Department of Defense
Legacy Resource Management Program

PROJECT 09-438

Ecological Monitoring on Wake Island Prior to Rat Removal

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Project Final Report

For
Legacy Resource Management Program
Project Number: 09-438

Ecological Monitoring on Wake Island Prior to Rat Removal

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Introduction

Introduced rats are known to dramatically affect island biodiversity (Varnham 2010). On Wake Island, a U.S. Air Force installation in the tropical Pacific, rats predate seabirds and may have extirpated several seabird species from the island. Rats may impact a range of other biota and ecological processes on Wake, such as precluding native *Pisonia*/*Cordia* forest regeneration and reducing land crab abundance. These natural resource considerations (compounded by recent mission costs after rats twice chewed through a wire controlling the barrier cable across the airfield and grounding several F-22 aircraft) prompted the U.S. Air Force to award a Fiscal Year 2011 contract to the U.S. Fish and Wildlife Service to eradicate rats from the island. The operation is currently scheduled for summer 2012.

Although rodents have been removed from approximately 300 islands worldwide (Howald et al 2007), predicting ecological responses to rat removal can be challenging due to the relatively high biodiversity and limited number of pre- and post-eradication monitoring studies on tropical islands (Varnham 2010). The Wake Island eradication provides a valuable opportunity to document ecological changes on such an island by monitoring various taxa before and after the operation.

The Department of Defense Legacy Resource Management Program funded Project 09-438 in Fiscal Year 2009 to study the ecological ramifications of removing rats from Wake Island. Originally, this project's goal was to conduct biological surveys before and after the eradication. However, the eradication, originally planned in 2009, was delayed until 2012 due to a variety of technical, logistical, and fiscal issues, and the transfer of management of Wake Island from the 15th Airlift Wing at Hickam Air Force Base, Hawaii, to the 611th Air Support Group at Joint-Base Elemendorf-Richardson, Alaska. Therefore, only pre-eradication data have been collected and are presented in this report. The funding provided by the DoD Legacy Program was used to augment a U.S. Air Force-funded project on seabird monitoring by expanding its scope to include monitoring of the following additional taxa: terrestrial vegetation, shorebirds, terrestrial arthropods, seabirds, rats, and intertidal organisms. This report is a compendium of 4 reports, the first three of which have already been submitted as deliverables to the U.S. Air Force. The reports are:

- Work Plan, Monitoring Protocol, and Sampling Designs for Seabird Monitoring, Shorebird Monitoring, Sea Turtle Monitoring, Vegetation Sampling, Arthropod Sampling, and Rodent Population Monitoring on Wake Island. 2008. Pacific Islands Conservation Research Association (PICRA).
- 2010 Data Summary and Report: Biological Monitoring on Wake Island. 2010. Pacific Islands Conservation Research Association (PICRA).
- Wake Island Insect and Other Terrestrial Arthropods. 2009. Pacific Islands Conservation Research Association (PICRA).
- Intertidal Monitoring for the Evaluation of the Impacts of Rats and Rat Eradication on Wake Island. 2009. Chela Zabin and Blu Forman, University of California, Davis.

The protocols and results described in the above reports, if replicated post eradication, can provide valuable documentation of ecological changes on Wake Island resulting from rat removal. These documented changes can then be used to generate predictions about ecological responses to potential rat eradications on other tropical islands on which the Department of Defense (DoD) has a management stake (see concurrent report delivered to the DoD Legacy Program under this project). We hope that this work, coupled with a successful rat eradication program on Wake Island, can positively contribute to natural resource management and mission sustainment on this and other DoD Islands across the world. This Legacy project was executed through Cooperative Agreement W912DY-09-2-0015 with the US Army Corps of Engineers, Huntsville Alabama.

References

Howald, G., C.J. Donlan, J.P. Galvan, J. Russell, A. Samaniego, Y. Wang, D. Veitch, P. Genovewi, J. Parkes, M. Pascal, A. Saunders, and B. Tershy. 2007. Invasive rodent eradications on islands. Conservation Biology. 21: 1258-1268.

Varnham, K (2010). Invasive rats on tropical islands: Their history, ecology, impacts and eradication. RSPB Research Report No. 41. Royal Society for the Protection of Birds, Sandy, Bedfordshire, UK. ISBN 978-1-905601-28-8.

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WORK PLAN, MONITORING PROTOCOL, AND SAMPLING DESIGNS FOR SEABIRD MONITORING, SHOREBIRD MONITORING, SEA TURTLE MONITORING, VEGETATION SAMPLING, ARTHROPOD SAMPLING, AND RODENT POPULATION MONITORING ON WAKE ISLAND

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PACIFIC ISLANDS CONSERVATION
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I. INTRODUCTION

Background

Wake Atoll, an unincorporated territory of the United States, is maintained and operated by the United States Air Force, 15th Airlift Wing of Pacific Air Forces. The facility contains an airfield for the Department of Defense and for emergency use by Trans-Pacific aircraft. As an active military installation, approximately 120 contract and military personnel reside on the island at any given time.

Wake Atoll is located in the central Pacific Ocean (19º18'55" N, 166º38'21" E) and approximately 2,460 mi. (3,956 km.) west of Honolulu and 1,590 mi. (2,545 km.) east of Guam. The island complex is comprised of three islets, including Wilkes, Wake, and Peale (Figure 1). These islets form a broken V-shape with a shallow lagoon in the center. The total area of the complex is 739 hectares and reaches a maximum elevation of 21ft. above sea level.

Biogeographically, Wake Atoll lies within the Trade Winds Division of the Tropical Domain (Bailey 1995) and is closest to the Marshall Islands. Wake has significant biological resources, including seabird colonies of regional importance, stands of Pisonia (*Pisonia grandis*) forest, and a healthy and diverse reef system. Table 1 lists the atoll's 15 breeding seabird species, as well as other rare and/or protected species and habitats.

The large bird populations have drawn significant conservation attention. A cat (*Felis sylvestris*) elimination program undertaken to protect the seabirds, was declared successful in 2007. Rat (*Rattus* spp.) eradication is also being planned for the island, to occur as early as summer 2009. Further, the Wake Atoll Integrated Natural Resources Management Plan (Hickam AFB 2008) considers Wake an ideal candidate location to experimentally translocate the endangered Guam Rail (*Gallirallus owstoni*) as a surrogate species to ecologically replace the now extinct Wake Island Rail (*Gallirallus wakensis*).

Purpose and Need

Authority for the Air Force to protect and restore natural resources on the Wake Island complex is supported by Federal laws and regulations, and elaborated upon and interpreted by Air Force policy. The following laws, regulations, and instructions provide the framework for the work carried out in this monitoring plan.

- Endangered Species Act of 1973, P.L. 93-205, 87 Statute 884, 16 USC 1531.
- Migratory Bird Treaty Act of 198, 16 USC 703-712, Chapter 128, 40 Statue 755.

- Lacey Act Amendments of 1981, P.L. 97-79, 95 Statute 1073, 16 USC 3371-3378 as amended by P.L. 98-327, 98 Statue 271.

- Code of Federal Regulations (CFR) 50 CFR Part 17, Endangered and Threatened Wildlife and Plants.

- Executive Order (E.O.) 13112, 1999; Invasive Species.

- Sikes Act Improvement Act, 1 USC 670a et seq.

- Department of Defense Instruction 4715.3, Environmental Conservation Program.

- Air Force Instruction 32-7064, Integrated Natural Resources Management.

- Wake Atoll Integrated Natural Resources Management Plan (2008-2012).

Natural Resource Management on Wake Island is conducted by Chugach Support Services Incorporated (CSSI), a base operations support contractor, with oversight from the 15 Air Wing Detachment 1 Commander and the Environmental Flight based at Hickam AFB.

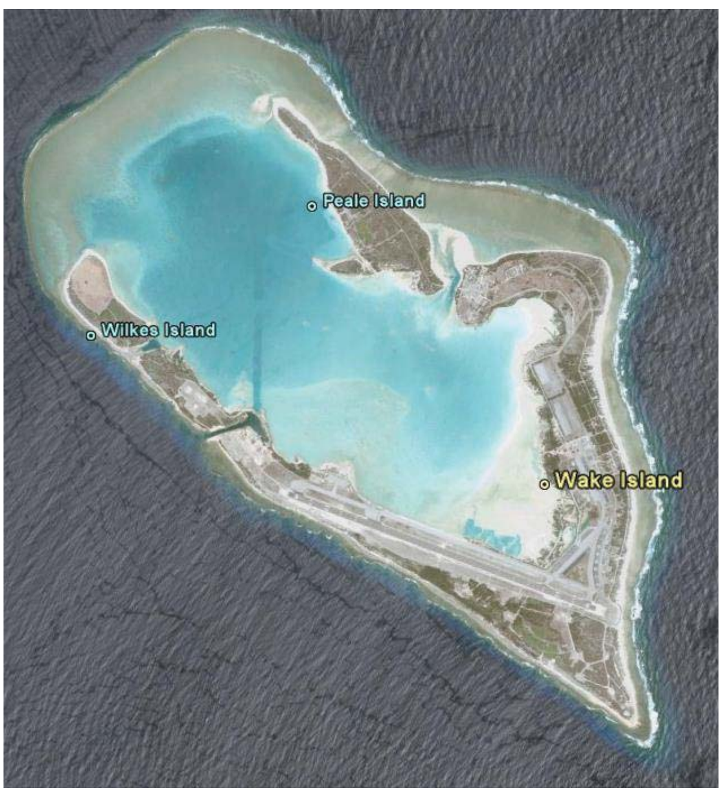

Figure 1. Islands comprising the Wake Atoll Complex in the Central Pacific Ocean.

Table 1. Species of interest occurring on Wake Island.

Species	Protected status
Laysan Albatross (*Phoebastria immutabilis*)	Migratory Bird Treaty Act Species of Conservation Concern
Black-footed Albatross (*Phoebastria nigripes*)	Migratory Bird Treaty Act Candidate for listing as threatened under Federal Endangered Species Act
Wedge-tailed Shearwater (*Puffinus pacificus*)	Migratory Bird Treaty Act
Christmas Shearwater (*Puffinus nativitatis*)	Migratory Bird Treaty Act
Red-tailed Tropicbird (*Phaethon rubricauda*)	Migratory Bird Treaty Act
White-tailed Tropicbird (*Phaethon lepturus*)	Migratory Bird Treaty Act
Great Frigatebird (*Fregata minor*)	Migratory Bird Treaty Act
Red-footed Booby (*Sula dactylatra*)	Migratory Bird Treaty Act
Brown Booby (*Sula leucogaster*)	Migratory Bird Treaty Act
Masked Booby (*Sula dactylatra*)	Migratory Bird Treaty Act
Sooty Tern (*Sterna fuscata*)	Migratory Bird Treaty Act
Grey-backed Tern (*Sterna lunata*)	Migratory Bird Treaty Act
Brown Noddy (*Anous stolidus*)	Migratory Bird Treaty Act
Black Noddy (*Anous minutus*)	Migratory Bird Treaty Act
White Tern (*Gygis alba*)	Migratory Bird Treaty Act
Bristle-thighed Curlew (*Numenius tahitiensis*)	Migratory Bird Treaty Act Species of Conservation Concern
Green sea turtle (*Chelonia mydas*)	Threatened, Endangered Species Act
Hawaiian monk seal (*Monachus schauinslandi*; occasional, none recently observed)	Endangered, Endangered Species Act Marine Mammal Protection Act
Bumphead parrotfish (*Bolbometopon muricatum*)	"vulnerable", IUCN red list NOAA species of concern
Napoleon wrasse (*Cheilinus undulatus*)	"endangered", IUCN red list NOAA species of concern
Giant clam (*Tridacna gigas*)	"threatened, low risk, conservation dependent", IUCN red list
Lepturus gasparricencis (near endemic grass)	
Coral Reefs (321 species of fish, 41 species of coral)	EO 13089
Wetlands (58 acres)	EO 11990, Clean Water Act

Under the Wake Atoll Integrated Natural Resources Management Plan (INRMP), the following requirements have been identified:

7.2.2.1 Monitor and Protect Nesting of Sensitive species. The 15 breeding seabird species and the migratory shorebirds and waterfowl that stop over on Wake Island need to be monitored to ensure their populations remain healthy and are not adversely impacted by human activities. In addition, knowledge of their population sizes and phenology (timing of breeding) over the course of the year will assist the Bird Airstrike Hazard (BASH) program in assessing and mitigating the risk of bird strikes. To implement this project, bird monitoring protocols will need to be created, with several alternative levels of effort built in to the protocols to take advantage of periods when more effort can be expended. At a minimum, however, yearly population estimates need to be conducted for each of the breeding seabirds, and reproductive success needs to be measured for the two species of albatross. Ideally, reproductive success estimates would be made for the remaining species, and relative abundances of migratory shorebirds and waterbirds would be determined. USFWS should review any monitoring plan.

7.2.2.2 Entomological surveys. Little information is known on the terrestrial arthropods of Wake Island. Basic baseline surveys need to be conducted in order to identify the presence of native arthropods in addition to the land crabs. Also, by providing a baseline, these surveys would assist in the early detection and identification of newly-arriving, potentially-invasive arthropods. Entomological surveys require special knowledge and tools and should be performed by a contractor with the assistance of the University of Hawaii and Bishop Museum.

7.2.2.3 Monitor Sea Turtle Activity - AFI 32-7064 (7.2) requires that all installations conduct basic reconnaissance surveys for federally listed threatened or endangered species. Follow-up reconnaissance surveys are required for federally listed species that may occur on the installation. It is common knowledge that the green sea turtle frequents the lagoon, nearshore reefs, and channel between Peale and Wake Island. Other species of sea turtles may also visit Wake Atoll, as may the Hawaiian monk seal. A formal monitoring program seems to be required. Short of that, at least a formalized documentation of all sightings should be prepared noting the species, dates, times, locations, and behavior of federally listed species. Especially important would be the documentation of “crawls,” suggesting nesting behavior. Photo documentation would be a beneficial addition. USFWS should be consulted to assist in development of a monitoring plan.

In addition to these specific requirements, the planned rat eradication has provided an opportunity to evaluate the effects of rat predation on the whole atoll's biological community. Conducting ecological monitoring across several taxonomic and functional groups allows for the creation of a pre-eradication baseline, from which we can compare species composition and abundance once the eradication is complete. Lessons learned from this investigation can then be applied to other tropical atolls whose biota may benefit from rat eradications.

Scope of Work

The ecological monitoring protocol laid out in this document seeks to establish ecological baseline data for the following groups of organisms: seabirds, shorebirds, vegetation, terrestrial arthropods, sea turtles (on land), and rats. Section 2 details the protocols for each specific group of organisms. The aim of this document is to detail a set of repeatable methodologies for CSSI to follow as part of their continuous monitoring responsibilities, and for more detailed follow-up work post-rat eradication. When followed appropriately, the protocols will provide thorough data on species occurrence, composition, population sizes, and other biological attributes for terrestrial organisms on Wake Atoll. The protocols outlined herein are separated into *primary* requirements that must be fulfilled, and *secondary* requirements that are not essential but nevertheless provide valuable information for successful resource management. Properly implemented protocols will provide data needed to establish baseline information for the focal fauna, and continued use will provide data to evaluate changes in species occurrence and abundance. However, methodologies used to evaluate data collected with these protocols can take many forms, none of which are included in this plan.

II. ECOLOGICAL MONITORING PROTOCOLS

Seabirds

Goal: To assess changes in phenology and abundance of focal populations on Wake Island. Breeding success of specified species will also be monitored. General nesting areas are illustrated schematically below (Figure 2).

Laysan Albatross (LAAL) and Black-footed Albatross (BFAL)

Primary requirements

Initial surveys will be conducted at previously known locations (Figure 2). Nest searches will begin during the first week of October, or as soon as albatross arrive on the island. Additional searches will be conducted weekly, and reports of nesting albatrosses will be verified immediately.

Laysan Albatross begin to lay eggs in late November or early December on Midway (*see* Whittow 1993). Hatching generally occurs from late January through mid-February. Incubation stage is 63-66 days. Fledgling is expected in the middle of July, but can occur at any time between late June and early August.

Black-footed Albatross may start breeding earlier. Egg laying may occur in early November (*see* Awkerman et al. 2008). Similar to Laysan Albatross, hatching occurs in late-January and early February after a mean incubation period of 65.6 ± 1.18 days. Fledglings may leave the nest as early as the middle of June.

