Foster

BASELINE MARINE BIOLOGICAL SURVEY
PEACOCK POINT OUTFALL AND OTHER POINT-SOURCE DISCHARGES
WAKE ATOLL, PACIFIC OCEAN

prepared by

U.S. Department of the Interior
Fish and Wildlife Service
Pacific Islands Ecoregion
Honolulu, Hawaii 96850

and

U.S. Department of Commerce
National Marine Fisheries Service
Pacific Area Office
Honolulu, Hawaii 96822

prepared for

Department of the Army
U.S. Army Space and Missile Defense Command
Post Office Box 1500
Huntsville, Alabama 35807

March 1999

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MAR - 5 1999

Mr. Dru Barrineau
Chief, Environmental Division
ATTN: SMDC-EN-V
P.O. Box 1500
Huntsville, AL 35907-3801

Re: Final Baseline Marine Biological Survey Report, Peacock Point Outfall and Other Point-Source Discharges, Wake Atoll

Dear Mr. Barrineau:

On behalf of the U.S. Army Space and Missile Defense Command, biologists from the U.S. Fish and Wildlife Service (Service) and the National Marine Fisheries Service (NMFS) were invited to Wake Atoll in June 1998. The purpose of the visit was to conduct baseline marine biological surveys at and adjacent to the Peacock Point outfall pipe and to examine the sites of other point-source discharges to the marine environment. The enclosed final report contains the results of these surveys.

We would like to express our sincere appreciation for the professional support extended to Service and NMFS staff during the survey. Special thanks are due to Randy Gallien and Gary Gunter of your staff for arranging the required logistical and funding support. Mike Timmons and Mark Henz of Chugach Development Corporation (CDC), and Prasert, a Thai national under contract to CDC, assisted with on-site diving support. As a result, our biologists were able to successfully work together to accomplish their objectives. Based on the survey results, recommendations to help reduce discharge-related impacts to the coral-reef resources of Wake Atoll were developed.

We hope you find the enclosed report to be beneficial in planning environmental protection at Wake Atoll. If you have questions concerning the report, please feel free to contact Service biologists Michael Molina or Kevin Foster at 808/541-3441 or NMFS biologist John Naughton at 808/973-2940.

Robert P. Smith
Pacific Islands Manager
Pacific Islands Ecoregion
US Fish and Wildlife Service

Charles Karnella
Administrator
Pacific Islands Area Office
National Marine Fisheries Service

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INTRODUCTION

Wake Atoll, located approximately 2,100 miles west of Honolulu at 19° 18' North Latitude and 166° 35' East Longitude, is one of the most isolated atolls in the world. The land closest to Wake is Taongi Atoll in the Marshall Islands, which is approximately 300 miles (mi) to the south. Wake is a possession of the United States. It is owned by the U.S. Air Force and leased to the U.S. Army Space and Missile Defense Command (SMDC) in support of the Ballistic Missile Defense Organization (BMDO). The facility is operated by Chugach Development Corporation (CDC), under contract to the SMDC, as a target missile launch complex. The atoll also serves as a refueling and logistical stop for various military and military-contracted aircraft. The atoll is inhabited by approximately 25 U.S. citizens and 100 foreign workers from Thailand, and it hosts a transient population that fluctuates for brief periods throughout the year.

The emergent land area of Wake Atoll is approximately 1,828 acres (ac). This area consists of three low-lying coral islets (Wake, Peale and Wilkes) that border the north, south, and east sides of a shallow lagoon. The western side of the atoll is comprised of a reef flat that is partially exposed at low tide. The area of submerged coral-reef habitat at Wake Atoll is approximately 7,907 ac (Hunter 1995). At the surface of the ocean, the atoll is approximately 4.5 mi long by 2.0 mi wide. The installation has only one sewage outfall pipe, which is located near Peacock Point at the southeastern corner of the atoll. Solids in the raw sewage are allowed an opportunity to settle within a series of basins before the liquids are allowed to pass, untreated, through the outfall pipe into the marine environment. The end of the outfall pipe is located approximately 70 feet (ft) from shore, at a depth of 35 ft. Normally, the effluent is discharged through the pipe for approximately 15 minutes, twice daily.

On behalf of the SMDC, biologists from the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) were invited to Wake Atoll in June 1998. The purpose of the visit was to conduct baseline marine biological surveys in the vicinity of the Peacock Point outfall pipe and to examine the sites of other point-source discharges to the marine environment (*i.e.*, power plant, desalinization plant, and stormwater outlets). The biologists were asked to (1) generally characterize the coral-reef habitats within the vicinity of the outfall, (2) document the primary species of reef fishes, corals, other macroinvertebrates, and algae that exist in those habitats, and (3) investigate whether the reef communities at the other sites appeared to have been impacted by the discharges. This report contains the results of these surveys.

SURVEY METHODOLOGY

For the purposes of the Peacock Point Outfall survey, six stations were established on the seaward reef slope along the southern exposure of the atoll (Figure 1). These included one station upcurrent of the outfall (W-1), a station that was centered at the end of the outfall pipe (W-2), two stations downcurrent of the outfall (W-3 and W-4), and two control stations that were downcurrent and estimated to be outside the influence of the outfall (W-5 and W-6).

Station W-1 was located at coordinates 19° 16.120' N and 166° 39.318' E, approximately 500 ft southeast (upcurrent) of the outfall pipe and within the discharge's Zone of Mixing (ZOM). Station W-2 was located at coordinates 19° 16.190' N and 166° 39.262' E, at the end of the outfall pipe and at the center of the discharge's Zone of Initial Dilution (ZID), which was estimated to have a radius of approximately 18 ft from the end of the pipe. Station W-3 was located at 19° 16.213' N and 166° 39.139' E, within the ZOM approximately 500 ft northwest (downcurrent) of the pipe. Station W-4 was located at coordinates 19°16.359' N and 166° 38.858' E, near the downcurrent limit of the ZOM approximately 1640 ft from the end of the pipe. Station W-5 was located at 19°16.819' N and 166° 37.710' E, approximately 1.5 mi northwest of the pipe. Finally, Station W-6 was located at 19°17.853' N and 166° 35.902' E, approximately 4.5 mi northwest of the pipe.

