

Short Communication

Extirpation of an insular subspecies by a single introduced cat: the case of the endemic deer mouse *Peromyscus guardia* on Estanque Island, Mexico

Ella Vázquez-Domínguez, Gerardo Ceballos and Juan Cruzado

Abstract The Angel de la Guarda deer mouse *Peromyscus guardia* on Estanque Island, in the Angel de la Guarda archipelago of the Gulf of California, was probably driven to extinction by a single introduced domestic cat. *P. guardia* was trapped on the island in October 1995, at which time the species was still relatively abundant. In 1998 a domestic cat was spotted on the island; no deer mice were found at that time nor during subsequent field work in 1999 and 2001. In 1998, c. 100 cat scats were collected, 2% of which contained *P. guardia* bone remains and 90% *P. guardia* hair. The cat, which was eradicated in 1999, was the only introduced predator on the island. Our results confirm the extreme vulnerability of island rodent populations to the introduction of alien mammalian predators. To our knowledge, apart from

the extermination of Stephens Island wren *Xenicus lyalli* in New Zealand in 1894 by the lighthouse keeper's cat, this is the first report of the destruction of the total population of an insular species by a single cat. With two of the three subspecies of *P. guardia* now extinct the only potentially extant population is on the larger Angel de la Guarda Island, where the species was last seen in 1991. A comprehensive survey of the island is required, with subsequent action for the species recovery and conservation if it is found to be extant.

Keywords Alien species, Angel de la Guarda deer mouse, Estanque Island, extinctions, island mammals, Mexico, *Peromyscus guardia*.

Islands have the highest extinction rates of vertebrates, largely as a result of small population sizes, habitat perturbations and introductions of alien species (Alcover *et al.*, 1998; MacPhee, 1999). Alien (exotic or non-native) species have severe negative impacts on native island species, mainly through the effects of predation, competition, habitat alteration and transmission of diseases (Dowding & Murphy, 2001; Case *et al.*, 2002). As an extreme example, the introduction of the brown tree snake *Boiga irregularis* to the island of Guam caused a cascade of vertebrate extinctions (Fritts & Rodda, 1998). Feral cats *Felis silvestris catus* have frequently been implicated in the extinction of vertebrates on islands, such as conilurine rodents in Australia (Smith & Quin, 1996) and birds and rodents in the Gulf of California (Keitt *et al.*, 2002; Mellink *et al.*, 2002; Álvarez-Castañeda & Ortega-Rubio, 2003). In some studies the examination of faecal pellets has proved that introduced cats eat small rodents (Smith *et al.*, 1993; Nogales & Medina, 1996).

The islands of the Gulf of California, Mexico, harbour a diverse and unique biota with a high percentage of endemic species (Lawlor, 1983; Case *et al.*, 2002) and have been classified as a priority area for the conservation of biodiversity in Mexico (Vázquez-Domínguez *et al.*, 1998). The small Angel de la Guarda deer mouse *Peromyscus guardia* (Townsend, 1912) is endemic to the Angel de la Guarda archipelago in the islands of the central region of the Gulf of California (Hall, 1981). Different subspecies have been reported from Angel de la Guarda Island (*P. guardia guardia*) and the northern islands of Mejía (*P. g. mejiae*) and Granito (*P. g. harbisoni*) (Lawlor, 1971). In the 1960s *P. guardia* was considered abundant but it has become rare and is currently listed as Endangered by the Mexican Government (Semarnat, 2002). Mellink *et al.* (2002) concluded that *P. g. harbisoni* is extinct, *P. g. mejiae* probably extinct, and *P. g. guardia* facing severe conservation threats.

In October 1995 Jesús Ramírez found a previously unrecorded population of *P. guardia* on Estanque Island, a tiny island (0.55 km²) with scarce desert scrub vegetation in the south of the Angel de la Guarda archipelago (Fig. 1). He used Sherman live traps for a total of 120 trap-nights and concluded that *P. guardia* was the only rodent species on the island; although we do not have the trapping success data, Ramírez indicated that the

Ella Vázquez-Domínguez (Corresponding author), Gerardo Ceballos and Juan Cruzado Instituto de Ecología, UNAM, CU, Apdo. Postal 70-275, México D.F. 04510, México. E-mail evazquez@ecologia.unam.mx

Received 14 October 2003. Revision requested 19 January 2004.
Accepted 25 March 2004.



