

**ATOLL RESEARCH BULLETIN**

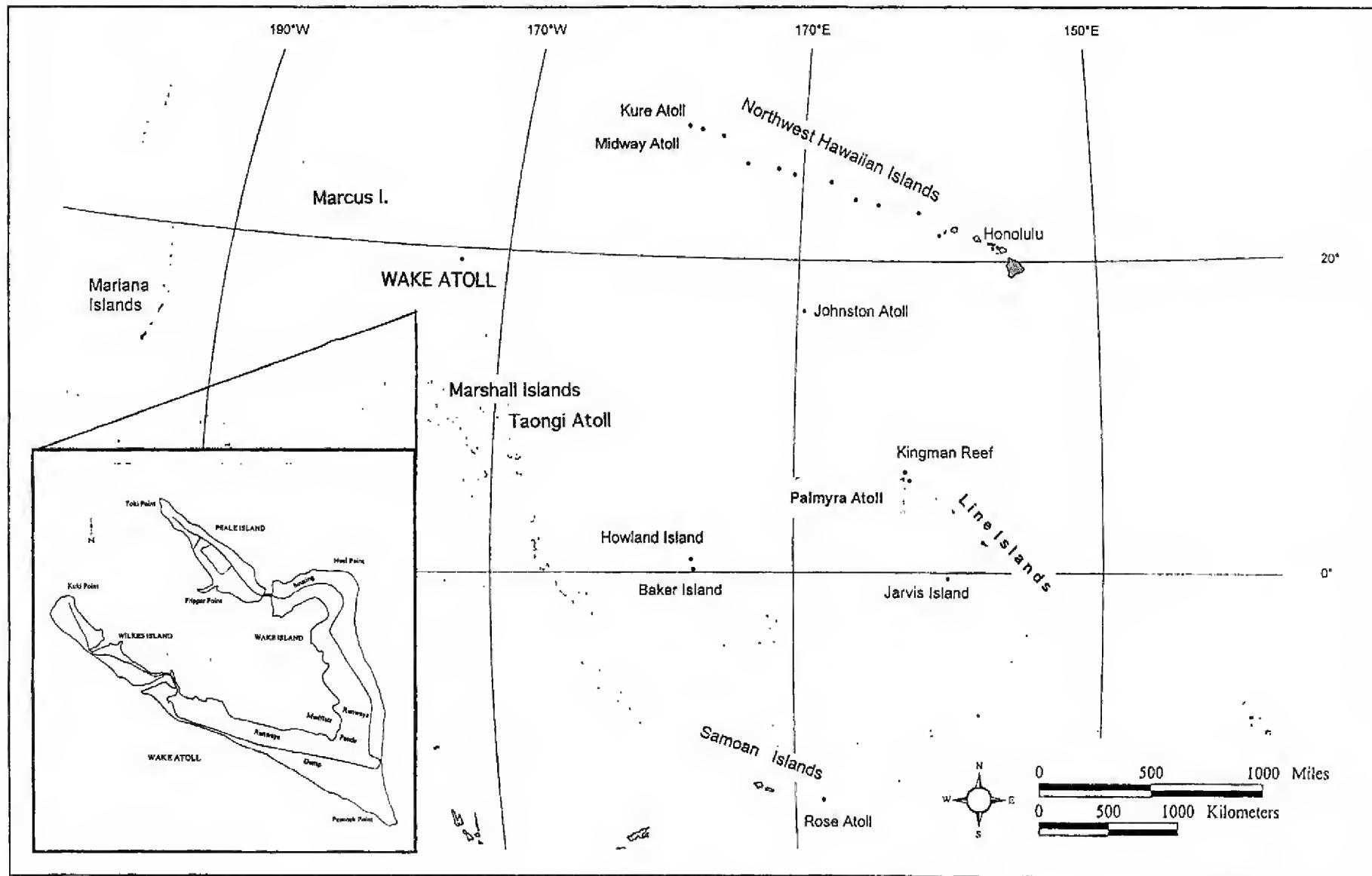
**NO. 560**

**ERADICATION OF FERAL CATS AT WAKE ATOLL,**

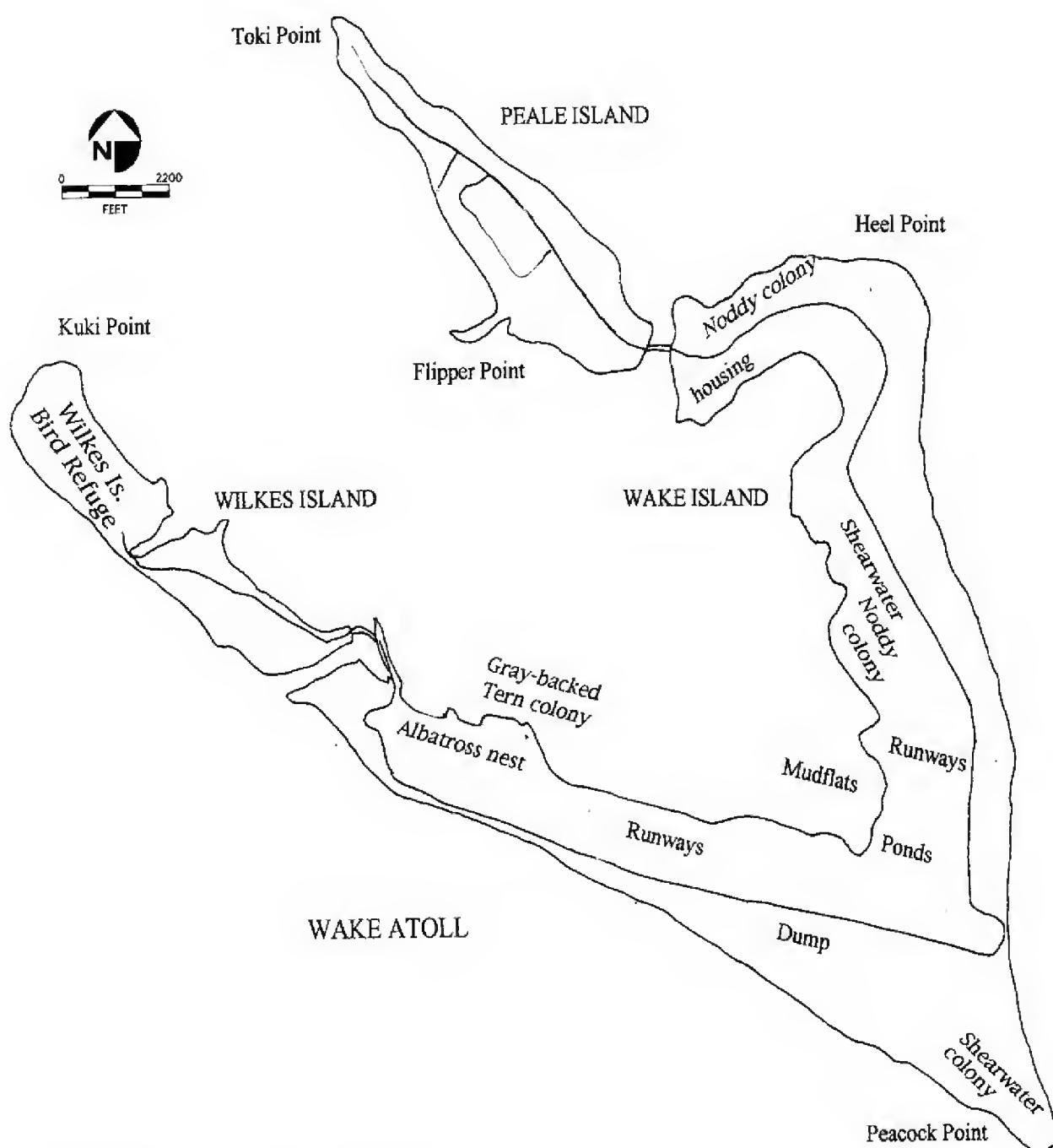
**BY**

**MARK J. RAUZON, WILLIAM T. EVERETT, DAVID BOYLE,  
LOUISE BELL, AND JOHN GILARDI**

**ISSUED BY  
NATIONAL MUSEUM OF NATURAL HISTORY  
SMITHSONIAN INSTITUTION  
WASHINGTON, D.C. U.S.A.  
NOVEMBER 2008**



**Figure 1.** U.S. Pacific Island map showing Wake Atoll's location in the Pacific.



**Figure 2.** Wake Atoll landscape features.

## ERADICATION OF FERAL CATS AT WAKE ATOLL

BY

MARK J. RAUZON,<sup>1</sup> WILLIAM T. EVERETT,<sup>2</sup> DAVID BOYLE,<sup>3</sup> LOUISE BELL,<sup>3</sup>  
and JOHN GILARDI<sup>1</sup>

### ABSTRACT

Feral cats (*Felis catus*) were introduced at Wake Atoll, (19°18' N, 166° 38' E) in the 1960s as pets and probably to control rats on this U.S. military base in the North Pacific Ocean. After base-downsizing in the 1970s, feral cats became a noticeable problem. Hunting and trapping to control their numbers has been sporadic over time but began seriously in 1996 and continued through 2002, during which time about 200 cats were removed. The eradication effort began in July 2003 and by January 2004 another 170 cats had been removed. During visits from late 2004 to 2007, two feral cats were seen but no cat reproduction was detected.

Bird populations responded quickly to the release of predation: Masked Boobies (*Sula dactylatra*) increased from three breeding pairs in 1996 to 25 by 2007; the Brown Booby (*S. leucogaster*) population rose from 73 nests in 1996 to 162 in 2003. Wedge-tailed Shearwaters (*Puffinus pacificus*) recolonized around 1998 and populations expanded to form at least three colonies with individuals in numerous locations around the atoll. Gray-backed Terns (*Onychoprion lunata*), not recorded breeding on the atoll since the 1980s, began nesting in two new sites, and Great Frigatebirds (*Fregata minor*), which had not been recorded nesting since the 1960s, renewed reproductive efforts in 2005. Due to feral cat removal and wet weather, Pacific Rats (*R. exulans*) greatly increased. Current rodent control effort was less effective than it should be because hermit crabs (*Coenobita perlata*) ate the bait before the rats did. A bait station model design to exclude crabs was designed and tested. The island managers continued to control rats at Wake around housing areas, and rodent populations have declined since their peak following cat eradication.