A standardized Rapid Ecological Assessment (REA) technique was used to record observations on species and habitat conditions at each station. The technique included timed 30-minute scuba dives from a 28-ft boat that was provided by the SMDC and operated by CDC staff. During each dive, biologists swam over the reef in a meandering fashion with a minimum amount of backtracking. Species of reef fishes, corals, other macroinvertebrates, and algae were recorded. Emphasis was given to identifying conspicuous, diurnally active species. As a result, small, cryptic, and nocturnally active species are under represented in the data. For molluscs, many species identifications were based on empty shells. Observations on the presence of sea turtles were made opportunistically.

The relative abundances of observed species were ranked as Abundant, Common, Occasional, or Rare. These categories were defined as follows: Abundant (A) = the species contributes substantial abundance or coverage (25+% of total) or is very numerous in the survey area or is dominant within parts of the survey area; Common (C) = the species is present as several or more individuals or as a few larger colonies or is conspicuous in only one or a few parts of the survey area; Occasional (O) = the species is uncommon or present only as a few individuals or as a few large colonies but not contributing substantially to abundance or substrate coverage anywhere within the survey area; and Rare (R) = the species is present on the basis of only one individual seen within the survey area.

In addition, a general description of the reef habitat at each station, including the percent composition of reef substrate cover, was recorded. The latter was calculated from 50 observation points that were evenly spaced along a 165-ft transect line located at a depth of 35 ft at each station. Seven general types of cover were used to characterize the reef substrate including Hard Coral, Soft Coral, Coralline Algae, Macroalgae, Turf-Covered Boulders, Coralline-Algal Rubble, and Sand.

The survey team responsible for the investigation included USFWS biologists Michael Molina (corals and reef substrate cover) and Kevin Foster (noncoral macroinvertebrates and algae) and NMFS biologist John Naughton (fishes and station habitat descriptions). The identity of certain species of algae were confirmed by Dr. Isabella Abott, Department of Botany, University of Hawaii.

RESULTS

Peacock Point Outfall

The types and percentages of substrate cover recorded at a depth of 35 ft at each of the six stations established for the Peacock Point outfall survey are given in Table 1. Lists of the dominant species of marine organisms observed at the six stations are presented in tables 2 through 7. These include reef fishes (Table 2), corals (Table 3), molluscs (Table 4), echinoderms (Table 5), other macroinvertebrates (Table 6), and macroalgae (Table 7).

Station W-1:

Habitat

This station is located in a high energy environment near the eastern tip of the atoll, which is exposed to the prevailing wind and swell. The reef slopes seaward at 25° to 45° and drops precipitously from approximately 30 to 60 feet. Steep ridges and deep channels form an irregular substrate that is comprised of coral (44%), macroalgae (22%), coralline algae (12%), sand (12%), soft coral (8%), and coralline-algal rubble (2%). Relatively high coral cover and bottom relief provided excellent habitat for a variety of marine life. Water clarity was relatively good with visibility being estimated to be approximately 100 ft. No evidence of algal fouling was observed.

Biota

Seventy-seven reef-fish species belonging to 21 families were observed. Most of these species were wrasses, surgeonfishes, parrotfishes, and butterflyfishes. The most abundant fish species included the surgeonfish *Zebrasoma flavescens*, the butterflyfishes *Chaetodon ephippium* and *C. ulietensis*, the damselfish *Chromis acares*, the snapper *Lutjanus monostigmus*, the goatfish *Mulloides vanicolensis*, the squirrelfish *Sargocentron spinniferum*, the soldierfish *Myrpristis murdjan*, and schools of the rudderfish *Kyphosus cinerascens*. Twenty-one species of corals from eight families were represented. Most of these corals belong to the families Faviidae and Acroporidae. The most abundant corals included *Pocillopora eydouxi* and *Porites lutea*. Twenty-two species of other macroinvertebrates were observed, including six molluscs, six echinoderms, and ten species from other phyla. The sea urchins *Echinometra mathaei* and *Echinostrephus* sp. were abundant. Twelve species of macroalgae, primarily belonging to the phyla Chlorophyta (green algae) and Phaeophyta (brown algae), were recorded. The most abundant algae were the blue-green alga *Lyngbya majuscula* and the brown alga *Dictyota divaricata*. An unidentified alga of the genus *Dictyota* was particularly abundant in the reef channels.

Station W-2:

Habitat

This station is located in a relatively low to moderate energy environment, which results from the natural protection from wind and swell afforded to it by the orientation of the atoll. The reef slopes gradually seaward, and widely spaced coral-covered pinnacles are present at depths from 35 to

60 ft. The pinnacles provided the best habitat for marine organisms. Dense swarms of newly recruited larval fish and suspended algal particles contributed to relatively poor water clarity with visibility estimated to be approximately 50 ft. In general, the substrate is comprised of sand (52%), coralline-algal rubble (30%), coralline algae (8%), coral (6%), and macroalgae (4%). No signs of algal fouling were observed although debris (*e.g.*, metal pipes, valves, wire, and parts of netting) clutters the bottom in the vicinity of the outfall.

