Howland, Baker and Jarvis Islands 25 years after cat eradication: the recovery of seabirds in a biogeographical context

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Abstract Feral cats (*Felis catus*) were eradicated from Howland, Baker and Jarvis Islands, all U.S. National Wildlife Refuges in the equatorial Central Pacific Ocean, by the 1980s. The cats were introduced during the 1930s to control rodents, and succeeded in extirpating Norway rats (*Rattus norvegicus*) and Pacific rats (*R. exulans*), but not mice (*Mus musculus*). The cats also extirpated small species of seabirds including grey-backed terns (*Onychoprion lunata*), blue noddies (*Procelsterna cerulea*), brown noddies (*Anous stolidus*), Christmas (*Puffinus nativitatis*) and Tropical (*Puffinus bailloni dichrous*) shearwaters and Polynesian storm-petrels (*Nesofregetta fuliginosa*), and ate chicks and adults of larger Pelecaniformes such as boobies and frigatebirds. With cats eradicated, the extirpated seabirds began to recolonise these islands. Grey-backed terns recolonised Jarvis Island within four years and 20 years later Polynesian storm-petrels were also thought to be breeding there. On Baker and Howland Islands, which are separated by less than 40 miles, military occupations, invasive plants, and pests, apparently made some species of birds move between the islands. However, by 1996, the seabird diversity and population levels were returning to historically recorded levels. The position of these three islands near the Equator and in the flow path of the Equatorial Undercurrent (EUC), a cold, nutrient-rich subsurface current, has enhanced the recovery of seabirds. Regional and local upwelling provides nutrients which fuels high productivity of zooplankton, the primary food of blue noddies. On occasions, severe climate-driven fluctuations can impede upwelling and deprive marine ecosystems of nutrients that in turn affects seabird productivity. The strongest El Niño on record occurred during the 1982 cat eradication effort on Jarvis Island, suppressing seabird populations and thereby helping to limit cat numbers.

Keywords: Feral cats, seabird restoration, Equatorial Undercurrent, El Niño, Central Pacific Ocean, eradication outcome, marine monuments

INTRODUCTION

This paper records the responses of seabirds to cat eradications at Howland, Baker, and Jarvis Islands, in the context of regional biogeography over a 25 year period.

These three small, isolated desert islands are located within 48 nautical miles (nm) of the equator (Fig. 1) and have experienced the destructive effects of introduced rodents, cats (*Felis catus*), and plants, guano mining, and military encampments. Following their protection (in 1973) as United States national wildlife refuges, personnel of the Pacific Reefs National Wildlife Refuge Complex began to restore these islands. In 2009 these islands were designated as part of the Pacific Remote Islands National Marine Monument, providing protection of the surrounding waters extending out to 50 nm (Bush 2009).

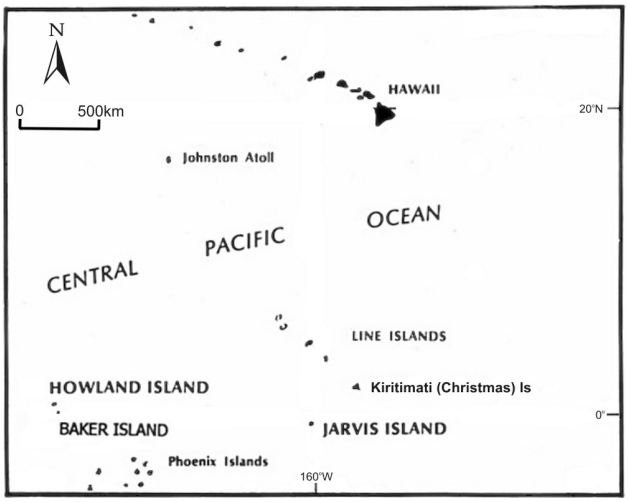

Fig. 1 Howland, Baker, and Jarvis Island locations in the Central Pacific Ocean.

Jarvis Island (0°23'S, 160°.01'W) (Fig.1) is the largest of the three islands with 445 ha of land. It is about 990 nm east of Howland and Baker Islands. Howland Island (0°49'N, 176°38'W) has an area of 162 ha and Baker Island (0°13'N, 176°31'W) has 138 ha of land. All islands are in a part of the tropical central Pacific Ocean where only low-lying atolls and submerged reefs occur.

