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December, 2, 2019

Hon, Robert L. Wilkie
Secretary of Veterans Affairs
810 Vermont Ave., NW
Washington, DC 20420

Re: Amplification of rulemaking request concerning the presence of herbcide on Guam, American Samoa and Johnston Island.

Dear Mr. Secretary:

I write in amplification of our rulemaking request dated December 3, 2018 to extend the presumption of exposure to herbicide to those veterans serving on Guam from January 9, 1962 through December 31, 1980 and on Johnston Island from January 1, 1972 until September 30, 1977. As you remember, we also met on that date.

During our December 3, 2018 meeting, we presented you with documents confirming the presence of dioxin on Guam. Additionally, there is a Public Health Assessment of the firefighting training area at Andersen Air Force Base revealing a dioxin concentration of 19,000 ppm. (Excerpt enclosed). Unfortunately, most veterans were assigned to this area for periodic firefighting training.

T he Guam Land Use plan, an excerpt of which I have enclosed, confirmed the use of herbicides on Guam through 1980. Included in the package we left with you were affidavits from several veterans who sprayed herbicide on the island.

On Johnston Island, the chemical was stored for several years until destroyed at sea. I have enclosed additional information concerning leakage from those steel drums stored in the open air. This resulted in the military contingent on Johnston Atoll being exposed to dioxin. Today the atoll is uninhabited. It is easy to see why.

I am also enclosing a press release from the Guam EPA confirming the presence of trace amounts of 2,4-D and 2,4,5-T based on random sampling. Earlier this year we funded our Director of Central Pacific Islands, Mr Brian Moyer, to travel to Guam. Mr. Moyer, a veteran of Guam, identified specific areas where spraying occurred. Unfortunately, we were denied access to Andersen Air Force base. The federal EPA and Guam EPA did take samples in off base areas identified by Mr. Moyer. Test results are expected by the end of January 2020.

On April 11, 2019 you wrote me that you were looking into the situation on Guam. I know you spent some time there this past summer. I also recognize that the rulemaking process can be lengthy. Based on current information, however, there is sufficient evidence to justify the favorable action. Additionally, our December 3, 2018 letter contained draft regulations which could easily be adopted.

A year has passed and we have not received a substantive response to our rulemaking request. Unfortunately, many of these veterans are sick and dying. Time is certainly of the essence. We understand that you may wish to see the results of the latest round of testing and I will forward that to you as soon as I receive it. Given the urgent health concerns, however, we must ask for expedited action. Accordingly, if we do not see the notice of proposed rulemaking or receive an estimated date of the promulgation of such notice within 60 days of your receipt of those results, we will assume that you are denying our request for rulemaking.

As always, our goal is to work with the VA and not against you. I am certain you understand, however, that the health concerns of the veterans come first.

Wishing you the best in the future I remain,

John B Wells
Commander USN (ret)
Director of Litigation

PUBLIC HEALTH ASSESSMENT

ANDERSEN AIR FORCE BASE
YIGO, GUAM
EPA FACILITY ID: GU6571999519

January 4, 2002

Prepared by:

Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

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EXHIBIT
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Figure 6. General Regions of On- and Off-base Biota Sampling Collection

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PUBLIC HEALTH ASSESSMENT

ANDERSEN AIR FORCE BASE
YIGO, GUAM

APPENDIX A: EVALUATION OF POTENTIAL IRP SITES AT ANDERSON AFB

Site	Site Description/Waste Disposal History	Investigation Results/ Environmental Monitoring Results*	Corrective Activities and/or Current Status	Evaluation of Public Health Hazards
Site No. 1 Landfill No. 1 (LF-1) (Operable Unit (OU): Main Base)	LF-1 opened in 1945 and continues to be used today as the base's only active landfill. Materials disposed of include sanitary trash, waste petroleum, oil, and lubricants (POL), solvents, ferrous metal, construction debris, and pesticides.	**Groundwater:** Trichloroethylene (TCE), tetrachloroethylene (PCE), chloroform, toluene, lead, and other organics were detected. Only lead was detected above Agency for Toxic Substances and Disease Registry (ATSDR) drinking water comparison values (CVs). **Soil:** Total petroleum hydrocarbons (TPH) and metals were detected.	**Corrective Activities:** The Air Force places soil cover on LF-1 daily. **Current Status:** LF-1 is still active and has been transferred to Resource Conservation and Recovery Act (RCRA) program.	**Groundwater:** No public health hazards are associated with LF-1. No drinking water wells are located in this area and none will be installed in the future. **Soil:** LF-1 is located in an industrial area not generally accessed by base personnel. Furthermore, a fence surrounds Andersen AFB and a gated entrance restricts access to the landfill; therefore, past, current, and future exposures to the general public are not expected.
Site No. 2 Landfill No. 2 (LF-2) Landfill No. 4 (LF-4) Landfill No. 5 (LF-	LF-4 and LF-5 are contained within LF-2. LF-2 was used from 1947 to 1975, with a small area remaining active until 1982. Materials disposed	**Groundwater:** TCE, PCE, toluene, lead, and other organics were detected. TCE was detected above the ATSDR CV. **Soil:** TPH, volatile organic compounds	**Corrective Activities:** Small area of LF-2 (all of LF-5) was capped as Remedial Action. **Current Status:** All other site areas in RI/FS process. LF-2 is inactive and currently	**Groundwater:** No public health hazards are associated with LF-2. No drinking water wells are located in this area and none will be installed in the future. **Soil:** LF-2 is located in

(LF-23) (OU: Harmon)	storage, release, or disposal of hazardous substances or petroleum products is known to have occurred at this site.	**Soil:** SVOCs and metals were detected below ATSDR CVs for soil.	presence of a "landfill" or hazardous waste, no further actions were recommended for this site.	hazards are associated with soil at this site. The site is generally inaccessible to the public and only low levels of contaminants were detected in soil.
Site No. 19 Landfill No. 24 (LF-24) (OU: Harmon)	LF-24 holds sanitary trash and possibly other types of debris from the 1950s.	**Groundwater:** No groundwater contamination has been associated with LF-24. **Soil:** SVOCs (up to 230 ppm), metals, and trace amounts of dioxins were detected. Only SVOC concentrations exceeded ATSDR CVs for soil.	**Current Status:** Cleanup is complete at LF-24.	**Groundwater:** No public health hazard is associated with this site. **Soil:** Access to this site was restricted; therefore, past exposures to the general public were not expected.
Site No. 20 Waste Pile No. 7 (WP-7) (formerly known as Landfill No. 25) (OU: MARBO Annex)	WP-7 was in use from 1945 to 1962. It contains sanitary trash, waste POL, solvents, scrap vehicles, and equipment, construction debris, and waste dry cleaning fluids.	**Groundwater:** TCE, PCE, 1,1,1-trichloroethane (TCA), carbon tetrachloride (CCl_4), toluene, xylene, lead, pesticides, and other organics were detected. TCE was detected slightly above the ATSDR drinking water CV. **Soil:** TPH and metals were detected in surface soil at levels below ATSDR CVs.	**Current Status:** As recommended in the ROD, the area was covered with clean fill to reduce the risk of exposure to contaminated soil.	**Groundwater:** No public health hazard is associated with WP-7 because no on-site production wells exist. WP-7 appears to be the source of TCE-contaminated groundwater in YU-2. **Soil:** No public health hazard is associated with soil at this site. The area is generally inaccessible to the public, only low levels of contaminants were detected, and the area has been covered with soil and vegetation.
Site No. 21 Landfill No. 26 (LF-26) (OU: Northwest Field)	LF-26 is filled with sanitary trash and construction debris from 1966.	**Groundwater:** Groundwater monitored at wells located 0.5 miles away indicate that no site contaminants exceeded CVs or MCLs. **Soil:** SVOCs (up to 42 ppm), metals, and dioxins were detected.	**Current Status:** LF-26 is a NFRAP site. Based on the results of a human health risk assessment indicating that exposure to surface soil would not increase the likelihood of cancer for residents, no further response actions were recommended.	**Groundwater:** No public health hazard is associated with this site because no on-site production wells exist. **Soil:** Access to LF-26 is restricted; therefore, past, current, and future exposures to the general public are not expected. No completed exposure pathway to site contaminants exists and no public health hazard is associated with this site.

Site No. 25 Fire Training Area No. 1 (FTA-1) (OU: Main Base)	From 1945 to 1958, waste solvents and contaminated fuels were used at FTA-1.	**Groundwater:** No groundwater contamination has been associated with FTA-1. **Soil:** Seven surface soil samples were analyzed for SVOCs, PAHs, pesticides, PCBs, and metals. Aluminum exceeded the CV for a child, but all other concentrations were below ATSDR's CVs for a child and adult.	**Current Status:** A NFRAP is recommend by the Air Force for this site based on the results of historical records search, document review, field investigations, and a risk assessment.	**Groundwater:** No public health hazard is associated with this site. **Soil:** No public health hazards are associated with soil at this site. The site is generally inaccessible to the public and only low levels of contaminants were detected in soil.
Site No. 26 Fire Training Area No. 2 (FTA-2) (OU: Main Base)	Between 1958 and 1988, contaminated JP-4, Mogas, diesel, waste POL, and solvents were spilled at FTA-2.	**Groundwater:** TCE and PCE were detected. BTEX (benzene, toluene, ethylbenzene, and xylene) were present at concentrations up to 7,200 ppb at levels above CVs. **Soil:** Dioxins (up to 19,000 ppm), VOCs (up to 109 ppm), SVOCs (up to 6.8 ppm), TPH, pesticides, and metals were detected at levels above CVs. .	**Corrective Activities:** The Air Force has not used FTA-2 since December 1988 due to closure by GEPA. **Current Status:** Bioventing will be used to remediate a subsurface plume of VOCs and BTEX compounds.	**Groundwater:** No public health hazard is associated with FTA-2 because no on-site production wells exist. FTA-2 is no longer in use, so toluene levels can be expected to decrease in the future. **Soil:** Access to FTA-2 is highly restricted; therefore, past, current, and future exposures to the general public are not expected.
Site No. 27 Hazardous Waste Storage Area No. 1 (HW-1) (OU: Main Base)	Beginning in 1950 and continuing through the 1970s, POL and solvents were stored at HW-1. From the late 1970s to 1983, HW-1 was used to store hazardous wastes.	**Groundwater:** Groundwater data from downgradient wells have reported only trace amounts of VOCs (TCE). **Soil:** Trace amounts of VOCs and SVOCs were detected. Metals concentrations in surface soil were below background concentrations. Metal concentrations at HW-1 in the shallow subsurface soil included arsenic (up to 201 ppm), chromium (up to 1,300 ppm), and lead (up to 8,600 ppm) at levels above CVs.	**Current Status:** HW-1 is a NFRAP site. Site investigations indicate that no contaminants above residential soil standards exist in surface soil, ; therefore, no further response actions were recommended.	**Groundwater:** No public health hazard is associated with this site. **Soil:** Access to HW-1 is restricted and contamination was limited to the inaccessible subsurface soil; therefore, past, current, and future exposures to the general public are not expected.
Site No. 28 Chemical Storage	In the early 1970s, the site may have been used for the disposal of waste	**Groundwater:** No groundwater contamination has been associated with CS-1.	**Current Status:** CS-1is a NFRAP site.Based on the results of a human health risk	**Groundwater:** No public health hazard is associated with this site. **Soil:** No public health

DRAFT ENVIRONMENTAL IMPACT STATEMENT

for the

Disposal and Reuse of Surplus Navy Property Identified in the *Guam Land Use Plan* *(GLUP '94)*

Department of the Navy

May 1999

Notes:
- – = Based on recent and historical information, it is believed that this material or item is not currently, nor has it historically been present, used, generated, stored, or disposed of on this property.
- ✔ = See corresponding subsection for more details.
- 1 = Ordnance may be present as a result of World War II battles on Guam.
- 2 = A portion of the property was not included in the available EBS, but were covered as an adjacent property. Therefore, an EBS is needed to properly assess the presence of possible sources of environmental contamination.

Source: Ogden (1996, 1997, 1998)

3.17.2 Northern Region

3.17.2.1 FAA Housing

Asbestos-Containing Material (ACM). The DoD BRAC policy on ACM is to repair or remove only friable, accessible, and damaged ACM. Friable asbestos is defined by the US EPA as any material containing more than one percent asbestos that, when dry, can be crumbled, pulverized, or reduced to powder by hand pressure. Friable asbestos is regulated under the National Emission Standards for Hazardous Air Pollutants (NESHAP) (40 C.F.R. §61.141). NESHAP requires that all friable materials be removed prior to building demolition or renovation. Navy will not perform remediation if: (1) the buildings are scheduled for demolition by the transferee; (2) the transfer document prohibits occupation of the buildings prior to demolition; and (3) the transferee assumes responsibility for the management of any ACM in accordance with applicable laws. Demolition of housing units that occupied the FAA Housing parcel due to irreparable damage from Typhoon Paka began in 1998; demolition is anticipated to be completed by 2001.

Lead-based Paint (LBP). The DoD BRAC policy is to manage LBP in a manner protective of human health and the environment and to comply with all federal, state, and local laws and regulations governing LBP and LBP hazards. Current standards for LBP address risks by focusing on the impact of LBP on children from dwellings and surrounding soil. The Residential Lead-Based Paint Hazard Reduction Act of 1992 (Title X of Public Law 102-550), which pertains to conveyance of federal property for residential use, is only applicable to "target housing" as defined by the Act. All of the houses at this parcel are being demolished. If conveyance occurs before demolition is completed, the conveyance document will prohibit occupancy of the houses. These structures will not be used as target housing.

