UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE
Silver Spring, Maryland 20910

CRUISE REPORT[1]

VESSEL: *Hi'ialakai*, Cruise HI-09-01

CRUISE PERIOD: 12 March–1 April 2009

AREA OF OPERATION: Wake Atoll (Fig. 1)

TYPE OF OPERATION: Personnel from the Coral Reef Ecosystem Division (CRED), Pacific Island Fisheries Science Center (PIFSC), National Marine Fisheries Service (NMFS), NOAA, and their partner agencies conducted coral reef assessment/monitoring and oceanographic studies in waters surrounding Wake Atoll.

ITINERARY:

12 March — Start of cruise. Embarked Ronald Hoeke (Chief Scientist, Oceanography), Paula Ayotte (REA Fish), James Bostick (Divemaster/Chamber Operator), Edmund Coccagna (Tow Team), Bonnie DeJoseph (Tow Team), Polly Fisher-Pool (Oceanography), Kerry Grimshaw (Line Point Intersect), Jason Helyer (Tow Team), Sun Kim (REA invertebrate), Kevin Lino (Tow Team), Kaylyn McCoy (REA Fish), Tracey McDole (Oceanography), Russell Moffitt (REA Benthic, ARMS), Marc Nadon (REA Fish), Kevin O'Brien (REA Fish), Noah Pomeroy (Oceanography), Russell Reardon (REA Benthic, ARMS), Cristi Richards (REA Benthic), Stephanie Schopmeyer (REA Benthic), Oliver Vetter (Oceanography), Rodney Withall (REA Benthic). Departure was slightly delayed to load Recompression Chamber at Kilo Wharf; departed Pearl Harbor at 1200 and began transit to Wake. Conducted ship's fire and abandon ship drills.

13-20 March — Transit days. Jim Bostick checked all scientist's dive gear and ran scientific personnel through injured diver drills. Edmund Coccagna reviewed contents of emergency medical kits with all scientific personnel. All dive gear was soaked in bleach solution to prevent the introduction of invasive microbes. Conducted O_2 administration and CPR training, baseline neurological examinations, and diver emergency. Scientists set up computer work stations and network and prepared field survey gear and

[1] PIFSC Cruise CR-09-009
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equipment. Fish and benthic rapid ecological assessment (REA) teams met to discuss site selections, and tow and mooring teams met to discuss operations. Most scientists also participated in (optional) trauma response exercises tailored to CRED small boat and dive operations. The exercises were led by the ship's medical officer.

21 March — Arrived at Wake ~ 1800. Transferred CRED Avon to small boat harbor for later use in Wake Lagoon. Completed 8 conductivity-temperature-depth (CTD) casts to 350 m, collected 16 chlorophyll/nutrient water samples, and collected ~ 50 km of acoustic Doppler current profiler (ADCP) data during oceanography transect to the west of the atoll during the night.

22 March — Small boat operations began immediately following the 0730 morning safety briefing; all teams working on the northwestern side of the atoll. The benthic and fish REA teams surveyed 3 established sites (WAK-12, WAK-07, WAK-08); deployed autonomous reef monitoring systems (ARMS) at WAK-08. The independent fish REA team established and surveyed 3 new sites (WAK-50, WAK-51, WAK-52) and the independent line point intercept (LPI) team surveyed sites WAK-50 and WAK-52; they also assisted oceanography team collect CTD and chlorophyll/nutrient/microbial water sample data at site WAK-12. Tow team completed 4 tows, surveying 7.4 km; they also assisted the oceanography team during 2 working dives as safety divers. Oceanography team deployed a 1300-lb anchor and mounted an ADCP on it; they also deployed an SBE37 and 2 subsurface temperature recorders (STRs) (SBE39). Benthic and fish REA team members on the small boat HI-1 performed an unconscious diver drill with members of the ship's crew. Total dives for all teams: 61. During nighttime oceanography operations, 3 CTDs and 12 chlorophyll/nutrient water samples were collected before ship's personnel canceled CTD operations due to high winds (30–40 knot squalls); ~ 50 km of ADCP transect data were collected.

23 March — Small boat operations began immediately following the 0730 morning safety briefing; all teams working along the eastern and northern sides of the atoll. The benthic and fish REA teams surveyed 3 established sites (WAK-09, WAK-14, WAK-13); deployed ARMS at WAK-09. The independent fish/LPI team established and surveyed 4 new sites (WAK-53, WAK-54, WAK-55, WAK-56); they also assisted the oceanography team in collecting CTD and chlorophyll/nutrient/microbial water sample data at site WAK-14. Tow team completed 6 tows: 4 regular surveys, 2 calibration tow; in total 12.8 km were surveyed; they also assisted the oceanography team during 1 working dive as safety divers. Oceanography team deployed a moored ADCP on a 250-lb anchor; they also deployed 2 SBE37s, 3 STRs (SBE39), and recovered and replaced an additional 2 STRs (SBE39). Total dives for all teams: 66. Nighttime oceanography operations completed 9 CTDs, and 14 chlorophyll/nutrient water samples

were collected, including all sites missed the night before; ~ 75 km of ADCP transect data were collected.

24 March Small boat operations began immediately following the 0730 morning safety briefing; all teams working on the southern side of the Atoll. The benthic and fish REA teams surveyed 3 established sites (WAK-04, WAK-05, and WAK-02). The independent fish team established and surveyed 4 new sites (WAK-57, WAK-58, WAK-59, WAK-60), and the independent LPI/invert team surveyed sites WAK-57, WAK-58 and WAK-60. Tow team completed 5 regular tows and 1 calibration drop dive; in total 9.5 km were surveyed. Oceanography team recovered and replaced 3 STRs (SBE39), deployed 2 new SBE37s, collected 10 shallow-water CTD casts, and 2 chlorophyll/nutrient/microbial water sample data at site WAK-05. The oceanography team also recorded video and sound of Bolbometopon muricatum to ground truth ecological acoustic recorder (EAR) data. Total dives for all teams: 59. Nighttime oceanography operations completed 8 CTDs, and 20 chlorophyll/nutrient water samples were collected; ~ 75 km of ADCP transect data were collected.

25 March Small boat operations began immediately following the 0730 morning safety briefing. The benthic and fish REA teams surveyed 3 established sites on the south side (WAK-03, WAK-06, and WAK-01); deployed ARMS at WAK-06. The independent fish team established and surveyed 4 new sites on the south side (WAK-61, WAK-62, WAK-63, WAK-64), and the independent LPI/invert team surveyed sites WAK-62, WAK-63 and WAK-64. Tow team completed 4 calibration tows along the south side and 2 calibration drop dives; in total 8.4 km were surveyed. Oceanography team worked in the lagoon the entire day. They serviced and redeployed the existing sea surface temperature (SST) buoy, EAR, and 3 STRs (SBE39); collected 4 shallow-water CTDs and 3 chlorophyll/nutrient/microbial water samples (2 at REA site WAK-10); and recorded video and sound of Bolbometopon muricatum to ground truth EAR data. Tow team members performed a DCS/dive chamber drill with members of the ship's crew. Total dives for all teams: 51. Nighttime oceanography operations completed 8 CTDs, and 20 chlorophyll/nutrient water samples were collected; ~ 75 km of ADCP transect data were collected.

26 March Small boat operations began immediately following the 0730 morning safety briefing. Benthic REA and independent LPI/invert teams made two trips across the lagoon to survey site WAK-10 (CRED Avon is too small to accommodate all team members and gear in one trip); they deployed ARMS at the site and performed additional invertebrate collections along the shore of the lagoon. The fish REA team established and surveyed 2 new sites (WAK-65, WAK-66) on the eastern and northern sides of the atoll. Tow team completed 2 calibration tows and 2

	calibration drop dives, in total 4.4 km. Oceanography team collected 10 CTDs and 2 chlorophyll/nutrient/microbial water samples; they also recorded video and sound of Bolbometopon muricatum to ground truth EAR data. All field data collection was completed by 1400; the CRED Avon was transferred from lagoon to the small boat harbor. Total dives for all teams: 27. All scientific personnel were given a tour of Wake Island by the Wake Island Environmental Specialist. All small boats were back onboard at 1700, and the ship began its transit to Guam as scheduled.
27-31 March	Transit days. Scientists performed data entry, preliminary analysis of data collected and worked on cruise and other reports.
1 April	Conducted post-cruise meeting. Arrived Apra Harbor in Guam at 0900. End of cruise.

Table 1.--Cruise statistics for HI-09-01.

Wake Atoll	
Towed-diver Habitat/Fish Surveys	13
Towed Diver Habitat Diver Calibration Tows/Dives	13
Combined tow lengths (km)	42.5
Fish Rapid Ecological Assessments	27
Benthic Rapid Ecological Assessments	13
Line Point Intercept Assessment	13
Invertebrate assessment/collection dives	13
ARMS site deployed (3 per site)	4
SST buoys recovered	1
SST buoys deployed	1
STRs recovered	8
STRs deployed	13
SBE37 deployed	6
ADCP/Wave gauges deployed	2
EARs recovered	1
EARs deployed	1
EAR video/audio calibration dives	3
Shallow-water CTDs (oceanography team)	26
Nutrient and chlorophyll samples collected in conjunction with shallow-water CTDs	11
Microbial Oceanography dives	5
Deepwater CTDs (from *Hi`ialakai*)	36
Nutrient and chlorophyll samples collected in conjunction with deepwater CTDs	82
ADCP Transects (from *Hi`ialakai*, approx. km)	325
SCUBA dives	264

MISSIONS:

A. Conduct ecosystem monitoring of the species composition, abundance, percent cover, size distribution, and general health of the fish, corals, other invertebrates, and algae of the shallow-water (< 35 m) coral reef ecosystems of the Wake Atoll. These efforts will be expanded in this cruise with the establishment of new LPI benthic sites, stationary-point-count fish sites, and the deployment of new ARMS.

B. Deploy new and maintain existing array of SST buoys, subsurface ADCPs, subsurface wave gauges, STRs, and temperature and salinity recorders to allow remote long-term monitoring of oceanographic and environmental conditions affecting coral reef ecosystems of Wake Atoll.

C. Recover and replace existing environmental acoustic recorder and service existing array of SST buoys, subsurface ADCPs, subsurface wave gauges, STRs, and temperature and salinity recorders to allow remote long-term monitoring of oceanographic and environmental conditions affecting coral reef ecosystems of Wake Atoll.

D. Collect both deep (> 35 m) and shallow (< 35 m) water samples for analysis of nutrient and chlorophyll levels to examine chemical and biological linkages supporting and maintaining these island and atoll ecosystems.

E. Conduct shipboard CTDs to a depth of 350 m, shallow-water CTDs from small boats to a depth of ~ 30 m, and shipboard ADCP surveys around reef ecosystems to examine physical and biological linkages supporting and maintaining these island and atoll ecosystems.

F. Collect ADCP data during all transits. The ADCP unit shall be configured to collect narrow-band data in 16-meter bins (deepwater mode).

G. Assist partner scientists with microbial oceanography sampling and invertebrate collections.

RESULTS:

See Appendix B.

SCIENTIFIC PERSONNEL:

Ronald Hoeke, Chief Scientist, Oceanography Team, University of Hawaii (UH)-Joint Institute for Marine and Atmospheric Research (JIMAR), Pacific Islands Fisheries Science Center (PIFSC)-Coral Reef Ecosystems Division (CRED)

Paula Ayotte, Fish Rapid Ecological Assessment (REA) Team, UH-JIMAR, PIFSC-CRED

Edmund Coccagna, Towed Diver Team, UH-JIMAR, PIFSC-CRED
Bonnie DeJoseph, Towed Diver Team, UH-JIMAR, PIFSC-CRED
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Kerry Grimshaw, Benthic REA Team, UH-JIMAR, PIFSC-CRED
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Sun Kim, Benthic REA/Invertebrate Collections, University of Guam
Kevin Lino, Towed Diver Team, UH-JIMAR, PIFSC-CRED
Kaylyn McCoy, Fish REA Team, UH-JIMAR, PIFSC-CRED
Tracey McDole, Microbial Oceanography, San Diego State University
Russell Moffitt, Benthic REA Team, ARMS, UH-JIMAR, PIFSC-CRED
Marc Nadon, Fish REA Team, UH-JIMAR, PIFSC-CRED
Kevin O'Brien, Fish REA Team, UH-JIMAR, PIFSC-CRED
Noah Pomeroy, Oceanography Team, UH-JIMAR, PIFSC-CRED
Russell Reardon, Benthic REA Team, ARMS, UH-JIMAR, PIFSC-CRED
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Oliver Vetter, Oceanography Team, UH-JIMAR, PIFSC-CRED
Rodney Withall, Benthic REA Team, UH-JIMAR, PIFSC-CRED

DATA COLLECTED:

Digital images from photoquadrats
Algal voucher specimens necessary for algal species identification
Benthic Line Point Intercept data
Number of coral colonies, by species, within belt transects of known area, and overall coral colony density at each site
Qualitative assessment (DACOR) of coral species' relative abundance at each site
Size class distributions of corals (by species and overall) at each site
Digital images of diseased coral
Field notes on signs of coral bleaching or disease
Samples of diseased coral for histopathological analysis
Density counts of targeted organisms within belt transects
Urchin test size diameters
Installation of ARMS to eventually provide an index of biodiversity
Digital images of non-coral marine invertebrates
Samples of targeted species undergoing genetic connectivity work throughout the Hawaiian Archipelago
Digital still photos of overall site character and typical benthos at each site
Transect surveys of all fish 1 cm or larger in 600 m^2 – ID to species and estimate size
Fish species presence checklists for community diversity estimates at each site
Digital images of rare or interesting fish species
Digital images of the benthic habitat from towboard surveys
Macroinvertebrate counts from towboard surveys
Quantitative surveys of reef fishes (larger than 50 cm TL) to species level from towboards
Habitat lineation from towboard surveys

Benthic composition estimations from towboard surveys
ADCP data
Shipboard Conductivity, Temperature and Depth (CTD) profiles to 350 m with fluorometer and dissolved oxygen sensor attached
Water Samples to 500 m: Chlorophyll and Nutrients 5 depths per cast
Shallow-water Conductivity, Temperature, Depth (CTD) casts to 30 m (or water column dpth with transmissometer and dissolved oxygen sensor attached
Shallow water samples (30 m): chlorophyll and nutrients 2 depths per cast
Shallow water microbial analysis samples
Sea surface and subsurface temperature at variable depths
Sea surface and subsurface salinity at variable depths
Spectral wave energy and tidal elevation
Moored ADCP data
Solar radiation, air temperature, barometric pressure, wind speed and direction, and photosynethtic active radiation
Shipboard Surface Temperature and Salinity Gauge (TSG) data
Shipboard Acoustic Doppler Current Profiler (SADCP) transects
EAR data

Submitted by: S. Ferguson
FOR Ronald K. Hoeke
Chief Scientist

Approved by: S. Thur
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Coral Reef Conservation Program

Attachments

Figure 1.0-1.--HI0901 Cruise Track.

Appendix A: Methods

A.1 Oceanography and Water Quality
(Oliver Vetter, Ron Hoeke, Tracey McDole, Noah Pomeroy, Polly Fisher-Pool, and SST Lillian Stuart)

The Coral Reef Ecosystem Division (CRED) has been conducting oceanographic research throughout the Hawai'ian Archipelago and the U.S. remote Pacific Territories since 2001. Research at Wake Atoll was first conducted in 2005. CRED's oceanographic investigations include in situ surveys, conductivity-temperature-depth (CTDs), water samples, and the replacement of instrument platforms to monitor and assess important physical, chemical and biological variables in the coral reef ecosystem. As a result of logistical constraints voyages to remote sites, such as Wake Atoll, are limited to biannual visits. Long-term oceanographic monitoring and assessment is accomplished by the deployment and retrieval of a variety of internally recording and near real-time telemetered instrument platforms. These instruments include:

- Sea Surface Temperature (SST) buoys: Measure and internally record high resolution surface water temperature and telemeter a subset of collected data in near real-time.

- Moored Acoustic Doppler Current Profiler (ADCP): Measures surface gravity waves, tides, current profiles, and subsurface water temperature.

- Subsurface Temperature Recorders (STR): Measure high resolution subsurface water temperature.

- Environmental Acoustic Recorders (EAR): Record ambient subsurface sound.

- Portable Environmental Acoustic Recorders (PEAR): Hand held ambient subsurface sound recorder used during free diving, recording visual and acoustic data from noises made by the bumphead parrotfish (*Bolbometopon muricatum)*. The PEAR device was used while free diving, rather than the noisy SCUBA rigs to avoid sound pollution and scaring the fish away. This survey was conducted near REA sites.

Detailed in situ oceanographic and water quality surveys are accomplished with the following sampling techniques:

- Shallow-water CTD casts (max depth 30 m) conducted from small boats at regularly spaced intervals on the 30 m contour around each island/atoll/shoal with an SBE 19+ and an auxiliary transmissometer (Wetlabs C-Star) and oxygen 18 sensor (SBE 43). Shallow vertical water profiles can provide insight into local water property variation and water mass interactions.

