

History and Status of Introduced Mammals and Impacts to Breeding Seabirds on the California Channel and Northwestern Baja California Islands

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Abstract.—The California Channel Islands, U.S.A., and Northwestern Baja California Islands, Mexico, host important breeding populations of several seabird species, including the endemic Black-vented Shearwater (*Puffinus opisthomelas*) and Xantus' Murrelet (*Synthliboramphus hypoleucus*). Mammals introduced to nearly all of the islands beginning in the late 1800s to early 1900s include: cats (*Felis catus*), dogs (*Canis familiaris*), Black Rats (*Rattus rattus*), rabbits and hares (Leporidae), goats (*Capra hircus*), sheep (*Ovis aries*), and other grazers. Cats, dogs and rats are seabird predators, grazers such as goats and sheep cause habitat degradation, and rabbits destroy habitat and compete with hole-nesting seabirds. Cats, which were introduced to at least 19 islands and currently occur on ten islands, have had the greatest impacts on seabirds, including the extinction of the endemic Guadalupe Storm-Petrel (*Oceanodroma macrodactyla*). Cats are known to have eliminated or severely reduced colonies of Black-vented Shearwaters, Cassin's Auklets (*Pychoramphus aleuticus*) and Xantus' Murrelets. Black Rats have occurred on a minimum of seven islands and have reduced numbers of small, hole-nesting alcids on at least one island. At many islands, defoliation and erosion caused by rabbits and large grazing mammals has been severe. Their effects on seabirds are not well documented but potentially are serious. Impacts from introduced mammals have been most severe on islands with no native mammalian predators. On the Northwestern Baja California Islands, temporary and permanent human settlements have led to a greater diversity and source of introductions. Programs to remove introduced mammals and to reduce the possibility of future introductions are needed to restore seabird populations and to preserve the biodiversity of the region. Surveys are needed particularly on the Northwestern Baja California Islands to update the status and distribution of seabirds and to further assess impacts from introduced mammals. Received 18 May 1998, accepted 20 July 1998.

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The California Channel Islands, United States and the islands off northwestern Baja California, Mexico (hereafter, collectively the California Islands) harbor a diverse assemblage of at least 18 extant and two recently extinct or extirpated species of breeding seabirds (Hunt *et al.* 1980, 1981; Everett and Anderson 1991; Carter *et al.* 1992; Table 1, Fig. 1). Two species are endemic breeders in the region and have small world population sizes: Black-vented Shearwater (*Puffinus opisthomelas*) and Xantus' Murrelet (*Synthliboramphus hypoleucus hypoleucus* and *S. h. scrippsii*). The extinct Guadalupe Storm-Petrel (*Oceanodroma macrodactyla*) occurred only on Guadalupe Island. Other species whose breeding ranges

extend just outside the region include: Ashy (*O. homochroa*), Black (*O. melania*) and Least (*Haloccyptena microsoma*) storm-petrels, and Craveri's Murrelet (*S. craveri*). About half of the world population of the Ashy Storm-Petrel breeds on the California Channel Islands (Carter *et al.* 1992). Black and Least storm-petrels and Craveri's Murrelet breed mostly in the Gulf of California, with isolated colonies in the region (Everett and Anderson 1991).

Historically, many of the California Islands were free of major mammalian predators. The relatively small, endemic Island Fox (*Urocyon littoralis*) occurs abundantly on San Miguel, Santa Rosa, Santa Cruz, San Nicolas, Santa Catalina, and San Clemente islands

