

## Current status of rodents on islands in the Gulf of California

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### Abstract

On islands in the Gulf of California, many species and subspecies of rodents are relict species, restricted to the islands, and now considered extinct or verging on extinction. From 1991 to 1999, each island was surveyed and an average of 15 work-nights were spent on each island, for a total of 15,000 trap-nights. A Fourier series was used to estimate population density. Five native taxa are now considered extinct (*Chaetodipus baileyi fornicatus*, *Peromyscus guardia mejiae*, *P. g. harbinsoni*, *P. pembertoni*, and *Neotoma bunkerii*). Two species are at risk of extinction (*Dipodomys insularis* and *Neotoma albigula varia*). The most probable cause for extinction is the introduction of nonnative species, specifically cats. We believe that the most vulnerable rodent populations of the islands in the Gulf of California to non-native species are *Neotoma lepida latirostra* on Danzante island and *Neotoma lepida abbreviata* on San Francisco island, both in the state of Baja California Sur. © 2002 Published by Elsevier Science Ltd.

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### 1. Introduction

Northwestern Mexico is an area with a large number of relict species (microendemic), mainly on the islands in the Gulf of California. Island populations are more vulnerable to human activity and to the introduction of nonnative species (World Conservation Monitoring Center, 1992). Fa and Morales (1993) mentioned that only 6% of Mexican fauna live on islands off the coasts of Mexico. The Gulf of California, by a considerable margin, has the largest number of insular endemic species. There are more than 900 islands, 35 of which have native mammals, including 28 endemic species and more than 220 endemic subspecies. Many taxa are considered by the Mexican government to be rare, threatened, or endangered (NOM, 2000).

This region also has the greatest number of extinct mammal taxa in Mexico (Álvarez-Castañeda and Patton, 1999). Beginning in the 1990s, the Mexican government compiled a list of the animal and plant species that were considered endangered, threatened, or rare (CT-CERN-001, 1991; NOM, 1993, 1994, 2000). No extinct species were listed, and some taxa that are

known to be extinct (*Peromyscus pembertoni*, *Neotoma bunkerii*) were listed as endangered (Table 1).

The Centro de Investigaciones Biológicas del Noroeste (CIBNOR) has ongoing studies of the current status of mammals of Northwestern Mexico and has been monitoring island populations. The result is the identification of many taxa that have become extinct in recent years (Álvarez-Castañeda, 1994; Álvarez-Castañeda and Cortés-Calva, 1996, 1999), and some that are very vulnerable to human changes (Álvarez-Castañeda, 1997).

All islands in the Gulf of California are part of a Biosphere Reserve, called “Islands of the Sea of Cortez,” for the protection of animals and plants. Some human activity is permitted, such as the building of fishing camps, ecotourism activities, mining guano and gypsum, and traditional activities such as goat grazing (Álvarez-Castañeda, 1997). All these activities are supposed to have low environmental impact (Tershy et al., 1997, 1999). Patrol of the islands by reserve personnel of the wildlife service only began near the end of 1997, so the islands have a long history of use without formal supervision. Currently, most supervision is restricted to the islands with the greatest tourist activity.

Mammalian extinctions on the islands are probably caused by the introduction of nonnative species (Fig. 1), primarily domestic cats (*Felis*), which prey on the

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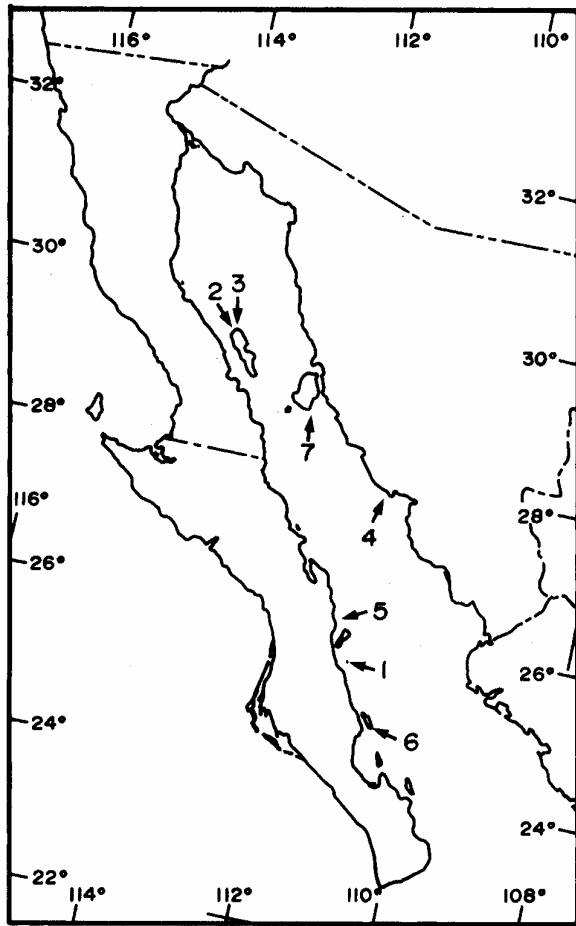


