Development in Sea of Cortés Calls for Mitigation

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Islands in the seas of northwestern Mexico have the largest number of insular endemic species in North America. The islands have the greatest number of extinct mammalian taxa in Mexico, and many of the remaining taxa are rare, threatened, or endangered. Thus the Mexican government's plan to build 24 modern ports—the "Escalera Nautica" project—will place enormous pressure on island species, which are exceptionally vulnerable to human activities, including the introduction of alien species. The intensified port activities would most likely lead to an ecological disaster. Several mammal species inhabiting the islands are already close to the limit of their capacity to survive. For many endangered species, a small change in habitat can be the final push into extinction. In this article, we make some recommendations to try to prevent the extinction of species at risk.

Keywords: extinction, mammals, Sea of Cortés, islands, Mexico

Islands in the Gulf of California Biosphere Reserve (DOF 1978) and on the Pacific side of the Baja California peninsula have, by a considerable margin, the largest number of insular endemic (microendemic) species of North America (Case et al. 2002). On more than 900 islands in this region (Álvarez-Castañeda and Ortega-Rubio 2003), there are currently 42 native species of mammals (33 endemic), 17 amphibians (3 endemic), 144 reptiles (74 endemic), and 649 plants (28 endemic). None of the 108 recorded bird species are endemic. More than 240 endemic subspecies of birds, mammals, plants, and reptiles coexist in this area (Álvarez-Castañeda 1997, Cody and Velarde 2002, Grismer 2002, Rebman 2002, Rebman et al. 2002). Human activities that are currently allowed on these islands include construction of fishing camps, ecotourism, mining of guano and gypsum, and goat grazing (Álvarez-Castañeda 1997). All these activities presumably have a low environmental impact (Tershy et al. 1997, 1999).

Island populations are exceptionally vulnerable to human activities and to the introduction of nonnative species (WCMC 1992). Many taxa on islands in the seas of northwestern Mexico are listed by the environmental laws of the Mexican government (table 1; NOM 2002) as rare, threatened, or endangered. This region also has the greatest number of extinct mammal taxa in Mexico (figure 1; Álvarez-Castañeda and Patton 1999, Álvarez-Castañeda and Ortega-Rubio 2003, Vázquez-Domínguez et al. 2004), probably caused by the introduction of nonnative species, primarily domestic cats (*Felis catus*), which prey on the endemic taxa (Álvarez-Castañeda and Ortega-Rubio 2003, Nogales et al. 2004), and rodents (*Mus* and *Rattus* spp.), which compete with native species for space and resources (Álvarez-Castañeda 1997). Both are known problems on islands around the world (Konecny 1987, Van Rensburg and Bester 1988, Nogales et al. 2004). Introductions of nonnative rodents have affected bird nesting colonies for many years by feeding on chicks (Álvarez-Castañeda and Cortés-Calva 1996).

Data obtained from our eight years of surveys (1991–1999) of all islands with endemic mammals (surveys conducted at more than four localities per island, with a total of 15,000 live-trap nights) show that eight native mammal taxa are now considered extinct on the islands (figure 1), and three are probably extinct or are at risk of extinction. The most vulnerable rodent populations of the islands in the Gulf of California are *Neotoma lepida latirostra* on Danzante Island and *N. lepida abbreviata* on San Francisco Island (Álvarez-Castañeda and Ortega-Rubio 2003)—a single cat can drive extinct an entire population of endemic rodents (Vázquez-Domínguez et al. 2004).

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Current data on plants and reptiles do not show conclusive evidence of extinction or extirpation of any taxa from the islands (Case et al. 2002, Grismer 2002). However, analyses of cats' fecal pellets (Arnaud et al. 1993, Rodríguez-Estrella et al. 2000) have shown an active predation on native reptile species. The effect of this predation has not been evaluated.

