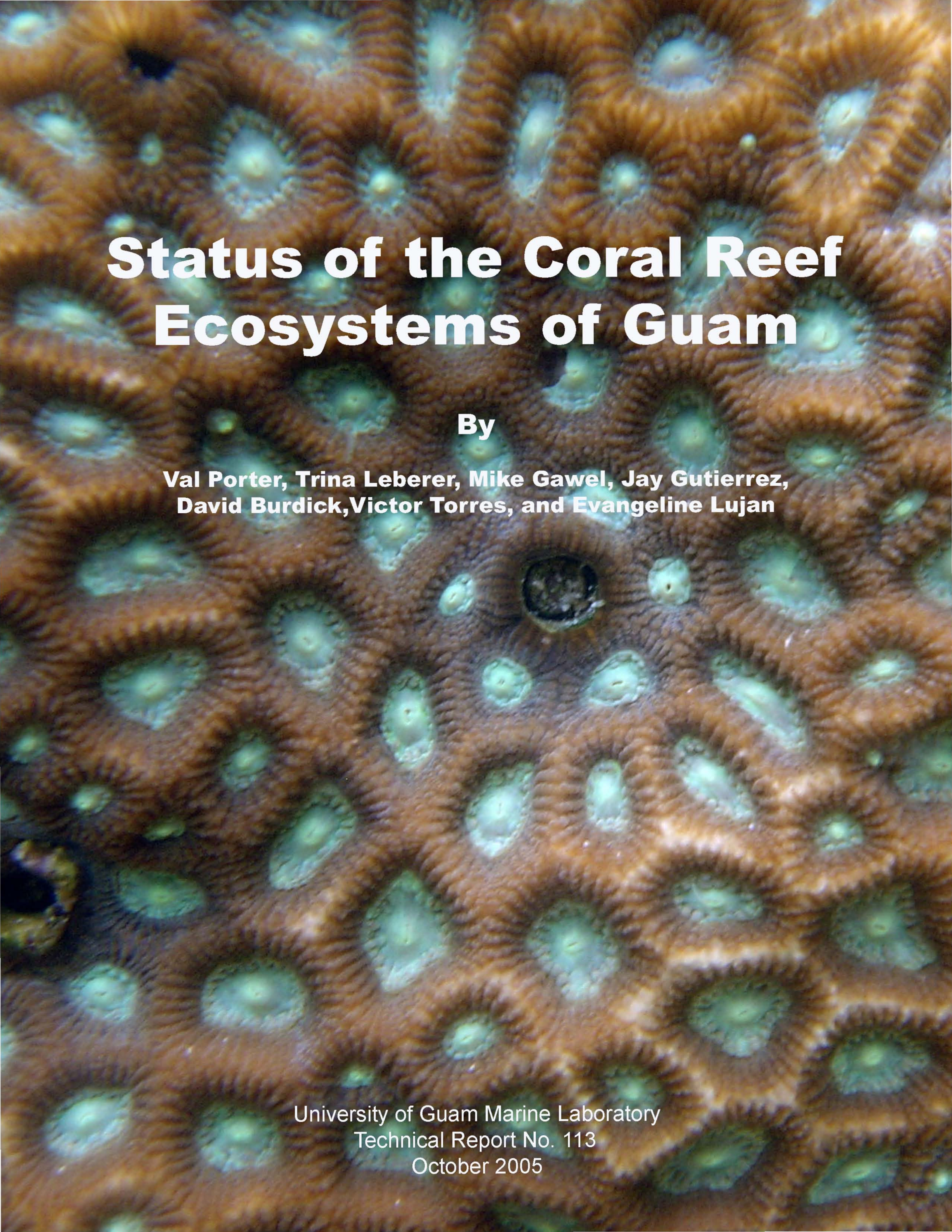

Status of the Coral Reef Ecosystems of Guam

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University of Guam Marine Laboratory
Technical Report No. 113
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Executive Summary

Guam is the southernmost island in the Mariana Archipelago, located at 13° 28' N, 144° 45' E. It is the largest and most heavily populated island in Micronesia. The island possesses a variety of coral reef habitat types with a combined area of approximately 69 km^2 in nearshore waters (Hunter, 1995). Over 5000 species of major coral reef organisms are currently documented on Guam, or in some cases for the Mariana Islands as a whole, including over 1000 species of reef fish and over 400 species of corals (Myers and Donaldson, 2003; Paulay, 2003; Paulay et al., 2003; Randall, 2003). For thousands of years, coral reefs have sustained and protected Chamorros, the indigenous people of Guam. Traditionally, coral reef fishery resources formed a substantial part of their diet and included finfish, invertebrates, and sea turtles (Amesbury and Hunter-Anderson, 2003). Today coral reef resources are both economically and culturally important. Reef fish, sea cucumbers, sea urchins, a variety of crustaceans, mollusks, and marine algae are all eaten locally and family and group fishing is still a common activity in Guam's coastal waters. Guam's coral reefs are also an important part of the tourism industry and protect the island from large waves associated with frequent typhoons.

Many of Guam's reefs have declined in health over the past 40 years. Nonetheless, many dedicated individuals and agencies have worked to try and conserve, protect, manage, study and restore Guam's coral reef resources. In 1997, Governor Carl T.C. Gutierrez signed Executive Order 97-10, adopting the Guam Coral Reef Initiative and creating the Guam Coral Reef Initiative Coordinating Committee (GCRICC) currently comprised primarily of the Guam Coastal Management Program (GCMP), the Department of Agriculture's Division of Aquatic and Wildlife Resources (DAWR) and Forestry and Soil Resources Division (FSRD), the Guam Environmental Protection Agency (GEPA), the University of Guam Marine Laboratory (UOGML) and Water and Environmental Research Institute (WERI), and the USDA Natural Resources Conservation Service (NRCS). In 1998, President Bill Clinton signed E.O. 13089, creating the U.S. Coral Reef Initiative and establishing the U.S. Coral Reef Task Force (USCRTF), of which Guam is a member.

In 2000, Congress passed the Coral Reef Conservation Act (CRCA), calling for the creation of a national action plan to address the loss and degradation of U.S. and international coral reef ecosystems. The CRCA also required that the National Oceanic and Atmospheric Administration (NOAA), in coordination with the USCRTF, develop a National Coral Reef Action Strategy (2002) to help monitor the status and effectiveness of implementation of the National Action Plan to Conserve Coral Reefs (USCRTF, 2000). In addition, NOAA, again in cooperation with the USCRTF, is tasked with assessing the status of coral reefs biennially. This document was compiled by a working group of the GCRICC over the past year. It is the most comprehensive effort yet to assess the status of Guam's coral reef resources. A large part of this document was submitted to NOAA for inclusion in their 2004 report on the status of U.S. coral reef ecosystems.

The health of Guam's coral reefs varies considerably, depending on a variety of factors including geology, human population density, level of coastal development, level and types of uses of marine resources, oceanic circulation patterns, and frequency of natural disturbances, such as typhoons and earthquakes. This document is separated into sections specifically addressing the original priority threats identified in the national action plan. Current coral reef monitoring efforts are also identified and the results of specific ongoing surveys are described in greater detail. The document concludes with current management actions being taken and future recommendations for addressing impacts to Guam's coral reefs.

In 2002, as part of a larger initiative to address the continuing decline of our nation's coral reefs in a more targeted and effective way, the GCRICC further prioritized the threats impacting Guam's coral reefs, identifying the top five upon which to focus. They are: land-based sources of pollution, overfishing, lack of public awareness, recreational misuse and overuse, and climate change/coral/beaching/disease. The GCRICC then selected local navigators to guide the development, in coordination with stakeholder groups, of 3-year local action strategies for each of these priority threats. Stakeholder input is essential to the success of these local action strategies, which will continue to guide Guam's management actions to address the primary threats to our coral reefs, helping to ensure the sustainability of Guam's coral reefs for future generations. For further information on each of Guam's local action strategies, please contact the navigators listed on the following page.