Fig. 1 Angel de la Guarda Archipelago, in Baja California, Mexico, with the location of Estanque Island.

mouse was 'relatively abundant and easily trapped' (pers. comm.). However, later surveys indicated that *P. guardia* was extinct (Mellink *et al.*, 2002). From the animals trapped in 1995, two females and two males were subsequently kept in captivity until they died in 1998, after which they were deposited as voucher specimens in the Mammal Collection at the Instituto de Ecología, UNAM. Additional fieldwork was carried out on the island in November 1998 (29 trap nights), November 1999 (40) and April 2001 (40; Mellink *et al.*, 2002), but no individuals were trapped. Given the island's small size and scarce vegetation, the trapping effort over a 4-year period is adequate and comparable with other studies on the California islands (Mellink 1992; Case *et al.*, 2002; Mellink *et al.*, 2002). During the 1998 field trip we collected *c.* 100 cat scats and saw one

cat. We analysed the contents of the scats to determine the cat's prey, including *c.* 25 scats analysed by Mellink *et al.* (2002) and *c.* 75 that had been stored. In 1999 eradication specialists removed the cat, which was a female, and confirmed there were no other cats on the island (B. Tershy, pers. comm.). No other cat was seen or cat scats found during the subsequent field trip in 2001.

The fact that no individuals could be captured in the visits of 1998, 1999 or 2001 indicates that the *P. guardia* population on Estanque Island is now extinct, and all available evidence suggests that the single cat, accidentally introduced to the island, was probably responsible. Our analysis of the cat's scats revealed that 2% contained *P. guardia* bone remains and 93% *P. guardia* hair, and that the cat also consumed endemic Baja California fishing bats *Myotis vivesi*, birds and lizards (Table 1, Plate 1).

There are several general conservation lessons from Estanque Island. Firstly, *P. guardia* is another addition to the long list of island species that have become extinct or are Critically Endangered (Smith & Quin, 1996; Alcover *et al.*, 1998; MacPhee, 1999). At a global scale 83% of all mammal extinctions are of island species, such as the Coronados Island packrat *Neotoma bunkeri* in Mexico, the Falkland Islands fox *Duscicyon australis*, and the Sardinian pika *Prolagus sardus* (Smith *et al.*, 1993; MacPhee, 1999). Considering the mammals exclusively inhabiting islands, at least 27% of species on the world's islands have gone extinct (Alcover *et al.*, 1998). Trends in Mexico are similar, with 40% of all extinct mammals being island species (Ceballos & Navarro, 1991). Secondly, this example further demonstrates the impacts that alien species have on island animals. Other threatened vertebrates on the Gulf of California islands include Bryant's woodrat *Neotoma bryanti*, San Lorenzo mouse *Peromyscus interparietalis*, black chuckwalla *Sauromalus hispidus*, Catalina rattlesnake *Crotalus catalinensis*, and elegant tern *Sterna elegans* (Mellink, 1992; McChesney & Tershy, 1998; Case *et al.*, 2002). Thirdly, this is one of the most extreme examples of the susceptibility of island rodent populations to introduced mammals. To our knowledge there are no other examples in which the total population of an

Table 1 Material found in the *c.* 100 cat scats collected on Estanque island during 1998, including species identification (where possible), percentage of the total scat weight, and description of the corresponding material.

Species or group	% of scat weight	Material
Angel de la Guarda deer mouse <i>Peromyscus guardia</i>	1.87	16 right inferior mandibles, 13 left inferior, 24 superior, 115 molar teeth (pieces)
Baja California fishing bat <i>Myotis vivesi</i>	2.50	16 right inferior mandibles, 7 left inferior, 3 complete, 26 superior maxillary teeth
Mammal	93.12	hair (with some pieces of stone)
Bird	2.5	feathers and bones
Reptile	insignificant	2 mandibles