- Shallow-water samples for nutrient and chlorophyll analysis are taken at select REA sites. Nutrient and chlorophyll samples are taken at the surface and at the reef near rapid ecological assessment sites (REA).

- Integrate macro- and microbiological coral reef ecosystem data. Collect water samples at REA sites from .5-1 meters above the reef surface for microbial-related analyses including: dissolved organic carbon (DOM), particulate organic material (POM), protist, microbial and viral abundance and microbial community composition.

- Shipboard deepwater CTD casts conducted from the NOAA Ship *Hi'ialakai* with an SBE 911+ and an auxiliary SBE 43 Dissolved Oxygen (DO) sensor and Wetlabs ECO FLNTU combination fluorometer and turbidity sensor. Shipboard CTD casts were conducted in linear transects from the cardinal points of Wake Atoll. Each of these transects entailed 8 CTD casts; the first five were spaced at 2 km apart, and the remaining three were spaced at 5 km. The first four casts per transect were complemented by water samples, collected at 20, 170, 180, and 230 m. These will be analyzed post-cruise for nutrient (NUT) and chlorophyll (CHL) concentrations.

- Surface and subsurface water temperatures, as a function of depth, are continuously recorded during all towed-diver operations, providing a broad and diverse spatial and thermal sampling method.

- Habitat/Fish Survey Team Activity Summary for site and isobath information. This data is part of the tow team Arcview project.

- Shipboard meteorological observations including wind speed and direction, relative humidity, air temperature, and barometric pressure.

- Shipboard oceanographic measurements of sea surface temperature, salinity, and currents using an ADCP.

A.1.1 Microbial Water Chemistry Analysis

1.) Microscopy

It is well known that bacteriophages (bacterial viruses) are the most abundant form of life in the ocean, ranging from 1×10^6 virus-like particles (VLPs) per ml of seawater in the open ocean to 1×10^8 VLPs per ml in more productive coastal waters. The number of microbial and protistan cells in seawater is typically 1×10^6 and 1×10^3 cells per ml, respectively. Microbial and viral loading and the dominance of heterotrophic bacteria in reef water are linked to coral disease (Dinsdale, et al., 2008). Trophic-level interactions among bacteria, phages, and protists also affect global nutrient and carbon cycling. The most direct method for assessing and monitoring changes in abundance of these microbiological components is by fluorescent microscopy using nucleic acid staining.

Enumeration of microbes and viruses: Five ml of water from each sample was fixed with paraformaldehyde, stained with the dsDNA stain SYBR-Gold, and filtered onto a 0.02 um filter.

Enumeration of protists: Fifty ml of water from each sample was fixed with glutaraldehyde, stained with the dsDNA stain DAPI, and filtered onto a 0.8 um black polycarbonate filter.

Frequency of dividing cells: Ten ml of water from each sample was fixed with glutaraldehyde, stained with the dsDNA stain DAPI, and filtered onto a 0.2 um filter.

Enumeration of microbial components and quantification of actively dividing microbial cells will be counted using fluorescent microscopy at San Diego State University (SDSU). All filters will be stored at - 20ºC for archival purposes.

2) Water chemistry

Spatial assessment of microbial, viral, and protist components with respect to dissolved organic carbon, nutrient levels, and particulate organics within coral reef ecosystems may identify important predictors of coral reef ecosystem degradation; information that will be essential for designing the most effective monitoring strategy possible.

Water samples were pushed through GF/F glass filters and the filtrate collected in pre-combusted glass bottles. Hydrochloric acid was added to each bottle to remove dissolved inorganic carbon and the bottles were stored upright at 4ºC. These samples will be analyzed for dissolved organic carbon levels at SDSU. The GF/F filters will be also be stored at - 20ºC and analyzed for particulate organic carbon and stable isotopes of carbon and nitrogen at SDSU.

3) Archive microbial DNA samples

The structure of the bacterial community will be assessed by metagenomic analysis. This involves collection of environmental DNA via filtration followed by 454 sequencing. Metagenomics is a powerful tool for studying environmental populations, as less than 1% of all environmental microbial diversity is currently cultivable (Rappe and Giovannoni, 2003).

The remaining water in each Niskin bottle was pushed through a 20-um pre-filter to remove large eukaryotic organisms. The 20-um filtrate was then pushed through 0.22 um Sterivex filters. The filters were stored at - 20ºC. DNA isolation and metagenomic analysis will be completed at San Diego State University.

4) Flow cytometry

Flow cytometry will be primarily used to characterize microbial community size structure. This technique will also provide complementary data for abundance counts, metagenomic analysis, and chlorophyll analysis.

Five ml of water from each site was pushed through a 20-um filter. The filtrate was dispensed into 5 × 1 ml cryovials, and glutaraldehyde added to each. Vials were inverted to mix and incubated in the dark for 15 min. Glutaraldehyde preserved samples were flash frozen in liquid nitrogen contained in a dry shipper. The samples will be shipped on dry ice to SDSU for flow cytometry analysis.

A.2 Benthic REA Methods

(Stephanie Schopmeyer, Kerry Grimshaw, Sun Kim, Russell Moffitt, Russell Reardon, Cristi Richards, and Rodney Withall)

A.2.1 Algae

Using the point-intercept method records the macroalgal species, algal functional group, coral species, non-coral invertebrate functional group, or substrate type at 20-cm (for permanent REA monitoring sites) and 50-cm (at new independent monitoring sites) intervals along two 25-m transect lines. Algal inventories and percent cover were generated from data collected at each site. Permanent historical records of benthic marine substrates at each permanent REA were collected using a high resolution digital camera mounted on a 0.18 m^2 photoquadrat.

Additionally, when time permits, a roving diver swim at the end of the dive that covers a swath on 3 m on either side of the transect line is used to record specimens not observed along the transects themselves. Only one specimen of each species that cannot be identified in the field will be collected by hand and frozen. Ultimately, field-collected algal specimens will be critically analyzed in the laboratory to ensure positive species identification, will be catalogued, and will subsequently be placed in research institutions where they can be accessed by researchers interested in a suite of topics. After identification, provisions are made to ensure appropriate preservation and curation of each algal specimen, providing a historical record that will be available to future researchers.

A.2.2 Corals

At each permanent REA monitoring site, two 25-m belt transects were laid out. Five 2.5-m segments were surveyed for each transect (beginning at points: 0, 5, 10, 15, and 20 m for a total of 25 m^2 per site. For each segment, all coral colonies whose center fell within 0.5 m of either side of the transect were identified to species and measured for size (maximum diameter and diameter perpendicular to the maximum diameter). In addition, the extent of mortality, both recent and long dead, was estimated for each colony. Observers paid special attention to identifying, as best as possible, the extent of the former live colony. When a coral colony exhibited signs of disease or compromised health, additional information was recorded including type of affliction (bleaching, skeletal growth anomaly, white syndrome, tissue loss other than white syndrome, trematodiasis, necrosis, other, pigmentation responses, algal overgrowth, and predation), severity of the affliction (mild, moderate, marked, severe, acute), as well as photographic documentation and sometimes tissue samples. Tissue samples were catalogued and fixed in buffered zinc-formalin solution for further histopathological analyses. Percent coral cover analysis was derived from the 20 and 50-cm line point intercept (LPI) methods conducted by the algal divers.

A.2.3. Non-coral Invertebrate Surveys

Quantitative counts and percent cover for specific target marine invertebrates are conducted along the two 25-m REA belt transects and the independent LPI transects at 5-m intervals. All invertebrates which fall within 1 m along either side of the transect are surveyed. Size frequency distribution of urchin species will be recorded for the first 25 individuals of each species. Based on data from previous rapid ecological assessments, a group of target species was chosen for quantitative counts. The species in this list have been shown to be common components of the reef habitats of the central and southern Pacific, and they are species that are generally visible (i.e., non-cryptic) and easily enumerated during the course of a single 50–60 min dive. Additionally, all species of urchins are counted and test size diameter for the first 25 of all species present are measured and recorded.

These target species are:
CNIDARIA
Octocorals – soft corals (*Sinularia, Cladiella, Lobophyton, Sarcophyton*, etc.)
Zoanthids – rubber corals
Actiniaria – Anemones (*Heteractis, Stichodactyla, Phymanthus*, etc.)
ECHINODERMS
Echinoids – sea urchins
Holothuroids – sea cucumbers
Asteroids – sea stars
MOLLUSCA
Bivalves – spondylid oysters, pearl oysters, tridacnid clams (Giant Clams)
Large Gastropods – *Charonia* (Triton's Trumpet) and *Lambis* sp. (Spider Conch)
Coralliophilidae gastropods
Cephalopods - octopus
CRUSTACEA
hermit crabs, lobsters, large crabs

A.2.3.1 Autonomous Reef Monitoring Systems (ARMS)

ARMS were deployed at three forereef habitats (WAK-06, WAK-08, and WAK-09) and one lagoon habitat (WAK-10) in the atoll systems. ARMS provide a mechanism to quantify marine invertebrates that are not easily identifiable or accountable on the transect lines. ARMS are installed on the benthos by pounding stainless steel rods by hand into bare substrate. They will remain on the benthos for 2 years enabling the recruitment and colonization of lesser known, cryptic marine invertebrates upon which time they will be collected and analyzed.

A.3 Fish Team Methods
(Marc Nadon, Paula Ayotte, Kaylyn McCoy, Kevin O'Brien)

The fish team, composed of four divers, conducted two types of surveys at preselected sites: belt transects (BLT) and stationary point counts (SPC). Two separate teams were deployed to conduct the surveys; each team consisted of two divers conducting either two SPCs and two BLTs, or just two SPCs.

The first team accompanied the Benthic REA team and surveyed previously visited sites. Surveys were performed using a 30-m line set along a single depth contour. As the line was set, two observers swam along either side of the line identifying, counting, and sizing all fishes > 20 cm in total length (TL). Each diver counted and sized fishes within an area 25 m long and 4 m wide. Afterwards, the divers returned along their respective sides of the line identifying, counting, and sizing all fishes < 20 cm TL in a 2 m wide by 25 m long belt.

Once the belt transect was completed, the divers moved to the 7.5-m and 22.5-m marks on the transect line to start the stationary point counts (7.5 m radius). For this method, each diver counted fishes in a cylindrical survey area by staying in the middle of their respective cylinders that had a 7.5-meter radius. During the first 5 min of the SPC, the divers only recorded the presence of species within their survey areas. Afterwards, the divers proceeded down their respective species list, sizing and counting all individuals within their 7.5-m radius cylinder, one species at a time. Individuals from a single species were only recorded once. Cryptic species missed during the initial 5-min survey could still be added to the list. Once completed, the transect line was moved to another location 5–10 m away at the same depth stratum, and the procedure was repeated.

The second team was deployed on a separate boat and surveyed new, randomly chosen sites that were in an either shallow (0–6 m) or deep (18–30 m) depth stratum using the SPC method. After settling on the bottom, a 2-person team laid a 30-m transect and then performed the SPC as described above. Once completed, the transect line was moved to another location 5–10 m away at the same depth stratum, and the procedure was repeated.

Fishes observed off transect or after the initial 5 min of the SPC were recorded for presence data. No collection efforts were made by the fish team at Wake during the survey period.

A.4 Towed-diver Survey Methods
(Edmund Coccagna, Jason Helyer, Kevin Lino, and Bonie DeJoseph)

Shallow-water habitats around each island, bank, or reef were surveyed using pairs of divers towed 60 m behind a 19-ft SAFE Boat survey launch. In each towed-diver buddy team, one diver is tasked with quantifying the benthos while the other quantifies fish populations. Each towed-diver survey lasts 50 min, broken into ten 5-min segments, and covers approximately 2 km. A Global Positioning System (GPS) track of the survey launch track is recorded at 5-sec intervals using a Garmin GPS76Map GPS unit. A custom algorithm is used to calculate the track of the divers based on the track, speed, and course of the boat and depth of the diver. Each towboard is equipped with a precision temperature and depth recorder (Seabird SBE39) recording at 5-sec intervals. At the end of each day data are downloaded, processed and presented in ArcGIS and can be displayed in conjunction with IKONOS satellite imagery, NOAA chart data and/or other spatial data layers.

A.4.1. Benthic Towed-diver Methods

The benthic towboard is equipped with a downward high resolution digital still camera with dual strobes. The downward-looking camera is maintained 1–2 m off the bottom and is programmed to photograph benthic substrate every 15 sec, creating a permanent visual record to evaluate and track potential changes in the benthos between subsequent cruises. The diver on the benthic towboard also observes and records habitat composition (habitat complexity, prevalent habitats and substrate types, hard coral, stressed hard, soft coral, macroalgae, coralline algae, sand and rubble), tallies conspicuous macroinvertebrates (crown-of-thorns starfish [COTS]), boring and free sea urchins, sea cucumbers, and giant clams) along a 10-m swath in 10 × 5-min time segments. Additional fields, including prevalent coral and algae genera (when applicable/time permitting) are also tracked. At the end of each day, the data are transcribed from field data sheets into a centralized MS Access database.

A.4.2. Fish Towed-diver Methods

The fish towboard is equipped with a forward-looking digital video camera which creates a visual archive of the survey track and can be used to evaluate stochastic changes in the reef environment, particularly following episodic events such as coral bleaching and vessel grounding. The diver on the fish towboard records, to the lowest possible taxon, all fishes greater than 50 cm total length (TL) along a 10-m swath in each time segment. Fishes are recorded in terms of species and length in centimeters. Species of particular concern observed outside the survey swath are classified as presence/absence data and are recorded separately from the quantitative swath data. At the end of each day, the data are transcribed from field data sheets into a centralized MS Access database. Biomass values are calculated using species specific length-weight parameters and are normalized by area (i.e., kg/100 m^2).

Appendix B: Results

B.1. Oceanography and Water Quality

Moorings recovered during HI0901 included five subsurface temperature recorders (STRs) and a sea surface temperature (SST) buoy (Fig. B.1.1). All the STRs show very similar pattern and temperature ranges, with a clear annual fluctuation due to seasonal warming and cooling (Fig. B.1.4). Warmest temperatures peaked at around 32^{o}C within the lagoon and 29^{o}C outside the lagoon and occurred during the summer months of July to October. Winter temperatures reached lows of 24^{o}C and occurred during December through March. Water temperature in the lagoon is significantly more affected by diurnal heating and cooling, and temperature fluctuations on this time scale are greater (2–3^{o}C) within the lagoon compared to those outside (< 0.5^{o}C).

A new suite of moorings were deployed at Wake Atoll as part of a remote islands internal tide and circulation investigation. The new moorings included a three-instrument temperature, current, wave and salinity array on the northwestern and southeastern points of the atoll (Table 1); as well as a latitudinal salinity and temperature transect of Seabird 37 Microcats at 20 m on the southwestern, southern, northeastern and northern exposures (Fig. B.1.1).

The portable environmental acoustic recorders (PEAR) device was used while free diving, rather than the noisy SCUBA rigs to avoid sound pollution and scaring the fish away. Sites where *Bolbometopon muricatum* was successfully recorded were near rapid ecological assessment (REA) sites WAK-05 and WAK-06. Free divers took turns recording visual and acoustic data from schools of *Bolbometopon muricatum.* Near site WAK-06, the fish were mostly solitary; a group of about 20 individuals were spotted and followed until they moved to deeper water. Near site WAK-05, a large school between 200 and 300 fishes was observed socializing and feeding. The divers stayed near them for nearly an hour.

Five REA sites (WAK-02, WAK-05, WAK-10, WAK-12, and WAK-14) were visited to collect water samples for microbiological, nutrient and chlorophyll analyses. All samples were collected between 30 and 50 feet. At each REA site, water samples for analysis of nutrient and chlorophyll levels were obtained from the surface and at depth. Chlorophyll samples were filtered and nutrient samples were frozen at -30^{o}C for post-cruise analysis. Microbial water samples were taken using diver-deployable Niskin bottles to collect 20 liters of seawater (4 bottles; 2 liters per bottle) at each study site. These samples were collected at 10–15 meters of depth and transported back to the ship. Shallow-water conductivity temperature and depth (CTD) casts were also conducted at these sites. In addition, CTD casts were taken around the perimeter of Wake Atoll and at select points within the lagoon.

Table 2.--Moorings.