Local Navigators

Land-based Sources of Pollution

Local Navigator: Mr. David Limtiaco
Chief, Forestry and Soil Resources Division
163 Dairy Road, Mangilao, Guam 96913
Tel: 671-735-3949; Fax: 671-734-0111
Email: dlimiti@vzpacifica.net

Coral Reef Fisheries Management

Local Navigator: Mr. Jay Gutierrez
Fisheries Supervisor,
Division of Aquatic and Wildlife Resources
163 Dairy Road, Mangilao, Guam 96913
Tel: 671-735-3955; Fax: 671-734-6570
Email: jaytgutierrez@yahoo.com

Education and Outreach

Local Navigator: Ms. Evangeline Lujan
Bureau of Statistics and Plans,
Guam Coastal Management Program
Governor Ricardo J. Bordallo Complex
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Email: vange@mail.gov.gu

Recreational Use

Local Navigator: Mr. Victor Torres
Bureau of Statistics and Plans
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Climate Change, Coral Bleaching, and Disease

Local Navigator: Dr. Laurie Raymundo
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Cover Photo by Dave Burdick, Guam Coastal Management Program, Bureau of Statistics and Plans, Government of Guam.

ACRONYMNS USED

CERCLA-Comprehensive Environmental Response, Compensation, and Liability Act

CITES – Convention on International Trade of Endangered Species

CNMI – Commonwealth of the Northern Marianas

CPUE-Catch per unit Effort

CRCA - Coral Reef Conservation Act

DoD - Department of Defense

DoAg – Department of Agriculture, Government of Guam

DPW-Department of Public Works

EMAP- Environmental Monitoring and Assessment Program

ERA – Ecological Reserve Area

FSRD – Forestry and Soil Resources Division, Government of Guam

GCMP – Guam Coastal Management Program

GCRICC – Guam Coral Reef Initiative Coordination Committee

DAWR – Guam Division of Aquatic and Wildlife Resources, Government of Guam

GEPA – Guam Environmental Protection Agency

GSPC-Guam Seashore Protection Commission (GSPC)

GVB – Guam Visitors Bureau

MARAMP-Marianas Archipelago Reef Assessment and Monitoring Program

MPA-Marine Protected Area

NOAA- National Oceanic and Atmospheric Administration

NOS- National Ocean Service

NRCS – Natural Resources Conservation Service, USDA

NPDES - National Pollutant Discharge Elimination System

RCRA-Resource Conservation and Recovery Act

STP-Sewage Treatment Plants

UOG – University of Guam

UOGML - University of Guam Marine Laboratory

USDA – United States Department of Agriculture

USCRTF - United States Coral Reef Task Force

WERI - Water and Environmental Research Institute

WPC - Waterhed Planning Committee

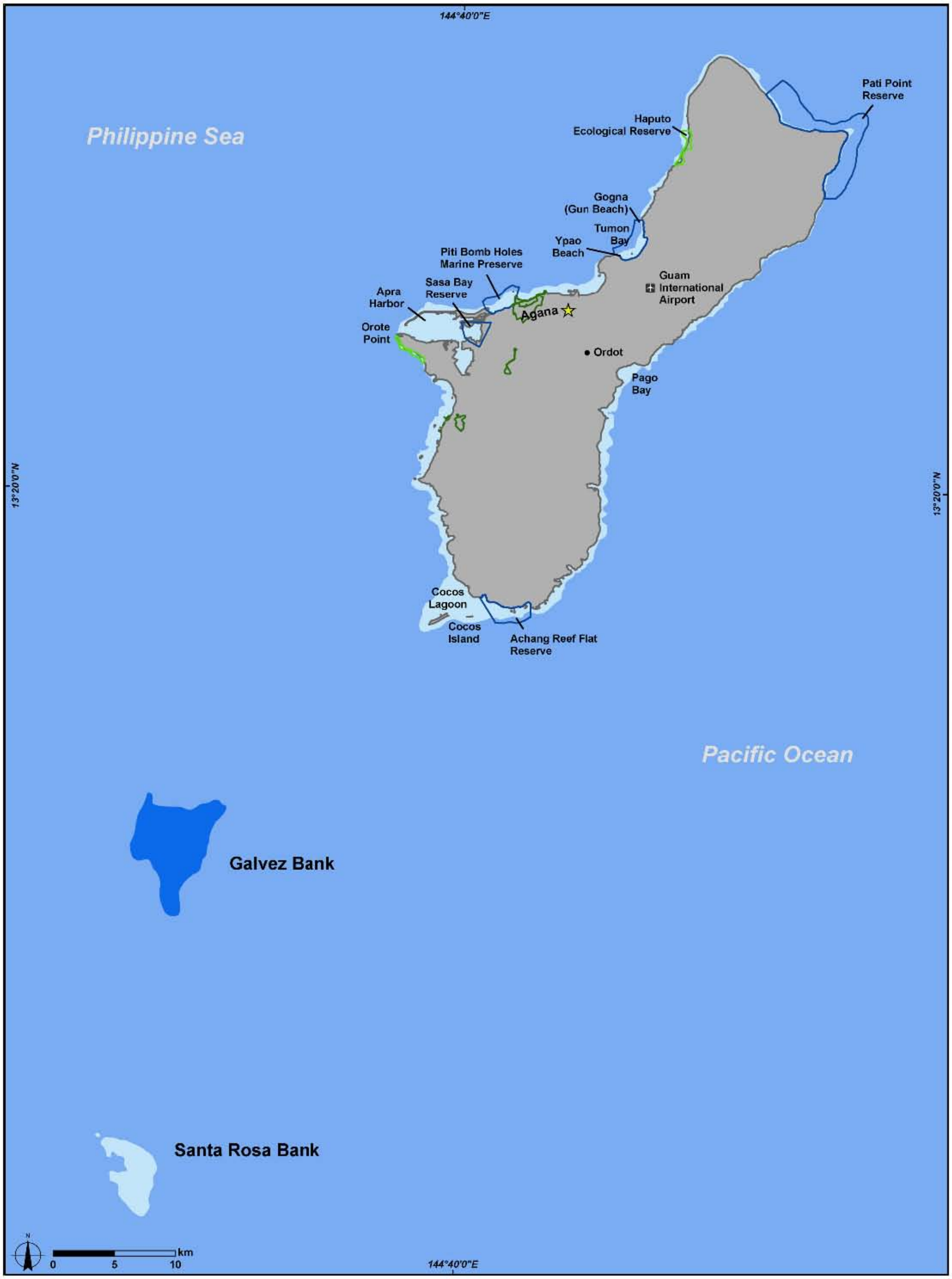

Figure 1. Locator map for Guam. Map: Waddell, 2005.

INTRODUCTION AND SETTING

Guam, a U.S. territory located at 13° 28' N, 144° 45' E, is the southernmost island in the Mariana Archipelago. It is the largest island in Micronesia, with a land mass of 560 km^2 and a maximum elevation of approximately 405 m (Figure 1). It is also the most heavily populated island in Micronesia, with a population of about 164,000 people (July 2003 est.). The northern portion of the island is relatively flat and consists primarily of uplifted limestone. The island's principle source aquifer "floats" on denser sea water within the limestone plateau. It is recharged from rainfall percolating through surface soils (Guam Water Planning Committee, 1998). The average annual rainfall is 218 cm (86 inches) (National Weather Service, http://www.prh.noaa.gov/guam/normal.html, Accessed 4/17/04). The southern half of the island is primarily volcanic, with more topographic relief and large areas of highly erodible lateritic soils (SCS, 1988). This topography creates a number of watersheds throughout the southern areas, drained by 96 rivers (Best and Davidson, 1981).