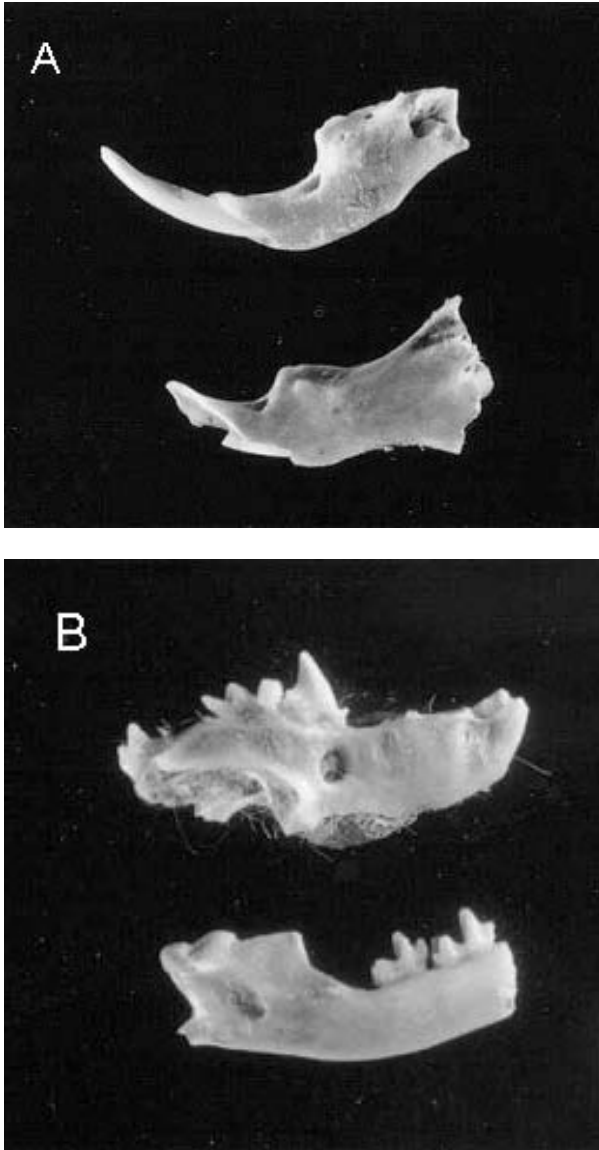


Plate 1 Mandibles found in cat scats from Estanque Island, belonging to (a) *Peromyscus guardia* and (b) *Myotis vivesi*.

insular mammal species has been destroyed by a single cat. A similar case was reported from New Zealand, where the lighthouse keeper's cat exterminated the Stephens Island wren *Xenicus lyalli* in 1894 (Greenway, 1967).

P. guardia was last recorded on Angel de la Guarda Island in 1991 (Mellink *et al.*, 2002). This is the second largest island in the Gulf of California (895 km²), and much of the island has not yet been surveyed for *P. guardia*. A comprehensive survey is required to determine whether the species still survives on the island and, if it is found to be extant, appropriate action will need to be taken for its recovery and conservation, including eradication of alien predators.

Reintroduction to Estanque Island could also be considered. A limited amount of information indicates that the genetic differences between *P. guardia* on Estanque and the Angel de la Guarda subspecies were not large. In an early study with six individuals from Angel de la Guarda Island (Avise *et al.*, 1974) *P. guardia* was found to have low levels of genetic variability. We carried out an allozyme analysis of the four individuals captured on Estanque in 1995 and found that the heterozygosity ($H = 0.010$, data available upon request from the authors) was similar to that reported for the species 22 years earlier ($H = 0.014$; Avise *et al.*, 1974).

Acknowledgements

We are most grateful to Eric Mellink, Bernie Tershie, José Sánchez and Carlos Gracia for sharing their unpublished information with us. E. Mellink, J. Patton and E. Lessa provided valuable comments on the manuscript. Logistic support and funding was provided by the Instituto de Ecología, UNAM. We affectionately remember our late colleague Jesús Ramírez, and dedicate this paper to him. Jesús devoted his career to the conservation of the islands of Baja California, to which he made important contributions such as the eradication of introduced species in Rasa island, and the final observations of *Peromyscus guardia* on Estanque Island.

References

- Alcover, J.A., Sans, A. & Palmer, M. (1998) The extent of extinctions of mammals on islands. *Journal of Biogeography*, **25**, 913–918.
- Álvarez-Castañeda, S.T. & Ortega-Rubio, A. (2003) Current status of rodents in the Gulf of California. *Biological Conservation*, **109**, 157–163.
- Avise, J.C., Smith, M.H., Selander, R.K., Lawlor, T.E. & Ramsey, P.R. (1974) Biochemical polymorphism and systematics in the genus *Peromyscus*: V. Insular and mainland species of the subgenus *Haplomylomys*. *Systematic Zoology*, **23**, 226–238.
- Case, T.J., Cody, M.L. & Ezcurra, E. (eds) (2002) *A New Island Biogeography of the Sea of Cortez*. Oxford University Press, Oxford, UK.
- Ceballos, G. & Navarro, D. (1991) Diversity and conservation of Mexican mammals. In *Latin American Mammalogy, History, Biodiversity and Conservation* (eds M.A. Mares & D.J. Schmidly), pp. 167–198. University of Oklahoma Press, Norman, USA.
- Dowding, J.E. & Murphy, E.C. (2001) The impact of predation by introduced mammals on endemic shorebirds in New Zealand: a conservation perspective. *Biological Conservation*, **99**, 47–64.
- Fritts, T.H. & Rodda, G.H. (1998) The role of introduced species in the degradation of island ecosystems: a case history of Guam. *Annual Review of Ecology and Systematics*, **29**, 113–140.
- Greenway, J.C., Jr. (1967) *Extinct and Vanishing Birds of the World*. Dover Publications, New York, USA.