On Aug. 31, 2006, Wake Island was struck by Super Typhoon Ioke. Winds over 130 mph knots broke many trees and damaged the island infrastructure but the island was soon functioning again. In June 2007, we returned and found a few cats survived. They appear to be the same cats known to remain at the end of our eradication, are likely the same sex since no kittens have been detected since then.

<sup>1</sup>Marine Endeavors, 4701 Edgewood Ave. Oakland, CA 94602

<sup>2</sup> Endangered Species Recovery Council, Julian, CA 92038

<sup>3</sup> Wildlife Management International Inc. Wellington, New Zealand

## INTRODUCTION

Birds that evolved on remote islands without mammalian predators are poorly adapted to escape introduced carnivores, particularly cats. Feral domestic cats (*Felis catus*) are considered primarily responsible for the extinction of 33 species of birds since the 1600s (Jackson, 1978). In New Zealand alone, cats were the principal factor in the extinction of eight species of birds and over 70 localized races (Merton, 1978; Algar et al., 2003). Cats exceed all other alien predators in severity of impact on birds (Moors and Atkinson, 1984). One of the earliest observations of the severe depredations of feral cats on island birds was made during the 1840's U.S. Exploring Expedition:

“The bird [Tooth-billed Pigeon (*Didunculus strigirostris*)] formerly abounded at the island of Upolu, one of the Samoan Islands, but now, it is considered a rare species by the natives, and one which will be entirely destroyed in the course of a few years, if the same causes exist which are now operating to their destruction... A few years since a passion arose for cats, and they were obtained by all possible means from the whale ships visiting the islands, were much esteemed for a whole, until the other pets were destroyed by them ; after which Pussy (a name generally adopted by the Polynesians for cats), not liking yams or taro... preferring Manu-mea, and took to the mountains in pursuit of them. There the cats have multiplied and become wild, and live upon our Didunculus, or little Dodo, the Manu-mea of the natives, which is believed will in a very few years cease to be known...” (Peale 1848).

(The Tooth-billed Pigeon is very rare today in the mountains of Samoa.)

Within the last 20 years, efforts to eliminate feral cat depredations on island birds have been increasingly successful around the world (Algar et al., 2003; Rauzon, 1985; Veitch, 2001; Twyford et al. 2000; Winter and Wallace, 2006; Wood et al., 2002). A recent review of feral cat eradication programs found that feral cats have been removed from at least 48 islands; 16 in Baja California (Mexico), 10 in New Zealand, 5 in Australia, 4 in the Pacific Ocean, 4 in Seychelles, 3 in the sub-Antarctic, 3 in Macronesia (Atlantic Ocean), 2 in Mauritius and 1 in the Caribbean (Nogales et al., 2004).

