

## Short Communication

### Was the removal of rabbits and house mice from Selvagem Grande beneficial to the breeding of Cory's shearwaters *Calonectris diomedea borealis*?

F. Zino, M.V. Hounsborne, A.P. Buckle and M. Bischoito

**Abstract** The breeding success of Cory's shearwaters *Calonectris diomedea borealis* at its important Atlantic colony on Selvagem Grande has been monitored periodically at two study plots since 1982. A successful eradication programme was implemented to remove two alien invasive mammals, rabbits *Oryctolagus cuniculus* and house mice *Mus musculus*, from the island during 2002. The availability of long-term breeding data for Cory's shearwaters on Selvagem Grande provided a unique opportunity to study the effects of the removal of rabbits and mice on seabird breeding. Annual observation of approximately 400 Cory's nests showed that significantly more birds fledged from both study sites in the five breeding seasons after the eradication than in the 13 seasons prior to it for which reliable breeding data were available. The numbers of young birds present at

the time of fledging were an average of 47 and 23% greater than pre-eradication numbers at the two study sites. The eradication of rabbits and mice was simultaneous and, therefore, it was impossible to attribute the increased breeding success of Cory's shearwaters to the removal of one or other species. However, both are known to have adverse impacts on the breeding of nesting seabirds. These observations provide important justification for the implementation of further programmes for the removal of alien invasive mammals from oceanic islands.

**Keywords** *Calonectris diomedea*, Cory's shearwater, invasive species, *Mus musculus*, house mouse, *Oryctolagus cuniculus*, rabbit, island eradication, Selvagem Grande.

Selvagem Grande (30°09'N, 15°52'W) is the largest island of the Portuguese sub-archipelago of the Selvagens and lies between Madeira and the Canary Islands in the north-east Atlantic. The island supports one of the most important Atlantic colonies of Cory's shearwaters *Calonectris diomedea borealis* (Granadeiro *et al.*, 2006) and the birds have been studied intensively since the expedition organised by the Museu Municipal do Funchal (História Natural) in 1963 (Pickering & Maul, 1965; Zino, 1971, 1985; Zino *et al.*, 1987; Mougin *et al.*, 2002a,b; Granadeiro *et al.*, 2006). Two study areas of c. 15 \* 100 m (site EFGH) and 16 \* 140 m (site ABCD) on the island's

cliff slopes have been defined for long-term monitoring (Zino *et al.*, 1987). These areas are on opposite sides of the island, one facing the north-east trade wind and one in the lee of it. Frequent expeditions were made to the sites in order to conduct the monitoring, with special emphasis on the time of egg laying (late May to mid June) and prior to fledging (late October). The breeding cycle of the birds on the island is remarkably consistent and predictable. After a period of recovery following a devastating illegal cull of birds in 1976 (Zino, 1985), demonstrated in the increasing number of nests monitored in the years between 1984 to 1989, the numbers of nests studied did not vary appreciably among the annual study periods (Fig. 1).

Populations of the rabbit *Oryctolagus cuniculus* and the house mouse *Mus musculus* inhabited the island, probably the result of ancient introductions by mariners, but were removed in a successful eradication programme carried out by the Parque Natural da Madeira involving the intensive application of baits containing the anticoagulant rodenticide brodifacoum (Oliveira *et al.*, 2003). The removal of the majority of mammals occurred during August 2002, coinciding with the period of hatching

**F. Zino** Freira Conservation Project, Av. do Infante, 26, 9000-015 Funchal, Madeira, Portugal. E-mail fzino@mail.telepac.pt

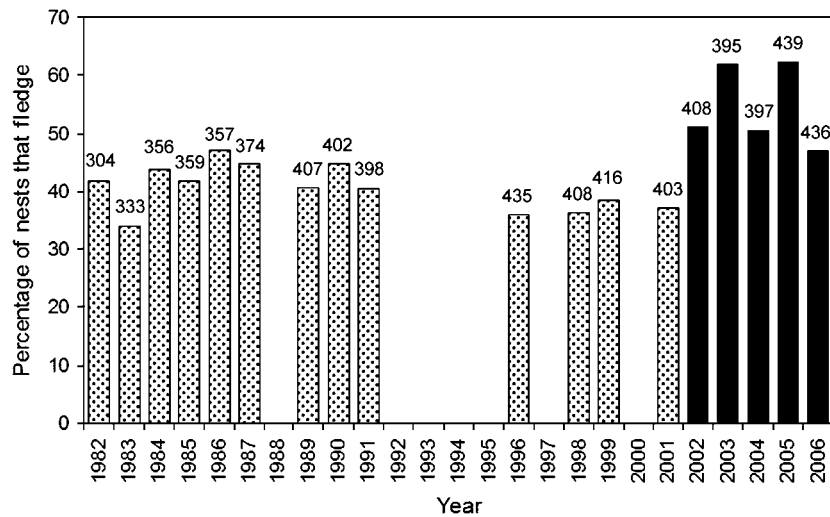
**M.V. Hounsborne** Hooper's Farm, Offwell, Honiton, Devon, EX14 9SR, UK.