The island possesses fringing reefs, patch reefs, submerged reefs, offshore banks, and barrier reefs surrounding Cocos Lagoon in the south and part of Apra Harbor (Randall and Eldredge, 1976). However, only Apra Harbor has substantial lagoonal habitats deeper than 10 m (Paulay, 2003a). The reef margin varies in width, from tens of meters along some of the windward areas, to over 781 meters in Pago Bay (Randall and Eldredge, 1976). The combined area of coral reef and lagoon is approximately 69 km^2 in nearshore waters between 0-3 nmi, and an additional 110 km^2 in federal waters greater than 3 nmi offshore (Hunter, 1995). Sea surface temperatures range from about 27-30°C, with higher temperatures measured on the reef flats and in portions of the lagoons (Paulay, 2003a). Although Guam's marine life is not as diverse as the neighboring islands to the south (Palau and Federated States of Micronesia), it lies relatively close to the Indo-Pacific center of coral reef biodiversity (Veron, 2000). Table 1 includes the number of currently documented species for major coral reef taxa on Guam or in some cases for the Mariana Islands as a whole.

Guam's coral reefs are an important component of the tourism industry. The reefs and the protection that they provide make Guam a popular tourist destination for Asian travelers. According to the Guam Economic Development Authority, the tourism industry accounts for up to 60% of the government's annual revenues and provides more than 20,000 direct and indirect jobs. Guam's tourist market comes primarily from Asia, with the majority of tourists arriving from Japan (70-80%). As such, Guam's economy is closely tied to Asia and has thus suffered a series of setbacks starting in the early 1990s with the Asian economic crisis, through a massive earthquake and several devastating typhoons, the terrorist attacks on September 11, 2001, and culminating in the 2003 war in Iraq and scare over severe acute respiratory syndrome (SARS). Despite these events, Guam still hosted nearly 1 million visitors in 2003 (GVB, 2004), and expects to host over 1 million in 2004 (GHRA, 2004).

Table 1. Guam's reefs support a diverse community of marine organisms. A recent compendium of marine life documented in Guam resulted in a list of over 5,000 species (Microsesica 35-36).

GROUP	NUMBER OF SPECIES	SOURCES
Sea Grasses	3	*Lobban and Tsuda 2003*
Benthic Macroalgae	237	*Lobban and Tsuda 2003*
Sponges	110	*Kelly et al 2003*
Foraminiferan	303	*Richardson and Clayshulte 2003*
Platyhelminthes	59	*Newman et al 2003*
Hydroids	42	*Kirkendale and Calder 2003*
Polychaetes	104	*Bailey-Brock 2003*
Non-scleractinian Corals	119	*Paulay et al 2003*
Scleractinian Coral	377*	*Randall 2003*
Hydrozoan Corals	26*	*Randall 2003*
Bivalves	339	*Paulay 2003*
Prosobranch Gastropods	895	*Smith 2003*
Opistobranch Gastropods	467	*Carlson and Hoff 2003*
Cephalopods	21	*Ward 2003*
Cirripedia	24	*Paulay and Ross 2003*
Crustaceans	663	*Ahyong and Erdmann 2003, Paulay et al 2003b, Castro 2003, Tan and Ng 2003, Kensley 2003*
Echinodermata	196	*Paulay 2003, Starmer 2003, Kirkendale and Messing 2003*
Ascidians	117	*Lambert 2003*
Sea Turtles	3	*Eldredge 2003*
Marine Mammals	13	*Eldredge 2003*
Shorefishes	1019*	*Myers and Donaldson 2003*
Total Species:	**5137**	

* Number of species is for the entire Mariana Archipelago. The actual number for Guam may be smaller.

Traditionally, coral reef fishery resources formed a substantial part of the local Chamorro community's diet and included finfish, invertebrates, and sea turtles (Amesbury and Hunter-Anderson, 2003). Today coral reef resources are both economically and culturally important. Reef fish, although somewhat displaced from the diet by westernization and declining stocks, are still found at the fiesta table, and at meals during the Catholic Lenten season. Many of the residents from other islands in Micronesia continue to include reef fish as a staple part of their diet (Amesbury and Hunter-Anderson, 2003). Sea cucumbers, sea urchins, a variety of crustaceans, molluscs, and marine algae are also eaten locally. In addition to the cash and subsistence value of edible fish and invertebrates, reef-related fisheries are culturally important as family and group fishing is a common activity in Guam's coastal waters.

Over 10% of Guam's coastline has been set aside in five Marine Preserves: Tumon Bay, Piti Bomb Holes, Sasa Bay, Achang Reef Flat, and Pati Point. The preserves were established in 1997 as a response to decreasing reef fish stocks, but were not fully enforced until 2001. Fishing activity is restricted in the preserves with limited cultural take permitted in three of the five areas. The preserves are complemented by the War in the Pacific National Historical Park, Ritidian National Wildlife Refuge, the Guam Territorial Seashore Park and the two Naval Ecological Reserve Areas, Orote and Haputo. While, the five marine preserves are enforced, the other areas currently have limited management and enforcement.

The health of Guam's coral reefs varies considerably, depending on a variety of factors including geology, human population density, level of coastal development, level and types of uses of marine resources, oceanic circulation patterns, and frequency of natural disturbances, such as typhoons and earthquakes. Many of Guam's reefs have declined in health over the past 40 years. The average live coral cover on the fore reef slopes was approximately 50% in the 1960s (Randall, 1971), but by the 1990s had dwindled to less than 25% live coral cover with only a few having over 50% live cover (Birkeland, 1997). Still, in the past, Guam's reefs have recovered after drastic declines. For example, an outbreak of the crown-of-thorns starfish in the early 1970s reduced coral cover in some areas from 50-60% to less than 1%. Twelve years later, greater than 60% live coral cover was recorded for these areas (Colgan, 1987). A more distressing indicator of the health of Guam's coral reefs is the marked decrease in rates of coral recruitment. In 1979, Birkeland et al. (1982) obtained 0.53 coral recruits per plexiglass fouling panel. The use of similar materials and experimental design in 1989 and 1992 resulted in just 0.004 and 0.009 coral recruits per plexiglass fouling plates, respectively (Birkeland, 1997).

ENVIRONMENTAL AND ANTHROPOGENIC STRESSORS

Climate Change and Coral Bleaching

Climate change in this document is considered to be the trend of increasing mean global temperatures over the last one hundred years for both air and sea surface. This warming is normally attributed to increases in carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs), and the resulting increase in ultraviolet radiation. Increases in sea surface temperature, CO2 levels, and ultraviolet radiation have resulted in coral bleaching, a term used to describe the loss of symbiotic algae called zooxanthellae by their coral hosts (Gleason and Wellington, 1993; Gattuso et al., 1999; Fitt et al., 1993).

