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# Can predation by invasive mice drive seabird extinctions?

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**The house mouse, *Mus musculus*, is one of the most widespread and well-studied invasive mammals on islands. It was thought to pose little risk to seabirds, but video evidence from Gough Island, South Atlantic Ocean shows house mice killing chicks of two IUCN-listed seabird species. Mouse-induced mortality in 2004 was a significant cause of extremely poor breeding success for Tristan albatrosses, *Diomedea dabbenena* (0.27 fledglings/pair), and Atlantic petrels, *Pterodroma incerta* (0.33). Population models show that these levels of predation are sufficient to cause population decreases. Unlike many other islands, mice are the only introduced mammals on Gough Island. However, restoration programmes to eradicate rats and other introduced mammals from islands are increasing the number of islands where mice are the sole alien mammals. If these mouse populations are released from the ecological effects of predators and competitors, they too may become predatory on seabird chicks.**

**Keywords:** invasive alien species; *Mus musculus*;  
island conservation; threatened seabirds

## 1. INTRODUCTION

Oceanic islands represent a small fraction of the Earth's land area, but hold a disproportionate percentage of global avian biodiversity (BirdLife International 2004). Many of these bird species are susceptible to extinction; more than 90% of avian extinctions since 1600 have been of island species, mainly due to predation by invasive mammals (Atkinson 1985; Steadman 1995). Rats, *Rattus* spp., are the most widely introduced mammals on islands and have devastating impacts on many bird populations (Atkinson 1985; BirdLife International 2004). Techniques are being developed to eradicate rats from ever larger islands, and conservation expenditure is increasingly devoted to this endeavour (figure 1). In contrast, mice are deemed to pose no serious threats to seabirds (Atkinson 1985). Consequently, eradication effort for rats in 2001–2005 was 25 times

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greater than mice and grew 50-fold from pre-1986 levels, while eradication efforts for mice remained virtually unchanged.

Gough Island (40° S, 9° W), South Atlantic Ocean is a World Heritage Site and a globally important seabird breeding colony (BirdLife International 2004). It has two endemic landbirds—the Gough moorhen *Gallinula comeri* (vulnerable) and Gough bunting *Rowletia goughensis* (vulnerable)—and the last viable breeding populations of two seabird species—the Tristan albatross *Diomedea dabbenena* (endangered) and the Atlantic petrel *Pterodroma incerta* (vulnerable) (BirdLife International 2004). House mice were introduced there before 1888 and are the only alien mammals present (Angel & Cooper 2006). In 2000/2001, unexpectedly high breeding failure of Tristan albatrosses and Atlantic petrels was reported on Gough (Cuthbert & Hilton 2004), and predation by mice was mooted. Here, we confirm that mice do attack and kill chicks up to 300 times their mass, and report a second season of low breeding success among affected seabirds. We argue that similar mouse predation may have been overlooked elsewhere, and may be most likely where mice are the sole alien mammal.

## 2. MATERIAL AND METHODS

Research was conducted between January and September 2004. The breeding success (fledglings/pair) of Tristan albatross was estimated by counting all incubating adults (January) and all large chicks (September). From approximately 300 monitored nests (16% of the island total) in four sub-colonies, 256 chicks were examined one to three times per month for wounds. We used a  $\chi^2$ -test to examine whether there was significant inter-colony variation in breeding success. Two wounded Tristan albatross chicks were filmed at night using an infrared video recorder. Evidence of attacks at other times was inferred from fresh wounds and stripped carcasses.

Three great shearwater *Puffinus gravis* and 60 Atlantic petrel chicks were monitored (January–April and July–September, respectively). Infrared cameras were deployed in nine Atlantic petrel and three great shearwater burrows and activities were recorded 24 hours per day on time-lapse recorders. Nests were filmed from hatching until the chick had fledged, died or we had left the island. Atlantic petrel nests were checked every 2–5 days and chicks were weighed and measured weekly; a healthy chick is defined as one that did not differ significantly from the expected weight for a given skeletal size measure.

## 3. RESULTS

Mice were filmed attacking and killing live healthy chicks of all the three study species. Both albatross chicks filmed being attacked died subsequently. Video evidence shows up to 10 mice attacking a chick, eating from three open wounds (figure 2a). Mice visited every filmed burrow, and attacked and killed one of the three great shearwater chicks and six out of nine Atlantic petrel chicks. No chicks displayed appropriate behavioural responses to attacks, even though mice had eaten through the body wall of one filmed albatross chick and were consuming the contents of the chick's abdominal cavity (figure 2b).