The entire island complex will be searched for Laysan Albatross nests every two weeks, starting in early November and continuing through March. The number and location of nests will be recorded, along with the data and observer location. Once nests are identified, reproductive status will continue to be monitored every two weeks or as soon as possible after storm events. Data will include location (geographic coordinates), date, time, status (number of eggs, nestlings, or fledged), and band number or color band combination if present. Occasionally, nests are found with two eggs; however, one egg may be removed from the nest after a few weeks (Young, pers. comm.). Egg loss and nest lost due to predation, abandonment, or storm events will be recorded.

Secondary requirements

Persons authorized by the United States Geological Survey (USGS) Patuxent Bird Banding Laboratory may mark adults and nestlings of sufficient size.

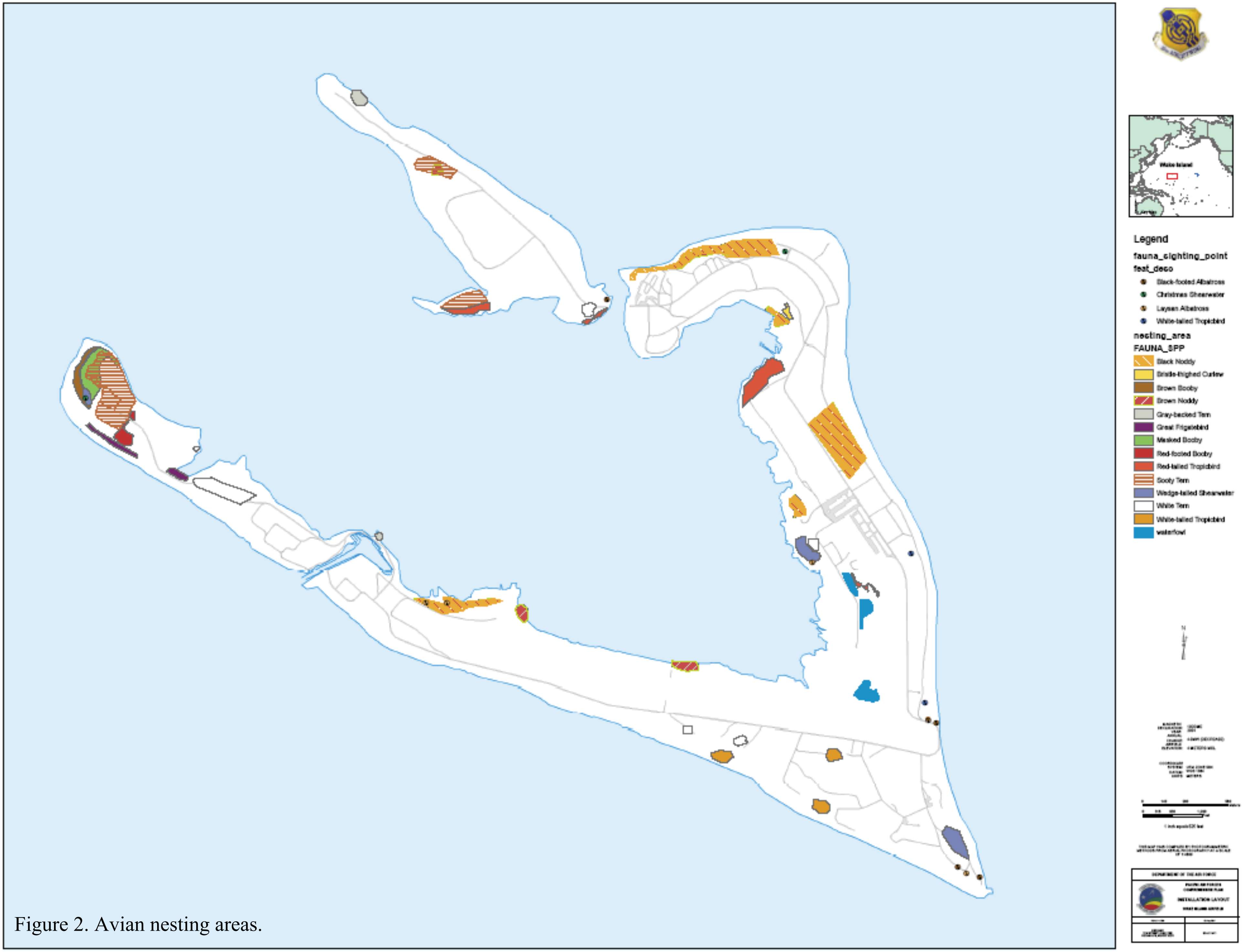

Figure 2. Avian nesting areas.

Sooty Tern (SOTE)

Sooty Terns are a widely dispersed seabird found in tropical and subtropical oceans (Schreiber et al. 2002). The breeding periodicity and degree of synchrony within populations vary throughout the range. Variation is likely due to environmental cues or a lack thereof (Ashmole 1965). Sooty Terns on Wake Island are asynchronous, leading to a range of developmental stages (incubation, nestling and post-fledgling) that occur simultaneously. Sooty Terns nest on the ground and in areas of sparse vegetation. Nest densities can be between 0.23 nest/m^2 to 9.29 nest/m^2. Mean incubation period is 28-30 days. Pipping may occur up to 36 hours prior to hatch. Chicks are vocal during this period (Dinsmore 1972 *in* Schreiber et al. 2002).

Nestlings are semi-precocial and capable of moving away from the nest site shortly after hatching, although they usually remain nearby for 4-10 days post-hatch. Nestlings may progressively spend more time away from the nest site, or abandon the nest site entirely. Chicks weigh 17.5–32.0 grams at hatch. Nestling mass increases to an average of 121 grams in three weeks. Adults weigh 178-208 grams. Growth is not uniform across the body (Ricklefs and White 1981). Age of fledging varies from 56 days to 9 months and relates to environmental conditions. Sooty Terns have extended post-fledge care. Young capable of flying may remain on the island for 18-21 days, however, adults and juveniles may remain together for two to three months.

Primary requirements

Monthly visits to known breeding areas will be used to assess breeding phenology. Timing of new nesting groups will be noted. The Sooty Tern colony will be mapped in a Geographic Information System (GIS; ArcView 9.2, ESRI, Redlands, CA) or through hand drawings later transcribed in a GIS to estimate colony area. The average density from experimental plots (see below) will be used to extrapolate Sooty Tern abundance. If experimental plots are not assessed because of limitations in manpower, density data from previous monitoring efforts will be used. Breeding phenology will be more precisely evaluated using data from each of the monitoring plots, if available.

Secondary requirements

From the colony areas, twelve permanent 7x7 m plots will be randomly selected and established to assess breeding population stage and density. These study plots will remain consistent throughout the monitoring period and from year to year. Plots will be marked at the corners with brightly painted wooden stakes and anodized aluminum tags. All nests will be counted inside of the plots to establish breeding bird densities. Developmental stage and breeding phenology will be monitored for up to 30 nests within each plot. If there are more than 30 nests in any particular plot, 30 nests will be randomly selected for research focus.

Grey-backed Tern (GBTE)

A relatively small population of Grey-backed Terns breed on Wake Atoll. Similar to other tropical species, Grey-backed Tern breeding is asynchronous and varies from year to year (Mostello et al. 2000). The incubation period is approximately 30 days. The nestling period is 38–47 days.

Primary requirements

Monthly surveys of known breeding areas will be made to assess presence and breeding phenology. Daily surveys will be made during the potential breeding season for the colony near the airfield, as part of daily airfield safety checks, to ensure that no nesting develops on the airfield. Population estimates will be made through direct counts on a monthly basis to assess changes in population size during the breeding period.

Brown Noddy (BRNO) and Black Noddy (BLNO)

Primary requirements

Noddies have asynchronous and unpredictable breeding seasons. Eight random locations within known breeding areas have been identified (Table 1, Figure 3). Four survey plots (15m x 15m) will be established at the first four suitable random locations to monitor BRNO and BLNO. The random locations will identify the northeast corner of each plot. If plots extend outside the nesting area, another random location will be selected and another plot will be established. Within each plot, the number of nests, and the stage of each nest will be recorded every two weeks to assess breeding chronology and changes in relative abundance.

Table 1. Random GIS locations for Black and Brown Noddy monitoring plots.

ID	Easting	Northing
1	672703	2135736
2	670479	2136318
3	672090	2135725
4	673131	2134646
5	672767	2135291
6	672084	2135658
7	672664	2135351
8	672640	2135381

Figure 3. Randomly selected monitoring plots for Brown Noddies and Black Noddies

Brown Booby (BRBO)

The breeding period for BRBO is protracted. Brown Boobies are a ground nesting species weighing 950-1,700 grams. One to three eggs are laid in a nest built of materials including bones, branches, grasses, and human debris. Siblicide is common and pairs rarely fledge more than one young per nesting attempt. The incubation period lasts 40-47 days. Nestlings become mobile at 2-3 weeks and progressively increase activity. Juveniles fledge at 95-120 days after clutch initiation, but this may be delayed if food is limited. Post-fledgling care continues for 3-8 weeks or longer (up to 51 weeks). The breeding colony delineation is depicted in Figure 2.

Primary requirements

Population census and determination of phenology will be carried out every three months. Three-month intervals account for the incubation period and the time for chicks to acquire retrices/remiges. Observations will include total number of nests and developmental stage (egg/small chick, downy chick, large downy/gawky, mostly feathered, fully feathered). Similar to photographs in Figure 5.

Secondary requirements

To assess reproductive success, Brown Booby nests will be monitored by tracking those nearest to randomly selected geographic coordinates (Figure 4, Table 2). Twenty Brown Booby nests will be visually monitored using a scope and tripod biweekly, until fledge or fail. If twenty nests cannot be found, all nests will be monitored. Observations will include date, time, nest identification number, and nest development stage.

Table 2. Random GIS locations for Brown Booby nest monitoring locations.

ID	Easting	Northing
BB1	668122	2134990
BB2	668179	2134743
BB3	668106	2134873
BB4	668127	2134973
BB5	668132	2134996
BB6	668119	2134878
BB7	668126	2135003
BB8	668112	2134948
BB9	668138	2134899
BB10	668196	2135092
BB11	668122	2134949
BB12	668209	2135104
BB13	668149	2134813
BB14	668121	2134897
BB15	668136	2135003
BB16	668118	2134860
BB17	668114	2134979
BB18	668161	2134774
BB19	668122	2134886
BB20	668250	2135125
BB21	668125	2134981
BB22	668148	2134794
BB23	668126	2134856
BB24	668116	2134962
BB25	668151	2135028
BB26	668128	2134944
BB27	668217	2135115
BB28	668110	2134940
BB29	668107	2134884
BB30	668196	2135108

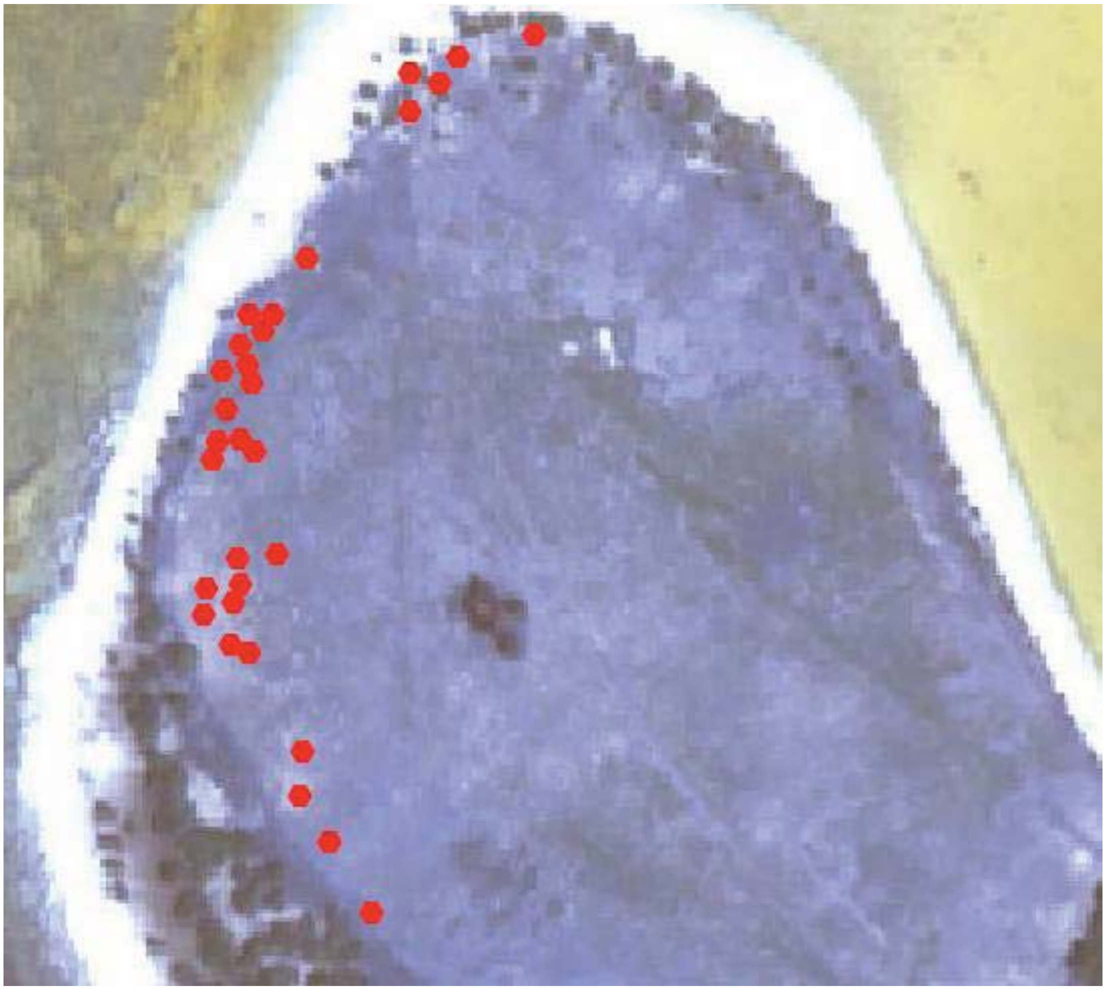

Figure 4. Randomly selected locations for monitoring nesting Brown Boobies.

Masked Booby (MABO)

Primary requirements

Population census will be performed every three months at the Wilkes Island colony (Figure 2). Three-month intervals account for the incubation period and the time for chicks to acquire retrices and remiges. Each survey will include date, number of new nests, and nest developmental stage, to assess annual abundance. Annual population size will be calculated by adding the number of new breeding pairs per check.

Adult with eggs

Downy chick

Large downy/gawky chick

Feathered juvenile with adult

Figure 5. Booby developmental stages. Photos are of masked boobies, but the same developmental stages are appropriate for Brown Boobies and Red-footed Boobies.

Red-footed Booby (RFBO)

Primary requirements

Nesting areas for RFBO will be indentified and visited monthly. Abandonment and die-off events will be recorded and described thoroughly. New breeding areas will also be documented as this may indicate population increases.

Shorebird and Waterbird Monitoring

Goal: To assess species composition, population sizes, and time of occurrence of wetland bird species.

Primary requirements

Shorebird and waterbird species composition and abundance is expected to vary through time and with season. Wetland species surveys occur weekly from three observation points within the wetland complex. Observation locations are depicted in Figure 6. Species composition may also be related to tidal fluctuations so initial surveys will be conducted to determine when in the tidal cycle surveys should be conducted to maximize bird counts. Using a scope and tripod, bird species and abundance will be recorded along with the date, time, and observation location.

Figure 6. Wetland bird observation locations.

Sea Turtle Monitoring

Goal: To document and monitor number of nests and beach crawls (beach visits) by sea turtles. If breeding occurs, hatch success will be recorded.

Primary requirements

Although sea turtle nesting has not been documented on Wake, frequent monitoring can help determine if the atoll becomes a breeding site. Sea turtles come to shore at night to breed. The best time to monitor activity is in the early morning after rain as new tracks should be more visible. Green sea turtles (*Chelonia mydas*) are commonly found in the waters around Wake Atoll. Leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricate*), loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) turtles may also visit the island as their distributions include the tropical and subtropical regions of the Pacific Ocean.

