Northwestern Hawaiian Islands/Kure Atoll Assessment and Monitoring Program

Final Report

March 2002

Grant Number NA070A0457

William j. Walsh[1], Ryan Okano[2], Robert Nishimoto[1], Brent Carman[1].

[1] Division of Aquatic Resources
1151 Punchbowl Street Rm. 330
Honolulu, HI 96813

[2] Botany Department
University of Hawai`i MŪnoa
Honolulu, HI 96822

INTRODUCTION

The Northwest Hawaiian Islands (NWHI) consist of 9,124 km^2 of land and approximately 13,000 km^2 of coral reef habitat. They comprise 70% of all coral reef areas under U.S. jurisdiction. This isolated archipelago of small islands, atolls, reefs and banks represent a unique and largely pristine coral reef ecosystem. The islands support millions of nesting seabirds and are breeding grounds for the critically endangered Hawaiian monk seal and threatened green sea turtle. The reefs include a wide range of habitats and support a diverse assemblage of indigenous and endemic reef species, many of which have yet to be described.

Kure Atoll, located at the northwestern end of the NWHI chain (approximately 28º 25' N latitude and 178º 20' W longitude) is the northernmost atoll in the world. The atoll is located 91 km northwest of Midway Islands and nearly 1,958 km northwest of Honolulu. It is a nearly circular atoll with a diameter of 10 km (6mi). The outer reef is continuous

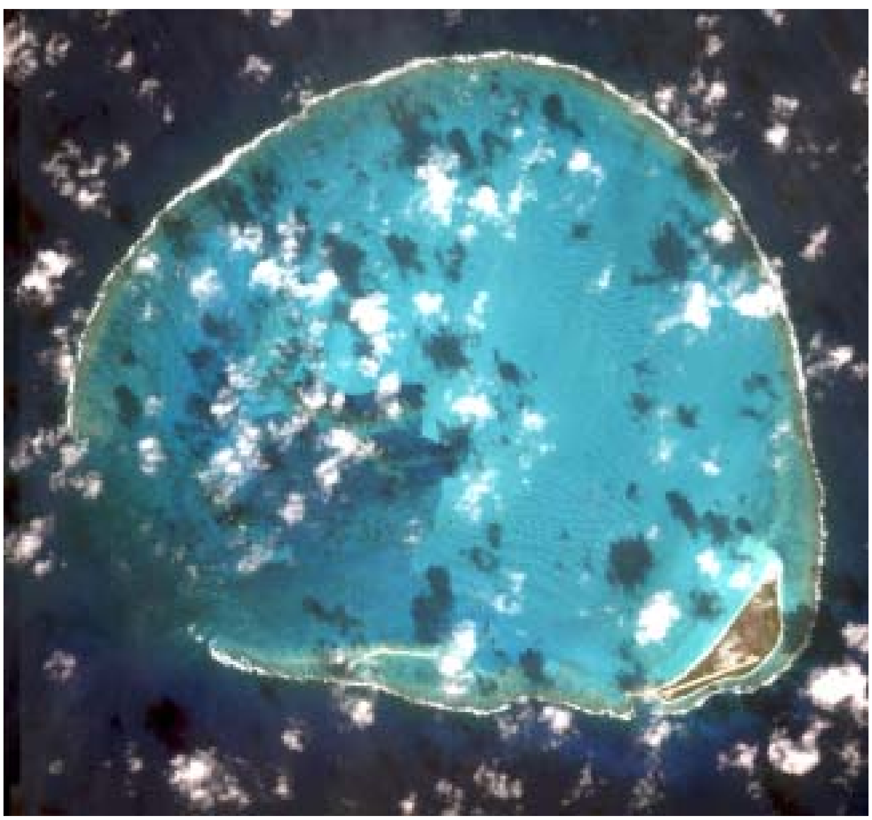


Figure 1. IKONOS satellite image of Kure Atoll

and almost encircles the atoll's lagoon except for passages to the southwest (Fig. 1). An emergent rock ledge consisting primarily of coralline algae and algally bound and encrusted coral is present along some sections of the reef crest. C-14 dating of this ledge indicates a present age of 1,510 ± 250 yrs. (Gross et al., 1969).

The interior of the atoll consists of a large sediment-built lagoon terrace with a maximum depth of 14 m. A series of elongate patch reefs of undetermined origin are located in the deeper section of the lagoon. The highest point of the atoll (6.1m) is on Green Island, the largest and most permanent land mass. It is located in the southeast sector and houses a Hawai`i Department of Land and Natural Resources (DLNR) field station. To the west of Green Island are a number of small sandbars collectively known as Sand Island. These sandbars may seasonally vary in size, shape and number.

Several agencies have management responsibility over the marine resources of the NWHI. The U.S. Fish and Wildlife Service administers two National Wildlife Refuges that protect all islands (excluding Kure), all reef areas at Midway, and all other reef areas to a depth of 10 fathoms. The National Marine Fisheries Service is responsible for monitoring and protecting monk seals and other marine mammals as well as sea turtles and fisheries resources within the U.S. Exclusive Economic Zone (EEZ). The State of Hawai`i Department of Land and Natural Resources (DLNR), Division of Aquatic Resources (DAR) has management responsibility for all marine resources out to 3 nm from all emergent lands, with the exception of Midway.

Kure Atoll is a state wildlife refuge under the jurisdiction of the Hawai`i Division of Forestry and Wildlife (DOFAW), DLNR. Although it is not part of the Hawaiian Island National Wildlife Refuge (HINWR), jurisdiction of the U.S. Fish and Wildlife Service and the National Marine Fisheries Service applies for the purposes of enforcing the Marine Mammal Protection and Endangered Species Acts. Additionally, waters and submerged lands from the seaward boundary of Hawai`i state waters out to a mean depth of 100 fathoms are designated as a Reserve Preservation Area within the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve.

Despite the actual and potential importance of the NWHI for biodiversity conservation, commercial and recreational fisheries as well as eco-tourism, its immense size and remoteness have challenged scientific observation, data gathering and effective management of this coral reef ecosystem. There is further concern that the islands and reefs have been degraded from the accumulation of derelict fishing gear which physically destroys reefs, entangles reef fauna and poses a risk of introducing alien species. Ship groundings have also impacted reef habitats by spilling fuel and scattering debris. An increased interest for access to the area by eco-tourism companies and proposals to develop additional coral reef fisheries such as bio-prospecting, marine ornamentals and precious corals have raised awareness by management agencies of the need to better assess and monitor this unique reef ecosystem. More comprehensive data is clearly needed for effective management and preservation.

Kure Atoll by virtue of its small size, northern-most location, and proximity to Midway (with potential charter boat and support facilities), may be particularly vulnerable to anthropogenic impact and ecosystem degradation. The State of Hawai`i also has primary management oversight for the reef resources within and around the Atoll. It is these factors which have prompted the current assessment and monitoring efforts.

The primary goal of this project was to characterize and document the shallow water community of Kure Atoll focusing primarily on back reef areas. This work is an initial description of these areas and serves as a baseline for future monitoring efforts. Specific objectives of this project were to:

- Characterize benthic habitats by estimating abundance and percent cover of important components including coral, coralline algae and macro algae.
- Describe the diversity and distribution of macro invertebrates.
- Describe the diversity, distribution and size composition of fishes.
- Describe the diversity and distribution of recently recruited fishes.
- Compile comprehensive species lists for fishes, corals and macroalgae
- Collect algal voucher specimens of all alien species, rare species, new records or new species.
- Attempt to locate recruitment habitats for larger apex predators particularly carangids.
- Conduct reconnaissance for the presence of alien species and derelict fishing gear.
- Collect fish specimens for genetic analysis.
- Deploy temperature data loggers.

Previous Marine Research in Kure waters

The earliest known study focusing on marine resources at Kure is by Gross et al. (1969) which provides a preliminary report on the geology of the atoll and a short discussion of its marine organisms and related environmental factors. Thomas F. Dana reported on the corals of Kure (Dana, 1971) as a result of field work with the Scripps Institution of Oceanography's 1968 STYX expedition and its 1969 Pacific Ocean Biological Survey Program (POBSP). Hobson and Chess (1979) investigated nocturnally emerging zooplankton from the lagoon floors of Kure and Midway.

Two major multi-agency research investigations focusing on marine resources have been conducted at Kure Atoll. The first, known as the **Tripartite Cooperative Agreement**, involved researchers from the National Marine Fisheries Service, The U.S. Fish and Wildlife Service, and what was then known as the Division of Fish and Game (now Division of Aquatic Resources). This project commenced in 1975 and continued for five years. Research efforts were wide ranging, encompassing onshore (turtles, seals, seabirds), nearshore (reefishes, ciguatera, lobsters) and offshore (plankton, bottomfishes, pelagics) resources.

A second research expedition was undertaken during September and October 2000. The **Northwestern Hawaiian Islands Reef Assessment and Monitoring Program (NOW-RAMP)** involved fifty scientists aboard two vessels. The primary object of this project was to conduct Rapid Ecological Assessments (REAs) of the Northwest Hawaiian Islands (NWHI) with the goal of acquiring adequate information to map, assess and eventually monitor and manage this unique coral reef ecosystem. The program encompassed a number of specific initiatives including:

- Inventory and assessment of benthos
- Fish and fisheries assessment
- Marine algal sampling and assessment
- Lagoon sediment and contaminants sampling
- Marine debris assessment and monitoring
- Mapping and remote sensing
- Hyperspectral sensing and imaging

A total of 35 REAs were conducted at Kure, the majority of which were at sites outside the lagoon and on patch reefs near the southwest sector (Fig. 2).

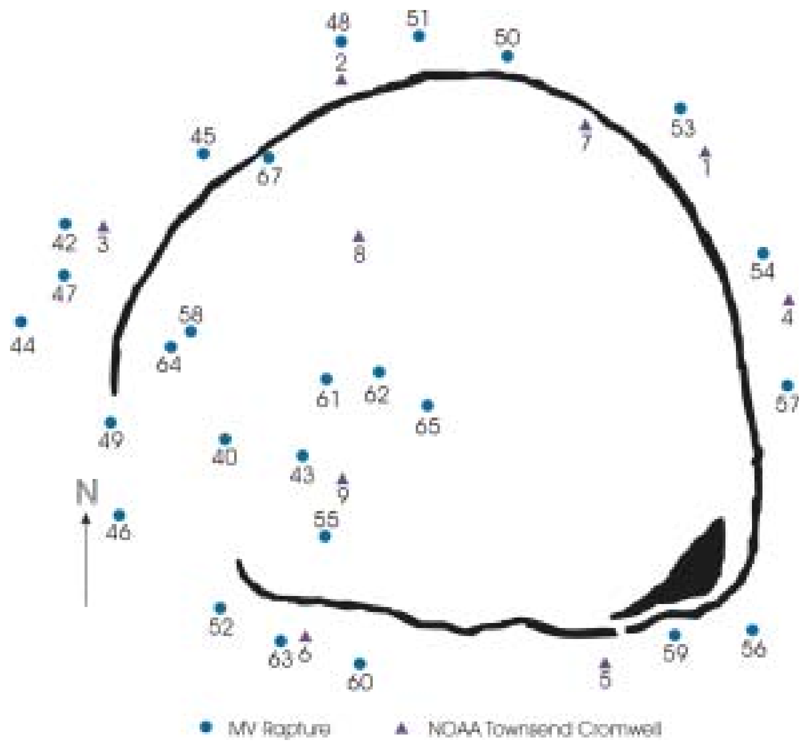


Figure 2. Kure Atoll NOW-RAMP REA sites - October 2000.

The site descriptions are included in Appendix 1. SCUBA was used for all REAs. The data from the NOW-RAMP program is presently under analysis.

DAR Kure 2001

In September 2001, the Division of Aquatic Resources initiated the first of what is anticipated to be regular field expeditions to Kure Atoll. The overall objectives of this long-term project are to further our understanding of the atoll's ecosystem and to increase the capacity and ability of DAR to monitor, assess and effectively manage the Atoll's marine resources.

Personnel from DAR (5), DOFAW (1) and the University of Hawai`i Mānoa (1) conducted field operations at Kure Atoll during the first two weeks of September. The focus of this expedition was to investigate shallow reef areas on the lagoon side of the reef crest and along the beaches adjacent to the islands. Previous NOW-RAMP REAs were conducted mostly in deeper SCUBA diving depths and shallow water environments were largely ignored. These shallower habitats are often important nursery areas in the main Hawaiian Islands for a number of species including carangids. Observations from the earlier NOW-RAMP expedition indicated that some predatory species such as giant ulua (*Caranx ignobilis*), and `Ǿmilu (*Caranx melampygus*), were larger and considerably more abundant overall than on reefs of the main Hawaiian Islands. Juvenile and small immature members of these species were scarce however, even though efforts were specifically made to locate them. Their virtual absence may be due to insufficient sampling or alternatively they may, in fact, be extremely scarce. If the latter is the case these seemingly robust populations of large predators may have an atypical, top heavy size distribution and therefore be extremely vulnerable to fishing pressure. Logistical constraints which precluded the use of SCUBA further directed the emphasis of the DAR Kure 2001 work to focus on assessing shallow (1-3m) habitats that had not been adequately investigated at any NWHI site.

REAs were conducted at 0.5 mi (0.8 km) intervals along the back reef just inside the reef crest, at three sites within the lagoon, and at a site adjacent to Green Island. A total of 28 sites were surveyed (Appendix 2). All sites were shallow (2-6 ft./0.6-1.8m) and were surveyed by snorkeling. In addition to the REAs, 3 reconnaissance snorkels were undertaken along the east and west sides of Green Island (Fig. 3).

METHODOLOGY

The REA methodology employed was compatible with that used during the NOW-RAMP expedition and ongoing surveys at other NWHI islands. Only snorkeling was done on this project however. The methodology consists of five primary elements:

1. Belt Transects for fishes:

The transecting method for fishes involves deploying a reeled 25m line from an initial haphazardly selected starting point. One of a pair of free divers swims a chosen bearing (parallel to reef or shore orientation) while unreeling the line. A second swims along side at least 2m away. As they swim, each diver visually estimates a corridor 2m wide by 4m high and records size specific counts (to the nearest 5cm) of all fishes >25cm TL. Upon reaching the end of the line the reel is affixed to the bottom and the divers commence to census fishes back to the starting point. On the return leg only fishes <25 cm TL are

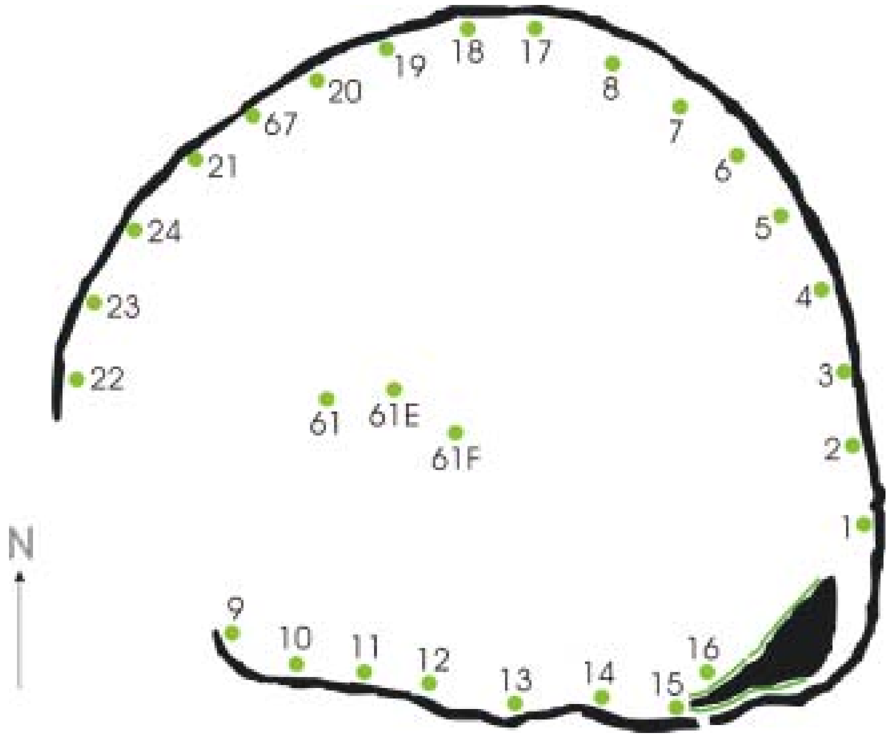


Figure 3. DAR Kure 2001 study sites. Lines along Green Island are recon snorkels.

recorded and they are grouped into 5cm bins based on Total Length (i.e. 1-5cm="A", 6-10cm="B", 11-15cm="C", etc. or classified as "recruits" or "juveniles" based on preestablished size limits. Recruits are fishes considered to have settled on the reefs within the past several weeks. Juveniles are those whose larger size presumably indicates earlier settlement but still within the present season. Together these two groups constitute the young of the year (YOY).

The fish transects at each site consisted of two adjacent 25m segments providing a total coverage per site of 200m^2. These data were used to estimate numerical and biomass densities and contributed to describing relative abundances (sensum DACOR) of the fish assemblage. In most instances density estimates are presented relative to a standard area of 100m^2.

2. DACOR for fishes:

Relative abundances of fishes in the general area of transects was determined by a free swim inspection after the belt transects were completed. Three snorkelers swam independently in areas adjacent to transects while recording the presence of additional species and noting relative abundances. The area was surveyed over a 25-30 minute period and typically encompassed at least 50m X 100m (5000m^2). Species were subsequently classified into the following relative abundance categories: **D**ominant (>100), **A**bundant (50-100), **C**ommon (11-49), **O**ccasional (6-10), and **R**are (1-5).

3. Belt Transects for Invertebrates:

Using a single pass along the two lines deployed for the fish transects a pair of divers censused 27 taxa of macro-invertebrates. Total area censused was 2 X 100m^2. Echinoderms (12 spp.) and Molluscs (9 spp.) were given particular emphasis due both to their censusability and for comparison with similar work done on the Big Island by DAR and the University of Hawai`i Hilo QUEST program (Quantitative Underwater Ecological Surveying Techniques).

4. Macroalgae:

Quantitative and qualitative algal data were collected at each site. To quantify macroalgal abundance by species, a 0.25 m^2 quadrat with 49 evenly spaced intersects (7 lines X 7 lines) was placed along each of the two transects at 5m intervals (n=10 placements/site.) Twenty of the 49 intersect points were randomly selected for analysis. When the quadrat was placed on the reef whatever was under these 20 intersects was determined and recorded. A total of 200 points were thus determined per site and since there were 28 study sites, a total of 5600 points were determined for the entire atoll.

Qualitative information on algae was obtained by observations along transects as well in the surrounding areas. These adjacent areas were typically smaller than those covered for fish DACOR. Algae that could be visually identified in the field were listed during the snorkel. Voucher specimens of turf algae and other algae that could not be identified in the field were collected to verify species identity. Every species of algae encountered at a site was either listed or collected

5. Benthic Characterization:

Digital videography methods developed in cooperation with the Hawai`i Coral Reef

Assessment and Monitoring Program (CRAMP) was used to estimate substratum abundance, diversity and distribution. A miniDV camcorder (Sony PC 100 - 1.07 mega pixels) in an underwater housing was held 0.5m off and perpendicular to the bottom. The diver-videographer snorkeled at a steady pace so as to cover the 25m line in approximately 8 minutes. Only the second of the two deployed transect lines at each site was videotaped for subsequent analysis. Due to technical difficulties, sites # 15 & 16 were not videotaped and thus not analyzed by this method.

PointCount 99 software was utilized for this analysis. Fifty randomly selected points on each of twenty randomly selected frames was employed to characterize the bottom. Due to the fact that a coral biologist was not on the expedition, most coral species identifications were subsequently made by examining the video images.

Coral abundance was also qualitatively documented through use of the DACOR method. Percent coverage for each species was based on a combination of colony size and number of colonies encountered along the transect. Species were classified as being Dominant (>50% coverage), Abundant (26%-50%), Common (6%-25%), Occasional (%1-5%), or Rare (<1%).