**A.P. Buckle** School of Biological Sciences, University of Reading, Whiteknights, PO Box 228, RG6 6AJ, UK.

**M. Bischoito** Museu Municipal do Funchal (História Natural), Rua da Mouraria, 31, 9004-546 Funchal, Madeira, Portugal.

Received 11 April 2007. Revision requested 28 June 2007.

Accepted 21 August 2007.



**Fig. 1** Percentage of monitored Cory's shearwaters nests on Selvagem Grande that produced fledged chicks (means for study areas ABCD and EFGH combined). Stippled bars are before eradication of mice and rabbits, and black bars after eradication. Values at the top of bars are the numbers of nests monitored. Rabbits and mice were eradicated during the 2002 breeding season. In breeding seasons for which no data are presented, logistical problems prevented adequate study. The number of nests studied in 2005 represents c. 1.5% of the total number of breeding pairs estimated to be present on the island in that year (Granadeiro *et al.*, 2006).

of Cory's shearwater chicks. Rabbits and house mice were the only alien mammals present on the island.

The removal of rats (*Rattus* spp.) from breeding colonies of seabirds can result in significant rises in productivity and survival because of their predation of adults, eggs and young (Zino *et al.*, 2001; Courchamp *et al.*, 2003; Buckle, 2004). Mice, mainly house mice, but also *Peromyscus* spp. and others, also inhabit many oceanic islands and in spite of their small size are able to predate nesting seabirds and their eggs and chicks (Blight *et al.*, 1999; Drever *et al.*, 2000; Cuthbert & Hilton, 2004; Wanless *et al.*, 2007). The removal of rabbits has also been shown to be beneficial in terms of island conservation (Courchamp *et al.*, 2003). However, the principal biota that benefit are plants and the major effects on breeding seabirds are probably indirect, mediated by vegetation changes, reduced soil erosion and the removal of the prey base of raptors that may take seabirds as secondary prey items (Priddel *et al.*, 2000; Bullock *et al.*, 2002).

The existence of a long-term data set on the breeding success of Cory's shearwater on Selvagem Grande provided a unique opportunity to study the benefits of the removal of the two alien invasive species, rabbits and house mice. Ideally, in breeding studies of seabirds, nests are monitored throughout the breeding season, the breeders ringed, the date of laying observed, and losses throughout incubation and the dates of hatching and fledging are noted (Zino *et al.*, 1987). It has not been possible, however, to obtain such complete data sets in every breeding season of Cory's shearwaters on Selvagem

Grande due to the difficulty of access to the island. In most years the ringing of the juveniles took place after late September and losses of juveniles after this date and prior to fledging are known to be minimal. Therefore, the numbers of nests monitored and of chicks ringed are used in this study as indicators of annual productivity in the two study areas.

A significant increase in Cory's shearwater productivity was observed in the years following the eradication programme in both study areas. (Table 1, Fig. 1). Fledgling productivity in study area ABCD increased from

**Table 1** The mean percentage of Cory's shearwater nests that produced fledglings in two study areas of Selvagem Grande before and after the eradication of rabbits and mice, together with two-tailed *t*-tests for the difference of means with unequal variances, hence the different degrees of freedom.

	Study area	
	ABCD	EFGH
<b>Before eradication</b>		
Mean	36.47	45.43
Standard Deviation	4.50	5.14
n	13	13
<b>After eradication</b>		
Mean	53.70	55.68
Standard Deviation	10.01	4.97
n	5	5
<b>Statistical comparison</b>		
<i>t</i>	5.16	3.82
df	9	16
P	0.0006	0.0015

a mean of 36.5 fledglings per 100 nests monitored in 13 breeding seasons before eradication to one of 53.7 per 100 nests in the 5 subsequent seasons. A similar effect was observed in study area EFGH, with fledgling productivity increasing from a mean of 45.4 to one of 55.7 per 100 nests. These increases represent, respectively, 47 and 23% more young birds in nests immediately prior to fledging after rabbit and mouse eradication.