Instrument	Action	Serial number	Latitude	Longitude	Action date	Depth (m)
RDI ADCP	Dep	6579	19.32583	166.60978	2009/03/22	18.29
SBE37	Dep	50483	19.32583	166.60978	2009/03/22	18.29
STR	Dep	3939038-1814	19.32583	166.60978	2009/03/22	13.72
STR	Dep	3939038-1810	19.32572	166.60973	2009/03/22	9.45
SBE37	Dep	37SM29741-2503	19.32547	166.60963	2009/03/22	20.12
AQD ADCP	Dep	AQD 5266 ASP 3405	19.27672	166.65725	2009/03/22	20.12
STR	Dep	3939038-1852	19.27672	166.65725	2009/03/22	14.33
STR	Dep	3939038-1813	19.27667	166.65705	2009/03/23	10.06
STR	Dep	3933179-1368	19.27665	166.65678	2009/03/23	26.21
STR	Ret	3936859-1655	19.30630	166.65157	2009/03/23	26.21
SBE37	Dep	37SM32102-2980	19.30630	166.65157	2009/03/23	20.73
STR	Dep	3933179-1366	19.30635	166.65142	2009/03/23	13.41
STR	Ret	3920707-0109	19.30615	166.65103	2009/03/23	13.41
SBE37	Dep	37SM27548-2144	19.30615	166.65103	2009/03/23	20.12
STR	Dep	3933179-1196	19.31588	166.62730	2009/03/23	26.21
STR	Ret	3936859-1652	19.31627	166.59797	2009/03/23	27.43
STR	Dep	3933179-1202	19.31627	166.59797	2009/03/23	10.36
STR	Ret	3936859 - 1673	19.31623	166.59825	2009/03/24	15.24
SBE37	Dep	37SM27531-2143	19.31618	166.59800	2009/03/24	19.81
SBE37	Dep	37SM27531-2142	19.30300	166.59487	2009/03/24	20.42
STR	Dep	3933179-1200	19.28010	166.62847	2009/03/24	13.41
STR	Ret	3939038-1854	19.28027	166.62867	2009/03/24	13.41
SST	Dep	1B3RE SBE39: 4598	19.28027	166.62867	2009/03/24	3.35
SST	Ret		19.30737	166.62210	2009/03/24	0.03
STR	Ret	3939038-1857	19.30737	166.62210	2009/03/24	3.35
STR	Dep	3933179-1194	19.30737	166.62210	2009/03/24	3.35
EAR	Dep	9300492-B109	19.30737	166.62210	2009/03/24	1.22
STR	Dep	3939038-1868	19.30092	166.63805	2009/03/25	1.22
EAR	Ret	25	19.30092	166.63805	2009/03/25	1.22
STR	Ret	3943236-3027	19.30092	166.63805	2009/03/25	1.22
STR	Dep	3933179-1195	19.30092	166.63805	2009/03/25	1.83
STR	Ret	3936859-1675	19.30867	166.60452	2009/03/25	1.83

Figure B.1.1.--Deployed instrument moorings Wake Atoll, HI0901.

Figure B.1.2.--Shallow-water CTD locations, Wake Atoll HI0901.

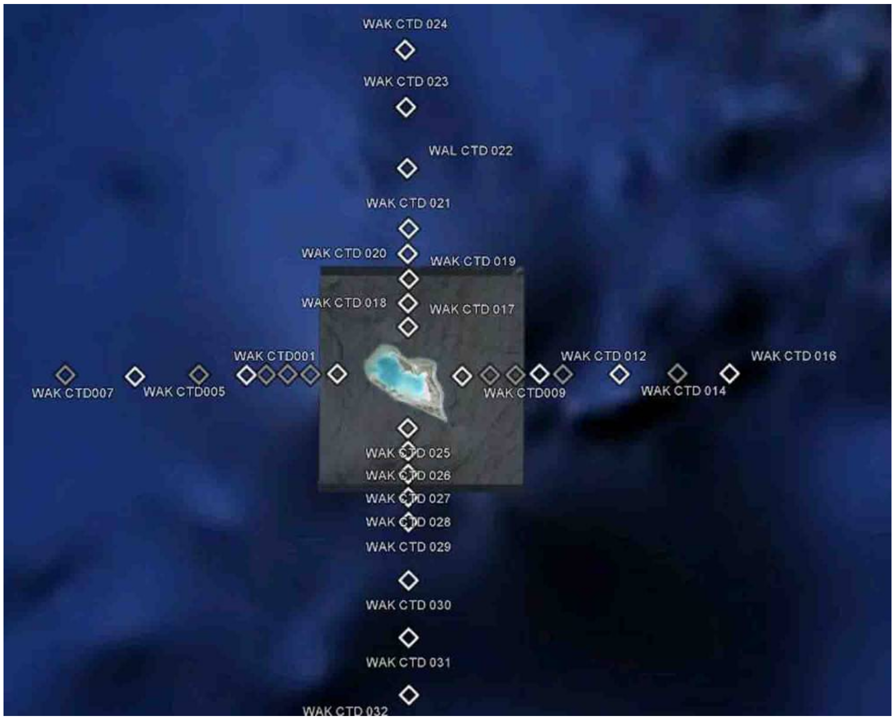


Figure B.1.3.--Deepwater CTD transects; East, 1-8; West 9-16, North 17-24 and South 25-32. Wake Atoll HI0901.

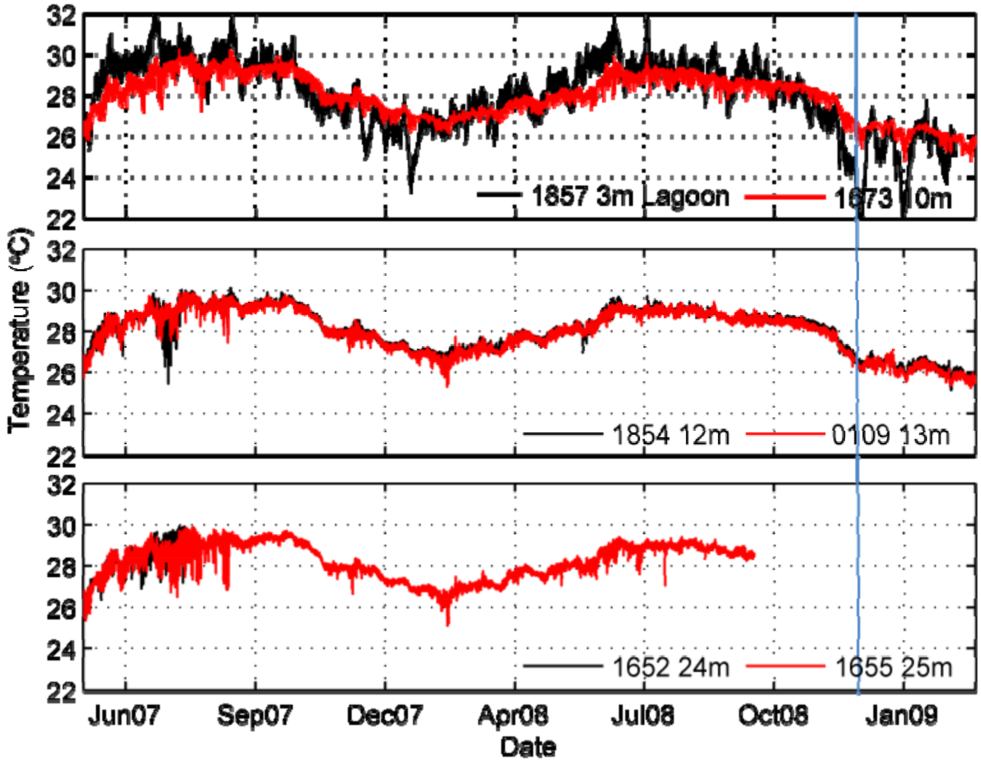


Figure B.1.4.--Temperature time-series from STR moorings at Wake Atoll. The solid blue line highlights the December 7th rogue event which inundated Wake Island.

The “Surge”

Interviews with Wake Island personnel indicate that on December 7, 2008, Wake Island was inundated by a “surge” of water up to a meter high in some areas. Evidence suggests that neighboring Peale Island was similarly inundated. Witnesses recount a wave, or series of waves, up to 10 m in height at breaking, forcing seawater over the northern part of Wake Atoll at 7:00 a.m. Wake Standard Time, with a second smaller event around 8:00 a.m. Before the actual inundation event, water levels in the lagoon were reported to be as high as the bridge pylons between Wake and Peale, approximately 3–4 m higher than its mean level. Evidence of this wave was clearly verifiable by high water marks, significant structural damage, and large amounts of sand and invertebrate, calcifying organisms that had been carried inland. Damage to Wake Island facilities was extensive, exceeding that of Super Typhoon Ioke. This is surprising, since Ioke, which passed over Wake in 2006 has been widely reported as the strongest hurricane ever recorded in the central Pacific.

A preliminary analysis of Wake’s NOAA COOP station data during the December 7 event indicates that northerly winds peaked at 21 m/s (41 knots), and sea-level barometric pressure bottomed out around 1008 mB. In contrast, northerly winds during Ioke reached 43 m/s (83 knots), and pressure dropped to 967 mB before station sensors failed; peak winds were estimated at 67 m/s (130 knots) (Fig. B.1.5). Unfortunately, no in situ wave devices were nearby for either event; however, NOAA/NCEP WaveWatch III model hindcasts suggest offshore (deepwater) wave heights during the December 7 event reached well over 8 m (26 ft) in height with periods longer than 15 s. WaveWatch III hindcasts at Wake during Ioke show far less energetic conditions: significant wave heights peaking around 6.5 m (21 ft) and dominant periods around 12 s (Fig. 1). Modeled wave heights around Wake during the December 7 event are the highest in the NOAA/NCEP WaveWatch III hindcasts, which began in 1997 (Fig. B.1.6).

The lack of either extreme winds or (low) barometric pressure during the December 7 event suggests that wave setup, or the shoreward increase in sea-level due to the dissipation of wave energy, was the primary cause of the flooding and destruction at Wake. This is consistent with the witnesses’ accounts: deepwater waves 8 m in height can “shoal” to heights in excess of 10 m, and observed wave-setup at Pacific atolls is on the order of 10% to 30% of incident wave heights. Most likely, exceptionally large “sets” of waves (wave groups) impacted the atoll, generating infra-gravity waves that inundated the island, both at 7:00 a.m. and 8:00 a.m. While both of these “surges” occurred within about an hour of high tide, it was not an exceptionally high astronomical tide. Surprisingly, observed water levels at the NOAA COOP station were not unusually high during this period. The station, located in the boat harbor on the south shore, is not connected to the lagoon, and thus must have been sheltered from the effects of waves from the north. This further suggests that low barometric pressures or other causes of sea level anomaly contributed little, if at all to the flooding of Wake. These exceptionally large waves appear to have been generated from two relatively distant sources: a small mid-latitude cyclone that attained hurricane strength (centered around 30ºN on December 6 UTC); and a large Aleutian Low cyclone with an extremely large area of storm force winds (centered around 50ºN on December 4 UTC).

This December 7 event highlights the vulnerability of the low-lying atolls of the North Pacific to catastrophic flooding and damaging waves generated by remote temperate and sub-polar cyclones. This same event was one of several to cause widespread flooding in the Marshall Islands. While the waves of the December 7 event were exceptionally large at Wake, according the NOAA/NCEP WaveWatch III hindcasts, the data show several other large wave events of similar or greater magnitude than of Ioke, occurring in 1998, 2003, and 2004. These exceptional events undoubtedly heavily impact the benthic communities of these atolls, as the large numbers of benthic invertebrates deposited on Wake and Peale Islands and the recorded 4ºC drop in lagoon temperatures (Fig. B.1.4) following the "surge" demonstrate.

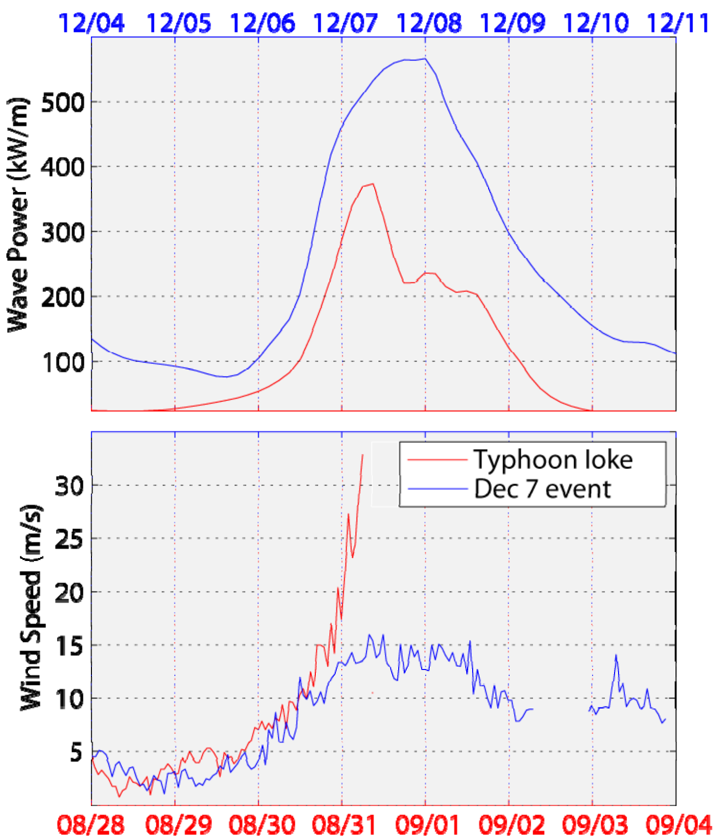


Figure B.1.5.--Upper panel: wave power (per unit wave face), based on NOAA/NCEP WaveWatch III model output, calculated for 10-m water depths for a 1-week period centered on Dec.ember 7, 2008 and Typhoon Ioke landfall (2006). Wave power is a better metric of destructive capacity and ability to cause increased water levels than wave height since it takes into account wave period as well as wave height. Lower panel: comparison of wind speeds at NOAA COOP Station during the two events. Winds during hurricane Ioke were estimated to have reached an additional 30 knots than indicated (after sensor failed). In both panels, date of respective events is indicated at the top of figure (December7 event) or at the bottom (Ioke).

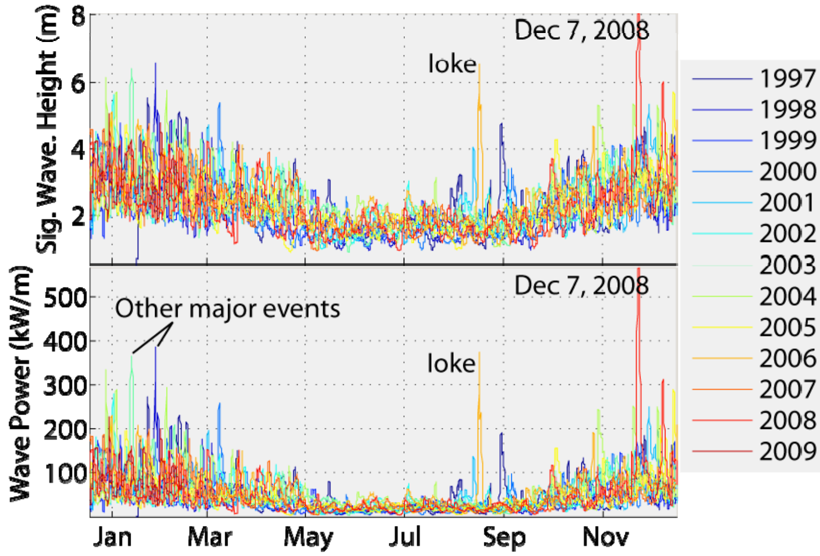


Figure B.1.6.--Upper panel: comparison of NOAA/NCEP WaveWatch III model significant wave height for all years available (1997–2009). Lower panel: comparison of wave power (per unit wave face), based on model output, calculated for 10-m water depths for the same time period

B.2. Rapid Ecological Assessment (REA) Site Descriptions

Thirteen REA sites were visited by a team of up to seven scientists around Wake Island between March 22 and March 26, 2008 (Fig. B.2.1). In addition, 12 stratified random fish, line point interecept (LPI), and invertebrate surveys were conducted. The site locations are listed below along with two site photos taken in 2009. Site descriptions are included for the following discipline communities: coral, coral disease, macro-invertebrates, algae, and fish.