Wake Island represents a large, complex eradication program that took place on a military air base in the Northwestern Pacific Ocean. We present the challenges, procedures and results of the eradication program that took place from 1996 to 2004 during which we removed 99.3% of the cats. In 2007, we detected two feral cats, and others were reported by island managers. Obtaining accurate and consistent reports of cat sightings is very difficult. However, the number of individuals is consistent at two animals and no kittens have been detected. At least five years of cat-free visits are needed to pronounce an island eradication successful, and we are not be able declare that Wake is cat-free.

## STUDY AREA

Wake Atoll is one of the most isolated islands in the world, approximately 2,240 km from Guam, 1,920 km from Midway Islands and 4,160 km west of Honolulu. The nearest landfall is Taongi Atoll, 600 km to the south in the Marshall Islands in Micronesia. To the east is Johnston Atoll (2,560 km); and north is Marcus or Minamitorii (1,440 km) (Fig. 1).

The total land area of Wake Atoll is approximately 739 hectares (1,826 acres or 2.85 square miles) with 19.3 km of coastline. The shore is composed of solid coral rock shelves, broken coral pieces and sandy beaches and encloses a “V” shaped lagoon opened on the northwest side by a barrier reef (Fig. 2).

The first mariner to record Wake was the Spanish explorer, Alvaro de Mandana, who noted on Oct. 4, 1568 that “the land swarms with a strange type of rat that runs about on its hind legs...and there are many birds of all sorts.” (Werstein, 1964). That hopping rats were already present indicated Micronesian or Polynesian voyagers had already discovered this remote atoll. However, Captain William Wake of the British schooner Prince William Henry is credited with discovery in 1796 and the U.S. Exploring Expedition put Wake Island on the map. Commodore Charles Wilkes of the U.S. Navy surveyed the atoll on December 20, 1841 as his ships U.S.S. *Flying Fish* and *Peacock* lay anchored offshore. (Peacock Point is named after that ship). Wilkes noted: “Wake’s Island is a low coral one, of triangular form, and eight feet above the surface...From appearances, the island must be at times submerged, or the sea makes a complete breach over it.” (Wilkes, 1844). The naturalist for the U.S. Exploring Expedition, Titian Ramsey Peale, described the island similarly: “The only remarkable part in the formation of this island is the enormous blocks of coral which have been thrown up by the violence of the sea.” (Poesch, 1961). The three islands of atoll, Wake, Wilkes and Peale Islands, were named for the first explorers; the latter two were named by Dr. Alexander Wetmore of the Smithsonian’s Tanager Expedition in 1923 (Olson, 1996).

Wake’s strategic military position was enhanced with the development of an air base. On March 12, 1935, the Sec. of the Navy gave Pan American Airways permission to construct a facility at Wake from which China Clippers, ‘airboats to the orient,’ could operate. Even at this time, cat predation was considered a threat: In a letter dated Aug. 16 1935, the Commandant of the 14 Naval District wrote to Pan American Airways: “We appreciate very greatly Rear Admiral Yarnell’s interest in the preservation of the unique birdlife found on Midway and Wake Islands, and the instructions he has been given regarding the introduction of cats, dogs, mice and other bird enemies on these Islands. The introduction of such domestic animals as swine, goats, and sheep on islands in other parts of the world has had equally disastrous effects on bird life by destroying vegetation and cover. May we suggest that these animals be included among those prohibited on the Islands?”

By 1939, construction was geared toward preparing for war. On December 8, 1941, Wake Island was attacked by the Japanese, and the ensuing battle became a rallying cry for the U.S. The war totally destroyed Wake Island’s vegetation and birdlife. Many trapped Japanese troops left starving. After the war and through the 1960s, up to 2,000 people lived on Wake and the island had many cleared areas, but when personnel were

reduced during the 1970's, introduced vegetation, especially ironwood trees (*Casuarina spp.*), spread around the atoll becoming a monoculture in some areas.

The three islets are linked by about 13 km of paved road and an equal length of unpaved roads (Fig. 2). A 3,300 meter runway, with associated taxiways and aprons, covers about half of Wake Island. The original channel between Wilkes and Wake islets is now a solid fill causeway and a bridge spanned the channel between Peale and Wake islets until it burnt down in 2003. The linkage of Wilkes and Wake and the placement of cement bridge anchors between Wake and Peale have caused the lagoon to become shallower due to decreased water circulation and increased sedimentation.

One of the most remote military facilities in the world, Wake Island, as it is referred to locally, is managed by the Department of Defense, specifically the US Air Force, 15<sup>th</sup> Wing based at Hickam Air Force Base, Honolulu, Hawaii, whose mission involves providing aviation support to pan-Pacific flights. In addition, the U.S. Army's Strategic Missile Defense Testing Program takes place on the island, periodically closing it to non-classified civilians. Wake is currently managed for the military under contract to the Chugach Development Corporation, an Alaskan native-owned corporation, which, until the recent typhoon, employed approximately 30 U.S. employees in management positions and 140 Thai nationals to run the infrastructure.

Wake Island was hit by Super Typhoon Ioke in early September 2006. The storm was a category 5 level typhoon for five days before it hit. By the time all 188 personnel were evacuated from Wake, the storm had build a 50' wave surge, and sustained 140 knots gusting to 170 knots. Luckily, the island was spared the 50' wave. Three million gallons of jet fuel remained intact. The new multi-million dollar runway resurfacing was largely unharmed. The Air Terminal building was intact, but it sustained roof damage as did many other buildings. The beach houses where Thai workers recreated were damaged and some were destroyed. Localized pollution occurred and many buildings were condemned. Asbestos was the most significant toxic hazard was that was spread around the island. After the storm, about 80 people in key positions returned to maintain the island at a minimal operational level that may be the state of operations for the foreseeable future. Natural resources appeared to suffer little permanent damage. Some of the beaches were rearranged by large waves, and many ironwood trees were toppled, broken and stripped of needles. By June 2007 many of the trees were releafing.