(von Bloeker 1967; Roemer *et al.* 1994). The rare Island Spotted Skunk (*Spilogale gracilis amphiala*) occurs on Santa Rosa and Santa Cruz islands (von Bloeker 1967; Crooks and van Vuren 1994). Otherwise, only small mammals occurred on the islands. Beginning as early as the 1700s, however, several species of exotic mammals were introduced to many of the islands, including: cats (*Felis catus*), dogs (*Canis familiaris*), rats (*Rattus* spp.), sheep (*Ovis aries*), goats (*Capra hircus*), cattle (*Bos* sp.), pigs (*Sus scrofa*), European Rabbits (*Oryctolagus cuniculus*) and European Hares (*Lepus europaeus*). Mammals such as foxes, feral cats, and rats often deplete or exclude many seabirds from breeding in areas where these predators occur, preying on adults, young or eggs (e.g., Moors and Atkinson 1984; Bailey 1993). Smaller species, such as storm-petrels and the smaller alcid, are most vulnerable to mammalian predation. Ungulates and rabbits have caused large-scale damage to vegetation and soil erosion on several islands (e.g., Sumner 1958; Jehl and Everett 1985; Coblenz 1980; Klinger *et al.* 1994; Schwartz 1994) and may affect seabirds through habitat destruction. Rabbits also may compete with seabirds for nesting burrows and rock crevices (Ainley and Lewis 1974). In this paper, we review the history and status of introduced mammals on the California Islands and their known or potential impacts on seabirds.

STUDY AREA

The California Channel Islands extend roughly from Point Conception, California (34°17'N, 120°28'W) to the United States-Mexico border (Fig. 1). The four Northern Channel and Santa Barbara islands are within the Channel Islands National Park, San Nicolas and San Clemente islands are active U.S. Navy bases, and Santa Catalina Island is privately-owned. The Northwestern Baja California Islands include the coastal islands between the border and Point San Roque, Baja California Sur (27°11'N, 114°26'W), and the offshore Guadalupe Island (29°05'N, 118°18'W). Most are government-owned and managed by the National Protected Areas Office. Los Coronados, North Todos Santos, Cedros and Guadalupe islands have active Mexican Navy garrisons. Natividad, San Roque and Asunción islands lie within the recently-established Vizcaino Biosphere Reserve but remain largely unprotected. The main islands of the study area range in size from about 0.4 to 348 km², and most islands have small numbers of outlying islets. The region in general receives low

amounts of annual rainfall, with desert-like conditions and sparse vegetation on most of the coastal Baja California islands.

METHODS

To summarize the history of mammalian introductions on the California Islands, we relied on published and unpublished literature as well as personal communications from researchers who have visited the islands. For more current information, we relied mostly on recent literature and our own experiences. McChesney and colleagues have conducted seabird research on the California Channel Islands since 1991. Tershy and colleagues have visited most of the Northwestern Baja California Islands since 1993, conducted surveys of seabirds, introduced mammals and other species, conducted removals of introduced mammals, and interviewed several island residents and fishermen. Since no detailed studies on interactions between seabirds and introduced mammals have been conducted on the California Islands, we relied on a combination of largely anecdotal observations, recent surveys at some islands, and other studies to assess impacts or potential impacts of introduced mammals.

RESULTS

Feral cats

Feral cats are known to have occurred on at least 19 and currently occur on at least ten of the California Islands (Table 2). In particular, most of the Northwestern Baja California Islands have harbored populations of feral cats. Anthony (1925: 279) reported that "within the past 25 years the fishermen of the Lower California coast, chiefly Japanese, have introduced cats on every island north of Magdalena Bay, and the effect is noticeable at this early day." Currently, fishing camps, military garrisons, small villages and other developments occur on most of the Northwestern Baja California Islands (Table 2), resulting in a continuing source for introductions.

Anacapa Island—On West Anacapa Island, small numbers of cats were introduced around the 1930s by the island's sole resident (Banks 1966; Anderson *et al.* 1989). By the late 1960s, only one cat remained, which apparently died in 1975 or 1976 (Anderson *et al.* 1989). The cats' impact on seabirds is unknown but several species were at risk (Table 1). Anderson *et al.* (1989) found no bird remains in nine fecal samples collected during the Brown Pelican (*Pelecanus occidentalis*)



Figure 1. Map of the California Channel Islands and Northwestern Baja California Islands.

breeding season in 1971-75, but their sample size was small and by this time populations of the smaller seabirds likely were already reduced by introduced rats (see below).