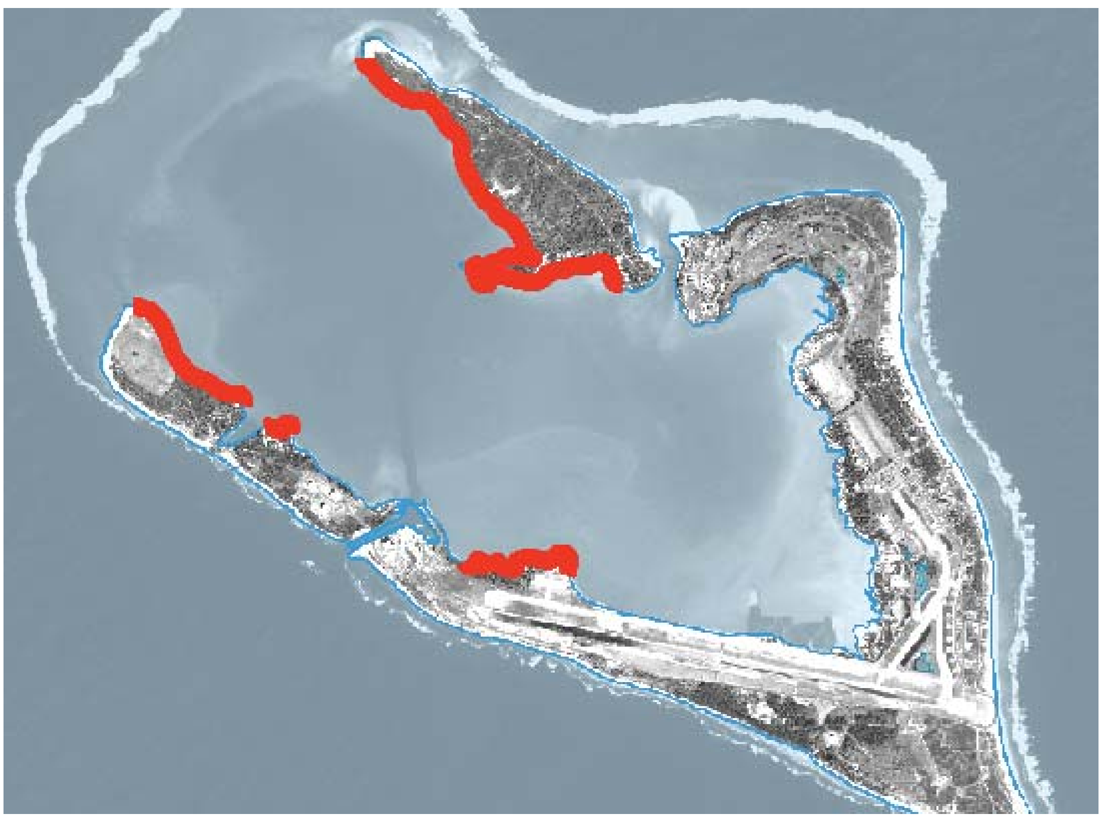

Figure 7. Beaches to be surveyed for turtle activity are delineated in red, if suitable habitat is present.

Surveys will focus on suitable nesting habitat for sea turtles. Currently, this includes the inner margin of Wilkes and Peale lagoons and the area around commander's beach house (northwest of west end or runway; Figure 7). Habitat conditions may be altered by storm events. Beaches can be selectively eliminated if site surveys reveal that habitat is not suitable for nesting (e.g., too coarse, rubble). Survey locations may be altered to reflect these changes.

Surveys will be conducted weekly in the early mornings, preferably after nighttime rain events. Tide levels may affect beach accessibility in some areas so survey times may be accordingly altered. Rain-smoothed beaches should increase detectability of new tracks. Surveys will not occur when high winds and blowing sand obscure tracks. Surveyor(s) will walk along the both the lower and upper portion of the beach. If tracks or nests are found the following data will be recorded:

- Species assessed by track size (see Figure 8).
- Date, time and current conditions.
- Nest found or beach crawl.
- Geographic coordinates for nest or highest point on the beach.
- Photos should be taken of tracks and nests.
- Comments on disturbance, erosion, or predation.
- If nests are found, area will be marked to reduce nest loss due to disturbance and trampling.

Identifying Turtle Tracks

SYMMETRIC	**ASYMMETRIC**
Leatherback	**Loggerhead**
150-230 cm	70-90 cm
Green	**Hawksbill**
100-130 cm	70-85 cm

Leatherback track

Loggerhead track

Green turtle track

Hawksbill track

Figure 8. Depiction and width of turtle tracks (material provided by COTERC).

Rat Abundance

Goal: To document and track changes in relative abundance of rats on Wake Island.

Primary requirements

An index of abundance will be based on driving transects that begin at downtown and terminate at boat harbor (red line, Figure 9). On the return trip, an additional segment through the water plant area along the dirt road on the lagoon side of the golf course will be surveyed (green line).

Figure 8. Transect route for rat abundance monitoring.

Transects will begin approximately one hour after sunset. The vehicle will travel at 25mph with high-beam lights illuminated to detect rats farther ahead. Data will include start time, end time at the marina, start and end time for the additional segment, and total number of rats seen on or near the road of each route. Counts will be tabulated separately for the different route components: 1) Town to east end of runway; 2) along runway; 3) return along runway; 4) east end of runway to spur; 5) spur; 6) end of spur to town. Driving transects will be conducted weekly.

Secondary requirements

Snap trap lines will be deployed once every two weeks to give a second estimate of seasonal changes in relative rat abundance. Lines of 10 traps will be deployed in each of the six segments described above. However, only one trap line will be deployed each week and all traps will be placed within a single segment. Focal segments will be rotated so that traps are placed in each approximately once three months. Within each trap line, traps will be placed 30m apart. Each trapping occasion will consist of two nights. On night 1, traps will be pre-baited with attractive bait but not set. Bait will be removed the following morning. On night 2, traps will be set. Traps will be mounted on plastic buckets to exclude crabs. Traps will be removed and the following data will be recorded: date, time, captured rats, trap tripped but no catch, trap not tripped, current weather conditions, weather conditions during previous 24 hours.

Vegetation Monitoring

Goal: To assess seedling abundance and survival of key species (Pisonia, Cordia, Tournefortia, and Ilima).

Secondary requirements

Twenty randomly selected points will be mapped within healthy native mixed Pisonia/Cordia/Tournefortia habitat on Wilkes and Peale islets (Figure 10 and 11). The points will be used as the start location for 20m plant transects. Starting points will be identified using Table 7 and then permanently marked. Orientation of the line transect will be randomly chosen from 0-360 degrees. Seedlings of *P. grandis*, *Cordia subcordata*, *Tournefortia argentea*, and *Sida fallax* that are within 0.5 m of the center of the 20m transect line will be identified and counted. Photos of each 5 m section of the transect line and close-ups of any unknown species will be recorded. Surveys will be conducted twice per year. Data will include date, transect number, species, and height of seedling.

Figure 10. Randomly selected locations for vegetation monitoring on Peale.

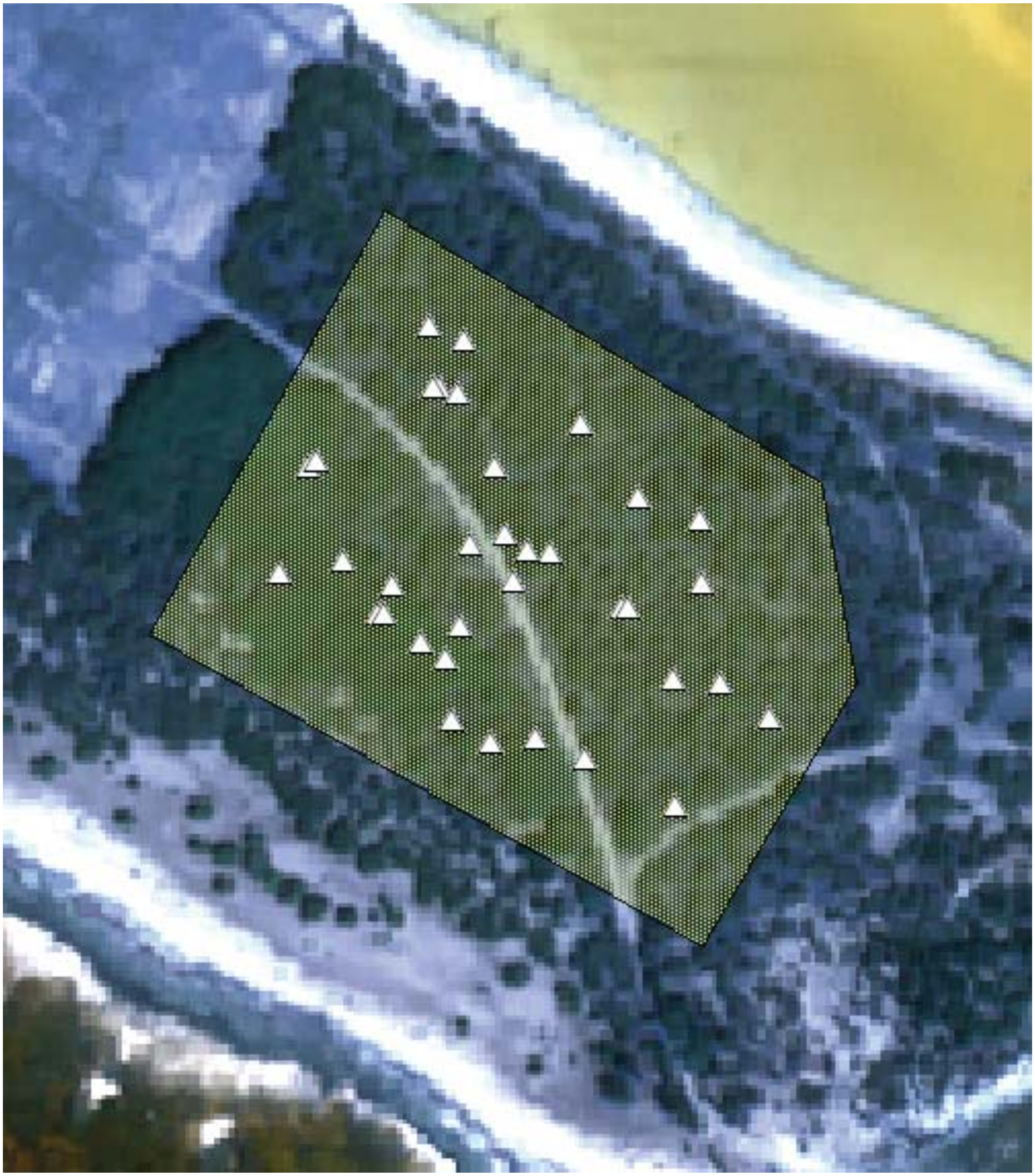

Figure 11. Randomly selected locations for vegetation monitoring on Wilkes.

Table 3. Geographic coordinates for random vegetation sampling locations on Peale and Wilkes islands. Multiple points are shown in case originals cannot be used for surveys.

Peale			Wilkes		
ID	Easting	Northing	ID	Easting	Northing
1	671113	2135776	1	668594	2134485
2	671011	2135692	2	668600	2134560
3	670738	2136025	3	668662	2134548
4	671053	2135696	4	668558	2134517
5	670824	2136098	5	668555	2134628
6	670692	2136168	6	668560	2134492
7	671067	2135967	7	668651	2134457
8	670917	2135925	8	668553	2134628
9	670979	2135786	9	668530	2134535
10	670862	2136048	10	668565	2134647
11	670794	2136107	11	668629	2134538
12	671124	2135912	12	668564	2134530
13	671040	2135880	13	668650	2134509
14	670992	2135712	14	668563	2134625
15	671172	2135682	15	668669	2134507
16	670943	2135813	16	668636	2134583
17	670683	2136155	17	668502	2134595
18	670818	2136031	18	668568	2134564
19	670884	2135883	19	668632	2134538
20	670975	2135767	20	668533	2134535
21	670728	2136206	21	668490	2134552
22	670869	2135934	22	668505	2134598
23	670933	2135861	23	668661	2134574
24	670838	2135969	24	668591	2134561
25	670785	2135991	25	668614	2134476
26	670807	2136123	26	668613	2134613
27	671232	2135834	27	668578	2134595
28	670851	2136023	28	668576	2134483
29	671161	2135838	29	668585	2134549
30	670916	2135863	30	668551	2134653
31	671127	2135807	31	668689	2134493
32	670863	2136050	32	668536	2134547
33	670937	2135862	33	668516	2134557
34	670789	2136031	34	668582	2134568
35	671024	2135678	35	668548	2134524

Arthropod Monitoring

Goal: To collect baseline information on the arthropod fauna, to identify the presence of native arthropods, and to assist in detection of harmful resident and newly arrived pest species.

Primary requirements

Twenty-four random points will be established to aid in the sampling of arthropods. Four points will be randomly selected in each of the 6 following habitat types; *Pisonia*/*Cordia*, *Tournifortia*, *Pemphis* wetland, seabird breeding colony, grassland, and *Casuarina* (Table 4, Figure 12). Pitfall traps will be set for three days at each point twice per year. Traps will be made using 24-ounce plastic containers so that the contents are protected from rain and sun. A six-ounce collecting cup will be placed inside the trap and will be 3/4 filled with water and 3-5 drops of a surfactant. The collecting cup will be flush with the ground. Pitfall traps will be removed upon collection.

Sweep nets and other opportunistic methods will be used to collect additional insects at each of the 24 sampling points. Captured insects will be aspirated into a 2-4 dram vial and filled with 80-95% ethyl alcohol. All collections will be carefully labeled with the geographic coordinates of the collection location, date, and collector. All samples will be stored in 80-95% ethyl alcohol for immediate shipping off Wake Atoll.

Figure 11. Arthropod sampling locations (see table 3 for geographic coordinates). Pink = seabird colony; blue = *Tournefortia*; brown = *Casuarina*; red = *Pemphis*; green = *Pisonia/Cordia*; purple = grassland.

Table 4. Random geographic coordinates for sampling arthropods. The first four locations listed below that fall within predicted habitat type will be used for sampling.

Id	Habitat	Northing	Easting
1	Casuarina	2134392	668661
2	Casuarina	2132646	671787
3	Casuarina	2134299	669146
4	Casuarina	2132569	672452
5	Casuarina	2135530	672988
6	Casuarina	2134037	669558
1	Grassland	2136308	670540
2	Grassland	2136275	670345
3	Grassland	2136310	670454
4	Grassland	2136287	670562
5	Grassland	2136255	670536
6	Grassland	2136338	670359
1	Pemphis	2134872	672497
2	Pemphis	2133561	673353
3	Pemphis	2133484	673309
4	Pemphis	2133725	672885
5	Pemphis	2134302	668936
6	Pemphis	2135405	670797
7	Pemphis	2133542	673288
8	Pemphis	2133486	673352
9	Pemphis	2135336	671349
10	Pemphis	2134806	672462
1	Pisonia	2136210	670810
2	Pisonia	2135633	671312
3	Pisonia	2135689	671266
4	Pisonia	2135917	670887
5	Pisonia	2135845	671167
6	Pisonia	2136153	670815
7	Pisonia	2135890	670966
8	Pisonia	2135911	670932
9	Pisonia	2135902	670990
10	Pisonia	2136045	670819
1	Seabird	2134771	668281
2	Seabird	2134611	668377
3	Seabird	2134993	668353
4	Seabird	2134814	668450
5	Seabird	2135010	668189
6	Seabird	2134959	668252
1	Tournefortia	2134590	668667
2	Tournefortia	2134548	668569
3	Tournefortia	2134033	669219
4	Tournefortia	2133083	673577
5	Tournefortia	2131931	673709
6	Tournefortia	2136001	670795
7	Tournefortia	2132342	672466
8	Tournefortia	2132271	672857

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APPENDIX: SAMPLE DATA SHEETS

Laysan Albatross (LAAL) and Black-footed Albatross (BFAL)

Nest Number	Location	Date	Time	Status	Band Numbers
1	Marina (672703, 2135736)	12/12/2008	1300	1 Egg	

Sooty Tern (SOTE)

Primary requirements: Density

Plot Number	Location	Date	Time	Number of nests
1	672703, 2135736	12/12/2008	1300	50

Secondary requirements: Nest monitoring

Plot Number	Nest Number	Location	Date	Time	Status
1	1	672703, 2135736	12/12/2008	1300	Egg

Grey-backed Tern (GBTE)

Location	Date	Time	Number of individuals	Number of nests	Number of nest with eggs	Number of nest with chicks
Airfield (672703, 2135736)	12/12/2008	1300	34	16	10	6

Brown Noddy (BRNO) and Black Noddy (BLNO)

Plot Number	Location (GPS)	Date	Time	Number of nests
1	672703, 2135736	12/12/2008	1300	50

Plot Number	Nest Number	Location (GPS)	Date	Time	Status
1	1	672703, 2135736	12/12/2008	1300	Egg

Brown Booby (BRBO)

Primary requirements: Census

Date	Number of nests	Number of nest with eggs/small chicks	Number of nest with downy chicks	Number of nest with large downy chicks	Number of mostly feathered chicks	Number of nest with fully feathered chicks
12/12/2008	30	10	6	6	4	4

Secondary requirements: Reproductive success

Nest Number	Location (GPS)	Date	Time	Status	Band Numbers
1	Marina (672703, 2135736)	12/12/2008	1300	1 Egg	

Masked Booby (MABO)

Date	Number of nests	Number of nest with eggs/small chicks	Number of nest with downy chicks	Number of nest with large downy chicks	Number of mostly feathered chicks	Number of nest with fully feathered chicks
12/12/2008	30	10	6	6	4	4

Shorebird and Waterbird Monitoring

Observation location	Date	Time	Species	Number of individuals	Cloud cover	Precipitation	Glare	Wind
1	12/12/2008	1300	RUTU	2	5%	None	5%	Calm

Sea Turtle Monitoring

Location (GPS)	Date	Time	Track size	Nests or beach crawl	Previous rain	Wind	Comments
672703, 2135736	12/12/2008	1300	100cm	Beach crawl	Yes	Calm	6

Rat Abundance

Date	Start time	End time	Segment	Number of rats
12/12/2008	1925	1945	1	7

Secondary requirements: Snap trap lines

Current weather conditions:

Previous (24 hours) weather conditions:

Location (GPS)	Segment	Date	Number of traps set	Number of traps tripped	Number of rats captured
672703, 2135736	3	12/12/2008	10	2	5

Vegetation Monitoring

Date: 12-15-2008
Location: Wilkes
Transect number: 5
Transect direction: 220 degrees

Dist. along transect	Date	Species	Height
5m	12/12/2008	*Pisonia*	10cm

2010 DATA SUMMARY AND REPORT: BIOLOGICAL MONITORING ON WAKE ISLAND

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INTRODUCTION

Background

Wake Atoll, an unincorporated territory of the United States, is maintained and operated by the United States Air Force, 15th Airlift Wing of Pacific Air Forces. The facility contains an airfield for the Department of Defense and for emergency use by Trans-Pacific aircraft. As an active military installation, approximately 120 contract and military personnel reside on the island.