Acacia filicifolia is the only known plant that may have been extirpated from Cerralvo Island. It was recorded by Cody and colleagues (1983), but it has not been found in later surveys of the island (Leon de la Luz and Rebman 2002). The main effect of livestock grazing in the islands is the modification of vegetation structure and plant composition (Álvarez-Cárdenas et al. 2000), resulting in changes in the occurrence of 36 vascular plant species that have been recorded from Espiritu Santo Island (Leon de la Luz and Dominguez-Cadena 2006).

No bird species has been recorded as endemic to the islands, and no bird population has been reported as extirpated. However, many of the breeding bird colonies show severe depredation from nonnative rodents, which have a strong effect on these populations (Cody and Velarde 2002). If domestic cats arrived at the islands where these birds breed, the additional effects on the colonies would probably be catastrophic.

Climatological and paleontological data show that the region has been growing more arid in the last few thousand years (Van Devender 1997). On the Baja California peninsula, some species have restricted their ranges as a consequence of the Pleistocene–Holocene climate change, though they are still present in relict populations. Climate changes are most likely increasing the pressure on some species. Moreover, some climatologic disturbances periodically affect this region, including El Niño–Southern Oscillations (Meserve et al. 1995, Lima and Jaksic 1998), sunspot activity (every 11 years), and Hale cycles (every 22 years; Salinas-Zavala et al. 1998). Thermal selection can cause changes in basic reproductive strategies, such as a shift from iteroparity to semelparity (Smith and Charnov 2001). Under these changing circumstances, different populations could be more vulnerable in certain periods of time. What would happen if human activity becomes more intense in one of the peaks of these cycles of vulnerability?

Table 1. The current situation of mammals in islands of northwestern Mexico.

Island	Species on Mexican government's endangered list	Endemic mammal taxa	Extinct mammal taxa	Exotic species	Current level of human activity	Island size (km²)	Island distance from nearest port of Escalera Nautica (km)
Gulf of California							
Cerralvo	2	2	0	3	Low	160	65
Espíritu Santo	6	6	0	2	Medium	112	25
San Francisco	2	2	0	1	Low	3	77
San José	6	7	0	5	Medium	194	82
San Diego	1	1	0	0	Low	1	90
Santa Cruz	1	1	0	1	Low	2	80
Montserrat	2	2	1	1	Low	14	23
Catalina	1	1	0	1	Low	43	52
Danzante	2	2	0	0	Low	5	5
Del Carmen	4	4	0	2	High	151	7
Coronados	3	3	1	1	Low	9	10
San Marcos	2	3	0	5	High	32	15
Tortuga	1	1	0	1	Low	6	28
San Pedro Nolasco	2	2	1	1	Low	3	27
San Esteban	1	1	0	0	Low	43	54
Datil	3	3	1?	0	Low	4	30
Tiburon	5	13	0	0	Low	1208	20
San Lorenzo	2	2	0	0	Low	8	70
Las Animas	2	2	0	0	Low	35	63
Salsipuedes	1	1	0	0	Low	1	60
Smith	1	2	0	0	Low	5	10
Angel de la Guarda	3	3	0	0	Low	895	30
Granito	1	1	1	0	Low	> 1	75
Mejia	2	2	1	0	Low	3	76
Willard	2	2	0	0	Low	2	1
Pacific Ocean							
Todos Santos	2	2	1	2	Medium	1.2	15
San Martín	3	3	1	1	Medium	2.3	110
San Gerónimo	1	1	0	1	Medium	0.4	32
Asuncion	1	1	0	3	High	–	1.2
Cedros	5	5	0	5	High	348	55
Natividad	1	1	0	3	Medium	5	35
San Roque	1	1	1	1	High	1.5	75
Magdalena	9	9	0	2	Medium	220	7
Margarita	7	7	0	4	Medium	200	30

km, kilometer.

Note: Exotic species on the islands include cats, rodents, goats, cows, horses, dogs, and introduced jackrabbits. Current human activities include fish camps, ecotourism, and mining.