6. Genetic Analysis:

In addition to the REAs and reconnaissance snorkels, tissue samples (gill arches) were collected from 96 speared specimens of three fish species for genetic analysis (Microsatellite DNA). This was part of a project to determine gene flow within the Hawaiian archipelago. The species sampled were the endemic pelagic spawner (*Thalassoma duperrey*), a nonendemic pelagic spawner (*Acanthurus triostegus*) and a nonendemic demersal spawner (*Stegastes fasciolatus*). These specimens will be compared with specimens collected from Kaua`i, O`ahu, and the Big Island. This work will be completed later this year.

RESULTS & DISCUSSION

Algae

A total of 92 species of algae were collected or observed in the lagoon of Kure atoll during the expedition (Appendix 3). The number of algae species per site ranged from 14 to 34 with a mean number of 22.25 ±4.61 (SD). No alien species were recorded. Of the 92 species, 53 are new records for Kure atoll (Table 1). This increases the total known Kure atoll algae from 45 to 98 species, a 118% increase. The large increase of known Kure atoll algae is undoubtedly due to the limited amount of phycological work previously carried out there.

Of the 92 species, 15 were green algae, 16 were brown algae and 61 were red algae. Based on this initial shallow water collection, Kure appears to have an unusually high number of brown algae relative to the other groups as compared to the main Hawaiian Islands.

Table 1. Species list of algae collected or observed from Kure Atoll as of 2001.

Green algae	First Kure record	Other locations in NWHI
Ulvales		
Enteromorpha sp 2	Tsuda 1966	Pearl & Hermes
Ulva fasciata	Abbott 1989	Laysan, Necker
Cladophorales		
Microdictyon japonicum	Abbott 1989	Midway, Pearl & Hermes, Lisianski, Laysan
Microdictyon setchellianum	Tsuda 1966	Midway, Pearl & Hermes, Laysan, Maro, French Frigate Shoals, Necker
Dictyosphaeria cavernosa	Tsuda 1966	Midway, Lisianski
D. versluysii	Tsuda 1966	Pearl & Hermes, Lisianski, Laysan, Necker, Nihoa
Siphonoclades		
Boodlea composita	Okano DAR 2001	Pearl & Hermes
Ventricaria ventricosa	Okano DAR 2001	
Bryopsidales		
Bryopsis hypnoides	Abbott 1989	
Bryopsis pennata	Okano DAR 2001	Necker, Laysan, Lisianski
Codium edule	Okano DAR 2001	French Frigate Shoals, Lisianski, Midway
Codium reediae	Balazs 1979	Midway,
Caulerpa racemosa var *peltata*	Abbott 1989	Midway, Pearl & Hermes, Laysan, Necker, Nihoa
Caulerpa webbiana	Okano DAR 2001	Maro, Laysan, Lisianski, Pearl & Hermes
Halimeda discoidea	Abbott 1989	Midway, Pearl & Hermes, Lisianski, Laysan, Necker
Halimeda tuna	Okano DAR 2001	

Dasycladales		
Acetabularia parvula	Okano DAR 2001	Laysan
Acetabularia clavata	Okano DAR 2001	
Neomeris annulata	Okano DAR 2001	

Brown algae	First Kure record	Other locations in NWHI
Ectocarpales		
Hincksia mitchelliae	Okano DAR 2001	Nihoa, Necker, French Frigate Shoals, Maro
Sphacelariales		
Sphacelaria tribuloides	BISH	
Dictyotales		
Dictyota acutiloba	Balazs 1979	Midway, Laysan, Maro
Dictyota divaricata	Okano DAR 2001	Necker, Maro, Laysan, Pearl & Hermes, Midway
Dictyota friabilis	Okano DAR 2001	Necker, Maro, Laysan, Pearl & Hermes
Dictyota sp.	Tsuda 1966	Midway, Laysan
Lobophora variegata	Abbott 1989	Midway, Lisianski, Laysan, La Perouse, Necker
Padina japonica	Okano DAR 2001	
Stypopodium Hawaiiensis	Tsuda 1966	Midway, Pearl & Hermes
Punctariales		
Hydroclathrus clathratus	Okano DAR 2001	Necker, Maro, Laysan, Lisianski
Fucales		
Sargassum Hawaiiensis	Balazs 1979	
Sargassum obtusifolium	Abbott 1989	Midway, Pearl & Hermes, Laysan
Sargassum polyphyllum	Abbott 1989	Midway, Laysan, Maro, Necker
Turbinaria ornata	Abbott 1989	Midway, Pearl & Hermes, Lisianski, Laysan, French Frigate Shoals, Nihoa

Red algae	First Kure record	Other locations in NWHI
Porphyridiales		
Stylonema alsidii	Okano DAR 2001	Midway
Nemaliales		
Galaxura rugosa	Okano DAR 2001	Midway
Liagora ceranoides	Abbott 1989	Midway, Pearl & Hermes
Bonnemaisoniales		
Asparagopsis taxiformis	Balazs 1979	Midway, Pearl & Hermes, Laysan, Gardner, French Frigate Shoals, Nihoa
Corallinales		
Jania adhaerens	Okano DAR 2001	Necker, Laysan
Jania capillacea	Tsuda 1966	Midway, Pearl & Hermes, Lisianski, Necker
Jania micrarrhrodia	Okano DAR 2001	Laysan
Gigartinales		
Hypnea pannosa	Okano DAR 2001	Necker, Laysan
Hypnea spinella	Okano DAR 2001	Midway
Hypnea valentiae	Okano DAR 2001	
Peyssonnelia inamoena	Okano DAR 2001	
Portieria hornemannii	Okano DAR 2001	
Pugetia sp	Abbott 1989	
Gelidiales		
Gelidiopsis intricate	Balazs 1979	
Ceramiales		

Atithamnion antillanum	Okano DAR 2001	Maro, Pearl & Hermes
Atitthamnionella breviramosa	Okano DAR 2001	Necker, Midway
Centroceras corallophilloides	Okano DAR 2001	
Centroceras minutum	Okano DAR 2001	Necker
Ceramium clarionensis	Okano DAR 2001	French Frigate Shoals, Gardner, Maro, Laysan
Ceramium clavulatum	Tsuda 1966	Midway, Laysan, Necker
Ceramium codii	Okano DAR 2001	Maro, Laysan
Ceramium dumosertum	Okano DAR 2001	Necker, Maro, Laysan, Pearl & Hermes
Ceramium fimbriatum	Okano DAR 2001	Laysan
Ceramium flaccidum	Abbott 1989	Midway, French Frigate Shoals
Ceramium hamatispinum	Balazs 1979	
Ceramium tenuissimum	Okano DAR 2001	
Chondria arcuata	Okano DAR 2001	
Chondria polyrhiza	Okano DAR 2001	Nihoa, Maro
Corallophila apiculata	Okano DAR 2001	
Corallophila huysmansii	Okano DAR 2001	
Dasya iridescens	BISH	
Dasya pilosa	Okano DAR 2001	French Frigate Shoals
Dasya villosa	Balazs 1979	
Diplothamnion jolyi	Okano DAR 2001	
Griffithsia heteromorpha	Okano DAR 2001	Laysan
Haloplegma duperreyi	BISH	
Herposiphonia delicatula	Okano DAR 2001	
Herposiphonia nuda	Okano DAR 2001	
Herposiphonia obscura	Okano DAR 2001	
Herposiphonia pacifica	Okano DAR 2001	
Heterosiphonia crispella	Okano DAR 2001	Necker, Maro, Laysan, Lisianski, Pearl & Hermes
Laurencia galtsoffii	Okano DAR 2001	Maro, Laysan, Pearl & Hermes
Laurencia obtuse	Tsuda 1966	Midway, Gardner, French Frigate Shoals
Laurencia parvipapillata	Okano DAR 2001	Midway
Laurencia sp 1	Abbott 1989	Midway, Pearl & Hermes, Necker
Laurencia sp 3	Tsuda 1966	Laysan
Neosiphonia beaudettei	Okano DAR 2001	Maro, Midway
Polysiphona sparsa	Okano DAR 2001	Necker, Maro, Laysan
Polysiphonia upolensis	Abbott 1989	Pearl & Hermes, Laysan
Spirocladia hodgsoniae	Okano DAR 2001	
Spyridia filamentosa	Abbott 1989	Midway, Laysan
Taenioma perpusillum	Okano DAR 2001	Midway
Tiffaniella saccorhiza	Okano DAR 2001	
Vanvoorstia coccinea	Okano DAR 2001	Necker, Maro, Pearl & Hermes, Midway
Womersleyella pacifica	Okano DAR 2001	Lisianski

Function and Form Groups:

When looking at function and form groups, macro-algae had the highest total percent cover (Table 2). The percent cover (quadrat) method detected 22 species of macro-algae (Appendix 4); while a total of 40 species of macro-algae were collected or observed. Macro-algae species play a key role on the reef that is analogous to that of trees in a forest. Both macro-algae and trees provide structure, protection and food for many other inhabitants.

Table 2. Percent coverage of major benthic categories as determined by quadrat technique.

Benthic Category	**% Cover**
Macro-algae	32.70
Turf algae	31.55
Crustose coralline algae	15.91
Sand	11.41
Corals	6.05
Urchins	1.16
Chaetopterus sp.	0.84
Sea cucumbers	0.25
Blue green algae	0.09
Conus sp.	0.02
Sponges	0.02

Turf algae had the second highest total percent cover of any group and were collected at every site. In this case a turf alga is defined as an alga with a thallus of less than a centimeter. Of the 92 species of algae collected or observed during this expedition 52 species (57 %) were turf algae. Of the 52 species, 3 were greens, 4 were browns and 45 were red. It is likely that turf algae are a major food source for a majority of herbivores in Kure lagoon. Many species of surgeonfish, urchins and mollusks feed exclusively on turf algae. Turf algae may comprise the majority of photosynthetic biomass, represented by living attached specimens and by those in the guts of herbivores.

Crustose coralline algae had the third highest total percent cover of any group and were observed at every site. A percent cover such as this is an indicator of a healthy reef. Crustose coralline algae act like glue, helping to maintain the structure of reefs. They are also reef builders, providing structure for the inhabitants of the reef. Large herbivores such as parrotfish have been seen feeding on and leaving scratch marks on crustose coralline algae. Crustose coralline algae are important members of any Hawaiian reef community.

Given the abundance of macro and turf algae at Kure including known food items for the green turtle *Chelonia mydas* (Russell and Balazs 2000, Balazs et al. 2001) it was somewhat surprising to note the paucity of turtles. Only a single turtle was seen at any of the survey sites and only two were noted resting on the beaches. Other researchers have similarly noted the lack of turtles at Kure (Balazs, pers. comm.). Woodward (1972) cites an earlier reference to Kure's turtles by Captain Benjamin Morrell (Morrell, 1841). Morrell reported that "Green turtles were found here in great abundance, and two hawk's bill turtles were seen." Although Morrell's coordinates are inaccurate for Kure, based upon sailing time and direction Woodward states that the island definitely was Kure. If this is accurate, there appears to have been a catastrophic decline of Kure's turtle population from the mid 1800's.

Habitats:

Algal collections and percent cover data reflect the two major habitat types in the lagoon of Kure Atoll. The first habitat type is the stand of patch reefs located southwest of the atoll center. This habitat type was represented by sites 61, 61E, and 61F. Algae species such as *Acetabularia sp., Peyssonnelia inamoena* and *Vanvoorstia coccinea* were detected by the percent cover method (Appendix 3) and collected or observed only at these patch reef sites. Algae species such as *Acetabularia parvula, A.clavata, Ventricaria ventricosa, Antithamnion antillanum, Chondria arcuata, Jania micrarthrodia* and *Monosporus sp.* were collected or observed only from patch reef sites. *Hypnea pannosa* was found on only two of 25 back reef sites but occurred on all three patch reef sites. Benthic coverage of this species was an order of magnitude greater on the patch reefs (0.67% vs. 0.06%) although not quite statistically significant (t-test, P =0.07).

The second more extensively sampled habitat type was the back reef located just inside the atoll's barrier reef. This habitat type was represented by the other 25 sites. Algae species such as *Dictyota acutiloba, Lobophora varigata* and *Turbinaria ornata* were detected by the percent cover method and collected or observed only at sites just inside the barrier reef. *Neomeris annulata, Dictyota divaricata, Sargassum sp., Centroceras minutum, Corallophila apiculata, Crouania sp.* and *Liagora sp.* were only collected or observed at sites just inside the barrier reef. *Microdictyon setchellianum* algal cover was significantly greater on the sites located on the back reef (25%) than on the patch reef sites (4%) (t-test, P<.006). This was also true for the red alga *Laurencia galtsoffii* (3.9% vs. 0.8%, P<0.1).

Significant Algae Species:

Although the back reef sites just inside the atoll barrier reef were largely homogenous, there were a few sites that were somewhat different. Site #7 was unique in that it was adjacent to a nearby shipwreck of a fishing boat which ran around in the late 1970's (Gulko, in prep). Temperature data loggers were affixed during this project to the two pieces of this wreck. It has been suggested that *Lyngbya majuscula,* a blue-green algae, is often associated with shipwrecks (Maragos, pers. comm.). Site #7 was one of only two sites where *L. majuscula* was found attached. Although *L. majuscula* was not found directly attached to the wreck, it was attached to substrata surrounding the wreck. Site #11, the other site where *L. majuscula* was found, had only small numbers of attached *L. majuscula*. At site #7, *L. majuscula* was found abundantly, suggesting that *L. majuscula* does indeed have an association with shipwrecks.

Lyngbya majuscula was also consistently observed as drift within sandy areas around the lagoon. The extent and density of the *L. majuscula* population at site #7 does not appear sufficient to support the amount of drift observed. Since no other large population of *L. majuscula* was observed inside the lagoon, it is possible that the source of this drift is located outside Kure Atoll, most likely to the northeast.

Microdictyon setchellianum had the highest total percent cover (23%) for a single species and was collected at all sites. It is thus one of the most abundant species inside the atoll. *Microdictyon setchellianum* is represented by an overlapping morphology that forms many layers in Kure lagoon. This type of morphology has many nooks and crannies. This alga provides food for some larger herbivores and substrate for a community of turf algae and smaller species of sponges, zoanthids and anemones. It also provides cover for recruits and juvenile fish and smaller species of crustaceans and mollusks. During periods of high surf, percent cover of *Microdictyon setchellianum* may be decline, but it is suspected that the lower portions of the alga's thallus remain resulting in a persistent year-round species.

Dictyospheria cavernosa had the 16th highest total percent cover (0.4%) and was collected at 75% of the sites. Although it is not a dominant member of Kure's lagoon community, it must be considered as common, as it was found at almost every site visited and covered enough area to show up in the percent cover data. This alga's highest percent cover was 6% in the lagoon patch reefs at site 61E. Kure lagoon's setting demonstrates how a so-called "invasive" alga can stay in balance with other species under pristine conditions. This is a marked contrast to KŪne'ohe Bay where this species is regarded as invasive and expanding its coverage. *Dictyospheria* coverage has already reached 100% at some locations in the bay.

The habitats of Kure Atoll's lagoon seem in many respects to be similar to places on the main eight Hawaiian Islands. The back reef habitat just inside the barrier reef is similar to reef flat habitats located on `Oahu and Kaua`i, specifically KŪhala, Lanikai and Limahuli. The patch reefs of the atoll are somewhat similar to the patch reefs of KŪne'ohe Bay. Although habitats may be similar, the composition of algae species found on the main island is quite different from Kure Atoll. Anthropogenic change such as nutrification, over fishing and the introduction of alien species may be part of the reason for the difference in species composition.

Based on these data, algae dominate the benthic community of Kure atoll's lagoon. Some have suggested that pristine near shore habitats of Hawai`i should be coral dominant and not algal dominant, but Kure's lagoon showcases algal dominance in healthy even pristine settings. Perhaps this serves as a reminder that not all algal dominated coastal areas around the main Hawaiian Islands should be considered problematic.

Benthic & Coral Coverage

Low relief, exposed carbonate pavement interspersed with coral rubble and sand patches were the dominant benthic elements of the majority of the sites surveyed (Fig. 4). This was particularly characteristic of the back reef sites of Kure Atoll. Pavement, rubble and dead coral were frequently covered by macro-, turf and coralline algae. Such algae were more apparent in the *in situ* quadrat method (Table 2) than by post-survey video analysis. This was due both to resolution limits of the video and the specialized expertise of the algologist conducting the quadrat analysis.

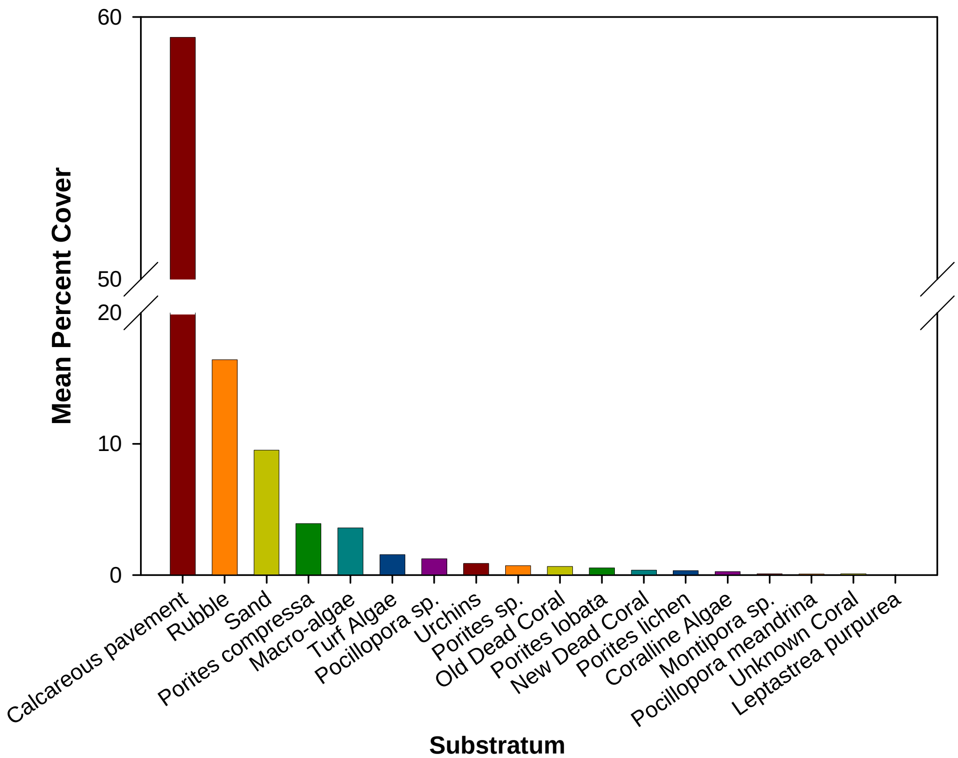


Figure 4. Mean percent benthic cover based upon video analyses.

Coral on the back reef was low-lying, patchy, and uncommon with coverage ranging from 0% to 9.3% (Fig. 5) with a mean value of 3.2% (±2.2SD). Fifteen taxa of stony corals were recorded at these sites by video analysis (Appendix 5). At 11 sites, clusters of small colonies of living coral, principally *Porites lichen*, appeared to be surviving segments of a much larger colony likely due to being broken apart by physical (wave) forces. Dead coral due to recent or near-term mortality was uncommon and *Acanthaster planci* were not observed at any location.