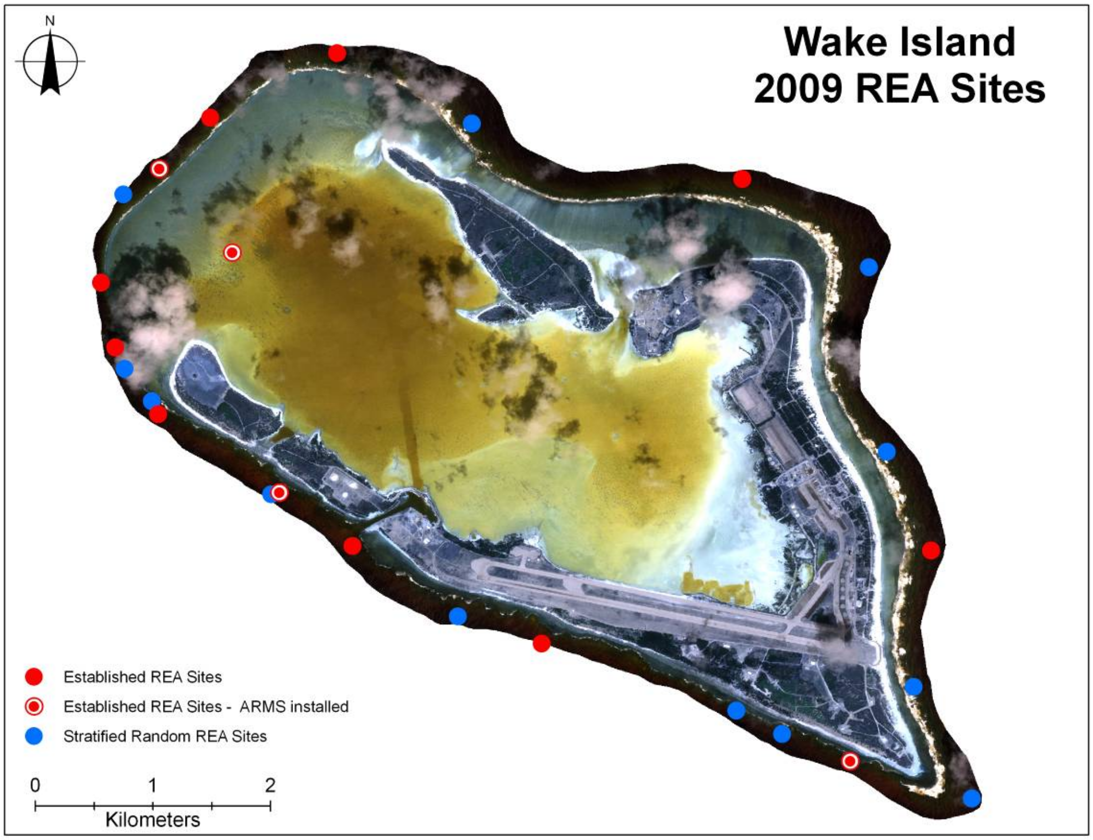


Figure B.2.1.--Location of REA, stratified random and autonomous reef matrix systems (ARMS) installation sites visited at Wake Island in 2009.

WAK-01
3/25/2009

E 166° 37.652
N 19° 16.809

Forereef
Mid

Depth: 14–18 m

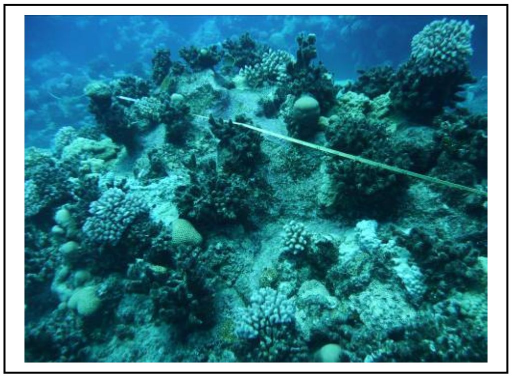
Site description: Southern spur-and-groove forereef with moderate coral cover.

WAK-02
3/24/2009

E 166° 36.782
N 19° 17.259

Forereef
Mid

Depth: 11–14 m



Site description: Southern forereef located outside dredged channel with large coral bommies and tanker wreckage.

WAK-03
3/25/2009

E 166° 35.890
N 19° 17.864

Forereef
Mid

Depth: 14–16 m

Site description: Southwest forereef with large coral bommies.

WAK-04
3/24/2009

E 166° 35.627
N 19° 18.469

Forereef
Mid

Depth: 12–17 m

Site description: Steep western forereef site with moderate coral cover.

WAK-05
3/24/2009

E 166° 35.692
N 19° 18.170

Forereef
Mid

Depth: 13–16 m

Site description: Steep western forereef site with moderate coral cover.

WAK-06
3/25/2009

E 166° 36.446
N 19° 17.503

Forereef
Mid

Depth: 13–15 m

Site description: Southern spur-and-groove forereef site with moderate coral cover.

WAK-07
3/22/2009

E 166° 36.128
N 19° 19.228

Forereef
Mid

Depth: 14–14 m

Site description: Steep northwestern forereef site with moderate coral cover.

WAK-08
3/22/2009

E 166° 35.894
N 19° 18.992

Forereef
Mid

Depth: 13–15 m

Site description: Steep northwestern forereef site with moderate coral cover.

WAK-09
3/23/2009

E 166° 39.069
N 19° 16.270

Forereef
Mid

Depth: 14–14 m

Site description: Spur-and-groove southeast forereef site with large coral bommies.

WAK-12
3/22/2009

E 166° 36.712
N 19° 19.524

Forereef
Mid

Depth: 13–15 m

Site description: Steep northern forereef with moderate coral cover.

WAK-13
3/23/2009

E 166° 38.573
N 19° 18.946

Forereef
Mid

Depth: 12–17 m

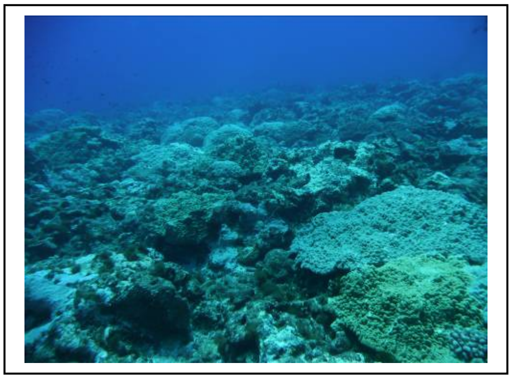
Site description: Northern forereef site with low coral cover and moderate macroalgae cover.

WAK-14
3/23/2009

E 166° 39.442
N 19° 17.237

Forereef
Mid

Depth: 13–17 m



Site description: Eastern forereef site with moderate coral cover.

WAK-50
3/22/2009

E 166° 37.330
N 19° 19.200

Forereef
Shallow

Depth: 6–6 m


Site description: Shallow exposed northern site with scoured pavement and some coral.

WAK-51
3/22/2009

E 166° 36.340
N 19° 19.433

Forereef
Deep

Depth: 24–24 m


Site description: Deep western site with moderate coral and complexity.

WAK-52
3/22/2009

E 166° 35.729
N 19° 18.875

Forereef
Deep

Depth: 22–22 m


Site description: Deep western site with moderate coral and complexity.

WAK-53
3/23/2009

E 166° 39.628
N 19° 16.098

Forereef
Deep

Depth: 20–20 m

Site description: Deep site off southeast tip with moderate coral and complexity.

WAK-54
3/23/2009

E 166° 39.360
N 19° 16.610

Forereef
Shallow

Depth: 3–3 m

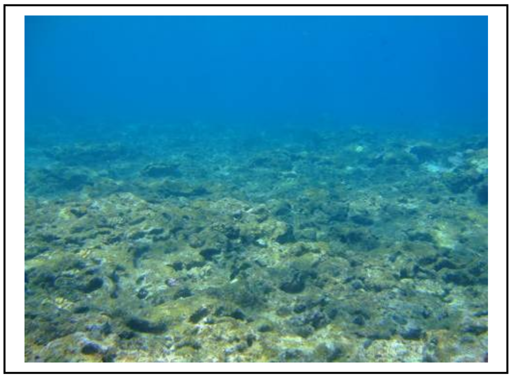
Site description: Shallow trade-wind exposed site with scoured pavement and deep narrow channels.

WAK-55
3/23/2009

E 166° 39.237
N 19° 17.692

Forereef
Shallow

Depth: 5–5 m



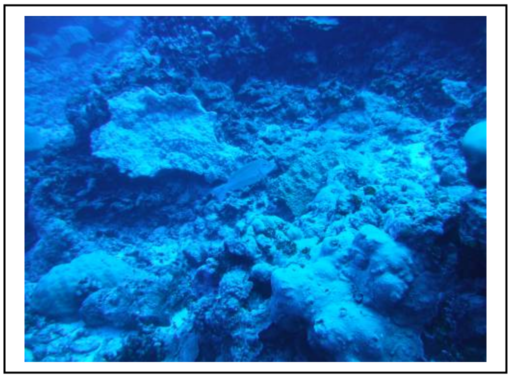
Site description: Shallow trade-wind exposed site with scoured pavement.

WAK-56
3/23/2009

E 166° 39.155
N 19° 18.540

Forereef
Deep

Depth: 25–25 m




Site description: Deep site off northeast tip with moderate coral and complexity.

WAK-57
3/24/2009

E 166° 35.735
N 19° 18.073

Forereef
Deep

Depth: 23–23 m

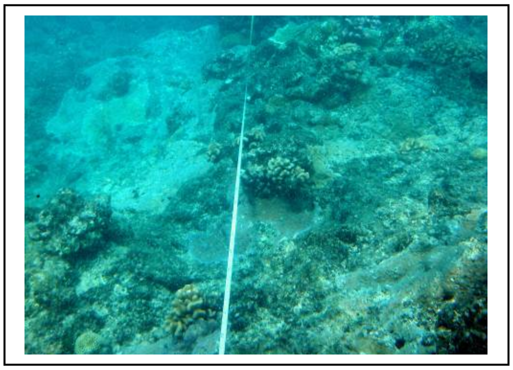

Site description: Deep drop-off southwest coast with high coral cover and low complexity.

WAK-58
3/24/2009

E 166° 35.861
N 19° 17.924

Forereef
Shallow

Depth: 4–5 m

Site description: Shallow southwest site composed of pavement with coral; low cover and complexity.

WAK-59
3/24/2009

E 166° 36.929
N 19° 17.154

Forereef
Shallow

Depth: 2–2 m

Site description: Shallow south site in surf break with low coral and complexity and a channel bisecting the transect.

WAK-60
3/24/2009

E 166° 36.408
N 19° 17.496

Forereef
Deep

Depth: 23–23 m

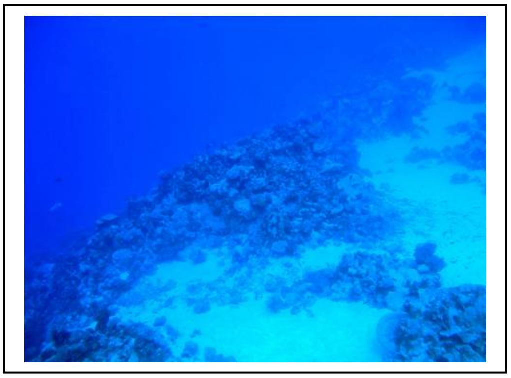
Site description: Deep south forereef on crest of drop-off with moderate cover and complexity.

WAK-61
3/25/2009

E 166° 39.306
N 19° 16.078

Forereef
Deep

Depth: 25–25 m



Site description: Deep site on the south side, patch reefs interspersed with sand on the lip of a steep drop-off.

WAK-62
3/25/2009

E 166° 38.757
N 19° 16.395

Forereef
Shallow

Depth: 4–4 m

Site description: Shallow site on the south side, deep spur-and-grove formations, moderate coral cover.

WAK-63
3/25/2009

E 166° 38.546
N 19° 16.502

Forereef
Shallow

Depth: 4–4 m

Site description: Shallow site on the south side, with scoured pavement and low coral cover.

WAK-64
3/25/2009

E 166° 37.266
N 19° 16.935

Forereef
Deep

Depth: 24–24 m

Site description: Deep site on the south side, steep wall with high coral cover.

WAK-65
3/26/2009

E 166° 37.641
N 19° 18.972

Forereef
Deep

Depth: 25–27 m

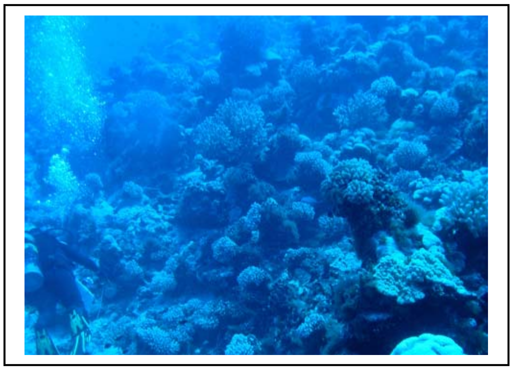
Site description: Deep northern site with moderate coral and complexity.

WAK-66
3/26/2009

E 166° 36.754
N 19° 17.230

Forereef
Deep

Depth: 25–29 m



Site description: Very deep wall site off eastern ship mooring with moderate coral and complexity. Follow anchor chain to site.

B.3. Benthic Environment

B.3.1. Algal and Coral Communities- Line Point Intercept Method

Benthic communities around Wake Atoll were documented along 25-m transects using a high resolution 20cm interval LPI method at established REA monitoring sites. All sites ranged from 13 to16 m deep with the lagoon site (WAK-10) being the exception at 2–3 m below the surface. Data reveal that benthic communities around Wake Island were dominated by scleractinian coral, turf algal, and macroalgal functional groups (Table B.3.1.1). Scleractinian coral percent cover exceeded that of other functional groups at 7 of the 13 sites surveyed, and turf algae was the dominant cover at 4 of the 13 sites (Table B.3.1.1). At site WAK-01 and WAK-13, macroalgae percent cover exceeded that of all other functional groups (38.8% and 49.6%, respectively).

Overall, a combined total of 11 species of macroalgae (6 chlorophytes, 2 ochrophytes, 2 rhodophytes, 1 unknown) were observed from the 13 sites surveyed (Tables B.3.1.1, B.3.1.2). *Dictyota* sp. dominated the macroalgal community at 4 of the 13 sites with a percent cover range of 14.0% to 18.4% at these sites (Table B.3.1.1). *Caulerpa serrulata* was the dominant algal cover at both WAK-02 and WAK-09 with 10.0% and 17.6% cover, respectively. *Halimeda* sp. represented the only macroalgae at WAK-04 (24.8% of the benthos) and was a large component of the macroalgal cover at WAK-08 (13.8%). *Liagora hawaiiana* was the most prevalent macroalgal species at site WAK 13 where it was observed in large beds and represented 42.4% of the benthic cover (Table B.3.1.1).

Table B.3.1.1.--Percent cover of algal functional groups at established long-term monitoring sites at Wake Island in 2009.

Site	Macroalgae	Turf Algae	Corralline Red Algae (crustose + upright)	Cyanobacteria	Scleractinian Coral	Octocoral
WAK-01	38.8%	18.4%	0.8%	0.0%	28.4%	1.2%
WAK-02	16.4%	54.4%	0.0%	0.0%	22.8%	0.0%
WAK-03	26.8%	28.8%	0.4%	0.0%	38.4%	0.0%
WAK-04	24.8%	20.8%	0.4%	0.0%	50.8%	3.2%
WAK-05	39.6%	10.8%	0.0%	0.0%	48.8%	0.0%
WAK-06	32.2%	23.4%	0.6%	0.0%	40.4%	0.0%
WAK-07	4.8%	37.6%	0.0%	0.0%	48.8%	5.6%
WAK-08	20.6%	46.3%	0.0%	0.0%	33.1%	0.0%
WAK-09	19.6%	22.4%	0.0%	0.0%	28.8%	0.4%
WAK-10	11.1%	25.3%	0.0%	0.0%	16.5%	0.0%
WAK-12	1.6%	60.8%	0.0%	0.0%	17.6%	20.0%
WAK-13	49.6%	10.0%	5.6%	0.0%	29.6%	5.2%
WAK-14	30.2%	22.7%	0.0%	0.4%	44.9%	0.9%

Table B.3.1.2.--Percent cover of macroalgal species at long-term monitoring sites at Wake Island. Sum totals for each row equal the percent cover of macroalgae recorded in Table B.3.1.1.