Fig. 1. Distribution of recent rodent extinctions in northwestern Mexico. (1) *Chaetodipus baileyi fornicatus*, (2) *Peromyscus guardia mejiae*, (3) *Peromyscus guardia harbinsoni*, (4) *Peromyscus pembertonii*, (5) *Neotoma bunkerii*, (6) *Dipodomys insularis*, (7) *Neotoma albigula varia*.

endemic taxa, and rodents (*Mus* and *Rattus*), which compete for space and resources. Both are known problems on islands around the world (Owen, 1977; Konecny, 1987a, b; Van Rensburg and Bester, 1988).

The goal of the present paper is to present a compilation of the bibliographic and field information concerning the status of the endemic populations of mammals on the islands of the Gulf of California, and to review possible causes of extinction. Past conclusions about the extinction of many subspecies was based only on small field sampling efforts. We revisited many of these sites to confirm the absence at these populations.

## 2. Methods

This study reviews the body of literature reporting extinctions of mammals on the islands in the Gulf of

California (Álvarez-Castañeda, 1994; Álvarez-Castañeda and Cortés-Calva, 1996, in press; Best, 1983; Ceballos and Navarro, 1991; Lawlor, 1983; Lawlor et al., in press; Mellink, 1992a, b). All the islands were surveyed at least once between 1991 and 1999, at more than four localities per island. Our efforts included an average of 15 work-nights per island for a total of 15,000 trap-nights. Some surveys were made with transport support of the Mexican Navy ship "Altair" and others were reached by private motor boat. The surveys were conducted at all times of the year, but concentrated in September through November to sample the populations at their peak densities, which is after the breeding season.

Transects of 40 Sherman traps were established on each island with 10 m intervals between traps. A Fourier series (Krebs, 1989) was used to estimate population density of the sampling area, and extrapolated to the entire island. Rodent densities were classified at three levels, based on the number of rodents collected: low (less than 10 individuals/km<sup>2</sup>), medium (10–25/km<sup>2</sup>) and high (>25/km<sup>2</sup>). For some species, no specimens were collected. The presence of cats is based in observation of feces and individuals. No density analysis of cats were made.

The number of transects varied, depending on the size of the island. For each island, we recorded the types of human activity, and when possible, we interviewed visitors about their activities. Additional information was provided by the administration of the Biosphere Reserve. Most of the captured rodents were released, but a small number were prepared for the mammal collection of CIBNOR for further cytological, karyotype, and morphological analyses. Nomenclature and taxonomy follow Álvarez-Castañeda and Patton (1999) and Riddle et al. (2000).

## 3. Results

The species considered extinct are listed in Table 1. Some details concerning our surveys are described here.

*Chaetodipus baileyi fornicatus* from Montserrat Island, 13 km east of Baja California Peninsula (Nieto-Garibay, 1999). The last specimens were collected 21 May 1975 by the Instituto de Biología of the Universidad Nacional Autónoma de México. Since that time, at least eight surveys by different institutions were made in different years and during different seasons. Four surveys were made by our own team (>3149 trap-nights). No *C. b. fornicatus* were collected, and only Burt's deer mouse (*Peromyscus caniceps*) was found on the island. Feral cat feces were found and dissected, but no *Chaetodipus* fur or bones were found (Álvarez-Castañeda and Cortés-Calva, in press).