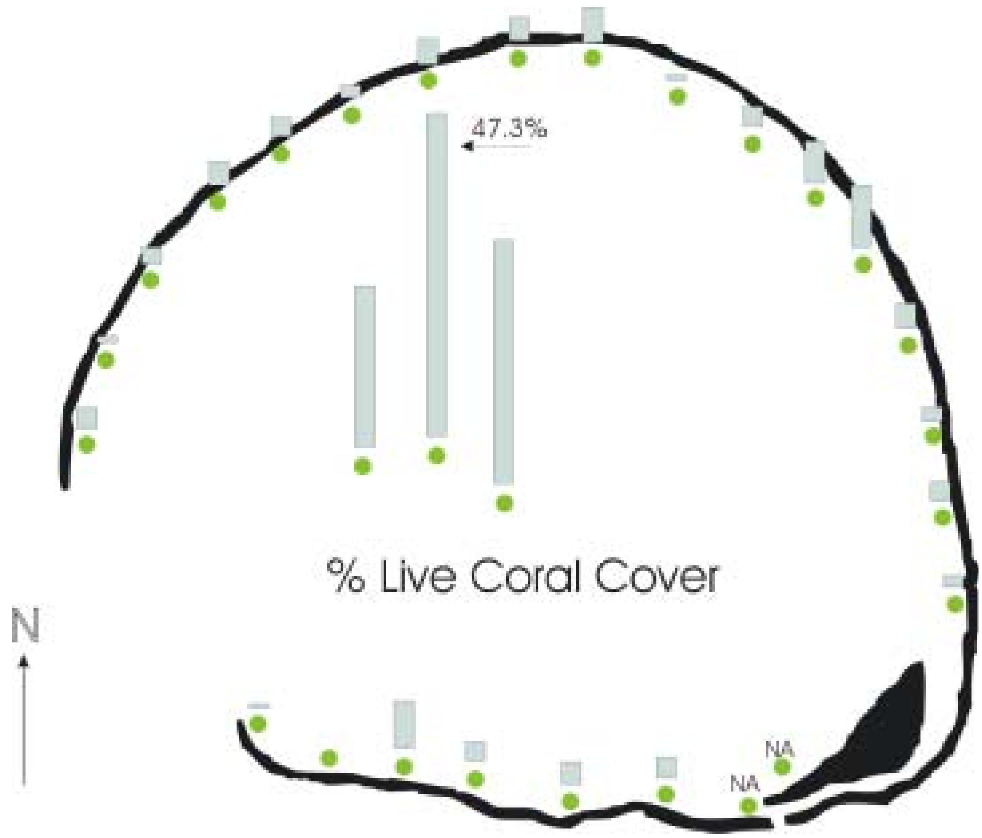


Figure 5. Percent Live Coral at Survey Sites

With regards to corals, one particularly noteworthy back reef site was #67 (see Fig. 3, pg. 8). This site was given the nickname “blue reef” due to the dramatic presence of the blue colored coral *Montipora flabellata*. This site was one of only two sites where *M. flabellata* was detected (by quadrat method only) with a cover of 7%. Site 67 also had the lowest percent cover of sand when compared to other back-reef sites. The other site where *M. flabellata* was detected was a patch reef site (#61) with a cover of 4%.

In contrast to the back reef sites, the patch reef sites near the center of the lagoon (#61, 61E & 61F) were characterized by substantially higher coral cover and spatial complexity. Cover at these sites ranged from 23.7% to 47.3% even in the shallow 4’ depths where the transects were run. The finger coral *Porites compressa* was the dominant coral at these depths often forming large continuous colonies. The bases of most of the coral fingers were overgrown with either fleshy (especially *Microdictyon setchellianum*) or calcareous algae. Many of the finger corals appeared to be very pale in comparison to high Island colonies. Finger coral rubble was abundant at these sites.

Invertebrates

Of the 27 invertebrate taxa surveyed, 20 were recorded on the belt transects. Most of these were uncommon or rare (Table 3).

Table 3. Invertebrates recorded on transects. Frequency (Freq.) is the proportion of transects in which the taxa occurred. Total No. is the total number of organisms recorded on all transects.

Scientific Name	Common Name	Freq.	Total No.	Mean No./100m^2
Echinometra mathaei	Rock-Boring Urchin	1.000	30,843	550.77
Echinostrephus aciculatus	Needle-Spined Urchin	0.821	3,804	67.93
Heterocentrotus mammillatus	Red Pencil Urchin	0.929	813	14.52
Actinopyga obesa	Plump Sea Cucumber	0.786	537	9.59
Spirobranchus giganteus	Christmas Tree Worm	0.429	108	1.93
Conus spp.	Cone shell	0.536	41	0.73
Holothuria atra	Black Sea Cucumber	0.464	27	0.48
Sabellastarte sanctijosephi	Feather Duster Worm	0.143	16	0.29
Holothuria whitmaei	Teated Sea Cucumber	0.143	10	0.18
Echinothrix diadema	Blue-Black Urchin	0.360	4	0.07
Turbo sandwicensis	Hawaiian Turban	0.143	4	0.07
Octopus cynea	Day Octopus	0.710	4	0.07
Ophiocoma erinaceus	Spiny Brittle Star	0.143	4	0.07
Spondylus violacescens	Cliff Oyster	0.360	3	0.05
Cypraea spp.	Cowries	0.710	3	0.05
Linkia multiflora	Spotted Linkia	0.360	3	0.05
Echinothrix calamaris	Banded Urchin	0.360	1	0.02
Ophiocoma pica	Pied Brittle Star	0.360	1	0.02
"Hermit Crab"	Hermit Crab	0.360	1	0.02
Pinctada margaritifera	Black-Lipped Pearl Oyster	0.360	1	0.02

Far and away the most abundant species was the rock-boring urchin, *Echinometra mathaei*. It occurred on all transects (Figure 6) ranging in abundance from 29.5/100 m^2 on one of the patch reefs to 2,450/100 m^2 at site 11 (Appendix 6). Patch reef sites had significantly less *E. mathaei* than the back reef sites (t-test P<.001). Based on quadrat counts, back reef sites had an average *E. mathaei* (urchin) cover of 1.12%, compared to 0.16% on the patch reef sites (p<.03). Although the density of this urchin seemed very high at several sites, the overall mean density of rock-boring urchins was no higher than reported in other shallow-water locations (<15') such as Kealakekua Bay (å1800/100m^2;

Doty 1969), HŐnaunau Bay (å700/100M^2; Doty, 1969), MŨalaea Bay (å3000/100m^2; Ogden et al. 1989), and Kenya (563/100m^2; Carreiro-Silva and McClanahan, 2001). The abundance of rock-boring urchins suggests they are a major sediment producer and algae consumer in the atoll. Based on rates determined in Kenya (Carreiro-Silva and McClanahan, 2001) the overall herbivory rate by this species in the lagoon would be about 85.4 gm algae/100m^2/day (±85.4 SD) and bioerosion would be 256.2 gm $CaCO_3$/100m^2/day (±228.9 SD).

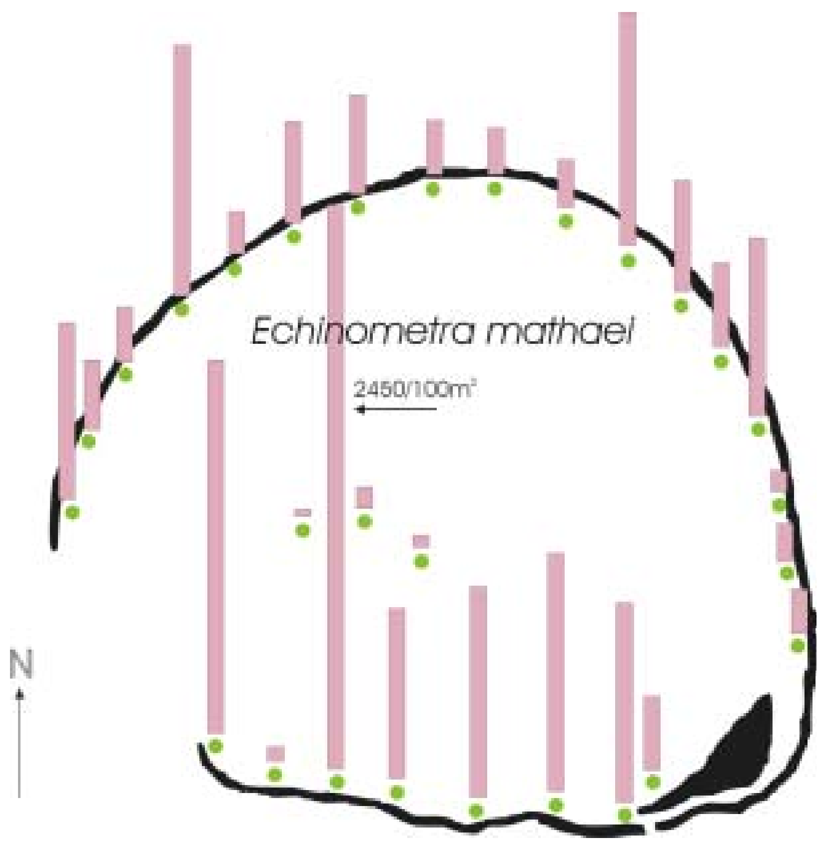


Figure 6. Distribution and abundance of the rock-boring urchin, *Echinometra mathaei*.

The second most abundant invertebrate censused was the needle-spined rock boring urchin *Echinostrephus aciculatus*. Its distribution was limited to only the back reef sites. There was no significant relationship between the abundance of *E. aciculatus* and *E. mathaei* (r^2=.025, P>.45). With the exception of the slate pencil urchin, *Heterocentrotus mammillatus*, all other urchin species were extremely uncommon at Kure including the oblong urchin *Echinometra* oblonga which was not observed at all. This species appears to be quite similar ecologically to *E. mathaei* and often occurs intermingled with it on exposed shallow shores of the main Hawaiian Islands (Ogden et al., 1989). Rather than being absent, the possibility exists that *E. oblonga* may not have its usual black coloration at Kure and thus was visually misidentified as *E. mathaei*.

Although not included on the list of surveyed species for the belt transects, the parchment worm, *Chaetopterus sp.* an annelid with parchment-like tubes was recorded on the quadrat surveys. It was found at three back reef sites in very low abundance. Noteworthy however was its presence at site 7, the site adjacent to the boat wreck. At this location *Chaetopterus sp.* had a percent cover of 21.5%. The second highest percent cover of *Chaetopterus sp.* was 1% at site 11 (Appendix 4). As noted previously the blue-green algae *Lyngbya majuscula* was also present at these two sites.

No *Acanthaster planci* were observed anywhere in the lagoon. Black-lipped pearl oysters *Pinctada margartifera,* were rare with only a single individual being recorded on transects. Only four Lobsters (*Panulirus marginatus*) were observed (outside of transects), three at site #61 and one at #17. A large barnacle, *Balanus sp*. reported to be locally abundant on the algal terraces near the reef edge at Kure (Gross et al., 1969) was not observed.

Fishes

A total of 111 species of 35 families were observed by all methods at Kure Atoll (Appendix 7). Endemics constituted 27% of the species, slightly higher than the overall level of endemism (23.1%) for nearshore Hawaiian fishes (Randall 1998). No introduced species (i.e. *Lutjanus kasmira*, *Lutjanus fulvus Cephalopholis argus*) were observed. The recent immigrant to Hawai`i, *Abudefduf vaigiensis* was noted at a single site (DACOR analysis - Appendix 8). Another recent immigrant that appears to have become established on one or more of the main Hawaiian Islands (MHI), the triggerfish *Balistes polylepis* was not observed. Indeed no balistids were recorded at any of the sites. The filefish *Pervagor spilosoma* was noted by DACOR as rare at only a single site (#16).

Sixty-one fish species (37.8% endemic) were recorded on belt transects with *Stethojulis balteata* and *Thalassoma duperrey*, both endemic labrids, found on all transects (Appendix 9). Patch reef sites had over three times as many fishes (434.5/100m^2 SD=51.4) as back reef sites (128.1/100m^2 SD=48.4, t-test $P<0.001$) although they did not generally have more species per transect (Table 4). Adult *Kyphosus bigibbus*, *Stegastes fasciolatus*, juvenile scarids (especially *Scarus dubius* and *Chlorurus sordidus*) and *Gomphosus varius* recruits were especially abundant in the shallows of the patch reefs. The two most common species overall, *Acanthurus triostegus* & *Stethojulis balteata,* were generally much more common on the back reefs than the patch reefs. As is often the case elsewhere, the endemic wrasse *Thalassoma duperrey* was ubiquitous.

Table 4. Summary table of fish Density (No./100m^2), Biomass (kg/100m^2) and Diversity (No. Species/100m^2) for Kure survey sites.

Site	Density	Biomass	Diversity
1	103.5	3.02	22
2	153	9.52	26
3	209	2.31	19
4	123.5	2.42	13
5	134	2.19	20
6	178.5	4.38	22
7	90.5	1.02	13
8	121	1.53	18
9	67	2.06	9
10	54	0.04	4
11	105.5	3.78	19
12	80.5	4.39	20
13	66	0.64	10
14	125	6.65	23
15	164.5	2.12	14
16	284	5.84	28
17	131	8.51	20
18	130	3.44	23
19	99.5	2.30	18
20	149.5	1.21	17
21	126	1.69	15
22	146.5	20.40	20
23	101	5.60	14
24	115.5	8.41	23
67	144.5	2.01	13
61	375.5	27.34	15
61E	458.5	23.15	21
61F	469.5	26.55	20

Overall fish biomass at the back reef sites was relatively low with the exception of site #22. These locations are quite exposed and undoubtedly subject to intense wave stresses during periods of strong winter swells. Nevertheless the biomass was still higher than at three of four MLCDs on `Oahu (Friedlander, 2001). The low spatial relief and lack of refugia at back reef sites appears to limit resident populations to large fish which can range widely and small bodied individuals (including YOY) which can utilize whatever small scale shelter is available. The greatest concentrations of site-resident fishes often occurred in cuts or depressions on the back reef. Cleaning stations of the adult cleaner wrasse *Labroides phthirophagus* were also in these low-lying areas in contrast to their usual prominent and exposed locations on MHI reefs. The relatively high fish biomass recorded at site #22 was due to a roving school of the herbivore *Acanthurus nigroris* which crossed the transect line. Of note was the fact that this species almost invariably exhibited a white band on its caudal peduncle in contrast to the island of Hawai`i, where it is usually observed without the white band.

As with *A. nigroris* a number of other isolated concentrations of fishes were seen within the atoll during the project. Foraging schools of hundreds of large (>15cm TL) *Acanthurus triostegus* were observed at two sites (#18 & #22), 5.6 km apart. A large school of *Acanthurus leucoparieus* was also noted at site #22. Small schools (å50 fish) of the clupeid *Spratelloides delicatulus* were present at most (71%) sites usually swimming just below the water's surface. Schools of the goatfishes *Mulloidichthys flavolineatus* and *Mulloidichthys vanicolensis* were also noted at several locations. *M. flavolineatus* was present throughout the atoll and common at every transect site except one (#9). Active foraging schools of this species with hundreds of adult individuals were observed at eight sites (Appendix 9) and small individuals (å12 cm TL.) were commonly seen in the shallows along the beaches. *M. vanicolensis* in comparison was much less abundant being common only at four sites. This species gathered in inactive resting schools and were not actively feeding during the day. The largest concentrations were found at the section of the fishing boat wreck near site #7 and the piece within the atoll lagoon proper. A large resting school of small (å20 cm TL) kŪhala, *Seriola dumerili,* also occurred at this later wreck. When one of the support boats motored rapidly over the school, the fish moved up off of the sandy bottom and followed the boat for approximately 20 m until it stopped.

Two large schools of adult Ūholehole, *Kuhlia xenura*, were observed on a recon snorkel of the east side of Green Island associated with rock piles close to the shore. One of these schools also contained akule, *Selar crumenopthalmus*, the only sighting of this species. While juvenile Ūholehole were observed widely distributed in the shallows along sandy shorelines, with the exception of the rock piles, adults were observed at only one other location, that being just inside the reef crest at site #03. Due to the difficulty of working so close to the reef crest and the large number of juveniles observed within the atoll, it is possible that substantial numbers of adult Ūholehole might inhabit these areas.

The largest single contributor to fish biomass at the survey sites was the rudderfish *Kyphosus bigibbus* (Table 5). It was present at 23 of 28 sites and common or dominant at nine of these (Appendix 9). Schools of this species were observed cruising the shallows along Green Island on a number of occasions. It was especially abundant at the patch reef sites where schools of hundreds of individuals were observed. Gold morphs of this species were noted on several occasions. The spectacled parrotfish, *Chlorurus perspicillatus* was likewise widely distributed on reefs within the lagoon (DACOR-25 of 28 sites). Single large terminal phase males were often sighted in the proximity of several (5-9) initial phase individuals, presumably his harem. This species tended to be somewhat wary of divers. While being observed at 25 of 28 sites (DACOR) it was recorded on only 25% of the transects. Its biomass, based upon transects counts is thus likely substantially underestimated. It is interesting to note that very few medium or small individuals of this species were observed at any of the sites.

In contrast to the behavior of *C. perspicillatus* a number of species were clearly attracted to the presence of divers in the water. This included species such as *Thalassoma ballieui*, *T. duperrey*, *Bodianus bilunulatus*, *K. bigibbus* and *Caranx ignobilis*.

Table 5. Fish biomass by species at Kure transect sites. Note: hectare=10,000m^2

Family	**Species name**	**kg/100m^2**	**kg/hectare**
Kyphosidae	*Kyphosus bigibbus*	2.501	250.145
Scaridae	***Chlorurus perspicillatus***	1.148	114.783
Labridae	***Thalassoma ballieui***	0.554	55.426
Mullidae	*Mulloidichthys flavolineatus*	0.346	34.606
Acanthuridae	*Acanthurus nigroris*	0.312	31.183
Labridae	*Bodianus bilunulatus*	0.309	30.867
Pomacentridae	*Stegastes fasciolatus*	0.309	30.863
Labridae	***Thalassoma duperrey***	0.293	29.273
Labridae	***Anampses cuvier***	0.106	10.552
Labridae	*Thalassoma pupureum*	0.075	7.534

Acanthuridae	*Zebrasoma veliferum*	0.070	6.997
Cirrhitidae	*Cirrhitus pinnulatus*	0.055	5.492
Labridae	***Coris flavovittata***	0.053	5.273
Labridae	***Stethojulis balteata***	0.048	4.795
Labridae	*Gomphosus varius*	0.028	2.768
Acanthuridae	*Ctenochaetus strigosus*	0.026	2.608
Acanthuridae	*Acanthurus triostegus*	0.025	2.532
Diodontidae	*Diodon holocanthus*	0.022	2.152
Chaetodontidae	*Chaetodon ornatissimus*	0.021	2.070
Scaridae	***Scarus dubius***	0.019	1.918
Chaetodontidae	*Chaetodon auriga*	0.018	1.843
Holocentridae	*Neoniphon sammara*	0.018	1.784
Zanclidae	*Zanclus cornutus*	0.013	1.279
Pomacentridae	*Plectroglyphidodon johnstonianus*	0.012	1.249
Acanthuridae	*Acanthurus leucoparieus*	0.012	1.244
Holocentridae	*Sargocentron punctatissimum*	0.012	1.218
Labridae	*Thalassoma trilobatum*	0.012	1.171
Chaetodontidae	***Chaetodon fremblii***	0.012	1.166
Tetraodontidae	***Canthigaster jactator***	0.010	1.043
Labridae	***Coris venusta***	0.010	0.951
Cirrhitidae	*Paracirrhites forsteri*	0.009	0.918
Labridae	***Macropharyngodon geoffroy***	0.008	0.835
Scaridae	*Chlorurus sordidus*	0.008	0.756
Mullidae	***Parupeneus porphyreus***	0.007	0.745
Blenniidae	***Cirripectes vanderbilti***	0.005	0.517
Mullidae	*Parupeneus pleurostigma*	0.005	0.486
Holocentridae	*Myripristis berndti*	0.004	0.403
Mullidae	*Mulloidichthys vanicolensis*	0.004	0.366
Holocentridae	*Myripristis amaena*	0.003	0.260
Chaetodontidae	***Chaetodon miliaris***	0.002	0.239
Fistulariidae	*Fistularia commersonii*	0.002	0.217
Cirrhitidae	*Cirrhitops fasciatus*	0.002	0.181
Synodontidae	*Saurida flamma*	0.002	0.172
Labridae	***Labroides phthirophagus***	0.001	0.141
Pomacentridae	***Abudefduf abdominalis***	0.001	0.134
Scorpaenidae	***Sebastapistes ballieui***	0.001	0.131
Labridae	*Oxycheilinus unifasciatus*	0.001	0.083
Muraenidae	*Gymnothorax eurostus*	0.001	0.075
Ostraciidae	*Ostracion meleagris*	0.001	0.055
Labridae	*Pseudocheilinus octotaenia*	0.000	0.034
Scaridae	***Calotomus zonarchus***	0.000	0.031
Blenniidae	*Exallias brevis*	0.000	0.029
Acanthuridae	*Zebrasoma flavescens*	0.000	0.023
Mullidae	*Parupeneus multifasciatus*	0.000	0.020
Scaridae	*Scarus psittacus*	0.000	0.017
Pinguipedidae	*Parapercis schauinslandii*	0.000	0.014
Clupeidae	*Spratelloides delicatulus*	0.000	0.011
Apogonidae	***Apogon maculiferus***	0.000	0.011
Cirrhitidae	*Paracirrhites arcatus*	0.000	0.006

Pomacentridae	*Chromis vanderbilti*	0.000	0.002
Pomacentridae	***Dascyllus albisella***	0.000	0.002
	Totals	6.517	651.699

On numerous occasions individuals of the first three species could be observed moving around the transect diver repeatedly entering and leaving the transect belt. It was thus very easy to count the same individual more than once thereby overestimating abundance.