Site	*Caulerpa racemosa*	*Caulerpa serrulata*	*Dictyosphaeria cavernosa*	*Dictyota friabilis*	*Dictyota sp*	*Halimeda sp*	*Liagora hawaiiana*	*Neomeris annulata*	*Peyssonnelia inamoena*	unknown algae
WAK-01	-	11.2%	-	-	18.4%	9.2%	-	-	-	-
WAK-02	-	10.0%	-	-	4.8%	1.6%	-	-	-	-
WAK-03	1.2%	1.2%	-	-	18.4%	6.0%	-	-	-	-
WAK-04	-	-	-	-	-	24.8%	-	-	-	-
WAK-05	1.2%	2.4%	-	-	26.8%	8.8%	-	-	-	0.4%
WAK-06	2.3%	5.8%	-	-	14.0%	8.8%	-	-	1.2%	-
WAK-07	-	-	-	-	-	4.8%	-	-	-	-
WAK-08	-	-	-	-	-	13.8%	6.9%	-	-	-
WAK-09	-	17.6%	-	1.2%	-	0.8%	-	-	-	-
WAK-10	-	9.9%	0.3%	0.3%	-	-	-	0.3%	0.3%	
WAK-12	-	-	-	-	-	1.6%	-	-	-	-
WAK-13	0.4%	-	-	-	-	5.6%	42.4%	1.2%	-	-
WAK-14	-	-	-	22.2%	0.4%	7.6%	-	-	-	-

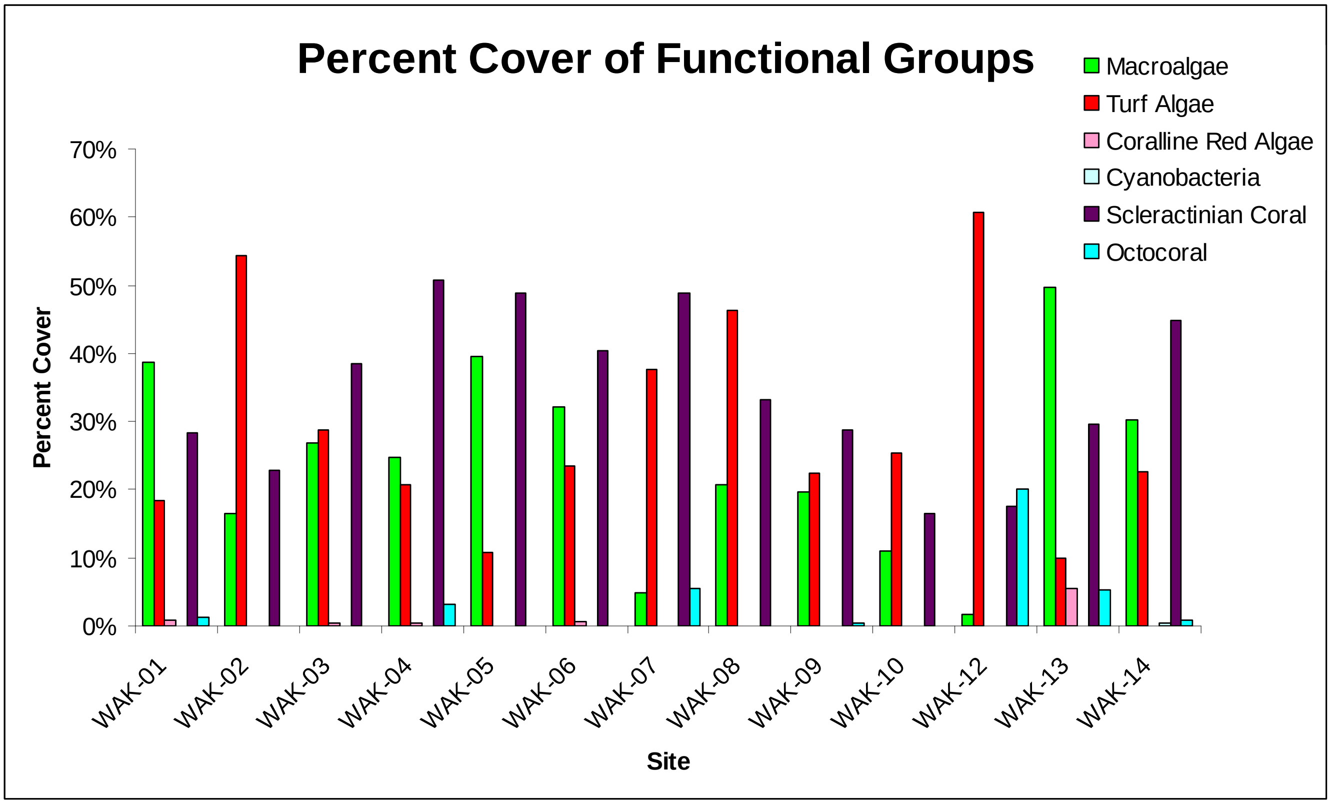


Figure B.3.1.1.--Percent cover of functional groups at permanent REA sites.

In 2009, independent surveys were conducted to document benthic communities around Wake Atoll at new deep and shallow randomly stratified sites along a 25-m transect line at 0.5-m intervals. Sites located at less than 10 m deep were dominated by macro and turf algal functional groups (Table B.3.1.4). Turf algae percent cover exceeded that of other functional groups at 5 of the 7 shallow sites surveyed, and macroalgae was the dominant cover at 2 of the 7 sites (Table B.3.1.4). Benthic communities at greater than 20 m deep were dominated by scleractinian coral and turf algal functional groups (Table B.3.1.4). Scleractinian coral percent cover exceeded that of other functional groups at 4 of the 6 deep sites surveyed, and turf algae was the dominant cover at 1 of the 6 sites (Table B.3.1.4). At site WAK-60, percent cover of scleractinian coral and turf algae was approximately equal (31.4%). A combined total of 13 species of macroalgae were observed (7 chlorophytes, 5 ochrophytes, 1 rhodophyte) from the 13 sites surveyed (Tables B.3.1.3, B.3.1.5). The Line Point Intercept method, at 50-cm intervals, used for benthic monitoring at these sites quantitatively describes the benthic functional group structure and qualitatively describes the macroalgal community structure. These observations showed that *Lobophora variegata* dominated the macroalgal community at 3 of the 7 shallow sites, and *Caulerpa serrulata* was the dominant macroalgae at shallow sites WAK-10 and WAK-62 (Table B.3.1.5). Also, at the shallow site WAK-55, *Dictyota* sp. *and Lobophora variegata* percent cover was approximately equal (Table B.3.1.5). Species of *Dictyota* dominated the macroalgal community at 4 of the 6 deep sites surveyed, and *Lobophora variegata* and species of *Halimeda* dominated at deep sites WAK-56 and WAK-52 (Table B.3.1.5)

Table B.3.1.3.--Additional species recorded at each site at Wake Island during roving diver surveys.

Site	**Chlorophyta**
WAK-01 WAK-02 WAK-06 WAK-07 WAK-10	*Caulerpa racemosa*
WAK-02 WAK-56	*Caulerpella serrulata*
WAK-50	*Halimeda sp.*
WAK-05 WAK-13 WAK-50 WAK-53 WAK-54 WAK-56 WAK-63	*Neomeris sp.*
WAK-06 WAK-63	*Valonia ventricosa*
	Ochrophyta
WAK-63	*Dictyota ceylanica*
WAK-06	*Dictyota friabilis*
WAK-02	*Dictyota* sp.
WAK-54	*Padina* sp.
	Rhodophyta
WAK-07 WAK-56	*Liagora hawaiiana*

Table B.3.1.4.-- Percent cover of functional groups at stratified random shallow and deep monitoring sites in 2009 around Wake Atoll.

Site	Depth	Macroalgae	Turf Algae	Coralline Red Algae (crustose + upright)	Cyanobacteria	Scleractinian Coral	Octocoral
WAK-10	< 10m	11.1%	25.3%	-	-	16.5%	-
WAK-50	< 10m	9.8%	45.1%	18.6%	-	26.5%	-
WAK-54	< 10m	21.6%	64.7%	7.8%	-	5.9%	-
WAK-55	< 10m	54.9%	27.5%	5.9%	-	11.8%	-
WAK-58	< 10m	35.3%	24.5%	7.8%	-	31.4%	-
WAK-62	< 10m	28.4%	40.2%	6.9%	2.0%	22.5%	-
WAK-63	< 10m	28.4%	50.0%	8.8%	2.0%	10.8%	-
WAK-52	> 20m	17.6%	13.7%	2.0%	-	66.7%	-
WAK-53	> 20m	23.5%	51.0%	-	-	9.8%	15.7%
WAK-56	> 20m	17.6%	17.6%	5.9%	-	52.9%	5.9%
WAK-57	> 20m	15.7%	25.5%	-	-	58.8%	-
WAK-60	> 20m	25.5%	31.4%	2.0%	-	31.4%	-
WAK-64	> 20m	29.4%	7.8%	21.6%	-	41.2%	-

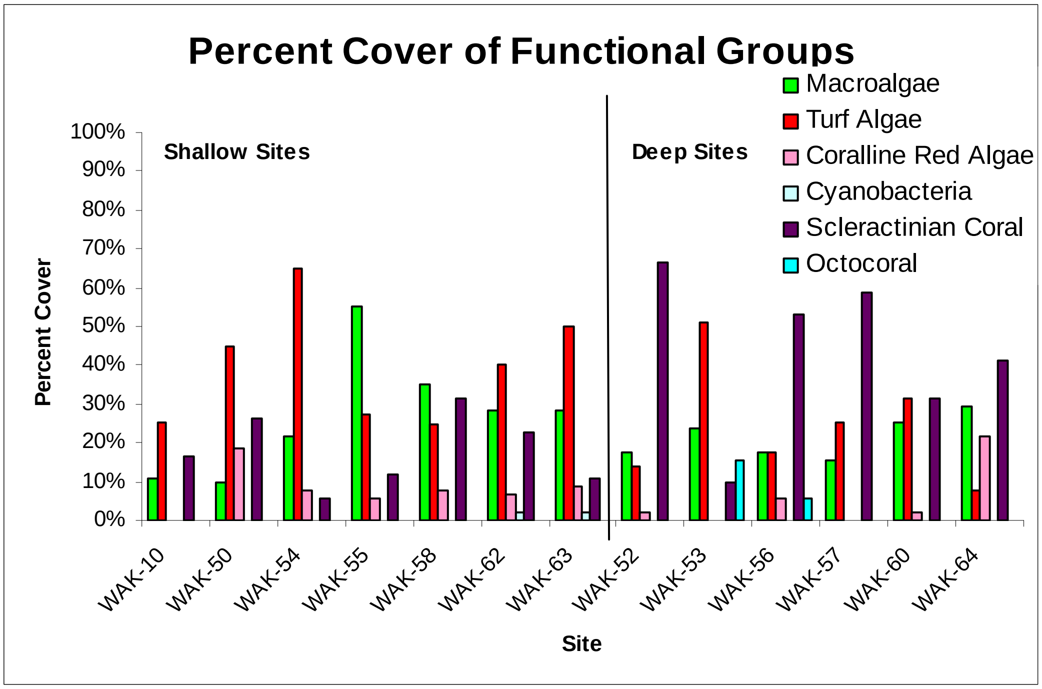


Figure B.3.1.2.--Percent cover of functional groups at shallow and deep monitoring sites established in 2009 around Wake Atoll.

Table B.3.1.5.--Percent cover of macroalgal species at stratified random shallow and deep monitoring sites in 2009 around Wake Atoll. Sum totals of each row equal the percent cover of macroalgae recorded in Table B.3.1.4.

Site	Depth	Caulerpa racemosa	Caulerpa serrulata	Dictyosphaeria cavernosa	Dictyosphaeria versluysii	Halimeda sp	Dictyota bartayresiana	Dictyota ceylanica	Dictyota sp	Lobophora variegata	Liagora sp
WAK-10	< 10m	-	9.9%	0.3%	0.3%	-	-	-	-	-	0.3%
WAK-50	< 10m	-	-	-	-	-	-	-	2.9%	6.9%	-
WAK-54	< 10m	-	2.0%	-	-	2.9%	-	-	4.9%	11.8%	-
WAK-55	< 10m	-	-	-	1.0%	-	-	-	27.5%	26.5%	-
WAK-58	< 10m	1.0%	6.9%	-	-	1.0%	-	-	2.9%	23.5%	-
WAK-62	< 10m	-	7.8%	-	-	6.9%	1.0%	8.8%	-	3.9%	-
WAK-63	< 10m	-	6.9%	-	-	9.8%	-	-	-	11.8%	-
WAK-52	> 20m	-	-	-	-	9.8%	-	-	-	7.8%	-
WAK-53	> 20m	-	2.0%	-	-	7.8%	-	-	13.7%	-	-
WAK-56	> 20m	-	-	-	-	5.9%	-	-	-	11.8%	-
WAK-57	> 20m	-	-	-	-	3.9%	-	11.8%	-	-	-
WAK-60	> 20m	-	2.0%	-	-	-	-	21.6%	-	2.0%	-
WAK-64	> 20m	-	2.0%	-	-	11.8%	-	13.7%	-	2.0%	-

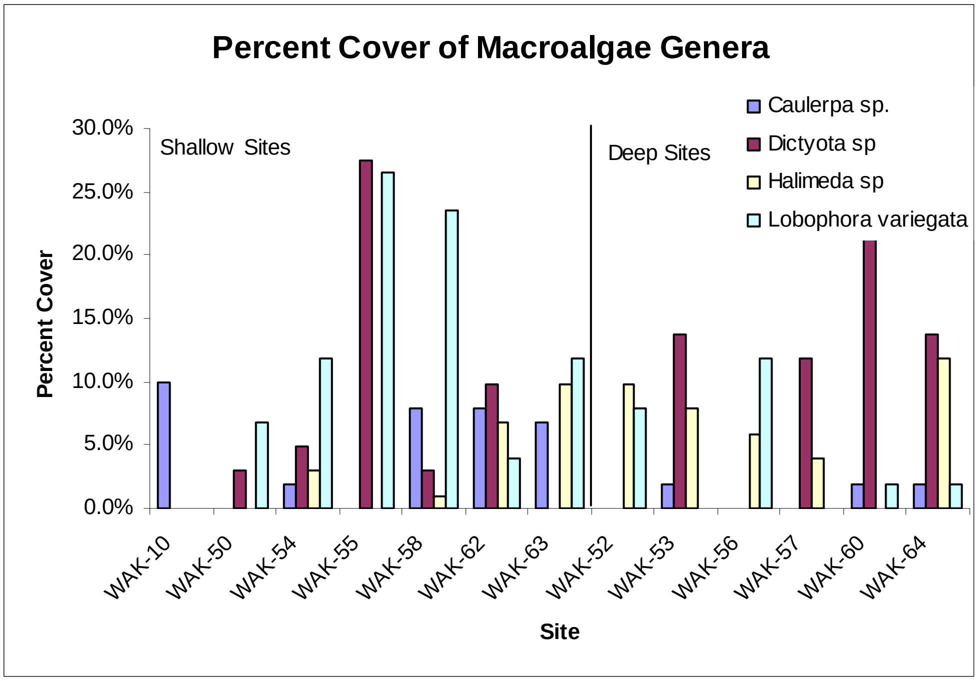


Figure B.3.1.3.--Percent cover of macroalgal species at shallow and deep monitoring sites established in 2009 around Wake Atoll.

B.3.2. Benthic Coral Communities- Belt Transect Method

Total percent cover calculated from independent LPI and permanent REA survey sites indicate moderate coral cover (32.8 ± 3.3%) around Wake Island in 2009 (Fig. B.3.2.1). At 12 permanent REA forereef sites, moderate coral cover was found (36.1 ± 3.2%) and low coral cover at one REA lagoon site (16%; Fig. B.3.2.1). Coral cover at independent LPI sites (30.8 ± 5.9%) was found to be similar to established REA monitoring sites (Fig. B.3.2.1). Generic richness varied between sites with 24 genera (19 scleractinian and 5 anthozoan) being represented within belt transect surveys (Table B.3.2.1). Seven of the scleractinian genera were also observed in the lagoon (Table B.3.2.1).

Coral composition was dominated by encrusting colonies of *Montipora* (27.5%) and *Favia* (18.0%) colonies and branching *Pocillopora* (12.9%) heads (Fig. B.3.2.2). Relative abundance indicates colonies of *Montipora* (26.0%), *Favia* (16.9%) and *Pocillopora* (12.3%) were the most common genera observed at forereef sites (Table B.3.2.1), while *Montipora* (79.0%) dominated the lagoon site, WAK-10.