In February 2001, the megaproject "Escalera Nautica" was formalized by the Mexican federal government, the tourism minister, and the governors of the states of Sonora, Baja California, Baja California Sur, and Sinaloa. Considered to be an economic stimulus for the region, the project is expected to transform the Gulf of California into a world-class tourist destination. According to the official data for the Escalera Nautica project (*www.escaleranautica.com*), in 1997, 1240 boats arrived in Ensenada by sea and probably the same number by trailer. Hence, fewer than 2500 boats are estimated to have arrived in this region in 1997. But by the end of 2006, if the Mexican government's goal is attained, the number of annual boat arrivals will rise to 14,109; by 2014, the government expects that 67,424 boats will be accommodated each year by the new facilities being built under the auspices of the Escalera Nautica project.

Four island zones in the Gulf of California—the Middle Rift, Guaymas, Loreto, and La Paz—have the largest number of mammals and the most important seabird breeding colonies in danger of extinction (figure 1). The potential increase in arriving boats from 1997 to 2014 is about 2457 percent for La Paz (from 325 to 7985 boats), Guaymas–San Carlos (from 275 to 6757), and Loreto (from 100 to 2456) (*www.escaleranautica.com*).

Human activities in most of northwestern Mexico have until now been of low intensity because of the region's isolation, and there are few supply facilities along the coasts of the Baja California peninsula and continental Mexico. The Escalera Nautica project will significantly boost the number of ports and supply facilities on these coasts, offering the boating public an opportunity to spend much more time in the sea near the islands and to explore areas that were previously difficult to reach.

Nor are the direct impacts of intensified human activities all that must be considered. Approximately 10 percent of all boats in the area have pets on board, pets that usually accompany members of the boating crews when they go ashore. Yet deliberately bringing domesticated animals to the islands is most likely not as problematic as the inadvertent introduction of mainland species that are related to native island species. Inadvertent introductions can be expected to increase significantly as the number of boats visiting the region grows exponentially from 2500 to 70,000. Related mainland species usually are more aggressive and competitive, and have less specific habitat requirements, than island species. When related species arrive on an island, extinction of the island varieties usually follows (Moors and Atkinson 1984, Blackburn et al. 2004, 2005).

Several mammal species currently inhabiting the islands are close to the limit of their capacity to survive, probably as a consequence of weather patterns that are changing faster than the species' capability to adapt to the changes (Álvarez-Castañeda 1997). Hence, for many endangered species, a small change in habitat—plant cover composition, introduction of nonnative species, new diseases, or an unusually strong dry period, for example—could provide the final push into extinction.

Before the Escalera Nautica project was formalized, some recommendations were made in an attempt to avoid the extinction of species at risk (Álvarez-Castañeda and Ortega-Rubio 2003). Options include (a) establishment of a captive breeding program of endangered endemic species, (b) strict