- Hall, E.R. (1981) *The Mammals of North America*. 2nd edition. Wiley and Sons, New York, USA.
- Keitt, B.S., Tershy, B.R., Croll, D.A. & Donlan, C.J. (2002) Use of a population model to assess the effects of feral cats on black-vented shearwaters (*Puffinus opisthomelas*) on Natividad Island, Mexico. *Animal Conservation*, **5**, 217–223.
- Lawlor, T.E. (1971) Evolution of *Peromyscus* on northern islands in the Gulf of California. *Transactions of the San Diego Society of Natural History*, **16**, 91–124.
- Lawlor, T.E. (1983) The mammals. In *Island Biogeography in the Sea of Cortez* (eds T.J. Case & M.L. Cody), pp. 265–289. University of California Press, Berkeley, USA.
- MacPhee, R.D.E. (ed.) (1999) *Extinctions in Near Time: Causes, Context, and Consequences*. Kluwer Academic/Plenum, New York, USA.
- McChesney, G.J. & Tershy, B.R. (1998) History and status of introduced mammals and impacts on breeding seabirds on the California channel and northwestern Baja California islands. *Colonial Waterbirds*, **21**, 335–347.
- Mellink, E. (1992) *Status de los Heteromidos y Cricetidos Endémicos del Estado de Baja California*. Informe Técnico. Comunicaciones Académicas serie Ecología. Centro de Investigaciones Científicas y Educación Superior de Ensenada, Ensenada, México.
- Mellink, E., Ceballos, G. & Luévano, J. (2002) Population demise and extinction threat of the Angel de la Guarda deer mouse (*Peromyscus guardia*). *Biological Conservation*, **180**, 107–111.
- Nogales, M. & Medina, F.M. (1996) A review of the diet of feral domestic cats (*Felis silvestris catus*) on the Canary Islands, with new data from the laurel forest of La Gomera. *Zeitschrift für Säugetierkunde-International Journal of Mammalian Biology*, **61**, 1–6.
- Semarnat (Secretaría de Medio Ambiente y Recursos Naturales) (2002) Norma Oficial Mexicana NOM-059-ECOL-2001, Protección ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Lista de especies en riesgo. *Diario Oficial*, **6 Marzo**, 1–56.
- Smith, A.P. & Quin, D.G. (1996) Patterns and causes of extinction and decline in Australian conilurine rodents. *Biological Conservation*, **77**, 243–267.
- Smith, F.A., Bestelmeyer, B.T., Biari, J. & Strong, M. (1993) Anthropogenic extinction of the endemic woodrat, *Neotoma bunkeri* Burt. *Biodiversity Letters*, **1**, 149–155.
- Townsend, C.H. (1912) Mammals collected by the “Albatros” expedition in Lower California in 1911, with descriptions of new species. *Bulletin of the American Museum of Natural History*, **31**, 117–130.
- Vázquez-Domínguez, E., Aguilar, C., Aguilar, V. & Arenas, V. (1998) Áreas prioritarias marinas de alta biodiversidad. In *Regiones Prioritarias Marinas de México* (eds L. Arriaga, E. Vázquez-Domínguez, J. González-Cano, R. Jiménez, L.E. Muñoz & V. Aguilar), pp. 109–126. CONABIO, México City, México.

Biographical sketches

Ella Vázquez Domínguez is interested in the link between genetic variability and fitness components in rodents in tropical systems, particularly as applied to the evaluation of population structure and conservation strategies. She is also carrying out research in molecular genetics, population ecology and phylogeography of rodents and fish, and on the macroecology of North American mammals.

Gerardo Ceballos has studied population dynamics, community ecology and conservation issues in small mammals from a tropical dry forest in western Mexico. He has extensive research experience on the conservation of threatened mammals.

Juan Cruzado is carrying out research on the small mammal community associated with prairie dogs on the prairies of northern Mexico.