Biota

Fifty-nine species of reef fish from nineteen families were observed. Most of these species were surgeonfishes, wrasses, parrotfishes, and butterflyfishes. The most abundant fish species included the surgeonfishes *Acanthurus triostegus* and *Ctenochaetus hawaiiensis* and the damselfish *Chromis acares*. Thirteen species of corals from six families were recorded. Most of these corals belong to the families Faviidae and Acroporidae. The most abundant corals included *Pocillopora eydouxi* and *Porites lutea*. Twenty three species of other macroinvertebrates were observed, including eight molluscs, ten echinoderms, and five species from other phyla. None of these species were considered abundant. Sixteen species of macroalgae, primarily belonging to the phyla Chlorophyta (green algae) and Phaeophyta (brown algae), were recorded. The most abundant alga present was the blue-green alga *Lyngbya majuscula*.

Station W-3:

Habitat

This station is also located in a relatively low to moderate energy environment due to it being protected from wind and swell by the atoll. The reef slopes gradually seaward with coral-covered pinnacles being denser than at Station W-2. Again, the pinnacles provided the best habitat for marine life, and suspended algal particles and larval fish contributed to relatively poor water clarity. Visibility at this station was fair and estimated to be approximately 65 ft. The substrate is generally comprised of sand (36%), coralline-algal rubble (28%), macroalgae (26%), turf-covered boulders (8%), and coral (2%). No signs of algal fouling were observed although some metal debris was observed on the bottom.

Biota

Fifty-eight species of reef fish within eighteen families were observed. The majority of these species were wrasses, butterflyfishes, parrotfishes, and surgeonfishes. The most abundant fish species included the surgeonfish *Ctenochaetus hawaiiensis* and the damselfish *Chromis acares*. Observed corals included 15 species belonging to six families, with the family Faviidae being most well represented. The corals *Favia pallida*, *Pocillopora eydouxi*, and *Porites lutea* were most abundant. Thirteen species of other macroinvertebrates were observed, including two molluscs, five echinoderms, and six species from other phyla. None of these species were considered abundant. Twelve species of macroalgae, primarily belonging to the phyla Chlorophyta (green algae) and Phaeophyta (brown algae), were recorded. The blue-green alga *Lyngbya majuscula*, the green alga *Halimeda opuntia*, the brown alga *Dictyota divaricata*, and the same unidentified species of *Dictyota* that was seen in the channels at Station W-1 were most abundant.

Station W-4:

Habitat

This station is also located in a relatively low to moderate energy environment. The reef drops sharply from 15 to 55 ft and from there slopes gradually seaward to a depth of approximately 90 ft with large pinnacles rising from the bottom. At 90 ft, the reef drops vertically to greater depths. Water clarity was fair with visibility estimated to be approximately 65 ft. The substrate at this station is comprised of coralline-algal rubble (38%), sand (26%), turf-covered boulders (16%), coral (14%), and macroalgae (6%).

Biota

Sixty-three species of reef fish belonging to 20 families were recorded. Most of these species were wrasses and surgeonfishes. The butterflyfish *Heniochus acuminatus* and the damselfishes *Chromis acares* and *C. agilis* were the most abundant species observed. Twenty-five species of coral from six families were seen. Most of these species belong to the families Faviidae and Acroporidae. *Favia pallida*, *Pocillopora eydouxi*, and *Porites lutea* were the most abundant corals. Twenty species of other macroinvertebrates were observed, including six molluscs, six echinoderms, and eight species from other orders. The giant clam *Tridacna maxima* was observed to be abundant. Three green sea turtles (*Chelonia mydas*) were seen at a depth of approximately 45 ft. Fourteen species of macroalgae, primarily belonging to the phyla Chlorophyta (green algae) and Phaeophyta (brown algae), were recorded. The blue-green alga *Lyngbya majuscula*, the green alga *Halimeda opuntia*, the brown alga *Dictyota divaricata*, and the same unidentified species of *Dictyota* that was seen in the channels at Station W-1 were most abundant.

Station W-5:

Habitat

Station 5 is located in a relatively low to moderate energy environment. A relatively wide reef shelf extends out from the shoreline and slopes seaward at an angle of approximately 20° from 5 to 15 ft in depth. From there, the reef drops sharply and levels at 55 ft before descending at an angle of approximately 30° to a depth of 90 ft. Below 90 ft, the reef drops sharply. High coral cover and vertical relief provides good habitat for marine life. Water clarity was good at this station with visibility estimated to be approximately 100 ft. The substrate is comprised of coral (54%), macroalgae (34%), coralline algae (10%), and soft coral (2%).

Biota

Sixty reef-fish species belonging to 19 families were observed. The majority of these species were surgeonfishes and wrasses. Only one fish species, the fairy basslet *Pseudanthias pascalus*, was considered abundant. Twenty-one species of coral within seven families were recorded, with the families Faviidae and Acroporidae being the most well represented. The corals *Favia pallida*, *Pocillopora eydouxi*, and *Porites lutea* were the most abundant species seen. Eighteen species of other macroinvertebrates, including five molluscs, seven echinoderms, and six species from other orders were observed. None of these species were considered to be abundant. Two adult *Chelonia*

mydas were observed at a depth of approximately 40 ft. Fourteen species of macroalgae, primarily from the phyla Cholorophyta (green algae) and Phaeophyta (brown algae), were identified at this station. The green alga *Halimeda opuntia*, the brown alga *Dictyota divaricata*, and the blue-green alga *Lyngbya majuscula* were the most abundant of these species.

Station W-6:

Habitat

This station is located in a relatively moderate energy environment. The reef gradually slopes seaward to 25 ft and then drops abruptly to 50 ft where it continues to descend at an angle of approximately 30° to a depth of 80 ft. Below 80 ft, the reef drops sharply into deeper water. Water clarity at this station was good with visibility estimated to be 100 ft. The substrate is comprised primarily of macro-algae (40%), coral (38%), coralline algae (10%), sand (8%), and coralline-algal rubble (4%).