## HISTORY OF CAT INTRODUCTION

During the 1950s the Civil Aviation Administration (CAA) expanded operations on Wake, partly as a result of the Korean War. Up to 500 civilians lived there; many brought pet cats. In 1952, botanist F. R. Fosberg reported domestic cats and dogs were on the island (Bryan, 1959). By 1958, cats were becoming a problem. A notice was issued that "due to the number of cats...all cats which could not be removed to homes on the other side of the island would be "put to rest." (Parker, 2007). In the 1960s, the Federal Aviation Administration (FAA) took over from the CAA and increased the human population to over a thousand including many families with children. Cats were valued as pets and for control of the Pacific Rat (*Rattus exulans*), an introduction made by prehistoric Polynesians. When the FAA ceased to manage the base and many families

departed, pet cats were left behind. (Tonnie Casey, pers. comm.). Cats can breed at around 7 months of age and may have 1-3 litters per year of up to 7 kittens. Many became feral (Fig. 3) and though they controlled the rat population they also had a serious impact on seabirds nesting on all the islets.

The first reported observations of the effects of cats were made by biologists with the Smithsonian Institution's Pacific Ocean Biological Survey Program (POBSP): "A few feral house cats are present but not in sufficient numbers to seriously damage the bird population...I have seen six cats so far, three on Wilkes and three on the west end of Wake. Two of those on Wilkes were obviously headed for the sooty terns..." "On January 7, large areas of Wake are being cleared of all vegetation in an effort to eliminate the rats near FAA transmitter. Found a cat-killed banded bird, 7/65." (McFarlane, 1965). Another POBSP biologist noted: "Feral cats were common on the atoll. Two adults were seen during the day at Flipper Point. One of these was collected and serum sampled. Three adults and two kittens were seen at Peacock Point on Wake Island and four adults were seen in the red-footed booby colony on Wilkes." (Fitch, 1968). Every ornithologist visiting Wake Atoll has noted feral cat depredations on seabirds and recommended cat control (Table 1). Interest in the conservation of Wake's natural resources began in earnest in the early 1980s as a result of periodic visits by U.S. Fish & Wildlife Service (USFWS) personnel. Their trip reports encouraged the removal of feral cats from Wake Atoll in order to make a significant contribution to tropical seabird conservation in the Micronesian region and in western Oceania.

Table 1: Recent Ornithological Visits and Observations/Recommendations

Trip Date	Authors	Observations
14-15 July, 1982	S. Fefer & C. S. Harrison-USFWS	Feral cats abundant, no rats. Feral dogs also present. Cat control eradication recommended.
29-30 March, 1983	S. Fefer & R.J. Shallenberger-USFWS	Evidence of feral cat predation on Sooty Terns noted. Shooting suggested.
4-11 April, 1989	C. Rowland-USFWS	Bird predation by cats and rats. Management Plan recommended.
24 Mar. -1 Apr. 1993	H. L. Jones	Reported bird observations and summarized the historical bird data (Jones 1995). Although he observed only one feral cat in a Sooty Tern colony, he did note numerous fresh bird carcasses and reported atoll resident L. Hitchcock indicated that cats caused significant mortality to Sooty Terns.
14-25 February, 1996	T. Sutterfield-US Navy	Feral cats seen at Peacock Pt.

In the early 1990s, USFWS-sponsored visits brought pest-control advisors from New Zealand and Hawaii to Wake Atoll along with members of the Endangered Species Recovery Council (ESRC). In 1996, ESRC began a series of visits to conduct resource surveys and to aid base personnel in ongoing cat control. Anticipating an eradication attempt, ESRC initiated a spay-neuter clinic with Army veterinarian Dr. Keith Lopez in December 1996 during which time ~15 cats were treated. Intermittent feral cat control by island personnel occurred during our absence accounting for about 200 animals (Appendix 1).

.In January 2000, we applied for funding from the Department of Defense Legacy Program to remove the feral cats and rats, but only the cat removal component was funded. In mid-2000, we encountered major obstacles in transporting our equipment and personnel to Wake. Ammunition could only travel on military cargo aircraft if specifically packed and certified by military cargo agents. In lieu of air travel, we arranged for ammunition and guns to travel by barge to Wake thereby eliminating the need for military safety inspections. The ammunition and guns were stored at the Wake Armory prior to our arrival.

Development of plans and personnel scheduling began in 2001. However, the U.S. Army, a tenant of the U.S. Air Force, denied our access by requiring an Environmental Assessment of the cat eradication effects on rats. We appealed to the Air Force because this effort would deplete our budget. While the appeal was pending, ESRC convened a meeting in 2002 in Auckland, N.Z., of advisors including internationally renowned leaders in feral mammal eradication, Brian Bell, Don Merton, Alan Saunders, and Dick Veitch, to discuss delays and contingency plans.

Wake Island Command informed us that the atoll was off-limits to civilians without security clearance by order of the Army and that the island likely would remain closed until late 2002 for missile testing. By the time we received entry authorization only 16 months remained of our five-year funding to complete our work. In late June 2003 we were allowed to proceed to Wake to begin a thorough eradication attempt. We needed at least 6-8 weeks of continuous access to Wake for the first phase of our fieldwork. ESRC contracted with Brian Bell's company, Wildlife Management International Inc., to provide expertise and labor. In addition ESRC personnel provided planning, adaptive management and additional labor (Table 2).

## METHODS

### Education

We began with an education program to instruct and inform the natural resource managers and supervising military commanders at Hickam Air Force Base, Honolulu, about the effects of cats and the ways and means to eradicate them. We circulated a Legacy-funded brochure “Don’t let your cats go AWOL” and our “Frequently Asked Questions” about our program. Once at Wake, we briefed the island managers on our plans and learned of island regulations for night hunting operations. In order to explain our program to the Thai workers, we visited the beach houses where they spent their off-

Table 2. Schedule of eradication actions and personnel at Wake Atoll.

<b>CONTROL VISITS</b>	
Dec. 5-10, 1996; Jul. 17-29, 1998;	Hunting, education, bird monitoring
Feb. 17-Mar. 8, 1999; Sep. 21-Oct. 4, 2000	
Personnel	Everett and Rauzon
<b>ERADICATION VISITS –</b>	
<b>PHASE 1</b>	
June 28-July 12, 2003	Initial cat assessment, education, trapping, hunting.
Personnel	Everett and Rauzon
July 12-26, 2003	Extensive trapping, education, bird monitoring.
Personnel	Gilardi and Rauzon
July 26-Aug. 23, 2003	On-going effort.
Personnel	Gilardi
<b>PHASE 2</b>	
Nov. 1-Dec. 16, 2003	Extensive trapping, education, bird monitoring.
Personnel	Bell, Boyle, and Rauzon
Dec. 7, 2003-Jan. 10, 2004	On-going effort.
Personnel	Boyle
<b>PHASE 3</b>	
Jul. 25-Aug. 27, 2004	Cat sign searching and rat control trials, Bird monitoring.
Personnel	Boyle, Everett, and Rauzon
<b>PHASE 4</b>	
May 22-Jun. 8, 2007; Sep. 23-Oct. 7, 2007	Cat sign searching and bird monitoring. Rat control trials, cat sign searching.
Personnel	Gilardi and Rauzon; Gilardi et al.

hours (and maintained cats). We also began to attend weekly Buddhist services and other social events. We periodically renewed our education efforts at the Thai beach houses by visiting each one and asking permission to trap around their property. We distributed rat snap traps, answered questions and learned which cats lived where (see Figure 3).