Wake Atoll is located in the central Pacific Ocean (19˚16' N, 166˚39' E), approximately 3,956 km west of Honolulu and 2,545 km east of Guam. The island complex is comprised of three islets, including Wilkes, Wake, and Peale (Fig. 1). These islets form a broken V-shape with a shallow lagoon in the center. The total area of the complex is 739 ha and reaches a maximum elevation of 3 m above sea level. Biogeographically, Wake Atoll lies within the Trade Winds Division of the Tropical Domain and is closest to the Marshall Islands (Bailey 1995).

Wake Island has significant biological resources, including seabird colonies of regional importance, stands of *Pisonia grandis* trees, and a healthy and diverse reef system. The large bird populations have drawn significant conservation attention. A cat (*Felis sylvestris*) elimination program undertaken to protect the seabirds, was declared successful in 2007. Rat (*Rattus* spp.) eradication is also being planned for the island. Further, Wake Atoll is considered to be an ideal candidate location to establish a translocated population of endangered Guam Rail (*Gallirallus owstoni*; Hickam AFB 2008), which would serves a surrogate species to ecologically replace the now-extinct Wake Island Rail (*Gallirallus wakensis*).

Biological Monitoring

The ecological monitoring described in this document in designed to establish baseline data for Wake Atoll's seabirds, shorebirds, vegetation, terrestrial arthropods, sea turtles (on land), and rats. The aim of this document is to provide a baseline set of data, upon which continuous monitoring can be established. Results presented herein provide data on species occurrence, composition, population sizes, and other biological attributes for terrestrial organisms on Wake Atoll.

Pacific Island Conservation Research Association (PICRA; Newport, OR) created, refined, and implemented the Work Plan, Monitoring Protocol, and Sampling Designs for Seabird Monitoring, Shorebird Monitoring, Sea Turtle Monitoring, Vegetation Sampling, Arthropod Sampling, and Rodent Population Monitoring on Wake Island (PICRA 2008). The purpose of the work is to collect data on the Wake Island biodiversity and assist the Air Force in accomplishing tasks prescribed in the Wake Atoll

Integrated Natural Resources Management Plan (USAF 2008), which was intended to address requirements under the following laws, regulations, and instructions:

- Endangered Species Act of 1973, P.L. 93-205, 87 Statute 884, 16 USC 1531.
- Migratory Bird Treaty Act of 198, 16 USC 703-712, Chapter 128, 40 Statue 755.
- Lacey Act Amendments of 1981, P.L. 97-79, 95 Statute 1073, 16 USC 3371-3378 as amended by P.L. 98-327, 98 Statue 271.
- Code of Federal Regulations (CFR) 50 CFR Part 17, Endangered and Threatened Wildlife and Plants.
- Executive Order (E.O.) 13112, 1999; Invasive Species.
- Sikes Act Improvement Act, 1 USC 670a et seq.
- Department of Defense Instruction 4715.3, Environmental Conservation Program.
- Air Force Instruction 32-7064, Integrated Natural Resources Management.
- Wake Atoll Integrated Natural Resources Management Plan (2008-2012).

This monitoring provided baseline data on information that is critical to evaluate changes in this ecosystem, such as species occurrence, composition, population sizes, breeding phenology, and other biological attributes during February, April, June and July 2010. These data will also provide a starting point from which the success of the U.S. Air Force's environmental programs.

Natural Resource Management on Wake Island is coordinated by Chugach Support Services Incorporated (CSSI), a base operations support contractor, with oversight from the 15th Air Wing Detachment 1 Commander and the Environmental Flight based at Hickam AFB.

FIELDWORK TIMELINE AND OVERVIEW

Surveys of Wake Island fauna were conducted during February, April, June and July 2010. Multiple surveys and accomplishments were associated with each season. Those are listed in subsequent sections.

Winter and Summer Survey Seasons

Two PICRA representatives worked on Wake Atoll during 2010 fieldwork. PICRA continued the baseline surveys developed from monitoring protocols refined during the 2008 and 2009 seasons.

Figure 1. Islands comprising the Wake Atoll Complex in the Central Pacific Ocean.

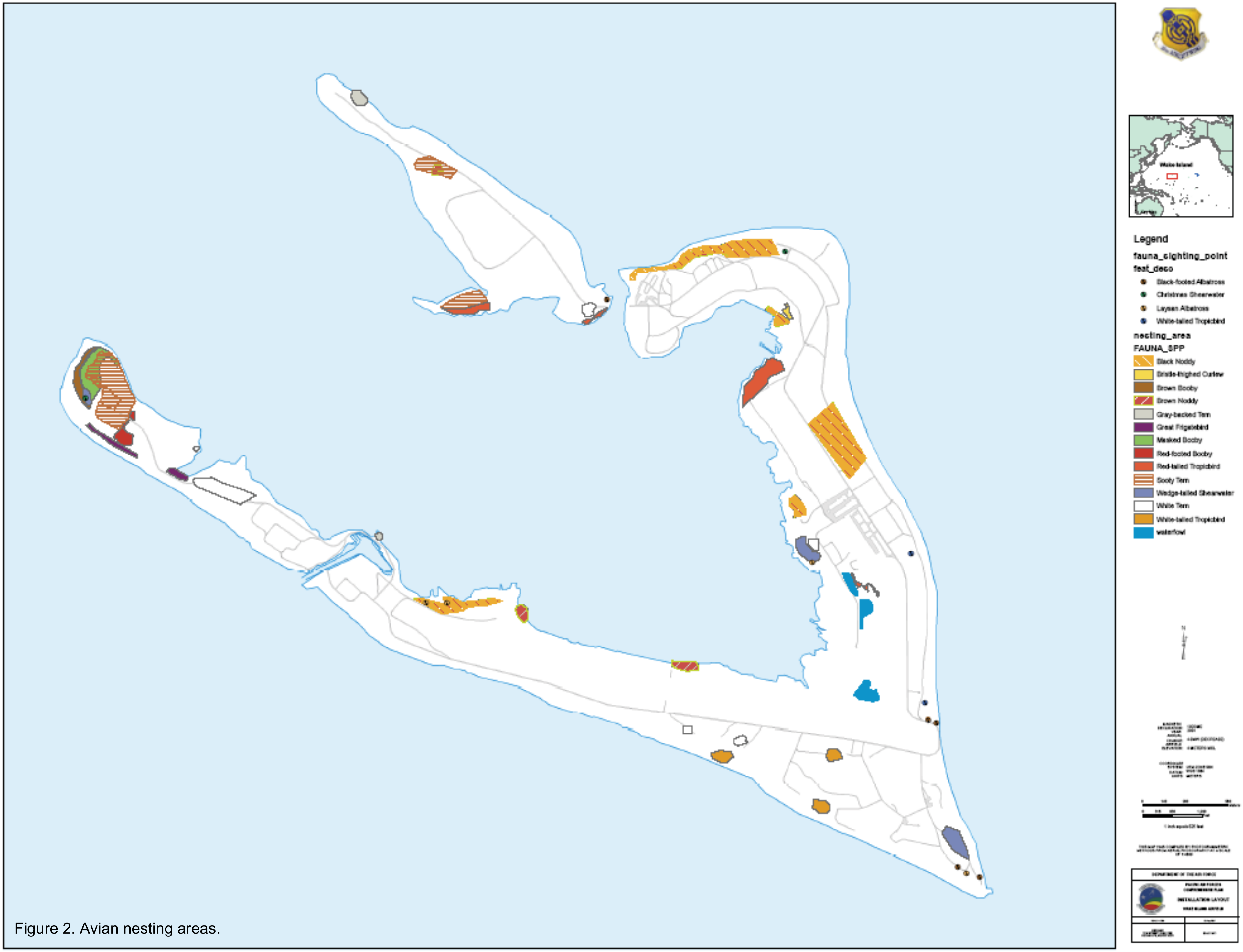

Figure 2. Avian nesting areas.

ECOLOGICAL MONITORING RESULTS

Results from ecological monitoring are provided below. In most cases, data collection followed protocols outlined in PICRA (2008). If field experiences demonstrated that the initial protocols did not adequately address the needs of several biological monitoring requirements, a detailed description of method modifications is provided below.

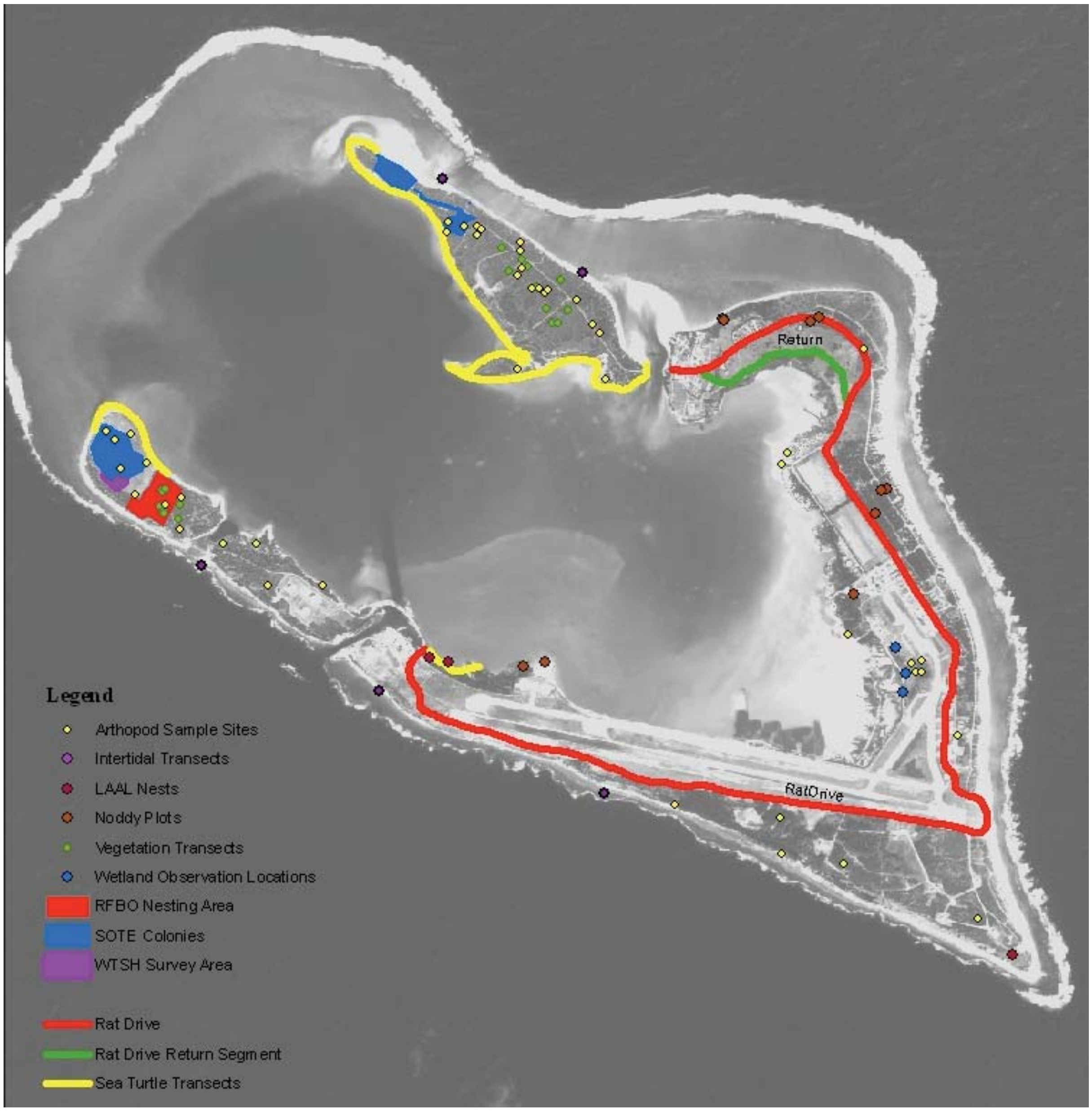

Figure 3. Composite figure showing biological monitoring locations on Wake Island in 2008 -2010

Laysan Albatross (Phoebastria immutabilis)

Natural History

No historic population demographic data were available for Laysan Albatross on Wake Island. Laysan Albatross typically lay eggs in late November or early December on Midway (Whittow 1993). Hatching generally occurs from late January through mid-February. Incubation lasts 63-66 days. Fledging is expected in the middle of July, but can occur at any time between late June and early August. Occasionally, nests might be found with two eggs (Young, pers. comm.).

Primary requirements

Initial surveys were conducted in 2008 at locations where Laysan Albatrosses historically occurred, and surveys at those same sites continued during 2009 and 2010. The entire island complex was searched for Laysan Albatross nests by on-island personnel while they were conducting normal work activities. The number and location of nests was recorded, along with the date and observer location. Once nests were identified, reproductive status was monitored every two weeks, or as soon as possible after storm events. Data included location (geographic coordinates), date, time, status (number of eggs, nestlings, or fledged), and band number or color band combination if present. Egg loss and nest lost due to predation, abandonment, or storm events were recorded.

Results

Three Laysan Albatross nests were identified by on-island personnel in mid- to late-November 2008, and prior to the arrival of PICRA personnel. PICRA and on-island personnel monitored albatross nests continuously every three to five days thereafter. No additional nests were identified during the prescribed searches in December 2008 and January 2009. None of these 3 nest locations were used in 2010, but one additional nest with an abandoned egg was located between February and April 2010. Picra personnel conducted intensive surveys on Peacock Point and Wilkes East in April, June and July of 2010 but neither individual Albatross nor additional nests were sighted. Several putative albatross nests reported by island residents were subsequently determined to be Red-tailed Tropicbird nests. (Appendix A)

Sooty Tern (Sterna fuscata)

Natural History

Sooty Terns are a widely distributed seabird found in tropical and subtropical oceans (Schreiber et al. 2002). Breeding periodicity and synchrony varies throughout the range, likely due to environmental cues, or a lack thereof (Ashmole 1965). Sooty Terns nest on the ground and in areas of sparse vegetation. Nest densities range from 0.23 nest/m^2 to 9.29 nest/m^2. Mean incubation is 28-30 days. Pipping may occur up to 36 hours prior to hatch. Chicks are vocal during this period (Schreiber et al. 2002).

Nestlings are semi-precocial and capable of moving away from the nest site shortly after hatching, although they usually remain nearby for four to 10 days post-hatch. Nestlings may progressively spend more time away from the nest site, or abandon the area entirely. Chicks weigh 17.5 – 32.0 g at hatch and increases to an average of 121 g in three weeks. Adults weigh 178 – 208 g. Growth is not uniform across the body (Ricklefs and White 1981). Age of fledging varies from 56 days to nine months and relates to environmental conditions. Sooty Terns have extended post-fledge care. Young capable of flying may remain on the island for 18 – 21 days, however, adults and juveniles may remain together for two to three months.