Biota

Fifty-two species from eighteen families of reef fishes were seen at this station. Among these species, butterflyfishes, surgeonfishes, parrotfishes, and wrasses were most well represented. The most abundant species included the butterflyfish *Chaetodon lunula*, the parrotfish *Bolbometopon muricatum*, and the damselfish *Chromis acares*. Thirty-four species of coral within nine families were recorded. The majority of these species belong to the families Faviidae and Acroporidae. *Favia pallida*, *Pocillopora eydouxi*, and *Porites lutea* were the most abundant corals. Seventeen species of macro-invertebrates were observed. Among these species were three molluscs, six echinoderms, and eight species from other phyla. The crab *Trapezia* sp. 1 was particularly abundant at this location and could easily be found in the branches of the coral *P. eydouxi*. One green sea turtle was observed at a depth of approximately 55 ft. Eleven species of macroalgae, primarily from the phyla Chlorophyta (green algae) and Phaeophyta (brown algae) were represented. The green alga *Caulerpa peltata* was the most abundant algal species at this site.

Other Point-Source Discharges

Power Plant:

The power plant discharges cooling water into the lagoon. The substrate fronting the plant was primarily sand, with less than 5% coral cover. Cooling water was being discharged at an established point and from an unexpected second point located about 100 ft to the west. A smell similar to that of hydrogen sulfide emanated from both drainage streams, and metal debris littered the bottom and shoreline adjacent to the plant. The temperature of the discharge is cooler than the ambient temperature of the receiving water in the lagoon, and no evidence of thermal stress was observed. *Enteromorpha* sp., a green alga, was present in the drainage plume, and corals (*Pocillopora damicornis*), green algae (*Caulerpa peltata*) and giant clams (*Tridacna maxima*) were commonly observed on the surrounding lagoon substrate.

Desalinization Plant:

Although the desalination plant was inactive during the survey period, it also discharges cooling water into the lagoon when operational. The ambient water temperature surrounding the discharge point was estimated to exceed 100 ° Fahrenheit at the time of the survey. The substrate fronting the plant was primarily sand that appeared to lack the invertebrate and algal species commonly seen at other locations in the lagoon, and this may be evidence of natural thermal stress. The bottom sediments near the discharge were dark colored and possibly anoxic due to frequently stagnant water conditions. When mobilized, the sediments gave off a strong smell similar to that of hydrogen sulfide.

Airport Runway:

Stormwater from the airport is collected and discharged onto the shallow, seaward reef flat located off the eastern end of the runway. This reef flat appeared to be typical of other similar reef flats found on Wake, with relatively low coral density and no sign of algal fouling. Surgeonfishes (*Acanthurus sordidus* and *A. triostegus*), parrotfishes (*Scarus* sp.), seacumbers (*Holothuria* sp.), corals (*Pocillopera verrucosa* and *P. eydouxi*), algae (*Caulerpa* sp.), giant clams (*Tridacna maxima*), and rock crabs (*Grapsus* sp.) were observed at the outfall site. These species appeared to be in good health and and behaving normally. There was no sign of algal fouling.

Fuel Farm:

Stormwater collected at the fuel farm is discharged into the lagoon through three outlets. The algal community fronting these drains appeared normal, with no sign of algal fouling. Animal species casually observed at these discharge points included: flounders (*Bothus mancus*), butterflyfishes (*Chaetodon ariga*), mullet (*Crenimugil crenilabis*), giant clams (*T. maxima*), rock crabs (*Grapsus* sp.), octopus, tube worms, and bryozoans. All of the organisms observed appeared to be healthy and behaving normally.

Housing Area (near bridge between Wake and Peale islets):

The outlet appears to have been covered by sediments and is no longer operable.

DISCUSSION

A total of 122 species of reef fishes, 41 species of corals, 39 species of other macroinvertebrates, and 19 species of macroalgae were recorded at Wake Atoll during this survey. Undoubtedly, many more species among all groups are present at the atoll, but a more complete inventory was beyond the scope of the survey. None of the species observed are considered to be endemic to Wake. Marine endemism at Wake is expected to be low due to the atoll's downcurrent proximity to sources of planktonic larval recruitment. Although relatively isolated, Wake receives larvae transported by the North Equatorial Current and the Subtropical Countercurrent from reefs in the Marshall, Caroline, and Mariana islands. Nevertheless, overall marine species diversity at Wake is expected to be much lower than it is within these other island chains due to its more northern latitude. For some marine species, Wake's location is very near or at the northern limit of their known range.

Peacock Point Outfall

The survey results indicate that the marine resources at Wake are not at risk from exposure to the sewage effluent discharged at the Peacock Point Outfall. There did not appear to be any algal fouling present either at the outfall or at any of the other survey stations. Reef fish and macroinvertebrate behavior appeared normal at all survey stations. The relative abundances and distributions of these species did not appear to vary significantly among stations. Although coral species diversity appeared to be least at and immediately downcurrent of the outfall, this is likely the result of a paucity of suitable substrate for successful coral establishment at stations W-2, W-3, and W-4, where sand, rubble, and boulders made up between 64% and 82% of the substrate cover. Furthermore, no sign of degradation or decay of corals was seen at any of the stations within the ZID and ZOM. However, without quantitative analyses of potential contaminant bioaccumulation and biomagnification in the tissues of these organisms, it is difficult to be absolutely certain of health of these resources.

A dense mat of blue-green algae was observed on the reef flat between the outfall and the east end of Peacock Point, which is also the site of an old WWII dump that is still used. Although it does not appear that the outfall discharge is adversely impacting the adjacent reef, it is possible that the dump is having a deleterious effect. The continued presence of the algal mat may be the result of elevated iron levels contained in runoff from the dump, which contains a very large concentration of metal debris at the end of the point. If this is the case, it is possible that the algal mat may grow in size and possibly spread to lower energy subtidal areas. Due to the close proximity of the algal mat to the outfall, the possibility of the algal mat fouling the outfall is plausible.