Twenty-four soil samples were collected in the vicinity of the housing. The sample results were compared to Housing and Urban Development (HUD) criteria. No action is required when lead concentrations in soil are less than 400 milligrams per kilogram (mg/kg); interim controls are recommended for concentrations between 400 and 2,000 mg/kg; and abatement is required for concentrations greater than 2,000 mg/kg. Two samples had concentrations greater than the no action criterion (410 mg/kg and 420 mg/kg).

Pesticides. The Insecticide, Fungicide, and Rodenticide Act (FIFRA), 7 U.S.C. §135 *et seq.*, and the Guam Pesticide Regulations regulate the formulation and use of pesticides. Department of the Navy policy indicates that a property is considered "uncontaminated" if contamination concerns are due solely to the "normal" application of pesticides and herbicides. Pesticides have been applied to DoD properties on Guam according to DoD policies. Chlordane was used for termite control at the FAA housing area from the 1950s until it was banned in 1987 by US EPA. Until 1980, (2,4,5-Trichlorophenoxy) acetic acid (2,4,5-T) was used for weed control along power lines and power substations and p,p'-dichlorophenyltriclrorethane (DDT) was used for mosquito control. Mosquitoes are currently controlled through the use of 57 percent and 80 percent malathion. Pesticides have not been stored, mixed, or disposed of at this property, and there is no evidence of improper use of pesticides on the property.

Radon. Radon is a naturally occurring radioactive gas that may pose a risk to human health. It is regulated by the Toxic Substance Control Act (TSCA), Subtitle III, 26 U.S.C. §2661-2671. Radon surveys are required to be conducted on all federal buildings to determine the extent of radon contamination. It is DoD policy that disclosure of potential elevated radon concentrations prior to conveyance meets the disclosure/action requirements of the indoor radon abatement provisions. Since housing is being demolished, there will be no enclosed space for radon to accumulate.

POI Sites. This property is considered a POI site (POI-24) because lead-based paint was identified in the housing. Since housing will be demolished, no further action is planned for this parcel.

3.17.2.2 Harmon Annex

Storage Tanks and Pipelines. Navy manages underground fuel storage tank compliance activities in accordance with 40 C.F.R. §280. Above-ground storage tanks (ASTs) are regulated under 40 C.F.R. §112. In 1993, three underground storage tanks (USTs) (Tanks 50-1, 50-2, and 50-3) were removed from the ground and stored on the southeastern part of the property. These tanks were observed on site during the EBS physical reconnaissance. The two larger tanks have an estimated capacity of 5,000 gallons (18.9 cubic meters) each, and the capacity of the smaller was estimated to be less than 1,000 gallons (3.79 cubic meters). These tanks were reported to contain diesel fuel and the two larger tanks were removed from the site in 1997. The contents have since been removed. Preliminary site assessment performed in 1997 recommended site closure. No information was available regarding the extent of possible diesel fuel contamination, and no evidence of releases was observed.

Two unused ASTs are located on the first floor of Building 50. The tanks were used for water storage. The larger tank has an estimated capacity of less than 3,000 gallons (11.4 cubic meters), while the capacity of the smaller tank is thought to be less than 500 gallons (1.9 cubic meters).

Asbestos. Friable ACM has been reported in portions of Building 50. Partial abatement of the east wall of the building and the ceiling of the first floor have taken place.

Hazardous Substances/Waste Management Sites. Hazardous substances and hazardous wastes are regulated under various environmental laws and regulations including CERCLA, RCRA, and Guam Hazardous Waste Regulations. Evidence of hazardous substances storage or waste management has been noted in several areas in and around the building. Oil stains were reported in the vicinity of the ASTs and apparent air conditioning equipment. Absorbent material was also reported spread over the floor in one area of the second floor. No information was available regarding the nature of possible spills on the second floor.

The Navy Publications and Printing Services Office was transferred to Building 50 in 1979, and chemicals associated with printing operations are known to have been used on the property. Small quantities of photo developer, offset etch, photo fixers, solvents, and lead-free ink were

17 Aspects of the Biology and Geomorphology of Johnston and Wake Atolls, Pacific Ocean

Phillip S. Lobel and Lisa Kerr Lobel

17.1 Introduction

Johnston Atoll and Wake Atoll are isolated and independent atolls in the North Pacific Ocean with a long history of military use. These atolls are also frequently referred to by the name of their main islands: Johnston Island and Wake Island. They have in common that they are both coral atolls located in the North Pacific Ocean (Fig. 17.1), both are exclusive properties of the US Department of Defense and neither had an indigenous islander population prior to military occupation. The two atolls are separated by 2,500 km (~1,600 miles) of open ocean. Both enjoyed the protection of being restricted access military bases until recently. In June 2003, Johnston Atoll was abandoned. Wake Atoll is currently in minimal caretaker status due to extensive damage from the last typhoon (Ioke on August 31, 2006). As of May 2007, the future of these atolls is uncertain because of a long-standing political quagmire among US Government agencies over natural resource management responsibilities and financing of the properties.

Johnston Atoll (Fig. 17.2) is isolated in the Central Pacific Ocean (16°45′ N 169°31′ W). The nearest landfall is French Frigate Shoals, 804 km (500 miles) north in the northwest Hawaiian Islands. It is about 1,287 km (800 miles) southwest of Honolulu, Hawaii. The Line Islands of Kiribati are about 1,440 km (900 miles) south and the Marshall Islands are about 2,560 km (1,600 miles) to the southwest.

Wake Atoll (Fig. 17.3) is isolated in the west-central Pacific (19°17′ N 166°36′ E). Wake is separated by 546 km (340 miles) of open ocean from the nearest reef system on Taongi Atoll in the Marshall Islands to the south. It is 2,000 km (1,250 miles) southwest of Midway Atoll, 1,400 km (840 miles) southeast of Minami-tori-shima (Marcus) Island, 2,260 km (1,350 miles) east of the Marianas Islands, and 1,100 km (660 miles) north of the Kwajalein Atoll.

Both atolls are in unique locations with respect to the biogeography of reef biota. Although, Johnston and Wake Atolls are not part of the Hawaiian–Emperor seamount chain as defined by position on the Pacific plate relative to the hotspot (Rotondo et al. 1981; see also Chapter 13, Rooney et al.). They both have intriguing patterns of marine species distributions that overlap with the Hawaiian Islands. The Hawaiian faunal connection has significant implications for interpreting biogeographic patterns that may have resulted either from dispersal of pelagic larvae or by vicariant events (Springer 1982). The stepping stone role of Johnston Atoll for reef animals, especially fishes from the equatorial Line Islands to the Hawaiian archipelago was defined by Gosline (1955), and subsequently further supported with additional data (Randall et al. 1985; Kosaki et al. 1991; Kobayashi 2006).

Until recently, The reef biota of both atolls was infrequently surveyed because access was/is limited due to their military missions (Lobel 2003; Lobel and Lobel 2004). Consequently, the marine biogeography and ecology of these atolls have not been completely detailed, especially with regard to more cryptic biota. The reef ecology and biota of Johnston Atoll has been more extensively studied

B.M. Riegl and R.E. Dodge (eds.), *Coral Reefs of the USA*,

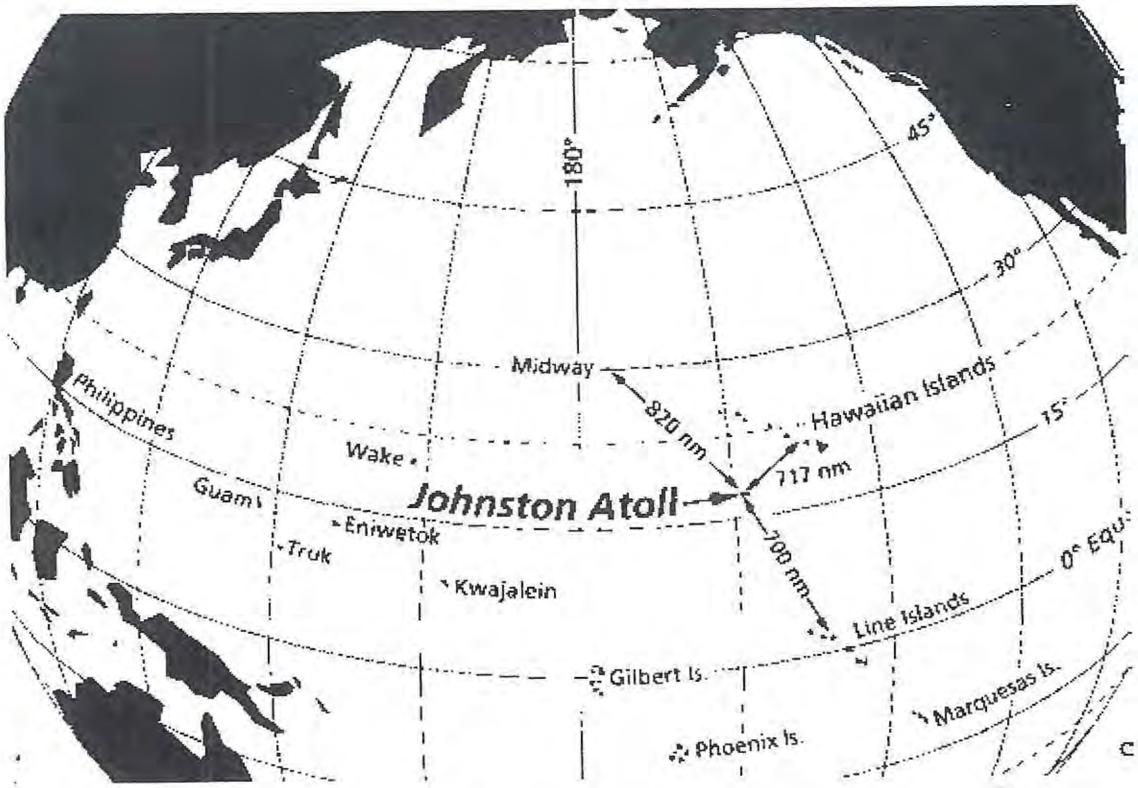

FIG. 17.1. Map of the Pacific Ocean showing the locations of Johnston and Wake Atolls

than has Wake. Even though these atolls were/are military bases and there were dramatic landscape alterations on land and in the water, today the coral reefs are in remarkably good condition. The positive side effect of the Department of Defense (DoD) mission was that fishing was very restricted at both atolls, at least until recently. The future of both atolls is somewhat uncertain and there are controversial political issues in play. The outcome of cooperative decisions to be made in 2007 and 2008 by DoD, DoI (Department of Interior) and NOAA (National Oceanographic and Atmospheric Administration) will ultimately define the future use of these atolls.

17.2 Johnston Atoll

Amerson and Shelton (1976) published a comprehensive scientific review of the natural history of Johnston Atoll. In some topics such as atoll geology, terrestrial vegetation and ecology, there has been very little added since. We have tried to focus on additional information since Amerson and Shelton (1976) and refer readers to their excellent review. A recent photographic review of the marine life of Johnston Atoll shows many of the reef species and habitats (Lobel 2003).

17.2.1 History of Johnston Atoll as a US territory

Johnston Atoll was discovered on 2 September 1796 by a whaling ship, the brig *Sally* from Boston, MA. The Sally was accompanied by the British trading schooner, Prince William Henry captained by William Wake. The Prince William Henry also documented Wake Atoll during this voyage. Capt. Charles Johnston of the British ship HMS Cornwallis later documented Johnston Island on 14 December 1807 and it is for him that the atoll and main island are named.

FIG. 17.2. Johnston Atoll, view looking west. The largest island is Johnston Island. The nearest neighboring island is Sand Island. North Island is to right, north, in photo and East Island is to the left, east. The emergent reef borders the northern margin of the platform. The atoll is tilted to the south and submerged along the southern margin

FIG. 17.3. Wake Atoll, view looking southward. Peale Island is in the foreground to the right and is separated from Wake Island by a small channel. Wake Island is the large V shaped land on the left that wraps around to a causeway connecting to Wilkes Island. The shallow lagoon area that is dry at lowest tides is partially exposed in this photo, at left inside adjacent to Wake Island

Johnston Atoll has no natural source of freshwater and if islanders did visit, they could not reside for very long. Originally, there were two islands: the larger Johnston Island $0.2\,km^2$ (40 acres) and the smaller Sand Island $0.04\,km^2$ (10 acres). The islands began as mounds of guano on coral rubble and sand. No evidence has been found of Pacific Islanders visitations prior to the late 1800s. However, the large guano deposits attracted US attention. After the US passed the Guano Act that guaranteed US Military protection to citizens establishing guano-mining operations on uninhabited and unclaimed guano-laden islands, Americans collecting guano claimed Johnston Atoll on 19 March 1858. The Kingdom of Hawaii contested this claim on 27 July 1858 when King Kamehameha proclaimed ownership of Johnston Atoll (named Kalama in Hawaiian). The US annexed Hawaii in 1898 ending the dispute to the atoll. In addition to the visits by ships collecting guano, whaling ships hunted the region. One such whaler, the "Howland" out of New Bedford, Massachusetts wrecked onto the reef at Johnston Atoll in December, 1889 (Fig. 17.4).

The first official scientific survey was in 1923 by Dr. Alexander Wetmore from the Bishop Museum, Oahu, Hawaii. The expedition was financed by the Departments of Agriculture and Navy. The scientific report of the survey team described the incredible diversity of seabirds, fishes and other marine life. The political impact of this study resulted in Executive Order No. 4467, signed by President Calvin Coolidge on 29 July 1926. This placed Johnston Atoll under the control of the Department of Agriculture as a sanctuary for breeding seabirds.