Although the While Ulua *C. ignobilis* was not observed on any transect, a similar attractive/following behavior was also noted. In several instances ulua only appeared after the dive team had been in the water for a while. Several times the numbers of fish increased with time as fish appeared to move from nearby areas and congregate around the divers. Ulua individually recognizable by body scars or by attached fishing tackle were seen to swim repeatedly past divers. Three ulua were seen with either hook or line attached to them. One individual had damage gills and an emaciated appearance (very concave belly), indicating a state of severe stress. One of the mates on the charter boat which ferried us over to Kure indicated that people from Midway were in fact fishing at Kure, and specifically targeting ulua.

A total of 22 *C. ignobilis* were observed during the entire course of this project (at transect sites & recon areas). One individually recognizable fish was seen on two consecutive days at three sites (#2, 5, & 7) spanning a distance of 4 km. A different individual was seen at three sites (#7, 22, & 23) over seven days spanning a minimum distance of 8 km. At site #22 this individual was noted throughout the dive right up until the time the divers exited. This fish was already present at the next site (#23), 0.8 km away, when the divers entered. It was clear that it had followed our boat from one site to another and did so at considerable speed.

Given these repeated sightings, the number of different ulua individuals observed within Kure lagoon was no more than 18. Relatively low numbers of *C. ignobilis* were also reported at Kure by *Rapture* REA teams which surveyed areas outside the reef as well. Although their numbers were relatively low compared to other NWHI reefs (pers. ob), the large size of the individuals present means that their contribution to the overall fish biomass of the lagoon was not insubstantial.

In terms of trophic categories, herbivores and benthic invertebrate feeders dominated the shallow reefs of the atoll comprising 80-90% of the 20 most abundant species present (Table 6). Endemics were disproportionately represented in terms of numbers (40%), biomass (35%), and relative abundance-DACOR (30%). There was fairly high level of agreement in the ranks of species as determined by the belt transect method and DACOR analysis (r_s=.690 P=.001). This was not the case in terms of biomass (r_s=.323, p=.165) which is not surprising given the wide range of body weights for the various species present.

Table 6. Top 20 fish species at Kure in terms of Number, Biomass, and relative abundance (DACOR). DACOR classification converted to numeric values (D=150, A=75, C=30, O=8, R=3) to establish rankings. Diet codes are: A=Algae, C=Corals, D=Detritus, F=Fish, I=Invertebrates, P=Plankton. Endemic species are in **bold** type.

Number		**Biomass**		**DACOR**	
Species	Diet	Species	Diet	Species	Diet
Acanthurus triostegus	A	*Kyphosus bigibbus*	A	*Acanthurus triostegus*	A
Stethojulis balteata	I	***Chlorurus perspicillatus***	A	*Spratelloides delicatulus*	P
Thalassoma duperrey	I	***Thalassoma ballieui***	I	*Mulloidichthys flavolineatus*	I
Scarus dubius	A	*Mulloidichthys flavolineatus*	I	***Stethojulis balteata***	I
Kyphosus bigibbus	A	*Acanthurus nigroris*	A	***Thalassoma duperrey***	I
Stegastes fasciolatus	A	*Bodianus bilunulatus*	I	*Stegastes fasciolatus*	A
Gomphosus varius	I	*Stegastes fasciolatus*	A	*Kyphosus bigibbus*	A
Chlorurus sordidus	A	***Thalassoma duperrey***	I	***Thalassoma ballieui***	I
Thalassoma ballieui	I	***Anampses cuvier***	I	*Gomphosus varius*	I
Plectroglyphidodon johnstonianus	D	*Thalassoma pupureum*	I	*Acanthurus nigroris*	A
Acanthurus nigroris	A	*Zebrasoma veliferum*	A	***Chlorurus perspicillatus***	A
Ctenochaetus strigosus	D	*Cirrhitus pinnulatus*	I	*Mulloidichthys vanicolensis*	I
Mulloidichthys flavolineatus	I	***Coris flavovittata***	I	*Chlorurus sordidus*	A
Macropharyngodon geoffroy	I	***Stethojulis balteata***	I	***Scarus dubius***	A
Spratelloides delicatulus	P	*Gomphosus varius*	I	*Ctenochaetus strigosus*	D
Coris venusta	I	*Ctenochaetus strigosus*	D	*Platybelone argalus*	F
Cirripectes vanderbilti	D	*Acanthurus triostegus*	A	*Plectroglyphidodon johnstonianus*	D
Cirrhitus pinnulatus	I	*Diodon holocanthus*	I	*Chaetodon auriga*	I
Anampses cuvier	I	*Chaetodon ornatissimus*	C	***Macropharyngodon geoffroy***	I
Chaetodon auriga	I	***Scarus dubius***	A	*Neoniphon sammara*	I

Piscivores were not a dominant element of the fauna within the lagoon (Table 6). As noted above, *Caranx ignobilis* was absent or rare almost everywhere. The ‘Ǿmilu, *Caranx melampygus* was more abundant being sited at 39% of the sites (Appendix 9). Yet with the exception of a single school comprising about 50 individuals (30cm TL) observed along the beach west of Green Island, these too were typically in low numbers. Limited sampling by rod & reel along the beaches of Green Island caught only *C. melampygus*, *Carangoides ferdau* and, *Polydactylus sexfilis (*moi*).* This latter species is generally not considered piscivorous. Approximately 13 individuals were seen repeatedly in the vicinity of the landing pier on the west side of the island. None of these three species were recorded on transects. Only a single small Galapagos shark,

Carcharhinus galapagensis was observed during the course of the project. As previously mentioned a school of small kŪhala was noted at one of the wreck sites. A single large individual (å120 cm TL) was seen chasing juvenile moi and Ūholehole along the shoreline of Green Island. It even beached itself several times in its feeding attempts.

Recruits

Recruits were observed for 24 of the 61 fish species recorded on transects. The top five species accounted for over 90% of the total (Table 7). Endemics represented 45.8% of the species and 34.7% of the number of recruits. Recruits were found at all sites. Highest densities occurred at two of the three patch reef sites (Figure 7) but overall mean recruit densities were just nonsignificant between back reef and patch reef sites (t-test, P=0.06). This was somewhat surprising given the dramatic differences between the habitat types in terms of reef complexity and available small-scale shelter (essentially unlimited on the patch reefs). Total recruit densities at Kure during this period were higher, with one exception, than historically (1993-2000) reported for Midway or French Frigate Shoals (DeMartini, in review). The exception was at Midway in 1997 when a large recruitment episode of ‘Ūweoweo, *Priacanthus meeki* occurred. Total recruit density during this period at Midway exceeded 130/100m^{2}.

Only a single species of recruit (*Oxycheilinus unifasciatus*) was found solely on the patch reefs while 12 species occurred exclusively on back reef sites (Table 7). This latter finding is likely an artifact of the large disparity in the number of survey sites between the two habitat types. Nevertheless it points out the importance of the entire lagoon as a nursery habitat for different species.

While recruitment occurred throughout the lagoon there were distinct patterns evident for a number of species. Distributional patterns for recruits could be due to a number of factors such as oceanographic processes, habitat settlement preferences or post-recruitment mortality.

Table 7: Total fish recruit abundance on transects-September 2001. Endemic species are in **bold** type. Total Number is the number of recruits on all transects. Density is number/100m^2. Species with * had recruits only on forereef sites.

Species	Common Name	No./100m^2	% of Total
Acanthurus triostegus	Convict Surgeonfish	30.55	43.57
Scarus dubius	Regal Parrotfish	13.33	19.02
Stethojulis balteata	Belted Wrasse	8.54	12.17
Chlorurus sordidus	Bullethead Parrotfish	6.21	8.86
Gomphosus varius	Bird Wrasse	4.98	7.11
Ctenochaetus strigosus[1]	Goldring Surgeonfish	2.18	3.11
Thalassoma duperrey	Saddle Wrasse	1.13	1.60
Acanthurus nigroris	Bluelined Surgeonfish	0.63	.89
Macrophryngodon geoffroy*	Shortnose Wrasse	0.48	.69
*Chaetodon auriga**	Threadfin Butterflyfish	0.41	.59
Abudefduf abdominalis*	Hawaiian Sergeant	0.27	.38
*Stegastes fasciolatus**	Yellow-eye Damsel	0.25	.36
Dascyllus albisella*	Hawaiian Dascyllus	0.23	.33
*Acanthurus leucoparieus**	Whitebar Surgeonfish	0.21	.30
Calotomus zonarchus*	Yellowbar Parrotfish	0.13	.17
Chaetodon ornatissimus	Ornate Butterflyfish	0.13	.17
Anampses cuvier*	Pearl Wrasse	0.11	.15
Scarus psittacus	Palenose Parrotfish	0.09	.12
Plectroglyphidodon johnstonianus	Blue-eye Damselfish	0.07	.10
Coris venusta*	Elegant Coris	0.05	.08
Oxycheilinus unifasciatus	Ringtail Wrasse	0.05	.08
Parupeneus porphyreus*	Whitesaddle Goatfish	0.04	.05
Thalassoma ballieui*	Blacktail Wrasse	0.04	.05
*Zebrasoma flavescens**	Yellow Tang	0.02	.03
	Total	70.13	99.98

[1] Yellow phase recruits were noted in addition to recruits of normal coloration.

Given the general lack of piscivores which prey on small fishes (e.g., *Aulostomus chinensis*, *Cephalopholis argus, Fistularia commersonii*, *Oxycheilinus unifasciatus*, scorpaenids and synodontids) it is likely that observed patterns are the result of one or both of the first two factors. At this point it is not possible to clearly distinguish between them and assess their relative importance.

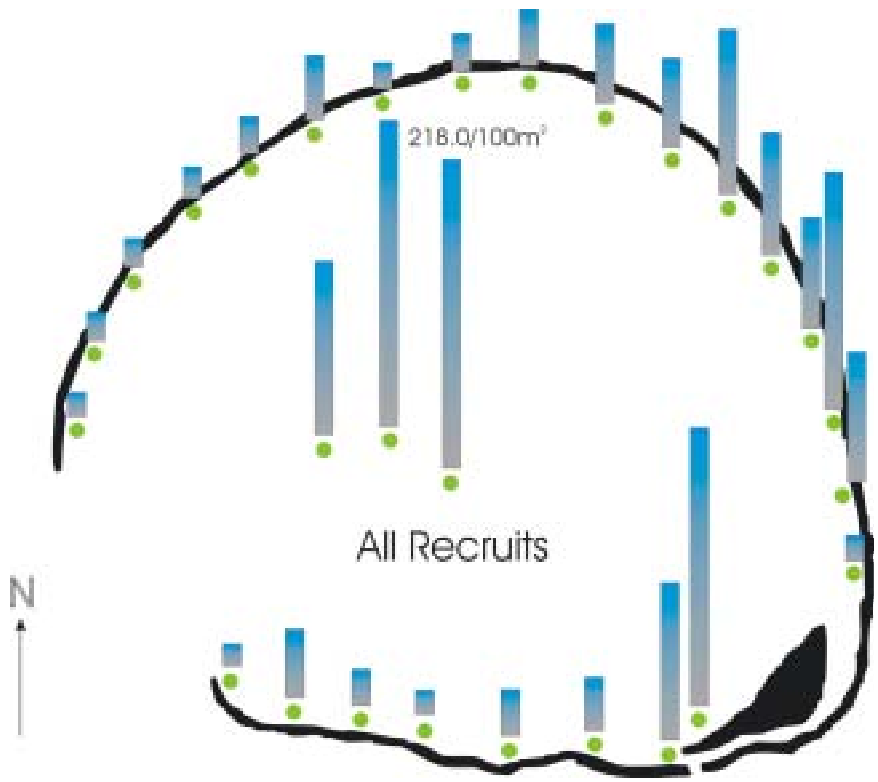


Figure 7. Relative abundance and distribution of all recruits on Kure transects, September 2001.

Two parrotfish species, *Chlorurus sordidus* and *Scarus dubius* were both quite similar in their settlement patterns. Abundance of these two combined species was dramatically higher on the patch reefs although low numbers occurred on the windward back reef sites (Figure 8). Food resources for these herbivores were plentiful in all habitats (Appendix 4) but small-scale shelter was markedly greater on the patch reefs. High scarid abundance on atoll patch reefs was also noted during the NOWRAMP expedition for other locations such as Midway, Pearl & Hermes and French Frigate Shoals (pers. obs.).

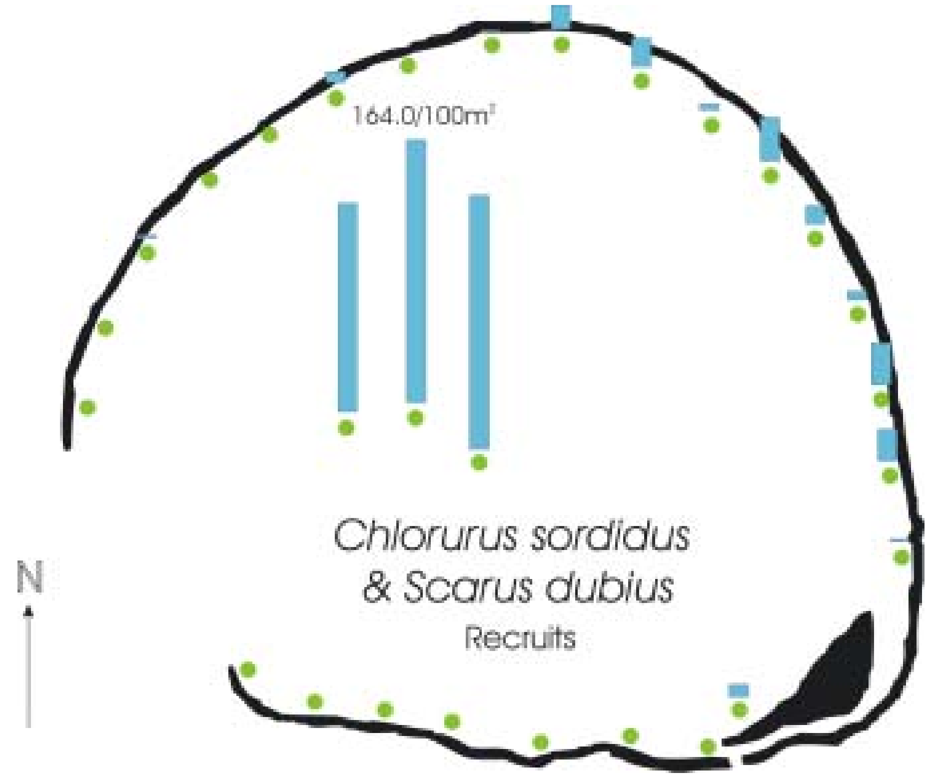


Figure 8. Distribution and abundance of recruits of two species of parrotfishes. Note scale is variable on recruitment graphs.

Recruits of the Bird Wrasse *Gomphosus varius* had a somewhat similar pattern in that densities were highest on the patch reefs (Figure 9). Compared to the parrotfishes however, bird wrasse recruits were scarce on the NE back reef but more abundant in the NW sector. Recruits of this species were much more abundant during 2001 than they were the previous year (NOWRAMP).

In contrast to these species which recruited predominately to patch reefs, the recruits of several others primarily occurred on back reef locations. This was particularly evident for the manini, *Acanthurus triostegus* whose recruits occurred primarily in the shallows of the eastern and southern back reef (Figure 10). These areas provided the requisite habitat requirements, namely algal food, small scale shelter and shallow water that form the pertinent settlement stimuli for by manini (Sale 1969). It is tempting to suggest that differences in recruit abundance along the back reef may reflect the influence of the

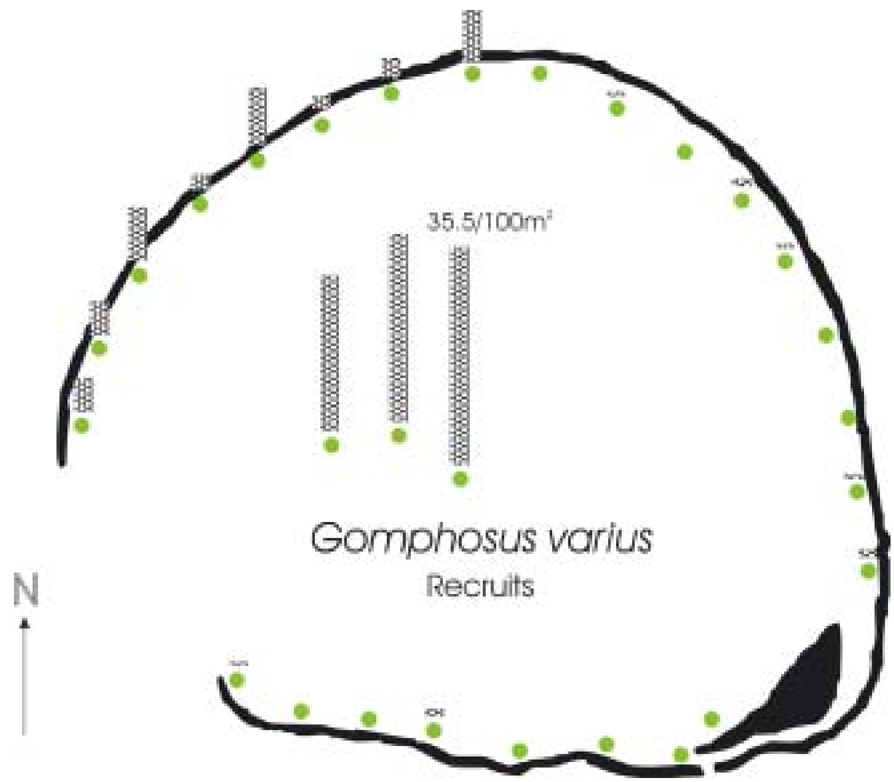


Figure 9. Distribution and abundance of recruits of the wrasse *Gomphosus varius*. Note variable scale on all recruitment graphs.

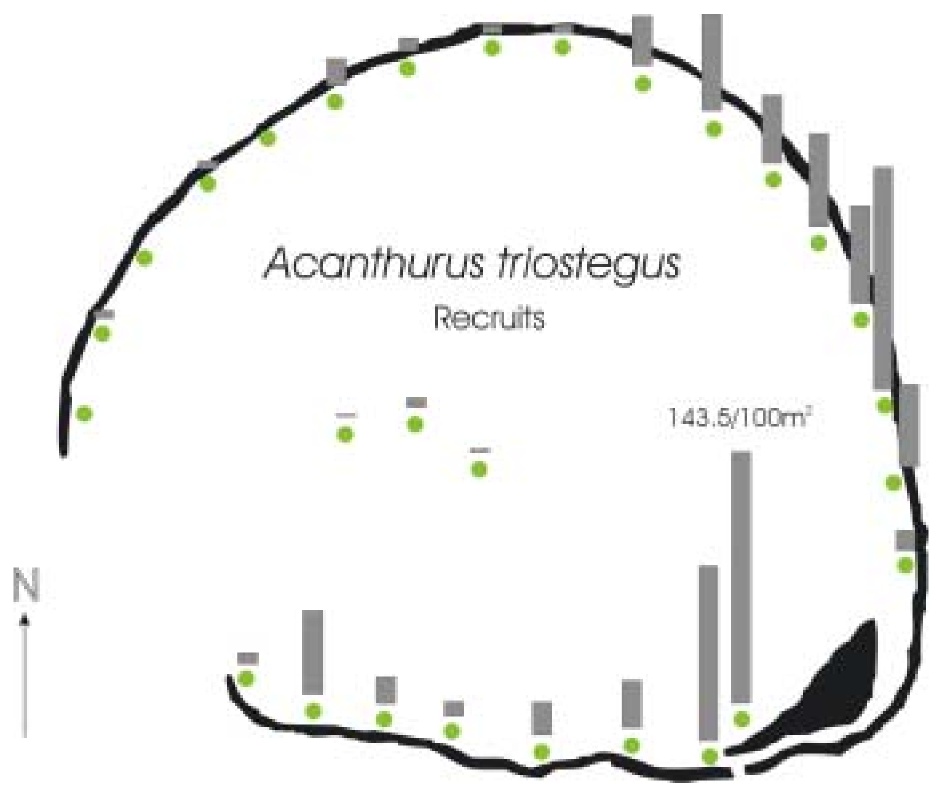


Figure 10. Distribution and abundance of recruits of the surgeonfish *Acanthurus triostegus*.

predominately northeast to southwest tradewind driven flow of water cross the atoll (Dana, 1971).