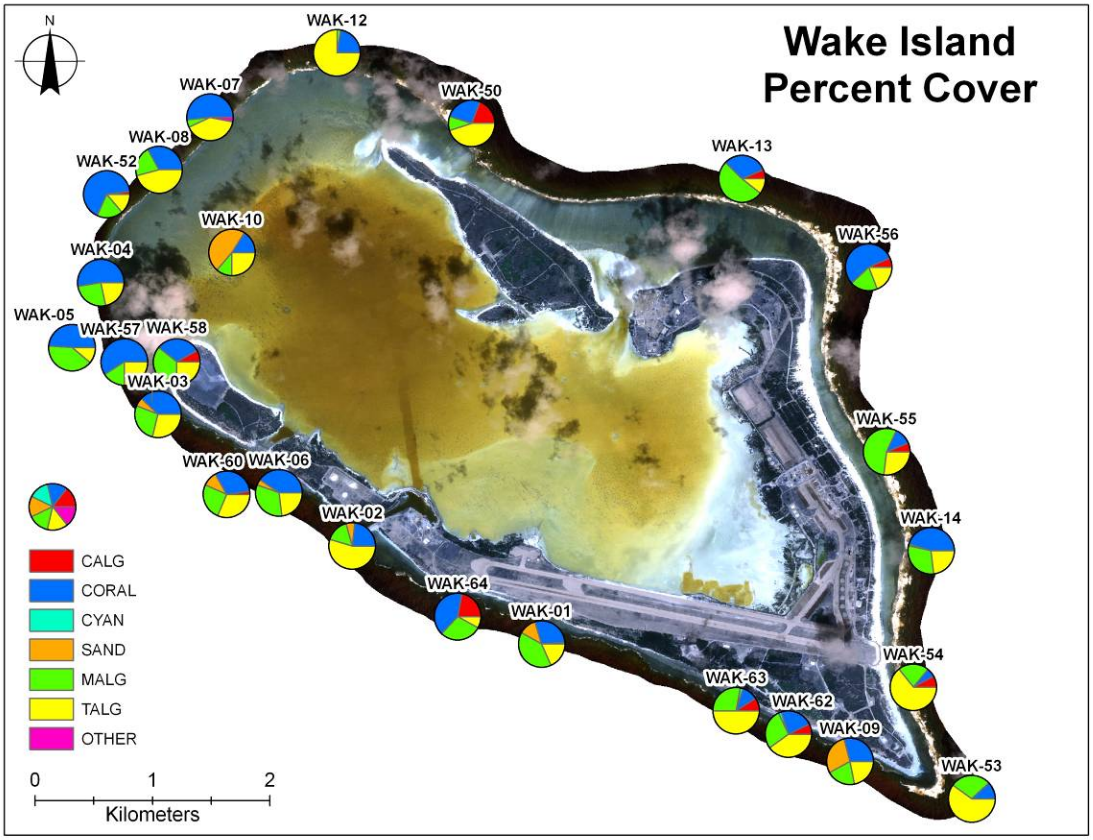


Figure B.3.2.1.--Spatial distribution of benthic cover for established REA and independent LPI sites at Wake Island in 2009.

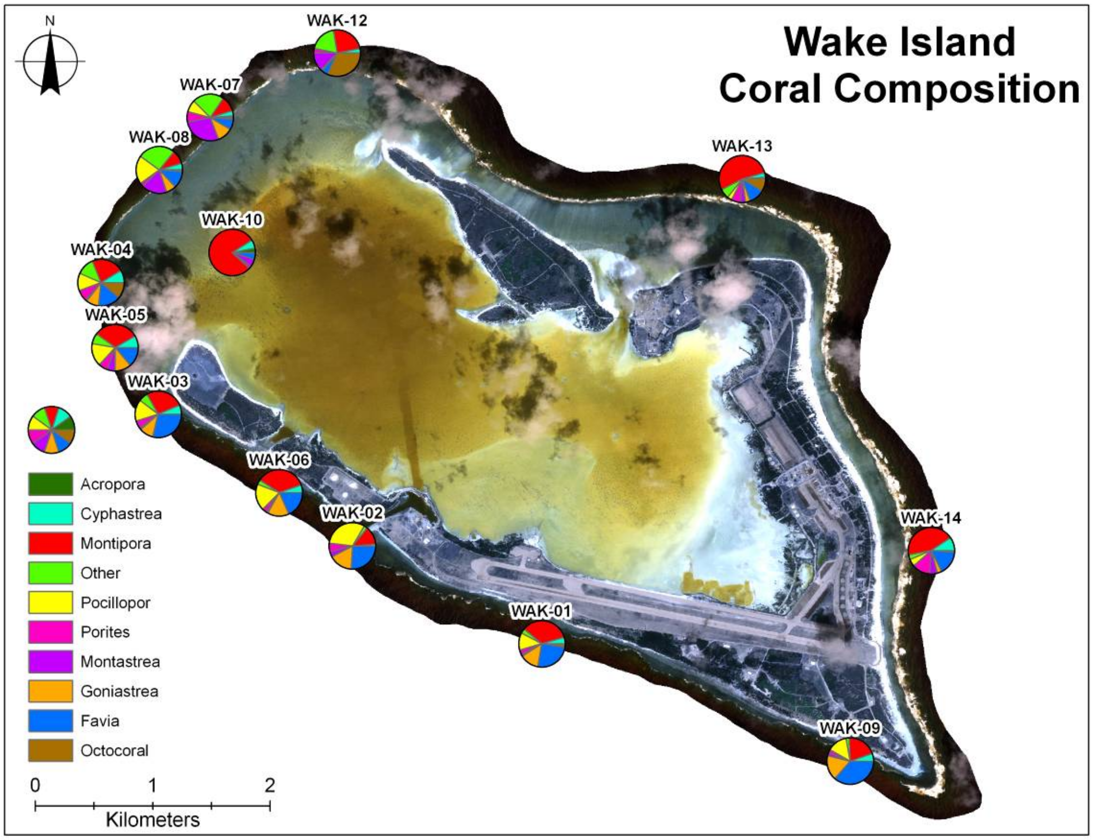


Figure B.3.2.2.--Spatial distribution of coral composition for REA sites at Wake Island in 2009.

Table B.3.2.1.--Relative percentage of coral genera enumerated within belt transects for two habitat strata at Wake Island in 2009.

REA Forereef Sites		REA Lagoon Site	
Genera	Percent	Genera	Percent
Montipora	25.97	Montipora	78.79
Favia	16.91	Cyphastrea	6.06
Pocillopora	12.28	Favia	4.55
Goniastrea	9.31	Montastrea	4.55
Acanthastrea	8.92	Acropora	3.03
Cyphastrea	5.35	Acanthastrea	1.52
Porites	5.01	Porites	1.52
Montastrea	4.93		
Soft Coral	3.36		
Pavona	1.83		
Astreopora	1.78		
Favites	1.49		
Echinopora	1.02		
Scapophyllia	0.34		
Fungia	0.25		
Acropora	0.21		
Leptastrea	0.21		
Lobophytum	0.17		
Palythoa	0.17		
Platygyra	0.13		
Psammocora	0.13		
Symphyllia	0.13		
Lobophyllia	0.04		
Sarcophyton	0.04		

B.3.3. Compromised Coral Health States

During 2009 REA surveys, occurrence of compromised coral health states was extremely low (78 cases; Fig. B.3.3.1). Members of the genera *Montipora* were the only colonies affected by skeletal growth anomalies. Algal overgrowth was observed on colonies of *Montipora*, *Pocillopora* and *Goniastrea*, and members of the genera *Porites* were found to be most commonly afflicted by predation.

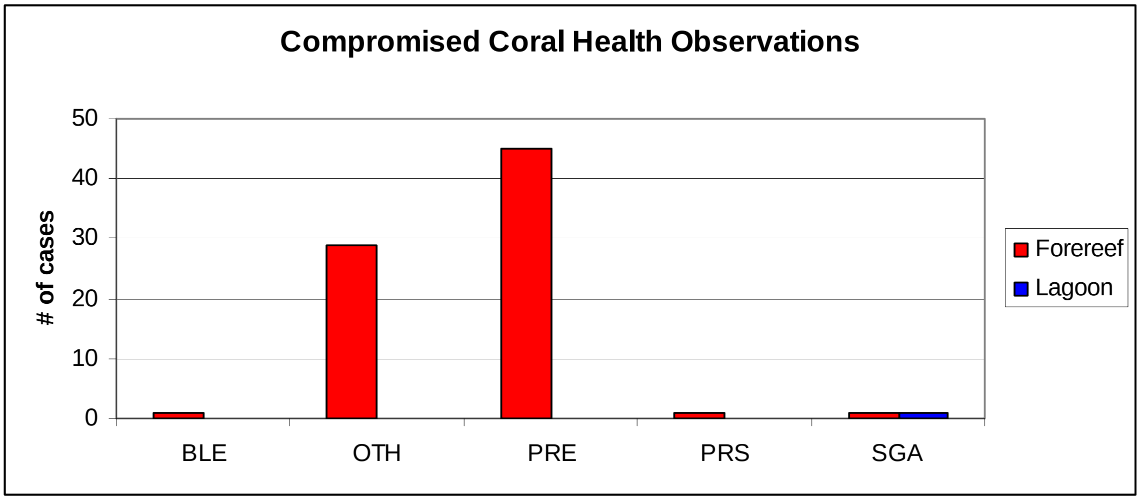


Figure B.3.3.1.--Observations of compromised coral health (number of cases) at Wake Island in 2009.

B.3.4. Macroinvertebrate Surveys (non-coral)

A total of 1438 individuals of benthic invertebrate target species or taxa groups were enumerated from 42 belt transects at 22 sites (Fig. B.3.4.1., Table B.3.4.2). Vermetids were abundant at almost all sites, but they were not enumerated during the belt surveys. The sea cucumber, *Holothuria edulis*, and small hermit crabs of the genus *Calcinus* were the most abundant non-coral invertebrates enumerated on belt transects (mean density 0.24 and 0.15/m², respectively). Other holothurians were encountered, including *Bohadschia argus* and others in the collection list in the following section, but most were found off transect. *H. edulis* was prevalent at many sites around Wake, mostly on the south and west forereef, in sand margins next to the reef and, when present, it was abundant. At sites with branching corals such as *Pocillopora* sp. (e.g., WAK-03), obligate species associated with those corals were relatively abundant such as trapezid crabs (0.33/m² at WAK-03), *Coralliophillidae* snails (*C. violacea* and *Quoyula madreporarum*) (0.09/m²), *Calcinus* hermit crabs (0.77/m^2), and brittle stars, *Ophiocoma* sp. (0.10/m^2) (Table B.3.4.1).

Only one site, WAK-10, was in the lagoon; all others were forereef. The reef crest and flat were not surveyed, although specimens were collected at the littoral zone of the lagoon. The invertebrate records from all sites reflect only what was visible on the reef. Rubble was searched through for collection specimens, but not enumerated in surveys. The urchin, *Echinostrephus aciculatus*, was present at many sites but never in abundant numbers. The other boring urchin, *Echinometra mathaei*, was present in low numbers at some forereef mid-depth (10–15 m) sites, but was highly abundant at shallow sites closer to the reef crest. *Tridacna* sp. were found on transects in low densities at 11 forereef sites (0.09/m^2 mean density where present), and they were spotted off transect at most other sites. *Tridacna* were counted in high density at the lagoon site WAK-10 (0.58/m^2).

Two divers conducted macroinvertebrate surveys at Wake, operating at separate sites. One diver visited previously established REA sites at middle depths (WAK-01 through WAK-14), while the other diver visited new random-stratified REA sites at deep through shallow depths (WAK-52 though 64). Observer biases have been noted between the two divers, and comparison of the long-term sites to the new sites needs to account for this. Invertebrates were not surveyed at WAK-08 due to ARMS installation, and only one transect was surveyed at WAK-09 and at WAK-06.

The findings in 2005 and 2007 of a lack of certain components in the invert fauna, such as anemones, corallimorphs, large urchins (e.g., *Diadema*, *Echinothrix*), hydroids, lobsters and large crustaceans, crinoids, large asteroids, and ascideans, and sponges, is again noted in 2009. Unlike those previous studies, octopus were seen at a few sites, with one on transect.

At sites surveyed around Wake Atoll, urchin test diameters and clam valve widths were measured for individuals encountered (urchins: *Echinometra mathaei*, *Echinostrephus aciculatus*; clams: *Tridacna maxima*, *Tridacna squamosa*, lumped together). The mean diameter and width for each species are represented for each REA site in Figure B.3.4.2. A size class frequency histogram for each group shows a generally normal distribution.

ARMS were deployed at the following REA sites around Wake Atoll (Table B.3.4.4, Fig. B.3.4.3). Three ARMS were installed at each REA site.

Additionally, specimens from numerous macroinvertebrate species were collected as museum specimens with genetic voucher samples and laboratory photography for the University of Guam and the Florida Natural History Museum (Table B.3.4.3).

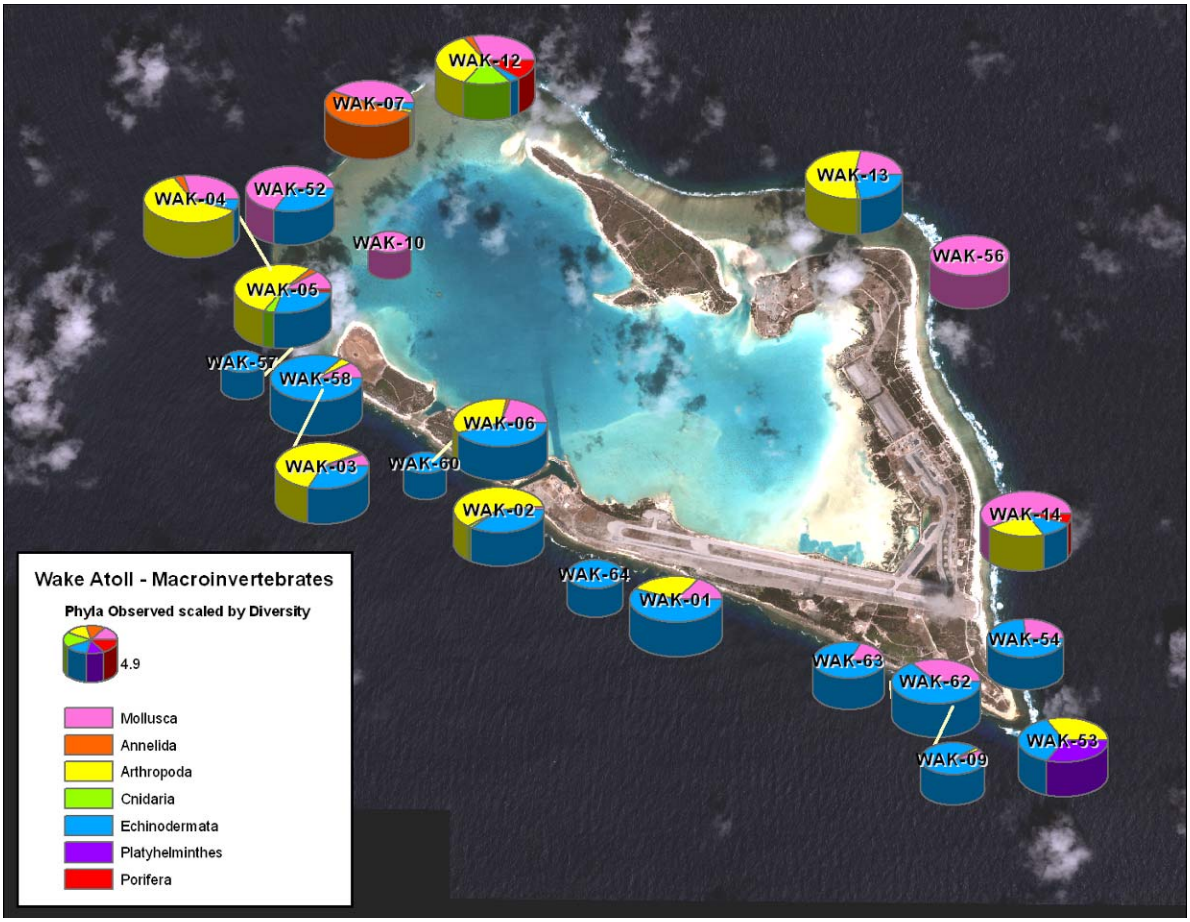


Figure B.3.4.1.--Macroinvertebrate belt transect surveys conducted at Wake Atoll in March 2009, shown with pie charts depicting the phyla represented at each site. Symbols are scaled according to the Shannon Diversity Index, with larger symbols representing higher biodiversity.

Table B.3.4.1.--Functional groups encountered on invertebrate belt transects at Wake. Density is number of individuals in 1 sqaure meter.

		WAK-01	WAK-02	WAK-03	WAK-04	WAK-05	WAK-06	WAK-07	WAK-09	WAK-10	WAK-12	WAK-13	WAK-14	WAK-52	WAK-53	WAK-54	WAK-56	WAK-57	WAK-58	WAK-60	WAK-62	WAK-63	WAK-64	Total Count	Mean Density
Porifera	***Sponges***					2					3		3											**8**	0.00
Cnidaria	***Anemones***		2									1												**3**	0.00
Platyhelminthes	***Flatworms***														1									**1**	0.00
Annelida	***Annelids (Worms)***	1		2	4	4	1	30	1		1													**44**	0.02
Echinodermata	***Holothurians (Sea Cucumbers)***	75	33	34		25	21		101						1	1		10	14	24	1		23	**363**	0.25
	Urchins (Rock Boring)	2		11	2	2		2				14	7	1		103			32		15	42		**233**	0.11
	Asteroids (Sea Stars)	1	1																		1		2	**5**	0.00
	Ophiuroids (Brittle Stars)	5	10	9	3	9	5		3		1	1												**46**	0.03
Mollusca	***Opisthobranchs (Slugs/Nudibranchs)***	3			3		2	4			2	7	29	1		1			2					**54**	0.03
	Large Snails (Lambids/Tritons)																				2			**2**	0.00
	Coralliophilidae (Coral Eating Snails)	10	1	8	19	12	9	8	8		2	1	1											**79**	0.05
	Other Snails (Conus, Cypraea,…)	6	1	1		1	1	2			3	4	4			36								**59**	0.03
	Pearl Oysters (Pinctada sp.)												1				1							**2**	0.00
	Giant Clams (Tridacna sp.)	3		2	3			11		58	1	3		1			1		3		8	9		**103**	0.05
	Octopus										1													**1**	0.00
Arthropoda	***Shrimp (Alpheids, …)***	10	2	1	1		1																	**15**	0.01
	Small Hermit Crabs (Calcinus sp.)	21	54	69	34	52	14	1			9	37	16		1				2					**310**	0.15
	Trapezia sp. (Coral Guard Crabs)	13	11	30	18	17	3		3															**95**	0.05
	Other Crabs (Xanthids, …)			2			1																	**3**	0.00
	Grand Total	150	115	169	87	124	58	58	116	58	23	68	61	3	3	141	2	10	53	24	27	51	25	1426	0.77
	Species Richness	23	13	15	13	14	12	11	6	1	12	15	11	3	3	7	2	1	7	1	7	4	2	*56*	
	Shannon Diversity Index	2.01	1.50	1.88	2.00	2.13	1.84	1.59	0.58	0.00	2.27	2.09	1.58	1.10	1.10	0.81	0.69	0.00	1.56	0.00	1.43	0.72	0.28	*2.67*	

Table B.3.4.2.--Species list of organisms encountered on invertebrate belt transects at Wake Atoll, March 2009, organized by site. Vermetids were encountered at almost all sites in high numbers but were not enumerated and do not appear in this list.