President F.D. Roosevelt signed Executive Order No. 6935 on 29 December 1934, which then transferred Johnston Atoll to the Department of the Navy. At this time, the atoll still included two islands, Johnston Island and the smaller, Sand Island. Sand Island was kept as a bird sanctuary under the Department of Agriculture. However, increasing military activity between 1939 to 1941 resulted in a buildup of facilities on both islands with a small shallow channel dredged in-between. Sand Island became the main occupied island while dredging and filling the shallow lagoon expanded Johnston's size. Dredging also deepened the shipping channels into the lagoon allowing larger ships to enter. Between 1939 and 1942 that the island was leveled and enlarged from 0.2 km^2 (40 acres) to 0.9 km^2 (211 acres) (Fig. 17.5). At this point none of the original shoreline or vegetation on Johnston Island remained. Both Johnston and Sand Islands were virtually covered with buildings, roads, gun emplacements and the runway on Johnston Island. A Naval Air Station was operational in August 1941. Executive order No. 8682 (February 1941) designated the area out to 3 miles from the atoll as a Naval Airspace Reservation and a Naval Defense Sea Area. During this time, Pan American Airways used the airfield between Hawaii and Asia.

The US forces on Johnston Atoll came under cannon fire by Japanese naval vessels on 15, 21 and 22 December 1941. Facilities were damaged but there were no casualties. During the war, the atoll served as a strategic site for refueling planes and submarines on patrol in defense of the Hawaiian Islands. During WWII, Johnston Island was further expanded in size to accommodate a longer runway and additional aircraft parking space.

After WWII, Johnston Atoll continued as an air station and was eventually transferred from the Navy to the US Air Force in July 1948. Lagoon dredging continued to create deeper and larger ship channels while slowly expanding the size of the islands by using the crushed coral as fill material (Fig. 17.5). The islands were in heavy use during the Korean War. The islands were built up in size and two new islands were created. Sand Island was expanded from about 0.04 to 0.09 km^2 (10–22 acres). Johnston Island was increased from 0.9 to 2.6 km^2 (211 to about 640 acres) (Fig. 17.6). By the mid-1960s, Johnston and Sand Islands were enlarged to their present sizes (Fig. 17.7). The two new artificial islands, North and East Islands, were built from dredge materials and are 0.1 and 0.07 km^2 (25 and 18 acres), respectively (Fig. 17.8). The overall lagoon is about 121.4 km^2 (30,000 acres).

A US Coast Guard Loran station was built on Sand Island in 1960 (Figs. 17.9 and 17.10). It was the master Loran station for the central Pacific until December 1992 when the Global Positioning Satellite navigational system became fully operational and rendered Loran obsolete. The former Loran station became a marine biological field station in 1993 and was used until base closure activities began in 2001.

During the nuclear test era of the 1960s, Johnston Atoll became a test site and staging area due to its isolation in all directions from other inhabited islands. In 1962, the US conducted a series of atomic tests. The USAF released operational control of the islands to the Atomic Energy Commission (AEC)

FIG. 17.4. The whaler ship, Howland, wrecked onto the reef at Johnston Atoll and sunk in 1889. Remains include iron ballast (photo), scattered anchors and various ship debris. The shipwreck was discovered by P. Lobel while conducting reef surveys

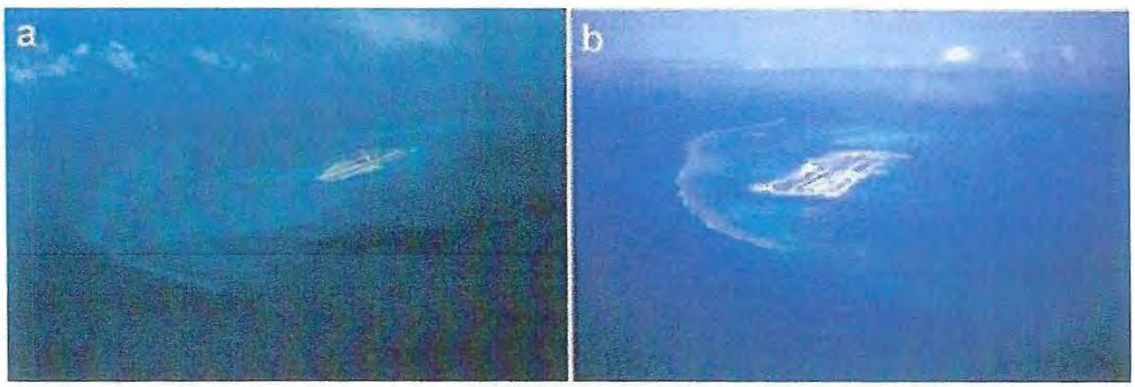

FIG. 17.5. (a) Johnston Atoll in 1952. Note that Johnston Island has been enlarged slightly. Sand Island had not yet been enlarged. North and East Islands did not exist yet (Photo by K.O. Emery and used with permission). (b) The atoll in 1993. When compared with the left photograph, notice how much closer the island is to the reef margin. The area of Sand Island has also been increased as well as the creation of two new islands, North and East. The semicircular shape of the atoll is evident. The emergent reef is to the north and the atoll platform tilts and is submerged to the south

and their military counterpart, Joint Task Force Eight (JTF-8). The atomic test series code-named DOMINIC included four high altitude and five low altitude successful tests, followed by a few THOR missile misfires. Radioactive contamination from fallout resulted. Today, the plutonium contaminated soils and other materials are buried in an EPA permitted landfill on Johnston Island. The Defense Threat Reduction Agency (formerly the Defense Nuclear Agency and then the Defense Special Weapons Agency) is responsible for any continuing radiological issues.

The comprehensive scientific study of Johnston Atoll's coral reefs was conducted by the University of Hawaii during 1963/64 (Brock et al. 1965, 1966). These biological surveys were conducted

FIG. 17.6. Johnston Island with the full development of the military–industrial complex in 1995

FIG. 17.7. Sand Island is in center, Johnston Island (partial) to right, North Island in foreground. The darker blue channel between Sand and Johnston was dredged from the reef to make a large ship channel and expand the islands. The coral carved from the rectangular basin adjacent North Island was crushed to create the artificial island

to characterize the reef ecosystem, measure the effects of dredging on the reefs and to estimate the prevalence of ciguatera and any changes in its occurrence associated with dredging. Ciguatera is a marine toxin from the dinoflagellate, *Gambierdiscus toxicus*. This dinoflagellate is epiphytic on other algae. Herbivorous fishes that consume algae with *G. toxicus* can then bioaccumulate the toxin. Depending on the level of toxicity, effects on humans eating ciguateric fishes can range from mild illness to death. One hypothesis is that environmental disturbances such as dredging and severe storms foster the dinoflagellate blooms (Anderson and Lobel 1987). Johnston Atoll became the source for ciguatoxic fishes collected and used in testing by University of Hawaii scientists into the late 1970s. The diets and feeding ecology of herbivorous surgeonfishes

FIG. 17.8. East Island is also completely artificial. The buildings were removed with base closure

FIG. 17.9. This photo gives an interesting perspective of the dredged channel next to Sand Island. The dark blue channel is about 40 ft (14 m) deep and was carved from reefs that were growing to the surface that still exist adjacent to the channel. The bright sandy area is very shallow sand flats (10 ft, 3 m depth or less). The buildings were removed in 2001 and buried in place as a small hill (landfill). The north side of this west end of Sand Island is where most PCB contamination was found. Plutonium radiation was found on the south side. North Island is in background. The reticulated pattern of shallow lagoon reefs made boat travel a maze game

(Acanthuridae) at Johnston and in Hawaii were studied by Jones (1968).

A comprehensive study of the seabirds with extensive notes on other aspects of the atoll's natural history was published by Amerson and Shelton (1976). This publication also included a detailed history and summary of research findings until that time.

FIG. 17.10. Sand Island. This photo from 1993 shows the LORAN tower (dismantled in 1995 after GPS become operational). The building on the causeway was the USCG station and later became the marine lab. The shore line around the east end of Sand Island (foreground with tower) is the only natural remaining shore geology remaining on the atoll with old emergent reef platform and tidepool habitat. Sand Island is the main breeding area for the migratory seabirds

In 1971, the US Army began using 0.2 km^2 (41 acres) of Johnston Island for chemical weapons storage. These weapons included nerve gas, mustard gas and other chemical agents contained in rockets, artillery shells, bombs and ton containers. In 1972, the USAF brought about 25,000 55 gal drums of the chemical Herbicide Orange (or Agent Orange) that came from Viet Nam and was being stored on Okinawa. This stock of Agent Orange was incinerated at sea in 1977 aboard the Dutch ship, *Vulcanus*. However, an unknown number of barrels leaked while stored on land and some barrels were dumped into the lagoon.

During the years 1970–1985, Johnston Atoll was maintained in caretaker status under the Defense Nuclear Agency, during which time the population averaged about 300 people including both military and civilian contractors. The atoll was in standby mode under "Safeguard C", which called for the resumption of nuclear weapons testing during the cold war era.

The building of the Johnston Atoll Chemical Agent Disposal System (JACADS) plant by the Army began in 1986 and with it, the island population grew to a level of about 1,200 personnel. The US Fish and Wildlife Service stationed a full-time refuge manager on the island with Army funding in 1990 to help manage the natural resources. The increased number of people on the island also resulted in an increased exploitation of fish and marine invertebrates. Some species such as whitetip sharks and certain marine snails (with pretty shells) were severely over-collected. Shark fishing activity was eventually restricted in 1995. Whitetip sharks were the most impacted by this time. Now with the atoll abandoned since late 2003, these shark populations are again vulnerable.

The next series of reef ecological studies began in 1983 as part of the program to evaluate the potential environmental impact of the Army's JACADS chemical weapons incineration project. One of the first results was a checklist of fishes that increased the number of fishes known from the reefs from a previous count of 183 to a new total of 271 (Randall et al. 1985). Subsequent surveys added 30 new records for a new total of 301 fish species (Kosaki et al. 1991) and several more recently discovered new records of rare species remain to be described (P. S. Lobel and L. K. Lobel, personal communication 2003).

After the conclusion of the Army JACADS project it took about 1 year to demolish and remove all but one building (the JOC) from Johnston Atoll. The Johnston Atoll base once supported vast accommodations supporting a workforce of about 1,200 people. All freshwater was made by a desalination plant and power was generated from burning JP5 jet fuel. There were about 300 buildings and facilities in operation at the peak period from 1985 to 2002 on the nearly 1.4 million square feet of space which comprised Johnston Island. Today it is an abandoned atoll. Although the Air Force closed all atoll operations, Executive Order 8682, which established the Naval Sea Defense Area and Airspace Reservation, is still in effect. This executive order provides broad powers to DoD to control access to Johnston Atoll and to maintain it as a protected area

17.2.2 Geomorphology of Johnston Atoll

Johnston Atoll has an unusual geomorphology, which is unlike most atolls that have surrounding barrier reefs. Johnston Atoll has only a semicircular emergent barrier reef confined to the northern and western margins of the atoll platform (Fig. 17.5). Reefs to the east and around the south are submerged. The prevailing trade winds blow in from the east and, without an emergent reef barrier, drive current flow across the atoll.

Johnston Atoll is estimated to be about 85 MY in age (Keating 1985, 1992). Two distinct submarine platform surfaces are evident: one at about 10 m and the other at 2 m depth. The 10 m terrace has numerous ridges, knolls and coral growth. The 20 m terrace has many sink holes, often extending to more than 30 m depth. Numerous caverns have also been observed from submersible surveys at depths about 200–250 m. Large caves were also observed at 360 m which contained both stalagmites and stalactites (Keating 1985) and only limestone has been found at Johnston Atoll (Keating 1985, 1992). Within the 200 miles exclusive economic zone of Johnston Atoll, manganese crusts in seafloor plateau areas have been found to contain economically attractive concentrations of rare earth elements as well as cobalt, nickel and platinum (Wiltshire 1990).

Johnston Atoll rises from an abyssal plain at 4,950 m depth. On top, the atoll is a shallow platform of approximately 158 km^2 of reef habitat (Maragos and Jokiel 1986). The atoll is tilted to the southeast due to subsidence of the platform (Emery 1956; Amerson and Shelton 1976; Jokiel and Tyler 1992; Keating 1985). The shallow reef platform extends outside of the lagoon to about 19 km east–southeast and 8 km south of the main island, Johnston Island. The platform slopes gently to about 18 m depth then increases steeply to 180 m. Depths in the lagoon vary about from about 3 to 10 m. The lagoon habitat is composed of patches of sand, loose coral and large formations of live coral, especially *Acropora* species. The area of coral reef flats exposed during very low tide is approximately 5.2 km^2. The majority of this area is formed by the main northwestern reef, which forms an arc of about 4 km long. The outer reef has a gentle slope cut with many surge channels.

17.2.3 Climate of Johnston Atoll

The weather patterns at Johnston Atoll fall into two broad "seasons". The winter season extends from December through March and is characterized by slightly cooler temperatures, variable winds and heavier precipitation than during the summer months of April through November (Amerson and Shelton 1976). The mean average temperature is 26.3°C with daily ranges of about 13°C. The surface wind speed averages 15.1 mph with monthly means varying from 13.6 to 16.0 mph. These strong easterly trade winds (NE through ESE) are fairly constant throughout the summer months while during the winter months trade winds occur less than 80% of the time. Winter is characterized by light and variable winds, occasional westerlies associated with passing disturbances and weak cold fronts. Hurricanes do occasionally impact Johnston Atoll, for example, Celeste in 1972, John in 1994 and Ioke in 2006. Significant damage to island infrastructure occurred during hurricane John. During hurricane Ioke, a category 2 storm, portions of the Johnston Island seawall were breached increasing the erosion of the island. Mean annual precipitation is highly variable. The lowest annual rainfall recorded was 32.8 cm (12.9 in) in 1953 while 107.4 cm (42.3 in) fell during 1968. The mean is 66.3 cm (26.1 in).