Other Point-source Discharges

The results of our inspections of the reef at the other point-source discharge sites revealed no indication that either the reef habitats or the biotic communities they support have been degraded by the discharges. No algal fouling was seen at any of the discharge points. Also, the marine organisms present at each discharge point appeared to be healthy and behaving normally.

At the power plant, the temperature of the discharge is actually lower than the ambient receiving water temperature and thermal stress from the discharge seems unlikely However, the second discharge noted at the power plant may have indicated the existence of a break in the discharge pipe, and it was noted that this second discharge was causing some shoreline erosion. At the desalination plant, little marine life was seen near the discharge point. This is probably the result of naturally elevated water temperatures due to stagnant water conditions rather than due to a discharge since the plant is currently not active. The discharge points at the fuel farm and airport runway exhibited no signs of algal fouling, and the marine communities present appeared healthy and normal.

Recommendations

1. Remove the metal debris at the eastern end of the dump as soon as possible;

2. Monitor the effects of the metal removal-activities on the blue-green algal mat;

3. Monitor the general reef area downcurrent (southwest) of the dump for the establishment of similar colonies of blue-green algae;

4. Sample and analyze tissues from reef organisms near the outfall for the presence of PCBs, metals, dioxin, and other contaminants; and

5. Investigate the power plant's discharge pipe for breaks, and repair the pipe as soon as possible, if necessary.

REFERENCES

Colin, P.L. and Arneson, C. 1995. Tropical Pacific Invertebrates - A Field Guide to the Marine Invertebrates Occurring on Tropical Pacific Coral Reefs, Seagrass Beds and Mangroves. Beverly Hills, California: Coral Reef Press. 296 p.

Hunter, C.L. 1995. Review of Status of Coral Reefs Around American Flag Pacific Islands and Assessment of Need, Value, and Feasibility of Establishing a Coral Reef Fishery Management Plan for the Western Pacific Region. Final report prepared for the Western Pacific Regional Fishery Management Council. 30 p.

Myers, R.F. 1989. Micronesian Reef Fishes - A Practical Guide to the Identification of the Coral Reef Fishes of the Tropical Central and Western Pacific (2nd ed.). Agana, Guam: Coral Graphics. 298 p.

Randal, J.E. and Randal, H.A. 1987. Annotated checklist of the fishes of Enewetak Atoll and other Marshall Islands. In: D.M. Devaney, E.S. Reese, B.L. Burch, and P.Helfrich (eds.), The Natural History of Enewetak Atoll, Volume II, Biogeography and Systematics. U.S. Department of Energy, Office of Scientific and Technical Information, Oak Ridge, Tennessee. Pages 289-324.

Veron, J.E.N. 1993. Corals of Australia and the Indo-Pacific. Honolulu, Hawaii: University of Hawaii Press. 644 p.

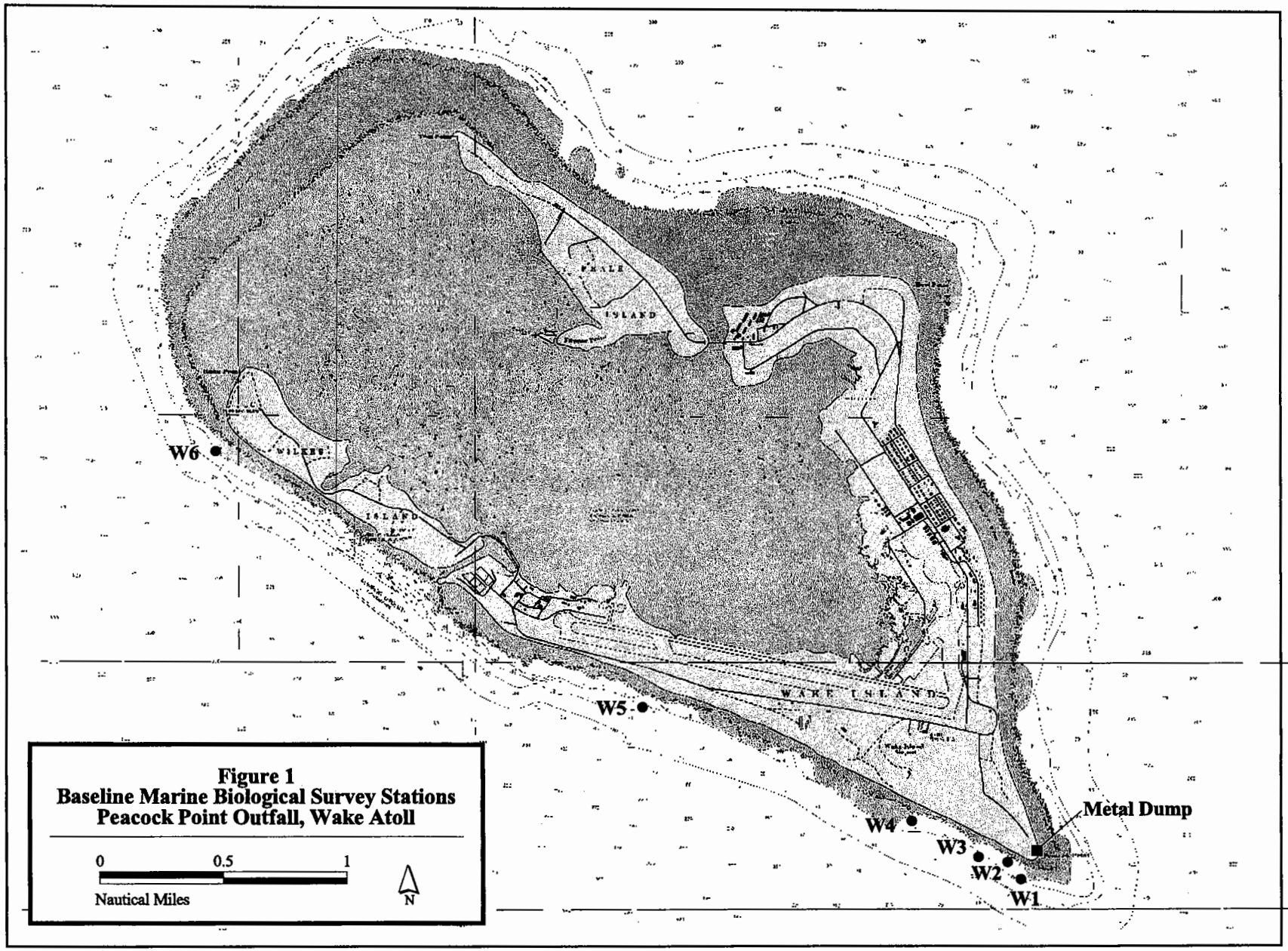

Figure 1
Baseline Marine Biological Survey Stations
Peacock Point Outfall, Wake Atoll

