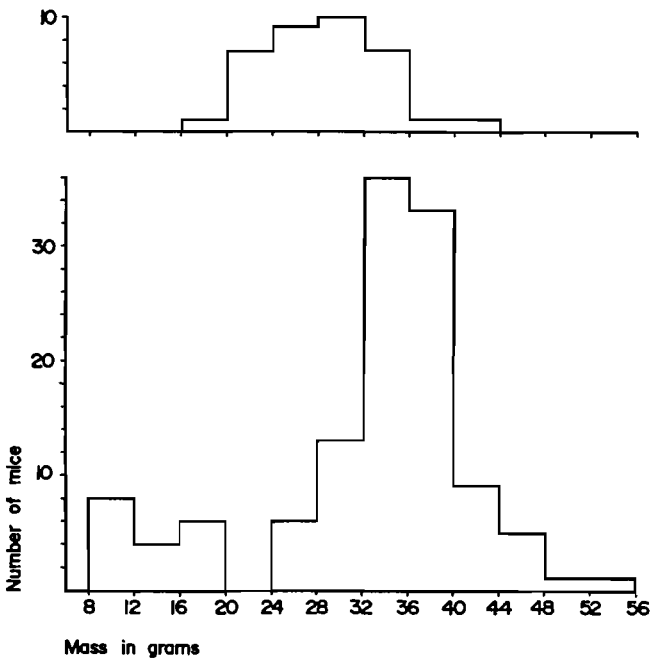

Figure 1 Distribution of mice, by 4-g mass classes, caught at high (upper histogram) and low (lower histogram) altitudes on Gough Island.

Table 3 Reproductive state of *Mus musculus* at low and high altitudes on Gough Island. The figures in parentheses indicate percentages of the samples

	Low altitudes	High altitudes	Total
Males (n)	53	25	78
♂ abdominal testes	8(15)	3(12)	11(14)
$\bar{x}$ testis length (mm)	3,5 ± 0,8	7	4,5 ± 1,8
♂ scrotal testes	45(85)	22(88)	67(86)
$\bar{x}$ testis length (mm)	8,4 ± 1,0	8,3 ± 0,5	8,4 ± 0,9
Females (n)	69	11	80
Imperforate	9(13)	2(18)	11(14)
Perforate	60(87)	9(82)	69(86)
Lactating	16(23)	0(0)	16(20)
Pregnant	17(25)	2(18)	19(24)
$\bar{x}$ n foetuses	9,1 ± 19	10	9,2 ± 1,8

Distribution, by mass classes, of mice from both high and low elevations is shown in Figure 1.

Reproduction

The reproductive state of mice from both low and high altitudes, and in the pooled sample, is presented in Table 3. The mean testis length of adult males from low altitude habitats did not differ significantly from that in the high-altitude sample. Five of the females collected at low altitudes were both pregnant and lactating. All lactating females had five pairs of mammae: three pairs pectoral and two pairs inguinal.

Discussion

Density, relative abundance, and biomass

The high trap success recorded on the grid suggests that insufficient live traps were used, and that the estimate of 224 mice/ha may be too low. Breytenbach (1986) estimated densities of between 80 and 170 mice/ha at four sites on Gough Island, which he too considered to be underestimates. As no assessment lines were set at the grid in our study, the area covered by the traps may not reflect the actual area for which density was estimated.

If the snap trapping relative catch densities are reliable then the indication is that mouse densites are lower in the open habitats at high altitudes than in the dense vegetation at low elevations. Possible reasons for the high densities at low altitude may be the greater availability of refuges and food in the *Phylica*-fern bush. Twelve of the 22 bird species that breed on Gough Island nest in burrows which they excavate. (These burrowing birds are prions and small petrels; Procellariidae.) Very few mouse burrows were located in the *Phylica*-fern bush, but mice were seen using bird burrows, which were numerous. Other shelter was available under roots of *Phylica* trees, fallen branches and logs, and amongst the dense understorey vegetation. Plenty of food is available in the form of lush green plants, seeds, invertebrates, and the carcases of small sea birds killed by sub-Antarctic skuas *Catharacta antarctica*. Examination of stomach contents has shown that the mice feed on all of these items (Crafford & Rowe-Rowe, unpubl.). In the exposed high-altitude habitats there are far fewer refuges, and mice have to excavate many of their own burrows. The substrata are, however, not always suitable: the water table is just below the surface in bogs and soil is shallow and stony on ridges. Food is also apparently less abundant.