17.2.4 Oceanography

The oceanographic environment around and within Johnston Atoll is one of well mixed oceanic water with surface salinities of 34.6–34.8‰ and annual temperatures ranging from 25°C to 27°C (Wennekens 1969). Our data show that sea surface temperatures (SST) generally vary less than 2°C during a daily cycle and seasonal SSTs range from lows of 23.2°C during February and March to highs of 29.2°C in late August to September (L. K. Lobel and P. S. Lobel 2000). SSTs within shallow portions of the lagoon exhibit higher variations due to solar warming (Fig. 17.11).

Ocean current flow patterns in and around Johnston Atoll were carefully studied by Kopenski and Wennekins (1966) using observational and empirical methods. The following oceanographic description is abstracted from their findings and supplemented with observations from another unpublished report included in the Army's JACADS EIA study (Lobel 1988).

The regional and local currents at Johnston Atoll are directly influenced by the flow of the North Equatorial Current. Grigg (1981) suggests that the atoll was also affected by the eastward flow of the Equatorial counter-current transporting water from tropical regions. The North Equatorial Current is driven primarily by the northeast trade wind system and is relatively strongest in January and weakest in July. The projection of the atoll into the flow of the North Equatorial Current produces two distinct but closely interrelated effects: (1) it deflects the current around and over the top of the atoll platform, and (2) it creates a wake on the downstream side of the platform (Fig. 17.12; Barkely 1972). The degree and intensity of these effects is driven by the mass flux of the North Equatorial Current.

The result of the North Equatorial Current flow interacting with the atoll geomorphology is a complex pattern of eddying and reversing currents in the shallow platform waters. These currents are also influenced by the tides. Although the prevailing current is transport to the west, the influence of the tide in shallow water makes the flow oscillate between the south and west, with short periods of flow to the south. The tidal effect is strongest in the summer, when the North Equatorial Current is weakest.

The circulation patterns outside the barrier reefs change with the variability in flow strength of the oceanic currents, which are strongest in winter. This water is forced through the reef and subsequently forms the almost continuous seaward flow out through the ship channels and reef cut. The oceanic currents are weakest in the summer. Because of lower current velocities at this time, strong convergence fronts behind the atoll were not evident. Although eddies also form during the summertime, it appears that their frequency and intensity is less than during the winter season.

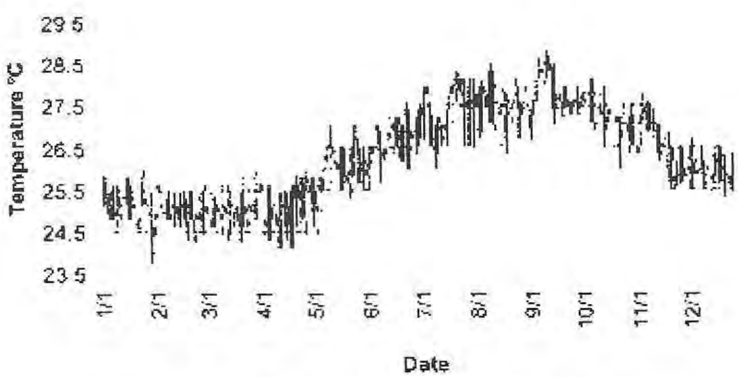

FIG. 17.11. Water temperature recordings (hourly) from the west end of Sand Island during 2000 (logger at 5 m)

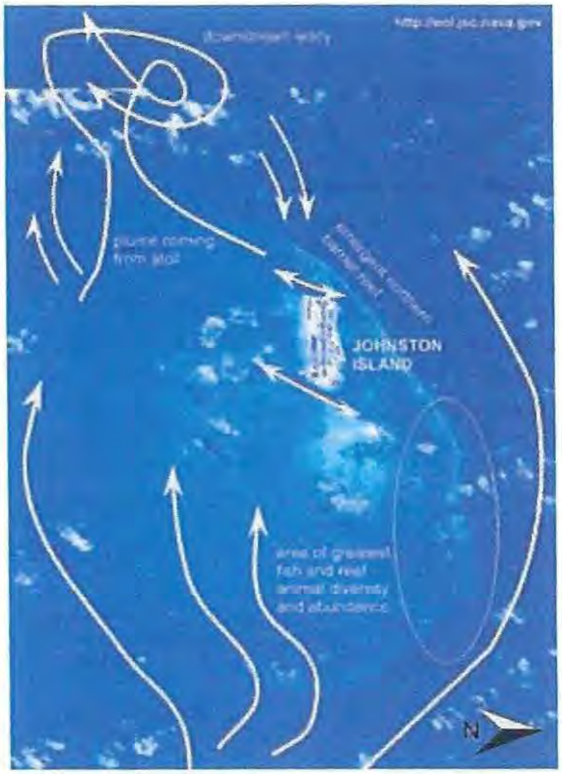

FIG. 17.12. Schematic of current flow at Johnston Atoll. Flow is normally from the east to west and fluctuates with the strength of the trade winds and equatorial currents. The hatched area in the oval shows the area of highest species diversity and abundance located on the eastern side of the atoll which is flushed with incoming open ocean water. Ocean eddies form on the leeward side of the atoll and can retain drifting buoys etc., near the reefs (Lobel 1997). Intense water flow with changing tides occurs in the two main channels (shown by small double ended arrows) and through small reef channels (Atoll satellite imagery adapted from a 1985 NASA Space Shuttle photograph)

The current flowing along the southern margin of the platform appears to be the main contributor to eddy formation. This current flows past a sharp topographic projection on the southwest corner of the island platform. Eddy formation is probably associated with a tip vortex formed by fast water flowing past this projection. In addition to eddies, strong current convergence fronts have been observed along the seaward westerly margin of the island platform. Ocean eddies forming behind Johnston Atoll have been observed by Barkley (1972), Boehlert et al. (1992) and Lobel (1997). These eddies can drift as far as 600 km downstream (Barkley 1972). A conceptual model of the current flow is shown in Fig. 17.12.

17.2.5 Seabirds

There are 13 seabird species that maintain annual breeding colonies on the islands and many more migratory birds that just stop over (Amerson and Shelton 1976). Over 20 years of careful census surveys by E.A. Schreiber and colleagues has shown that the populations have risen steadily (Schreiber et al. 2001; also Schreiber in Lobel et al. 2003). The population increase is due to the protection of the breeding colonies as well as increased space that was made available on the outer islands. Now that the main island is also vacant, seabirds have more room to expand. This raises the question of what will be the ecological consequences of an abundance of seabirds on the Johnston Atoll marine ecosystem. Before man's alterations of the atoll, only two islands of a total of approximately 0.2 km^2 (50 acres) existed, thereby limiting the space for the total number of seabirds. Today there is one 2.6 km^2 (640 acre) island and three more of 0.06–0.1 km^2 (15–25 acres) each. It is reasonable to predict that increased seabird abundances will result in greater feeding pressures on the atoll's fish and cephalopods and also increasing the nutrient loading in the lagoon from the increased guano production. The future ecological consequence of a rapid and unnaturally steep increase in abundance of seabirds on this small reef area has not been evaluated.

17.2.6 Coral Reef Biology

Johnston Atoll has had a long series of intermittent scientific surveys since the 1960s. Most of these surveys were focused efforts and to date there is still little detailed inventory of cryptic invertebrate species and the fauna in the offshore deeper habitats. Johnston Atoll and Hawaii have significant overlap in species distributions of shore fishes and reef corals. The majority of Johnston Atoll fish and invertebrate species are Hawaiian although some Line Islands species also occur at Johnston Atoll but not in Hawaii (Randall et al. 1985; Coles et al. 2001). The coral fauna at Johnston Atoll is essentially a subset of Hawaiian species with the majority of the Johnston species also occurring in Hawaii (Maragos and Jokiel 1986). For such close faunal affinities to occur between Johnston Atoll and Hawaii, ocean currents must exist, at least in some years, which transport pelagic larvae between locations. Johnston Atoll is isolated; however, it lies within the domain of an Archipelago-sized ocean current gyre feature during March–April (illustrated in Wyrtki 1975). Various evidence supports the hypothesis of an oceanographic link between Johnston Atoll and the Hawaiian Islands (Lobel 1989; Kobayashi 2006).

17.2.6.1 Algae

One hundred species of benthic algae have been identified from Johnston Atoll (Amerson and Shelton 1976; Coles et al. 2001). Buggeln and Tsuda (1966) found 12 algal species confined to the marginal reef while 33 species were only found within the lagoon. Of these 33 species, 11 exclusively occurred within the inshore areas of Johnston Island and two within the inshore area of Sand Island. Deep algae surveyed by submersible were reviewed by Agegian (1985). Lagoon dredging did impact algal distribution such that lagoon areas that were silted during the 1963/64 dredging were less diverse (Buggeln and Tsuda 1966; Brock et al. 1966). However, algal growth along the south side of Johnston Island is dense with green sea turtles feeding on abundant *Bryopsis pennata* and *Caulerpa racemosa*. During 2006, the NOAA Coral Reef Ecosystem Division survey teams (NMFS Pacific Islands Fisheries Science Center) reported low abundances of macroalgae with little change in algal communities since the previous survey in 2004 (PIFSC/CRED Cruise report NOAA 2006a). The most common macroalgae found included *Caulerpa*, *Dictyosphaeria*, and *Ventricaria* while turf algae was the most common component of the algal community (NOAA 2006a).

17.2.6.2 Corals

Coral coverage within the lagoon of Johnston Atoll is extensive, ranging from 80% to 100% of available habitat, although the diversity is low (Fig. 17.13). This low diversity results from low recruitment due to the natural geographic isolation of the atoll. Maragos and Jokiel (1986) reported 29 species of scleractinian and three species of hydrozoan corals in the first scuba based coral survey. Subsequent surveys have increased the number of coral species known to occur at Johnston to about 40 with the additional species mostly being uncommon (NOAA 2006a). The coral fauna is depauperate when compared to, for example, the Marshall Islands, with 366 species. Ecologically, Johnston's marine species are more closely related to those found in Hawaii, with 24 of the 29 Johnston species described in Maragos and Jokiel (1986) also occurring in Hawaii. However, some common Hawaiian corals are absent from Johnston and the most abundant coral at Johnston, *Acropora cytherea*, very rarely occurs in Hawaii (Kenyon et al. 2007). Even though strong zoogeographical affinities in coral faunas between Johnston and Hawaii exist, there are significant differences in the ecological relationships and dominant groups (Maragos and Jokiel 1986). At Johnston, the dominant corals in descending order of abundance are *Acropora*, *Montipora*, *Pocillopora* and *Porites*. In Hawaii the dominant corals are *Porites*, *Pocillopora* and *Montipora* (Maragos and Jokiel 1986). The 2006 NMFS Pacific Islands Fisheries Science Center (PIFSC) CRED Rapid Ecological Assessment (REA) surveys (by J. Maragos, B. Vargas Angel and collaborators) conducted at 18 locations in a variety of habitats found montiporid corals, specifically *Montipora capitata* and *M. patula* to be the most abundant (NOAA 2006a). Other important coral taxa from these surveys included *Acropora cytherea*, *A. valida*, *Pocillopora*, *Pavona*, and *Porites* (NOAA 2006a). Coral cover varied by exposure with cover ranging between 2% and 15% in exposed forereef areas compared to 65–80% coral cover found in protected back-reef areas (NOAA 2006a). Differences between the 2004 and 2006 rapid ecological assessment surveys in coral population parameters including declines in mean coral diameter, loss of large corals, and large declines in coral cover call for continued monitoring and study (NOAA 2006a).

The distribution of *Acropora* corals suggests that occasional larval transport occurs from Johnston Atoll to the northwest Hawaiian Islands and Kauai (Grigg 1981; Grigg et al. 1981; Kobayashi 2006; Kenyon et al. 2007). Initially, it was unclear if populations of *Acropora* coral living at French

FIG. 17.13. Typical lagoon reef at Johnston Atoll. Dominant coral is *Acropora cythera*

Frigate Shoals and nearby reefs were sexually reproductive and, had they all been asexual, would have all derived from larvae spawned at Johnston Atoll (Grigg 1981). However, later study found occasional sexual reproduction in these populations (Kenyon 1992). In contrast, recent discovery of *Acropora cytherea* on Kauai suggests Johnston Atoll as the larval source (Kenyon et al. 2007).

Many of the lagoon corals near Johnston Island were destroyed during the dredging between 1942 and 1964. Amerson and Shelton (1976) report that the dredging operations destroyed $4.5\,km^2$ (1,100 acres) of coral habitat. The dredging itself covered an area of $2.8\,km^2$ (700 acres) while newly deposited coral aggregate affected an additional $1.6\,km^2$ (400 acres). Additional impacts from the silt created during dredging reduced the percentage of living coral from 0% to 40% (10% average) in an area covering $28.3\,km^2$ (7,000 acres) (Amerson and Shelton 1976). Many areas have recovered to the extent that all available hard substrate in the formerly dredged channels now has extensive coral growth. However, the 2006 NMFS Pacific Islands Fisheries Science Center (PIFSC) CRED rapid ecological assessment (REA) surveys still found signs of sedimentation stress in corals at locations south of Johnston and East (Hikina) Islands (NOAA 2006a)

A major coral bleaching event was documented during the El Niño of 1996. Cohen et al. (1997) found that bleaching was confined to corals in the lagoon and that no bleaching occurred along the emergent reef (with the exception of one bleached colony *(Pocillopora meandrina)* noted on the inside of the eastern reef edge. They also found the bleaching to be species specific with all *Montipora* spp. and *Pocillopora* spp. affected, although to different degrees, while beaching was not observed in *Acropora cytherea*, the dominant coral species on Johnston Atoll.