Table 1. Substrate cover at each of six stations surrounding the Peacock Point Outfall, Wake Atoll, in June 1998. Values are expressed as the percentage of total cover contributed by each substrate type. Blanks in the table indicate that the respective substrate type was not recorded on the transect at a particular station. See text for additional details.

SUBSTRATE TYPE	Survey Stations					
	W-1	W-2	W-3	W-4	W-5	W-6
Hard Coral	44	6	2	14	54	38
Soft Coral	8				2	
Coralline Algae	12	8			10	10
Macroalgae	22	4	26	6	34	40
Turf-Covered Boulders			8	16		
Coralline-Algal Rubble	2	30	28	38		4
Sand	12	52	36	26		8
TOTAL	100	100	100	100	100	100

Table 2. Reef-fish species observed at six stations surrounding the Peacock Point Outfall, Wake Atoll, in June 1998. Relative abundance is indicated as A = Abundant, C = Common, O = Occasional, and R = Rare. Observed fish schools are indicated by an asterisk (*). Blanks in the table indicate that the respective species was not recorded at a particular station. See text for additional details.

FAMILY *Genus/species*	Survey Stations					
	W-1	W-2	W-3	W-4	W-5	W-6
CARCHARHINDIDAE (Requiem Sharks)						
Carcharhinus amblyrhynchos	R			R		
MYLIOBATIDAE (Eagle Rays)						
Aetobatis narinari	R					
MURAENIDAE (Moray Eels)						
Gymnothorax javanicus	R			R		R
CHANIDAE (Milkfish)						
Chanos chanos			R			C*
HOLOCENTRIDAE (Squirrelfishes, Soldierfishes)						
Myripristis berndti	C		O		C	
M. murdjan	A				C	
Neoniphon opercularis					O	
Sargocentrum spiniferum	A	O	O		C	
FISTULARIIDAE (Coronetfishes)						
Fistularia commersonii		R		O*		R
SERRANIDAE (Fairy Basslets, Groupers)						
Pseudanthias pascalus					A	A
Cephalopholis argus	C	C	C	C	C	C
C. urodeta			R	R		
Epinephelus fasciatus		R	R	R		O
E. merra	R			R	R	
E. microdon	R	R	R			R
E. tauvina	R		O		R	
E. hexagonatus	R					
CIRRHITIDAE (Hawkfishes)						
Paracirrhites arcatus	C	R	O	O	O	
P. forsteri		O	O	O	O	
P. hemistictus				R	R	

Table 2. (Continued)

FAMILY *Genus/species*	Survey Stations					
	W-1	W-2	W-3	W-4	W-5	W-6
CARANGIDAE (Jacks, Trevallies)						
Decapterus macarellus		C		O	C	
Carangoides orthogrammus			R			
Caranx lugubris	R	R				O
C. melampygus	O	C	C	C*	C*	O
C. sexfaciatus						C*
Scomberoides lysan		C*				R
Trachinotus bailloni						O
LUTJANIDAE (Snappers)						
Aphareus furca	R					R
Macolor niger	R					
Lutjanus fulvus	C	O	O	O	O	R
L. monostigmus	A	C	R	O	C	
LETHRINIDAE (Emperors)						
Monotaxis grandoculus	C	O	R	O	O	O
Lethrinus kallopterus				C		R
L. ramak	C	R	R			R
MULLIDAE (Goatfishes)						
Mulloides vanicolensis	A				O	
Parupeneus barberinus		R	O	R		
P. bifasciatus	C	O	O	O	O	O
P. multifasciatus	O		R		O	
PEMPHERIDAE (Sweepers)						
Pempheris oualensis					C	R
KYPHOSIDAE (Rudderfishes)						
Kyphosus bigibbus	O			O	R	O
K. cinerascens	A*	C	O	C		C
CHAETONDONTIDAE (Butterflyfishes)						
Chaetodon auriga	O		C	R		R
C. ephippium			R			R
C. lunula	A	C	C	C	O	A
C. lineolatus		R				
C. ornatissimus	O	O	R			O
C. oxycephalus			R			
C. quadrimaculatus	R	C	C	O	O	R
C. punctatofasciatus					R	
C. ulietensis		O		R	O	R
Hemitaurichthys thompsoni	A			A		
Heniochus acuminatus	R					

Table 2. (Continued)