Santa Barbara Island—Cats were introduced on the main island about 1900. Philbrick's (1972) report that cats were abundant before 1896 did not provide addi-

tional details. Visits in 1897 (Grinnell 1897) and 1899 (Robertson 1903) documented large numbers of breeding seabirds, including a large colony of Cassin's Auklets. However, by 1908 cats had destroyed the auklet colony (Willett 1912; Howell 1917) and Howell (1917: 22) stated that Xantus' Murrelets were "... surely destined to be driven

COLONIAL WATERBIRDS

Table 1. Breeding seabirds of the California Islands and the islands where they occur. X, present; E, extirpated or extinct; (E?), not known to occur at present, possibly occurred historically.¹

Species	San Miguel	Santa Rosa	Santa Cruz	Anacapa	Santa Barbara	San Nicolas	Santa Catalina	San Clemente	Los Coronados	Todos Santos	San Martin	San Gerónimo	San Benitos	Cedros	Natividad	San Roque	Asunción	Guadalupe	
Laysan Albatross																			
Black-vented Shearwater																			X
Leach's Storm-petrel	X				X				X						X				X
Ashy Storm-petrel	X		X	?			X		X										X
Black Storm-petrel					X				X										X
Guadalupe Storm-petrel																			
Least Storm-petrel																			E
Brown Pelican					X				X										
Double-crested Cormorant	X	X	E	X	X				X	E					X				E?
Brandt's Cormorant	X	X	X	X	X		E		X	X					X				X?
Pelagic Cormorant	X	X	X	X	X	X	E		X	X					X				X
Heermann's Gull																			
Western Gull	X	X	X	X	X				X	X									X
Common Murre	E					X		X	X						X				X
Pigeon Guillemot	X	X	X	X	X				X										
Xantus' Murrelet	X?		X?	X?	X?		X?		X?										
Crawley's Murrelet																			
Cassin's Auklet	X		X	?	X				X	X									X?
Rhinoceros Auklet	X		X		X				X										
Tufted Puffin	X		E	E	E				X						E				E

¹Sources: Bancroft (1987); Grinnell (1928); Jehl and Bond (1975); Hunt et al. (1980); Everett and Anderson (1991); Carter et al. (1992, 1995; unpublished data); McChesney and H. R. Carter (unpublished data); McChesney et al. (1995); Tershy (unpublished data).
²Subspecies *Synthliboramphus hypoleucus scrippsii*.
³Subspecies *Synthliboramphus hypoleucus hypoleucus*.

Keith 1999 Xantus report

Probably Nesting based on vocalizations

X
E?
E?
E?

Table 2. Current and extirpated introduced mammals and human occupation of the California Islands.

Island name	Current	Extirpated	Human occupation
CALIFORNIA CHANNEL ISLANDS¹			
San Miguel Island	Black Rats	Cats (domestic), sheep, pigs, horses	CINP ²
Santa Cruz Island	Sheep, pigs, horses	Cats (domestic)	The Nature Conservancy, CINP
Santa Rosa Island	Cattle, deer, elk	Sheep, pigs	CINP, Ranching
Anacapa Island			
East Anacapa I.	Black Rats	Rabbits, sheep	CINP
Middle Anacapa I.	Black Rats	Sheep	CINP
West Anacapa I.	Black Rats	Cats, sheep	CINP
Santa Barbara Island	None	Cats, rabbits, sheep, goats, pigs	CINP
San Nicolas Island	Cats	Sheep, horses	U.S. Navy
Santa Catalina Island	Cats, Black and Brown rats, goats, cattle, Bison, horses	Sheep	Residential, Santa Catalina Island Conservancy
San Clemente Island	Cats, Black Rats	Goats, sheep	U.S. Navy
NORTHWESTERN BAJA CALIFORNIA ISLANDS			
Los Coronados Islands			
North Coronado I.	None	Cats (1995-96) ³	None (formerly, temporary fishing camp)
Middle Coronado I.	None		None
South Coronado I.	Cats, dogs, goats, burros	Rabbits?	Mexican Navy, Lighthouse
Todos Santos Islands			
North Todos Santos I.	Cats, dogs, burros, rabbits	Goats	Mexican Navy, Lighthouse
South Todos Santos I.	Dogs	Cats (1998) ³ , Rabbits (1998) ³	Abalone farm
San Gerónimo Island	Cats, dogs, burros		Permanent fishing camp
San Martín Island	Cats, dogs, rabbits		Permanent fishing camp
San Benito Islands			
East Benito I.	Rabbits	Cats	None
Middle Benito I.	None	Cats, rabbits (1998) ³	None
West Benito I.	Dogs, burros (corraled, 1998)	Cats, goats (1998) ³ , rabbits (1998) ³	Permanent fishing camp

¹All California Channel Islands formerly were ranches extensively.