Large-scale coral bleaching events and associated coral mortality are not common on Guam. Since the establishment of the University of Guam Marine Laboratory in 1970, there have been only two recorded large-scale bleaching events. In 1994, 68% of surveyed taxa bleached on Guam (Paulay and Benayahu, 1999). The event was characterized by considerable inter-specific variation in bleaching response, little mortality, and did not appear to be associated with above-average sea surface temperatures. In 1996, about half of *Acropora* species showed moderate to heavy bleaching, similar to the bleaching response of *Acropora* species in 1994 (G. Paulay, pers. comm.). There was also little mortality, except for a localized die-off on Piti Reef Flat due to extreme tidal conditions (G. Davis, pers. comm.). A recent bleaching event in Pago Bay appears to be linked to freshwater influx from the record rainfall associated with Tropical Storm Tingting in June 2004 (P. Schupp, pers. comm.). Bonito and Richmond (2004) reported that, Dr. Robert Rowan (UOGML), observed cases of coral bleaching on Guam every year for at least the past seven years, but again, they were not accompanied by mass mortality. However, as sea surface temperatures continue to rise, coral bleaching events may become more frequent and more deleterious on Guam.

Diseases

While coral diseases appear to be a more serious problem for Caribbean and Atlantic reefs than Pacific reefs, the recent increase in observations of disease from the Indo-Pacific (Sutherland et al 2004), suggests that it may become a serious threat to the health of Guam’s reefs. Scientists believe that the frequency and severity of coral disease outbreaks may increase with changing environmental conditions such as increases in seawater temperature due to climate change and anthropogenic impacts such as sedimentation and eutrophication (Sutherland et al 2004; Rogers, 1990). Although a number of common coral diseases have been identified on Guam’s reefs, no systematic survey specifically addressing disease has been undertaken.

Tropical Storms

Due to their geographical locations, coral reef ecosystems are often exposed to cyclonic storm events. Although such “pulse disturbances” can heavily impact communities, population structure, and the physical environment, reefs have clearly been resilient to these disturbances in the absence of anthropogenic stresses (Pickett and White, 1985). In fact, cyclonic storm events are thought to help maintain high species diversity, by opening up bare substratum available for increased recruitment. Unfortunately, in highly populated areas where anthropogenic threats are high, coral reefs may not recover as fully from storm disturbances.

In the last decade, Guam has been hit directly by four typhoons with sustained winds of greater than 150 miles per hour and suffered high waves and winds from large systems passing close to Guam (Figure 2; Guard et al., 2003). These systems have had a tremendous impact on the island. In 2002, Guam was hit with two tropical storms, Typhoon Chata'an and Super Typhoon Pongsona. At Chata'an's closest approach, wind speeds of 100-120 mph were recorded. Six months later, Pongsona passed directly over the island, with wind speeds reaching super typhoon strength at 150 mph (Guard et al., 2003). These storms caused considerable damage on land and also impacted the marine environment, especially Guam's coral reefs (Figure 3).

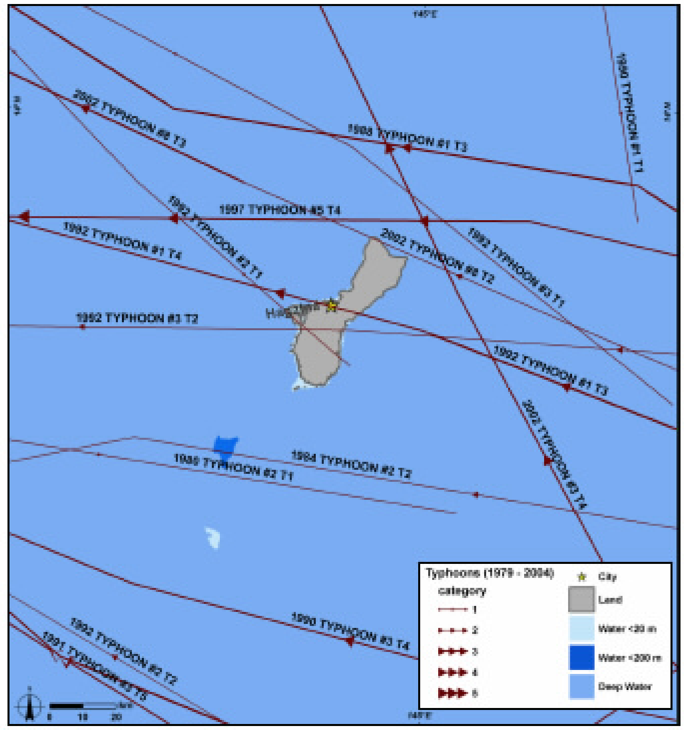

Figure 2. The path and intensity of typhoons passing near Guam from 1979-2004. Four major storms (sustained winds >150 mph) have hit Guam in the past 10 years. Map: Waddell, 2005. Data: Unisys, http://weather.unisys.com/hurricane.

According to the Bureau of Statistics and Plans (2002), 175 sites were surveyed by damage assessment teams after Chata'an. The survey identified problems with erosion, turbidity at river mouths, debris accumulation and debris staging sites. Of the sites identified as beach/shore, river, inland, reef, and infrastructure (bridge, drain, road, seawall), 76% showed signs of erosion. Beach and shore erosion were highest in the southern part of Guam with over twenty eroded sites identified.

The assessment teams identified many types of debris including a combination of metallic, household trash, natural wood, lumber, bamboo, coconut leaves, coconuts, dead animals, other vegetation, tires, and rubber materials. The report indicated that the southern part of Guam had the highest concentration of medium to heavy debris from the ten sites surveyed. A total of 69 pieces of debris were collected from ten sites. The Guam Diving Industry Association assisted with the Water/Ocean Assessment portion of the study. Dive groups observed debris at six popular dive sites and reported that excess trash and debris were believed to be typhoon related. The items included cans, leaves, tree fronds, and pieces of plastics. The assessment after Super Typhoon Pongsona suggested that the debris from Typhoon Chata'an were moved off the reef and placed farther offshore by Super Typhoon Pongsona.

Figure 3. In 1997, Super Typhoon Paka scattered debris across the island, including the reef flats. Photo: Guam Coastal Management Program.

The effects of tropical storms are not limited to debris and erosion. Typhoon Chata'an caused waste oil to spill from a Navy storage waste oil barge into Apra Harbor in July of 2002. In December 2002, Super Typhoon Pongsona caused three large fuel storage tanks to catch on fire and burn for six days at the Guam Commercial Port. This fire deposited a large amount of soot in the adjacent harbor. Fire retardants applied to control this fire may have entered the adjacent marine environment.

Coastal Development and Runoff

Human populations in many countries, including the U.S., have increased in coastal areas over the past several decades. This shift in human settlement has resulted in more substantial impacts on coral reef ecosystems from activities such as dredging, construction and infrastructure development. In Guam, the entire island is designated as coastal zone, both locally and federally, so any development island-wide has the potential to negatively impact coral reefs.

The resident population of Guam grew from 133,152 in 1990 to 154,805 in 2000, a 16.3% increase, with an associated population density increase from 634.5 to 737.7 individuals/ mi^2 (U.S. Census Bureau, 2003). This rate was lower than the population increases observed between 1980 and 1990 (25.6%) and 1970 and 1980 (24.7%). The population growth rate in 1990 was 2.3, compared to 1.51 in 2000, and predictions estimate the growth rate to steadily decrease over the next 50 years. Still, the population is expected to reach 203,000 by 2020 and 242,000 by 2050 (U.S. Census Bureau International Programs Center, 2003).

Slow economic growth since 2001 has limited new development on Guam. During this time, development has primarily been residential or other small-scale construction. No major building construction projects (e.g., hotels, large office buildings), requiring review by Guam's Application Review Committee (ARC), were undertaken and no new applications for large development were submitted to the committee in 2003 (DPW, 2004a). However, a small number of large developments that did not require review by the ARC (i.e., proposals that met all of the requirements set forth by Guam's existing rules and regulations), have been completed or are currently underway (DPW, 2004a).