FAMILY *Genus/species*	Survey Stations					
	W-1	W-2	W-3	W-4	W-5	W-6
POMACANTHIDAE (Angelfishes)						
Centropyge flavissimus	C	C	O	C	C	O
C. loriculus	R	O			R	
OPLEGNATHIDAE						
Oplegnathus punctatus	O				R	
POMACENTRIDAE (Damselfishes)						
Chromis acares	A	A	A	A	C	A
C. agilis	C	C	C	A	C	
C. vanderbilti	C		C			
Abudefduf saxatilis				C		
A. sordidus				O		
LABRIDAE (Wrasses)						
Cheilinus chlorourus	R	R	O		R	
C. undulatus	R	R	R	R		R
C. unifasciatus	O	R	R	O	R	
C. fasciatus	O					
Epibulus insidiator	O	O	O	R		R
Novaculichthys taeniourus				R		
Anampses caeruleopunctatus	R			R	R	
Coris aygula	R		R	O	R	R
Gomphosus varius	R	C	C		O	
Halichoeres hartzfeldii					R	
H. chrysus					O	
H. margaritaceus		O				O
H. melanurus	R					
Hemigymnus fasciatus	R	O		O	R	R
H. melapterus	R	R			R	
Stethojulis bandanensis	R			C		
Thalassoma amblycephalum	O		C	C	C	
T. lutescens		C	C	C	C	O
T. quinquevittatum					R	
Labroides bicolor					R	
L. pectoralis	R		R	R	R	
SCARIDAE (Parrotfishes)						
Bolbometopon muricatum	R	R		R		A
Cetoscarus bicolor	O					
Hipposcarus longiceps	O	O	O	R		

Table 2. (Continued)

FAMILY *Genus/species*	Survey Stations					
	W-1	W-2	W-3	W-4	W-5	W-6
SCARIDAE (continued)						
Scarus altipinnis			C	O		O
S. forsteni	C	C	C	C	C	C
S. frontalis		C	C			C
S. ghobban		O			C	
S. globiceps	O					
S. microrhinus	C		O		R	C
S. oviceps	O		R			R
S. rubroviolaceus	O	O				
S. sordidus	R				O	O
SPHYRAENIDAE (Barracudas)						
Sphyraena barracuda		R				R
ACANTHURIDAE (Surgeonfishes)						
Acanthurus achilles	R			C	C	C
A. blochii	O	O				
A. guttatus		C			C	
A. nigricauda		O	C		O	O
A. nigrofuscus		O		O	C	
A. nigroris	C	C	C	C	C	C
A. olivaceus	O	O	O			
A. triostegus	C	A	A	C	C	O
Ctenochaetus hawaiiensis	C	A	C	C	C	
C. striatus	C					O
Zebrasoma flavescens	A	C	C	C	C	O
Z. veliferum	O	O			R	
Naso hexacanthus	R			C*		
N. lituratus	C	O	C	C	C	O
N. unicornis			C			
ZANCLIDAE (Moorish Idols)						
Zanclus cornutus	O		R		R	
SIGANIDAE (Rabbitfishes)						
Siganus argenteus		R	R	O		
BOTHIDAE (Lefteye Flounders)						
Bothus mancus	R					

Table 2. (Continued).

FAMILY *Genus species*	Survey Stations					
	W-1	W-2	W-3	W-4	W-5	W-6
BALISTIDAE (Triggerfishes)						
Balistoides viridescens				R		
Melichthys niger	O	O		C		C
M. vidua	C	C	C	O	C	O
Rhinecanthus aculeatus			R			
R. rectangulus						
Sufflamen bursa	R	R	O	O		O
TETRAODONTIDAE (Puffers)						
Arothron meleagris				R		
A. stellatus				R		
Canthigaster amboinensis						
DIODONTIDAE (Porcupinefishes)						
Diodon hystrix				R		
TOTAL FAMILIES	21	19	18	20	19	18
TOTAL SPECIES	77	59	58	63	50	62

Table 3. Coral species observed at six stations surrounding the Peacock Point Outfall, Wake Atoll, in June 1998. Relative abundance is indicated as A = Abundant, C = Common, O = Occasional, and R = Rare. Blanks in the table indicate that the respective species was not recorded at a particular station. See text for additional details.

FAMILY *Genus/species*	Survey Stations					
	W-1	W-2	W-3	W-4	W-5	W-6
POCILLOPORIDAE						
Pocillopora eydouxi	A	A	A	A	A	A
P. meandrina	O	R		R	O	R
P. verrucosa						R
ACROPORIDAE						
Montipora danae					R	
M. foveolata				R		O
M. hoffmeisteri	O	O		C	C	C
M. informis						R
M. monasteriata	O	O	R	O	O	O
M. verrucosa		R	R		R	O
Acropora aculeus					R	R
A. nasuta				O	R	R
A. valida						R
Astreopora myriophthalma	O			O		
PORITIDAE						
Porites lutea	A	A	A	A	A	A
P. solida				O		R
AGARICIIDAE						
Pavona varians			R	R	C	O
Leptoseris mycetoseroides					R	R
FUNGIIDAE						
Fungia scutaria	O					R
MUSSIDAE						
Acanthastrea echinata	C	C	C	C	C	C
Symphyllia radians				R	R	
S. recta	O	R	R			
MERULINIDAE						
Merulina ampliata	R	R				R

Table 3. (Continued)

FAMILY *Genus/species*	Survey Stations					
	W-1	W-2	W-3	W-4	W-5	W-6
FAVIIDAE						
Favia favus	O		O	O	C	C
F. pallida	C	C	A	A	A	A
F. stelligera	R					
F. abdita	O		O	O	R	O
F. flexuosa					R	R
F. halicora						R
Goniastrea retiformis	C	O	C	C	C	C
G. pectinata					R	O
G. favulus					R	
Platygyra daedalea	O			O		O
P. sinensis	O		R	R		O
Leptoria phyrgia			R		R	R
Montastrea curta						R
M. valenciennesi		R		R	R	R
Leptastrea purpurea			O	O	O	
Cyphastrea microphthalma	O	O		C		O
C. serailia	R			O	R	R
Echinophora lamellosa	O		O	R		R
MILLEPORIDAE						
Millepora exaesa	R				R	O
TOTAL FAMILIES	8	6	6	6	7	9
TOTAL SPECIES	21	13	15	23	25	34

Table 4. Mollusc species observed at six stations surrounding the Peacock Point Outfall, Wake Atoll, in June 1998. Relative abundance is indicated as A = Abundant, C = Common, O = Occasional, and R = Rare. Blanks in the table indicate that the respective species was not recorded at a particular station. See text for additional details.