Another recruitment pattern was exhibited by the Belted Wrasse *Stethojulis balteata* which was distributed relatively uniformly throughout the atoll (Figure 11). Unlike manini, tradewind driven current influence wasn't directly apparent. If anything settlement appeared to be somewhat higher in the northwest sector.

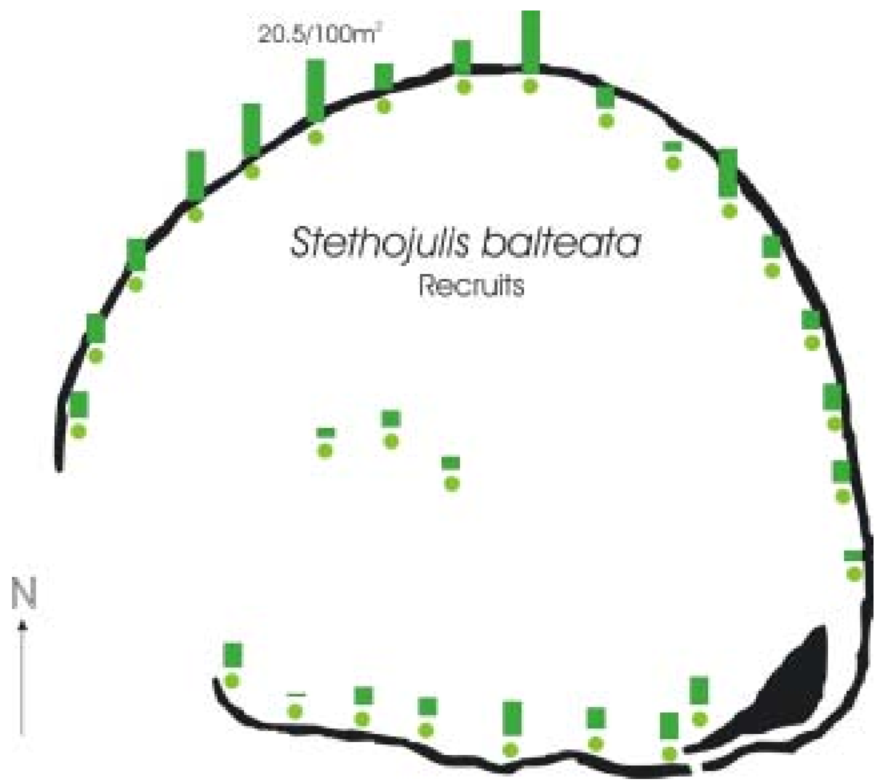


Figure 11. Distribution and abundance of recruits of the wrasse *Stethojulis balteata*.

The recruitment pattern of another species deserves mention. This is the Threadfin Butterflyfish *Chaetodon auriga*. While not abundant, it was the most common butterflyfish recorded within the lagoon both on transects and by DACOR. A total of 6 adult pairs were noted on the transects. Recruits of this species occurred only on a single transect (site # 16, Figure 12) and at a density which I (WjW) have not observed for any butterflyfish in almost 30 years of Hawai'i diving. The only other recruits of this species noted anywhere were three at site #61E observed during the DACOR swim.

The reef in at Site #16 was low-lying and patchy and not especially noteworthy other than it was adjacent to Green Island and had an inordinate number of recruits (Figure 7). It also had twice as many adult *C. auriga* (2 pairs) than any other site. Recon snorkels along other areas by Green Island indicated that recruits did not occur in these areas. The reefs at site #16 were separated from other reef areas by large expanses of barren sand and it is unlikely that recruits aggregated at this site post-settlement. Given the extreme localized distribution and similar size of this species' recruits it is highly likely that they settled together possibly as a sort of larval school. Such behaviors have been reported by night-lighting fishermen on the MHI. This raises the possibility that they may be the result of a single spawning event and thus could all be siblings.

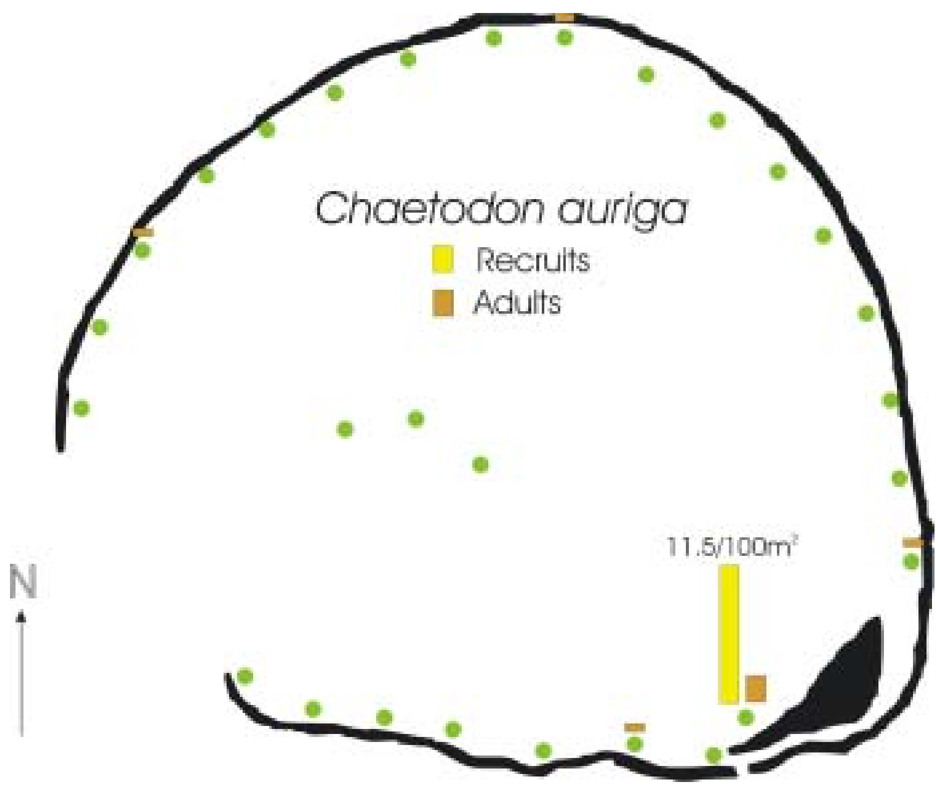


Figure 12. Distribution and abundance of recruits and adults of the butterflyfish *Chaetodon auriga*.

Recruitment outside of transect sites was also noted. Structural relief such as provided by wrecks or pier pillars (West side of Green Island) appeared to be important for a number of recruiting species. The wreck just southwest of site #07 sheltered hundreds of recruits (å4 cm TL) of the Spotfin Squirrelfish *Neoniphon sammara*. Although adults of this species were widely distributed at Kure (71% of sites) recruits were observed only at this wreck. Although no recent recruits of *M. vanicolensis* were seen on the wrecks, small individuals (12cm TL) were abundant and likely represent earlier recruitment events.

The pier by Green Island also harbored substantial numbers of recruits and juveniles of Ūholehole (*Kuhlia xenura*) and moi (*Polydactylus sexfilis*). While Ūholehole were fairly abundant in many areas just below the edge of the beach, they seemed to be more concentrated in the area around the pier. Small Ūholehole were not seen in the two locations where adults were found.

Moi, or more properly moili'i and manamoi were not observed in any numbers outside of pier area. Throw net sampling in this area revealed a bimodal size distribution suggesting two recruitment episodes (Fig. 13).

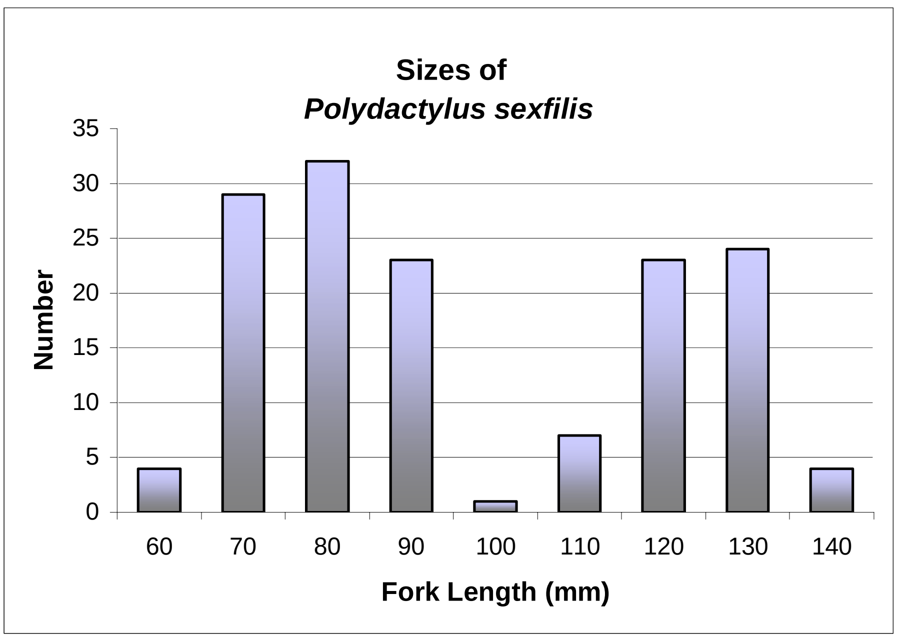


Figure 13. Size distribution of *Polydactylus sexfilis* sampled in vicinity of Green Island Pier.

One set of data from the MHI indicates that moili'i recruit to the Diamond Head FMA at 70-80mm FL. Mean post-settlement growth rate was estimated to be 1.6 mm/day (Iwai, in review). Based on this data the two observed Kure size peaks suggest recent recruitment (early September) and recruitment approximately one month earlier

(August). Recruitment at Waikiki in 2001 occurred over two months later, during the last week of November. On the windward side of `Oahu, recruitment normally occurs in late August/early September but in 2001 it did not peak until November (Friedlander, pers. comm.). Smallest fish captured in this latter study was 50 mm (FL?) but settlement check marks on otoliths indicate that settlement may actually occur at 10-15 mm or about 15-20 days after hatching.

Although it is not known whether subsequent recruitment of *P. sexfilis* occurred at Kure, it does appear that in 2001 initial recruitment at Kure was earlier than on `Oahu by about two months. Although numerous in September 2001, moi recruits were not observed to be present in this area in October 2000 (E. Shiinoki, pers. comm.).

One of the primary objectives of this project was to investigate shallow reef and beach areas for the presence of recruit and juvenile carangids, particularly *Caranx ignobilis*. Observations on the NOWRAMP expedition indicated that populations of *C. ignobilis* in many areas of the NWHI were considerably greater than on the MHI. While large specimens could often be relatively numerous small individuals were scarce. Most of the work conducted on NOWRAMP was in diving depths >30'. Thus the lack of juveniles could have been a sampling artifact in that typical shallow water areas were under sampled.

The entire Kure 2001 project was focused on such shallow water areas. Not a single recruit, juvenile or small individual (<100 cm TL) of *C. ignobilis* was observed however. Small numbers of other immature jacks were caught or noted but not *C. ignobilis*. At this point it seems clear that at Kure small individuals of this species are not found either inside or outside atoll in diving depths (Appendix 1) or on the shallows of the back reef, patch reef or sandy beach habitats.

One extensive habitat still remains to be investigated. It is the large sand bottom lagoon terrace which occupies about 77% of the area of the lagoon (Gross et al. 1969). On the MHI very small carangids (3 cm) have been reported to school over open sand areas in depths of 18 - 30 ft. (R. Prohoroff, pers. comm.). *C. ignobilis* has also been reported to gather in spring “milling” (spawning?) aggregations in Midway’s lagoon (R. Gaffney, pers. comm.). These areas warrant additional investigation.

Sediment Analysis

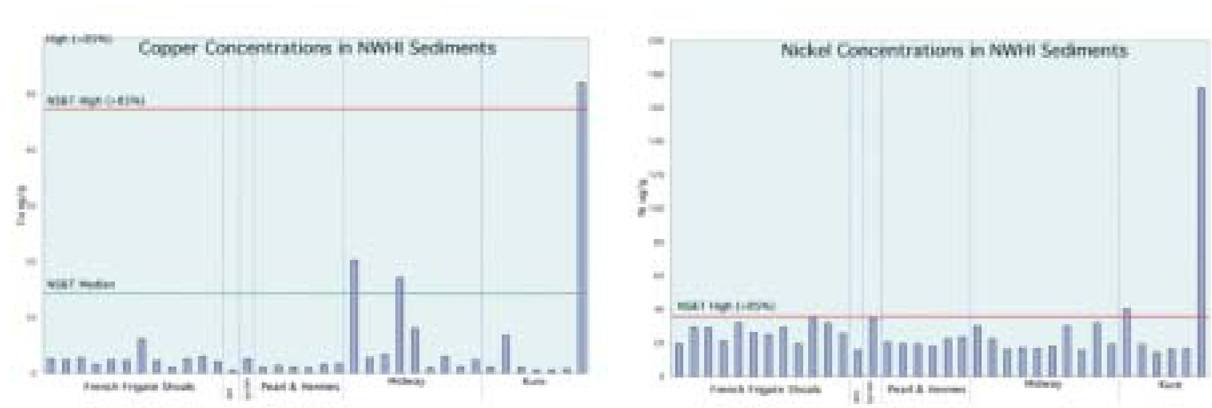
During the 2000 NOWRAMP expedition, near-shore sediment samples were collected from 36 sites at six of the NWHI. Analyses of the samples for over 70 different potentially toxic contaminants revealed that chemical concentrations were unexpectedly high at several locations particularly at Midway and Kure. Concentrations are considered high if they are above the 85th percentile of concentrations measured in the coastal United States by the NOAA National Status and Trends (NS&T) Program (Maragos and Gulko 2002). Such high concentrations of contaminants are remarkable in that these levels were found in sediments that were over 99% sand and gravel, not fine-grained ones such as those measured by the NS&T Program (D. Turgeon, pers. comm.)

Six sites were sampled at Kure. One of these sites showed the highest concentrations of copper and nickel at any NWHI location (Figure 14). This sediment sampling site was inside the southern barrier reef 283m from DAR survey site #10. No shipwreck or other source for this metal contamination was obvious (D. Turgeon, pers. comm.) although a fishing vessel, *Paradise Queen II,* did run aground on the barrier reef in 1998 approximately 6km to the east of this location (Gulko in prep). Site #10 was noteworthy for a number of reasons such as:

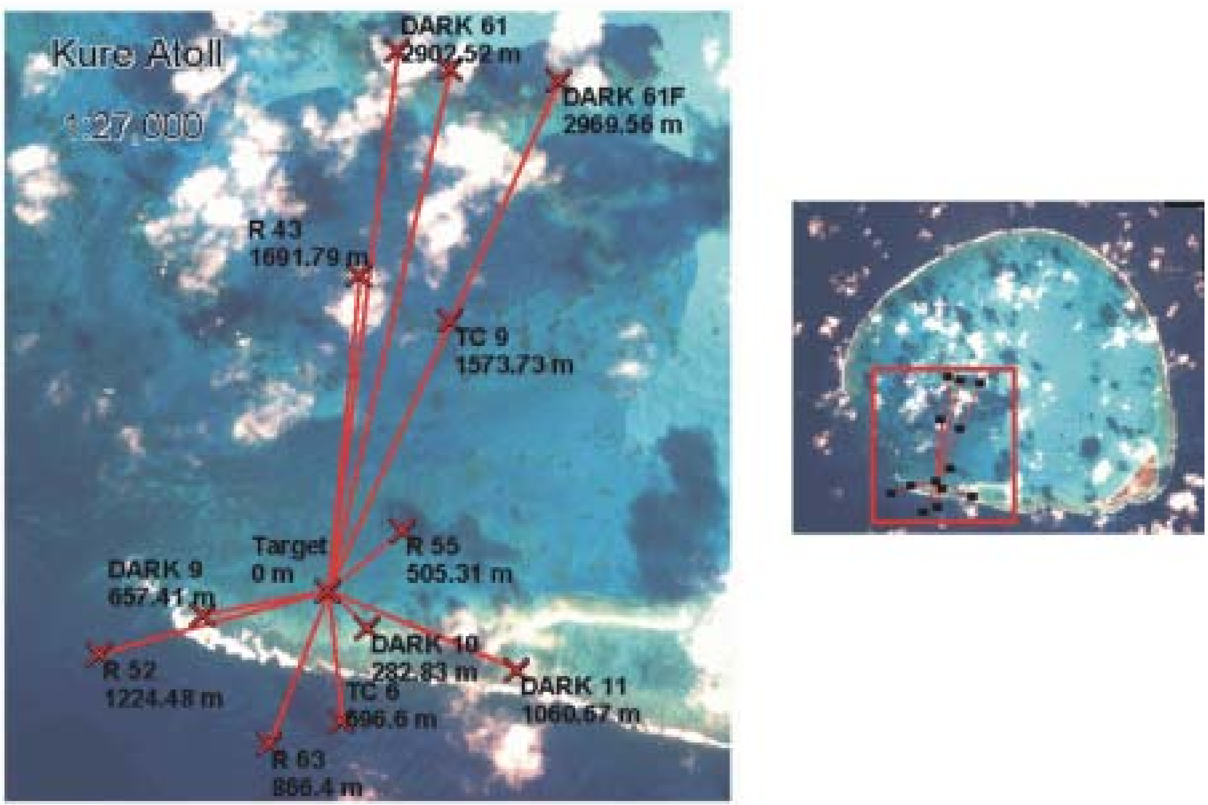
- Lowest fish density on transect of all Kure sites (Table 4, Appendix 8)
- Lowest fish biomass on transect of all Kure sites (Table 4, Appendix 8)
- Lowest number of fish species on transect of all Kure sites (Table 4, Appendix 8)
- Lowest number of fish species on DACOR (Appendix 9)
- Only Kure site with no live coral (Figure 5, Appendix 5)
- Fewest algal species collected or observed (w/ site #16-Appendix 3)
- Lowest number of surveyed invertebrates species (w/ site #9-Appendix #6)
- Lowest density of all surveyed invertebrates (Appendix 6)
- Lowest density of *E. mathaei* on all back reef areas (Figure 6, Appendix 6)

The depauperate nature of this site was quite evident and appeared to be relatively localized. For example rock boring urchins *E. Mathaei* were 25.7X greater at adjacent site #9 and 38.9X greater at site #11 (Figure 6). Both these sites are 0.8km from site

#10. These finding suggest that metal contamination from a yet undetermined source is negatively impacting the reef community in this area.



A.



B.

Figure 14. Metal contamination of Kure sediments. A. Concentrations of copper and nickel at NWHI sampling locations. B. Distance of sediment sampling site (Target) from DAR sites (DARK) and NOWRAMP sites (R=MV *Rapture*, TC=NOAA *Townsend Cromwell*).

CONCLUSIONS

- Low relief, exposed carbonate pavement interspersed with coral rubble and sand patches were the major structural elements of the atoll's back reef. Live coral in these areas was low lying, patchy and uncommon. Although coral coverage was no greater than 10%, diversity was relatively high and corals appeared healthy.

- Patch reefs within the lagoon were characterized by high coral cover, diversity and spatial complexity. Massive colonies of living *Porites compressa* grew upon the skeletal remnants of previous colonies implying long term stability of these areas and substantial age of the colonies.

- Algae dominated the benthic community of Kure Atoll. Fifty-three new algal records were obtained. Species composition of the algal community differs considerably from the MHI and there were an unusually high proportion of brown algae. No alien species were noted and no species could be regarded as being "invasive."

- The blue green alga, *Lyngbya majuscula*, appears to have an association with shipwrecks. This species also occurred as drift material within the lagoon and may have a source outside the atoll. The abundance of the parchment worm *Chaetopterus sp.* may likewise be increased by the nearby presence of a shipwreck.