The islands lie in the Equatorial Dry Zone. The nearest weather station is Kiritimati (Christmas) Island (Fig. 1) (USFWS 1998) where average monthly rainfall is approximately 75mm (range 0-500mm) per month, with precipitation consistent throughout the year (NOAA 1991). Howland, Baker and Jarvis are closer to the equator and drier than Kiritimati, in part because convective heating of these desert islands repels rain squalls.

All three islands share a common human history, as well as geography. Howland was visited by ancient Polynesian voyagers, as evidenced by an introduced population of kou trees (*Cordia subcordata*) and Pacific rats (*Rattus exulans*). It is likely that Baker and Jarvis were also visited (Hutchinson 1950), but the islands were too dry for permanent habitation. Whaling ships visited these islands in the early part of the 19th Century and ships were wrecked on them, probably introducing Norway rats (*R. norvegicus*) (Hague 1862).

Knowledge of historical numbers and species of wildlife is limited to a few historical accounts by early visitors, who noted the great abundance of seabirds and mined vast amounts of guano (Table 1). After more than a century of ecological degradation, small ground-nesting seabirds were extirpated and there was reduction in abundance of all birds (Hague 1862).

Cats were introduced to all three islands in 1936 for rodent control. They did not survive on Baker, and were eradicated from Howland by 1986 and Jarvis by 1990 (Table 1). Rats died out on all three islands, but house mice (*Mus musculus*) remain (Table 1).

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Table 1 Historical timeline of introduction and eradication of predators, and selected human activities at Howland, Baker and Jarvis Islands.

Year	Howland	Baker	Jarvis
Pre-history	*Rattus exulans* introduced		
Early 1860s	Guano miners and whalers brought rodents. Species and islands not specified		
1858 - 1878	104,000 tons guano taken	300,000 tons guano taken	300,000 tons guano taken
1935	All three islands colonised, cats introduced		
		Norway rats named as present	
Post WW II	Cats probably exterminated Pacific rats	Cats probably exterminated Norway rats. Mice remain	
1963 -– 64	Cats removed from these two islands		211 cats killed (80% of popn)
1965	Cats allegedly introduced to these two islands by military		
1965		Mosquitoes introduced, island sprayed with DDT	
1982	Cats present	Cats died out naturally by now	118 cats killed (99% of popn)
1986	Final 17 cats killed		
1990			Last cat killed
2010	No introduced predators		Mice still present

METHODS AND MATERIALS

During irregular visits bird counts were non-standardised and were dependent on the number of observers and time on the island. Usually, there was insufficient time to do a complete census: only a description of which species were breeding and estimated numbers. At other times, teams walked abreast across swaths of land, tallying all species and numbers seen, until the island was completed surveyed. During the spring, when the largest numbers of birds were breeding, it took three to four days and nights for two people to count most of the birds, and in the autumn at one to two days to cover an island. Observer techniques, flock seasonality and El Niño events confounded estimation of sooty tern numbers.

RESULTS

Jarvis Island

On Jarvis Island the diversity of seabirds changed from 6-7 breeding species in 1982 to 14-15 species breeding in 2004. The species diversity has doubled and is now a full seabird community (Table 2).

The removal of most cats from Jarvis in 1982 (and the last one by 1990) was followed by a rapid increase in numbers of ground-nesting lesser frigatebirds (*Fregata ariel*). By 2004, there were two large lesser frigatebird colonies estimated to contain about 4000 birds. Colony phenology was variable; with birds at one colony beginning courtship whilst those at the other had post-fledging chicks.

Table 2 Seabird counts at the time of cat eradication for Jarvis, Baker, and Howland Islands and subsequent seabird counts on each island several years after cat eradication. The numbers represent the largest count of birds documented on a single trip but not the total population, as birds nest throughout the year.

Scientific Name	Common Name	Jarvis 1982	Jarvis 2004	Baker 1965	Baker 2002	Howland 1986	Howland 2007
Phaethon rubricauda	Red-tailed tropicbird	2500	2500	15	72	122	496
Sula dactylatra	Masked booby	3000	7000	400	3134	2387	3763
Sula leucogaster	Brown booby	500	2000	10	375	15	275
Sula sula	Red-footed booby	550	1000	1	714	41	825
Fregata minor	Great frigatebird	50	2400	3	900	0	550
Fregata ariel	Lesser frigatebird	1500	4000	0	16,200	0	3850
Onychoprion fuscatus	Sooty tern	1,000,000	+1,000,000	6000	1,600,000	0	150,000
Onychoprion lunatus	Grey-backed tern	6	1100	25	2000	0	2000
Anous stolidus	Brown noddy	1	10,000	1000	3600	50	1000
Procelsterna cerulea	Blue noddy	1	650	0	26	0	11
Gygis alba	White tern	12	11	0	38	2	50
Nesofregetta fuliginosa	Polynesian storm-petrel	1*	3	0	0	1	0
Puffinus nativitatis	Christmas shearwater	0	20	0	0	0	0
Puffinus bailloni	Tropical shearwater	0	20	0	0	0	0
Puffinus pacificus	Wedge-tailed shearwater	100	41	0	10	0	1*