Incidences of coral disease and altered coral morphology were documented during both CRED/ REA cruises (2004 and 2006). Morphological changes potentially indicative of poor coral health were observed at 11 of 12 sites surveyed during 2004 and at 14 of 18 sites surveyed during 2006 (NOAA 2006a). Data collected by G. Aeby in 2004 included 120 cases of coral disease ranging from bleaching, plague-like signs, tumors, patchy necrosis and ring syndrome (NOAA 2006a). Tissue loss and skeletal growth anomalies were the primary afflictions observed within 97 cases of "diseased" corals observed during 2006 (NOAA 2006a). Additionally, coral predation by *Acanthaster planci* and *Drupella* sp. were observed (NOAA 2006a).

Mass coral spawning usually occurs in late May–June with an occasional second spawning event in July. In some years, the coral spawn produced a very thick surface layer of planulae (Lobel 2003) with a permeating stringent odor that triggered the Army's chemical weapons sensors for mustard gas.

17.2.6.3 Macroinvertebrates

The first reports of invertebrate surveys from Johnston Atoll were from the Tanager expedition of 1923 (Edmondson et al. 1925; Clark 1949). Baseline invertebrate diversity data were collected by Brock et al. 1965 and 1966. A total of 182 species of invertebrates including the orders Annelida (12 spp), Echinodermata (37 spp), Crustacea (75 spp) and Mollusca (58 spp) were reported by Amerson and Shelton (1976). Cryptic invertebrate species have not yet been thoroughly documented. The Coles et al. (2001) survey and literature review increased the number of invertebrate species recorded from Johnston including one species of aschelminth, 20 polychaete species, 135 crustacean species, 221 mollusc species, 69 echinoderm species, 16 sponge species, 4 sipunculid species, 30 bryozoan species and 13 ascidian species.

17.2.6.4 Fishes

The fish fauna of Johnston Atoll has been the subject of surveys dating to the late 1880s (Smith and Swain 1882; Fowler and Ball 1925; Schultz et al. 1953; Halstead and Bunker 1954; Gosline 1955; Brock et al. 1965, 1966; Randall et al. 1985; Kosaki et al. 1991; Chave and Mundy 1994; Chave and Malahoff 1998; Lobel 2003). The known fish fauna of Johnston Atoll currently totals 301 species (Randall et al. 1985; Kosaki et al. 1991). In comparison, about 612 species are found in the Hawaiian Islands, about 844 species in the Mariana Islands and about 1,357 species in the Palau and Yap Island groups (Randall 1992, 2007). The lower number of species on Johnston Atoll is probably the simple result of there being fewer habitat types compared to Hawaii or other archipelagoes.

Johnston's fish fauna is dominated by Hawaiian species. Only 17 non-Hawaiian fish species compared to 53 endemic Hawaiian species occur at Johnston Atoll but not farther south in the Line Islands. Eleven other species are indigenous to Johnston Atoll and the Line Islands but are not found farther north in Hawaii (Randall et al. 1985; Kosaki et al. 1991; Lobel 2003).

Conspicuously absent from Johnston Atoll are any species of "algal farming" damselfish (Pomacentridae: *Stegastes* spp.), the blacktip shark (*Carcharhinus melanopterus*) and any of the goby–shrimp symbiotic species. There is one species (*S. fasciolatus*) of algal farming damselfish in Hawaii (Randall 1996) and two species: *Stegastes albofasciatus* and *S. nigricans,* in the Line Islands (Chave and Eckert 1974). The blacktip shark occurs in Hawaii but is rare (Gosline and Brock 1960). There is no evidence that either of these fishes were ever present at Johnston Atoll. This is an extremely interesting biogeographic anomaly. It is easy to consider that the ecological role of the blacktip shark may be compensated for by an abundance of other roving piscivores including large carangids and other sharks. However, algal farming damselfish influence fundamental reef processes including nitrogen cycling and micro-invertebrate densities (Lobel 1980). How the absence of any *Stegastes* spp. at Johnston Atoll may have (or not) altered reef processes there is still being pondered.

Twenty-five percent (of a total of 612 species) of the Hawaiian shore fishes (occurring to 200 m depth) are taxonomically recognized as endemic species (Randall 2007). Many of these species have planktonic larval phases lasting up to 3 months (Ralston 1981; Lobel 1997) and therefore have the potential for long range dispersal (Kobyashi 2006). One conceptual model proposes that the coincidence of fish spawning patterns in Hawaiian waters to ocean eddy current patterns entrains and retains pelagic larvae near home islands (Lobel 1978, 1989, 1997; Lobel and Robinson 1983, 1986). Limited evidence also suggests that Johnston Atoll may also have some degree of local retention of pelagic larvae and that fish populations on the atoll are mostly derived from the resident populations on the atoll rather than from larvae drifting in from other island groups (Lobel 1997).

Several Johnston Atoll fishes exhibit color patterns suggesting they are sub-species and therefore distinct from their sister species in Hawaii (Randall et al. 1985; Lobel 2003). These Johnston Atoll fish populations that appear distinctly colored from their nearest relatives in Hawaii include a surgeon fish (*Ctenochaetus strigosus*), a parrotfish (*Scarus perspicillatus*), a wrasse (*Labroides phthirophagus*) and two butterflyfishes (*Chaetodon multicinctus* and *C. tinkeri*) (Randall 1955; Randall et al. 1985; Kosaki et al. 1991). Only one fish, the pygmy angelfish, *Centropyge nahackyi*, is recognized as endemic to the atoll (Fig. 17.14; Kosaki

1989; Lobel 2003; Randall 2007). Additionally, another population unique to Johnston Atoll is a hybrid (Fig. 17.15) between two sister species; the Hawaiian endemic wrasse *Thalassoma duppery* and its nearest relative in the Line Islands and West Pacific, *T. lutescens*.

Recent invasions to the Johnston fish fauna include the Hawaiian sergeant major damselfish (*Abudefduf abdominalis*) as well as the Indo-Pacific sergeant major (*A. vaigiensis*). Both species are recent immigrants as spawning populations were not historically present (Lobel 2003). *A. abdominalis* individuals were observed once at Johnston Atoll in 1986 but they were determined to be several waifs that eventually died off (Irons et al. 1990). A few *A. vaigiensis* were first observed in 1997 and in 1998, but in 1999 *A. vagiensis* were observed spawning at several locations in the lagoon. By 2001, both species had well-established populations at multiple reef sites throughout the atoll.

17.2.7 Threatened and Endangered Species

The green sea turtle is the only threatened species commonly observed throughout the year. Other threatened or endangered species have been observed at Johnston Atoll, including the humpback whale, Cuvier's beaked whale, and the Hawaiian monk seal.

The green sea turtle, *Chelonia mydas*, has been frequently observed feeding on the south side of Johnston Island and swimming in the lagoon. The first known nest was observed by USFWS in 1996 on the south side of Johnston Atoll near the JACADS facility. The eggs in the nest did not hatch and reason why eggs were not viable is still to be determined (USFWS 1998, personal communication). An estimated 200 turtles use Johnston as a feeding area; this is one of the highest concentrations of green sea turtles in a non-nesting area in the Pacific (D. Forsell, 1990, USFWS, personal communication). Other studies have shown that the Hawaiian and Johnston populations are probably the same (Balazs 1986).

Reef sharks are at risk now that Johnston Atoll is without protection. The grey reef shark, *Carcharhinus amblyrhynchos*, and the reef whitetip shark, *Triaenodon obsesus*, are the most common sharks. An annual aggregation of female grey reef sharks (*Carcharhinus amblyrhynchos*) occurs between late February and May in the shallow waters off of Sand Island (Economakis and Lobel 1998).

17.2.8 Contamination Issues

Johnston Atoll was a very active military base beginning in the 1930s until June 2003. Lobel and

FIG. 17.14. This pygmy angelfish, *Centropyge nahackyi*, is endemic to Johnston Atoll. It lives in a rubble habitat along caves and ledges at depths below 60 ft (20 m)

FIG. 17.15. The wrasse, *Thalassoma dupperry* × *lutescens* hybrid, an incipient species? The Johnston Atoll population is dominantly composed of hydrids of the Hawaiian endemic, *T. dupperry*, and the widely distributed *T. lutescens* (also photos in Randall 1996; Lobel 2003)

Kerr (2002) reported the results of an atoll-wide survey of lagoon sediments that revealed the presence of a variety of contaminants including metals (antimony, arsenic, barium, chromium, copper, lead, mercury and zinc) and organics [polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), herbicides, dioxins and furans]. These contaminants were mainly concentrated near two particular sites: Sand Island (former US Coast Guard LORAN Station) and the northwest corner of Johnston Island (former "Agent Orange" storage site, burn pit, and fire training area, Fig. 17.16). The herbicides 2,4 D and 2,4,5 T as well as tetrachlorodibenzo-*p*-dioxin (TCDD) were of particular interest due to the storage and subsequent leakage of agent (herbicide) orange while it was being stored on Johnston Island. TCDD and other polychlorinated dibenzodioxins/furans (PCDDs/PCDFs) are extremely toxic contaminants found within the agent orange mixture. Sand Island was targeted for sampling due to the large amount of metal debris and electrical equipment, including PCB filled transformers, that were found in the lagoon. Large concentrations of disposed lead acid batteries used to power the aids to navigation were also found close to Sand Island.

The study was based upon 216 samples at 13 locations throughout the atoll (Lobel and Kerr 2002). In general, remote sites with no known adjacent sources of contamination had low levels of metals and organics. Metals at these remote sites usually included barium, chromium and zinc with an occasional detection of lead or arsenic. Organic contaminants at sites with no known contaminant history included low levels of PCBs, and PCDDs/PCDFs in some samples. Tetrachlorodibenzo-*p*-dioxin (TCDD) was not detected at any of the remote sites.

At sample locations offshore of Sand Island and Northwestern Johnston Island which were adjacent to potential contaminant sources, metal concentrations were low with antimony, arsenic, cadmium, chromium and mercury concentrations all falling below screening levels for marine sediments (Table 17.1). Lead, zinc, and copper rarely exceeded the screening guidelines. However, barium was found in 99% of sediment samples and exceeded the screening guideline in 53 samples (50%). PCBs were detected in most of the samples analyzed, but concentrations exceeded screening guidelines in only eight samples (14.5%) collected from Sand Island. PAHs exceeded the screening guideline for total PAHs in two (2%) samples collected offshore of the northwestern side of Johnston Atoll where the fire training and refuse burning pits were located. Herbicides were only detected in one sample. Dioxins and furans were detected in 80%

FIG. 17.16. The most contaminated reef area of the atoll was restricted close to shore of the northwest part (yellow arrow) of Johnston Island. Onshore was the Herbicide Orange storage, open burn pit for trash, fire training area, and other hazardous materials disposal operations. 1993 photo. Dredged channel is near island, thick reef area in foreground

of the samples although the majority of the detections were at fairly low concentrations. Dioxin/furan concentrations, expressed as toxic equivalents (TEQ), exceeded the screening guideline of 3.6 pg/g in nine (9%) samples collected directly adjacent to the shoreline of the former herbicide orange storage site. The most toxic dioxin isomer, 2,3,7,8 tetrachlorodibenzo-*p*-dioxin (TCDD) was detected in 28% of the samples.

PCB contamination was also found in sediments and fishes from localized areas around the northern side of Sand Island and within the small lagoon next to the former Navy pier on Johnston Island. In order to provide baseline monitoring criteria and evaluate sediment quality benchmarks used for ecological risk assessments in tropical regions, studies were conducted investigating PCB accumulation and adverse effects in an indicator species. The indicator species chosen was the damselfish, *Abudefduf sordidus*, due to its habit of consuming sediments along with its omnivorous diet, relatively small home range, long life, and demersal spawning (Kerr et al. 1997; Kerr Lobel 2005). Monitored adverse effects included the occurrence of embryonic abnormalities (offspring survival) within PCB contaminated and uncontaminated sites around the atoll. Increased concentrations of PCBs were detected using immunohistochemical methods in embryos and larvae from contaminated areas (Fig. 17.17; Kerr Lobel and Davis 2002). Mean whole adult body concentrations of total PCBs ranged from 364.6 to 138,032.5 ng/g lipid and a significant residue-effect relationship was found between total PCB concentration and embryo abnormalities. The occurrence of embryo abnormalities was positively related to fish PCB concentration (Kerr 1997; Kerr Lobel 2005).

Overall, the northwest end of Johnston Island was the area of the atoll with the most variety of contaminants in fishes and sediments. This was the site of the island's open burn pit and trash dump, a fire training and explosives detonation area, and the former storage site of Agent (Herbicide) Orange (Fig. 17.16). After the Vietnam War, in 1972, 5.19 million liters (1.37 million gallons) of unused Agent Orange (AO) were transferred to Johnston Island for temporary storage. Due to corrosion of the metal drums, some AO product leaked onto the site. This required an active maintenance and re-drumming operation on site. It was estimated that approximately 49,000 lb (22.3 t) of AO escaped into the environment from 1972 to

TABLE 17.1. Summary of analyses completed on Johnston Atoll marine sediments showing average, minimum and maximum contaminant concentrations as well as the number of samples exceeding screening guidelines across the atoll. Samples were collected from 13 lagoon locations. Average, minimum and maximum concentrations were calculated using only those samples with detectable concentrations (Screening guidelines are from the NOAA SQuirTs website. Updated table from Lobel and Kerr 2002.