²CINP, Channel Islands National Park. Includes personnel housing, maintenance, camping and other recreation.

³Removal by Mexican Instituto Nacional de Ecología and the Island Conservation and Ecology Group.

⁴Removal in progress.

⁵Removal by Vizcaino Biosphere Reserve, Island Conservation and Ecology Group, and the local fishing cooperative.

Table 2. (Continued) Current and extirpated introduced mammals and human occupation of the California Islands.

Island name	Current	Extirpated	Human occupation
Natividad Island	Cats ^{4,5} , dogs	goats (1998) ⁵ , sheep (1998) ⁵	Town, fish cannery
Cedros Island	Cats, dogs, rats, goats, burros	Cats (1994) ⁵ , rats (1994) ⁵	Large town, factories, Mexican Navy
San Roque Island	None	Cats (1994) ⁵	None
Asunción Island	None	Cats (1994) ⁵	None
Guadalupe Island	Cats, dogs, Black and brown rats, House Mice, goats		Mexican Navy, town

¹All California Channel Islands formerly were ranched extensively.

²CINP, Channel Islands National Park. Includes personnel housing, maintenance, camping and other recreation.

³Removal by Mexican Instituto Nacional de Ecología and the Island Conservation and Ecology Group.

⁴Removal in progress.

⁵Removal by Vizcaino Biosphere Reserve, Island Conservation and Ecology Group, and the local fishing cooperative.

from this locality, as have the auklets, by the cats." An eradication program severely reduced the cat population by the 1950s (Sumner 1958), and the last cat was removed in 1978 (Murray *et al.* 1983). During the cat occupation, auklets apparently persisted on adjacent, cat-free Sutil Island (Hunt *et al.* 1981). Murrelets probably persisted on Sutil and the inaccessible cliffs of Santa Barbara Island, and Sumner and Bond (1939) found the remains of a cat-killed murrelet in April 1939. Santa Barbara Island now holds the largest Xantus' Murrelet colony in the Channel Islands and Cassin's Auklets nest in small numbers (Hunt *et al.* 1980, 1981; Carter *et al.* 1992). Storm-petrels or other species also may have been affected, although the storm-petrels currently nest only in the cliffs.

Los Coronados Islands—Cats initially were known only from South Coronado Island. Probable cat predation on Xantus' Murrelets was recorded as early as 1908 (Wright 1909). On 30 June 1961, Don Bleitz (unpublished field notes) noted many murrelet and storm-petrel carcasses on South Coronado Island, which he attributed to cat predation.

Cats were introduced onto North Coronado Island in the 1970s or 1980s (Everett 1991), although earlier introductions (with subsequent extirpations) may have occurred. R. L. Pitman (unpublished data) estimated no more than ten feral cats in 1989-1990. Of the most vulnerable species, Leach's (*Oceanodroma leucorhoa*) and Black storm-petrels, Xantus' Murrelets, and Cassin's Auklets were recorded as breeders on North Coronado Island (Grinnell and Daggett 1903; van Rossem 1915; Stephens 1921; DeLong 1968a). Ashy Storm-Petrel also may breed (Jehl 1977; Everett and Anderson 1991; Carter *et al.* 1996). Leach's Storm-Petrels were last reported on North Coronado Island in 1902 (Grinnell and Daggett 1903) and were extirpated by 1915 (van Rossem 1915), although they still occur on cat-free Middle Rock (Everett 1991) and probably on Middle Island (van Rossem 1915; DeLong 1968a). The large Cassin's Auklet colony was reported at least until 1921 (Stephens 1921) but subsequently was extirpated (Jehl 1977) for unknown reasons

(possibly cat predation). Auklets were recently rediscovered in small numbers on Middle Rock (Everett 1991; Everett and Anderson 1991). On North Coronado Island, R. L. Pitman (unpublished data) collected 174 and 30 cat-depredated Xantus' Murrelets in 1989 and 1990, respectively, as well as 285 Black, two Ashy and two Leach's storm-petrels. Pitman also estimated that cats kept murrelet populations to about ten percent of potential, based on habitat availability. In 1995-1996, the Mexican Instituto Nacional de Ecología and the Island Conservation and Ecology Group trapped and removed all 38 cats found on North Coronado Island.