The estimated biomass of *Mus musculus* in the *Phylica*-fern bush is 6,9 kg/ha, based on a mean mass of 31 g and an estimated density of 224 mice/ha. If mouse density on Tafelkop is about one quarter of that at low elevations (*cf.* snap-trapping data, Table 1), then the biomass in this exposed habitat is roughly 1,7 kg/ha.

At Marion Island, Rowe-Rowe, Green & Crafford (1989) estimated the daily food consumption of feral *Mus musculus* to be 3,5 g (dry mass), where the mean mass of the mice was 19,5 g and mean air temperature mas 7°C. At Gough Island the mice are larger, and on an energy consumption basis ($mass^{0,75}$), could require 1,4 times as much food as the Marion Island mice (i.e. 4,9 g/day dry mass), at the same ambient temperature. As the temperatures on Gough Island

are higher than on Marion Island, daily food consumption is likely to be lower than the extrapolated 4,9 g.

External measurennents

The house mice measured on Gough Island during this study are larger in respect of all field measurements given by Van den Brink (1967) for Europe, Burt & Grossenheider (1976) for North America, and Berry (1981) for various other localities. They are also significantly greater in respect of the means for mass, head and body, and tail than those in samples from six islands (Berry, Peters & van Aarde 1978): $p < 0{,}001$; 0,001; and 0,02 respectively.

Hill (1959) provided mean and extreme measurements of 90 *Mus musculus* collected on Gough Island during 1955–56, viz. head and body 89 mm (71–108), tail 90 mm (76–108), hind foot 18,8 mm (17–20,4). The means and maximum measurements of the mice collected during our study are greater than those of the earlier collection (Hill 1959), but cannot be compared statistically because standard deviations were not given. The specimens collected on Gough Island during 1955–56, as well as those collected during this study, are larger than specimens from Tristan da Cunha, 380 km from Gough Island (Hill 1959). The Tristan specimens were collected during 1937–38, however, and may no longer be typical of the mice on that island. Cranial measurements of the series of house mice ($n = 30$), collected during this study, and deposited in the Durban Natural Science Museum, are greater than those from the earlier Gough Island and Tristan da Cunha collections (Hill 1959) (P.J. Taylor, pers. comm.).

A suggested possibility for the currently larger mice on Gough Island is that in this isolated population selection may be taking place for large-bodied (= most successful?) individuals, and that even in the space of 35 years since the first collection was made (Hill 1959), the mice have increased in size. Alternatively, the time of year at which we trapped the mice may provide an answer to morphometric differences. Most of the animals were adults and probably cohorts that had survived the previous winter (only 18 were obviously young of the current breeding season). Since environmental conditions on Gough Island are mild when compared with those on sub-Antarctic and sub-Arctic islands, a greater proportion of mice may survive through winter than on islands where they experience more severe conditions.

Although the mice collected at low altitudes were significantly larger than those from the high altitudes, the difference may not be real. It is possible that a younger population was sampled at the higher elevation (Figure 1), assuming that the mice have roughly a 12 month life expectancy and that none survive two winters (Berry 1981). In the Drakensberg Rowe-Rowe & Meester (1982) found that breeding in the rodent *Rhabdomys pumilio* and the shrew *Myosorex varius* commenced later at the colder, high altitudes, than was found in these animals at lower altitudes.

Reproduction

It is not known whether mice breed throughout the year on Gough Island. At the time of this study reproduction was well under way (Table 3), and had obviously commenced some time earlier, since juveniles had already entered the trappable population at the lower altitudes (mean air temperature 11°C), where 18 mice of between 8 and 19 g were caught (Figure 1). Although the sample size from the high altitudes, where temperatures are lower, is small, the data do suggest that breeding had only recently commenced there: the only two pregnant females trapped contained 3 mm and 6 mm long foetuses, and no juveniles were caught.

The mean number of foetuses (9,2) recorded at Gough Island is higher than the means of 6,9 and 7,5 reported on other islands (Berry 1968; Gleeson 1981). The Gough Island mean may, however, not be typical of the entire breeding season, since the number of embryos reaches a peak at the height of the breeding season (Berry 1968; 1981). Litter size may also be dependent on one or more factors e.g. genotypes, maternal size, or environmental factors such as temperature (Batten & Berry 1967).

Conclusions

House mice have apparently been on Gough Idand for 180 years. Subsequent accidental introductions may have occurred between 1810 when the first sealers lived ashore, and 1956 when the South African meteorological station was established. Since then the South African authorities have attempted to prevent any further introductions. Except for the mice in the meteorological base station, they have been independent of humans. This brief study has shown that they are larger than other *Mus musculus*, and there is a suggestion that they may produce larger litters.