*Peromyscus guardia mejiae*, from Mejia Island, 1.0 km north of Angel de la Guarda Island. Mellink (1992b)

cited correspondence with Banks (1964) and Lawlor (1971) that *P. g. mejiae* and *P. g. harbinsoni* were very common at the beginning and end of the 1960s. Mellink (1992b) trapped here in the summer of 1991 and had no success. He concluded that *P. g. mejiae* was sparse or possibly extinct. In 1997, our group devoted 500 trap-nights to the island, covering all possible habitats, but only *Mus musculus* was collected (5% trap success). This result, in combination with the previous report by Mellink (1992a), led us to conclude that this subspecies is extinct.

*Peromyscus guardia harbinsoni*, from Granito Island, 1.2 km north of Angel de la Guarda Island (Mellink, 1992b). This island is an important nesting ground for sea birds, particularly gulls (*Larus* sp.), cormorants (*Phalacrocorax* sp.), and the brown pelican (*Pelecanus occidentalis*). Guano mining occurs in some years and there is a semi-permanent fish camp that is used all year. As a consequence of the human activities, we collected specimens of *Mus* and *Rattus* (>10% trap success), but no *Peromyscus*. Nonnative species were collected in 1991 by Mellink (1992a), and by our group in 1997. For these reasons, we consider this species extinct.

*Peromyscus pambertoni* from San Pedro Nolasco Island, 10 km off the coast of Sonora. The island has Sonoran scrub vegetation, including succulents and cacti. The vegetation is very dense and difficult to traverse. The base rock is sedimentary in origin, with large stones, steep slopes, and numerous cavities and cliffs. Cats are probably absent since sea birds nest on the ground. Lawlor (1971) reported that he did not collect specimens of *P. pambertoni*, only *P. boylii*, and suggested that *P. pambertoni* was probably extinct. In the 1980s, Bernardo Villa (personal communication) tried to collect specimens of *P. pambertoni*, but had no success after one week. The same result was obtained by our group in 1997 after an effort of 823 trap-nights in all types of habitats. *P. boylii* were captured (17% trap

success). Álvarez-Castañeda and Cortés-Calva (1999) state that habitats were in good condition. Perhaps this species was replaced by *P. boylii*.

*Neotoma bunkeri* from Coronados Island, 3.5 km off the east coast of Baja California Sur and 11 km north of Carmen Island. Coronados Island is of volcanic origin. Bahre (1983) commented that in recent decades increasing population pressure and accessibility of the island to tourists and local fishermen have exacerbated human impact on endemic species. Feral cats have been introduced to Coronados Island. Dissection of fecal cat pellets indicate that they consume small rodents (Smith et al., 1993), who also suggest that depletion of food resources and the presence of feral cats have led to the decline. Since the 1980s, no specimens of *Neotoma* have been collected (Smith et al., 1993; Álvarez-Castañeda, 1997; Álvarez-Castañeda and Cortés-Calva, 1999). Our group made four surveys, (>2000 traps-nights), collecting specimens of *Chaetodipus spinatus* and *P. pseudocritinitus* (20% trap success), but not *Neotoma*. We believe *N. bunkeri* is extinct.

Other species near extinction or at risk of extinction include the following rodents:

*Dipodomys insularis* from San Jose Island, north of Bahia de La Paz and about 8 km east of San Evaristo (Álvarez-Castañeda, 1997). It is probably on the edge of extinction or is very rare. Our group had no success collecting it since 1993, after setting many (>4000 night-traps) in areas where Best (personal communication) had collected this species. On this island, there are few cats, and there are areas suitable for supporting the species. We may eventually find some specimens. Rodríguez-Estrella et al. (2000) recorded a skull of *D. insularis* from feces of the ringtail cat (*Bassariscus astutus*) on the northern part of the island. In an area of many mountains without flat areas, there may not be a suitable habitat for the species. A small colony may persist on the north side of the island where no survey has been made.

Table 1

Species and subspecies considered extinct, probably extinct, or nearly extinct, with location and area of former occurrence and number of traps that were set in our surveys

Species	Island	NOM (1993)	NOM (1994)	NOM (2000)	IUCN (1996)	CITES (1989)	Area (km <sup>2</sup> )	Traps
<i>Chaetodipus baileyi fornicatus</i>	Montserrat		R	SP			14.4	3149
<i>Dipodomys insularis</i>	San José		T	T	T		194.0	3500
<i>Neotoma bunkeri</i>	Coronados		D	D	T		8.5	2000
<i>Neotoma varia</i>	Turner		T	T	T		2.0	478
<i>Peromyscus guardia harbitsoni</i>	Granito		T	D	LR		0.4	250
<i>Peromyscus guardia mejiae</i>	Mejía		T	D	LR		3.0	320
<i>Peromyscus pambertoni</i>	San Pedro Nolasco		D	D	EX		3.2	823

In the conservation lists cited, status of the species are: R (rare), LR (low risk), T (threatened), D (danger of extinction), SP (special protection), and EX (extinct).