Todos Santos, San Martín, and San Gerónimo islands—At the Todos Santos Islands, Howell (1912) found no cats on a visit from 15-20 April 1910. However, following a 24-30 May 1923 visit, van Denburgh (1924: 68) reported on their introduction and speculated that cats would "... soon exterminate the native mammals, reptiles, and smaller birds" of the Todos Santos. On South Todos Santos Island, van Denburgh (1924) found the remains of several cat-killed Xantus' Murrelets, J. Jehl (pers. comm.) noted cat-killed Cassin's Auklets in the 1970s and in March 1984, and in May 1997 Tershy (unpubl. data) found the fresh remains of a murrelet that was probably a cat-kill.

Xantus' Murrelets historically bred on all three islands (Kaeding 1905; Table 1). Jehl and Bond (1975) suggested murrelets were extirpated from these islands by cats or rats, although no known surveys have been done for this or other hole-nesting species in recent decades. Cassin's Auklets also have bred on these islands, with a very large colony on San Gerónimo (Kaeding 1905; Willett 1913; Everett and Anderson 1991). Cats likely have impacted these colonies (e.g., Jehl 1984), and the San Martín Island colony probably no longer exists (Everett and Anderson 1991).

San Benito Islands—Cats were reported as abundant on all three islands in August 1922 and had killed large numbers of storm-petrels and Black-vented Shearwaters (Anthony 1925; Hanna 1925). The lack of cat

reports from surveys in 1968 (DeLong 1968b; DeLong and Brownell 1968) may indicate their extirpation by that time. Observations of cats on West Benito Island in the late 1960s or early 1970s (J. Jehl, pers. comm.) and 1980s (W. T. Everett, pers. comm.) indicated possible reintroduction or continued survival at low numbers. However, cats have not been present since at least 1992 (Tershy, pers. obs.).

Natividad Island—Cats caused havoc in the massive Black-vented Shearwater colony as early as 1924 (Bancroft 1927). Banks (1964) in 1963, DeLong (1968c), and DeLong and Crossin (1968) in 1968 noted remains of large numbers of cat-killed shearwaters about the colony. DeLong and Crossin (1968: 2) saw about 20 cats "... hunting in one colony on the northeast end of the island" in April 1968, and in June 1968 DeLong (1968c) estimated a population of ca. 100 cats. In July 1987, Everett (1988) noted an abundance of dried scat but no live cats. Cat removal was initiated in 1998.

Cedros, San Roque and Asunción islands—Feral and pet cats are widespread and numerous in the large town on Cedros Island. Cats occurred on San Roque (introduced in the 1970s) and Asunción islands and exterminated large colonies of Cassin's Auklets and possibly other hole-nesting species sometime before 1992. Removal efforts were started in the late 1980s by Instituto Nacional de Ecología in collaboration with local fisherman and hunters. Funding for this ran out but hunting was continued by a local fisherman, Francisco Morales. In 1994, the newly-formed Vizcaino Biosphere Reserve and Island Conservation and Ecology Group trapped and removed the remaining cats.

Guadalupe Island—Feral cats were introduced early in the island's human history. Thayer and Bangs (1908: 102) reported that cats were introduced "many years ago," and blamed cats in particular for the elimination of several of the island's bird species. Cats were known to prey on Guadalupe and Leach's storm-petrels, and cat predation is mainly blamed for the extinction of the endemic Guadalupe Storm-Petrel, last seen in 1912 (Jehl and Everett 1985). Fortunately,

cats are not known to occur on any of Guadalupe's offshore islets where most of the island's seabirds now occur.