In a recent report to the U.S. Congress on Water Quality (GEPA, 2003) the major causes of decline in water quality to marine bays were development (paving and creation of impervious surfaces), encroachment onto the shoreline without the use of pollution management measures, marine debris, mechanical beach sand raking, and construction without the use of management measures. Increased urban runoff associated with greater impervious surface cover and reduced vegetation cover, is of particular concern for reefs fringing near the more densely populated and urbanized northern portion of Guam. Road construction has decreased considerably since the early 1990s and has remained relatively constant over the past six years. Three major road construction projects, totaling approximately 8.6 miles of roadway, have been ongoing during the past two years and are expected to be completed in 2004 (DPW, 2004b). Two of the projects (Rt. 14 in Tumon and Rt. 4 in Yona) are located near the coastline and involve a total of five miles of heavily traveled roads. The required use of siltation fences has occurred at the Tumon site, but fences initially installed at the Yona site have not been properly maintained (T. Leberer, pers. comm.). The other project, involving the reconstruction of a section of Rt. 1 in Dededo, is farther from the coastline and is believed to be less of a threat to reef systems. In addition to these on-going projects, 10.81 miles of highway have been constructed or repaired since 2000. This figure is approximately equal to the miles of road construction/repair between 1996 and 1999 (10.88 miles) and much lower than between 1992 and 1995 (26.25 miles) (DPW Highway Planning Section, 2004).

Figure 4. Upland erosion leads to serious problems for Guam's coral reefs. Sediment plumes like this are a common sight after heavy rainfalls. Source: Guam Forestry and Soil Resources Division.

Sedimentation, resulting from construction projects and accelerated rates of upland erosion, is commonly considered one of the primary non-point source pollution threats to Guam's reefs. In southern Guam, sedimentation is exacerbated by steep slopes and underlying volcanic rock, which allow significant surface water flow and enhanced transport of sediments to coastal waters (Figure 4). For example, a road construction project along the southern shores of the island in the early 1990s resulted in the particularly heavy sedimentation of a 10 km section of fringing reef, killing much of the coral (R. Richmond, pers. comm.). A study conducted by the Natural Resources Conservation Service (NRCS, U.S. Department of

Agriculture, 1995) examined four types of habitat within the Ugum watershed in southern Guam. Using the Revised Universal Soil Loss Equation NRCS estimated that sediment yield at the mouth of the watershed totaled 5.5 tons per acre. The estimates showed that erosion in the ravine forests averaged 12 tons per acre per year (t/a/yr), in agriculture lands 20 t/a/yr, in savannah grasslands 31 t/a/yr, and in the unvegetated badlands 243 t/a/yr. Findings indicated that inappropriate road construction, off-road vehicle traffic and wild land fires accelerated the erosion processes.

A recent study by Wolanski et al. (2003) suggested that land erosion in the La Sa Fua River catchment area caused significant sedimentation in Fouha Bay. This problem was exacerbated by the formation of muddy marine snow which has a much higher settling velocity than the unconsolidated clay particles in the river discharge. Wolanski et al. (2003) estimated that approximately 75% of the riverine sediments settle in the receiving bay and may smother juvenile corals. This sediment can become resuspended by storm swells a few times each year causing high suspended sediment concentrations (1000 mgl-1) in the upper few meters of the bay.

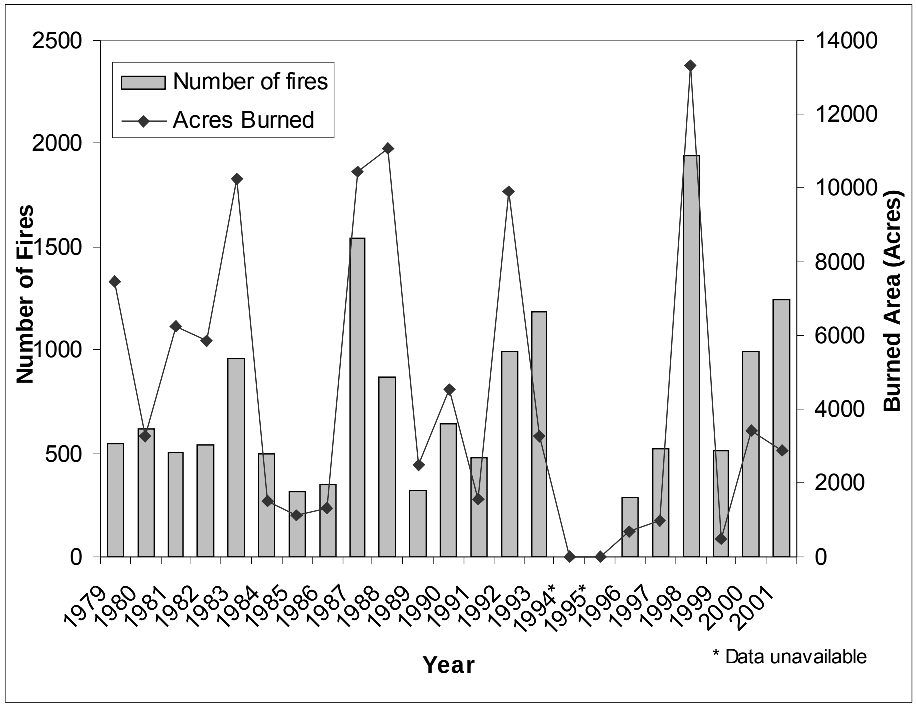

Figure 5. With up to 13,000 acres burned in a single year, wildfires can have serious consequences for Guam's reefs. This graph shows the frequency and acreage of wildfires in Guam from 1979-2001. (Data unavailable for 1994-1995.) Source: D.Limtiaco, DFSD, unpublished data.

Accelerated rates of upland erosion due to wildfires, clearing and grading forested land, recreational off-road vehicle use, and wild populations of introduced mammals continue to result in increased rates of sedimentation in southern Guam. Estimates suggest that between 1975 and 1999, Guam has lost nearly a quarter of its tree cover, while increases in the acreage of badlands (bare soil with extremely high erosion rates) and other erosion-prone surface cover types, have been observed (FSRD, 1999). The numerous fires set

Table 2. Vegetated areas have decreased in Guam due to development and wildfires. This table shows the current land and water resources of Guam (David Limtiaco, FSRD, unpublished data).

RESOURCE	TOTAL ACREAGE
Crop Land	14,227
Pasture Land	11,826
Range Land	21,454
Forest Land	51,058
Urban Areas	36,919
Fresh Water	196
TOTAL	**135,680**

each year and the popular use of off-road vehicles are believed to be major contributors to the development and persistence of these erosion-prone surface cover types. According to figures from the Department of Agriculture's Forestry and Soil Resources Division, an average of over 750 fires have been reported annually between 1979 and 2001, burning over 100,000 acres during this time period (Figure 5). Considering Guam's area is comprised of less than 136,000 acres and the amount of vegetated land is even less (Table 2), the impact of these fires is of great concern.

It is difficult to regulate the pollution in runoff and infiltration from the many small scale agriculture activities on Guam. A study by Duenas and Associates (2003) stated that, in 1998, only about 647 acres of land were under cultivation and the average farm size was 3.65 acres. Pig and poultry farms (commercial and non-commercial) censused prior to the severe typhoons of 2002 totaled 75 (averaging 30 pigs each) and 42 (with a total of 11,500 birds) respectively. The more significant use of fertilizers and pesticides on Guam's nine golf courses is carefully controlled through requiring GEPA approved Turf Management Plans and continuous monitoring through monitoring wells (Figure 6). Excluding the two military golf courses, for which there are no data available, the civilian courses cover over 1,400 acres(Duenas and Associates, 2003).