Analyte	Total # samples	% Detections	Average conc.	Minimum conc.	Maximum conc.	Screening guideline	# Samples >guidelines
Organics (ng/g)[a]							
PCBs	85	87	39.8	0.4	389.0	22.7	8
PAHs	105	30	589.6	9.2	7,243.0	4022.0	2
2,4-D	87	1	–	6.5	6.5	5	1
2,4,5-T	87	1	–	24.0	24.0	3	0
TEQs (pg/g)	105	80	11.849	0.001	901.286	3.6	9
TCDD (pg/g)	105	28	25.210	0.615	901.000	3.6	9
Metals (μg/g)							
Antimony	100	16	0.7	0.2	1.8	9.3	0
Arsenic	205	47	0.6	0.2	2.3	8.2	0
Barium	105	99	76.8	3.2	294.7	48.0	53
Cadmium	205	0	ND	–	–	1.2	0
Chromium	105	81	8.9	3.5	60.1	81.0	0
Copper	205	21	11.5	1.1	171	34.0	2
Lead	205	24	19.6	1.6	82.6	46.7	1
Mercury	205	8	0.02	0.005	0.078	0.15	0
Zinc	205	82	14.9	1.2	163.3	150.0	1

ND – None detected, NA – Not analyzed
[a]Note that units for TEQ and TCDD are pg/g

1977 at which time the AO was taken offshore and incinerated at sea. The former Agent Orange storage area encompassed approximately 0.02 km^2 (5.4 acres) of coastal property on the northwest corner of Johnston. The leaked AO product introduced dioxin into the adjacent reef area. It is assumed that the contamination of marine sediments by dioxin compounds was caused by soil transport (wind or rain erosion runoff) into the near-shore marine environment. A cement berm surrounding the former AO storage site was constructed in 1995 and was designed to prevent further contamination by erosion. The dioxin was removed from the entire terrestrial site surface material by soil remediation methods before the island base was closed.

The coral reef area immediately adjacent to the northwest end of Johnston Island (the AO-Burn Pit site) was calculated to be approximately 0.5 km^2 (116 acres). The total coral reef area of the atoll is approximately 157.8 km^2 (46.6 nm^2 or 39,000 acres; excluding landmass area), calculated using the 10 fathom isobath contour. Thus, the affected area is about 0.3% of the total atoll reef area. Contamination in biota was found only at the sites within 20 m of the AO shore (Lobel and Kerr 1996, 1998). These reefs provide habitat to a diversity of fishes, invertebrates and algae. Upon visual reconnaissance, no readily apparent impacts from the presence of chemical contamination were obvious.

Less well studied is the plutonium contamination within the lagoon that occurred as a result of three failed atmospheric nuclear tests in the 1960s. These failed nuclear rockets tests resulted in radioactive fallout over Johnston Atoll. The Deptartment of Energy subsequently performed extensive cleanup operations with most terrestrial areas cleaned at the upper layer and the contaminated soils buried in the designated plutonium landfill on the north side of Johnston Island. In 1995–1996, key lagoon areas were surveyed for plutonium using an underwater radiation detector. Residual radiation was found mostly off of Sand Island (Johnson et al. 1997).

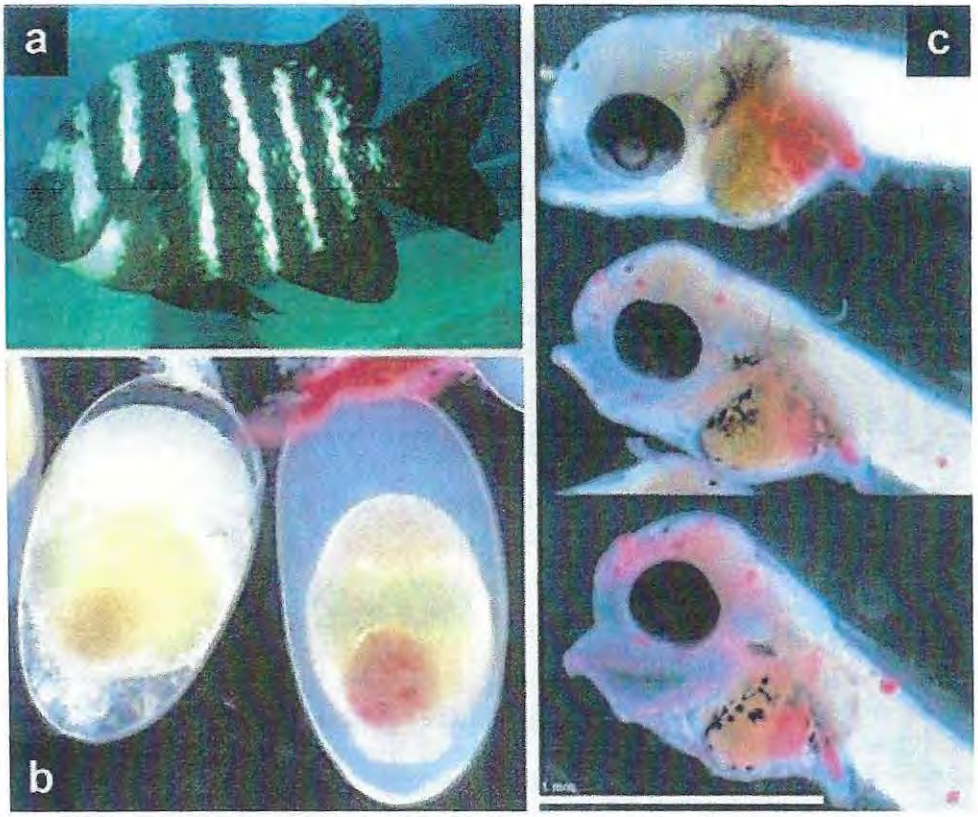

FIG. 17.17. (**a**) Adult male *Abudefduf sordidus* in breeding coloration. Immunohistochemical localization of PCBs in *A. sordidus* embryos and larvae. (**b**) PCB localization in embryos. PCBs are shown in pink found around the lipid rich oil globule of an early stage embryo (**c**) PCB localization in larvae. Top photo shows background staining as in gut; Middle photo shows little staining in larva from reference location with low PCB contamination; bottom photo shows increased staining in larva from PCB contaminated location (see Kerr Lobel and Davis 2002)

17.3 Wake Atoll

17.3.1 Introduction to Wake Atoll

Wake Island (Figs. 17.3, 17.8) is a possession of the United States under the ownership of the Department of the Interior by means of Executive Order No. 11048, Part I (5 September 1962). However, the property is managed by the US Air Force Pacific Command while atoll facilities are administered by the US Army Strategic and Missile Defense Command under a caretaker permit from the US Air Force. It is used as a support facility for testing intermediate range target missiles that are launched from Kwajalein Atoll in the Marshall Islands, located 1,100 km to the south. Current use of the atoll also includes housing a NOAA regional weather forecasting and data collection station and a University of Hawaii (Manoa) seismic monitoring station.

17.3.2 History of Wake Atoll as a US Territory

The first reported European sighting of Wake Atoll occurred on 2 October 1568 by Captain Alvaro de Mendaña. He named it San Francisco although his longitude coordinates were inaccurate. The atoll was renamed for Captain William Wake of the British trading schooner Prince William Henry who documented the atoll in 1796. Reports vary

FIG. 17.18. Wake Atoll viewed looking east. Wilkes Island is foreground to right, Peale Island in the back, Wake Island wraps around and connects to both

as to whether this was the first European landing on Wake Atoll or whether the islands were documented but not claimed. Additionally Wake was "discovered" and named in different positions by various explorers because of the difficulty of accurate navigation during the nineteenth century. Synonyms and misspellings found on charts included Halcyon, Helsion, Wilson, Waker's, Weeks and Wreck. The US Exploring Expedition led by Lt. Wilkes arrived on 19 December 1841 aboard the US warship Vincennes provided the first surveys, maps and detailed descriptions of the atoll. During the Spanish American War, Wake was formally claimed for the US by Major General Wesley Merritt and the US officially took possession of the atoll on 17 January 1899. A second scientific expedition followed in 1923 led by Alexander Wetmore of the Bishop Museum, Honolulu. During this expedition, the small western island was named for Lt. (later Commodore) Wilkes and the third Island for Titian Peale a naturalist and artist that accompanied Lt. Wilkes on the first expedition.

The US Navy was given responsibility for Wake in 1934. A proposed submarine base was under construction including a submarine channel through Wilkes Island that was never completed due to the outbreak of WWII. Wake was established as a transpacific refueling base by Pan American Airlines in 1935. The Japanese attacked Wake several hours after the attack on Pearl Harbor and the atoll was captured on 23 December 1941 to remain in Japanese possession until 1945. Many of the captured civilians and military personnel were sent to prison camps, but the 98 civilians kept at Wake to construct Japanese fortifications were later executed by order of the Japanese commander. After WWII, the Federal Aviation Administration and later the US Air Force resumed use of the atoll as a transpacific refueling site.

Wake Atoll was designated a National Historic Landmark in 1985 (US Department of Interior 1984) to preserve the battlefield and Japanese and American structures where important WWII events occurred. Historic structures include several pillboxes, bunkers, aircraft revetments as well as the Pan American facilities and the US Naval submarine and aircraft base. The prisoner of war "rock" (actually a large coral head) inscribed with a US POW number remains a poignant reminder of WWII events (Fig. 17.19).

17.3.3 Geomorphology of Wake Atoll

The atoll is approximately 3 km wide by 6.5 km long and the three islands have a land area of approximately 6.5 km^2. The three individual islands, Wilkes, Wake and Peale have land areas of 0.8 km^2 (206 acres), 5.5 km^2 (1,350 acres) and 1.1 km^2 (270 acres) respectively (Fig. 17.19). The Islands are essentially flat with average elevations

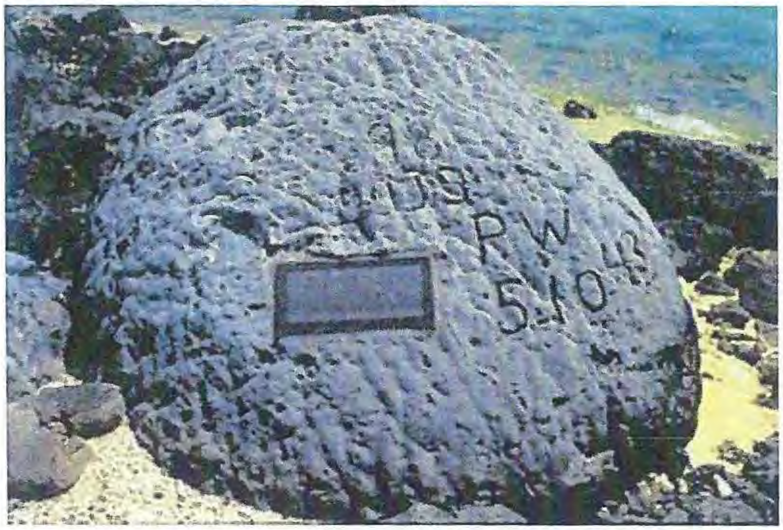

FIG. 17.19. "POW rock". Coral on beach with the carved number of a US POW on Wake Island, WWII

of 3.7 m (12 ft). The maximum elevation of Wake and Peale islands is 6.4 m (21 ft) while Wilkes has a maximum elevation of 5.5 m (18 ft). The highest features are coral and shell ridges parallel to the shore found 3–15.2 m (10–50 ft) from the sand beaches. From these ridges, the terrain slopes gently to the lagoon. The area of the enclosed lagoon (water and sand flat) is approximately 9.7 km^2 (3.75 $miles^2$; Bryan 1959), while the lagoon itself is less than 7.8 km^2 (3 $miles^2$).

The atoll has an emergent reef on the western boundary (Fig. 17.3) over which most water exchange between the lagoon and open ocean takes place. Additional water flows during high tide through the channel between Peale and Wake Islands (Fig. 17.20) and the old submarine channel in the middle of Wilkes Island (Fig. 17.21). The small boat harbor was previously open to the lagoon but it was sealed off by construction of a seawall (Fig. 17.22). Water circulation in the lagoon was severely reduced when the causeway between Wake and Wilkes islands was built, resulting in the closure of the small boat harbor inlet into the lagoon. There have been reports of large-scale fish die-offs in the lagoon due to high temperatures when tidal flushing is low, resulting in low levels of dissolved oxygen.

Island soils consist of highly permeable sand and coral rubble covered in vegetated areas by a thin layer of organic material. The geological profile of the islands consists of alternating and often mixed layers of sand, shells, coral and soft limestone (US Army Space and Strategic Defense Command 1992). There is limited brackish groundwater due to the small land mass, flat topography and porous soils (US Army Space and Strategic Defense Command 1992).

17.3.4 Climate of Wake Atoll

Annual climate is uniform with average daily low and high temperatures of 24°C (75°F) and 30°C (85°F). Humidity averages 76% (NOAA 1992). The prevailing wind direction is east–northeast with a mean speed of 22.2 km/h (NOAA 1992, US Army Space and Strategic Defense Command 1992). Annual precipitation averages 89 cm (35 in.; NOAA 1992). Typhoons (tropical cyclones) threaten Wake from late summer to autumn. Severe flooding and wind damage occurred during the typhoons of 1957, 1967, 1978, 1986, 1992, and 2006. Typhoon Ioke of 2006 was one of the few storms both categorized as a hurricane in the eastern Pacific (also impacting Johnston Atoll) and a typhoon in the western pacific

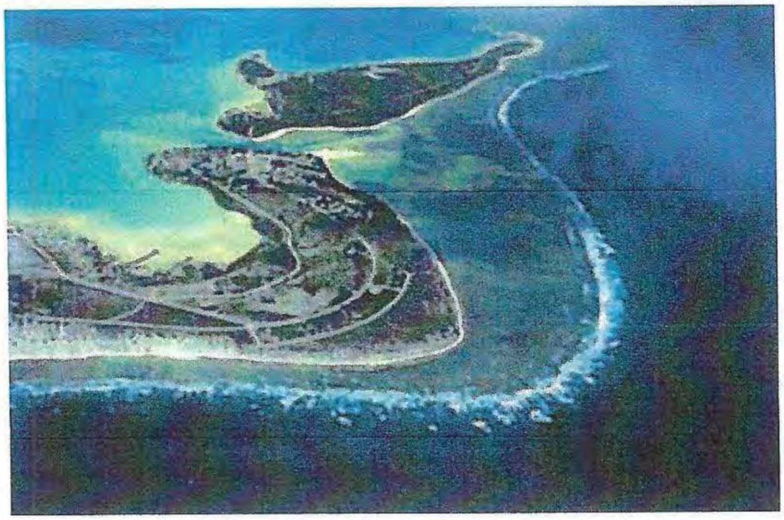

Fig. 17.20. The channel between Wake Island and Peale Island (top). The main base complex is located in this area. Photo was taken at low tide and shows broad reef flats. At high tide water flows through the channel. The channel to lagoon is excellent bone fishing grounds

Fig. 17.21. The never-completed submarine channel started at the beginning of WWII, through the middle of Wilkes Island. Peale Island in background across the lagoon

("hurricane" and "typhoon" are regional names for tropical cyclones with winds of at least 33 m/s). It reached category 5 but passed close to Wake Atoll as a category 4 storm. Damage suffered by island infrastructure was so severe that the Department of Defense decided to place the atoll in caretaker status and reduced the workforce from 120 personnel to approximately a dozen as of February 2007.