Other islands—Feral cats currently occur on two or three other California Channel Islands (Table 2) that also harbor Island Fox. The impact of cats likely is less severe than on islands with no native mammalian predators.

Dogs

Domestic dogs occur on nine of the Northwestern Baja California Islands where they often roam freely. Dogs apparently have become feral on Guadalupe Island (W. T. Everett, pers. comm.) and Cedros islands. The impacts from dogs have not been well-documented. At Natividad Island, Everett (1988) noted that domestic dogs occasionally entered the shearwater colony and excavated burrows. Outside the study area, Murphy (1936) provided examples of dogs causing destruction to South American seabird colonies, and Bent (1922) noted Leach's Storm-Petrel colonies in the western Atlantic that were nearly exterminated by dogs.

Rats

Introduced rats, mostly Black (*Rattus rattus*) but also Norway (*R. norvegicus*) rats, have occurred on at least nine and currently are known to be on eight of the California Islands (Table 2).

San Miguel Island—As of the late 1980s, a small Black Rat population appeared to have been restricted to the coastline on the west end of the island, from Harris Point to Tyler Bight. Rats reside primarily among driftwood piles in back of a few beaches, but also occur among the cliff tops (Collins 1979; Erickson and Halvorson 1990). Collins (1979) noted rats using seabird nesting burrows for denning. The cliff areas south of Harris Point, where large numbers of crevice-nesting seabirds occur, may be especially vulnerable if rats occur or spread to that area.

Anacapa Island—Black Rats are fairly common on all three islands, likely introduced via shipwreck sometime between the

mid-1800s and early 1900s (Collins 1979; Erickson and Halvorson 1990; Tershy *et al.* 1998). In recent times, small alcids and storm-petrels have been almost unreported. Historically, Xantus' Murrelets may have been rather common (Howell 1917) and Hunt *et al.* (1981) summarized at least 21 egg and three bird records collected between 1911 and 1938, in addition to other records. Drost and Lewis (1995) reported rat predation on Xantus' Murrelet eggs and speculated that rats severely reduced murrelet numbers. Surveys in 1994 indicated that small populations of Ashy Storm-Petrels, Xantus' Murrelets and Cassin's Auklets still occur (H. R. Carter, unpubl. data). In 1997, rat feces and other sign found in most potential nesting sites for crevice-nesting seabirds, and depredated murrelet eggshells, suggested that rats keep populations of murrelets and other small seabirds to low levels (McChesney and H. R. Carter, unpubl. data).

Other islands—Very little information on rats exists for the other California Islands where they occur. At San Roque Island, rats were eradicated in 1994. Reports of rats at other islands, e.g., Todos Santos Islands (Howell 1912; Willett 1913), may have been endemic wood rats (*Neotoma* sp.) that occurred on Los Coronados, Todos Santos, and San Martín islands (Nelson 1922; Huey 1964). Wood rats are vegetarian species (e.g., Hoffmeister 1986) and pose little threat to seabirds.

Rabbits and Hares

Rabbits and hares were introduced to at least nine and currently occur on at least three California islands (Table 2). *Rabbits*

East Anacapa Island—European ~~Hares~~ *Hares* (*Lepus europaeus*)² were introduced during the World War II era and along with the sheep caused considerable floral damage before being removed sometime after 1965 (Banks 1966; Dowty 1990; Erickson and Halvorson 1990).

Santa Barbara Island—Belgian Hares were introduced by island ranchers between 1926 and 1928. In the 1940s the U.S. Navy introduced "New Zealand Red" European Rabbits

(Sumner 1958, 1959). Impacts from rabbits on the island were low until about 1952 when the "New Zealand Red" population exploded, and by 1955 had increased to an estimated 2,621 animals, with resultant large-scale destruction of the vegetation. In 1954 a rabbit control program was initiated by the National Park Service and U.S. Fish and Wildlife Service, and by 1957 the population was reduced to an estimated 560. In the summer of 1959, an accidental fire burned nearly all of the island and eliminated most of the remaining rabbits (Sumner 1958). The National Park Service removed the last rabbit in 1981 (Junak *et al.* 1993).