*Birds found dead
Sources: Clapp and Sibley 1965; Forsell and Berendzen 1986; Sibley and Clapp 1965; Skaggs 1994; US Fish and Wildlife Service 2007

Masked boobies (*Sula dactylatra*) are now widely scattered over Jarvis. The 2004 estimate of 5000 includes several 'clubs' or groups of roosting birds of 1000 or more individuals and represents one of the largest colonies in the world. In 1977, Forsell found hundreds of masked booby carcasses scattered about Jarvis Island. Most were adults, as indicated by the >50 USFWS bands found on the remains. Band recoveries at the 'club' on Jarvis included some from non-breeding birds from Howland and Baker Islands. Cats were observed hunting in groups of up to 20 individuals, killing adult masked boobies (R. Clapp pers. comm.).

In 1982, cats also preyed heavily on sooty terns (*Onychoprion fuscatus*), but by 2004 several hundred thousand were estimated to be in flight over Jarvis. Other visitors have recently estimated numbers of sooty terns there at more than one million individuals (USFWS 2007).

Grey-backed terns (*O. lunata*) were seen occasionally on Jarvis Island when cats were still present. In 1986, biologists found the first grey-backed tern breeding colony of 18 pairs. In 1990, about 50 pairs bred. In 1996, about 100 nests were found at all stages, and by 2004, several hundred birds were breeding.

Brown noddies (*Anous stolidus*) increased from two in 1982 to more than 300 birds in 1986 and by 2004 several thousand were widely scattered over Jarvis Island. Blue noddies (*Procelsterna cerulea*) have also dramatically increased. In 1990, a colony of 36 birds were counted with 11 nests. In 1996, 100 birds were counted. In 2004, we estimated 650, with 274 birds counted at one site.

Procellariiformes were the last seabirds to recover. In 1992 tropical shearwater (*Puffinus bailloni dichrous*, formerly Audubon's, Austin *et al*. 2004) were found nesting. There were no previous records of this species at Jarvis although they nest at Kiritimati. Polynesian storm-petrels, which also nest at Kiritimati, had not been reported alive from Jarvis Island since the 1930s (Bryan 1974) until 2002, when three were seen under coral slabs on the beach crest. None were seen during visits in 2004, 2006 and 2010.

Howland and Baker Islands

The first bird survey of Howland, by the Whippoorwill Expedition in September 1924, recorded 11 breeding species. Expedition members were unable to land on Baker Island, but made estimates from their vessel.

Fig. 2 Pacific crabgrass (*Digitaria pacifica*) covers Howland Island in 1988.

Military activities on Baker Island during World War II eliminated nesting seabirds and by the 1960s, only a few brown noddies were nesting on a small islet in a man-made lagoon, inaccessible to cats. In July 1964, when the cat population had been reduced from 30+ to 4, blue-faced boobies (200 birds, 10 nests), red-tailed tropicbirds (10 birds, 1 nest) and grey-backed terns (3 nests) were nesting, in addition to the noddy terns in the small lagoon (POBSP 1964). In the 1930s, the Pacific crabgrass (*Digitaria pacifica*) was extensive on Baker Island, but not on Howland Island (E. Bryan pers. comm.), suggesting that Pacific rats kept the grass from establishing there until they were extirpated by cats. By the end of 1960s, the rats had been eliminated, the cats had died out, and the aggressive grass was greatly reduced during military operations, but house mice remained (Table 1). A heavy stand of *Digitaria* covered more than half of Howland Island in 1988 (Fig. 2) and this may have played a role in driving nesting seabirds to the more open Baker Island.