FIG. 17.22. The small boat harbor was originally open to the lagoon but was sealed by construction of a seawall. The small boat channel that was once used is evident but was closed off when the causeway connecting Wake Island (left) to Wilkes Island (right, with the three fuel storage tanks) was constructed. The overall best diving was in the immediate area on the outside reefs by this harbor. The wreck of an oil tanker is in shallow water by the harbor entrance and is colonized by corals

17.3.5 Oceanography

There is very little data on the ocean current patterns around Wake Atoll. The first Reef Assessment cruise (PIFSC Cruise Report CR-06-024) to Wake deployed sea surface and subsurface temperature recorders and collected shallow and deep water oceanographic data around the atoll (NOAA 2006b). Initial data from conductivity-temperature-depth (CTD) profiles around the atoll show that surface waters (<50 m) in the forereef and offshore areas are well mixed with little stratification (NOAA 2006b). However, slightly lower temperatures (0.1–0.2 °C) and higher salinities (0.05 PSU) suggest very weak upwelling along the north and eastern margins of the atoll (NOAA 2006b). Interestingly, CTD data from within the lagoon (surface only due to shallow depths) varied by location within the lagoon and relative to forereef measurements indicating little exchange between oceanic and lagoon waters (NOAA 2006b). An intermittent ocean current flow connecting Hawaii and Wake Atoll seems to be caused by ocean eddies formed off of the island of Hawaii which flow westward eventually impinging on Wake (Mitchum 1995). Other evidence of current flow between these two locations includes reports of Hawaiian fish aggregation devices (FADS) recovered from Wake (Lobel and Lobel 2004).

17.3.6 Terrestrial Vegetation on Wake Atoll

Prior to human occupation, Wake Atoll was vegetated by only about 20 indigenous plant species and none were rare, unique or endemic to Wake (Bryan 1959). The relatively low diversity of terrestrial plant species on Wake has been correlated to the low overall annual rainfall in comparison to other Pacific Atolls (Wiens 1962).

17.3.7 Seabirds on Wake Atoll

There are 26 species of migratory seabirds listed for Wake Atoll (http://www.bsc-eoc.org/avibase/). Two of these birds are globally threatened species: the Laysan Albatross (*Phoebastria immutabilis*) and the black-footed Albatross (*Phoebastria nigripes*). Seabird nesting occurs mainly on Wilkes Island.

17.3.8 Coral Reef Biology on Wake Atoll

17.3.8.1 Marine Habitats

Four basic aquatic habitat types occur within Wake Atoll. A shallow and turbid lagoon with scattered patch reefs (Fig. 17.23) is land bound on one side and a large proportion of the lagoon habitat is occupied by sand flats that are fully exposed at lowest tides (Fig. 17.24). The lagoon is murky and shallow averaging 3 m (10 ft) depth with maximum depths reported of up to 4.5 m (15 ft) in 1923 (Bryan 1959). In all areas of the lagoon surveyed, the bottom was sand mixed with occasional corals and *Tridacna* clams. The lagoon was very turbid with water clarity scarcely a few feet. In sand areas that were regularly exposed at low tides, the bottom was sand with a limited variety of snails, crabs and other sand-burrowing invertebrates. The intertidal is a hard substrate, ocean reef flat, which is exposed at low tide (Figs. 17.25 and 17.26). The reef crest top is also exposed at very low tides (Figs. 17.27 and 17.28). The outer reef drops rapidly in depth on both the exposed windward and sheltered leeward sides (Figs. 17.27 and 17.29). The ocean reefs had spectacular water clarity with visibility in excess of 30 m (100 ft). The bottom varied with mostly boulder type coral colonies growing over eroded older coral formations (Fig. 17.30). Reefs were in excellent ecological condition with no obvious signs of environmental problems when surveyed in 1997 and 1999 (Lobel and Lobel 2004).

17.3.8.2 Algae

A total of 40 species of benthic algae have been documented from Wake from a limited field collection (Tsuda et al. 2006). The algal species were common to both Hawaii and Micronesia, with a slightly closer affinity to Hawaii (Tsuda et al. 2006). Only 3 of the 40 species found at Wake have not been recorded from Hawaii. Sea grass beds, algal flats and mangroves habitats were not found at Wake Atoll during surveys in 1997–1999 (Lobel and Lobel 2004). The most common macroalgae observed in photoquadrats during the most recent reef surveys (PIFSC Cruise Report CR-06-024) were *Halimeda* sp., *Dictyota* sp., *Caulerpa* sp., and *Lobophora variegata* (NOAA 2006b). Common algae found within the lagoon included blue-green algal mats and *Caulerpa serrulata* (NOAA 2006b).

FIG. 17.23. The west margin of the atoll is a vast area of shallow reef that drops off rapidly. Inside the lagoon, scattered small patch reefs are spread over an even sand bottom. Peale Island is to the right

FIG. 17.24. This is the shallowest portion of the lagoon also shown in Fig. 17.3. This area is exposed during daily low tide. The dominant substrate type is sand mixed with many dead mollusks. It is unknown at this time, whether the mass amounts of dead mollusks is the result of long time natural accumulations or high mortality due to adverse ecological impacts. The lagoon is next to the airfield runway and air traffic and refueling operations may very possibly have added pollutants. The potential effects remain to be determined

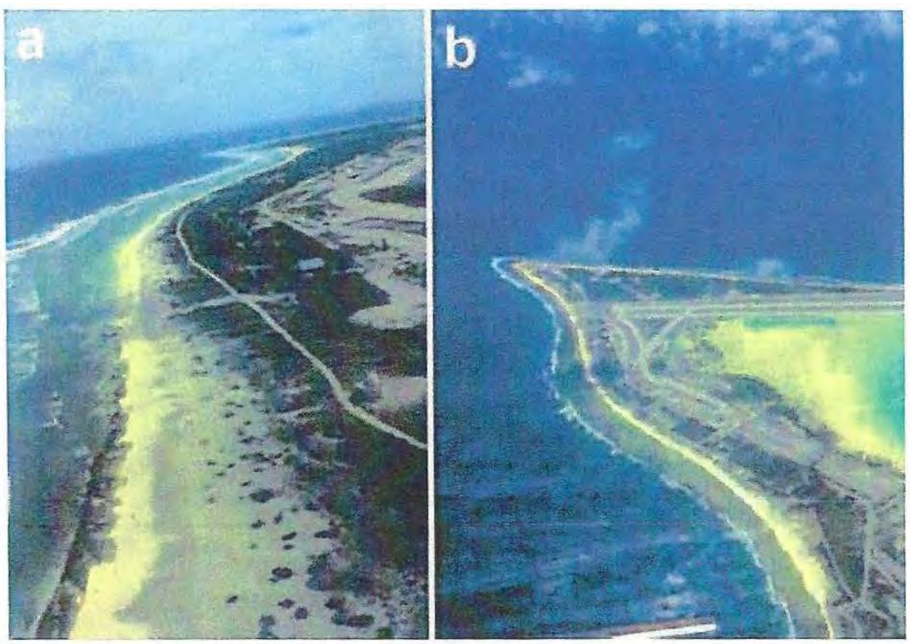

FIG. 17.25. Long sand beaches extend along most of the islands. This stretch of beach (**a**) on Wake yielded several washed up glass balls almost daily. A different view of the same coast (**b**) showing the broad reef flat, as well as the extent of development on the island

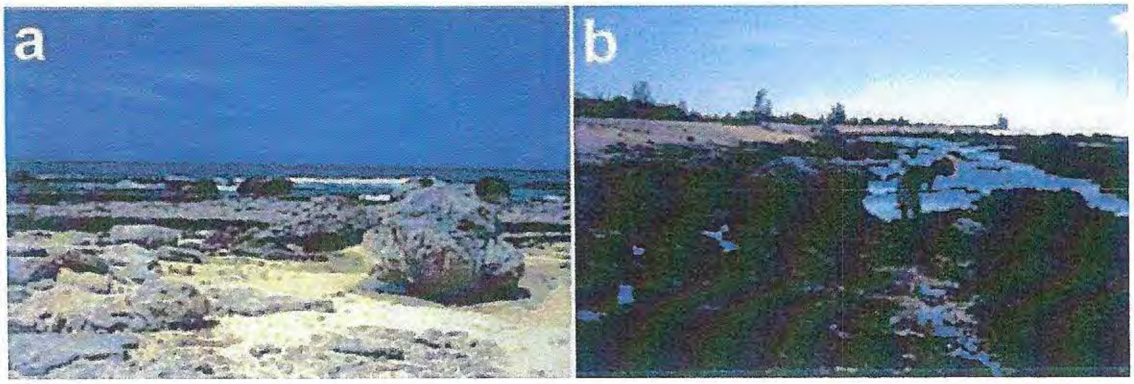

FIG. 17.26. The south seaward shoreline of Wake and Wilkes Islands are mostly exposed coralline platform with tidepools

FIG. 17.27. Wilkes Island in foreground was cleared of vegetation as part of a cleanup effort and to provide habitat for nesting seabirds. The shallow lagoon reef habitat on the western margin of the atoll is generally less turbid than the shallow lagoon nearest the airfield (back). The western reef area has abundant fishes and live coral with large groups of bumphead parrotfish and the Maori wrasse

17.3.8.3 Corals

Initial coral identifications from Wake Atoll generated a list of 50 scleractian corals (NOAA 2006b citing Maragos 1979, unpublished data; US Department of Interior, Fish and Wildlife Service 1999). During the 2005 Coral Reef Ecosystem Division cruise (OES-05-13; www.soest.Hawaii.edu/pibhmc/website/cruise.catalog.htm) the current number of scleractian corals reported from Wake Atoll increased to 102 (NOAA 2006b). Additionally two species of *Millepora*, a zooanthid and five genera of octocorals are reported from Wake (NOAA 2006b)

During the 2005 Coral Reef Ecosystem Division cruise, extensive data on percentage coral cover, cnidarian biodiversity, relative proportion live coral cover to macro/corraline algae cover, and size class distribution were collected. Within forereef sites, the dominant corals included *Favia*, *Montipora*

FIG. 17.28. The atoll is mostly landlocked on three sides with an emergent reef on the western boundary (Fig. 17.2). It is over this western reef that most water exchange between the lagoon and open ocean takes place although additional water flows during high tide through the channel between Peale and Wake Islands

FIG. 17.29. The leeward south side of Wake Island has a very narrow reef margin that drops rapidly

and *Pocillopora* (NOAA 2006b). *Montipora* dominated the single lagoon transect (NOAA 2006b). Percent live coral cover varied with exposure with the lowest coral cover found along southern and southwestern exposures (22.5–27.5%), higher cover along the western and eastern exposures (35.3–63.7%), and the highest coral cover found along northerly exposures (76.7–81.4%) (NOAA 2006b). Coral cover within the lagoon was 14.7% (NOAA 2006b). Biodiversity patterns reflected those of coral cover with the highest cnidarian biodiversity found along the northwest and northern reef margins (NOAA 2006b). Size class measurements found that 39.8% of lagoon coral colonies and 77.3% of forereef colonies were >20 cm maximum diameter (NOAA 2006b).

FIG. 17.30. Wake Atoll typical leeward reef

17.3.8.4 *Macroinvertebrates*

Preliminary results from the 2005 CRED cruise (PIFSC Cruise Report CR-06-024) found at least 92 species of macroinvertebrates at Wake Atoll (NOAA 2006b). These included 5 echinoids, 8 holothurian species, 4 ophiuroid species, 3 asteroid species, 32 crustacean species, and 36 mollusc species (NOAA 2006b). *Tridacna* were particularly abundant in shallow reef areas and within the lagoon. *Holothuria edulis* was also abundant in shallow soft-bottom reef areas but surprisingly not within the primarily shallow soft-bottom lagoon habitat (NOAA 2006b).

17.3.8.5 *Fishes*

A total of 323 fish species in 63 families were documented at Wake Atoll (Lobel and Lobel 2004). This species richness is similar to that found on other isolated Central Pacific atolls and islands including Johnston Atoll (N = 301; Randall et al. 1985; Kosaki et al. 1991), Rapa (N = 268; Randall et al. 1990) and Midway (N = 258; Randall et al. 1993). The low number of species at these locations is correlated to their small area, limited habitat diversity, geographic isolation and relatively large distance separating them from other population sources (Randall 1992, 1998). Fish species that are found abundantly at Wake Atoll are typical of those on other Pacific Islands and include coastal shore fishes (299 spp.), elasmobranchs (6 spp.), and offshore pelagic fishes (18 spp.).

The central location of Wake in the Northern Pacific results in a fauna with a mixture of different zoogeographic affinities between east and west. Wake's fish fauna has the most commonality with the Marianas Islands and some similarity to Hawaii. Comparison with the four nearest neighboring archipelagos indicates that the greatest species overlap occurs with the Southern Marianas Islands (85%) and the Marshall Islands (81%). The Northern Marianas have 65% of species in common with Wake.