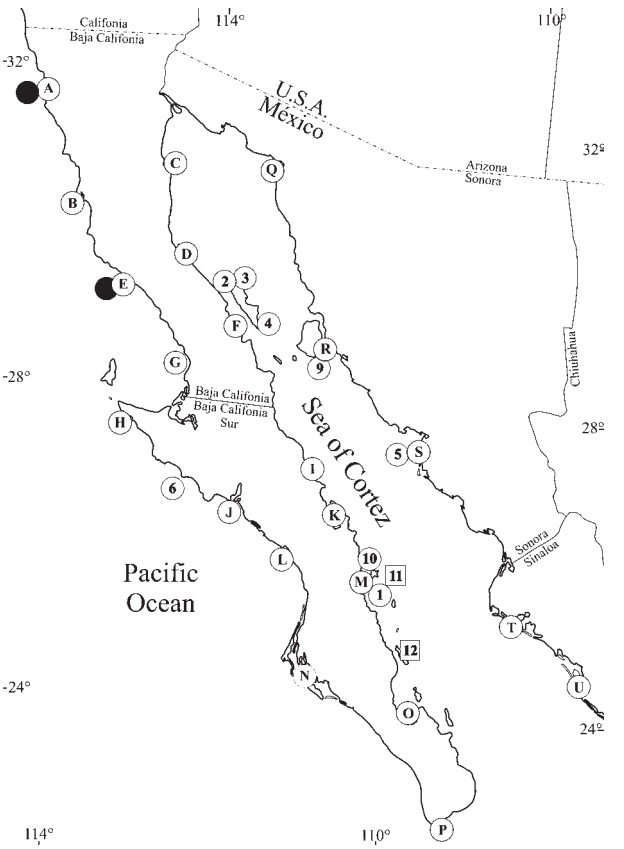

Figure 1. Distribution of recently extinct (shaded circles) and possibly extinct (shaded squares) rodents in northwestern Mexico: (1)* Chaetodipus baileyi fornicatus*, (2)* Peromyscus guardia mejiae*, (3)* P. guardia harbinsoni*, (4)* P. guardia*, (5)* Peromyscus pembertoni*, (6)* Peromyscus maniculatus cineritius*, (7)* Neotoma anthonyi*, (8)* Neotoma martinensis*, (9)* Neotoma albigula varia*, (10)* Neotoma bunkeri*, (11)* Peromyscus slevini*, and (12)* Dipodomys insularis*. The facilities of the Escalera Nautica (open circles) will be at (A) Ensenada, (B) Cabo Colonet, (C) San Felipe, (D) San Luis Gonzaga, (E) Punta San Carlos, (F) Bahía de Los Angeles, (G) Santa Rosalita, (H) Bahía de Tortugas, (I) Santa Rosalía, (J) Punta Abreojos, (K) Mulegé, (L) San Juanico, (M) Loreto, (N) Puerto San Carlos, (O) La Paz, (P) Cabo San Lucas, (Q) Puerto Peñasco, (R) Bahía Kino, (S) Bahía San Carlos-Guaymas, (T) Huatabampo, (U) Topolobampo, (V) Altata, (W) Mazatlán, and (X) Teacapán (last three are not shown on the map). The most important seabird breeding colonies are in the areas of Middle Rift, Guaymas, Loreto, and La Paz (gray rectangles).

control of human access to islands that harbor species at risk, and (c) habitat restoration and cat extirpation programs. Supervision of fishing camps on the islands is also necessary, because most nonnative species were introduced by fishermen, either accidentally (e.g., *Mus musculus* and *Rattus rattus*) or intentionally (e.g., *Lepus californicus* on Cerralvo, *Caprinus* and *Felis catus*) by fishermen. This casual introduction of nonnative species has devastated endemic species. Annual surveys and a program for monitoring the native vertebrate populations of the Gulf of California islands were also strongly recommended (Álvarez-Castañeda and Ortega-Rubio 2003).

The Mexican tourism ministry gave the environmental ministry an environmental impact assessment report (EIAR) for the integrated Escalera Nautica project, which the environmental ministry approved. Therefore, the Escalera Nautica project will most likely become a reality. However, because of the broad scope of this regional EIAR and the large area that the project encompasses, the environmental authorities offered no specific measures to ameliorate, mitigate, or avoid the greater risk of extinction to endangered mammal, reptile, and bird species. We believe that the general measures suggested by project developers, as well as the general recommendations of the environmental authorities, are not adequate to cope with the increased risk of extinction for endangered island species.

Mexican authorities—including environmental personnel and rangers, police, and naval units—have insufficient resources, in terms of numbers, compensation, facilities, and equipment (air and sea vessels), to improve the level of protection of the islands. There is little supervision now of the activities of the 5000 boats arriving annually near the islands. Is it reasonable to expect that vigilance will be improved enough to cope with the arrival of 70,000 boats a year? The Mexican economy is currently very weak—this is the third year of a deep recession. The economic resources devoted to environmental research and protection shrinks each year.