Nesting density

Sooty Tern monitoring plots were randomly selected from the colony map provided by Hickam Air Force Base (Fig. 2). Plots were permanently marked and bird abundance was recorded for 6 plots in April 2010. Average nest density was determined by averaging six 1 m^2 quadrates per plot. The open field portion of the Wilkes islet colony was abandoned en masse by Sooty terns, Masked and Brown Boobies throughout April and May 2010. The reason for the abandonment was unknown. Areas remaining occupied were along the north lagoon side and eastern tree line sides of the field. Sooty Terns also occupied approximately 200 m along the old road. The northwestern end of the colony continued to expand and adults continued to incubate eggs in May.

Displaced Sooty terns started breeding on a new site near the Wilkes wetland area. They nested in areas with small to large openings in the canopy and along the lagoon beach and on northeastern rocky point. The shoreline and point nesting area are potentially more vulnerable to storms, high tide events, and disturbance. The habitat at inland wetland area sites was characterized by rocky bare ground intermixed with grass and forbs surrounded by trees and shrubs. Nest density in three plots ranged from 3 nests/m^2 to 6.2 nests/m^2. The plot in the wetland area averaged 4.8 nests/m^2. However this may not represent densities throughout the new nesting area as sooty terns were found breeding in areas of varying size with open canopy.

Nest density was also estimated along a 20 meter transect outside of the plot areas where nesting was less dense. Nest (eggs and chicks) counts recorded along 6 transects during on 14 April 2010 (n = 254), which averaged 2.08 nests/transect meter. (Appendix B)

Grey-backed Terns (Sterna lunata)

Natural History

Similar to other tropical species, Grey-backed Tern breeding is asynchronous and varies from year to year (Mostello et al. 2000). The incubation period is approximately 30 days. The nestling period is 38 – 47 days.

Primary requirements

Monthly surveys of known breeding areas were made to assess presence and breeding phenology. Daily surveys were made during the potential breeding season for the colony near the airfield, as part of daily airfield safety checks, to ensure that no nesting develops on the airfield. Population estimates were made through direct counts on a monthly basis to assess changes in population size during the breeding period.

Results

A relatively small population of Grey-backed Terns bred on Wake Atoll. Though the entire island was searched, Grey-backed Terns were only observed nesting on the lagoon side of Wake Island near the east end of the runway in 2008 and 2009 (referred within this document as the Vortec area). A colony of 45 – 55 individuals with nests was observed in this same area during the first week of April 2010. Due to runway proximity base personnel used multiple techniques to dissuade the birds from nesting in order to minimize bird aircraft strike hazards (BASH).

Brown Noddy (Anous stolidus)

Primary requirements

Brown Noddies have asynchronous and unpredictable breeding seasons. Eight random locations within known breeding areas were identified (PICRA 2008). Four survey plots (15m x 15m) were established previously at the first four suitable random locations to monitor Brown Noddies. Each location identified the northeast corner of the plot. If plots extended outside the nesting area, a new random location was selected so that the plot was completely within the nesting area. Within each plot, the number of nests, and the stage of each nest were recorded every two weeks to assess breeding chronology and changes in relative abundance.

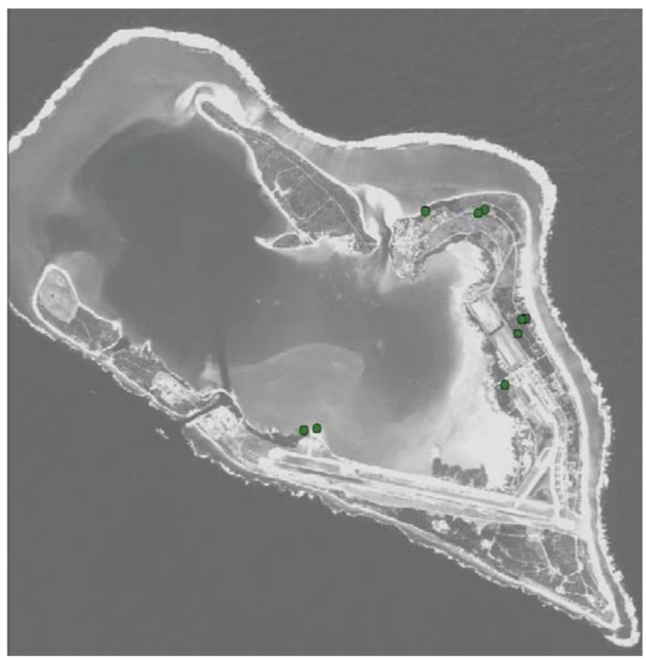

Figure 4. Randomly selected monitoring plots for Brown Noddies and Black Noddies.

Results

Noddies were detected in the trees on Wake Island during the second week of June 2010, but no active nests were found. Tree trimming equipment and subsequent removal of ironwood trees and limbs resulted in noddies being absent from at least one previously active location. Two nests, each with an individual egg, were observed during the last week of July 2010. A juvenile noddy was also noted during this time period (Appendix C).

Brown Booby (Sula leucogaster) and Masked Booby (Sula dactylatra)

Natural History

The breeding period for Boobies is protracted. Brown Boobies and Masked Boobies are ground nesting birds. One to three eggs are laid in a nest built of materials including bones, branches, grasses, and human debris. Siblicide is common and pairs rarely fledge more than one young per nesting attempt. The incubation period lasts 40–49 days (Schreiber and Norton 2002, Grace and Anderson 2009). Brown Booby chicks reach the mostly feathered stage at approximately 11 weeks and fully feathered classification at 13–14 weeks, while Masked Boobies require 15 weeks to reach fully feathered stage. Juveniles fledge at 95–120 days and 150–170 days, respectively.

Primary requirements

Population censuses and determinations of phonologies were carried out by PICRA and on-island personnel during 2009 and 2010. Three-month intervals accounted for the incubation period and the time for chicks to acquire retrices/remiges. Observations included total number of nests and developmental stage (egg/small chick, downy chick, large downy/gawky, mostly feathered, fully feathered).

Results

Brown Booby and Masked Booby population censuses were conducted on four occasions. On 4 February 2010, a total of eleven Brown Booby and 23 Masked Booby nests were counted that contained eggs (Appendix D and E). Three Brown Booby nests contained fully feathered chicks and an additional 26 adults were observed off of nests. Masked Booby nests contained chicks in all stages of nest development were present and 8 adults were observed off of nests. Population censuses were also conducted on 14 April, 10 June and 27 July 2010. Masked Booby nest numbers and phenology remained fairly constant for the duration of the surveys but Brown Booby numbers peaked in April with a high of 79 nests. Brown Booby nest counts fell to only 22 active nests in June and July, but off nest adults remained numerous, peaking at 197 during the July census event.

Wedge-tailed Shearwaters (*Puffinus pacificus*)

Monitoring of Wedge-tailed Shearwaters was not included in the original requirements, but it was added to the plan during the summer of 2009. Population monitoring was based on burrow occupancy – a common population index for this species. The area southwest of the twisted metal rods (UTM 668315, 2134694) to the berm and northwest to the edge of the Sooty Tern colony was searched (Fig. 5).

Burrows were initially marked as occupied if an adult was observed nearby. Criteria for occupancy or apparent occupancy included evidence of fresh digging, footprints, feathers, scent, or through visual detection of an egg, chick or adult. Visual inspections may include direct examination with a burrow-scope.

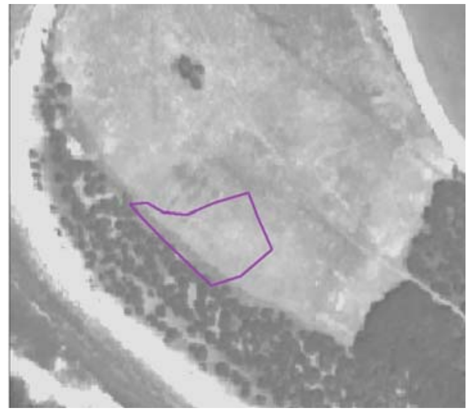

Figure 5. Wedge-tailed Shearwater occupancy survey area.

Results

Three burrows were determined to be active and an additional 27 bird were observed sitting on the ground during the census preformed on 14 April 2010. Burrows were counted again on 18 June 2010 and 26 additional burrows were located. Eighteen of the nests contained eggs and 11 were unoccupied. (Appendix F)

Shorebird and Waterbird Monitoring

Primary requirements

Wetland species surveys occurred weekly from three observation points within the wetland complex (Fig. 6). Using a scope and tripod, bird species and abundance were recorded along with the date, time, and observation location.

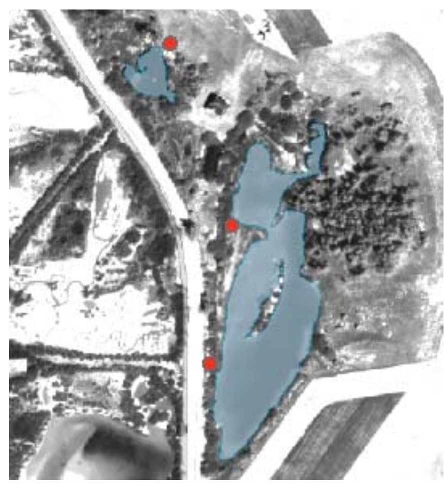

Figure 6. Wetland bird observation locations.

Results

Protocols remained unchanged during the entire survey period (February, April, June and July 2010), but due to low water levels birds were primarily only detected during the 9 February 2010 survey (Appendix G). Ruddy Turnstones (*Arenaria interpres*) were most common, while Golden-plover (*Pluvialis fulva*), and Red-tailed Tropicbird (*Phaethon rubricauda*) were also present.

Sea Turtle Monitoring

Natural History

Although sea turtle nesting has not been documented on Wake, frequent monitoring can help determine if the atoll becomes a breeding site. Sea turtles come to shore at night to breed. The best time to monitor activity is in the early morning after evening rain, as new tracks should be more visible. Green sea turtles (*Chelonia mydas*) are commonly found in the waters around Wake Atoll. Leatherback (*Dermochelys coriacea*), Hawksbill (*Eretmochelys imbricate*), Loggerhead (*Caretta caretta*), and Olive Ridley (*Lepidochelys olivacea*) turtles may also visit the island as their distributions include the tropical and subtropical regions of the Pacific Ocean.

Primary Requirements

Surveys focused on suitable nesting habitat for sea turtles. Potential areas included the inner margin of Wilkes and Peale lagoons and the area around commander's beach house (northwest of west end or runway; Fig. 7). Habitat conditions were altered by storm events so beaches were selectively eliminated if site surveys revealed that habitat was not suitable for nesting (e.g., too coarse, rubble).

Weekly surveys were conducted in the early mornings, preferably after nighttime rain events. Tide levels might affect beach accessibility in some areas so survey times were accordingly altered. Surveys did not occur when high winds and blowing sand obscured tracks. Surveyor(s) walked along the both the lower and upper portion of the beach. If tracks or nests were found, the following data were to be recorded: 1) Species assessed by track size; 2) Date, time and current conditions; 3) Whether a nest was found or beach crawl; 4) Geographic coordinates for nest or highest point on the beach; 5) Photos of tracks and nests; 6) Comments on disturbance, erosion, or predation. If nests were found, the area was marked to reduce nest loss due to disturbance and trampling.

Results

Weekly site surveys of potential sea turtle habitat were conducted throughout the survey periods (Appendix H). A total of 18 full surveys were completed with 5 surveys of the beach on Wilkes, 6 surveys on Peale and 7 surveys on Wake. No signs of sea turtles were observed during surveys

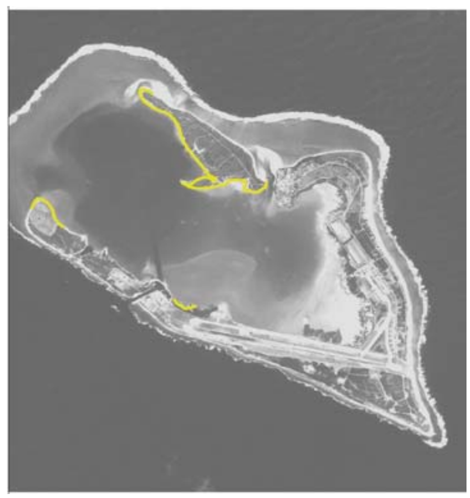

Figure 7. Sea turtle survey sights.

Rat Abundances

Primary requirements

An index of abundance was based on driving transects that began at downtown and ended at boat harbor (red line, Fig. 8). On the return trip, an additional segment through the water plant area along the dirt road on the lagoon side of the golf course was surveyed (green line, Fig. 8).

Transects began approximately one hour after sunset. The vehicle traveled at 25mph with high-beam lights illuminated to detect rats farther ahead. Original protocols were modified during the preliminary surveys in December 2008 and were solidified by early January 2009. Protocols developed in 2009 were utilized in 2010. Twelve surveys were conducted during 2010 over the course winter/spring and summer monitoring visits.

Results

The first survey took place in early February 2010, in which 22 rats were observed. Three surveys took place during both April and June 2010 and 4 surveys occurred in July of 2010. Rat abundance during spring and summer 2010 surveys ranged from 16 to 63 per survey. April surveys had the highest mean rat abundance with 37 rats per survey. June surveys had a slightly lower but similar mean abundance with 34 rats per survey (Appendix I).

Figure 8. Transect route for rat abundance monitoring.

Vegetation Monitoring

Secondary requirements

Twenty randomly selected locations were mapped within healthy native mixed *P. grandis, Cordia subcordata*, and *Tournefortia argentea* habitat on Wilkes and Peale islets (PICRA 2008). The points were used as the start location for 20 m plant transects. Orientation of the line transect was randomly chosen from 0 – 360 degrees. Each transect included the following data: a line intercept estimate of canopy cover, the number of seedlings present in a strip 50 cm on either side of the transect line, and an estimate of the percentage of ground covered by bare ground, leaf litter, or plants within the strip and identification of any seedlings of *P. grandis*, *C. subcordata*, *T. argentea*, and *Sida fallax* that were within 0.5 m of the center of the 20m transect line. Close-up photos of any unknown species were recorded.

Results

No seedlings of native plants were located during the 2009 summer round of surveys. The only seedlings found in any abundance were located on Peale Island and belong to the non-native *Desmanthus pernambucanus*. This species is considered an invasive on other Pacific islands and may be expanding its distribution on Wake Island.

Leaf litter was the prevalent cover type on both Wilkes and Peale survey sites, followed by bare ground. Grass was the least common ground cover on Peale islet and was absent from all of the Wilkes sites. Litter cover ranged from 1% to 100% on both Wilkes and Peale. The percent cover of bare ground ranged from 1% to 88% on Wilkes and 1% to 80% on Peale transect sites.

Overstory coverage along 7 of the 10 transects differed between 2009 and 2010 on Peale Islet, but remained the same on Wilkes. These changes could be the result of transects on Peale not being run along the same azimuth reading as 2009 or initiation of the transect at a different marker point. (Appendix J – L). Nonetheless, species composition did not vary significantly and *T. argentea* and open canopies were common at a majority of the sites regardless of year. Peale sites had a greater diversity of cover types including occurrences of both *Cordifolia subcordata* and *Casuarina equisetifolia.*

MONITORING RECOMMENDATIONS

These data represent the second year of a long-term research design. Future data should incorporate this baseline information and draw comparisons between years and management policies. In addition to documenting the results of rat eradication, these data can be used to inform management actions and comply with federal statutes.

Overall, the monitoring plan functioned as expected with minor alterations based on local information. These modifications, such as the relocation of observation location, Wetland 2, addition of Wedge-tailed Shearwater monitoring and vegetation sampling design, should remain in place because consistency over time will improve the power of these analyses. Below are suggestions for some species based on the knowledge gained while obtaining these baseline data.

Laysan Albatross

The protocols provided the necessary information on phenology and reproductive success of Laysan Albatross on Wake Island. Banding of adults should take place in the late incubation phase to reduce abandonment while the parents consistently attend the nest.

The island residents took an active interest in the nestling that fledged during 2009. They observed from a distance, noted behaviors, reported possible nests, and gained a general interest in the fauna on the island. Many expressed an interest in tracking the juvenile’s movements. This could be accomplished with the current technology and would provide both research information and function as community education.

Sooty Tern

General breeding stages were recorded. However, assessing reproductive success was not feasible due the limited visibility related to vegetation cover. Reproductive success could be obtained using mark-resight techniques and camera-based monitoring. Camera-based monitoring would be useful to assess hatch success, general attendance within a marked area, and to document predation events. However, banding and resight efforts would be necessary to determine survival probabilities for chicks more than a few days old because of their mobility.