**Figure 3:** Feral cat on Wake Island

### Trapping

We began removing cats during the first week using Havahart™ live traps around the beach houses on Wake baited with fresh fish or canned cat food as bait. Victor™ 1.5 *softcatch* traps were used in the bush on all islets. Traps sets were hidden carefully just beneath the ground surface and wired to anchoring objects. In order to attract cats to the sets, we used scents, both commercial bobcat scent and “*pongo*” made of cat feces and urine mixed with glycerine. Additional pongo would later be made from cats on Peale or Wilkes islets and used on Wake. Auditory lures (FAP) were also used to attract cats to trap sets. In the third week, we reset our traps after cleaning and rust proofing them using Crisco™ vegetable shortening.

### Hunting

During the second week, we began hunting at night primarily with a shotgun (stainless steel Mossburg 12 gauge using #4 shot). During the day we used a .22 rifle and a pellet rifle. A pellet pistol was used at close range to put down trapped cats. For long-range shots, we had a .223 rifle with scope but this was never used. For night hunting, we wore hardhats with attached lights and had a powerful hand-held light for illuminating distant areas. Base Operations were kept informed of our hunting locations each night including the garbage dump, the bird colonies, and around the harbor. Guns and ammunition were stored in the armory and replaced there nightly after each hunt.

## RESULTS

In total we visited Wake Atoll 12 times over a ten-year period (1996-2007), four visits were spent on cat control, five visits on eradication that took place during three phases in 2003 –2004 (Table 2), and three monitoring periods in 2005 and 2007.

Phase One: Jun. 28-Aug. 23, 2003

Island personnel were largely supportive of our eradication program. It was evident to most people that there were too many cats around the beach huts. Sporadic cat control had taken place in the past and about 130 cats had been removed (Appendix 1). But local control had ceased with the knowledge that our project was funded. Delays in getting our team to Wake permitted the feral cat numbers to build up. Some beach houses had up to 20 cats associated with them when we arrived (Fig. 3).

Our educational efforts made island managers more aware of breeding seabirds. As a result, access to Wilkes Island was restricted, the road gated and posted with a sign designating a Wilkes Island Bird Sanctuary. The island was closed unless permission from island managers was obtained (Fig. 4).



**Figure 4.** Wilkes Wildlife Refuge Signage.

At the end of the second week in July, we had completed 343 trap nights, caught 37 cats and shot 39 for a total of 76. By the end of the first month, 104 cats had been removed. In the fifth week, we resumed trapping but cats were wary. Nevertheless, previously unknown cats were discovered and lured into live traps. By the end of the sixth week, 120 cats had been removed. We finished the first phase knowing that about 20 cats remained.

The island was extremely dry in July 2003 as an extended drought stressed the vegetation and presumably also the cats. Visibility in the underbrush was excellent for spotting and hunting cats. In addition, cat prey items, birds and rats, were at a low point

in abundance. Excellent sanitation efforts by base managers limited garbage at the dump. Thus, food for cats was becoming a limiting factor making them more likely to enter a trap to feed.

On Wilkes Island, Sooty Terns (*Onychoprion fuscata*) were almost finished breeding and only several dozen fledglings were left to attract the cats. Also a few tree-nesting Red-footed Boobies (*Sula sula*) were killed by cats. On Wake, we noted cats climbing trees to prey on terns and noddies, a new behavior we had not observed before. Their cumulative depredations of arboreal terns are shown in Figures 5 and 6.



**Figures 5 and 6.** Cat Predation on Terns

In the sixth week, we began to try to determine rat densities by using snap traps. As with cat trapping, hermit crabs (*Coenobita perlata*) were very disruptive, quickly triggering traps, so few rats were caught (67 trap/nights yielded 7 rats for a 10% success rate).

We surveyed bird populations and noted increases since our 1998 surveys. In July 2003, there were 162 Brown Booby nests, up from 107 in July 1998. Masked Boobies had increased from 5-to-75 by 2004. Wedge-tailed Shearwaters were nesting in new locations as well as increasing in number in the original Wilkes I. colony.

#### Phase Two: Nov. 1, 2003-Jan. 10, 2004

In the two-month break between phases one and two, cats became less cautious. During this interval, the drought ended and the island grew lush dense undergrowth, making it more difficult to hunt cats. Rodent numbers increased owing to decreased cat predation and increased food supplies. In addition, many more people were on the island involved with extensive construction activities such as the runway reconstruction, harbor maintenance and fuel tank retrofitting.

Ten weeks of intensive leg-hold trapping took place in phase two. Because cats were wary from prior hunting and difficult to shoot, much of our work consisted of trapping around beach huts where safety considerations did not allow gun use. We also covered about two thirds of the island with a trap grid spaced ca. 200 meters apart, focusing on the home ranges of known cats. In the first two weeks of phase two, 22 cats were caught.

Peale Island appeared be cat-free after four cats were removed in the first week of this phase. In the latter part of phase two, the bridge to Peale burned down. Due to costs, it is unlikely that the bridge would replaced, so Peale Island was isolated and cat free. Wilkes Island also was suspected to be free of cats as we found no cat footprints on sandy roads or beaches. In addition, we saw no cat eye shine at night or evidence of eaten birds. Also, Sooty Terns that were injured in mid-air collisions, were not consumed by cats. Nor was there any sign of predation in the Red-footed Booby or Wedge-tailed Shearwater colonies on Wilkes Island.

By the fourth week, cats were very difficult to locate on Wake. We failed to catch any, despite targeting four or five known animals. By the fifth week, we trapped the last section of Wake Island, resulting in the elimination of one known cat. By the seventh week, several unknown cats appeared; five kittens were caught along with three adults. By the tenth week and at the end of phase two, 36 cats had been removed and a few feral cats were known to remain in the bush on Wake Island.