Most breeding failures in the albatross and petrels occurred when healthy chicks either disappeared or were reduced to stripped carcasses between nest checks. The first wounded albatross chicks (some of which were still being brooded) were found in March and attacks continued into September in all sub-colonies. Out of 256 monitored chicks, 19 were found wounded (of which 17 died) and 100 (39%)

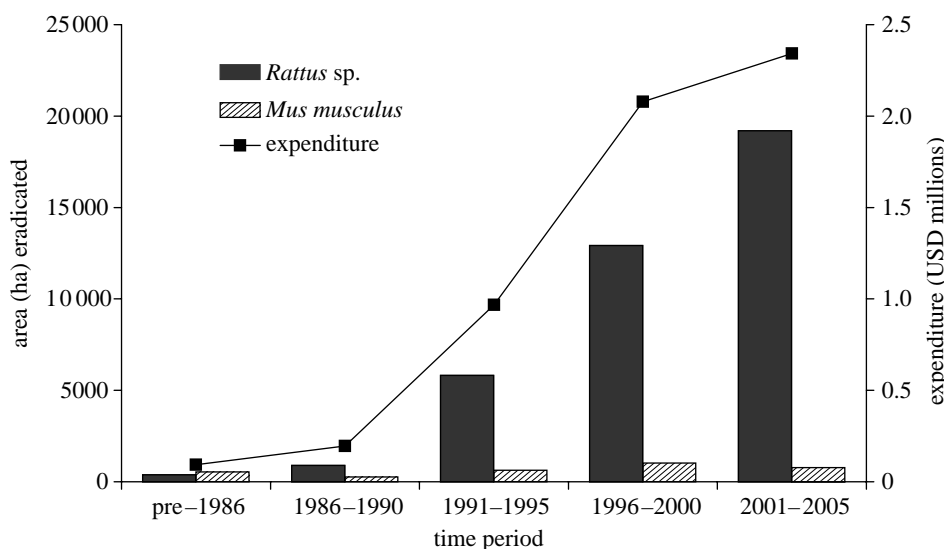


Figure 1. Island area cleared of rats (*Rattus* sp.) and mice (*Mus musculus*). All known efforts prior to 1986 are summed. The expenditure (*Rattus* only) is estimated for individual islands (Martins *et al.* 2006) and then summed. Data were accessed from an online database (Howald *et al.* 2005).

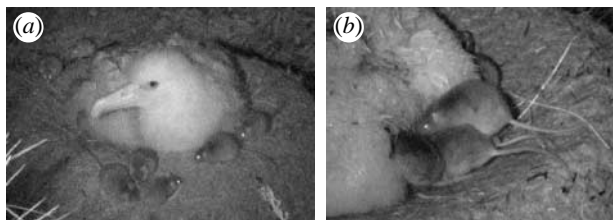


Figure 2. Images captured from video showing (a) 10 house mice attacking a Tristan albatross chick and (b) mice feeding at a hole eaten through the rump of the chick. The chick was dead the following morning.

had died by late September. However, estimated breeding success differed significantly in sub-colonies ( $\chi^2_3=177$ ,  $p<0.001$ , range 0.12–0.89). Island-wide breeding success in 2004 was 0.27, identical to 2001. Attacks on Atlantic petrel chicks commenced at hatching in July, and by September, 20 out of 60 monitored chicks (33.3%) survived.

Chicks were all apparently healthy (as defined previously) when attacked, whereas we found three dead/moribund chicks without wounds. Mice do not appear to target weak or sick individuals. We conclude that the unusually high chick mortality in both species can be ascribed to mouse attacks with confidence.

#### 4. DISCUSSION

An annual breeding success as low as 27% is unprecedented among *Diomedea* albatrosses (typically 60–75%; e.g. Croxall *et al.* 1990; Weimerskirch 1992; Elliott & Walker 2005). Cuthbert *et al.* (2004) reported a 28% decrease in the Tristan albatross population over 46 years and their population model identified low chick survival as a significant driver. Similarly, a population model for the Atlantic petrel predicts a decrease, given the observed low chick production (Cuthbert 2004). Mice appear to be largely responsible for high rates of chick mortality in both the species on Gough, and negative population trends are probable unless predation is reduced.