- Kure's lagoon showcases algal dominance in a healthy even pristine setting. This serves as a reminder that not all algal dominated coastal areas around the MHI should be considered problematic or the result of anthropogenic influences.

- Rock-boring urchins were a numerically dominant and conspicuous element of the invertebrate fauna and important algae consumers and bioeroders. Their density was within the range found on other coral reefs both within and outside of Hawai`i.

- With the exception of urchins and sea cucumbers, most invertebrates were not visibly abundant at the study sites. *Pinctada margaritifera* were rare and there were no sightings of *Acanthaster planci.*

- Green turtles, *Chelonia mydas* were uncommon even though potential food resources appeared plentiful. Historical records suggest that they may have been much more abundant in the past.

- Fish populations were diverse and robust especially considering the emphasis placed on the shallow, low relief, shelter-poor, wave stressed back reef habitat. Overall biomass was dominated by a small number of species and biomass density was higher than most MLCDs on Oahu.

- Endemic species were an especially important element of the fish fauna being disproportionately represented in terms of the numbers of species, adult fish, recruits and biomass. No introduced species were present.

- Herbivores and benthic invertebrate feeders predominated among the most abundant fish species. In contrast to other NWHI sites, piscivores were not a dominant element of the fish fauna.

- Relatively few individuals of the White Ulua, *Caranx ignobilis* were observed within the lagoon. A high proportion of them (17%) exhibited evidence of encounters with fishing gear. Other large piscivores were uncommon.

- A number of fish species including carangids, labrids and kyphosids exhibited a clear tendency to be attracted to and aggregate around divers. In the main Hawaiian Islands this behavior has been attributed to feeding of fish by humans but it is now appears to occur even without such influence. *Some* carangids will follow a moving boat. *C. ignobilis* will do so for at least 0.8 km. The tendency of certain fish to congregate around divers may lead to an overestimation of their overall abundance.

∉ Several species of fish had very limited distributions and were concentrated in a single or relatively few locations making them extremely vulnerable to disturbances such as fishing or natural perturbations.

∉ The lagoon as a whole, including both back reef and patch reef habitats, was an important nursery area for a variety of fish species. Several species appeared to have distinct settlement patterns and recruitment could be extremely localized.

∉ Seasonality of recruitment for observed species was generally quite similar to that known for the MHI with the notable exception of moi which seemed to have recruited up to two months earlier than on `Oahu.

∉ Although efforts were specifically made to locate juvenile and small immature *C. ignobilis,* none were observed. Their absence may be due to still insufficient sampling (i.e. sandy lagoon bottom) or alternatively they may, in fact, be extremely scarce. If the latter is the case the population of these large predators may have an atypical, top heavy size distribution and thus be extremely vulnerable to fishing pressure.

∉ Different assessment methodologies generally provided good agreement in observed patterns subject to the varying expertise and focus of the observer.

∉ Copper and nickel contamination from an unknown source appears to have negatively impacted the reef community at a back reef site. The effect of this contamination seems to be relatively localized.

∉ The overall impression of Kure Atoll was that of a vibrant, healthy, largely pristine ecosystem whose small size, accessibility and unique biological features make it highly vulnerable to human impact. If this ecosystem is to remain intact, human influence must be carefully managed and minimized wherever possible.

ACKNOWLEDGEMENTS

A number of people were instrumental in making this project a reality. We'd like to thank Athline Clark of DAR for her efforts both before during and after. John Kahiapo and Shelly Alexander of DAR were important additions to the field team. Chris Walsh, Dave Gulko, Lisa Wedding, Brian Tissot and Noe Puniwai assisted in data analysis. Christian Kerr provided GIS assistance and Stephani Holzwarth of NMFS was helpful in providing information on NOWRAMP. Alan Friedlander most graciously provided length/weight fitting parameters. Fieldwork on Kure was made possible with the enthusiastic assistance of Ethan Shiinoki of the Division of Forestry and Wildlife (DOFAW/DLNR). Kudos and aloha to the folks at Midway Phoenix Corporation for their logistic support. During our stay at Kure our thoughts and sympathies were with those affected by the maelstrom of September 11th. This research was funded by a grant from the National Center for Ocean and Coastal Science (NA070A0457).

LITERATURE CITED

Abbott, I. A. 1989. Marine algae from the Northwestern Hawaiian Islands. Pac. Sci. 43: 223-233.

Balazs, G.H., R.R. Rice, N. Hoffman, S.K. Murakawa, D.M. Parker, and R.J. Shallenberger. (in press). Green turtle foraging and resting habitats at Midway Atoll: Significant findings over 25 years, 1975-2000. Proceed. 21st. Annual Symposium on Sea Turtle Biology and Conservation, February 24-28, 2001. 5 pp.

Carreiro-Silva, M. and T.R. McClanahan. 2001. Echinoid bioerosion and herbivory on Kenyan coral reefs: the role of protection from fishing. Jour. Exp. Mar. Biol. Ecol. 262 (2001):133-153.

Dana, T.F. 1971. On the reef corals of the world's most northern atoll (Kure: Hawaiian archipelago). Pac. Sci. 25: 80-87.

DeMartini, E.E. (in review). Habitat affinities and endemism of recruits to shallow reef fish populations at two isolated oceanic atolls. Bull. Mar. Sci.

Doty, M.S. 1968. Biological and physical features of Kealakekua Bay, Hawai`i. University of Hawai`i, Hawai`i Botanical Science Paper No. 8, 210 pp.

Doty, M. S. 1969. The ecology of Honaunau Bay, Hawai`i. University of Hawai`i, Hawai`i Botanical Science Paper No. 14, 221 pp.

Friedlander, A.M. 2001. Essential fish habitat and the effective design of marine reserves: Application for marine ornamental fishes. Aquarium Sciences and conservation 3: 135-150.

Gross, M.G., J.D. Milliman, J.I. Tracey, Jr., and H.S. Ladd. 1969. Marine Geology of Kure and Midway Atolls, Hawai`i: A preliminary report. Pac. Sci 23:17-25.

Gulko, D.A. (in prep.). Vessel groundings in Hawai`i: Threats and impacts to nearshore coral reef ecosystems.

Hobson, E.S. and J.R. Chess. 1979. Zooplankters that emerge from the lagoon floor at night at Kure and Midway Atolls, Hawai`i. Fish. Bull. 77(1) 275-280.

Iwai, TY Jr., et al. (in review). Preliminary investigation into the enhancement of the Pacific Threadfin, Moi (Polydactylus sexfilis), population within the Waikiki-Diamond Head Marine Reserve, Oahu, Hawai`i.

Maragos, J. and D. Gulko. 2002. Coral Reef Ecosystems of the Northwestern Hawaiian Islands: Interim Results Emphasizing the 2000 Surveys. U.S. Fish and Wildlife Service and the Hawai`i Department of Land and Natural Resources, Honolulu, Hawai`i. 46 pp.

Morrell, G. Jr. 1841. A narrative of four voyages to the south seas, north and south Pacific Ocean, Chinese Sea, Ethiopia, and southern Atlantic Ocean, Indian and Antarctic Ocean from the year 1822 to 1831. Harper Bros. New York. 92 pp.

Ogden N.B., J.C. Ogden, and I.A. Abbott. 1989. Distribution, abundance and food of sea urchins on a leeward Hawaiian reef. Bull. Mar. Sci. 45(2):539-549.

Randall, J.E. 1998. Zoogeography of Shore Fishes of the Indo-Pacific Region. Zoological Studies 37(4): 227-268.

Russell, D.J. and G.H. Balazs. 2000. Identification manual for dietary vegetation of the Hawaiian Green Turtle *Chelonia mydas*. NOAA Technical Memorandum, NOAA-TM-NMFS-SWFSC-294, 49 pp.

Sale, P.F. 1969. Pertinent stimuli for habitat selection by the juvenile manini, *Acanthurus triostegus sandvicensis*. Ecology 50(4):616-623.

Balazs, G. H. 1979. Marine benthic algae collected from Kure Atoll, Maro Reef and Necker Bank, Northwestern Hawaiian Islands. ‘Elepaio 39: 110-111.

Tsuda, R. T. 1965. Marine algae from Laysan Island with additional notes on the vascular flora. Atoll Research Bulletin 110: 1-31.

Woodward, P.W. 1972. The natural history of Kure Atoll, Northwestern Hawaiian Islands. Atoll Research Bull. 164: 1-318.

Appendix 1. NOW-RAMP 2000 Kure REA sites. TC denotes NOAA vessel *Townsend Cromwell* and R indicates MV *Rapture*.

Site #	Ship	Date	Depth (ft.)	N. Latitude	W. Longitude
1	TC	10/2/00	60	28° 26.668’	178° 17.793’
2	TC	10/2/00	55	28° 27.211’	178° 20.574’
3	TC	10/2/00	53	28° 26.132’	178° 22.101’
4	TC	10/3/00	58	28° 25.640’	178° 17.168’
5	TC	10/3/00	50	28° 23.003’	178° 18.413’
6	TC	10/3/00	50	28° 23.193’	178° 20.862’
7	TC	10/4/00	6 - 8	28°26.942’	178° 18.481’
8	TC	10/4/00	8 -10	28° 26.131’	178° 20.473’
9	TC	10/4/00	24	28° 24.353’	178° 20.533’
40	R	10/1/00	2 - 15	28° 24.615’	178° 21.584’
42	R	10/2/00	60 - 80	28° 26.146’	178° 22.352’
43	R	10/1/00	10 -22	28° 24.481’	178° 20.823’
44	R	10/2/00	45 - 65	28° 25.450’	178° 22.690’
45	R	10/2/00	45 - 50	28° 26.756’	178° 21.662’
46	R	10/2/00	25 - 40	28° 24.217’	178° 22.450’
47	R	10/2/00	33 - 60	28° 25.788’	178° 22.357’
48	R	10/3/00	50 - 80	28° 27.419’	178° 20.536’
49	R	10/2/00	14 - 18	28° 24.733’	178° 22.441’
50	R	10/3/00	40 - 65	28° 27.532’	178° 19.293’
51	R	10/3/00	42 - 51	28° 27.565’	178° 19.890’
52	R	10/3/00	35 - 45	28° 23.377’	178° 21.626’
53	R	10/3/00	45 - 50	28° 26.985’	178° 17.949’
54	R	10/4/00	50 - 60	28° 25.950’	178° 17.381’
55	R	10/3/00	10 - 16	28° 23.746’	178° 20.673’
56	R	10/4/00	25 - 40	28° 23.355’	178° 17.267’
57	R	10/4/00	27 - 46	28° 24.989’	178° 16.994’
58	R	10/4/ 00	10 - 20	28° 25.418’	178° 21.920’
59	R	10/4/00	32 - 38	28° 23.075’	178° 17.664’
60	R	10/5/00	50 - 60	28° 23.015’	178° 20.250’
61	R	10/4/00	10 - 18	28° 25.117’	178° 20.753’
62	R	10/5/00	10 - 30	28° 24.864’	178° 20.327’
63	R	10/5/00	46 - 50	28° 23.127’	178° 21.089’
64	R	10/5/00	2 - 20	28° 25.372’	178° 22.036’
65	R	10/5/00	7 - 10	28° 24.825’	178° 19.677’
67	R	10/5/00	2 - 5	28° 26.691’	178° 21.073’

Appendix 2. DAR Kure 2001 site location information. A & B refers to two 25m transects at each site.

Site #	Date	Depths A,B (ft.)	Surface Water Temperature (F°)	N. Latitude	W. longitude
1	9/12/01	3,3	80	28° 24.496'	178° 17.102'
2	9/04/01	6,6	80	28° 24.923'	178° 17.244'
3	9/04/01	4,4	81	28° 25.330'	178° 17.343'
4	9/04/01	4,3	81	28° 25.809'	178° 17.490'
5	9/05/01	4,3	81	28° 26.174'	178° 17.697'
6	9/05/01	4,4	81	28° 26.531'	178° 17.984'
7	9/05/01	3,3	81	28° 26.851'	178° 18.370'
8	9/05/01	4,4	81	28° 27.082'	178° 18.768'
9	9/06/01	3,3	80	28° 23.495'	178° 21.302
10	9/06/01	2,2	80	28° 23.462'	178° 20.783'
11	9/06/01	4,4	80	28° 23.346'	178° 20.309'
12	9/06/01	3,3	80	28° 23.273'	178° 19.837'
13	9/07/01	4,4	80	28° 23.175'	178° 19.380'
14	9/07/01	3,3	80	28° 23.257'	178° 18.906'
15	9/07/01	3,3	80	28° 23.204'	178° 18.445'
16	9/07/01	2,2	81	28° 23.351'	178° 18.176'
17	9/10/01	4,4	80	28° 27.236'	178° 19.213'
18	9/10/01	4,4	80	28° 27.233'	178° 19.723'
19	9/10/01	4,4	80	28° 27.112'	178° 20.189'
20	9/10/01	4,4	80	28° 26.964'	178° 20.667'
21	9/11/01	5,5	80	28° 26.473'	178° 21.459'
22	9/12/01	4,4	80	28° 25.165'	178° 22.332'
23	9/12/01	3,3	80	28° 25.601'	178° 22.174'
24	9/12/01	4,4	80	28° 25.998'	178° 21.934'
67	9/11/01	4,4	80	28° 26.691'	178° 21.073'
61	9/08/01	4,4	80	28° 25.130'	178° 20.711'
61E	9/08/01	4,4	80	28° 25.079'	178° 20.542'
61F	9/08/01	4,4	80	28° 25.048'	178° 20.197'

Appendix 3. Algae collected or observed at Kure study sites. (t) denotes turf species, * indicates new record.

Species	Freq.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	67	61	61E	61F
CHLOROPHYTA (15)																													
*Acetabularia parvula (t) **	0.04																											X	
*Acetabularia clavata (t) **	0.04																											X	
*Boodlea composita **	0.07																							X				X	
*Bryopsis pennata **	0.07																X											X	
Caulerpa racemosa	0.11									X		X												X					
*Caulerpa webbiana (t) **	0.14	X								X	X	X																	
Codium sp. (encrusting)	0.14						X	X							X													X	
*Codium edule **	0.11							X								X												X	
Dictyosphaeria cavernosa	0.75	X			X		X	X	X	X	X	X	X	X	X	X	X		X	X		X			X	X	X	X	X
Dictyosphaeria versluysii	0.86	X	X	X	X	X	X	X	X	X	X			X	X	X	X			X	X	X	X	X	X	X	X	X	X
Halimeda discoidea	0.79	X	X	X	X	X		X	X	X		X		X	X	X		X	X	X	X	X	X		X		X	X	X
*Halimeda tuna **	0.21	X				X			X				X			X										X			
Microdictyon setchellianum	1.00	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
*Neomeris annulata **	0.36	X			X	X	X					X			X			X	X		X	X							
*Ventricaria ventricosa **	0.04																												X
PHAEOPHYTA (16)																													
Dictyota sp.	0.11						X	X																				X	
Dictyota sp. (lg.)	0.07	X				X																							
Dictyota acutiloba	0.29									X	X	X	X	X	X	X	X												
*Dictyota divaricata **	0.21			X							X	X		X	X	X													
*Dictyota friabilis **	0.18	X		X																	X		X						X
*Hydroclathrus clathratus **	0.04																	X											
*Hincksia mitchelliae (t) **	0.07						X						X																
Lobophora variegata	0.68	X	X	X	X	X	X		X	X			X	X				X	X	X	X	X	X	X	X	X			
Padina sp.	0.07														X	X													
*Padina japonica **	0.04	X																											
Sargassum sp.	0.29		X	X						X		X						X	X	X			X						
Sphacelaria sp. (t)	0.18									X			X		X	X												X	
Sphacelaria tribuloides (t)	0.04														X														
Stypopodium hawaiiensis	0.64	X		X			X			X	X			X	X	X		X	X	X	X	X	X	X	X	X		X	
Turbinaria ornata	0.68	X	X	X	X	X	X		X	X	X	X		X				X	X	X	X	X	X	X		X			
"Vaunella phase (padina)"	0.07			X									X																
RHODOPHYTA (61)																													
Acrochaetium sp. (t)	0.04					X																							
Antithamnion sp. (t)	0.36	X	X		X	X						X			X				X					X	X	X			
Antithamnion antillanum (t	0.04																												X
Antithamnionella breviram	0.07	X			X																								
Asparagopsis taxiformis	0.11																				X					X		X	
Centroceras sp. (t)	0.04																						X						
Centroceras corallophilloid	0.07											X															X		
*Centroceras minutum (t) **	0.57	X		X		X		X	X	X	X		X		X	X		X	X		X		X	X		X			
Ceramium sp. (t)	0.12								X	X		X				X							X		X				
Ceramium clarionensis (t)	0.07																										X	X	
*Ceramium codii (t) **	0.36		X	X		X	X		X				X	X	X								X					X	
Ceramium dumosertum (t)	0.14		X						X											X					X				
*Ceramium fimbriatum (t) **	0.42	X					X		X			X	X		X	X		X	X					X	X		X		
Ceramium tenuissimum (t)	0.50	X				X	X	X		X		X	X		X						X		X	X		X		X	X
Chondria sp. (t)	0.50		X	X				X		X	X		X		X	X	X			X			X			X		X	X
*Chondria arcuata (t) **	0.04																										X		
*Chondria polyrhiza (t) **	0.39	X	X		X	X			X									X		X	X	X		X	X				
Corallophila sp. (t)	0.11					X							X											X					
*Corallophila apiculata (t) **	0.29	X	X															X	X	X	X	X	X						
Corallophila huysmansii (t)	0.07												X												X				
Crouania sp. (t)	0.39		X		X	X			X			X	X		X				X			X	X		X				
Dasya sp.	0.07						X														X								
*Dasya pilosa **	0.04											X																	
Dasya iridescens	0.14	X												X							X					X			
*Diplothamnion jolyi (t) **	0.04												X																
"Falkenbergia phase" (t)	0.50	X		X			X	X		X	X	X	X	X			X	X									X	X	X
*Galaxaura rugosa **	0.07	X		X																									
Griffithsia heteromorpha (t	0.50	X		X				X	X			X					X	X	X		X	X	X	X		X	X		
Haloplegma duperreyi	0.18							X				X	X	X	X														
Herposiphonia sp. (t)	0.18		X	X	X			X					X																
Herposiphonia delicatula (	0.04									X																			

Appendix 3. Algae collected or observed at Kure study sites. (t) denotes turf species, * indicates new record.