The Pacific Rat population increased due to the lack of cat predation coupled with abundant rain and fresh vegetation. We also noted the prevalence of rats in the stomachs of dissected cats. As rodent numbers increased, so did public health concerns among island residents. However, the insular rat population has very little exposure to outside pathogenic sources and unless new rodents were accidentally introduced from ships or barges arriving during this period of heavy construction, new disease introduction was unlikely. Rodent control techniques, such as poison and trapping were initiated to lower the density of rats around the housing areas.

Seabird habitat management was also initiated during phase two. By supervising mowing activities on Wilkes Island, we were able to delineate the shearwater colony and prevent accidental crushing of burrows by mowers. Apart from cat control, this constituted the first pro-active management of the seabird colony on Wilkes Island. In addition, we opportunistically destroyed many ironwood trees, an invasive species that threatens to overtake the remaining native coastal strand ecosystem on Wake Atoll. Ironwood has already created large areas of monoculture forest and should be managed island-wide in the future in order to prevent loss of native shrub habitat.

#### Phase Three: Jul. 25-Aug. 27, 2004

We revisited Wake again in late summer of 2004 to search for the last known cats. In the first week, one set of tracks was found on Wake Island by the lagoon near the fuel farm. No other tracks were encountered in spite of intensive checking at sandy beaches and road margins for tracks and other signs of cat and spotlighting at night around the rest of the atoll. Island personnel had not seen any cats except the two remaining pets spayed during our initial visit.

During the three phases of eradication on Wake (July 2003-January 2004) about 170 cats were removed; 70 were hunted and 98 trapped during 3692 leg-hold trap nights. Table 3 and 4 provide details of effort and results. More cats were hunted than trapped, largely due to pre-eradication control efforts. At least 300 animals were removed over an eight-year period. The sex ratio was almost exactly equal (68 males verses 70 female),

with 30 animals of unknown sex (Table 5). Rough age estimates based on random sampling for all cats caught in the population was 60% adult and 40% juvenile. (Table 6). After eradication efforts were well underway, the age ratio shifted to slightly more adults with the removal of breeders. In mid 2004, we concluded our funding, knowing a few cats remained.

Table 3: Catch Summary.

Hunt Nights	
1996-2000	= 118 cats removed
2003	= 70 cats removed
Trap Nights	
2003-04	= 98 cats removed
TOTAL	= 286 cats removed

Table 4: Sex and age ratios.

Males	=68
Females	=70
Unknown	=30
Adults	=61%
Sub-adults	=18%
Kittens	=33%

Table 5: Age and gender captures by date.

AGES	Jul. 2003	Nov. 2003	Total
Adults	77/59%	25/66%	102/61%
Subadults	28/22%	2/5%	30/18%
Kittens	22/17%	11/29%	33/33%
Unknown	3/2%	0/0	3/1%
Total	130	38	168
Gender Total	Male 68	Female 70	Sex ? 30

Table 6: Summary of trap nights and success rates by gender and age at Wake Atoll

Islet	Wilkes				Wake				Peale				Total
	M	F	?	All	M	F	?	All	M	F	?	All	
Hunting	4	2	3	9	15	16	17	48	4	7	2	13	70
Box Trap	1	0	0	1	25	25	6	56	2	3	0	5	62
Hard Jaw	7	4	0	11	6	7	1	14	4	2	0	6	31
Soft Jaw	0	1	1	2	0	3	0	3	0	0	0	0	5
Total	12	7	4	23	46	1	24	121	10	12	2	24	168

Phase Four: May 26 to Jun. 11; Sep. 23-Oct. 7, 2007

On Aug. 31, 2006, Wake Island Air Station was struck by Super Typhoon Ioke. Wake Island was fortunate there were no major damages to the newly refurbished runway and the island was functioning soon. We visited Wake Atoll from May 26 to June 11, 2007, to assess the recovery of the island's natural resources from the effects of feral cat eradication and from the impacts of Super Typhoon Ioke.

We searched for cat sign and found that two feral cats and two pet cats survived, and matched the descriptions of known cats from 2004. We engaged in trapping efforts for two weeks, resulting in 221 trap nights, including 159 leg holds and 62 live traps. All efforts were unsuccessful for feral cats (we captured one pet) and the remaining feral cats are very aware of our traps. Tracks in the sand showed that a cat approached within inches of a box trap to investigate. See Table 7 for techniques of trapping analysis.

Although there was a report that a new cat was introduced from Guam when a barge brought telephone poles to Wake in late 2006, we did not see any evidence of this animal. During Oct. 2007, a rat assessment team, including one of our team members, searched for cat sign and interviewed islanders. Obtaining accurate and consistent reports of cat sightings is very difficult. All the sightings reported jibed with descriptions of known animals. No new cats or kittens were detected.

Extensive rodent trapping was done and a new species was discovered, the Asian ship rat, *R. tanezumi*, which likely arrived during the mid-sixties with Vietnamese refugees (L. Hitchcock pers. comm.). Bait station and bait uptake was assessed and a rat eradication plan was started.

## DISCUSSION

The Wake Island feral cat eradication program was conducted in a diverse community setting. Almost everyone on the island knew about our work and many had an observation, sighting, opinion, suggestion, or concern that needed to be addressed. People often asked, "How many did you get today?" An expectation of increasing numbers was built in, adding public pressure on the hunt. "One Hundred Cats" was the goal the community expected after four weeks of phase one. Several residents speculated it was only "the tip of the iceberg." Luckily it was not. Earlier control efforts prevented population buildup, but relaxing local control when our initial project was funded allowed populations to recover.

Thai workers fed the cats but they would not adopt them as traditional pet. Their cats were unspayed, fed along with chickens and also hunted on their own, often eating rats and birds. When we began our program, the cat population was poised to double in size as most cats were associated with the beach houses where food and refuge were constantly available. Cats fed primarily on human refuse on Peale and Wake Island, and on seabirds on Wilkes Island.

In total, about 170 cats inhabited Wake Atoll (4.3 cats per hectare) and this may be near the carrying capacity because 118 were removed in the run-up to eradication

Table 7: Techniques of trapping analysis.