This is the first unequivocal proof that house mice are significant predators of healthy seabird chicks. Three published records of possible house mouse predation (Fugler *et al.* 1987; Ainley *et al.* 1990; Campos & Granadeiro 1999) were all on small chicks (less than 50 g) and could have been the result of mice scavenging/killing moribund chicks or taking abandoned eggs. Gough mice are relatively large compared with natural populations elsewhere (Berry *et al.* 1979). Nevertheless, they are much smaller than rats and it is astonishing that they can successfully attack Tristan albatross chicks that are more than 300 times heavier. Tristan albatross chicks thwart avian predators such as sub-Antarctic skuas, *Catharacta antarctica*, and southern giant petrels *Macronectes giganteus*. Why then are healthy, well-developed albatross chicks, weighing more than 8 kg, incapable of defending themselves against such diminutive predators? Island birds are particularly vulnerable to attacks from novel predators because they lack appropriate behavioural responses (Kepler 1967; Atkinson 1985). Also, not all attacks were fatal. Albatross chicks typically took several days to die, during which time the mice fed repeatedly on them, often opening multiple wounds. In some ways, this is closer to parasitism than to predation, analogous to finches in Galapagos pecking at tail feathers of seabird chicks and drinking their blood (Grant 1986), although, in that case, the chick seldom dies.

This is the first record of widespread and devastating predation by house mice on seabird chicks, despite mice having been introduced to many seabird islands. Has it been overlooked? Or is there something peculiar about Gough Island? The climate and native biota are not unusual, and it seems unlikely that some other condition, as yet undefined, could have given rise to predatory behaviour. Perhaps of more importance is that among 385 islands with bird species known to be sensitive to invasive species, only six, including Gough, have house mice as the only invasive mammal (Brooke & Hilton 2002). We suspect that where house

mice are part of a complex of invasive mammals, the effects of dominance, competition and predation by larger species render mice less of a threat to native vertebrates (Courchamp *et al.* 1999). Recent events on Marion Island (46° S, 37° E) support this hypothesis. House mice became the sole introduced mammal following the eradication of cats, *Felis catus*, in the 1990s (Bester *et al.* 2000). Since 2004, several wandering albatross *Diomedea exulans* chicks have succumbed to wounds consistent with mouse attacks. This is the first time in over 20 years of intensive study that wounds of this nature have been recorded (Peter G. Ryan, unpublished data).

These findings are significant for both Gough and Marion islands and, more generally, for island conservation and the emerging discipline of invasion biology. On Gough, unmitigated predation by mice could contribute to the local extinction of Tristan albatrosses and Atlantic petrels. The winter timing of attacks makes grey petrels, *Procellaria cinerea*, and great-winged petrels, *Pterodroma macroptera*, both winter-breeding, burrowing species, likely to experience mouse predation. The Gough bunting population is likely to have decreased as a result of nest predation by mice (Cuthbert & Hilton 2004). If attacks on albatrosses are confirmed on Marion Island, several other species (e.g. winter-breeding, burrowing petrels) are likely to be subject to mouse predation there.

In a broader context, the conservation status of seabirds breeding on islands where mice are the sole introduced mammals needs to be studied. We predict that this phenomenon is more widespread than has been documented. In addition, costly mammal eradications are premised on projected conservation benefits (Krajick 2005). Our findings support the mesopredator release and competitor release hypotheses (Courchamp *et al.* 1999; Caut *et al.* in press) that the value of eradicating competitors and predators of mice (e.g. rats and cats) would be greatly enhanced also by eradicating mice. Conversely, some long-term benefits could be compromised if they are not. In light of these results, the prioritization given to mouse eradications in island restoration projects should be reviewed.

Invasion biologists seek to predict the risks and consequences of alien species introductions. Islands are often studied to understand the general principles of invasive patterns and processes. It is surprising that major discoveries can still be made about the behaviour of a well-studied species with a history of invasion stretching back several centuries. Our findings reveal how the characteristics of invasive species can be context specific and thus difficult to predict. In a more positive vein, they also generate testable predictions and suggest avenues for research into ecological interactions, which will benefit invasion biology theory and conservation practice.

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