Information related to movement ecology of Sooty Terns and other seabirds could provide valuable information for management and reduction of BASH hazards. Anecdotal observations suggest that birds on Peale and Wilkes may use different foraging areas and represent different risks to aircraft. In addition to determining frequently used areas, behavioral information such as mass arrival or departures could inform flight schedules. The design of these projects would depend on the associated questions and management goals.

Brown Noddy

The number of nests and occupied plots were limited. Depending on nesting site fidelity and habitat changes, it may be necessary to increase the number of random plots surveyed. Any additional sites should be selected from occupied areas. It may also be beneficial to increase the sample size of ground nesting sites as these represent an additional nesting structure type that may have a high probability of predation.

Wedge-tailed Shearwaters

The population of Wedge-tailed Shearwaters is still relatively small. Future surveys should identify and map the main colonies. Like many seabirds, Wedge-tailed Shearwaters show site fidelity in other locations (Whittow 1997). Provided they remain in the current survey area, burrow occupancy surveys should continue and others may be added as colonies form or move. Reproductive success may provide useful information about predation levels and environment variables. This can be accomplished through repeated surveys of marked burrows. Artificial burrows may aid in this effort and could provide stable burrows for returning adults.

Long-term population trends can be assessed through band-resighting techniques. With the current population size it may be possible to mark most of the fledglings. However, resighting of these marked young-of-the-year individuals when they return to breed would likely occur after 4 years since first reproduction occurs at four years of age (Whittow 1997). More immediate results could be obtained by marking adults, but care must be taken to reduce abandonment.

Rat Abundances

When rat population levels are low or moderate, we could also assess land crab population levels while conducting the rat abundance driving transects. At higher rat abundance, vehicle speed may need to be altered. Land crabs are a native predator which might be competing with or prey for rats. Additionally, anecdotal counts during routine actions could provide supporting information for patterns of abundance seen elsewhere.

Information on rat deterrents (i.e. sound devices) and poisoning efforts should be recorded as they may affect the results. Specifically, times and dates of bait deployments should be tracked.

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Appendix A : Laysan Albatross surveys and nests

Survey/Observation date	Location	Individuals	Nest With Egg	Status
February 2 - 10 2010	Peacock point	0	1	Abandoned
April 7 - 23 2010	Peacock point	0	0	Abandoned
June 6 - 17 2010	Peacock point	0	0	
June 6 - 17 2010	Wilkes East	0	0	
July 17 - 30 2010	Peacock point	0	0	

Appendix B: Sooty Tern nest transects (Note transect survey only when nesting)

Plot	Date	Easting	Northing	Nests	Status	Chicks
1	4/15/14	668345	2134748	31	abandoned	
2	4/15/14	668415	2134793	28	active	6 (all dead)
3	4/15/14	668299	2134924	77	active	0
4	4/15/14	668387	2134902	51	active	11
5	4/15/14	668422	2134912	44		
6	4/15/14	668444	2134789	18	active	27 (4 dead)

Appendix C: Brown Noddy Nests

Plot Location	Date Observed	Adults in Plot	Nests with Eggs	Nests With Chicks	Juveniles
1	6/8/10	1	0	0	0
2	6/8/10	18	0	0	0
3	6/8/10	0	0	0	0
4	6/8/10	0	0	0	0
5	6/8/10	0	0	0	0
6	6/8/10	0	0	0	0
7	6/8/10	0	0	0	0
8	6/8/10	0	0	0	0
1	7/25/10	0	0	0	0
2	7/25/10	5	0	0	0
3	7/25/10	1	0	0	0
4	7/25/10	1	0	0	0
5	7/25/10	0	2	0	0
6	7/25/10	0	0	0	0
7	7/25/10	0	0	0	0
8	7/25/10	0	0	0	0
9	7/25/10	0	0	0	1

Appendix D. Phenology and stage-based abundance of Wake Island Brown Boobies in 2010

Date	Eggs/small chick	Downy	Gawky	Mostly Feathered	Fully Feathered	Individuals
2/5/10	11	0	0	0	3	26
4/15/10	79	4	2		3	42
6/11/10	27	12	2	0	0	68
7/28/10	36	9	4	8	23	197

Appendix E. Phenology and stage-based abundance of Wake Island Masked Boobies in 2010

Date	Eggs/small chick	Downy	Gawky	Mostly Feathered	Fully Feathered	Individuals
2/5/10	30	14	0	1	4	8
4/15/10	23		5		3	31
6/11/10	17	0	2	0	0	25
7/28/10	26	13	3	5	12	53

Appendix F: Wedgetailed Shearwaters

Date	Northing	Easting	Burrows	with eggs	Unoccupied	Individuals
4/15/10	668189	2134745	3			41
6/18/10	668208	2134731	29	18	11	

Appendix G: Shore and water bird surveys

Date observed	Location	Species Observed	No. Observed	Water Level
February 2010	1	Pacific golden plover	2	High
		Ruddy Turnstone	8	
	2	Red-tailed tropic bird	2	
		Pacific golden plover	3	High
	3	Ruddy Turnstone	7	
		Red-tailed tropic bird	4	
		Pacific golden plover	2	High
		Red-tailed tropic bird	3	
April 2010	1	0	0	Low
	2	0	0	Low
	3	0	0	Low
June 2010	1	0	0	Low
	2	0	0	Low
	3	0	0	Low
July 2010	1	0	0	Low
	2	0	0	Low
	3	0	0	Low

Appendix H: Sea Turtle Surveys

	Location	Turtle Sign
February 2010	Wake	No
April 4 - 24 2010	Peale	No
	Peale	No
	Wilkes	No
	Wake	No
	Wake	No
	Wilkes	No
	Peale	No
June 7 - 17 2010	Peale	No
	Wilkes	No
	Wake	No
	Peale	No
	Wilkes	No
	Wake	No
July 24 - 30 2010	Wake	No
	Peale	No
	Wilkes	No
	Wake	No

Appendix I: Rat Transects

Location	Date Observed	Alive	Dead
WINTER			
Segment 1	2/9/14	7	2
Segment 2	2/9/14	3	1
Segment 3	2/9/14	2	1
Segment 4	2/9/14	4	2
Segment 1	4/9/14	6	0
Segment 2	4/9/14	8	0
Segment 3	4/9/14	13	1
Segment 4	4/9/14	10	1
Segment 5	4/9/14	0	0
Segment 6	4/9/14	0	0
SPRING			
Segment 1	4/15/14	7	1
Segment 2	4/15/14	11	0
Segment 3	4/15/14	9	0
Segment 4	4/15/14	14	1
Segment 5	4/15/14	1	0
Segment 6	4/15/14	0	0
Segment 1	4/19/14	4	1
Segment 2	4/19/14	14	0
Segment 3	4/19/14	6	0
Segment 4	4/19/14	2	1
Segment 5	4/19/14	0	0
Segment 6	4/19/14	0	0

SUMMER			
Segment 1	6/7/14	7	2
Segment 2	6/7/14	1	0
Segment 3	6/7/14	3	0
Segment 4	6/7/14	3	0
Segment 5	6/7/14	1	0
Segment 6	6/7/14	0	0
Segment 1	6/11/14	15	1
Segment 2	6/11/14	18	1
Segment 3	6/11/14	21	1
Segment 4	6/11/14	4	0
Segment 5	6/11/14	2	0
Segment 6	6/11/14	0	0
Segment 1	6/18/14	7	1
Segment 2	6/18/14	8	0
Segment 3	6/18/14	4	2
Segment 4	6/18/14	1	0
Segment 5	6/18/14	0	0
Segment 6	6/18/14	0	0
Segment 1	7/20/14	8	2
Segment 2	7/20/14	4	0
Segment 3	7/20/14	5	0
Segment 4	7/20/14	3	2
Segment 5	7/20/14	1	0
Segment 6	7/20/14	0	0
Segment 1	7/24/14	6	0
Segment 2	7/24/14	1	0
Segment 3	7/24/14	4	0
Segment 4	7/24/14	2	1
Segment 5	7/24/14	3	0
Segment 6	7/24/14	0	0
Segment 1	7/28/14	1	1
Segment 2	7/28/14	4	0
Segment 3	7/28/14	9	1
Segment 4	7/28/14	0	0
Segment 5	7/28/14	0	0
Segment 6	7/28/14	0	0
Segment 1	7/30/14	7	1
Segment 2	7/30/14	4	0
Segment 3	7/30/14	5	0
Segment 4	7/30/14	3	1
Segment 5	7/30/14	1	0
Segment 6	7/30/14	0	0

Appendix J: Seedlings

Island	Transect	Transect Point (m)	Species	Height (cm)
Wilkes	5	6.8	*Portulaca lutea*	
		6	*Portulaca lutea*	
Wilkes	8	19.6	*Portulaca lutea*	17
Peale	5	1.2	*unknown*	5
Peale	10	10.5	*Desmanthus pernambucanus*	5
		11.1	*Desmanthus pernambucanus*	25
		11	*Desmanthus pernambucanus*	20
		11.4	*Desmanthus pernambucanus*	15
		11.7	*Desmanthus pernambucanus*	5
		11.9	*Desmanthus pernambucanus*	17
		12.3	*Desmanthus pernambucanus*	5
		12.6	*Desmanthus pernambucanus*	20
		12.9	*Desmanthus pernambucanus*	20
		13.3	*Desmanthus pernambucanus*	35
		13.3	*Desmanthus pernambucanus*	30
		19.6	*Desmanthus pernambucanus*	35
		5	*Desmanthus pernambucanus*	5
		5.3	*Desmanthus pernambucanus*	10

Appendix K: Ground cover

Island	Transect	Cover type	mean % total cover	% cover range
Peale	1	open	5	2 - 9
		litter	36	2 - 85
Peale	2	open	11	1 - 18
		litter	22	2 - 44
Peale	3	open	41	1 - 74
		litter	7	7 - 8
		forb	15	9 - 23
		grass	10	1 - 23
Peale	4	open	20	9 - 42
		litter	19	5 - 36
		grass	2	
Peale	5	open	23	5 - 80
		litter	26	2 - 80
Peale	6	open	17	1 - 26
		litter	20	6 - 30
		grass	2	1 - 4
Peale	7	litter	100	
Peale	8	open	8	3 - 30

		litter	20	10 - 30
		forb	3	2 - 3
		rusted metal	26	24 - 30
		Chamaesyce hirta	2	
Peale	9	open	15	4 - 30
		litter	37	9 - 60
		forb	13	4 - 20
		grass	9	4 - 10
Peale	10	open	12	9 - 16
		litter	20	10 - 30
		forb	17	3 - 30
		grass	7	5 - 10
Wilkes	1	open	42	8 - 88
		litter	19	8 - 50
		forb	3	
		Portulaca lutea	13	
Wilkes	2	open	17	6 - 15
		litter	35	2 - 68
Wilkes	3	open	10	1 - 37
		litter	16	1 - 50
		forb	2	
Wilkes	4	open	9	6 - 15
		litter	27	1 - 80
Wilkes	5	open	17	
		litter	13	
Willkes	6	open	19	
		litter	27	5 - 52
Wilkes	7	open	14	3 - 45
		litter	14	3 - 30
		forb	1	
Wilkes	8	open	13	1 - 45
		litter	25	8 - 43
Wilkes	9	litter	81	42 - 100
Wilkes	10	open	5	1 - 10
		litter	11	1 - 38
		forb	3	0.03 - 9

Appendix L: Canopy cover and species

Island	Transect	Species	Mean Distance (m)	Mean % Cover
Peale	1	Pisonia grandis	12.15	61
		Casuarina equisetifolia	8.15	41
		Bare	0.50	3
		Casuarina equisetifolia	1.83	9
Peale	2	Open	3.30	17
		Casuarina equisetifolia	2.05	10
		Tournefortia argentea	3.38	17
		Open	2.85	14
		Casuarina equisetifolia	2.95	15
		Pisonia grandis	8.78	44
Peale	3	Tournefortia argentea	2.05	10
		Tournefortia argentea	18.00	90
		Open	17.73	89
Peale	4	Open	7.23	36
		Tournefortia argentea	0.23	1
		Open	4.05	20
		Casuarina equisetifolia	8.35	42
		Open	0.15	1
Peale	5	Open	1.25	6
		Heliotropium procumben	2.10	11
		Tournefortia argentea	7.03	35
		unknown	1.83	9
		Tournefortia argentea	7.60	4
		Open	1.78	9
		Tournefortia argentea	9.73	49
Peale	6	Tournefortia argentea	4.00	20
		Tournefortia argentea	11.05	56
		Open	1.20	6
		Tournefortia argentea	5.30	27
		Open	7.10	36
		Tournefortia argentea	2.15	11
Peale	7	Ipomoea violacae	1.34	7
		Cordia subcordata	20.00	100
Peale	8	Tournefortia argentea	4.90	25
		Open	1.80	9
		Tournefortia argentea	6.70	34
		Open	6.98	35
		unknown	4.53	23
		Tournefortia argentea	1.25	13
Peale	9	Tournefortia argentea	2.55	13
		Open	0.95	5

		Tournefortia argentea	7.55	38
		Open	1.20	6
		Tournefortia argentea	4.40	22
		Open	2.20	11
		Tournefortia argentea	1.15	6
Peale	10	Open	2.83	14
		Tournefortia argentea	4.85	24
		Open	9.60	48
		unknown	3.50	18
Wilkes	1	Tournefortia argentea	10.40	52
		Open	0.35	2
		Tournefortia argentea	5.20	26
		Open	1.15	6
		Portulaca lutea	0.80	4
		Tournefortia argentea	2.30	13
Wilkes	2	Cordia subcordata	15.10	76
		open	2.40	12
		Tournefortia argentea	7.40	37
Wilkes	3	Tournefortia argentea	3.55	18
		Open	5.35	27
		Tournefortia argentea	10.05	50
		Open	1.05	5
Wilkes	4	Cordia subcordata	20	100
Wilkes	5	Tournefortia argentea	0.5	3
		Open	6.9	35
		Tournefortia argentea	7	35
		Open	1.15	6
		Tournefortia argentea	4.7	24
Wilkes	6	Tournefortia argentea	4.85	24
		open	6.25	31
		Tournefortia argentea	2	10
		Cordia subcordata	7.9	40
Wilkes	7	Open	9.65	48
		Tournefortia argentea	9.95	50
		Open	0.4	20
Wilkes	8	Open	1.75	9
		Tournefortia argentea	5.25	26
		Open	3.75	19
		Tournefortia argentea	9.25	46
Wilkes	9	Tournefortia argentea	4.3	22
		Cordia subcordata	16.35	82
		Tournefortia argentea	3	15
Wilkes	10	Tournefortia argentea	9.85	49
		Open	1.125	6
		Tournefortia argentea	4.975	25
		Open	0.95	5
		Tournefortia argentea	3.1	16

WAKE ISLAND INSECT AND OTHER TERRESTRIAL ARTHROPODS 2009

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PACIFIC ISLANDS CONSERVATION
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I. INTRODUCTION

Wake Atoll, an unincorporated territory of the United States, is maintained and operated by the United States Air Force, 15th Airlift Wing of Pacific Air Forces. The facility contains an airfield for the Department of Defense and for emergency use by Trans-Pacific aircraft. As an active military installation, approximately 120 contract and military personnel reside on the island at any given time.

Wake Atoll is located in the central Pacific Ocean (19º18'55" N, 166º38'21" E) and approximately 2,460 mi. (3,956 km.) west of Honolulu and 1,590 mi. (2,545 km.) east of Guam. The island complex is comprised of three islets, including Wilkes, Wake, and Peale (Figure 1). These islets form a broken V-shape with a shallow lagoon in the center. The total area of the complex is 739 hectares and reaches a maximum elevation of 21ft. above sea level.

Biogeographically, Wake Atoll lies within the Trade Winds Division of the Tropical Domain and is closest to the Marshall Islands. Wake has significant biological resources, including seabird colonies of regional importance, stands of Pisonia (*Pisonia grandis*) forest, and a healthy and diverse reef system.

Purpose and Need

Authority for the Air Force to protect and restore natural resources on the Wake Island complex is supported by Federal laws and regulations, and elaborated upon and interpreted by Air Force policy. The following laws, regulations, and instructions provide the framework for the work carried out in this monitoring plan.