Figure 6. Golf course run-off is a pressing concern on Guam where over 1,400 acres have been converted to golf courses. Guam EPA requires turf management plans for each course and requires continuous monitoring through monitoring wells. Still, this course in Mangilao, is located directly on the coast. Source: DAWR.

Coastal Pollution

Good water quality is essential to maintaining healthy, fully functioning coral reef ecosystems. Polluted waters threaten coral reefs in various ways. Certain pollutants can kill adult coral reef species, while others disrupt reproduction, and impede the normal settlement and growth of larvae (Richmond, in press). Increased levels of nitrogen from sources such as fertilizer and sewage can also lead to algal blooms, which smother coral reefs. Pollution can enter coral reef ecosystems via specific point-source discharges, such as sewage outfalls and leaking vessels, or as more diffuse runoff from sources such as agriculture, coastal development, road construction, and golf course irrigation.

The primary pollutants, to most Guam waters, and specifically recreational beaches, are microbial organisms, petroleum hydrocarbons and sediment. The Guam Environmental Protection Agency (GEPA) administers the Water Quality Certification (Section 401) and National Pollutant Discharge Elimination System (NPDES) permits locally for the U.S. EPA. Presently there are nineteen active NPDES permits on Guam (Table 3.) The permitted facilities include discharges of treated wastewater from the sewage treatment plants (STP), thermal effluent from the Guam Power Authority (GPA) power plants and a number of discharges that could contain minor amounts of oil and other toxic or biological materials. The guidelines for effluent limitations are based on the Guam Water Quality Standards, which underwent major revision in 2001 (GEPA, 2001). All permittees are routinely monitored by the GEPA staff to verify compliance with applicable permit requirements and compliance schedules.

The 2003 NPDES reports indicated that the shoreline monitoring stations at the Northern and Hagatna STPs did not register fecal coliform counts above the permit standards of 400 fecal coliform units (CU)/100ml. Offshore monitoring stations for these STPs were not measured. Water samples taken at the shoreline stations at the mouth of the Togcha River, downstream from Baza Gardens STP, were within standards for orthophosphates and fecal coliforms, but exceeded nitrate-nitrogen of 0.10 mg/l half the time. Turbidity at these shoreline stations regularly exceeds water quality standards, but ambient turbidity, measured upstream from the discharge, likewise exceeds the standards currently set in the permit. The Umatac-Merizo (Toguan) STP monitoring showed orthophosphates and nitrate below standards, but turbidity usually above the standard of 1.0 nephelometric turbidity unit (NTU). The turbidity was related to rainfall and, out of 27 recent samples, most registered turbidity less than 2.0 NTU and the only samples over 3.0 NTU were two at about 7 NTU, one at 13.6 and one at 14.2 NTU. It should be noted that when the five-year duration NPDES permits are renewed in 2006, they will have the new 2001 Guam Water Quality Standards applied, but currently they are monitored according to standards in place when they were issued (GEPA, 2003).

Three of the island's outfall pipes discharge within 200 m of the shallow reef crest, in depths of 20-25 m and in areas where corals are found. These outfalls can be problematic as stormwater leaks into aging sewer lines. During heavy rain, this additional water forces the sewage treatment plants to divert wastewater directly into the ocean outfall pipes. In addition, during 2003 the effluent from the Hagatna STP was partly discharging into a shallow coral reef area due to a break in the outfall line caused by Super Typhoon Pongsona.

Nonpoint pollutants in the north, such as nutrients from septic tank systems and agriculture or chemical pollutants from urban runoff and illegal dumping, infiltrate basal groundwater, which discharges in springs along the seashore and subtidally on the reefs. A two-year study of spring water discharge from the Northern Guam Aquifer into the marine preserve of Tumon Bay has recently been completed (PCR Environmental, 2002a; PCR Environmental, 2002b; and PCR Environmental, 2002c). The springs discharge an estimated 17 million gallons per day. Chemicals detected above Guam EPA water quality

Table 3. Guam EPA currently enforces nineteen NPDES permits on Guam. These facilities include wastewater treatment plants (WWTP), power plants, and fuel facilities (GEPA 2003).

FACILITY	PERMITTEE	TYPE	VOLUME (millions of gallons/day)	LOCATION	RECEIVING WATER
Northern District WWTP	Guam Waterworks Authority (GWA)	Municipal Wastewater	12	13E 33' 7.36" N 144°48' 24.03" E	Philippine Sea
Tanguisson Steam Power Plant	Hawaiian Electric, Inc.	Cooling/ Low Volume WW	97.92	13E 32' 25" N 144° 48' 17" E	Philippine Sea
Hagatna WWTP	GWA	Municipal Wastewater	12	13E 29' 3.3" N 144° 44' 37.1" E	Philippine Sea
Cabras Power Plant (Units 1-4)	Guam Power Authority (GPA)	Cooling Water	1) 173 2)65.2	13E 27' 13" N 144° 40' 33" E	Piti Channel
ESSO Eastern Cabras Terminal	ESSO Eastern, Inc. (Guam)	Stormwater	Varies	13E 27' 42" N 144° 39' 49" E	Apra Harbor
Mobil Cabras Terminal	Mobil Oil Guam, Inc.	Stormwater/ Tank Bottom Draws	Varies	13E 27" 36" N 144° 38' 30" E	Apra Harbor
				13E 27' 51" N 144° 39' 42" E	Apra Harbor
Shell Cabras Island Docking Facility	Shell Guam, Inc.	Stormwater/ Tank Bottom Draws	Varies	13E 27' 31" N 144° 39' 37" E	Apra Harbor
Unitek	Unitek	Stormwater	Varies	13E 28' 00" N 144° 40' 30" E	Piti Channel
				13E 27' 34" N 144° 40' 00" E	Piti Channel
				13E 27' 45" N 144° 39' 00" E	Piti Channel
Dry Dock (AFDM8)	Guam Shipyard	Industrial WW/ Ballast	Varies	13E 26' 30" N 144° 09' 24" E	Inner Apra Harbor
GPA Piti Bulk Storage	GPA	Stormwater/Tank Bottom Draws	Varies	13E 27' 32" N 144° 41' 05 E	Piti Channel
				13E 26' 29" N 144° 40' 59" E	Piti Channel
Naval Station WWTP	Navy PWC	Municipal Wastewater	4.3	13E 24' 48" N 144° 38' 30" E	Philippine Sea (Tipalao Bay)
				13E22' 38" N 144°40' 51" E	Philippine Sea (Tipalao Bay)
Agat-Santa Rita WWTP	GWA	Municipal Wastewater	1.5	13E 24' 48" N 144° 38' 30" E	Philippine Sea (Tipalao Bay)
Umatac-Merizo WWTP	GWA	Municipal Wastewater	0.391	13E 17' 02" N 144° 40' 00" E	Toguan River & Philippine Sea
Leo Palace WWTP	Leo Palace Resort	Municipal Wastewater	0.1	13E 23' 45" N 144° 45' 00" E	Irrigation (Yona)
Guam International Airport Parking Aprons	GIAA	Stormwater	Varies	13E 29' 29.70" N 144° 44' 57.18" E	Harmon Sink (Tamuning)
Continental Aprons	Continental Micronesia Airlines	Stormwater/Tank Bottom Draws	Varies	13E 28' 54" N 144° 47' 36" E	Harmon Sink (Tamuning)
Baza Gardens WWTP	GWA	Municipal Wastewater	0.6	13E 22' 16" N 144°44' 49" E	Togcha River (Talofofo)
UOG Marine Laboratory	University of Guam Marine Lab	Sea Water	0.216	13E25' 36" N 144°47' 44" E	Pacific Ocean
Shell Agat Terminal	Shell Guam, Inc.	Stormwater/Tank Bottom Draws	Varies	13° 25' 10" N 144° 41' 00" E	Big Guatali River (Piti)

standards in the discharges included PCE, TCE, Aluminum, Antimony, Arsenic, Magnesium, Sulfate, Oil & Grease, Total Coliform Bacteria and Fecal Coliform Bacteria. Pesticides Dieldrin, Alpha-Chlordane, and Gamma Chlordane were also detected in discharges. A recent dye study on water flows from Harmon Sink indicates the stormwater drained from the Guam International Airport and surrounding industrial areas, entered this karst formation sinkhole, discharged through the aquifer to Tumon Bay and East Agana Bay coastal waters (Moran, 2002). Some of the flows reached East Agana Bay within four days of dye injection (traveling 360 to 645 m/day) and Tumon Bay within seventeen days (80 to 175 m/day). A new dye study will determine the relation of stormwater discharges from Tiyan, south of Harmon Sink to East Agana Bay and Tumon Bay.