What *can* be done to protect endemic and at-risk species? We propose the following:

- Levy an environmental protection fee on each boat arriving in the Gulf of California. This tax will vary in accordance with the size of the boat, the number of crew members, and the length of the stay in the protected area.
- Use all the funds generated by the fee directly for law enforcement patrols, environmental education, and conservation programs in the region, and specifically for habitat conservation on islands designated as a priority for conservation.
- Prohibit unregulated landings on the following islands, because our analyses show that they are the most fragile: San Francisco, Santa Cruz, San Diego, Danzante, Animas, Salsipuedes, Datíl, and San Luis Gonzaga. The only way to land at these islands will be through a weekly guided tour authorized by the environmental authorities. A Mexican naval boat will be stationed near each island, and each tourist wishing to visit the island must use this boat as the point of entry for going ashore. No pets will be allowed ashore. A Mexican biologist will explain the history and current status of ecological relationships on the island. The guide will ensure that all tourists follow the designated paths, prevent them from leaving trash or accidentally introducing exotic species, and enforce the "no natural souvenirs" regulations.
- Use the environmental fees collected on these eight islands to develop an endemic species breeding program and a restoration program, including removal or elimination of pests.

If these obvious, logical proposals are not implemented, the Escalera Nautica project will most likely bring about the extinction of the endemic and endangered mammals of the Gulf of California and the Pacific coastal islands. Although our proposals have been publicized—in part, by the Mexican environmental protection agency (Secretaría de Medio Ambiente y Recursos Naturales)—we remain concerned about the environmental tragedy that could occur in the absence of adequate protections.

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References cited

Álvarez-Cárdenas S, Galina P, Ortega-Rubio A, Castellanos-Vera A. 2000. Conservation of Isla Socorro Mexico: The impact of domestic sheep on the native plant communities. Texas Journal of Science 52: 293–302.

Álvarez-Castañeda ST. 1997. Diversidad y conservación de mamíferos terrestres en el estado de Baja California Sur, México. PhD dissertation. Universidad Nacional Autónoma de México, Mexico.

Álvarez-Castañeda ST, Cortés-Calva P. 1996. Anthropogenic extinction of the endemic deer mouse, *Peromyscus maniculatus cineritius,* on San Roque island, Baja California Sur, Mexico. Southwestern Naturalist 41: 459–461.

Álvarez-Castañeda ST, Ortega-Rubio A. 2003. Current status of rodents on islands in the Gulf of California. Conservation Biology 109: 157–163.

Álvarez-Castañeda ST, Patton JL. 1999. Mamíferos del Noroeste de México. La Paz (Mexico): Centro de Investigaciones Biologicas del Noroeste.

Arnaud G, Rodriguez G, Ortega-Rubio A, Álvarez-Cardenas S. 1993. Predation by cats on the unique endemic lizard of Socorro Island (*Urosaurus auriculatus*), Revillagigedo Mexico. Ohio Journal of Science 93: 101–104.

Blackburn TM, Cassey P, Duncan RP, Evans KL, Gaston KJ. 2004. Avian extinction and mammalian introductions on oceanic islands. Science 305: 1955–1958.

———. 2005. Response to comment on "Avian extinction and mammalian introductions on oceanic islands." Science 307: 1412.

Case TJ, Cody ML, Ezcurra E, eds. 2002. A New Island Biogeography of the Sea of Cortés. New York: Oxford University Press.

Cody ML, Ezcurra E, eds. 2002. A New Island Biogeography of the Sea of Cortés. New York: Oxford University Press.

Cody ML, Velarde E. 2002. Land birds. Pages 271[end[312 in Case TJ, Cody ML, Ezcurra E, eds. A New Island Biogeography of the Sea of Cortés. New York: Oxford University.

Cody ML, Moran R, Thompson H. 1983. The plants. Pages 63–111 in Case TJ, Cody ML, eds. Island Biogeography of the Sea of Cortez. Berkeley: University of California Press.

[DOF] Diario Oficial De la Federación. 1978. DECRETO por el que se establece una zona de reserva y refugio de aves migratorias y de la fauna silvestre, en las islas que se relacionan, situadas en el Golfo de California. 2 August. Mexico City, Mexico.