	WAK-01	WAK-02	WAK-03	WAK-04	WAK-05	WAK-06	WAK-07	WAK-09	WAK-10	WAK-12	WAK-13	WAK-14	WAK-52	WAK-53	WAK-54	WAK-56	WAK-57	WAK-58	WAK-60	WAK-62	WAK-63	WAK-64	Total Count	Mean Density (#/m^2)
Actinopyga mauritiana	1							1												1			**3**	0.00
Actinopyga obesa															1								**1**	0.00
Alpheus deuteropus	8																						**8**	0.00
Alpheus lottini	2	1	1	1		1																	**6**	0.00
Bohadschia argus	1																						**1**	0.00
Calcinus areolatus											1												**1**	0.00
Calcinus hazletti	1				8					5	3	16											**33**	0.02
Calcinus isabellae											13												**13**	0.01
Calcinus sp.	20	54	69	34	44	14	1			4	20			1				2					**263**	0.13
Cerithium echinatum												1											**1**	0.00
Chromodoris sp.				3																			**3**	0.00
Conus ebraeus												1											**1**	0.00
Conus imperialis	1																						**1**	0.00
Conus miles		1																					**1**	0.00
Conus sp.	2		1		1	1	1				1				34								**41**	0.02
Coralliophila violacea				2		9	8	8		2	1	1											**31**	0.02
Coralliophilidae	10		6	15	9																		**40**	0.02
Cypraea sp.												1			2								**3**	0.00
Discosoma sp.		1																					**1**	0.00
Drupa ricina											1	1											**2**	0.00
Echinometra mathaei											12	4			100			24		14	40		**194**	0.09
Echinometra oblonga															2								**2**	0.00
Echinostrephus aciculatus	2		11	2	2		2				2	3	1		1			8		1	2		**37**	0.02
Glossodoris sp.	1																						**1**	0.00
Haminoea cymbalum						2																	**2**	0.00
Holothuria edulis	73	33	34		23	21		100						1			10	4	24			23	**346**	0.24
Lambis truncate																				2			**2**	0.00
Latirus nodatus	2						1				1												**4**	0.00

Linckia guildingi	1																					2	**3**	0.00
Linckia multifora		1																		1			**2**	0.00
Loimia medusa								1		1													**2**	0.00
Muricidae										1													**1**	0.00
Nudibranchia																		2					**2**	0.00
Octopus cyanea										1													**1**	0.00
Ophiocoma erinaceus			1			1																	**2**	0.00
Ophiocoma pica	5	10	8	3	9	4		3		1	1												**44**	0.02
Palythoa sp.		1									1												**2**	0.00
Periclimenes sp.		1																					**1**	0.00
Phyllidia pustulosa	2						3			2			1		1								**9**	0.00
Pinctada margaritifera												1											**1**	0.00
Pinctada sp.																1							**1**	0.00
Platyhelminthes														1									**1**	0.00
Porifera					2					3		3											**8**	0.00
Quoyula madreporarum		1	2	2	3																		**8**	0.00
Spirobranchus giganteus	1		2	4	4	1	30																**42**	0.02
Stichopus chloronotus					2													10					**12**	0.01
Thuridilla bayeri							1				7	29											**37**	0.02
Trapezia flavopunctata	8	1	21	4		2																	**36**	0.02
Trapezia rufopunctata	2	9	6	10	12	1		3															**43**	0.02
Trapezia sp.	3	1	3	4	5																		**16**	0.01
Tridacna maxima	2		2	3			9		58	1	3		1			1		3		6	7		**96**	0.04
Tridacna sp.							1																**1**	0.00
Tridacna squamosa	1						1													2	2		**6**	0.00
Tubastrea coccinea					6					6													**12**	0.01
Turbo argyrostomus	1									2	1												**4**	0.00
Xanthidae			2			1																	**3**	0.00
Grand Total	**150**	**115**	**169**	**87**	**130**	**58**	**58**	**116**	**58**	**29**	**68**	**61**	**3**	**3**	**141**	**2**	**10**	**53**	**24**	**27**	**51**	**25**	**1438**	**0.78**
Species Richness	**23**	**13**	**15**	**13**	**14**	**12**	**11**	**6**	**1**	**12**	**15**	**11**	**3**	**3**	**7**	**2**	**1**	**7**	**1**	**7**	**4**	**2**	***56***	
Shannon Diversity Index	**2.01**	**1.50**	**1.88**	**2.00**	**2.13**	**1.84**	**1.59**	**0.58**	**0.00**	**2.27**	**2.09**	**1.58**	**1.10**	**1.10**	**0.81**	**0.69**	**0.00**	**1.56**	**0.00**	**1.43**	**0.72**	**0.28**	***2.67***	

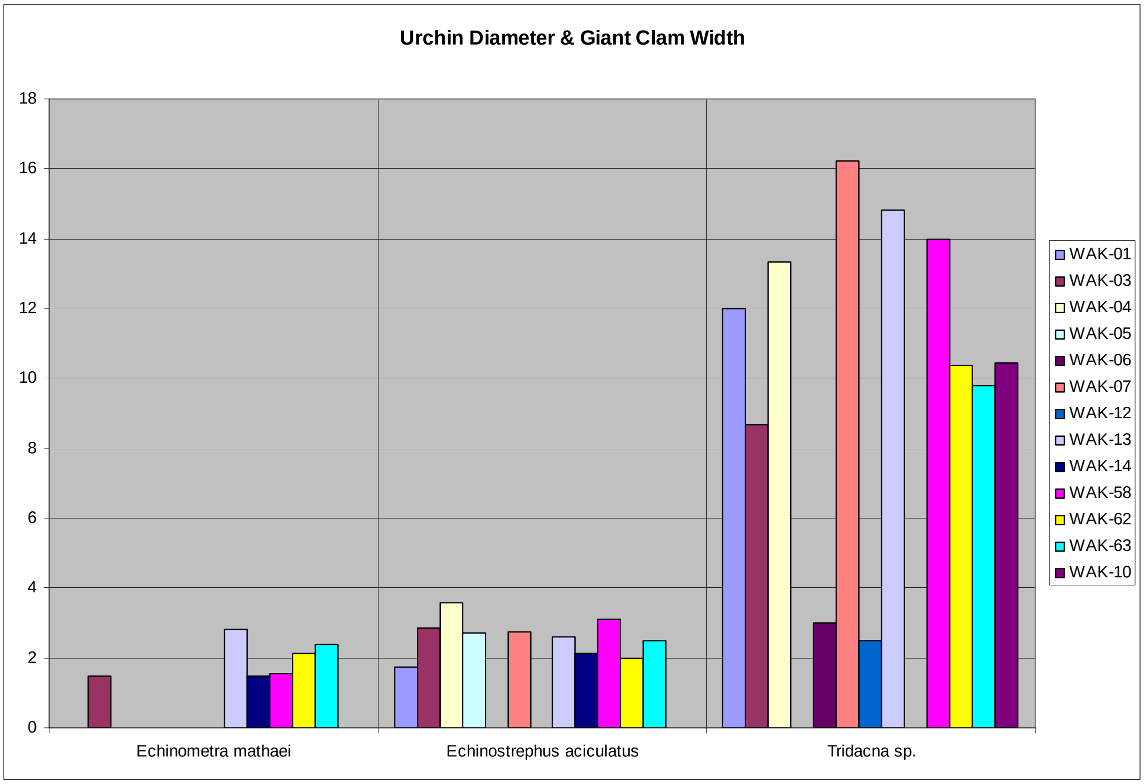


Figure B.3.4.2.--Chart revealing the mean test diameter of urchins and mean valve width of giant clams (*Tridacna maxima* and *T. squammosa*) encountered at each site.

Table B.3.4.3.--ARMS deployment locations around Wake Atoll.

REA site	Date deployed	Reef zone	Approx. depth(ft)	# of ARMS	Latitude		Longitude	
					Deg	*Min*	*Deg*	*Min*
WAK-08	03/22/2009	Forereef	43	3	19	18.9920	166	35.8940
WAK-09	03/23/2009	Forereef	46	3	19	16.2394	166	39.0946
WAK-06	03/25/2009	Forereef	43	3	19	16.8482	166	37.6637
WAK-10	03/26/2009	Lagoon	4	3	19	18.6303	166	36.2168

Figure B.3.4.3.--Sites where ARMS were installed at Wake Atoll in March 2009.

Table B.3.4.4.--Specimens collected at Wake Atoll, March 2009.

Genus	species	Count	Station
Phyllidiella	*pustulosa*	1	WAK-1
Phyllidiella	*pustulosa*	2	WAK-1
Andeadoris	*egrettae*	1	WAK-1
Thuridilla	*bayeri*	1	WAK-1
Roboastra	*arika*	1	WAK-2
Holothuria	*edulis*	1	WAK-4
Holothuria	*edulis*	1	WAK-4
Holothuria	*edulis*	1	WAK-4
Lissocarcinus	*orbicularis*	1	WAK-4
Holothuria	*atra*	1	WAK-5
Actinopyga	*mauritiana*	1	WAK-5
Actinopyga	*mauritiana*	1	WAK-5
Cypraea	*helvola*	1	WAK-6
Calcinus		2	WAK-6
Linckia	*laevigata*	1	WAK-7
Lybia	*tessellata*	1	WAK-7
Galatheid		3	WAK-7
Xanthid		1	WAK-7
Majid		1	WAK-7
Xanthid		3	WAK-7
Alpheid		1	WAK-7
Chromodoris		1	WAK-8
Chromodoris		4	WAK-8
Stichopus	*chloronotus*	1	WAK-8
Calcinus		2	WAK-9
Ophiuroid		2	WAK-9
Linckia	*laevigata*	1	WAK-9
Holothuria	*hilla*	1	WAK-10
Holothuria	*difficilis*	1	WAK-10
Holothuria	*difficilis*	3	WAK-10
Stichopus	*horrens*	1	WAK-10
Euapta	*godeffroyi*	1	WAK-10
Linckia	*multifora*	2	WAK-10
Culcita	*schmideliana*	1	WAK-11
Glossodoris		1	WAK-11
Haminoea	*symbalum*	2	WAK-11
Ophiuroid		2	WAK-11
Ophiuroid		1	WAK-11
Lima		2	WAK-11
Amphinomid		1	WAK-11
Ophiuroid		1	WAK-12
Xanthid		1	WAK-12
Conus	*textile*	1	WAK-12
Cypraea	*isabella*	1	WAK-12
Holothuria	*arenicola*	1	WAK-14
Holothuria	*arenicola*	4	WAK-14
Linckia	*guildingi*	1	WAK-13
Sipunculan		2	WAK-14
Eriphia	*sebana*	1	WAK-14
Petrolisthes		3	WAK-14
Xanthid		1	WAK-14
Xanthid		1	WAK-14
Xanthid		2	WAK-14
Xanthid		1	WAK-14

Genus	species	Count	Station
Culcita		1	WAK-9
Bohadschia	*argus*	1	WAK-9
Bohadschia	*argus*	1	WAK-9
Linckia	*guildingi*	1	WAK-9
Holothuria	*pervicax*	1	WAK-10
Holothuria	*arenicola*	1	WAK-10
Holothuria	*atra*	1	WAK-10

Genus	species	Count	Station
Xanthid		1	WAK-14
Alpheid		1	WAK-14
hermits		4	WAK-14
Alpheid		1	WAK-14
Grapsid		1	WAK-14
Cypraea	*mauritiana*	1	WAK-14

B.3.5 Benthic Towed-diver Surveys

During the 2009 reef assessment monitoring program (RAMP) mission, the Coral Reef Ecosystem Division (CRED) towed-diver team completed 21 surveys at Wake Island covering 42.2 km (42.2 ha) of ocean floor. Mean survey length was 2.0 km with a maximum length of 2.7 km and a minimum of 0.8 km. Mean survey depth was 14.8 m with a maximum depth of 19.7 m and a minimum of 8.5 m. Mean temperature on these surveys was 25.6°C with a maximum temperature of 25.9°C and a minimum of 25.3°C.

Seventeen benthic towed-diver surveys were completed at Wake in 2009 including four calibration tows. Habitats covered during surveys were consistent with continuous reef being the predominant habitat along the eastern, northern, and western forereefs. The southern forereef was composed of mostly patch reefs with some large pinnacles interspersed with sand and rubble.

Benthic Category	Mean ± SE
Hard Coral	22.4 ± 0.7
Soft Coral	6.5 ± 0.5
Sand	8 ± 0.9
Rubble	10.6 ± 1.3
Macroalgae	12 ± 0.8
Coralline Algae	3.7 ± 0.3
Sea cucumbers	31947*
Giant Clams	579*

* Sum of observed individuals

Hard coral was the most abundant benthic feature, accounting for 22.4% of total benthic cover island-wide. Hard coral was most abundant along the eastern reef flats where one survey recorded 35% coverage. Other areas of high cover include the western reef crest and patch reef and sections of the northern reef crest. The dominant hard coral genera observed were the *Favidae, Astreopora, Montipora, Porites*, and *Pocillopora*. Very little or no amounts of coral stress were observed throughout all surveys in 2009. Octocorals averaged 6.5% island-wide with elevated numbers along the northern reef crests.

Macroalgae accounted for 12% of benthic cover island-wide. The greatest coverage occurred in the northeast and small sections of the northwest, where species of the genera *Liagora* formed dense aggregations covering the benthos. *Liagora* in the northeast was also covered by an epiphyte that was not observed amongst other aggregations in the northwest. Elsewhere, species of the genera *Dictyota* and *Halimeda* were consistently observed throughout all other surveys. Very little or no amounts of coralline algae were observed during 2009 surveys.

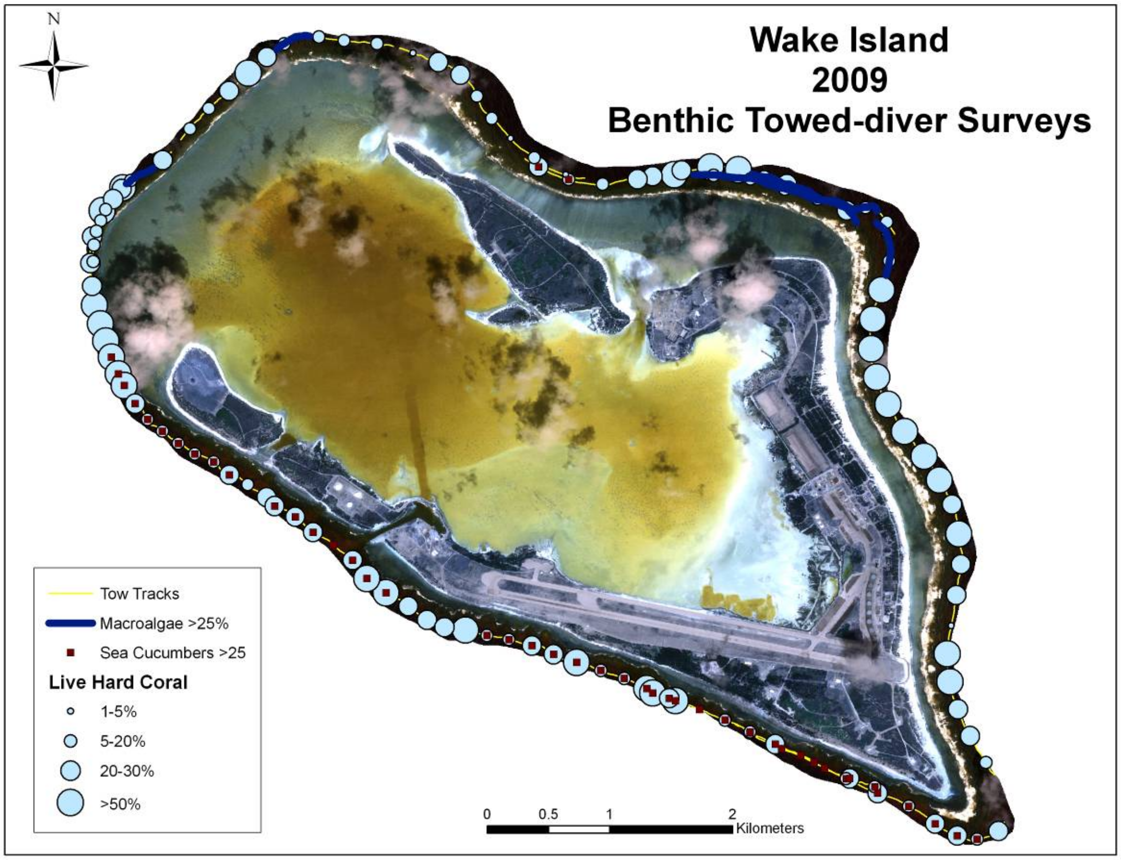


Figure B.3.5.1.--Hard coral cover, elevated macroalgae cover (> 25%), and elevated sea cucumber abundances during tow segments at Wake in 2009.