Recent studies of heavy metals, PCBs and PAHs in recent marine sediments and associated food chains in the four main harbor areas of Guam (Denton, et al., 1997; Denton et al., 1999) showed a moderate enrichment of contaminants in the harbors, especially Apra Harbor. Sponges, soft corals, sea cucumbers and fish from Apra Harbor were enriched with PCBs, while the invertebrates also showed concentrations of arsenic. Oysters showed copper and zinc contamination in Apra and in Hagatna Boat Basin, but none of the fish or shellfish exceeded US FDA food standards or guidance limits (GEPA, 2000b).

The Navy has been assessing and restoring fifteen Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA) sites, which could potentially impact coral reefs in Apra Harbor or Agat Bay coral reefs. In 2001, it was determined that PCBs had entered the food chain offshore from the Orote Landfill site and off Gabgab Beach. The source of the PCBs has yet to be determined. However, PCBs, as well as other chemicals, are present in buried material at the landfill, which makes the site a potential source, even though it has been capped and contained by a restoration project costing over $15,000,000. Monitoring wells and other sampling techniques are being used to determine if the Orote Landfill was the source of the contamination. Seafood monitoring has detected PCBs in deep and shallow water reef fishes in the Philippine Sea off Orote Peninsula and the public have been advised on the danger of consuming seafood from this area.

The Public Landfill located in the village of Ordot has been a source of leachate tentatively entering the Pago Bay reefs via the Lonfit/Pago watershed. Baseline monitoring of the Pago Bay marine environment is planned by the Water and Environmental Research Institute of the University of Guam in 2005 to reflect changes related to the landfill and its closing and capping.

Tourism and Recreation

Tourism and recreation are the fastest growing sector of the ocean economy. Coral reefs are a major source of this important economy. A recent study in Hawaii found that tourism and recreation activities associated with coral reefs contribute over $304 million a year to Hawaii's economy (Cesar et al 2002). Approximately 90% of new economic development in Guam and the Northern Marianas is related to coastal tourism (NOAA Coral Reef Initiative, 1997). The tourism and recreation services associated with coral reefs generate a considerable income for local communities. People engaged in reef related recreational activities purchase goods and services, such as fishing gear, charter boat trips, diving and snorkeling equipment, and diving trips via dive centers. In addition, they spend money on lodging, travel, food and beverages, etc. These benefits could decline, however, if the coral reef resources are degraded by overuse.

A total of 909,506 people visited Guam in the 2003 calendar year (GVB, 2004), and visitor arrivals were expected to exceed one million in 2004 (GHRA, 2004). According to the December 2003 Visitor's Arrival Statistical Report, 77% of the visitors came to the island for pleasure. An exit survey of Japanese visitors in 2000 noted that the highest rated optional tour categories were: Parasailing, Health Spas, Underwater Observation, and Jet-skiing (GVB, 2001). This suggests that marine resources are very important to the tourist industry. A study similar to the one conducted in Hawaii is currently being conducted in Guam and the results are expected to be released in 2005.

A number of recreational activities utilize or impact coral reefs including snorkeling and SCUBA diving, charter fishing, and jet skiing. SCUBA diving and snorkeling are popular activities for both tourists and residents. Scientific studies have now shown that divers and snorkelers can have a significant negative impact on coral reefs in terms of physical damage and a concomitant reduction of the aesthetic appeal (Hawkins and Roberts, 1993; Hawkins et al., 1999; Rouphael and Inglis, 2001). The Pacific Association of Dive Industry estimates that over 5,000 entry level certifications were issued in Guam in 2003 alone (J. Bent, pers. comm.). This indicates that there are a large number of newly

Figure 7. Guam certifies a large number of new divers each year, and even more people try snorkeling in Guam's clear tropical waters. Unfortunately, these new divers and snorkelers often damage the environment by stepping on coral. Source: D. Burdick, GCMP.

certified divers visiting Guam's reefs. One of the sites often visited by newly certified divers is Piti Bomb Holes Marine Preserve. Tsuda and Donaldson (2004) noted that snorkelers and scuba divers have caused a considerable disturbance to the seagrass bed at this site. This disturbance includes physical impacts, an increase in turbidity, and decreases in fish abundance and diversity. Other signs are broken pieces of coral or obviously worn or damaged coral heads (Figure 7). A number of popular sites, including Gun Beach, Tumon Bay, and Ritidian, may also be impacted by the physical impacts of snorkeling, diving, and reef walking activities. Fish-feeding by snorkelers and divers at popular dive sites is also a concern on Guam. Feeding fish negatively impacts both the fish and habitat in several ways. Fish fed by snorkelers and divers consume food that is very different to their normal diets. In addition, the concentration of fish at feeding stations disrupts normal distribution/abundance patterns and may cause behavior changes with some individuals or aggregations exhibiting abnormal aggression. Reef habitats are also altered by the additional nutrients and incidental damage to benthic structure can result in an increase of macroalgae (Perrine, 1989; Alevizon, 2004). This activity occurs regularly at sites such as Piti Bomb Holes Preserve, Tumon Bay Preserve, and Gabgab.

Charter bottomfishing may also impact the reefs. According to an unpublished survey of fishing vessels conducted by Mr. John Calvo, the Guam Onsite Coordinator for the Western Pacific Regional Fisheries Management Council, there are approximately 10 locally-based charter fishing boats consistently operating in Guam. Most of these have little effect on the reefs as they target pelagic species. However, there are a few operations that offer bottomfishing charters targeting reef species on a regular, but infrequent basis and one operation that offers daily bottomfishing charters out of the Agat Marina. Such charters normally work in depths of 10 to 60 fathoms. There are an estimated 800 charter trips targeting the shallow water complex each year (Flores, 2003). In 2003, 2.1 metric tons of bottomfish were harvested, up from 1.3 metric tons in 2002, despite the decrease in the number of people participating in this sport (Flores, 2003).

Jet skis are another popular tourist attraction in Guam. This activity may have several impacts on the reef due to their use within the reef margin. These devices are loud, leak fuel, and may damage sea grass beds and corals, especially during low tides. Due to these impacts, jet ski use is limited to four locations within the reef margin: East Agana Bay, Apra Harbor, Cocos Lagoon, and Tumon Bay on a limited scale. A quantitative study on jet ski impacts is scheduled to begin in 2005 due to determine the damage these watercraft may cause.