Species	Freq.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	67	61	61E	61F
*Herposiphonia nuda (t) **	0.14	X							X				X				X												
Herposiphonia obscura (t)	0.07	X				X																							
Herposiphonia pacifica (t)	0.71		X	X	X	X	X		X	X					X		X	X	X	X	X		X	X	X	X	X	X	X
Heterosiphonia crispella (t	0.54	X	X			X	X			X		X	X	X					X	X	X		X	X	X				X
*Hypnea pannosa **	0.39	X															X	X	X		X	X	X		X		X	X	X
*Hypnea spinella (t)**	0.04																								X				
*Hypnea valentiae **	0.04															X													
*Jania adhaerens (t) **	0.11																						X			X	X		
*Jania micrarthrodia (t) **	0.04																											X	
Jania pumila (t)	0.79	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X		X			X	X	
Laurencia sp.	0.11		X									X			X														
*Laurencia galtsoffii **	0.93	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
*Laurencia parvipapillata **	0.43	X		X								X	X	X	X				X		X	X				X		X	X
Liagora sp.	0.39	X	X		X	X			X	X	X	X						X	X						X				
Monosporus sp. (t)	0.04																										X		
Neosiphonia sp. (t)	0.04						X																						
Neosiphonia beaudettei (t)	0.07				X																						X		
*Peyssonnelia inamoena **	0.11																										X	X	X
Polysiphonia sp. (t)	0.75		X	X			X		X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	
*Polysiphonia sparsa (t) **	0.07	X					X																						
Polysiphonia upolensis (t)	0.07																									X	X		
*Portieria hornemannii **	0.07																										X		X
Spermothamnion sp. (t)	0.04									X																			
Spirocladia hodgsoniae (t)	0.04						X																						
Spyridia filamentosa	0.11			X				X				X																	
*Stylonema alsidii (t) **	0.57	X			X	X			X	X		X	X	X		X		X		X			X	X	X		X		X
*Taenioma perpusillum (t) **	0.18							X								X	X										X	X	
*Tiffaniella saccorhiza (t) **	0.14		X							X					X											X			
*Vanvoorstia coccinea **	0.11																										X	X	X
Womersleyella pacifica (t)	0.18						X		X					X				X							X				
OTHERS																													
Lyngbya sp.	0.07							X				X																	
Number of spp. at each site		34	22	23	18	23	24	19	23	27	14	30	27	19	27	21	14	22	22	18	23	16	24	20	21	21	23	29	19

Benthic Category	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13.00**	**14**
Turf algae	49	23.5	37.5	18.5	22	16.5	32.5	16.5	40	31.5	14	38	13.00	33.5
Microdictyon setchellianum	29	38.5	20.5	29.5	20.5	21	24.5	25.5	15	21.5	20	31.5	39.00	30
Crustose coralline algae	6.5	4	19	19	31.5	21	7.5	15	15	34	31	7	24.00	13
Sand	5	28	19	6.5	19	14	11	23.5	18	10.5	11	9.5	8.50	12
Laurencia galtsoffii		4.5		14	0.5	4	1.5	5	5			1.5	5.50	4.5
Porites compressa														
Porites lichen				4.5		6.5					7	10		0.5
Turbinaria ornata				2.5		7.5		5	0.5					
Echinometra mathaei		0.5			0.5	0.5	1.5	0.5	1		9	0.5	1.00	3
Jania sp.				0.5	3	2		7						
Chaetopterus sp.	0.5						21.5				1			0.5
Lobophora variegata	2.5		2		0.5	5.5		1	1.5					
Porcillopora ligulata	0.5			3	0.5	0.5			1.5		0.5	1	2.00	1.5
Laurencia sp.														
Dictyota acutiloba									1	2	4		4.50	0.5
Dictyosphaeria cavernosa	0.5										1	0.5		
Dictyosphaeria versluysii				0.5	1.5									
Stypopodium hawaiiensis	0.5	0.5				0.5			1.5		0.5		1.50	0.5
Montipora flabellata														
Halimeda discoidea	4.5		1	0.5	0.5									
Pocillopora damicornis														
Pavona duerdeni						0.5								
Heterocentrotus mammillatus				1										
Chondria sp.														
Hypnea pannosa														
Peyssonnelia inamoena														
Actinopyga obesa													1.00	
Laurencia parvipapillata	1													
blue green algae			1											
Echinostrephus aciculatus												0.5		
Coral sp. (5 sided)		0.5												
Vanvoorstia coccinea														
Coral sp. (6 star)														
Liagora sp.								0.5		0.5	0.5			
Dictyota divaricata											0.5			0.5
Portieria hornemannii														
Acetabularia sp.														
Dictyota friabilis	0.5													
Padina japonica														
Conus abbreviatus														
Holothuria atra								0.5						
Sponge sp.														

Benthic Category	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**67**	**61**	**61E**	**61F**	Mean
Turf algae	32	9.5	49.5	38.5	37	41	16	48.5	47	51.5	26	43	31.5	26.5	31.55
Microdictyon setchellianum	21.5	28	18	27.5	20	28	39.5	16.5	13	21.5	35	3.5	0.5	9.5	23.14
Crustose coralline algae	8.5	23	7.5	9.5	8	10.5	19.5	15	14	13	16.5	17.5	16	19.5	15.91
Sand	26.5	23	13	8	4.5	6.5	4	6.5	20	6.5	3		2.5		11.41
Laurencia galtsoffii	2.5	5.5	6	1	9.5	7.5	3.5	8	4	0.5	2.5	2	0.5		3.54
Porites compressa												23	22	29.5	2.66
Porites lichen			0.5	8.5		0.5	5.5			0.5	3				1.68
Turbinaria ornata			2.5	3.5	9		0.5	0.5			1				1.16
Echinometra mathaei	3.5	1	0.5		0.5		1.5	2		1			0.5		1.02
Jania sp.	1.5	0.5	0.5	0.5	0.5	1				1		2.5	2.5	1	0.86
Chaetopterus sp.															0.84
Lobophora variegata			0.5	1	2	2.5	1.5	0.5		0.5	0.5				0.79
Porcillopora ligulata				0.5	1	1	3.5		1	1.5	2.5				0.79
Laurencia sp.													10	8	0.64
Dictyota acutiloba	0.5	1													0.48
Dictyosphaeria cavernosa	0.5	1											5.5	2.5	0.41
Dictyosphaeria versluysii	1	1.5										1	3	2	0.38
Stypopodium hawaiiensis	1.5		0.5		1	0.5									0.32
Montipora flabellata											7	2			0.32
Halimeda discoidea				0.5											0.25
Pocillopora damicornis				0.5				0.5			2	2.5	0.5	0.5	0.23
Pavona duerdeni					3.5		2								0.21
Heterocentrotus mammillatus				0.5	1	0.5			1			0.5			0.16
Chondria sp.		4													0.14
Hypnea pannosa			0.5				1					1	0.5	0.5	0.13
Peyssonnelia inamoena												0.5	2.5	0.5	0.13
Actinopyga obesa						0.5	0.5	0.5			0.5	0.5			0.13
Laurencia parvipapillata					1.5										0.09
blue green algae		1.5													0.09
Echinostrephus aciculatus								1		1					0.09
Coral sp. (5 sided)							1.5				0.5				0.09
Vanvoorstia coccinea												0.5	1.5		0.07
Coral sp. (6 star)			0.5							1.5					0.07
Liagora sp .															0.05
Dictyota divaricata															0.04
Portieria hornemannii					1										0.04
Acetabularia sp.													0.5		0.02
Dictyota friabilis															0.02
Padina japonica	0.5														0.02
Conus abbreviatus								0.5							0.02
Holothuria atra															0.02
Sponge sp.		0.5													0.02

Appendix 5. Live coral abundance at Kure study sites. A. Percent cover as determined by video analysis. B. Qualitative DACOR analysis. Question mark (?) indicates identification is uncertain.

A. % Cover (Video)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	17	18	19	20	21	22	23	24	67	61	61E	61F	Mean
Species																											
Leptastrea purpurea																			0.2								0.01
Montipora spp.															0.3			0.2	0.2			0.2		1.5			0.09
Pocillopora meandrina			2.1			0.1											0.1										0.09
Pocillopora spp.		2.6		2.6	0.1	0.5		0.6	0.4		1.1	0.5	3.6	3.1	3.2	0.2	3.5	0.2	1.1	1.8	0.7	0.5	2.4	2.6	0.6		1.23
Porites compressa								0.1																19.6	46.7	35.7	3.92
Porites lichen							3.0												2.2	1.4		1.6	0.7				0.34
Porites lobata	1.7			1.3		5.5						2.2		0.1	1.6		0.3	1.5									0.55
Porites spp.					9.2						6.0					3.3											0.71
Total	1.7	2.6	2.1	3.9	9.3	6.1	3.0	0.7	0.4	0.0	7.0	2.7	3.6	3.2	5.1	3.5	3.9	1.9	3.7	3.2	0.7	2.3	3.1	23.7	47.3	35.7	6.95

B. DACOR

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	17	18	19	20	21	22	23	24	67	61	61E	61F
Species																										
Leptastraea purpurea																R			R							
Montipora sp.															O											
Pocillorora meandrina			R?				R?												R?			R?				
Pocillorora sp.		R		R		R		R	R		R	R			R	R	R	R	R	R	R	R	O		R	
Porites compressa								R?																A	A	D
Porites lichen					R		R?	R?			R?		R?	R		O?	C	C	O	O		O	O	R	R	
Porites lobata	R?			O?	O?	R					R?	R?			O?	R?										
Porites sp.					R			R														R				
Cyphastrea ocellina															R?											
Cyphastrea sp.							R?																	R?		
Montipora capitata																								R?		
Montipora turgescens																	R?	R?	R?			R?		O?		
Pavona duerdeni																	R		R							
Pocillopora damicornis	R?	R		R?	R?			R?	R?						R?			R?	R?	R	R	R	R?	A	R	C
Pocillopora ligulata	R?	R?	R	O	R		R?		R		R	R	R	R	R?	R	C	C	O	C	R	O	O		R?	
Porites evermani											R															

Appendix 6. Density (No./100m^2) of surveyed invertebrates at Kure study sites.

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	67	61	61E	61F
Echinometra mathaei	216	190.5	95	775.5	368.5	482	1008	207.5	1621.5	63	2450	742	910.5	1033	870	323.5	204	235	431.5	438.5	1090	771	302.5	240.5	183	26.5	50.5	92
Echinostrephus aciculatus	18.5	43.5	3	85	13.5	31.5	13	53	2.5		5.5	81	110	72	14.5		128.5	108	146.5	208.5	148	215	35.5	109	256.5			
Heterocentrotus mammillatus	2.5	1.5		24	13	11.5	4	14.5	5	0.5	18	37.5	7.5	3		1.5	25.5	19.5	14.5	28	26	25.5	23	45	24	12.5	16	3
Actinopyga obesa	4.5	5	22	5	7	17.5	1.5	23.5							0.5	14	12	5	4	6	4.5	16.5	3.5	14.5	8	77.5	4	12.5
Spirobranchus giganteus		1			1	2		0.5				1	1.5	33.5	1		8	2	2									0.5
Conus spp.			0.5		2.5	0.5	2	0.5		1.5	1		1.5	0.5	2					1	0.5				1		0.5	
Holothuria atra				0.5		1.5	1				0.5	0.5				0.5	2		1.5			1	0.5	3	0.5	0.5		
Sabellastarte sanctijosephi							2.5	0.5			1	4																
Holothuria whitmaei	0.5																0.5	0.5	1	0.5	0.5		0.5	1				
Echinothrix diadema															2													
Turbo sandwicensis					0.5															0.5	0.5			0.5				
Octopus cyanea			0.5										1.5															
Ophiocoma erinaceus					0.5	0.5									0.5							0.5						
Cypraea spp.						1					0.5																	
Spondylus violacescens																												1.5
Linkia multiflora																												1.5
Echinothrix calamaris				0.5																								
Ophiocoma pica																												0.5
hermit crab																			0.5									
Pinctada margartifera																												0.5

Appendix 7. List of fish species recorded on surveys. DACOR and Recon include only those species not observed on belt transects. Endemic species are in **bold** type.

Family	Species	Transects	DACOR	Recon
Acanthuridae	*Acanthurus leucopareius*	X		
Acanthuridae	*Acanthurus nigroris*	X		
Acanthuridae	*Acanthurus olivaceous*			X
Acanthuridae	*Acanthurus triostegus*	X		
Acanthuridae	*Ctenochaetus strigosus*	X		
Acanthuridae	*Naso hexacanthus*			X
Acanthuridae	*Naso lituratus*		X	
Acanthuridae	*Naso unicornis*		X	
Acanthuridae	*Zebrasoma flavescens*	X		
Acanthuridae	*Zebrasoma veliferum*	X		
Apogonidae	*Apogon kallopterus*		X	
Apogonidae	***Apogon maculiferus***	X		
Atherinidae	***Atherinomorus insularum***		X	
Aulostomidae	*Aulostomus chinensis*		X	
Belonidae	*Platybelone argalus*		X	
Blenniidae	*Blenniela gibbifrons*		X	
Blenniidae	***Cirripectes vanderbilti***	X		
Blenniidae	*Exallias brevis*	X		
Carangidae	*Carangoides ferdau*		X	
Carangidae	*Caranx ignobilis*		X	
Carangidae	*Caranx melampygus*		X	
Carangidae	*Decapterus macarellus*		X	
Carangidae	*Psuedocaranx dentex*		X	
Carangidae	*Selar crumenopthalmus*			X
Carangidae	*Seriola dumerili*			X
Carcharhinidae	*Carcharhinus galapagensis*			X
Chaetodontidae	*Chaetodon auriga*	X		
Chaetodontidae	***Chaetodon fremblii***	X		
Chaetodontidae	*Chaetodon lunulatus*		X	
Chaetodontidae	***Chaetodon miliaris***	X		
Chaetodontidae	*Chaetodon ornatissimus*	X		
Chaetodontidae	*Chaetodon unimaculatus*		X	
Chaetodontidae	*Forcipiger flavissimus*		X	
Cheilodactylidae	*Cheilodactylus vittatus*		X	
Cirrhitidae	*Cirrhitops fasciatus*	X		
Cirrhitidae	*Cirrhitus pinnulatus*	X		
Cirrhitidae	*Paracirrhites arcatus*	X		
Cirrhitidae	*Paracirrhites forsteri*	X		
Clupeidae	*Spratelloides delicatulus*	X		
Diodontidae	*Diodon holocanthus*	X		
Fistulariidae	*Fistularia commersonii*	X		
Holocentridae	*Myripristis amaena*	X		
Holocentridae	*Myripristis berndti*	X		
Holocentridae	*Neoniphon sammara*	X		
Holocentridae	*Sargocentron punctatissimum*	X		
Kuhliidae	***Kuhlia sandvicensis***			X
Kuhliidae	*Kuhlia xenura*		X	
Kyphosidae	*Kyphosus bigibbus*	X		
Kyphosidae	*Kyphosus vaigiensis*		X	
Labridae	***Anampses cuvier***	X		

Appendix 7. List of fish species recorded on surveys. DACOR and Recon include only those species not observed on belt transects. Endemic species are in **bold** type.

Family	Species	Transects	DACOR	Recon
Labridae	*Bodianus bilunulatus*	X		
Labridae	*Cheilio inermis*		X	
Labridae	***Coris flavovittata***	X		
Labridae	***Coris venusta***	X		
Labridae	*Epibulus insidiator*		X	
Labridae	*Gomphosus varius*	X		
Labridae	*Halichoeres ornatissimus*		X	
Labridae	***Labroides phthirophagus***	X		
Labridae	***Macropharyngodon geoffroy***	X		
Labridae	*Novaculichthys taeniourus*		X	
Labridae	*Oxycheilinus unifasciatus*	X		
Labridae	*Pseudocheilinus octotaenia*	X		
Labridae	***Stethojulis balteata***	X		
Labridae	***Thalassoma ballieui***	X		
Labridae	***Thalassoma duperrey***	X		
Labridae	*Thalassoma purpureum*	X		
Labridae	*Thalassoma trilobatum*	X		
Lutjanidae	*Aprion virescens*		X	
Monacanthidae	*Aluterus scriptus*		X	
Monacanthidae	*Cantherhines dumerilii*		X	
Monacanthidae	***Pervagor spilosoma***		X	
Mugilidae	*Mugil cephalus*		X	
Mullidae	*Mulloidichthys flavolineatus*	X		
Mullidae	*Mulloidichthys vanicolensis*	X		
Mullidae	*Parupeneus cyclostomus*		X	
Mullidae	*Parupeneus multifasciatus*	X		
Mullidae	*Parupeneus pleurostigma*	X		
Mullidae	***Parupeneus porphyreus***	X		
Muraenidae	*Gymnothorax eurostus*	X		
Muraenidae	*Gymnothorax undulatus*		X	
Muraenidae	***Gynmothorax steindachneri***			X
Oplegnathidae	*Oplegnathus fasciatus*		X	
Oplegnathidae	*Oplegnathus punctatus*		X	
Ostraciidae	*Ostracion meleagris*	X		
Pinguipedidae	*Parapercis schauinslandii*	X		
Polynemidae	*Polydactylus sexfilis*			X
Pomacanthidae	***Centropyge potteri***		X	
Pomacentridae	***Abudefduf abdominalis***	X		
Pomacentridae	*Abudefduf vaigiensis*		X	
Pomacentridae	***Chromis hanui***		X	
Pomacentridae	*Chromis lecura*			X
Pomacentridae	***Chromis ovalis***		X	
Pomacentridae	*Chromis vanderbilti*	X		
Pomacentridae	***Dascyllus albisella***	X		
Pomacentridae	*Plectroglyphidodon jonstonianus*	X		
Pomacentridae	*Stegastes fasciolatus*	X		
Priacanthidae	***Priacanthus meeki***		X	
Scaridae	***Calotomus zonarchus***	X		
Scaridae	***Chlorurus perspicillatus***	X		

Appendix 7. List of fish species recorded on surveys. DACOR and Recon include only those species not observed on belt transects. Endemic species are in **bold** type.

Family	Species	Transects	DACOR	Recon
Scaridae	*Chlorurus sordidus*	X		
Scaridae	***Scarus dubius***	X		
Scaridae	*Scarus psittacus*	X		
Scorpaenidae	***Dendrochirus barberi***		X	
Scorpaenidae	***Pterois sphex***		X	
Scorpaenidae	***Sebastapistes ballieui***	X		
Scorpaenidae	*Sebastapistes coniorta*		X	
Syngnathidae	*Doryrhamphus excisus*		X	
Synodontidae	*Saurida flamma*	X		
Synodontidae	*Synodus variegatus*		X	
Tetraodontidae	***Canthigaster jactator***	X		
Zanclidae	*Zanclus cornutus*	X		
	Totals	61	41	9

Appendix 8. Density (#/100m^2) of fishes on belt transects ranked in order of overall abundance. Endemic species are in **bold** type.

Family	Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Acanthuridae	*Acanthurus triostegus*	34.0	49.0	128.0	58.0	53.0	67.5	57.0	29.5	11.5	48.0	28.5	5.0	19.5	44.0	115.5
Labridae	***Stethojulis balteata***	17.5	16.0	15.0	12.5	11.5	16.0	10.0	12.5	18.5	2.5	14.0	12.0	14.5	12.5	20.0
Labridae	***Thalassoma duperrey***	17.0	11.0	10.0	17.5	16.0	16.5	10.0	13.0	19.0	1.0	20.0	15.5	23.5	24.5	12.5
Scaridae	***Scarus dubius***	1.0	0.5	13.5	5.0	7.0	17.5	2.0	13.5							
Kyphosidae	*Kyphosus bigibbus*	0.5	3.5										2.5		3.0	
Pomacentridae	*Stegastes fasciolatus*	8.5	10.0	7.5	10.5	12.0	9.0	1.5	7.0	2.5		8.0	9.5	1.0	7.0	
Labridae	*Gomphosus varius*	1.0	0.5			0.5	1.0		0.5	0.5			1.0			
Scaridae	*Chlorurus sordidus*		19.5	15.5	0.5	7.0	12.0	1.5	6.5							
Labridae	***Thalassoma ballieui***	6.0	6.0	2.5	5.5	8.0	8.0	2.0	3.0	3.0		3.5	4.5	1.0	1.0	2.0
Pomacentridae	*Plectroglyphidodon johnstonianus*	2.0	3.0	0.5	1.0	1.0		1.0				0.5	1.0	1.5	2.5	2.0
Acanthuridae	*Acanthurus nigroris*	5.0	4.5	3.0	4.0	5.0	4.5		1.0	5.5		6.0	3.5	0.5	10.0	2.5
Acanthuridae	*Ctenochaetus strigosus*	0.5	10.5	1.0	5.5	2.5	8.0						0.5			
Mullidae	*Mulloidichthys flavolineatus*		4.5									5.5			3.0	
Labridae	***Macropharyngodon geoffroy***	1.5	1.0	1.0	1.0	2.5		1.0	1.5	4.5	0.5	4.0	4.5	0.5	0.5	1.5
Clupeidae	*Spratelloides delicatulus*								25.0				15.0			
Labridae	***Coris venusta***	0.5	1.5	3.0	1.0	1.0		1.5	2.0	1.0	2.0			2.5		2.0
Blenniidae	***Cirripectes vanderbilti***	0.5							0.5				0.5			0.5
Cirrhitidae	*Cirrhitus pinnulatus*	2.0	0.5	0.5	1.0	0.5	1.0		1.0			0.5	1.0	0.5	0.5	0.5
Labridae	***Anampses cuvier***	1.5	2.0	0.5		2.0	0.5		0.5	1.0		1.0			3.0	2.5
Chaetodontidae	*Chaetodon auriga*	1.0													1.0	
Labridae	***Labroides pthirophagus***	0.5	0.5				2.0		0.5			0.5			1.0	
Cirrhitidae	*Cirrhitops fasciatus*		1.0			1.5	1.0					1.0			0.5	
Scaridae	***Chlorurus perspicillatus***	0.5					0.5									
Holocentridae	*Sargocentron punctatissimum*						4.0					4.0			4.0	
Labridae	*Thalassoma pupureum*	0.5	1.0	0.5		0.5	2.0					1.0	0.5	1.0	1.0	0.5
Acanthuridae	*Acanthurus leucoparieus*	0.5										0.5			1.5	1.5
Pomacentridae	***Abudefduf abdominalis***															
Tetraodontidae	***Canthigaster jactator***	1.0	1.0			0.5			2.0							
Cirrhitidae	*Paracirrhites forsteri*		1.0					0.5				1.0	1.0		1.0	
Chaetodontidae	*Chaetodon ornatissimus*						0.5								1.0	
Pomacentridae	***Dascyllus albisella***		1.5	0.5		1.0	1.0	1.0					1.0			
Scorpaenidae	***Sebastapistes ballieui***						1.5					5.0				
Labridae	*Bodianus bilunulatus*		2.0	0.5					0.5				0.5			
Chaetodontidae	***Chaetodon fremblii***			0.5				0.5				0.5			1.0	0.5
Scaridae	***Calatomus zonarchus***					0.5	1.0									
Fistulariidae	*Fistularia commersonii*			4.5												
Mullidae	***Parupeneus porphyreus***												0.5			
Holocentridae	*Neoniphon sammara*						3.0								0.5	
Labridae	***Coris flavovittata***		0.5					1.0							0.5	0.5
Labridae	*Pseudochelinus octotaenia*															
Labridae	*Oxycheilinus unifasciatus*						0.5									
Scaridae	*Scarus psittacus*								1.0							
Chaetodontidae	***Chaetodon miliaris***															
Labridae	*Thalassoma trilobatum*		0.5	1.0	0.5											
Blenniidae	*Exallias brevis*															
Ostraciidae	*Ostracion meleagris*															
Zanclidae	*Zanclus cornutus*												0.5			
Pomacentridae	*Chromis vanderbilti*												0.5			
Muraenidae	*Gymnothorax eurostus*		0.5													
Holocentridae	*Myripristis berndti*															
Cirrhitidae	*Paracirrhites arcatus*	0.5										0.5				
Mullidae	*Parupeneus multifasciatus*					0.5										
Mullidae	*Parupeneus pleurostigma*															
Acanthuridae	*Zebrasoma veliferum*															
Apogonidae	***Apogon maculiferus***															
Diodontidae	*Diodon holocanthus*															
Mullidae	*Mulloidichthys vanicolensis*															
Holocentridae	*Myripristis amaena*															
Parapercidae	*Parapercus schauinslandii*															
Synodontidae	*Saurida flamma*														0.5	
Acanthuridae	*Zebrasoma flavescens*															
	Number of Species	22	26	19	13	20	22	13	18	9	4	19	20	10	23	14
	Total Number of Fishes/100m^2	103.5	153.0	209.0	123.5	134.0	178.5	90.5	121.0	67.0	54.0	105.5	80.5	66.0	125.0	164.5

Appendix 8. Density (#/100m^2) of fishes on belt transects ranked in order of overall abundance. Endemic species are in **bold** type.