Todos Santos Islands—European rabbits have caused extensive damage to vegetation on both the North and South islands. They were removed from South Island in 1998.

San Benito Islands—European rabbits were introduced to West Island in 1991 and East and Middle islands between 1994 and 1996 by island fishermen. In this brief period they severely overgrazed most the islands' vegetation and caused the near extinction of at least one endemic plant species. Removal from West and Middle islands in 1998 appears to have been successful. Removal from East Island also is planned.

Ungulates

Other grazing mammals, such as goats, sheep, and burros (*Equus asinus*), occur on several islands, either domestically or in a feral state (Table 2). Sheep were introduced to all of the California Channel Islands in the mid-1800s, where populations sometimes reached the tens of thousands and greatly exceeded carrying capacity (e.g., von Bloeker 1967; O'Malley 1994; Klinger *et al.* 1994; Schwartz 1994). Destruction to native flora, erosion and soil compaction resulted. Currently, sheep remain only on the east end of Santa Cruz Island. A small group of domestic sheep was removed from Natividad in 1997.

A large feral goat population on San Clemente Island severely degraded biota before being eradicated in 1991 (Keegan *et al.* 1994). Feral goats were introduced to Guadalupe Island as early as the 1700s, when they

were released to provide food for sealers and other mariners. By 1875, this population numbered in the tens of thousands. Goats stripped the island nearly bare of all vegetation, resulting in the loss of much of the flora and fauna (Jehl and Everett 1985). Goats were removed from Natividad and West Benito islands in 1998.

DISCUSSION

Seabird colonial nesting and habitat selection has developed, in part, from predator pressure (e.g., Buckley and Buckley 1980). Most seabirds nest on islands or steep cliffs that are free of mammalian predators. On the California Islands, seabirds have a number of native predators that they have contended with for many centuries. On the Channel Islands, breeding seabirds are mostly limited to areas inaccessible to Island Fox. At Santa Barbara Island, Deer mice (*Peromyscus maniculatus*) prey on eggs and reduce breeding success of Xantus' Murrelets (Murray *et al.* 1983; Drost and Lewis 1995). Avian predators include Peregrine Falcon (*Falco peregrinus*), Western Gull (*Larus occidentalis*) and Barn Owl (*Tyto alba*). The introduction of other mammals posed new and often dire threats to seabirds in areas that formerly were safe havens from predatory or otherwise destructive mammals.

Cats prey on a wide range of seabirds, taking adults, eggs and chicks. All small species are highly vulnerable to cat predation, including storm-petrels, shearwaters, and alcid, but larger species also may be taken. Cats have disrupted many colonies worldwide and are capable of consuming very large numbers of seabirds, sometimes leading to complete elimination of one or more species from a nesting island (summarized in Moors and Atkinson 1984). Cats have occurred on several of the California Islands since the late 1800s and early 1900s and, among the introduced mammals, have caused the greatest impacts to seabirds. Cats eliminated colonies of Cassin's Auklets at Santa Barbara, Natividad, San Roque and Asunción islands, and caused the extinction of the endemic Guadalupe Storm-Petrel. Cats also may have elim-

inated colonies of Xantus' Murrelets at Todos Santos, San Martín, San Gerónimo and Asunción islands, and Cassin's Auklets at Los Coronados and San Martín islands. Cats have been blamed for population reductions of other seabirds at Santa Barbara (Xantus' Murrelet), Los Coronados (e.g., Xantus' Murrelets, probably storm-petrels), Todos Santos and San Gerónimo (Cassin's Auklet), Natividad (Black-vented Shearwater), and Guadalupe islands (e.g., Black-vented Shearwater, Leach's Storm-Petrel, Xantus' Murrelet). Cat predation on larger species in the region, such as pelicans, cormorants, and gulls, has not been well-documented. Anderson *et al.* (1989) reported cat predation on up to five-week old Brown Pelican chicks at Magdalena Island, but cats were not found to prey on live pelican adults, eggs or young at three other study colonies, including West Anacapa Island.