Grismer LL. 2002. Amphibians and Reptiles of Baja California, Including Its Pacific Islands and the Islands in the Sea of Cortés. Berkeley (CA): University of California Press.

Konecny MJ. 1987. Home range and activity patterns of feral house cats in the Galapagos Islands. Oikos 50: 17–23.

Leon de la Luz JL, Dominguez-Cadena R. 2006. Herbivory of feral goats on Isla Espiritu Santo, Gulf of California, Mexico. SIDA 22. Forthcoming.

Leon de la Luz JL, Rebman JP. 2002. Appendix 4.2, Vascular flora of Cerralvo Island. Pages 512–526 in Case TJ, Cody ML, Ezcurra E, eds. A New Island Biogeography of the Sea of Cortés. New York: Oxford University Press.

Lima M, Jaksic M. 1998. Population variability among three small mammal species in the semiarid Neotropics: The role of density-dependent and density-independent factors. Ecogeography 21: 175–180.

Meserve PL, et al. 1995. Heterogeneous responses of small mammals to an El Niño Southern Oscillation event in Northcentral semiarid Chile and the importance of ecological scale. Journal of Mammalogy 76: 580–595.

Moors PJ, Atkinson IAE. 1984. Predation on seabirds by introduced animals, and factors affecting its severity. Pages 667–690 in Croxall JP, Evans PGH, Schreiber RW. Status and Conservation of the World's Seabirds. Cambridge (United Kingdom): International Council for Bird Preservation.

Nogales M, Martin A, Tershy BR, Donlan CJ, Veitch D, Puerta N, Wood B, Alonso J. 2004. A review of feral cat eradication on islands. Conservation Biology 18: 10–319.

[NOM] Norma Oficial Mexicana. 2002. 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 de la Federación, 6 March.

Rebman JP. 2002. Appendix 4.5. Pages 540–544 in Case TJ, Cody ML, Ezcurra E, eds. A New Island Biogeography of the Sea of Cortés. New York: Oxford University Press.

Rebman JP, Leon de la Luz JL, Moran RV. 2002. Appendix 4.1. Pages 465–511 in Case TJ, Cody ML, Ezcurra E, eds. A New Island Biogeography of the Sea of Cortés. New York: Oxford University Press.

Rodríguez-Estrella R, Grajales-Tam K, Rodríguez-Moreno A. 2000. Spring diet of the endemic ring-tailed cat (*Bassariscus astutus insulicola*) population on an island in the Gulf of California, Mexico. Journal of Arid Environments 44: 241–246.

Salinas-Zavala CA, Lluch Belda D, Hernandez-Vazquez S, Lluch-Cota DB. 1998. La aridez en el Noroeste de Mexico: Un análisis de la variación especial y temporal. Atmosfera 11: 29–44.

Smith FA, Charnov EL. 2001. Fitness trade-offs select for semelparous (suicidal) reproduction in an extreme environment. Evolutionary Ecology Research 2: 595–602.

Tershy BR, Breese D, Croll DA. 1997. Human perturbations and conservation strategies for San Pedro Mártir Island, Islas del Golfo de California Reserve, México. Environmental Conservation 24: 261–278.

Tershy BR, Bourillon L, Metzler L, Barnes J. 1999. A survey of ecotourism on islands in northwestern México. Environmental Conservation 26: 212–217.

Van Devender TR. 1997. 21,000 years of vegetation change in the northern Vizcaino, Baja California. Paper presented at the Second Annual Botanical Symposium; 14–16 August 1997, San Diego, California.

Van Rensburg PJJ, Bester MN. 1988. The effect of cats *Felis catus* predation on three breeding Procellariidae species on Marion Island. South Africa Journal of Zoology 15: 261–278.

Vázquez-Domínguez E, Ceballos G, Cruzado J. 2004. Devastating alien predators on islands: The case of the Mexican endemic deer mouse, *Peromyscus guardia.* Oryx 38: 347–350.

[WCMC] World Conservation Monitoring Centre. 1992. Global Biodiversity: Status of the Earth's Living Resources. London: Chapman and Hall.