Until Selvagem Grande was classified as a Nature Reserve in 1971, and permanently wardened from 1980, the island's Cory's shearwaters were intensively, and latterly illegally, exploited for meat, oil and feathers (Mougin & Stahl, 1982; Zino, 1985). This resulted in a population decline from an estimated 130,000–150,000 breeding pairs to 7,000 pairs in 1980 (Mougin & Mougin, 2000). Since the last extensive culls in 1975 and 1976 the population of Cory's shearwaters on Selvagem Grande appears to have been increasing at an annual rate of c. 5% and has now recovered to an estimated 29,540 breeding pairs (Granadeiro *et al.*, 2006). It is also clear, however, that a highly significant increase in the number of fledglings produced in the two study areas in the last five consecutive breeding seasons has coincided with the removal of rabbits and mice from Selvagem Grande. If the increase seen in the study plots is typical of the nests on the island as a whole it is likely that the rate of growth of the island's population will also increase. A similar increase in the breeding success of Cory's shearwater was found by Igual *et al.* (2006) who controlled, but did not eliminate, black rats *Rattus rattus* at Cory's shearwater breeding sites on the Chafarinas Islands in the Mediterranean.

Our observations do not prove a causative link between the eradication of alien mammals and improved breeding success of Cory's shearwaters. However, competition between rabbits and seabirds for burrows has been noted on some oceanic islands (Courchamp *et al.*, 2003) but, as previously stated, Selvagem Grande once supported, in the presence of rabbits, a much larger population of Cory's shearwater than it does now. Thus, the removal of competition for burrows seems an unlikely explanation for their increased breeding success, although disturbance may have been important. Also, if the eradication of rabbits resulted in a benefit to the birds through reduced soil erosion and vegetation recovery we would have anticipated a more gradual change in breeding success than was apparent. Mice may have direct impact on breeding seabirds through predation (Blight *et al.*, 1999; Cuthbert & Hilton, 2004; Wanless *et al.*, 2007). However, while very high densities of mice frequently occurred on Selvagem Grande, no obvious sign of their predation of Cory's adults, chicks and eggs was ever seen. Therefore, attributing the increased fledging rate of Cory's shearwater either to

mouse or rabbit removal, or to a combination of both, must remain speculative. Nevertheless, the adverse impacts of both rabbits and mice on the breeding of nesting seabirds is well established (Courchamp *et al.*, 2003) and their removal from Selvagem Grande appears to have had an immediate and dramatic effect in increased breeding productivity of Cory's shearwater. The increase was apparent in the 2002 breeding season during which the rabbit and mouse eradication took place. This suggests that the impact of the alien mammals may have been on the birds' chicks, rather than their eggs, because the mammals were present throughout laying and incubation in 2002 and effective removal occurred only around the time of hatching. In spite of their necessarily speculative nature, these observations will provide encouragement and stimulus to those planning programmes for the removal of alien vertebrates from other oceanic islands.

## Acknowledgements

We thank the Parque Natural da Madeira for permission to study Cory's shearwaters on Selvagem Grande and Nicholas Carlile and anonymous reviewers for constructive comments on earlier drafts of the paper.

## References

- Blight, L.K., Ryder, J.L. & Bertram, D.F. (1999) Predation of rhinoceros auklet eggs by native population of *Peromyscus*. *The Condor*, **101**, 871–876.
- Buckle, A.P. (2004) Management of rodent pests and island conservation. *Outlooks on Pest Management*, **15**, 131–134.
- Bullock, D.J., North, S.G., Dullo, M.E. & Thorsen, M. (2002) The impact of rabbit and goat eradication on the ecology of Round Island, Mauritius. In *Turning the Tide: The Eradication of Invasive Species* (eds C.R. Veitch & M.N. Clout), pp. 53–63. IUCN, Gland, Switzerland.
- Courchamp, F., Chapuis, J.-L. & Pascal, M. (2003) Mammal invaders on islands: impacts, control and control impact. *Biological Reviews*, **78**, 347–383.
- Cuthbert, R. & Hilton, G. (2004) Introduced house mice *Mus musculus*: a significant predator of threatened and endemic birds on Gough Island, South Atlantic Ocean? *Biological Conservation*, **117**, 483–489.
- Drever, M.C., Blight, L.K., Hobson, K.A. & Bertram, D.F. (2000) Predation on seabird eggs by Keen's mice (*Peromyscus keeni*): using stable isotopes to decipher the diet of a terrestrial omnivore on a remote offshore island. *Canadian Journal of Zoology*, **78**, 2010–2018.
- Granadeiro, J.P., Dias, M.P., Rebelo, R., Santos, C.D. & Catry, P. (2006) Numbers and populations trends of Cory's shearwater *Calonectris diomedea* at Salvagem Grande, Northeast Atlantic. *Waterbirds*, **29**, 56–60.
- Igual, J.M., Forero, M.G., Gomez, T., Orueta, J.F. & Oro, D. (2006) Rat control and breeding performance in Cory's shearwater (*Calonectris diomedea*): effects of poisoning effort and habitat features. *Animal Conservation*, **9**, 59–65.