- Endangered Species Act of 1973, P.L. 93-205, 87 Statute 884, 16 USC 1531.
- Migratory Bird Treaty Act of 198, 16 USC 703-712, Chapter 128, 40 Statue 755.
- Lacey Act Amendments of 1981, P.L. 97-79, 95 Statute 1073, 16 USC 3371-3378 as amended by P.L. 98-327, 98 Statue 271.
- Code of Federal Regulations (CFR) 50 CFR Part 17, Endangered and Threatened Wildlife and Plants.
- Executive Order (E.O.) 13112, 1999; Invasive Species.
- Sikes Act Improvement Act, 1 USC 670a et seq.
- Department of Defense Instruction 4715.3, Environmental Conservation Program.
- Air Force Instruction 32-7064, Integrated Natural Resources Management.
- Wake Atoll Integrated Natural Resources Management Plan (2008-2012).

Natural Resource Management on Wake Island is conducted by Chugach Support Services Incorporated (CSSI), a base operations support contractor, with oversight from the 15 Air Wing Detachment 1 Commander and the Environmental Flight based at Hickam AFB.

Figure 1. Islands comprising the Wake Atoll Complex in the Central Pacific Ocean.

Arthropod Monitoring

Twenty-four random points were established to aid in the sampling of arthropods. Four points were randomly selected in each of the 6 following habitat types; *Pisonia*/*Cordia*, *Tournifortia*, *Pemphis* wetland, seabird breeding colony, grassland, and *Casuarina* (Table 1, Figure 2). Pitfall traps were set for three days at each point twice per year. Traps were made using 24-ounce plastic containers so that contents were protected from rain and sun. A six-ounce collecting cup was placed inside the trap and filled 3/4 with water and 3-5 drops of a surfactant. The collecting cup was flush with the ground. Pitfall traps were removed upon collection.

Sweep nets and other opportunistic methods were used to collect additional insects at each of the 24 sampling points. Captured insects were aspirated into a 2-4 dram vial and filled with 80-95% ethyl alcohol. All collections were carefully labeled with the geographic coordinates of the collection location, date, and collector. All samples were stored in 80-95% ethyl alcohol for immediate shipping off Wake Atoll.

Figure 2. Arthropod sampling locations (see table 3 for geographic coordinates). Pink = seabird colony; blue = *Tournefortia*; brown = *Casuarina*; red = *Pemphis*; green = *Pisonia/Cordia*; purple = grassland.

Table 4. Random geographic coordinates for sampling arthropods. The first four locations listed below that fall within predicted habitat type will be used for sampling.

Id	Habitat	Northing	Easting
1	Casuarina	2134392	668661
2	Casuarina	2132646	671787
3	Casuarina	2134299	669146
4	Casuarina	2132569	672452
5	Casuarina	2135530	672988
6	Casuarina	2134037	669558
1	Grassland	2136308	670540
2	Grassland	2136275	670345
3	Grassland	2136310	670454
4	Grassland	2136287	670562
5	Grassland	2136255	670536
6	Grassland	2136338	670359
1	Pemphis	2134872	672497
2	Pemphis	2133561	673353
3	Pemphis	2133484	673309
4	Pemphis	2133725	672885
5	Pemphis	2134302	668936
6	Pemphis	2135405	670797
7	Pemphis	2133542	673288
8	Pemphis	2133486	673352
9	Pemphis	2135336	671349
10	Pemphis	2134806	672462
1	Pisonia	2136210	670810
2	Pisonia	2135633	671312
3	Pisonia	2135689	671266
4	Pisonia	2135917	670887
5	Pisonia	2135845	671167
6	Pisonia	2136153	670815
7	Pisonia	2135890	670966
8	Pisonia	2135911	670932
9	Pisonia	2135902	670990
10	Pisonia	2136045	670819
1	Seabird	2134771	668281
2	Seabird	2134611	668377
3	Seabird	2134993	668353
4	Seabird	2134814	668450
5	Seabird	2135010	668189
6	Seabird	2134959	668252
1	Tournefortia	2134590	668667
2	Tournefortia	2134548	668569
3	Tournefortia	2134033	669219
4	Tournefortia	2133083	673577
5	Tournefortia	2131931	673709
6	Tournefortia	2136001	670795
7	Tournefortia	2132342	672466
8	Tournefortia	2132271	672857

APPENDIX A. TERRESTRIAL INVERTEBRATE SPECIMENS

Attached is the list of invertebrate specimens collected by on Wake Atoll that were deposited at the Bishop Museum in January 2010. This list totals 2,170 specimens among at least 148 species, of which 393 are identified to the species level. We added several previously unreported species to the Wake invertebrate list. Bishop Museum Accession Number 2010.010 has been applied to this lot.

Wake Island invertebrates accessioned under Bishop Museum Accession No. 2010.010 on 30 January 2010

Data compiled by L.E. Stevens, Stevens Ecological Consulting, LLC, Flagstaff, AZ

≥148 species detected, 393 identified to species, 2170 individuals prepared and curated

		Habitat Type							
Species	**Date**	**Casuarina**	**Grass-lands**	**Pemphis**	**Pisonia**	**Tourne-fortia**	**Seabird Colony**	**Other**	**Column Total**
Amphipoda	Mar-Apr 2009	0	0	0	0	0	1	0	1
ARAN Sp. 10	Mar-Apr 2009	0	0	0	0	0	2	0	2
ARAN-Gnaphosid?	June-July 2009	1	3	0	1	1	0	0	6
ARAN-Gnaphosid? (Sm Blck)	June-July 2009	0	2	0	0	1	0	0	3
ARAN-Gnaphosidae 1	Mar-Apr 2009	1	4	4	0	1	0	0	10
ARAN-Imm.	June-July 2009	14	3	8	5	1	1	0	32
ARAN-Pholcidae?	Mar-Apr 2009	0	0	1	0	0	0	0	1
ARAN-Salticid?	June-July 2009	2	1	2	1	0	1	0	7
ARAN-Salticidae - brown	Mar-Apr 2009	1	2	2	3	2	0	0	10
ARAN-Sp. 1 (red, powerful legs)	Mar-Apr 2009	4	1	4	2	1	5	0	17
ARAN-Sp. 1(Red & Leggy)	June-July 2009	0	7	12	4	3	1	0	27
ARAN-Sp. 2(Green & Leggy)	June-July 2009	1	0	4	0	1	0	0	6
ARAN-Sp. 2(green, powerful legs)	Mar-Apr 2009	0	0	1	1	0	0	0	2
ARAN-Sp. 3 (yellow, abdominal stripe)	Mar-Apr 2009	13	12	19	2	2	1	0	49
ARAN-Sp. 3 (Yellow, Stripey)	June-July 2009	1	0	0	0	0	0	0	1
ARAN-Sp. 4(Large, Striped-Araneidae?)	June-July 2009	1	0	0	0	0	0	0	1
ARAN-Sp. 5 (Brown, big pedipalps; red wolf)	Mar-Apr 2009	1	2	2	0	0	0	0	5
ARAN-Sp. 5(Brown, big pedipalps)	June-July 2009	0	0	1	0	0	0	0	1
ARAN-Sp. 6(Large, Striped-Araneidae?)	June-July 2009	0	0	0	1	0	0	0	1
ARAN-Sp. 7(Gray)	June-July 2009	0	4	0	0	0	0	0	4
ARAN-Sp. 8(Drk Gray)	June-July 2009	2	0	0	0	1	1	0	4
ARAN-SP. 9 (globose abdomen, gray)	Mar-Apr 2009	0	0	0	0	0	2	0	2
ARAN-SP. 9(Round Gray)	June-July 2009	1	0	0	0	0	0	0	1
ARAN-undet eggs	Mar-Apr 2009	17	0	0	0	0	0	0	17
CLL-Sp. 1(Green)	June-July 2009	10	78	40	16	0	0	0	144
CLL-Sp. 2 (black)	Mar-Apr 2009	0	0	0	0	1	0	0	1
CLL-Sp. 2(Black)	June-July 2009	2	0	7	0	0	0	1	10
CLL-Sp. 3	June-July 2009	75	35	40	304	15	0	0	469
CLL-Sp. 4	June-July 2009	0	0	55	0	0	0	0	55
COL Bostrichidae *Amphicerus cornutus*	Mar-Apr 2009	0	0	1	2	1	0	0	4
COL Bostrichidae *Amphicerus cornutus*	June-July 2009	1	0	0	4	0	0	0	5
COL Bostrichidae *Ips?*	Mar-Apr 2009	2	0	0	0	0	0	0	2
COL Dermestidae *Dermestes ater* Debeer	June-July 2009	0	0	0	0	1	0	0	1
COL Staphylinidae sm black	Mar-Apr 2009	4	0	1	24	7	0	0	36
COL Staphylinidae? minute	Mar-Apr 2009	0	0	1	0	1	0	0	2
COL undet 2-tiny red	Mar-Apr 2009	1	0	0	0	0	0	0	1
COL Undet larva 1	Mar-Apr 2009	0	0	0	1	0	0	0	1
COL Undet larva 2	Mar-Apr 2009	0	1	1	0	0	0	0	2
COL-Cantharidae	June-July 2009	0	0	0	0	0	0	1	1
COL-Cerambycidae	June-July 2009	0	0	0	2	0	0	0	2
COL-Cerambycidae adult	Mar-Apr 2009	0	0	0	2	0	0	0	2
COL-Cerambycidae? larvae	Mar-Apr 2009	0	0	0	1	0	0	0	1
COL-Chrysomelid Sp. 1	June-July 2009	0	0	1	0	0	0	0	1
COL-Chrysomelid? (Black and Yellow)	June-July 2009	0	1	0	0	0	0	0	1
COL-Cleridae? Sm brn	Mar-Apr 2009	0	0	1	0	0	0	0	1
COL-Coccinellidae	June-July 2009	1	0	2	0	0	0	0	3
COL-Curculionidae (*Anthonomus*?)	June-July 2009	0	0	1	0	0	0	0	1
COL-Curculionidae (med red)	Mar-Apr 2009	0	0	0	6	0	0	0	6
COL-Curculionidae (sm brown)	Mar-Apr 2009	1	0	1	0	0	0	0	2
COL-Curculionidae (Sm brown)	June-July 2009	0	0	0	1	0	0	0	1
COL-Curculionidae (tiny black)	Mar-Apr 2009	0	0	0	4	0	0	0	4
COL-Curculionidae (Tiny Black)	June-July 2009	0	2	0	0	0	0	0	2
COL-Elateridae *Agriotes* sp.	June-July 2009	0	1	0	0	0	0	0	1
COL-Elateridae *Conodens pallipes* Escholtz	Mar-Apr 2009	0	0	0	1	0	0	0	1
COL-Elateridae *Conodens pallipes* Escholtz	June-July 2009	0	0	0	0	0	0	1	1
COL-Elateridae *Megapenthes brunniventris* Candeze	Mar-Apr 2009	0	0	0	2	0	0	0	2
COL-Elateridae *Megapenthes brunniventris* Candeze	June-July 2009	0	0	0	0	0	0	1	1
COL-Larvae (Big Black & Hairy)	June-July 2009	0	1	0	0	0	0	0	1
COL-Larvae 1(skinny, striped)	June-July 2009	0	3	0	0	0	0	0	3
Collembola - reddist, elongate	Mar-Apr 2009	1	11	11	1	1	11	0	36
Collembola elongate	Mar-Apr 2009	30	7	8	15	4	1	0	65
Collembola-Sp. Globose	Mar-Apr 2009	12	1	1	2	0	0	0	16
COL-Tenebrionidae (*Coniontis*?)	June-July 2009	0	0	0	0	1	0	0	1
COL-Tiny Black	June-July 2009	0	2	0	0	0	0	4	6
COL-Tiny Brown	June-July 2009	1	0	0	0	0	1	0	2
COL-Tiny Carabid?	Mar-Apr 2009	0	0	3	0	0	1	0	4
COL-Tiny Carabid?	June-July 2009	0	3	2	0	0	0	2	7
COL-Undetermined (tiny brown)	Mar-Apr 2009	0	0	1	0	0	0	0	1
DECA Hermit crab	Mar-Apr 2009	0	0	0	1	0	2	0	3
DECA-Paguroidae	June-July 2009	3	0	0	0	0	0	0	3
Dermaptera - thin dark	Mar-Apr 2009	4	0	4	2	2	0	0	12
DIP Cecidiomyiidae	Mar-Apr 2009	0	0	1	0	3	1	0	5
DIP Ceratopogonidae	Mar-Apr 2009	0	0	0	0	1	1	0	2
DIP Hippoboscidae *Olfarsia aenescens* Thoms.	June-July 2009	0	0	0	0	0	0	1	1

DIP Otidae *Notogramma cimiciforme* Lowe 1868	Mar-Apr 2009	0	0	0	2	0	0	0	2
DIP Phoridae	Mar-Apr 2009	0	0	0	0	2	0	0	2
DIP Therevidae?	Mar-Apr 2009	0	1	1	0	0	0	0	2
DIP Undet 2	Mar-Apr 2009	0	0	0	3	0	0	0	3
DIP?-fragment	Mar-Apr 2009	0	1	1	0	0	0	0	2
DIP?-Partial	June-July 2009	0	1	0	0	0	0	0	1
DIP-Cecidomyiidae	June-July 2009	0	0	0	1	0	0	0	1
DIP-Chloropidae	June-July 2009	0	0	0	0	0	0	11	11
DIP-Drosophilidae	June-July 2009	3	1	2	2	0	0	3	11
DIP-Drosophilidae large green eyed	Mar-Apr 2009	0	0	0	4	0	0	0	4
DIP-Drosophilidae med brown	Mar-Apr 2009	0	0	30	0	1	0	0	31
DIP-Drosophilidae small red eyed	Mar-Apr 2009	0	0	1	5	1	0	0	7
DIP-Drosophilidae small striped	Mar-Apr 2009	0	0	0	2	0	0	0	2
DIPL Polyzenidae *Polyxenus* sp. 1	Mar-Apr 2009	25	0	11	0	8	15	0	59
DIPL Polyzenidae *Polyxenus* sp. 1	June-July 2009	1	0	12	1	0	22	0	36
DIP-Sarcophagidae	June-July 2009	1	0	0	0	0	0	2	3
DIP-Sarcophagidae 2	Mar-Apr 2009	0	0	0	0	0	1	0	1
DIP-Small Bee-Like	June-July 2009	0	3	0	0	1	0	0	4
DIP-Small Black	June-July 2009	0	1	0	2	3	0	1	7
DIP-Tephritidae	June-July 2009	2	8	1	1	1	0	7	20
DIP-Undet 1	Mar-Apr 2009	0	0	0	1	0	0	0	1
DIP-UNK	June-July 2009	0	0	0	0	0	0	1	1
EMB Oligotomidae *Oligotoma saundersii* (Westwood)	Mar-Apr 2009	0	0	0	1	2	0	0	3
EMB Oligotomidae *Oligotoma saundersii* (Westwood)	June-July 2009	5	12	0	1	1	4	1	24
HEM-Geocorid?	June-July 2009	0	0	0	0	0	1	0	1
HOM-Aphididae	Mar-Apr 2009	2	0	0	0	0	0	0	2
HOM-Cicadellidae leafhopper	Mar-Apr 2009	0	0	0	1	0	0	0	1
HOM-Leafhopper	June-July 2009	0	0	0	0	0	0	2	2
HYM- Black parasitoid 1	Mar-Apr 2009	6	0	0	1	0	0	0	7
HYM Mymaridae	Mar-Apr 2009	0	0	0	0	1	0	0	1
HYM- Small black parasitoid 2	Mar-Apr 2009	0	2	2	0	0	0	0	4
HYM Sphecidae *Prionyx* cf. *parkeri* (not *P. thomas*)	June-July 2009	0	1	0	0	0	0	0	1
HYM-Formicidae*Anoplolepis gracilipes* (F. Smith 1857)	Mar-Apr 2009	0	0	0	168	16	0	0	184
HYM-Formicidae*Anoplolepis gracilipes* (F. Smith 1857)	June-July 2009	4	0	0	58	39	0	0	101
HYM-Black & Red Wasp, Tiny	June-July 2009	2	0	0	0	0	0	0	2
HYM-Brachonidae	June-July 2009	4	1	1	2	5	1	0	14
HYM-Male ant without geniculate antennae	June-July 2009	0	1	0	0	0	0	12	13
IXO Argasidae *Ornithodoros* nr. *capensis*	June-July 2009	0	2	0	0	0	6	0	8
IXO Argasidae *Ornithodoros* nr. *capensis*	Mar-Apr 2009	0	0	1	0	0	1	0	2
IXOD-Pale med	Mar-Apr 2009	0	2	2	0	0	0	0	4
IXOD-Pale Tiny	Mar-Apr 2009	6	2	2	4	1	0	0	15
IXOD-Red-black Tiny	Mar-Apr 2009	2	0	0	6	0	0	0	8
IXO-Little Tiny	June-July 2009	70	0	0	1	0	1	0	72
LEP Geometridae larva	Mar-Apr 2009	0	0	1	0	0	0	0	1
LEP Undet larva	Mar-Apr 2009	0	0	0	0	1	0	0	1
LEP?-Pupae	June-July 2009	0	1	0	0	0	0	0	1
LEP-Arctiidae *Utetheisa pulchelloides*	June-July 2009	0	0	0	0	0	0	4	4
LEP-Cat. 1	June-July 2009	0	1	0	0	5	0	0	6
LEP-Cat. 2	June-July 2009	0	0	0	0	2	0	0	2
LEP-Large Brown	June-July 2009	0	0	0	0	0	0	3	3
LEP-Large light brown totricid	Mar-Apr 2009	1	0	0	1	0	0	0	2
LEP-Pyraloidea	Mar-Apr 2009	0	0	0	8	0	0	0	8
LEP-Pyraloidea	June-July 2009	0	0	0	0	0	0	2	2
LEP-Sm Brown gracillariid? with spots	Mar-Apr 2009	3	0	0	0	0	0	0	3
LEP-Sm Brown with Spots	June-July 2009	0	0	6	0	0	0	50	56
LEP-Tiny Brown gracillariid	Mar-Apr 2009	0	3	4	7	0	0	0	14
LEP-Tiny Brown Gracillariidae	June-July 2009	0	1	0	1	1	0	30	33
MOLL	June-July 2009	0	0	0	1	0	0	0	1
MOLL Globose landsnail Pupillidae	Mar-Apr 2009	0	0	0	1	0	0	0	1
MOLL Marine	June-July 2009	0	0	0	0	0	2	0	2
MOLL Pupillidae 1	Mar-Apr 2009	0	0	0	0	8	0	0	8
MOLL Pupillidae 2	Mar-Apr 2009	0	0	0	0	1	0	0	1
ORT - Gryllidae larva - very short femur - *Ornebius?*	Mar-Apr 2009	1	0	0	0	0	0	0	1
ORT - Gryllidae larval *Ornebius?* short femur	June-July 2009	12	2	7	4	1	0	0	26
ORT - Gryllidae near *Ornebius* short femur	June-July 2009	2	0	1	0	0	0	0	3
ORT - near *Ornebius?* short femur	Mar-Apr 2009	2	1	1	3	0	0	0	7
ORT Gryllidae *Gryllodes sigillatus* Walker	Mar-Apr 2009	0	0	5	0	1	0	0	6
ORT Gryllidae *Gryllodes sigillatus* Walker	June-July 2009	0	0	4	0	1	0	0	5
Psocoptera	June-July 2009	7	2	14	1	0	0	0	24
PSO-Psocidae?	Mar-Apr 2009	11	14	16	53	0	0	0	94
Thysanoptera	Mar-Apr 2009	0	0	0	2	0	0	0	2
Thysanura	Mar-Apr 2009	0	0	0	1	0	0	0	1
Undetermined 1	Mar-Apr 2009	0	0	0	1	0	0	0	1
Undetermined 2	June-July 2009	2	1	1	7	1	10	4	26
Row Total	**Both**	**382**	**252**	**370**	**769**	**156**	**97**	**144**	**2170**