*Neotoma albigula varia* from Datil Island. In 1997, our group set 456 night-traps to collect *N. a. varia*, but only collected *Peromyscus collatus* and *Chaetodipus intermedius* (10% trap success). Bogan (1997) said that they tried to collect the species one night (80 Sherman and Victor rat traps) in 1976, but had no success. One year later, the last known wood rats were trapped by E. Roth (Bogan, 1997). Based on the small size of the island and the pattern of mammal extinctions on other small islands, this wood rat may now be extinct. However, a specific survey is needed before firm conclusions about its status can be reached.

*Neotoma lepida latirostra* on Danzante island and *Neotoma lepida abbreviata* on San Francisco island, both part of the state of Baja California Sur, are the two most vulnerable rodent populations of the two islands. This conclusion is based on the small size of the island, history of extinction of species of this genera on the northwestern islands of Mexico (*N. anthonyi*, *N. martinensis*, *N. bunkerii*), and increase in the body size of *N. l. latirostrata*. Smith (1992) suggest that the increase in size results from stress conditions. For these reasons, if nonnative species are introduced to these islands, both subspecies can be extinct in a very short time.

Additionally our field surveys and literature review permit a update of the status of populations not presently at risk.

*Chaetodipus spinatus* is present on 10 islands with the same number of subspecies. No specimens were collected on Angel de la Guarda Island, but the effort was insufficient to assess the status of *C. spinatus* on this island. On San Marcos, Coronados, Carmen, Danzante, San José, and Espiritu Santo Islands, there are nonnative competitors that may cause a problem in the future. No risks were identified for the populations on San Lorenzo, Animas, and San Francisco Islands.

*Ammospermophilus insularis* is present on Espiritu Santo Island and *A. leucurus* on San Marcos Island, probably by human introduction. On both islands, this ground squirrel is very common, mainly in canyon areas.

*Neotoma lepida* has populations on seven islands (Table 2). No specimens were collected on Angel de la Guarda Island, which has a large area of suitable habitat. On Danzante Island, numbers are low, and the only specimens collected were at high elevations; cats were not seen during our surveys. San Marcos and San Francisco Islands have nonnative species, but they do not appear to be affecting the rodent populations at this time. On Carmen, San Jose, and Espiritu Santo Islands the rodent populations were of good size, however, some nonnative species are present. *N. albigula seri* was very abundant on Tiburon Island; their nests were found throughout the island.

Large populations of *C. arenarius siccus*, are mostly located on the southwestern part of Cerralvo Island. *C. intermedius minimus*, *C. penicillatus seri*, and *C. baileyi*

*insularis*, are found on Tiburon Island and *C. baileyi* on Smith Island.

*Peromyscus fraterculus caniceps* on Montserrat Island are not very common, found mainly in the vegetation in the canyons. *Peromyscus merriami dickey* is very common throughout Tortuga Island. *P. eremicus*, is present and common on seven islands, including *P. eremicus interparietalis* (Hafner et al., 2001). Also common is *P. crinitus pallidissimus* and *P. maniculatus hueyi* on San Luis Gonzaga Island, *P. pseudocrinitus*, on Coronados Island, *P. stephani* on San Esteban Island, *P. collatus* on Datil Island, and *P. eva* on Carmen Island. *P. segujis* is very common on San Diego Island, but is much reduced on Santa Cruz Island by the presence of cats. Only a few specimens of *P. slevini* were found on the highest parts of Catalina Island.

#### 4. Discussion

Extinction of rodent species is related on one hand to the small size of many islands compared to the body size of the rodents and on the other hand, to the introduction of nonnative species, which is related to the establishment of fishing camps and others human activities. Islands with frequent human activity should be considered hot spots for the extinction of native species. The genus with the greatest rate of extinction on the islands of the northwestern Mexico is *Neotoma* (Álvarez-Castañeda, 1997). The small size, the presence of cats, and the extinction pattern known on other small islands make *Neotoma* on Danzante Island, the most vulnerable rodent population in the Gulf of California.