From 1942 to the late 1960s most seabird nesting was on Howland Island. In this period rats had been eliminated from both islands. Cats were eradicated from Baker Island by about 1970, but remained on Howland Island. By 1975, most of the nesting seabird species had moved to Baker Island, with the exception of a few thousand frigatebirds that completed their move by 1978 and the last sooty terns moved to Baker by the early 1980s (Table 2). Through the early 1980s the only birds nesting on Howland Island were those that could withstand cat predation. Red-tailed tropicbirds (*Phaethon rubricauda*) nested under coral slabs on the beaches, giving them some protection, but in 1986 cats were preying on some tropicbirds, as feathers were found in a cat stomach and two dead adults, believed to have been killed by cats, were found. Some red-footed boobies (*S. sula*) and frigatebirds no longer nested, but roosted in the kou trees. Several thousand adult masked boobies and a few brown boobies (*S. leucogaster*) that nested in the open on the ground were probably able to avoid predation due to their size and the low numbers of cats. Although there were probably <20 cats present, they seemed to have prevented frigatebirds and terns from re-colonising the island.

In spring 1986, Berendzen and Forsell (1986) removed the remaining 17 cats from Howland Island. In 1988, two years after the cats were removed, the chronology of nesting masked boobies was similar between Howland and Baker Islands. In 1986, similar numbers of boobies were on territories and eggs on both islands, but there were significantly fewer nests with young. Apparently, the boobies are able to protect their eggs and small chicks from cats, but when both adults begin to forage leaving the young unattended, these larger chicks are vulnerable to the cats. This was reflected in the stomach contents of 16 cats examined, of which three had the remains of young boobies.

White terns (*Gygis alba*) returned to Howland by 1992, and brown noddies, grey-backed, and sooty terns by 1998. Red-footed boobies and great frigatebirds (*F. minor)* returned by 1998, and lesser frigatebirds by 2002. A small colony of wedge-tailed shearwaters (*Puffinus pacificus*) was found on Baker Island in 1986 and blue noddies were first found on Baker and Howland Islands in 1993. Numbers of shorebirds rose quickly after cat removal, but surveys in April or later are not a good measure of shorebird abundance as birds migrate back to their Arctic breeding grounds.

The recovery of red-footed booby and great frigatebird numbers on Baker Island was hampered by enormous amounts of debris, primarily thousands of old rusting 55

US gallon (200 L) drums. Some roosting birds, or young on nests built on the rusted tops of the drums, fell in and starved. These hazards were mitigated by turning barrels over so birds could escape, and oil and tar were burned by the U.S. Army Corps of Engineers in 1986. By 1992, most of the debris and entrapment hazards had been mitigated, so it is expected that numbers of great frigatebird and red-footed boobies will grow faster than in the past.

DISCUSSION

Cat predation affected the three islands in different ways. Cats probably extirpated Norway rats from Baker and Jarvis Islands, and Pacific rats from Howland Island (King 1973), but house mice still persist on Baker and Jarvis Islands. They are more resistant to drought than rats, surviving on moisture in insects and condensation (B. Bell pers. comm.).

On Jarvis Island the presence of hundreds of cats eliminated Procellariiformes, shorebirds, and terns, with the exception of sooty terns which still numbered in the hundreds of thousands and were able to sustain a high level of predation at this site (Rauzon 1985). Terns appeared to be a preferred food of cats on all islands (Kirkpatrick and Rauzon 1986). The rapid response of both terns and shorebirds to the removal of cats indicates the impact cats had on the smallest birds. Observations from Howland Island, where less than 20 cats ate chicks and occasional eggs, indicates that masked boobies and tropicbirds can withstand cat predation for many years. Here, a few cats, combined with heavy vegetation, provided enough disturbance to cause the more vulnerable birds to move to Baker Island. Cats then preyed on the remaining boobies and tropicbirds enough to reduce their reproduction. On Baker Island the cats prevented the birds from recolonising, but once cats were eliminated, the colony grew quickly, likely moving from Howland Island. Band recoveries on Jarvis Island show that cats there could have affected birds from a large area, and that the eradication of cats on Jarvis may have contributed to the recovery of masked boobies on other islands (Clapp 1967).

Unlike Jarvis Island, which is separated from the nearest seabird colony, Kiritimati (Christmas) Island, by about 184 nm, Howland and Baker Islands are only 36 nm apart and could be considered a colony complex. Birds have suffered extreme perturbations by man over the past 150 years, but these have often affected only one island at a time, allowing most birds to move back and forth between the islands depending on the severity and type of disturbance on a particular island. When cats were removed from Howland, the birds returned to breed there from Baker (Fig. 3).