TRAPPING EFFORT		2003-2007				
TRAPS		Hardcatch	Softcatch	Box Trap	Total Leghold	Total Traps
<b>Summer 2003</b>						
Trap Night (tn)		468	164	511	632	1,143
Captures (cap)		13	3	57	16	73
tn/cap		36	54.67	8.96	39.5	15.66
<b>Fall 2003</b>						
Trap Night		1832	0	262	1832	2094
Captures		20	0	6	20	26
tn/cap		91.6	0	43.6		80.5
<b>Summer 2007</b>						
Trap Night		0	159	62	159	221
Captures		0	0	0	0	0
Grand Total		2300	323	835	73.9	3458 /34.9
TRAPS		ISLANDS				
		Wake I.	Wilkes I.	Peale I.	Total	
<b>Summer 2003</b>						
Trap Night (tn)		475	421	247		1143
Captures (cap)		53	14	6		73
tn/cap		8.96	30.07	41.17		15.66
<b>Fall 2003</b>						
Trap Night		1694	222	178		2094
Captures		21	1	4		26
tn/cap		80.66	222	44.5		80.5
<b>Summer 2007</b>						
Trap Night		221	0	0		221
Captures						
tn/cap						
<b>Grand Total</b>		<b>2390</b>	<b>643</b>	<b>425</b>		<b>3458</b>

that did not include a final sweep of the island. The numbers of cats removed from the islands were: Wilkes-23; Peale-24; Wake-121. Considering all program expenses, it cost about \$1050 dollars for each animal removed.

### Bird Recovery

The benefits of removing the feral cats were quickly evident. Masked Boobies increased from three breeding pairs in 1996 to 25 pairs by 2007. Brown Boobies increased from 73 nests in 1996, 162 in 2003 and 164 in 2007. Wedge-tailed Shearwater populations expanded to at least three colonies from one, with individuals seen at many places around the atoll. Gray-backed Terns, a species not recorded breeding on the atoll since the 1980s, were raising young in two new colony sites on Wake and Peale Islands by August 2004. By December 2004, a few Great Frigatebirds were reported to have resumed breeding after a hiatus of about 35 years. Based on band returns, the majority of the colonizing birds came from French Frigate Shoals, Northwestern Hawaiian Islands and from Johnston Atoll. In addition, Bristle-thighed Curlews (*Numieus tahitiensis*) have been reported to over winter. This species undergoes a complete simultaneous molt in winter that renders it flightless and especially vulnerable to predation.

### Rat Control

Due in part to the feral cat removal, and enhanced by wet season conditions, Pacific Rats increased quickly to the point of becoming a conspicuous nuisance. Before cat eradication (Aug. 2003), 67 trap nights (t/n) yielded 7 rats, for a 10% success rate. A year later, in Aug. 2004, 65 trap nights (t/n) yielded 27 rats, for a 41% success ratio. The rat trapping effort focused on the harbor area because if other rat species were present, they would likely have been introduced here. No rodent other than Pacific Rats were caught, although in late August 2004, a container ship arrived from California carrying a squirrel spp. that was reported to be an 11-inch (27.94 cm) Gray Squirrel (*Sciurus carolinensis*). We provided Pacific Rat specimens to several museums, 20 alcohol-preserved specimens to the U.S. Fish and Wildlife Service and 6 skeletons to the Smithsonian Institution. In 2007, we trapped again in the harbor and dump and caught large rats that were later identified as *R. tanezumi*.

Island personnel controlled rats using several rodenticides. As a result, rats were uncommon around the main living and working areas but were common in large, open, grassy areas next to shrub cover. Current rodent control effort is less effective than it should be because hermit crabs eat the bait before rats can consume it (rat bait is not toxic to crabs). Current tree-placed bait station designs are only partially successful and effective rat control or eradication will require a method for placing poison bait without crab interference (Figures 7-10). We tried new designs to deny bait to crabs. The most successful was a specially designed plastic box elevated about 7 inches off the ground with indented supports denied crabs access to the bait while rats were able to jump in the container. (Fig. 11-12).



**Figures 7-10.** Rat bait stations that allow crab interference. Note all locally produced bait stations, except the bucket, are against trees that allow for rats and crabs to enter and take bait. Only the bait bucket, designed by Brian Bell, Wildlife Management International Ltd. of New Zealand excluded crabs.



**Figure 11.** Rat-Go™ Elevated Bait Station



**Figure 12.** Rat-Go™ Elevated Bait Station with Ship Rat taking bait at Palmyra Atoll, photograph by Alex Wegmann.

## CONCLUSION

The timing of this eradication was optimal. It is unlikely we could have access to the island at the level needed today, due to enhanced security measures, impacts of the typhoon, and personnel changes. Military officers are based there now, and access is more highly controlled in missile testing areas while support resources are strained. Also the burned bridge to Peale and typhoon damage to the road to Wilkes severely limit access around the atoll.

Wake is a very different place now than it was in 2003-04. However, in 2003, shipping ammo, foreign personnel travel, and logistical requirements presented serious challenges to this project's success. Island closures limited our time to 16 months for accomplishing eradication. However, once we were on the island, work went relatively well due in large part to support from island personnel. After initial knock-down by hunting, specific trapping with leg-hold traps proved effective, especially when using *pongo*. Live-trapping was required around housing areas, but special permission was granted to shoot here early in the morning. This was very effective in removing specific animals and eventually almost all were accounted for. At the end of the concerted effort, 99.3% were removed. Follow-up visits determined that two feral cats remained, animals we knew about when we ended our hunt.

We consider this eradication successful because although there have been sightings of feral cats, no evidence of cat reproduction has been detected over the period of three years. We are reasonably certain that if cats were reproducing, young kittens would have been seen during the three years of monitoring. Further monitoring is necessary to insure that cats remain unproductive and that no new cats are introduced. Unfortunately, logistics, security, and travel expenses for Wake Atoll are prohibitive and prevent a complete perspective of recovery.

At the very least, cats have been ecologically eradicated. The release from predation was rapid. Seabirds expanded their populations; birds in existing colonies colonies shifted into new areas and new colonies were founded until the typhoon hit. Shorebird diversity increased and especially notable, Bristle-thighed Curlews are over wintering during which time they undergo a complete molt that renders them flightless. Rats have also returned to historic levels. Their recovery during cat eradication was enhanced by a significant rainy period after a prolonged drought. Island personnel express concern about the human health implications of rising rat populations. Rodent control efforts manage to limit rat depredations around housing areas but better trap placement would limit hermit crab depredations on bait.