To avoid extinction of *Neotoma*, options include: (1) establish a program of captive breeding of endangered endemic species, (2) establish strict, controlled human access to the islands with species at risk, and (3) implement habitat restoration and a cat extirpation program. After exotic species have been removed, native species can be returned to the critical islands. If the extirpation program does not work or cannot be implemented, we would at least have a colony of native rodents for reintroduction in the future.

Supervision of fishing camps on the islands is also necessary because most nonnative species were introduced accidentally or intentionally by fishermen. This casual way for introducing nonnative species has devastated the natives species. A monitoring program of the native vertebrate population of the Gulf of California islands and surveys at intervals of at least every two years are strongly recommended. We propose surveys at intervals of 2 years because financial support is limited, the effect of nonnative species is not strong, and we can observe variations in weather between survey years.

Table 2  
Distribution of rodents on Gulf of California islands, including native species, human activities, nonnative species, number of native extinct species, and densities of rodents estimated by a Fourier series, in five categories<sup>a</sup>

Island	Nonnative species													Human activity													Native species of rodents													Mammal/ extinct	Area (km)
	A	B	C	D	E	F	G <sup>b</sup>	H <sup>b</sup>	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE										
Cerralvo	X	X				X		X	X	X				M						M																	2/0	160.0			
Espirito Santo	X	X				X		X	X	X				M		L				L																	6/0	112.0			
San Francisco	X	X				X		X	X	X					M																						2/0	2.6			
San José	X	X	X	X	X			X	X	X				N						M																7/0	194.0				
San Diego	X																									H										1/0	1.3				
Santa Cruz	X							X																		M										1/0	2.0				
Montserrat	X																																			2/1	14.4				
Catalina	X								X						E		L																			1/0	43.0				
Danzante	X															L																				2/0	4.9				
Carmen	X	X						X	X	X					M																						4/0	151.0			
Coronados	X	X						X	X	X					H																					3/1	8.5				
San Marcos	X	X	X	X	X	X	X	X	X	X					M																					3/0	32.0				
Tortuga	X							X																												1/0	6.3				
San Pedro Nolasco	X																																			2/1	3.2				
San Esteban	X																																			1/0	43.0				
Datil <sup>c</sup>	X																																			3/0	4.0				
Tiburón	X							X	X	X					M																						13/0	1208.0			
San Lorenzo	X							X	X	X					M																						2/0	7.5			
Las Animas <sup>c</sup>	X							X	X	X					M																						2/0	35.0			
Salsipuedes	X							X	X	X					M																						1/0	1.2			
Smith <sup>c</sup>	X							X	X	X																											2/0	5.0			
Angel de la Guarda	X							X	X	X					N																					3/0	895.0				
Granito	X							X	X	X																											1/1	0.4			
Mejía	X							X	X	X																											2/1	3.0			
Willard	X							X	X	X					m																						2/0	2.0			

A, cats; B, rodents; C, goats; D, cows; E, horses; F, dogs; G, jackrabbits; H, *Amnospermophilus leucurus*; I, fish camps; J, gypsum or salt mining; K, ecotourism; L, *A. insularis*; M, *Dipodomys insularis*; N, *Chaetodipus arenarius*; O, *C. baileyi*; P, *C. spinatus*; Q, *C. intermedium*; R, *Peromyscus caniceps*; S, *P. merriami*; T, *P. eremicus*; U, *P. eva*; V, *P. guardia*; W, *P. maniculatus*; X, *P. penbertoni*; Y, *P. pseudocrinitus*; Z, *P. seguyi*; AA, *P. slevini*; BB, *P. stephani*; CC, *Neotoma albigula*; DD, *N. bunkeri*; EE, *N. lepida*.

<sup>a</sup> N (none collected), L (low, <10/km<sup>2</sup>), M (medium, 10–25/km<sup>2</sup>), H (high, >25/km<sup>2</sup>), and E (extinct). Bold letters denote an endemic subspecies. Lower case letters denote a new record of the species to the island. X denotes nonnative species and economic activity on the island.

<sup>b</sup> Denotes a species native to the peninsula that was recently introduced to the island.

<sup>c</sup> Datil is also known as Turner, Las Animas as San Lorenzo Norte, and Smith as Coronados.

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