Family	Species	16	17	18	19	20	21	22	23	24	67	61	61E	61F	Total
Acanthuridae	*Acanthurus triostegus*	158.0	9.0	10.0	13.0	29.5	8.0	3.0	12.5		0.5	1.0	7.0	2.5	1002.0
Labridae	***Stethojulis balteata***	22.0	42.0	28.0	35.0	45.5	47.5	43.0	40.0	29.0	58.5	8.0	10.5	6.5	620.5
Labridae	***Thalassoma duperrey***	13.5	16.5	11.0	23.5	25.0	25.0	27.5	20.5	23.0	31.0	20.0	16.0	9.5	489.0
Scaridae	***Scarus dubius***	7.0	11.0	0.5	0.5	5.5	0.5		1.0	1.0		68.0	154.0	106.5	415.5
Kyphosidae	*Kyphosus bigibbus*	0.5		0.5						4.0		139.0	100.0	137.5	391.0
Pomacentridae	*Stegastes fasciolatus*	7.0	13.0	14.5	7.0	9.0	15.5	16.5	11.5	18.5	15.5	41.0	49.5	40.5	353.0
Labridae	*Gomphosus varius*		0.5	10.0	4.0	4.5	8.0	9.5	7.0	17.5	18.0	48.0	45.5	46.5	224.0
Scaridae	*Chlorurus sordidus*	1.0	11.5			9.5				0.5		15.5	16.0	70.5	187.0
Labridae	***Thalassoma ballieui***	3.0	7.5	5.5	4.0	4.5	6.0	4.0	2.5	4.0	9.5	10.5	9.0	8.5	134.5
Pomacentridae	*Plectroglyphidodon johnstonianus*	5.5	0.5	4.0	1.0	2.0	2.0	6.0	0.5	1.5	3.5	9.5	16.0	11.0	79.0
Acanthuridae	*Acanthurus nigroris*	2.0			2.5			12.0	0.5	0.5				3.5	76.0
Acanthuridae	*Ctenochaetus strigosus*	8.0		0.5	0.5			8.5				5.0	12.0	11.5	74.5
Mullidae	*Mulloidichthys flavolineatus*	11.0	4.0	32.0						2.0	4.0				66.0
Labridae	***Macropharyngodon geoffroy***	2.0	3.0	1.5	0.5	3.0	5.0	1.5			0.5				42.5
Clupeidae	*Spratelloides delicatulus*														40.0
Labridae	***Coris venusta***	5.5	3.5	1.5	1.0	5.5	1.5		0.5	0.5	0.5				38.0
Blenniidae	***Cirripectes vanderbilti***	1.0	0.5				1.5			2.5		4.5	12.0	4.0	28.0
Cirrhitidae	*Cirrhitus pinnulatus*		1.0	2.5	2.5	1.0		1.5	0.5	0.5			1.0		20.0
Labridae	***Anampses cuvier***	0.5	2.0			1.0	0.5	1.0							19.5
Chaetodontidae	*Chaetodon auriga*	13.5	1.0							1.0					17.5
Labridae	***Labroides pthirophagus***			1.0						1.0	0.5	3.5	3.5	2.5	17.0
Cirrhitidae	*Cirrhitops fasciatus*		1.5	1.0	0.5	1.0	2.5	0.5	0.5	1.5	0.5				14.5
Scaridae	***Chlorurus perspicillatus***		1.5	1.0	0.5			5.0	1.5	2.0			0.5		13.0
Holocentridae	*Sargocentron punctatissimum*												0.5	0.5	13.0
Labridae	*Thalassoma pupureum*	0.5		1.5	1.0	0.5	1.0								13.0
Acanthuridae	*Acanthurus leucoparieus*			0.5	1.0	1.5	1.0	2.5							10.5
Pomacentridae	***Abudefduf abdominalis***	10.0													10.0
Tetraodontidae	***Canthigaster jactator***							0.5		2.0	1.5				8.5
Cirrhitidae	*Paracirrhites forsteri*					0.5		1.5	1.0	1.0					8.5
Chaetodontidae	*Chaetodon ornatissimus*			1.0						1.0		1.0	2.0	1.5	8.0
Pomacentridae	***Dascyllus albisella***		0.5												6.5
Scorpaenidae	***Sebastapistes ballieui***														6.5
Labridae	*Bodianus bilunulatus*								1.0	0.5				0.5	5.5
Chaetodontidae	***Chaetodon fremblii***	0.5		0.5	1.0		0.5								5.5
Scaridae	***Calatomus zonarchus***	2.5				0.5									4.5
Fistulariidae	*Fistularia commersonii*														4.5
Mullidae	***Parupeneus porphyreus***	4.0													4.5
Holocentridae	*Neoniphon sammara*												0.5		4.0
Labridae	***Coris flavovittata***	0.5						0.5							3.5
Labridae	*Pseudochelinus octotaenia*												1.5	2.0	3.5
Labridae	*Oxycheilinus unifasciatus*											0.5		2.0	3.0
Scaridae	*Scarus psittacus*													1.5	2.5
Chaetodontidae	***Chaetodon miliaris***	2.0													2.0
Labridae	*Thalassoma trilobatum*														2.0
Blenniidae	*Exallias brevis*	0.5		0.5	0.5										1.5
Ostraciidae	*Ostracion meleagris*											0.5	0.5	0.5	1.5
Zanclidae	*Zanclus cornutus*		0.5	0.5											1.5
Pomacentridae	*Chromis vanderbilti*										0.5				1.0
Muraenidae	*Gymnothorax eurostus*									0.5					1.0
Holocentridae	*Myripristis berndti*							0.5					0.5		1.0
Cirrhitidae	*Paracirrhites arcatus*														1.0
Mullidae	*Parupeneus multifasciatus*	0.5													1.0
Mullidae	*Parupeneus pleurostigma*	1.0													1.0
Acanthuridae	*Zebrasoma veliferum*							1.0							1.0
Apogonidae	***Apogon maculiferus***	0.5													0.5
Diodontidae	*Diodon holocanthus*		0.5												0.5
Mullidae	*Mulloidichthys vanicolensis*												0.5		0.5
Holocentridae	*Myripristis amaena*							0.5							0.5
Parapercidae	*Parapercus schauinslandii*			0.5											0.5
Synodontidae	*Saurida flamma*														0.5
Acanthuridae	*Zebrasoma flavescens*	0.5													0.5
	Number of Species	28	20	23	18	17	15	20	14	23	13	15	21	20	
	Total Number of Fishes/100m^2	284.0	131.0	130.0	99.5	149.5	126.0	146.5	101.0	115.5	144.5	375.5	458.5	469.5	4506.5

Appendix 9. Relative abundances (DACOR) of fishes in vicinity of transect sites. D=>100, A=50-100, C=11-49, O=6-10, R=1-5. Endemic species are in **bold** type.

Family	Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	67	61	61E	61F
Acanthuridae	*Acanthurus leucopareius*	R		R		R		R			R		R	R	R	R	R	R	R	R	R	R	O	R	R	R			R
Acanthuridae	*Acanthurus nigroris*	O	C	O	O	C	C	O	C	C	R	C	C	O	C	O	R	C	C	C	O	O	C	O	R	O			R
Acanthuridae	*Acanthurus triostegus*	A	D	D	D	D	D	D	D	D	D	A	C	A	D	D	D	O	D	C	A	D	C	C	R	O	O	C	O
Acanthuridae	*Ctenochaetus strigosus*	R	C	C	O	C	C						O				C		R	R	R	R	C	R	R	R	O	C	C
Acanthuridae	*Naso lituratus*																												R
Acanthuridae	*Naso unicornis*	R	O	R	R	R	R		R	R		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	
Acanthuridae	*Zebrasoma flavescens*		R			R			R								R										R	R	R
Acanthuridae	*Zebrasoma veliferum*	R	R		R		R										O	R	R		R		R	R	R	R	R		R
Apogonidae	*Apogon kallopterus*								R																		O		O
Apogonidae	***Apogon maculiferus***							A									R												
Atherinidae	***Atherinomorus insularum***							D																					
Aulostomidae	*Aulostomus chinensis*						R										R							R			R		
Belonidae	*Platybelone argalus*	R	O				O	C	C			O		C	O	R		R	R	R	R			R	R	O	C	C	
Blenniidae	*Blenniella gibbifrons*	R																					R						
Blenniidae	***Cirripectes vanderbilti***	R		R	R	R	R		R			R	O		R	R	R	R			R	R			R	R	O		O
Blenniidae	*Exallias brevis*	R													R		O		R	R	R	R							
Carangidae	*Carangoides ferdau*																R										R		R
Carangidae	*Caranx ignobilis*		R		R	O		O	R					R								R	R	R	R				R
Carangidae	*Caranx melampygus*		R	O	O		R	R				R		R						R	R	R			R				
Carangidae	*Decapterus macarellus*																										R		R
Carangidae	*Psuedocaranx dentex*																										R		
Chaetodontidae	*Chaetodon auriga*	R	R	O	R	O	O	O	O			R	R	R	R	R	A	R	R	R	R	R	R	R	R	R	R	R	R
Chaetodontidae	***Chaetodon fremblii***	R		R			R	R	R	R		R	R	O	R	R	R	R	R	R	R	R	R	R		R	R	R	R
Chaetodontidae	*Chaetodon lunulatus*								R									R			R				R	R	R	R	R
Chaetodontidae	***Chaetodon miliaris***			R	R		R	O					R		R		R	R		R	R					R	R	R	
Chaetodontidae	*Chaetodon ornatissimus*				R	R	R		R				R	R	R		O	R	R	R	R	R	R	R	R	R	O	R	O
Chaetodontidae	*Chaetodon unimaculatus*						R																						
Chaetodontidae	*Forcipiger flavissimus*							R				R					R								R				
Cheilodactylidae	*Cheilodactylus vittatus*																										C		
Cirrhitidae	*Cirrhitops fasciatus*	R	R		R	R	R	R	R			R	O	R	R	R		R	R	R	R	R	R	R	R	R	R	R	
Cirrhitidae	*Cirrhitus pinnulatus*	R	R	R	R	R	R	R	R	R		R	O	O	R	R		R	R	R	R	R	R	R	R	R	R	R	
Cirrhitidae	*Paracirrhites arcatus*	R										R	R			R													
Cirrhitidae	*Paracirrhites forsteri*	R	R				R	R	R	R		R	O	R	R	R		R	R		R	R	R	R	R	R	R		
Clupeidae	*Spratelloides delicatulus*		D	D	D	D	A	A	D			A	A	D	D	D		A	C	D			C	C			A	C	
Diodontidae	*Diodon holocanthus*								R				R					R								R		R	
Fistulariidae	*Fistularia commersonii*			O		C	R	R	R	R		R				R		R		A	R		R	R		R			
Holocentridae	*Myripristis amaena*	C																					R	C			R		
Holocentridae	*Myripristis berndti*							O								O	C									R	R	R	O
Holocentridae	*Neoniphon sammara*	R		R	R	O	O		A			R	O		R	O	O	R			R	R	R		R	R	R	R	O
Holocentridae	*Sargocentron punctatissimum*					R	O	R				O	C	R	O		O	R										R	R
Kuhliidae	***Kuhlia xenura***																							R					
Kyphosidae	*Kyphosus bigibbus*	R	C		O	O	O	R	R			R	C	C	C		R	R	R	R	O	O		C	C	C	D	D	D
Kyphosidae	*Kyphosus vaigiensis*				O	R	R					R			R														
Labridae	***Anampses cuvier***	R	O	O	R	O	R	O	R	O		O	R	R	O	O	R	R	R	R	R	R	R	R	R	R		R	R
Labridae	*Bodianus bilunulatus*	R	O	O	R	R	R	R	R	R		R	R	R	R	R		R	R	R	R	R	R	R		R	R	R	R
Labridae	*Cheilio inermis*																						R	R					
Labridae	***Coris flavovittata***	R	R	R	R	R	R	O	R	R		R	R	R	O	O	R	R	R	R	R	R	R	R		R	R	R	R
Labridae	***Coris venusta***	R	O	O	R	O	R	R	R	O	O	R	O	O	O	R	O	R	R	R	O	R	R	R		R			
Labridae	*Epibulus insidiator*																												R
Labridae	*Gomphosus varius*	R	R			R	R		R	R			R					R	C	R	O	O	O	C		C	D	A	D
Labridae	*Halichoeres ornatissimus*														R														
Labridae	***Labroides phthirophagus***	R	R		R	O	O		O			R	O	R	R	R		R	R	R	R	R	R	R		R	O	O	O
Labridae	***Macropharyngodon geoffroy***	R	O	O	R	O	R	R	R	C	R	O	C	R	R	O	R	O	R	R	R	O	R		R	R	R		R
Labridae	*Novaculichthys taeniourus*									R																			
Labridae	*Oxycheilinus unifasciatus*						R																		R		O	O	O
Labridae	*Pseudocheilinus octotaenia*																										R	R	R
Labridae	***Stethojulis balteata***	C	A	A	C	C	C	C	C	O	O	C	C	C	C	C	A	A	C	A	A	D	A	A	A	D	C	C	C
Labridae	***Thalassoma ballieui***	O	C	C	C	C	C	O	C	A		C	C	O	O	O	O	C	O	R	O	O	O	O	O	C	C	C	C
Labridae	***Thalassoma duperrey***	C	A	C	A	A	A	A	C	A		C	C	C	C	C	C	C	C	A	A	A	A	C	C	C	A	C	C
Labridae	*Thalassoma purpureum*	R		R	R	R	O			R		R	R	R	O	R	R	R	R	R	R	R	R		R				
Labridae	*Thalassoma trilobatum*	R	R	R	R																	R	R	R		R			
Lutjanidae	*Aprion virescens*																										R		
Monacanthidae	*Aluterus scriptus*																										R		
Monacanthidae	*Cantherhines dumerilii*																						R	R	R				
Monacanthidae	***Pervagor spilosoma***																R												
Mugilidae	*Mugil cephalus*															R													
Mullidae	*Mulloidichthys flavolineatus*	A	C	C	D	C	D	D	A		O	C	C	O	C	D	D	C	A	A	D	O	C	O	O	D	D	C	A
Mullidae	*Mulloidichthys vanicolensis*							D									D				R			O	O		A	C	
Mullidae	*Parupeneus cyclostomus*																												R
Mullidae	*Parupeneus multifasciatus*			R	R	R	R	R		R							R	R								R	R	R	R
Mullidae	*Parupeneus pleurostigma*	R		R		R		R				R		R	R	R	R					R	R			R		R	
Mullidae	***Parupeneus porphyreus***												R				O	R						R					
Muraenidae	*Gymnothorax eurostus*		R		R	R															R								R
Muraenidae	*Gymnothorax undulatus*																						R	R					
Oplegnathidae	*Oplegnathus fasciatus*																										R		
Oplegnathidae	*Oplegnathus punctatus*																R						R						
Ostraciidae	*Ostracion meleagris*							R					R		R		R			R	R		R	R			R	R	O
Pinguipedidae	*Parapercis schauinslandi*																		R										
Pomacanthidae	***Centropyge potteri***																												R

Appendix 9. Relative abundances (DACOR) of fishes in vicinity of transect sites. D=>100, A=50-100, C=11-49, O=6-10, R=1-5. Endemic species are in **bold** type.

Family	*Species*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	67	61	61E	61F
Pomacentridae	***Abudefduf abdominalis***							R									C								R			R	
Pomacentridae	*Abudefduf vaigiensis*																						R						
Pomacentridae	***Chromis hanui***	R											R	R		R									R		R		
Pomacentridae	***Chromis ovalis***																										R	R	R
Pomacentridae	*Chromis vanderbilti*												R													R			
Pomacentridae	***Dascyllus albisella***	O	O	O		R	R	R	R				R	R			R	R		R	R	R	O	O			C	R	
Pomacentridae	*Plectroglyphidodon johnstonianus*	R	C	O	R	R		R				R	R	R	R	R	O	R	R	R		R	R	O	R	O	C	C	C
Pomacentridae	*Stegastes fasciolatus*	C	C	C	C	C	C	R	C	O		C	C	O	O	R	C	C	C	O	C	C	C	C	C	C	A	D	A
Priacanthidae	***Priacanthus meeki***												R				R												
Scaridae	***Calotomus zonarchus***	R		R		R	R			R				R			R	R		R	R	R	R			R		R	
Scaridae	***Chlorurus perspicillatus***	R	O	C	O	C	A	C	C	O		R	C	O			C	O	R	O	O	R	O	O	R	R	C	C	C
Scaridae	*Chlorurus sordidus*		C	C	R	C	C	R	C								R	C	R		O	R			R	R	C	C	D
Scaridae	***Scarus dubius***	R															R	O	R	R	O	R	R	R	R	R	C	D	D
Scaridae	*Scarus psittacus*						R	R	R																				
Scorpaenidae	***Dendrochirus barberi***						R									R							R						
Scorpaenidae	***Pterois sphex***	R																											
Scorpaenidae	***Sebastapistes ballieui***						R	R																					
Scorpaenidae	*Sebastapistes coniorta*								R			O		R															
Syngnathidae	*Doryrhamphus excisus*																						R	R					
Synodontidae	*Saurida flamma*					R									R														
Synodontidae	*Synodus variegatus*																										R		
Tetraodontidae	***Canthigaster jactator***	R			R	R	R	R	R				R					R	R	R	R	R	R	R	R	R	R	R	R
Zanclidae	*Zanclus cornutus*	R	R		R		R		R	R			O	R	R			R	R	R	R	R	R		R	R		R	R