At the time of this study (mid-spring) mice were present at high densities, particularly in areas where there was plenty of food and cover. It is not known whether these represent peak densities, which have been recorded in some populations during spring (De Long 1967), whereas other studies have revealed peak densities during summer (Gleeson 1981), or just before autumn (Berry 1968). The biomass in suitable mouse habitats on Gough Island is high, where the omnivorous feral mice are likely to have (or perhaps have already had) a significant impact on other biota (Breytenbach 1986; Ryan, Moloney & Watkins 1989).

At the time of sampling the percentage of pregnant and lactating female mice was close to that recorded at breeding peaks in some populations during spring (De Long 1967), and in others during summer (Berry 1968; Gleeson 1981). Whether breeding ceases at the end of autumn, or continues through winter (possibly in sheltered habitats), is not known.

Acknowledgements

We thank the Director of the Percy FitzPatrick Institute of African Ornithology, University of Cape Town for inviting us to participate in the ecological studies on Gough Island; the South African Committee for Antarctic Research of the Department of Environment Affairs who supported the research, and the Administrator and Island Council of Tristan da Cunha for permission to work on Gough Island. Gratitude is expressed to other expedition members who collected the small samples of mice while they were away from the base station, and special thanks are due to our expedition leader, John Cooper, for his assistance, efficient organization, and guidance. The Natal Parks Board is

thanked for granting one of us (DTRR) special leave to participate in the research. John Cooper, Prof. J. Meester, and Peter Ryan kindly commented on the manuscript, which was typed by Michelle Hamilton.

References

BATTEN, C.A. & BERRY, R.J. 1967. Prenatal mortality in wild-caught house mice. *J. Anim. Ecol.* 36: 453–463.

BERRY, R.J. 1968. The ecology of an island population of the house mouse. J. Anim. Ecol. 37: 445–470.

BERRY, R.J. 1981. Town mouse, country mouse: adaptation and adaptability in *Mus domesticus (M. musculus domesticus). Mammal Review* 11: 91–136.

BERRY, R.J., PETERS, J. & VAN AARDE, R.J. 1978. Sub-antarctic house mice: colonization, survival and selection. *J. Zool., Lond.* 184: 127–141.

BESTER, M.N. 1981. Seasonal changes in the population composition of the fur seal *Arctocephalus tropicalis* at Gough Island. *S. Afr. J. Wildl. Res.* 11: 49–55.

BREYTENBACH, G.J. 1986. Dispersal: the case of the missing ant and the introduced mouse. *S. Afr. J. Bot.* 52: 463–466.

BURT, W.H. & GROSSENHEIDER, R.P. 1976. A field guide to the mammals. Houghton Mifflin Company, Boston.

CAUGHLEY, G. 1977. Analysis of vertebrate populations. John Wiley & Sons, London.

DE LONG, K.T. 1967. Population ecology of feral house mice. *Ecology* 48: 611–634.

GLEESON, J.P. 1981. The ecology of the house mouse, *Mus musculus* Linnaeus, on Marion Island. M.Sc. thesis, Univ. of Pretoria, Pretoria.

HILL, J.E. 1959. Rats and mice from the islands of Tristan da Cunha and Gough, South Atlantic Ocean. Results of the Norwegian Scientific Expedition to Tristan da Cunha 1937–1938, No. 46: 1–5.

HOLDGATE, M.W. 1965. Part III. The fauna of the Tristan da Cunha Islands. *Phil. Trans. R. Soc., Ser. B.* 249: 361–402.

ROWE-ROWE, D.T., GREEN, B., & CRAFFORD, J.E. 1989. Estimated impact of feral house mice on Sub-antarctic invertebrates at Marion Island. *Polar Biology* 9: 457–460.

ROWE-ROWE, D.T., & MEESTER, J. 1982. Population dynamics of small mammals in the Drakensberg of Natal, South Africa. *Z. Säugetierkunde* 47: 347–356.

RYAN, P.G, MOLONEY, C.L., & WATKINS, B.P. 1989. Concern about the adverse effect of introduced mice on island tree *Phylica arborea* regeneration. *S. Afr. J. Sci.* 85: 626–627.

SWALES, M.K. 1965. The sea-birds of Gough Island. *Ibis* 107: 17–42.

VAN DEN BRINK, F.H. 1967. A field guide to the mammals of Britain and Europe. Collins, London.

VERRIL, S.E. 1895. On some birds and eggs colleded by Mr Geo Comer at Gough Island, Kergeulen Island and the islands of South Georgia, with extracts from his notes including a meteorological record for about six months. *Trans. Connect. Acad. Arts & Science* 9: 430–478.

WACE, N.M. 1961. The vegetation of Gough Island. *Ecological Monographs* 31: 337–367.