Intertidal monitoring for the evaluation of the impacts of rats and rat eradication on Wake Island

by Chela J. Zabin, PhD and Blu Forman
University of California Davis

Methods

Photoquadrats on rocky shores.

We use a standardized protocol developed by the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) to assess the composition and cover of benthic organisms on rocky shorelines: photographing 480 cm^2 quadrats every 5 m along 50 m transects laid parallel to the shoreline. At Wake Island, permanent transects were established using stainless steel eye bolts drilled into the substrate at each end, secured with marine epoxy. The quadrats were placed on the shoreward side of the transect lines (so you face the water and can watch waves), with the upper left and lower right corners of each photoquadrat marked with marine epoxy. Quadrats were first photographed in March-April 2009 at five sites on Wake, Wilkes and Peale. The permanent photoquadrats are to be photographed quarterly.

Field method: locate start and/or end bolts (see Site Locations table and photographs below). Set up transect tape between bolts. Quadrats start at the 0 mark and are every 5 m through the 45 m mark. Place the PVC quadrat between the marine epoxy corner guides. Place a ruler along one edge of the quadrat. Indicate the date, transect # and quadrat # on the ruler. (We did this by using duct tape which we could write the info on; see sample photos.) Use the macro setting and zoom until the quadrat is framed and the ruler is also in focus. Shoot the photo, then doublecheck to make sure you got a good shot. Write down the critters you see in the photoquadrat. This will help with interpreting the photos later. The whelks in particular can really be covered with algae and indistinguishable unless you've turned them over and looked at the opercula. See info on typical photoquadrat organisms, below. If you cannot ID an organism, remove from quadrat after you've shot it, take a super macro shot of both top and bottom and note which quadrat it was in. If the quadrat is covered with lots of sand/scum, shoot it once as is, then rinse off/remove sand and reshoot.

There are extra bolts and marine epoxy left with the Environmental Office. If these are missing from any transect/photo quadrat you should replace them. Prepare the substrate by scraping off as much as you can down to the bare rock. It should not feel slimy to the touch or the epoxy won't stick. Open the lids on the marine epoxy cans. Wet your hands. Take a scoop of ~equal sizes of each color and mix them together by kneading. Keep your hands wet! This is very important, otherwise the epoxy will stick to your skin and if really difficult to get off. If the epoxy starts to get sticky, mix it in water. Press onto the prepared surface. We suggest removing rings before mixing because this stuff is hard to get off.

Fig 1. A sample photoquadrat showing the ruler with site and date information.

Site information

Transect name	#	GPS start	GPS end	Site Description & Notes
Wake nr Wilkes	1	N 19°17.219 E 166°37.022 ±11 ft	N 19°17.200 E 166°37.023 ±10 ft	Probably the highest site. Access this on a less than perfect tide.
Peale far reef	2	N 19°18.971 E 166°37.272 ±10 ft	N 19°18.960 E 166°37.245 ±12 ft	Site is in view of big rusted cannon. Transect runs along a bench essentially **perpendicular** to shore. The 0 end is at the water's edge.
Wilkes	3	N 19°17.654 E 166°36.386 ±15 ft	N 19°17.666 E 166°36.360 ±17 ft	Bench outside old road at seaward end of the submarine channel. Transect

				starts at big rock.
Peale closer reef	4	N 19°18.642 E 166°37.771 ±13 ft	N 19°18.627 E 166°37.796 ±13 ft	Really the first bench you come to walking along the shore from Wake. Zero end is the end farthest from Wake.
Wake South Shore	5	N 19°16.858 E 166°37.832 ±10 ft	N 19°16.857 E 166°37.859 ±9 ft	Access site at weather station, then veer to the left. Transect starts not far from a high boulder. Start bolt is in a crevice.

Access to the transects will be tide and swell dependent. Use the transect numbers to set priority if you have limited days.

Figure 1. Sighting toward shore from the start of Transect 1 (Wake near Wilkes).

Figure 2. Chela standing at the start of Transect 1. Note: the view she sees is the previous photo. Transect extends from here in the direction of Peacock Point.

Figure 3. Blu is standing near the end bolt of Transect 2, far Peale reef.


Figure 4. Another view of the end of Transect 2.

Figure 5. Looking toward the beginning of Transect 2 (at rock near waterline) from the end of the transect.

Figure 6. The beginning of Transect 3, Wilkes looking toward end of Wilkes.

Figure 7. The end of Transect 3, looking toward Wake.


Figure 8. Transect 4, Peale near reef, looking toward Wake along transect.

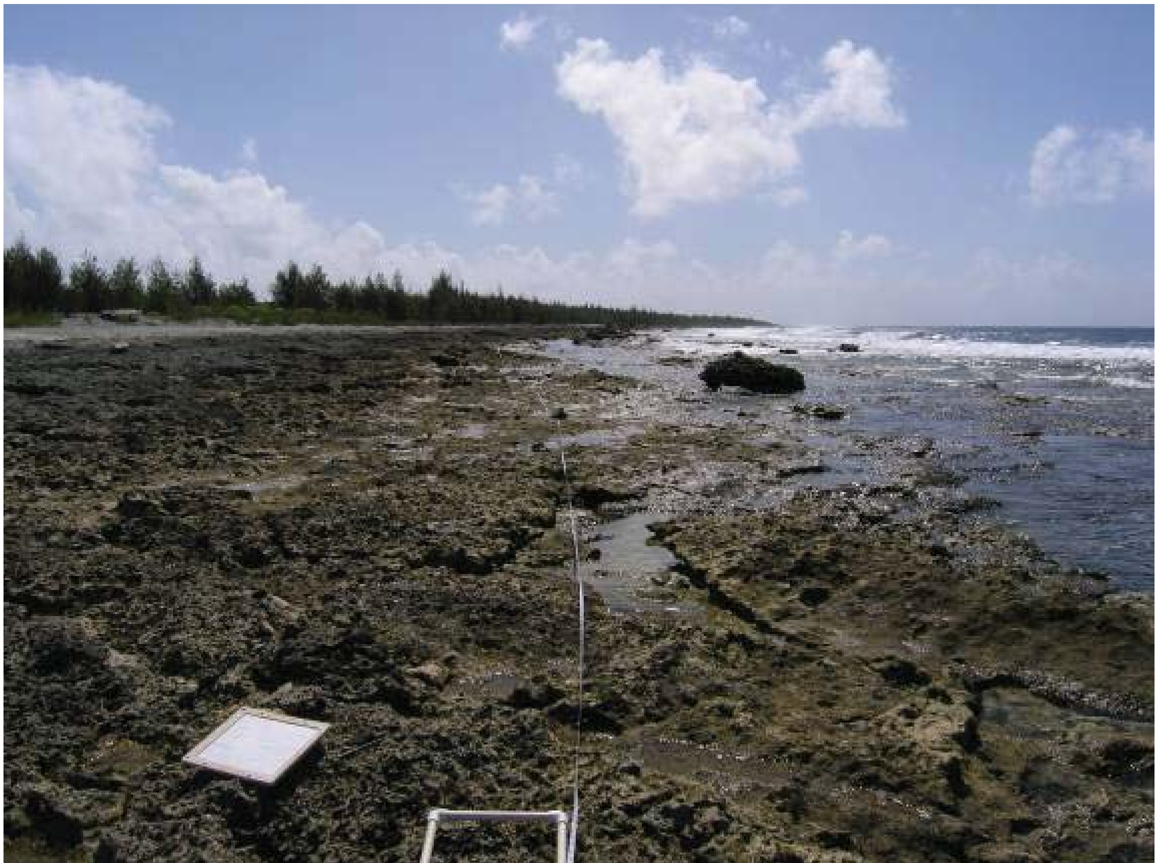

Figure 9. Transect 5 Wake South Shore, shown looking down transect (above). Transect 5 starts near the unusually shaped rock to the right (bottom picture).

Organisms found in first round of photoquadrats:

Vermetids wormlike calcified structures on rocks, often white or pink. At least two species, one very small and one larger. Opercula (openings) are usually black (Fig. 10).
Barnacles (Fig. 10)
Limpets (Fig. 10)
Whelks (these may be so covered with algae and scum that they just look like rocky knobs, so check these out by turning over, which will reveal their apertures and help you ID them):
Drupa morum: largest of the common whelks we saw, to about 1.5 in long with blunt, knobby projections. Has a bright purple aperture. Bottom of the shell is whitish-grayish-yellowish. (Fig. 12)
Drupa ricina: Whitish shells with black spikey knobs, which may be low and blunt (Figs. 12-13) or quite spiny (Fig. 14). Animal is green. Apeture is whitish-yellowish.
Morula uva: Similar to *Drupa ricina,* but has a purple aperture.
Morula granulata: Has low, rounded knobs, is black, with blackish-brownish-gray aperture (Fig. 15).
Unidentified whelk #1 (Fig. 18).

Two types of algae:
Caulerpa sp. Very reduced, long runners with small zig-zag or corkscrew type blades (Fig. 16).
Dictyosphaeria sp. Low-growing green alga, bubbly looking, quite firm to touch (Fig. 17)


Figure 10. Vermetids, barnacle and limpets.

Figure 11. Large vermetid species. Compare size to small vermetids near by.

Figure 12. Three *Drupa ricina* and one *Drupa morum.*

Figure 13. Young *Drupa ricina.*

Figure 14. An example of a very spikey *D. ricina.*

Figure15. *Morula granulata.*

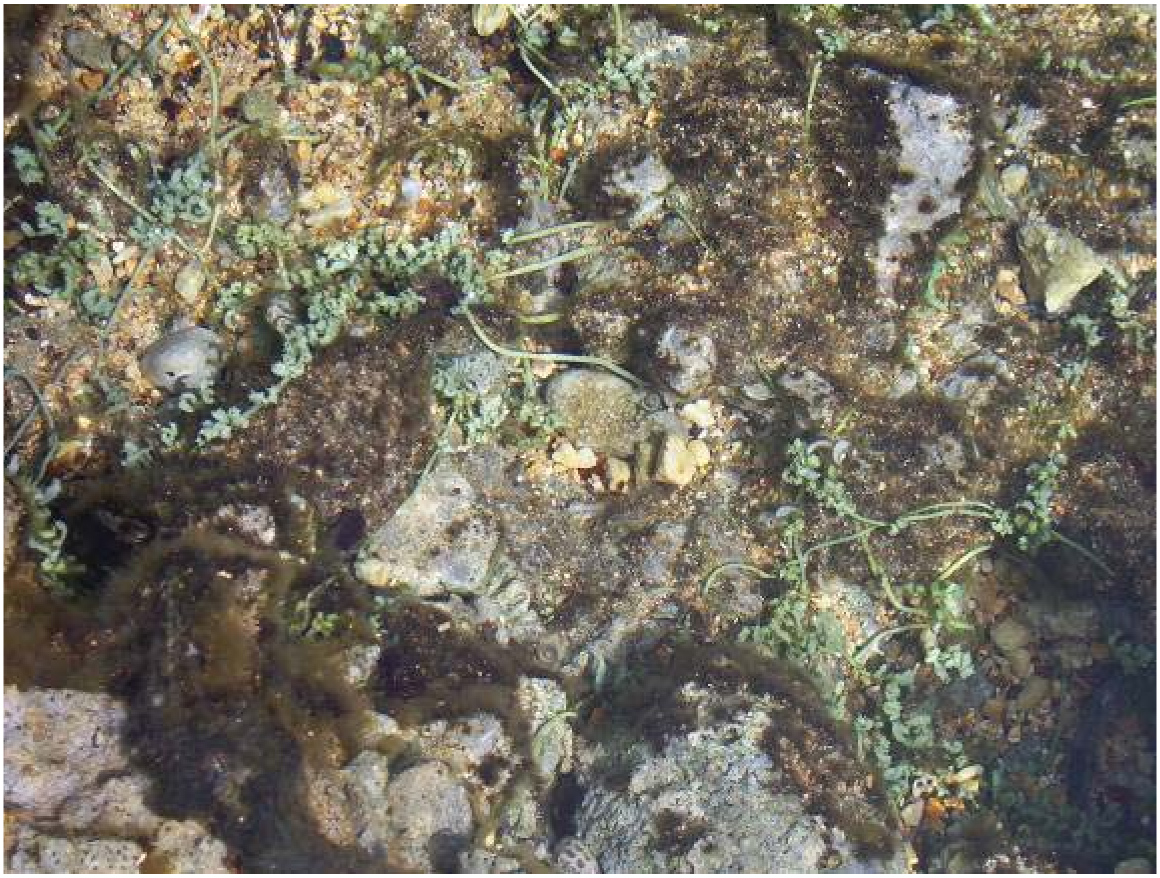
Figure 16. ***Caulerpa* sp.**

Figure 17. ***Dictyosphaeria*** **sp. Bottom left shows unbroken algae. This photo was taken in Hawaii, where this species gets bigger (there are actually two species in Hawaii). The texture of the species in the upper right demonstrates the bubbly look of this alga, but we have only seen a low-growing encrusting growth form on Wake.**

Figure 18. This whelk, shown with its eggs, is also common at Wake Island. ID is pending. For now, it is unidentified whelk #1.

Field gear needed for photoquadrats:

GPS unit
50 m transect tape (on Wake)
PVC photoquadrat (on Wake)
Digital camera
Field notebook or clipboard and paper
Pencils
Sharpies
Ruler
Duct Tape
Bottle or small bucket for helping to wash sand out of quadrats
For repairs:
Marine epoxy (2 cans) (on Wake)
Wire brushes (for cleaning substrate)
Screwdriver for opening cans
Extra ibolts (on Wake)