FAMILY *Genus/species*	Survey Stations					
	W-1	W-2	W-3	W-4	W-5	W-6
TRIDACNIDAE (Giant Clams)						
Tridacna maxima	C	C	C	A	C	O
STROMBIDAE (Conchs)						
Lambis truncata	O			O		
CONIDAE (Cones)						
Conus sp.	R					
C. imperialis	O	O		R	O	
C. flavidus		O			R	O
C. marmoreus		R	O			
C. abreviata	O	O		R	R	
TEREBRIDAE (Augers)						
Terebra maculata		R		O		
FASCIOLARRIDAE (Tulips)						
Pleuroploca sp.	R	R				
Fasciolaria sp.				R		
CYMATIIDAE (Tritons)						
Cymatium muricinum		R				
LIMIDAE (Files)						
Lima sp.					R	
OCTOPODIDAE (Octopus)						
Octopus cyanea						R
TOTAL FAMILIES	4	5	2	5	3	3
TOTAL SPECIES	6	8	2	6	5	3

Table 5. Echinoderm species observed at six stations surrounding the Peacock Point Outfall, Wake Atoll, in June 1998. Relative abundance is indicated as A = Abundant, C = Common, O = Occasional, and R = Rare. Blanks in the table indicate that the respective species was not recorded at a particular station. See text for additional details.

FAMILY *Genus/species*	Survey Stations					
	W-1	W-2	W-3	W-4	W-5	W-6
OPHIDIASTERIDAE (Starfishes)						
Linckia multifora	C	C	C	C	C	C
OPHIONEREIDAE (Brittle Stars)						
Ophioneris sp.		O				
OPHIOCOMIDAE (Brittle Stars)						
Ophiomastix sp.				O	O	O
HOLOTHURIDAE (Sea Cucumbers)						
Bohadschia sp.		O				
Holothuria atra		O				O
Holothuria edulis	C	C	C	C	C	C
STICHOPODIDAE (Sea Cucumbers)						
Thelenota ananas		O				
T. anax			O	C	C	
Stichopus sp.		O				
ECHINOMETRIDAE (Sea Urchins)						
Echinometra mathaei	A	C	C	C	C	C
Heterocentrotus trigonarius	C	O			R	
Echinostrephus sp.	A	C	C	C	C	C
SPATANGIDAE (Heart Urchins)						
Maretia planulata	C					
TOTAL FAMILIES	4	5	4	5	5	4
TOTAL SPECIES	6	10	5	6	7	6

Table 6. Other macroinvertebrate species observed at six stations surrounding the Peacock Point Outfall, Wake Atoll, in June 1998. Relative abundance is indicated as A = Abundant, C = Common, O = Occasional, and R = Rare. Blanks in the table indicate that the respective species was not recorded at a particular station. See text for additional details.

FAMILY *Genus/species*	Survey Stations					
	W-1	W-2	W-3	W-4	W-5	W-6
PALINURIDAE (Spiny Lobsters)						
Panulirus pencillatus	R			R	R	R
XANTHIDAE (True Crabs)						
Trapezia sp. 1	O	C	O	C	C	A
Trapezia sp. 2	C	C	C	C	C	C
Trapezia sp. 3	C	C	C	C	C	C
Trapezia sp. 4	C	C	C	C	C	C
STENOPODIDAE (Coral Shrimp)						
Stenopus hispidus				C		C
MELITHAEIDAE (Sea Fans)						
Acabaria sp.	O					
SPONGIIDAE (Sponges)						
Hippospongia sp.			O	O	R	O
DIDEMNIDAE (Sea Squirts)						
Diplosoma virens	O					
POLYCITORIDAE (Sea Squirts)						
Eudistoma sp.	O					
Clavelina sp.		R				
SERPULIDAE (Tube Worms)						
Spirobranchus giganteus	C		O	O		O
TERREBELLIDAE (Tube Worms)						
Unidentified Terrebellid	O					
TOTAL FAMILIES	6	2	2	5	3	5
TOTAL SPECIES	10	5	6	8	6	8
TOTAL OF ALL OBSERVED NONCORAL MACROINVERTEBRATE SPECIES	22	23	13	20	18	17

Table 7. Macroalage species observed at six stations surrounding the Peacock Point Outfall, Wake Atoll, in June 1998. Relative abundance is indicated as A = Abundant, C = Common, O = Occasional, and R = Rare. Blanks in the table indicate that the respective species was not recorded at a particular station. See text for additional details.

FAMILY *Genus species*	Survey Stations					
	W-1	W-2	W-3	W-4	W-5	W-6
CYANOPHYTA (Blue-green Algae)						
Lyngbya majuscula	A	A	A	A	A	O
Phormidium crosbyanum		C	O	C	O	
CHLOROPHYTA (Green Algae)						
Halimeda opuntia	C	C	A	A	A	C
Neomeris annulata	R	C	C	C	C	C
Caulerpa peltata	C	C	C	C	C	A
Caulerpa cupressoides	C	C	O	C	C	O
Caulerpa serrulata	C	C	C	C	C	O
Chladophora sp.		O	O	O		
Rhipilia orientalis	O	R		R		C
PHAEOPHYTA (Brown Algae)						
Dictyota divaricata	A	A	A	A	A	C
Dictyota sp. 1		C	O	C	C	
Dictyota sp. 2					C	C
Dictyopteris repens	O	R			O	C
Padina sp.		O				
Lobophora variegata	O	R	O	O		
Hincksia breviarticulata				O	O	
RHODOPHYTA (Red Algae)						
Liagora sp.	R					R
Jania micarthrodia		O	R	O	O	
Agloathamnion boergensenii		O		R		
TOTAL FAMILIES	4	4	4	4	4	4
TOTAL SPECIES	12	16	12	15	13	11