Black Rats also have been responsible for the severe reduction of many seabird nesting colonies. Examples include Dark-rumped Petrels (*Pterodroma phaeopygia phaeopygia*) on the Galapagos Islands, Bonin Petrels (*Pterodroma hypoleuca*) on Midway Island, and Kerguelen Petrels (*Pterodroma brevirostris*) on Possession Island (in the Crozet Archipelago; see Moors and Atkinson 1984 and references therein). These rats are known to take adults, chicks, and especially eggs of a number of species of varying sizes, but primarily affect smaller species. At Midway Island, Black Rats preyed on both attended and unattended eggs and caused a substantial reduction in breeding success of Bonin Petrels (Seto and Conant 1996). In the California Islands, rats, along with the cats, likely played a role in the loss of Cassin's Auklets at San Roque Island. At Anacapa Island, rats appear to greatly affect smaller species such as Xantus' Murrelets but do not appear to be a threat to larger species such as Brown Pelicans (Anderson *et al.* 1989) and Western Gulls (Channel Islands National Park, unpublished data). An increase or spread of rats at San Miguel Island could impact several species that nest among the island's cliffs.

Evidence of effects from grazing mammals is more circumstantial but potential im-

pacts cannot be ignored. Xantus' Murrelets, for example, often nest under shrubs or shrub-like vegetation (Kaeding 1905; Murray *et al.* 1983; Drost and Lewis 1995) and likely experienced habitat loss from excessive grazing by sheep, goats, and rabbits at Anacapa, Santa Barbara, San Benitos, Todos Santos, and Guadalupe islands. Competition with rabbits for nests may have further affected species such as storm-petrels, auklets, and murrelets at several islands. The larger grazers also may trample habitat and nesting burrows, and erosion and soil compaction may have longer-term effects. Rabbits also may have important indirect impacts on seabirds, because they can sustain cat populations at high levels during the late summer through early winter, when there are no breeding seabirds at the islands.

Removal of introduced mammals should be conducted whenever possible. Removal of feral cats and rats, in particular, may be necessary for the recovery and long-term viability of some populations. Populations of endemic Black-vented Shearwaters and Xantus' Murrelets, among the rarest of North Pacific seabirds, appear diminished by introduced mammals. Cassin's Auklets have been eliminated at the southern-most historic colonies, Natividad, San Roque and Asunción islands (Grinnell 1928; Everett and Anderson 1991; Tershy, unpubl. data). Most islands where impacts are substantial are less than three square kilometers in size, so that removal of feral mammals is currently feasible. Since the eradication of cats and other introduced mammals at Santa Barbara Island, seabird numbers have at least partially recovered there. The island now holds one of the largest known Xantus' Murrelet colonies (Drost and Lewis 1995) and Cassin's Auklets again breed, but only in small numbers. Recent cat eradications at North Coronado, South Todos Santos, San Roque and Asunción islands may lead to the restoration of formerly large seabird colonies. Currently, cat removal is planned or underway on three other islands.

Measures to reduce the likelihood of future introductions also are needed. In Baja California, members of fishing camps and

villages often bring cats and other domestic animals to the islands, where the potential for them to become feral is high. On some islands, cats may have experienced natural extirpations only to be reintroduced later. Rats often are introduced to islands via shipwreck or in cargo. Consequently, eradications of introduced mammals and other conservation measures for these islands must be accompanied by programs to educate island users about potential impacts of introduced species and what measures can be taken to avoid accidental introductions (see Tershy and Breese 1994; Flores 1995; Skydancer 1995; Tershy *et al.* 1997). Shipwreck response plans and rat monitoring should be developed at more sensitive islands.

Finally, managers need updated information on seabird population status for several islands in the region. Although many surveys have been conducted in the California Channel Islands in recent years (e.g., Hunt *et al.* 1980, 1981; Carter *et al.* 1992, 1995, unpubl. data; McChesney *et al.* 1995; McChesney and H. R. Carter, unpubl. data), most of the Northwestern Baja California Islands have not been surveyed in detail for three or more decades. Nocturnal, hole-nesting species such as storm-petrels and murrelets often require special sampling efforts to estimate abundance or just to determine presence. Also, to determine the effects of eradications, status assessments and monitoring should be conducted before and after eradications.

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