A total of 31,947 sea cucumbers were recorded during surveys at Wake in 2009. The majority of observations occurred on southern-facing reefs, most often amongst the rubble patches between patch reefs. The sea cucumbers, *Actinopyga mauritiana* and *A. edula* accounted for nearly all observations in the south. Observations of *Holothuria argus* were observed in other surveys.

Observer Calibration

A total of 40 paired observations of benthic cover were made at Wake in 2009 to investigate interobserver calibration between benthic divers. For each paired observation, the difference between binned observations from both observers was calculated and then the cumulative relative frequencies of the difference were calculated (Table B.3.5.1). Macroalgae, coralline algae, sand and hard coral had the high agreement between observers with almost 90% of observations being within 1% cover bin. Soft coral and rubble had lower agreement possibly due to their patchy nature.

Table B.3.5.1.—Paired observations of benthic cover results.

Difference	Hard Coral	Soft Coral	Sand	Rubble	Macro-algae	Coralline algae
0	57.5	35	57.5	55	62.5	42.5
1	87.5	65	92.5	77.5	97.5	92.5
2	100	72.5	100	90	100	100
+2	100	72.5	102.5	100	100	100

B.4 Fish Surveys

B.4.1 REA Fish Surveys

Wake Island

Stationary point count data (SPC)

During the survey period, SPC surveys were conducted at 29 sites around Wake. Parrotfishes were the largest contributors to total biomass with 7.5 kg 100 m^{-2}. Surgeonfishes were the second largest contributors to total biomass with 0.7 kg 100 m^{-2}, followed by jacks at 0.6 kg 100 m^{-2} (Fig. B.4.1.1).

Overall observations

A total of 171 fish species were observed during the survey period by all divers. Nine new species were identified for Wake Island (see range extension page). The average total fish biomass around Wake during the survey period was 11 kg 100m^{-2} for the SPC surveys.

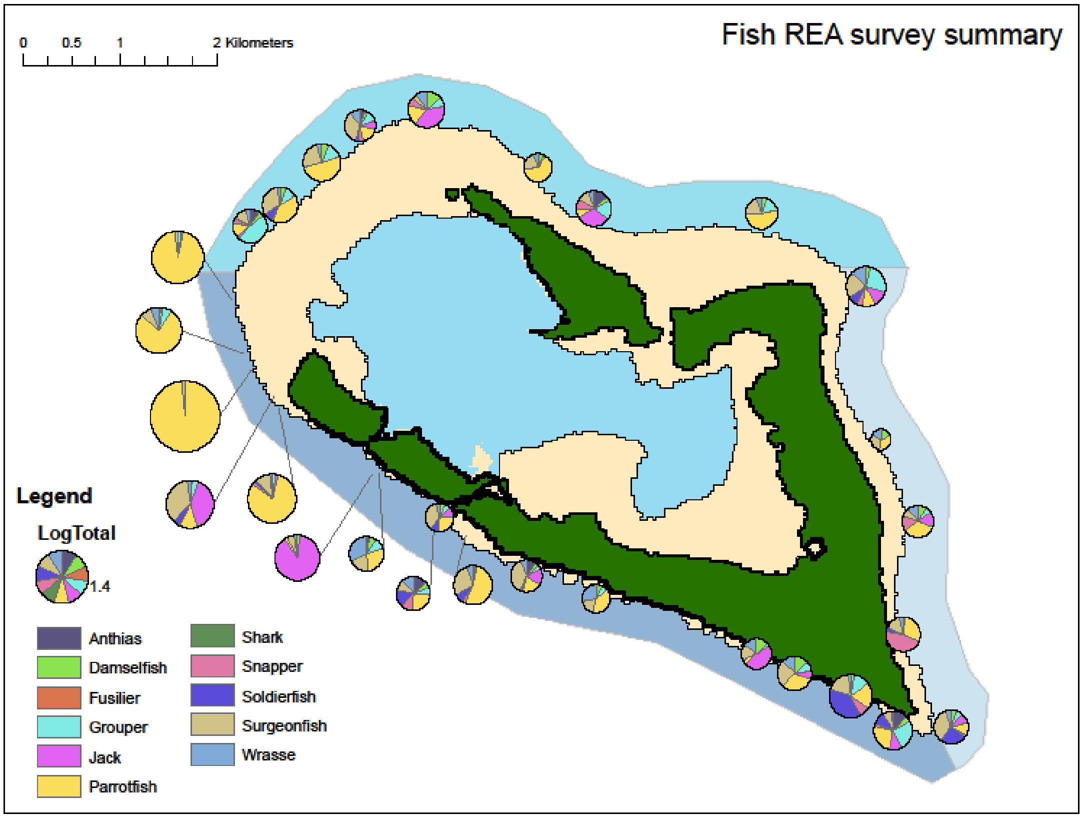


Figure B.4.1.1.—Site location and distribution of total fish biomass by family. The size of the pie chart is proportional to fish biomass.

Wake Atoll Range Extensions

Lethrinus xanthochilus

Observed by three divers, (MON, KOB, and KSM) on multiple occasions on the south side of Wake Atoll. Photo: Marc Nadon.

Calatomus carolinus

Observed by two divers (KOB, PMA) on multiple occasions on the south side of Wake Atoll. Divers obtained good sightings and are 90% sure of proper identification. Photo: Kevin O'Brien

Scarus altipinnis
Observed by four divers (KOB, MON, PMA, KSM) on multiple occasions on the south side of Wake Atoll, specifically at site Wake-59. Divers are 100% certain of proper identification. Photos: Kevin O'Brien, Marc Nadon.


Arothron nigropunctatus
Observed once by diver Paula Ayotte at site Wake-60 (south side of Wake Atoll). Cues for identification include body shape and ventral profile, fin coloration, and spot pattern on body. Photo: Paula Ayotte

Macolor niger

Observed on two occasions on the southeast side of Wake Atoll by divers Kevin Lino and Edmund Coccagna. One photo was obtained, but a positive identification could not be made. According to the observers, the eye was much larger than it appears in the photo. Photo: Kevin Lino

Oplegnathus fasciatus

Observed on two separate occasions by divers Marc Nadon and Kevin Lino on the south side of Wake Atoll. Photo: Marc Nadon

Cheilio inermis
Observed on one occasion by diver Paula Ayotte at 85 ft. This sighting was made at site Wake-65 on the north side of the atoll. Diver is 70% sure of proper identification. No picture was obtained.

Acanthurus olivaceus
Observed on one occasion by two divers (MON, KSM) on the southeast tip of Wake Atoll. Very clear sighting. Divers are 100% sure of proper identification. No picture was obtained.

Acanthurus dussumieri
Observed on one occasion near Stoner shipwreck by one diver (MON). Diver 70% sure of proper identification in retrospect. No picture was obtained.

B.4.2 Towed-diver Fish Surveys

During the 2009 RAMP mission, the CRED towed-diver team completed 21 surveys at Wake Island covering 42.2 km (42.2 ha) of ocean floor. Mean survey length was 2.0 km with a maximum length of 2.7 km and a minimum of 0.8 km. Mean survey depth was 14.8 m with a maximum depth of 19.7 m and a minimum of 8.5 m. Mean temperature on these surveys was 25.6°C with a maximum temperature of 25.9°C and a minimum of 25.3°C.

Table B.4.2.1--Survey statistics for towboard sampling during HI0901.

Species	#	#/100m^2	#/ha	Biomass (kg/100m^2)	t/ha
Caranx melampygus	23	0.005	0.541	0.060	0.006
Seriola dumerili	2	0.000	0.047	0.002	0.000
Carcharhinus amblyrhynchos	61	0.014	1.435	0.092	0.009
Chanos chanos	5	0.001	0.118	0.005	0.000
Diodon hystrix	1	0.000	0.024	0.002	0.000
Fistularia commersonii	52	0.012	1.224	0.002	0.000
Cheilinus undulatus	30	0.007	0.706	0.117	0.012
Aprion virescens	1	0.000	0.024	0.000	0.000
Gymnothorax javanicus	9	0.002	0.212	0.019	0.002
Gymnothorax sp.	1	0.000	0.024	0.001	0.000
Aetobatus narinari	32	0.008	0.753	0.026	0.003
Bolbometopon muricatum	276	0.065	6.494	1.135	0.113
Chlorurus microrhinos	5	0.001	0.118	0.003	0.000
Hipposcarus longiceps	1	0.000	0.024	0.001	0.000
Scarus altipinnis	5	0.001	0.118	0.003	0.000
Scarus rubroviolaceus	1	0.000	0.024	0.001	0.000
Epinephelus polyphekadion	4	0.001	0.094	0.003	0.000
Epinephelus sp.	1	0.000	0.024	0.001	0.000

Species	#	#/100m^2	#/ha	Biomass (kg/100m^2)	t/ha
Epinephelus tauvina	2	0.000	0.047	0.001	0.000
Grouper sp.	2	0.000	0.047	0.001	0.000
Sphyraena barracuda	1	0.000	0.024	0.001	0.000
Sphyraena helleri	29	0.007	0.682	0.006	0.001
Grand Total	544	0.128	12.800	1.280	0.128
# of Species	22				

Five hundred forty-four individual large-bodied reef fish (> 50 cm TL) of 22 different species and 12 different families were encountered at Wake Island (Table B.4.2.1.). Overall numeric density for this class of reef fishes was 0.054 #/100 m^2 (5.361 #/ha) with a biomass density of 0.285 g/100 m^2 (0.028 t/ha). In terms of numeric density, the most prevalent species were *Bolbometopon muricatum* and *Carcharhinus amblyrhynchos* while for biomass density, *Bolbometopon muricatum* and *Cheilinus undulates* were the most prevalent.

Numeric density was dominated by the Scaridae (52%) family (Fig. B.4.2.1). Biomass was also dominated by Scaridae (78%) followed by Labridae (9%) (Fig. B.4.2.2.).

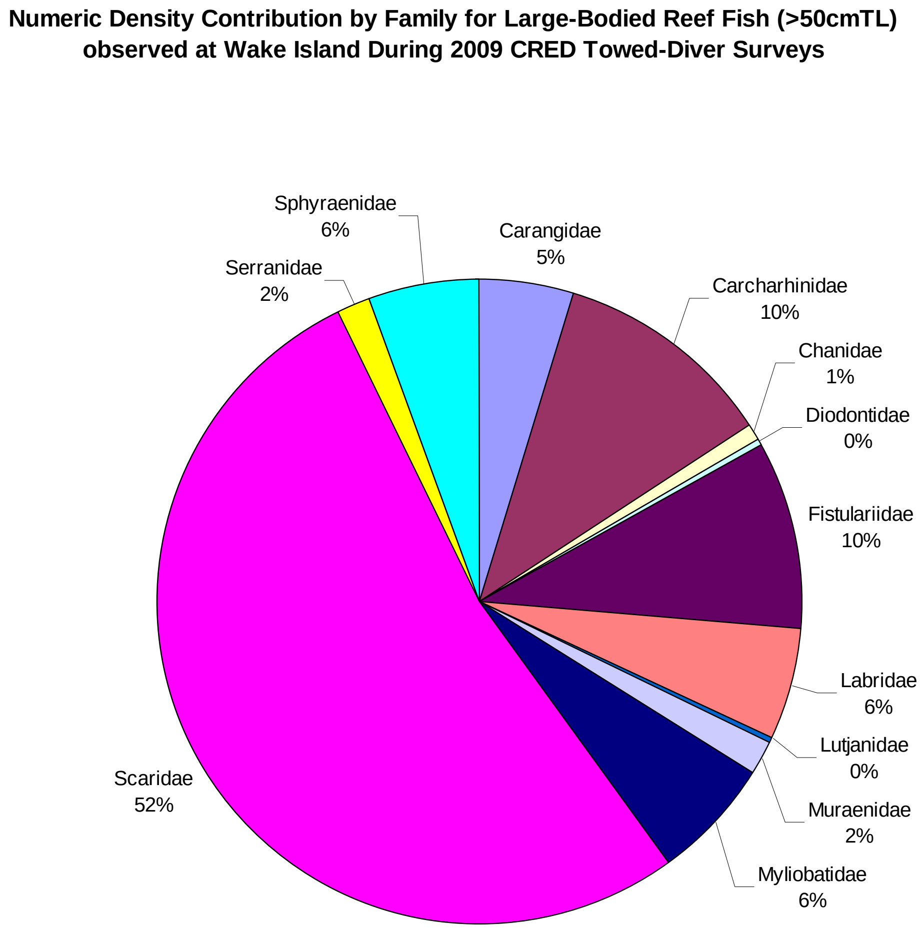


Figure B.4.2.1--Numeric density of observed fish by family at Wake Island.

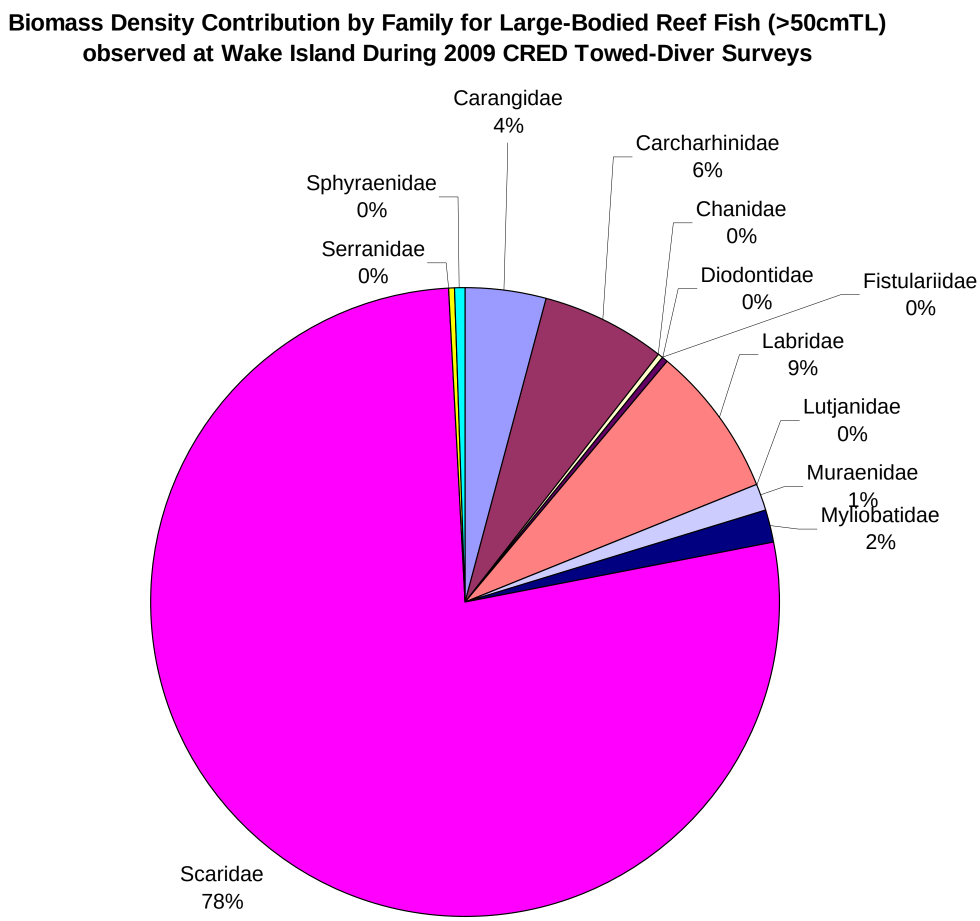


Figure B.4.2.2 --Biomass density of observed fish by family at Wake Island.