- Mougin, J.-L., Jouanin, C., Roux, F., Zino, P.A. & Zino, F. (2002a) La constance de la date de ponte au cours de la vie reproductrice chez le Puffin Cendré, *Calonectris diomedea*. *Boletim do Museu Municipal do Funchal*, **53**, 63–70.
- Mougin, J.-L., Jouanin, C., Roux, F., Zino, P.A. & Zino, F. (2002b) Variation de la durée d'incubation en fonction de la date de ponte chez le Puffin Cendré, *Calonectris diomedea*. *Boletim do Museu Municipal do Funchal*, **53**, 71–77.
- Mougin, J.-L. & Mougin, M.-C. (2000) L'évolution des effectifs reproducteurs des Puffins cendrés, *Calonectris diomedea borealis*, de Selvagem Grande (30°09'N, 15°52'W) de 1995 à 1998. *Boletim do Museu Municipal do Funchal*, **52**, 45–50.
- Mougin, J.-L. & Stahl, J.-C. (1982) Essai de dénombrement des Puffins cendrés, *Calonectris diomedea borealis*, de l'île Selvagem Grande (30°09'N, 15°52'W) en 1980. *Bocagiana*, **63**, 1–17.
- Oliveira, P., Trout, R., Menezes, D., Geraldès, P., Buckle, A. & Domingues, M. (2003) Recuperação dos habitats terrestres da Selvagem Grande. In *Control de vertebrados invasores en Islas Espana e Portugal* (ed. J. Rodrigues-Luengo), pp. 18–19. Consejería de Medio Ambiente y Ordenación Territorial del Gobierno de Canarias, Tenerife, Spain.
- Pickering, C.H.C. & Maul, G.E. (1965) Scientific expedition to the Salvage Islands, July 1963. I. Introduction. *Boletim do Museu Municipal do Funchal*, **18**, 129–131.
- Priddel, D., Carlile, N. & Wheeler, R. (2000) Eradication of European rabbits (*Oryctolagus cuniculus*) from Cabbage Tree Island, NSW, Australia, to protect the breeding habitat of Gould's petrel (*Pterodroma leucoptera leucoptera*). *Biological Conservation*, **94**, 115–125.
- Wanless, R.M., Angel, A., Cuthbert, R.J., Hilton, G.M. & Ryan, P.G. (2007) Can predation by invasive mice drive seabird extinctions? *Biology Letters*, **3**, 241–244.
- Zino, F., Oliveira, P., King, S., Buckle, A., Biscoito, M., Costa Neves, H. & Vasconcelos, A. (2001) Conservation of Zino's petrel *Pterodroma madeira* in the Archipelago of Madeira. *Oryx*, **35**, 128–136.
- Zino, P.A. (1971) The breeding of Cory's shearwater, *Calonectris diomedea*, on the Salvage Islands. *Ibis*, **113**, 212–217.
- Zino, P.A. (1985) A short history of the shearwater hunt on the Great Salvage and recent developments on this island. *Bocagiana*, **84**, 1–14.
- Zino, P.A., Zino, F., Maul, T. & Biscoito, M. (1987) The laying, incubation and fledging periods of Cory's shearwater *Calonectris diomedea borealis* on Selvagem Grande in 1984. *Ibis*, **129**, 393–398.

### Biographical sketches

Frank Zino has been associated with the Selvagens since 1963, where he has studied Cory's shearwaters and other seabirds. He is founder of the Freira Conservation Project, responsible for the initiative to protect Zino's petrels and purchase their breeding grounds. Mike Hounsomes research interests are mainly ornithological and include the evolution of island forms, biostatistics and population modelling. Alan Buckle specializes in vertebrate pest management, particularly rodenticide use in public health, agriculture and conservation, and has been technical advisor for numerous island eradication programmes. Manuel Biscoito was nominated head of the Natural Park of Madeira soon after its creation. He was responsible for the setting up of the Desertas Nature Reserve and was a co-founder of the Freira Conservation Project. He is now Curator of the Natural History Museum of Funchal.