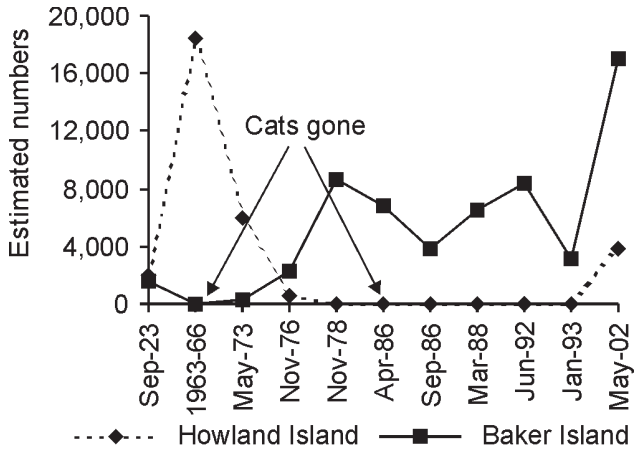

Fig. 3 Combined abundance of great and lesser frigatebirds on Baker (solid line and squares) and Howland (dashed line and diamonds) Islands, before and after cat eradication.

Even though the predation-free period has been longer for Baker than Jarvis Island, fewer new species have recolonised Baker. One reason for this may be the great distance to other colonies that could serve as a source and the condition of those colonies. Another reason is exemplified in the extirpation of Procellariiformes; their high degree of natal philopatry and relative rarity makes them slow to repopulate former colonies. Phoenix petrels (*Pterodroma alba*) were reported from Howland Island in the 1960s, but they did not breed there; and the nearest colony is McKean Island, 352 nm to the southeast. Likewise, Phoenix petrels are expected to visit Jarvis since they also nest at Kiritimati, but unlike Howland or Baker, none are reported in any of the literature reviewed. In 2004, a short-term experiment to attract them with audio recordings failed. Although Polynesian storm petrels nest at Kiritimati, they took 20 years to recolonise Jarvis (where mice may still be a predator) and they still have not been recorded from Baker or Howland, where they were last seen in 1938 (Munro 1944). This may be due to the fact that foraging areas are to the east of Jarvis and Kiritimati, and they are most abundant south of the equator to about 8º S, to the northern edge of the South Equatorial Current, and east to about Marquesas (140º W) (L. Spear pers. comm.).

The 1982-1983 El Niño was the strongest on record and resulted in a severe weakening of trade winds across the Pacific and a significant slackening of the EUC (Firing *et al*. 1983). This effectively caused a complete halt to both regional and local upwelling and resulted in a substantial warming of surface temperatures at each of the islands. With no upwelling, the seabird productivity crashed at Kiritimati. Schreiber and Schreiber (1984) reported that the highest seabird mortality in a 13 year study occurred during the 1982-83 El Niño: "no young fledged during 1982 as they were left to starve to death in their nests by deserting adults." These same oceanographic conditions probably aided the Jarvis eradication in 1982 by stressing cats with low food supplies. Bird populations reached a historic minimum at this time, and seabird recovery began with the cessation of cat predation and the transition to a more productive oceanographic regime.

In contrast to an El Niño phase, the La Niña phase enhances Trade winds and the EUC, and therefore the productivity near these islands (Gove *et. al* 2006). The numbers of blue noddies seen in 2004 are a reflection of the historic strength of the upwelling at Jarvis. These zooplanktivorous, neuston-feeders are more abundant at Jarvis than any other colony. Cats were the apex predators of this marine-based trophic system, which masked the role that upwelling played in the recovery of blue noddies. This recovery may not be only local colony reproduction, but could also reflect immigration from Kiritimati, where this vulnerable tern nests on a few cat and rat-free islets. Kiritimati seabirds never recovered from the 1982-83 El Niño and subsequent human disturbances, and Jarvis Island has become the most significant seabird colony in the central Pacific, as King (1973) predicted it would with cat eradication.

Rats and guano mining destroyed the seabird colonies before ornithologists were able to record the immense populations and diversity of seabirds that this oceanographic and geographic confluence created. After a century of destruction by humans and their commensals, the ecosystems began to recover with the eradication

of rats by feral cats. The 25-year effort to control and eradicate cats has allowed almost complete recovery of the seabird biodiversity, if not the numbers, and the islands full status as 'wildlife refuges' has almost been achieved. Mice remain on Baker and Jarvis Islands, and while no predation on seabirds has been observed, their eradication would restore the islands to predator/grazer-free aboriginal conditions.

Continued recovery of these guano island ecosystems is assured with the 2009 protection of their surrounding waters. Most of the recovery parameters needed to reconstitute a guano island ecosystem are in place. However, climatic and oceanographic conditions will ultimately determine if these vulnerable atolls can ever reclaim their immense seabird populations.

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