Rat eradication is currently proposed and appears feasible if funding is sufficient, but this goal remains problematic due to the unquarantined wharf area. Cargo ships tie up directly to the wharf in the harbor and invasive species could escape. The large amount of containerized imported material that Wake receives increases the risk that other species of rodent or alien vertebrates such as Brown Tree Snakes (*Boiga irregularis*) could arrive on Wake Atoll, especially as the majority of ship and plane cargo comes in from Guam, where snakes have become a tremendous pest. Bio-security procedures such as poison baiting and trapping around the harbor are required and if

an eradication program is attempted, the wharf area must be better bio-sanitized. Also, island policy needs to clearly communicate and enforce a “no-cats” policy for Wake. With rats visible during the day, some islanders want sterilized cats to control them.

We were able to direct the mowing of vegetation on Wilkes Island in November 2004 in order to prevent crushing of shearwater burrows. But Typhoon Ioke damaged the road to Wilkes and vegetation control now is impossible. Monitoring typhoon damaged vegetation and seabird recovery is necessary to determine the full range of ecological release from cat eradication. The elimination of feral cats should allow Wake Atoll to reach its full potential as the premier wildlife refuge in the Micronesian region. An experimental population of the endangered Guam Rail (*Rallus owsteni*) could be transplanted to Wake as an ecological replacement for the extinct Wake Rail (*Rallus wakensis*). Such a reintroduction requires rat eradication and additional research to be completed, but the forests of Wilkes Island Bird Sanctuary likely would be the best release site.

## ACKNOWLEDGEMENTS

We thank our Endangered Species Recovery Council advisors, especially Brian Bell, Wildlife Management International Ltd. New Zealand, who provided labor and advice. USFWS biologists E. Flint, C. Rowland and K. Swift supported our effort in Honolulu. We are grateful to the many Thai workers and Chugach Native Corporation management for outstanding on-island support and for those who helped us succeed at Wake including J. Hanna, M. Henz, L. Hitchcock, T. Tiley, R. Wheeler and the many military and civilian personnel at Anderson and Hickam Air Force Bases who helped us, especially Civil Engineering Dept. A. Buckman, and A. Hebshi, Natural Resources Program contract support for 15<sup>th</sup> Air Lift Wing of Pacific Air Force. We greatly appreciate the funding from the Department of Defense Legacy Resource Management Program for the 2000 Project: Conservation of Indigenous Birds at Wake Atoll, # DACA87-00-H-0016, and for 2006 funding for Legacy Resource Management Program: Natural Resource Assessment of Wake Island After Feral Cat Eradication and Super Typhoon Ioke, # W912DY-07-2-0016. We are especially grateful to P. Morales who administered these projects. Special thanks to the S. Olson for reviewing this paper and to the Smithsonian Institution for a small visitor grant.

## REFERENCES

- Algar, D., G.J. Angus, R.I. Brazell, C. Gilbert, and D.J. Tonkin.  
2003. Feral cats in Paradise: Focus on Cocos. *Atoll Research Bull.* 505:1-12.
- Bryan, E.H. Jr.  
1959. Notes of the geography and natural history of Wake Island. *Atoll Research Bull.* 66:22.
- Kirkpatrick, R.D., and M.J. Rauzon.  
1986. Foods of feral cats (*Felis catus*) on Jarvis and Howland Islands, Central Pacific Ocean. *Biotropica.* 18(1): 72-75.

- Jackson, J.A.
1978. Alleviating problems of competition, predation, parasitism and disease in endangered birds. Pp. 75-84. In Temple, S.A. (ed.) Endangered birds: management techniques for preserving threatened species. Proc. of the symposium on management techniques for preserving endangered birds. University of Wisconsin Press, Madison, WI.
- Fitch, J.H.
1968. Preliminary report survey of Wake Island September 4-7, 1968, Smithsonian Institute POBSP unpubl. rept..
- Merton, D.V.
1978. Controlling introduced predators and competitors on islands. Pp. 121-128 in Temple, S.A. (ed.) Endangered birds: management techniques for preserving threatened species. Proc. of the symposium on management techniques for preserving endangered birds. Univ. Wisconsin Press. Madison, WI.
- McFarlane, R.W.
1965. Wake Island field observations. 1965. Smithsonian Institute POBSP unpubl.rept.
- Moors, P.J., and I.A.E. Atkinson.
1984. Predation on seabirds by introduced animals, and factors affecting its severity. ICBP Tech. Publ. No. 3. Cambridge.
- Nogales, M., A. Martin, B.R. Tershy, C.J. Donlan, C.R. Veitch, N. Puerta, B. Wood, and J. Alonso.
2004. A review of feral cat eradication on islands. Conservation Biology. 18(2)310-319.
- Olson, S.L.
1996. History and ornithological journals of the Tanager Expedition of 1923 to the Northwestern Hawaiian Islands, Johnston and Wake Islands. Atoll Research Bulletin 433:1-210.
- Parker, S.
2007. My Wake Island Cat. The Wake Island Spirit. 38:2.
- Peale, T.R.
1848. Mammalia and Ornithology U.S. Exploring Expedition 1838-1842. pp 211. C. Sherman Publishers Philadelphia.
- Poesch, J.
1961. Titian Ramsey Peale 1799-1885 and His Journals of the Wilkes Expedition. Philadelphia: American Philosophical Society.
- Rauzon, M.J.
1985. Feral cats of Jarvis Island, their effects and their eradication. Atoll Research Bull. 283:1-32.
- Twyford, K.L., P.G. Humphrey, R.P. Nunn, and L. Willoughby.
2000. Eradication of feral cats (*Felis catus*) from Gabo Island, South-east Victoria. Ecological Management and Restoration. 1(1)42-49.
- Werstein, I.
1964. Wake: The Story of a Battle. Thomas Y. Crowell Company. New York:
- Wilkes, C.
1844. Narrative of the U.S. Exploring Expedition, during the years 1838-1842. 5:285. C. Sherman, Philadelphia.

- Winter, L., and G.E. Wallace.
2006. Impacts of feral and free-ranging cats on bird species of conservation concern: A five-state review of New York, New Jersey, Florida, California, and Hawaii. Special Report. American Bird Conservancy.
- Wood, B., B.R. Tershy, M.A. Hermosillo, C.J. Donlon, J.A. Sanchez, B.S. Keitt, D.A. Croll, G.R. Howald, and N. Biavaschi.
2002. Removing cats from islands in north-west Mexico. Pg. 374-380 *In* Veitch, C.R. and Clout, M.N. (eds). Turning the tide: the eradication of invasive species. IUCN SSC Invasive Species Specialist Group, Gland, Switzerland, and Cambridge, UK.