The wrasse *Ammolabrus dicrus* has only been found at Oahu, Hawaii and Wake (a similar or sister species was observed but not collected in the Ogasawara Islands, Japan (Randall and Carlson 1997). The spotted knifejaw, *Oplegnathus punctatus* is found in Hawaii, Japan, Johnston and Wake. The Hawaiian endemic *Sebastipistes ballieui* is also found at Wake. Two additional Hawaiian endemics (*Entomacrodus marmoratus* and *Eviota epiphanes*) were listed in the

Bernice P. Bishop Museum collection as being from Wake but the specimens could not be verified and none were found in later field collections (Lobel and Lobel 2004).

Absent from Wake are the trumpetfish *Aulostomus chinensis* (Aulostomidae) and the blacktip reef shark *Carcharhinus melanopterus* (Lobel and Lobel 2004). The blacktip reef shark was reported to have occurred at Wake in earlier literature. Our surveys, which were conducted mainly along the southern reefs found the grey reef shark, *Carcharhinus amblyrhynchos* to be present but rare. The most recent reef survey (PIFSC Cruise Report CR-06-024) found only 11 grey reef sharks at the 13 sites (belt transects) surveyed around the entire atoll (NOAA 2006b). However, the report states that during the towed diver surveys, grey reef sharks were observed both singly and in aggregations, and were in the top three most abundant species observed (NOAA 2006b). Reasons for the low abundance of grey reef sharks along the southern margin (and perhaps the absence of blacktip reef sharks) are not clearly understood. Lobel and Lobel (personal observation) noted that the island civilian work force frequently fished for sharks and dried their fins, a practice left uncontrolled by the DoD. Since the calmest sea conditions and small boat harbor are found along the southern reef margin, the greatest fishing pressure would occur in this area.

17.3.9 Contamination Issues on Wake Atoll

The shallowest portion of the lagoon is located next to the airfield and main military facilities on the eastern portion of the atoll. A large portion of this area is exposed daily during low tide. The dominant substrate type is sand mixed with dead seashells. It is unknown at this time, whether the mass amounts of dead mollusks is the result of long time, natural accumulations or the result of pollution in the lagoon. The lagoon is next to the airfield runway and long term air traffic and refueling operations may possibly have added pollutants (e.g. arsenic, PAHs and various solvents). Other sources of pollutants to the lagoon include the long term application of herbicides and pesticides to the runway area for vegetation and insect control. Pathways into the lagoon and nearshore habitats for these potential contaminants include runoff and percolation through the porous coral rubble of which much of the island is made up. The issue of contamination in the groundwater, lagoon and nearshore marine environment remains to be determined.

The oil tanker Stoner ran aground and broke up o the reef offshore from the small boat harbor in 1970. The oil spill resulted in significant reef damage along the ocean reef of Wake Island (Gooding 1971). No lingering effects of the spill are apparent (P.S. Lobel and L. K. Lobel 1997, 1999 pers. observ.).

Assessment of the contaminant situation is currently under study by the USAF. In February/March 2002, the Air Force conducted fish tissue sampling from Wake Island lagoon as part of a human health risk screening evaluation. Only lagoon areas were sampled and preliminary data from fish caught within Wake Island Lagoon indicated arsenic levels exceed screening values in fish tissue. The Wake Island Commander issued (5 February 2003) an advisory notice recommending that people not eat seafood caught in the lagoon.

17.4 Conservation Issues for Wake and Johnston Atolls

The protection of Wake Atoll's natural resources is under stewardship of the US Air Force. This is achieved primarily through base regulations that exclude commercial fishing ventures and ban reef fish spearfishing. Regulations can change and enforcement differs under each subsequent base commander. It is unclear what is currently being implemented for fish and wildlife management on the atoll. One reef fish of particular concern is the Maori wrasse (*Cheilinus undulatus*) which is listed on the IUCN redlist (www.iucnredlist.org) as endangered and in October of 2004 was listed under CITES Appendix II (http://www.cites.org). The Maori wrasse is a prized food fish and juveniles are targeted for the live reef fish food trade (LRFFT) (Donaldson and Sadovy 2001). This species is abundant at Wake and previous commanders had prohibited it being fished. However, fishing within the lagoon and on the reefs does occur by the residents and visitors of Wake. Specifically, the local workers (recruited from Thailand) reportedly fish for sharks as well as other reef species, presumably for their own consumption, but the extent to which this occurred and whether this has negatively impacted populations was not assessable.

In addition to the Maori wrasse, several teleost fishes and elasmobranchs on Johnston and Wake's reefs are threatened by over-exploitation elsewhere in the Pacific (Table 17.2). The most recent survey of Wake's reefs (PIFSC cruise 2005 and 2007; NOAA 2006b, 2007) found an abundance of Maori wrasse (*Cheilinus undulatus*) in addition to the large population of bumphead parrotfish (*Bolbometopon muricatum*) also observed during earlier surveys. Bumphead parrotfish sightings at other US Pacific reefs surveyed by CRED are rare (NOAA 2006b). Additionally, spotted eagle rays (*Aetobatis narinari*) were abundant at Wake (NOAA 2006b). Large biannual aggregations of female grey reef sharks (up to 160) were documented at Johnston Atoll (Economakis and Lobel 1998) and the Johnston Atoll pygmy angelfish, *Centropyge nahackyi*, warrants attention due to its being found exclusively at this atoll. The large numbers of these species that are often rare at other Pacific locations emphasizes the need for continued supervision and protection of these coral reef ecosystems.

Johnston Atoll is still a US military installation owned by the US Air Force Pacific Command (15th Air Wing, Hickam Air Force Base). The eventual disposition of the atoll is yet to be determined. One option was to transfer ownership to the US Fish and Wildlife Service. However, before USFWS was to accept the atoll, it required DoD to completely remove any traces of contamination from the islands and atoll lagoon including residual plutonium. Newspaper articles often questioned the future of Johnston Atoll as a USFWS Refuge because of the plutonium landfill on Johnston Atoll and plutonium contamination in the lagoon (*New York Times* 27 January 2003, *Honolulu Star Bulletin* 28 January 2003). A quote from a spokesperson for the Defense Threat Reduction Agency stated that they will continue to be responsible for the costs associated with the plutonium issue. One cost estimate places periodic seawall maintenance at approximately \$1,000,000/100 ft to repair. With approximately 5 miles of seawall at risk of degradation at Johnston Atoll, the potential cost of maintenance and repair is \$264 million. While all sources of contamination on the islands were cleaned up and the plutonium laced soil packed into a consolidated landfill, cleanup of the lagoon was not feasible and not warranted according to the ecological risk assessment. The cost for this cleanup would have ranged in the many millions of dollars and even then the remedial dredging of reef areas would likely have done more harm than good. However, if the island's seawalls were to deteriorate and allow the landfills to erode into the lagoon, sediment, turbidity and increased contaminant loading can be expected to have measurable impact on the adjacent coral reef communities.

A major issue in 2007 is that Johnston Atoll is abandoned (no people or facilities remaining) and without any effective measures in place to ensure that the atoll fishes and other natural resources are not illegally exploited. There is a concern that illegal shark fishing may have already occurred. Reef fish that are potentially tainted with PCBs or other contaminants could also be illegally fished and sold commercially.

17.5 Future of the Atolls

The future of Johnston and Wake Atolls is uncertain. At Johnston, a sea level increase of only a few inches will increase the frequency of the seawalls being breached by waves during storms and increase erosion. Land restrained by the seawall sequesters areas of landfill containing high concentrations of plutonium, lead paint, dioxins and other contaminants. It is unlikely that these landfills would represent serious ecological threats as long as seawall containment continues. But with the abandonment of

TABLE 17.2. Pacific fishes of special concern for conservation found at Wake and Johnston Atolls (Updated table from Lobel and Lobel 2004).

Species	Common name	IUCN category	Wake	Johnston
Manta birostris	Manta ray	NT	X	X
Aetobatus narinari	Spotted eagle ray	NT	X	X
Carcharhinus amblyrhynchos	Grey reef shark	LR/nt	X	X
Carcharhinus melanopterus	Blacktip reef shark	LR/nt	X	
Carcharhinus galapagensis	Galapagos shark	NT	X	
Galeocerdo cuvier	Tiger shark	LR/nt	X	
Triaenodon obesus	Whitetip reef shark	LR/nt	X	X
Cheilinus undulatus	Humphead/Maori Wrasse	EN CITES Appendix II	X	
Bolbometopon muricatum	Giant bumphead parrotfish		X	
Epinephalus lanceolatus	Giant grouper	VU	X	X
Epinephalus polyphekadion	Camouflage grouper	NT	X	
Epinephelus quernus	Hawaiian grouper	NT		X
Centropyge nahackyi	Rainbow pygmy angelfish			X

the atoll, a program for long-term maintenance no longer exists. If there were a catastrophic collapse of island seawalls and mass erosion of sediment into the lagoon, turbidity and silt on corals would be an adverse impact in itself, at least during initial stages.

The current state of affairs at Johnston is also a serious concern because it is without any on-site management and trespassing or illegal fishing thus cannot be prevented. The USAF has made several attempts to transfer the property to the US Fish and Wildlife Service or any other entity. The key issue for the Air Force is that they no longer have a military mission for the atoll property. However, no other federal agency is willing to inherit the financial burden from the legacy of contaminants and future seawall maintenance costs. Thus, what may eventually become of Johnston Atoll is uncertain. If no other federal agency is willing to step up and take a lead in its future, the Air Force will seek other uses.

Proposals for island uses have ranged from using the island as a rocket launch facility for shooting satellites into orbit, to ecotourist resort, to use as a hazardous waste storage site again. In this context it is worthwhile to review one of the repeated proposals for use of these remote pacific islands. There has been longtime historical consideration for the storage of spent nuclear fuel on these islands. Fosberg (1993) reviewed the advantages and planning considerations for placing such a facility at Wake and Johnston Atoll as well as several other atolls that are no longer possible considerations. In late 1978, the US Department of Energy circulated a draft Environmental Impact Statement entitled "Storage of Foreign Spent Power Reactor Fuel" which detailed the various options under which the United States would be prepared to accept a limited amount of spent fuel from foreign sources when such actions would contribute to non-proliferation (Department of Energy 1978. Environmental Impact Statement. Storage of Foreign Spent Power Reactor Fuel. DOE/EIS-0040-D). In 1979, the US Army Corps of Engineers, directed by the Department of Energy, conducted a preliminary environmental assessment of the construction and operation of a temporary storage facility for foreign nuclear spent fuel at Wake Island. The study was in response to the passage of the Non-Proliferation Act of 1978 which was developed to identify alternatives to large scale commercial reprocessing of spent power reactor fuel, particularly providing foreign nations with viable alternatives to commercial reprocessing. One specific action to implement the nonproliferation policy involved the offer by the US to establish an internationally managed temporary storage facility for nuclear spent fuel to service countries in the Western Pacific. The concept was for the USA to provide a temporary centralized storage facility for spent nuclear fuel at an isolated island in the Pacific. Given the world situation today, this may still be a political option. In the meanwhile, Midway was transferred from the Navy to DOI and became a National Wildlife Refuge and ecotourism destination with endangered monk seals. Palmyra was purchased by the US Fish and Wildlife Service in partnership with the Nature Conservancy and is also a wildlife refuge. Wake Atoll and Johnston Atoll remain as the last available remote atolls belonging to the USA. Let us hope that whichever agency or organization has stewardship responsibility for these atolls will accept coral reef and marine wildlife conservation as part of their agenda.

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FOR IMMEDIATE RELEASE: Agent Orange Survivors of Guam founder assists with follow up sampling

October 4, 2019 – (Tiyan, Guam) – On Wednesday, the Guam Environmental Protection Agency (Guam EPA) and the United States Environmental Protection Agency (US EPA) Superfund Technical Assessment & Response Team (START) performed follow up soil sampling at off-base locations with the assistance of Agent Orange Survivors of Guam founder Brian Moyer. The follow up soil sampling was completed on Thursday.

Off-base soil sampling for Agent Orange first occurred in November 2018, at areas off of NCS road along Route 3, Potts Junction, Nimitz Hill and a pipe line tie-in located in Tiyan. Guam EPA, US EPA and Moyer agreed to schedule Moyer's visit to Guam to assist with future soil samplings.

In an October 2018 teleconference with Guam EPA and US EPA, Mr. Moyer stated to the agency, "I'm at your service, at your beck and call." Moyer arrived on Guam on September 30, 2019, and offered assistance with site identification for the joint agency investigation into veteran claims of the alleged use of Agent Orange on Guam. Moyer's travel and lodging was privately funded by the Military Veterans Advocacy, Agent Orange Survivors of Guam and the Blue Water Navy Association.

"We are pleased with the furthered support and continued commitment with this investigation from our counterparts at US EPA Region IX," said Guam EPA acting administrator Jesse T. Cruz. "We are especially appreciative of the assistance lent by Mr. Moyer's presence on island towards our investigation," Cruz further stated.

Wednesday's follow up soil sampling occurred at Polaris Point off of Route 1, Nimitz Hill, Yigo and Tiyan. Unlike the November 2018 analysis, the follow up samples will be tested for dioxins. Preliminary analysis is expected to be completed in 12 weeks.

Preliminary results from the November 2018 soil sampling indicated the presence of 2,4-D and 2,4,5-T, the primary constituents of Agent Orange, at non-toxic levels in one sample location. A draft report of the November 2018 soil sampling is still under review with Guam EPA and will be released upon completion.

[END OF RELEASE]

For more information about this release, please contact Guam EPA Public Information Officer Nic Rupley Lee at 300-4753 or nic.rupley@epa.guam.gov

EXHIBIT
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