The tourism industry is an important part of Guam's economy. It accounts for up to 60% of the government's annual revenues and providing more than 20,000 direct and indirect jobs (GHRA, 2004). The growth of this industry will improve Guam's economy; however, it is important that Guam takes steps to avoid the indirect impacts to reefs related to tourism. These include the development of hotels and resorts, the infrastructure needed to support these resorts, seafood consumption, beach replenishment, and construction or expansion of airports, marinas, and ports. The impacts resulting from these activities include increased sedimentation, nutrient enrichment, pollution, exploitation of endangered species and increased litter and waste (UNEP, 2002). Mitigation of the impacts of tourism often involves raising awareness and educating for behavior change (UNEP, 2002). Although no known beach nourishment projects have occurred recently, several of these projects occurred after Typhoon Yuri in 1992 including Cocos Island Resort, Tumon Bay, and Jeff's Pirates Cove in Ypan, Talofofo (G. Davis, pers. comm.). There are also on-going mechanical beach cleaning operations in Tumon Bay and East Agana Bay. Determining the carrying capacity for tourism development and reef related recreational activities will be critical to the long-term sustainability and growth of Guam's tourism industry.

Fishing

Guam's coral reef fisheries are both economically and culturally important. Guam's coral reefs support over 1,000 species of fish in addition to a large number of marine plants and invertebrates. Guam's fisheries target a large number of reef fishes and invertebrates and use a variety of fishing gears. They support local communities by providing both food and income. Unfortunately, these resources are under increasing threat from overfishing and fishery-associated impacts on coral reef ecosystems. These impacts include: over-exploitation of fish, invertebrate, and algal species; changes over a wide range of trophic levels due to the removal of a species or group of species; by-catch and mortality of non-target species; and physical damage to reef environments associated with fishing techniques, abandoned fishing gear, and anchoring. In addition, there is increasing evidence that overfishing on reefs is a major driver of shifts in the ecological balance of the reef ecosystem, contributing to shifts in fish size, abundance, and species composition, and the overall degradation of coral reef ecosystems (Bellwood et al., 2004). Depletion of herbivorous fish species has been linked to "phase-shifts" from high-diversity, coral-dominated systems to low-productivity, algal-dominated communities (Hughes, 1994).

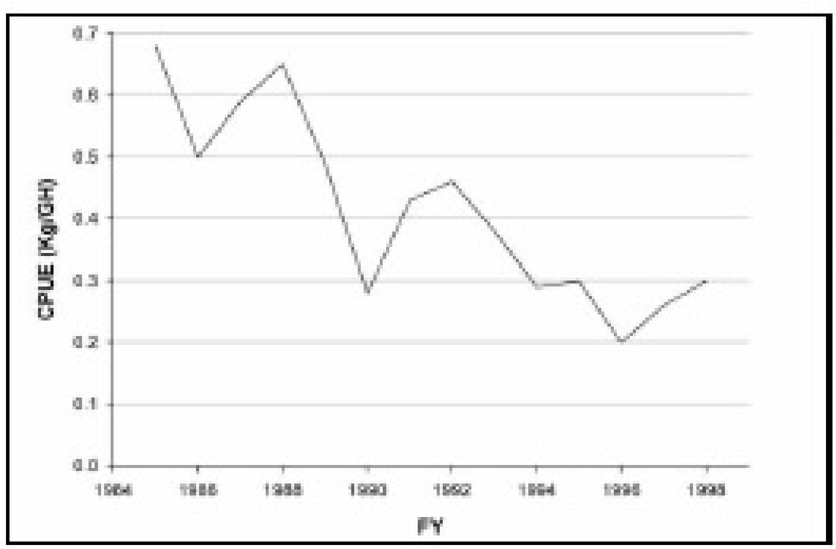

Figure 8. Catch per Unit Effort (CPUE) declined sharply in the 1980s. Source: DAWR.

The threat of overfishing in Guam is a serious concern that became more apparent in the 1980s. At that time, inshore fisheries data indicated that the number of hours spent fishing almost doubled, from 161,602 hours in 1984 to 300,861 in 1987, while the average catch per hour for reef fish declined (Sherwood, 1989). Overall, the catch per unit effort (CPUE) in Guam decreased nearly 50% from 1985 to 2000. Data from recent creel surveys suggest that Guam's fisheries have not recovered from the decrease in the 1980s (Figure 8). In addition, in-situ visual surveys have indicated that large reef fish are conspicuously absent from many of Guam's reefs (Figure 9; Paulay et al., 2001; Amesbury et al., 2001; Schroeder, unpublished data).

Marine Preserves

Many reef fish species found in Guam have relatively slow growth rates, late maturity, and irregular recruitment. This makes them extremely vulnerable to overexploitation. Increased coastal pollution and newer fishing technology such as night-time scuba spearfishing and electric reels have accelerated fisheries resource depletion. In 1997, Guam established five marine preserves to address this concern. The size of the preserves varies, but all preserves extend from 10 m above the mean high tide mark to the six hundred foot depth contour. The following fishing activities are prohibited in all five marine preserves: dip netting, gill netting, drag netting, surround netting, spear fishing, the use of gaffs, shell collecting, gleaning and removal of sand or rocks. Trolling may be conducted from the reef margin seaward, but only for pelagic fish. In Tumon Bay Preserve only, bottomfishing may be conducted seaward of the one hundred foot depth contour. Limited fishing is allowed in Tumon Bay, Pati Point, and Achang Reef Flat Preserves.

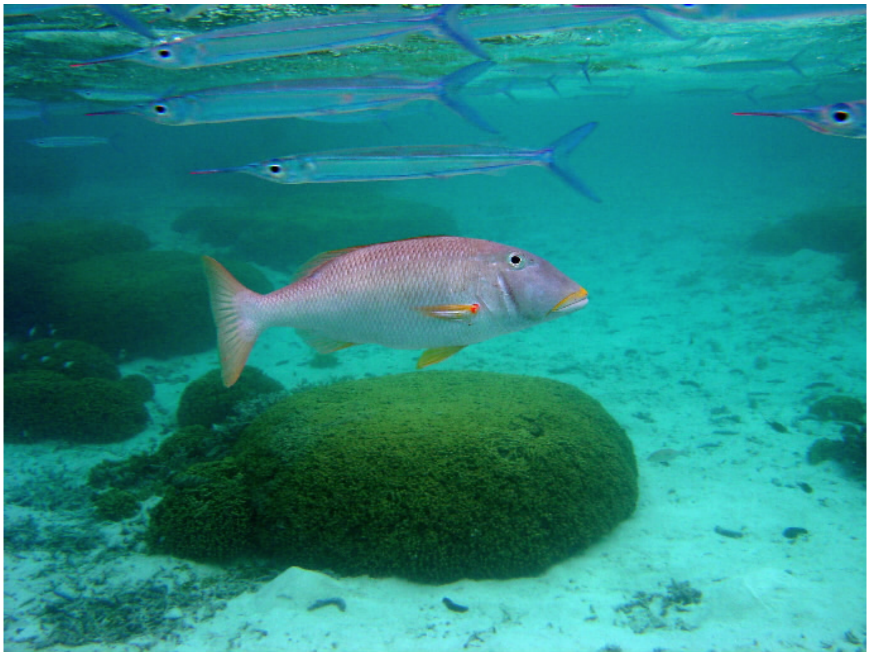

Figure 9. Large fish like this 55cm Yellowlip emperor (*Lethrinus xanthochilus*) are rare in Guam. This fish has taken up residence in Tumon Bay Marine Preserve, where it is seen regularly. Source: D. Burdick, GCMP.

In Tumon Bay, hook-and-line from shore and cast net (talaya) from shore and along the reef margin are permitted for certain species. All other methods are prohibited. From shore, catch is limited to rabbitfish (sesyon, mañahak), juvenile goatfish (ti'ao), juvenile jacks (i'e') and convict tangs (kichu). All other fish must be released immediately. Cast net fishing along the reef margin is allowed for rabbitfish and convict tangs only. There are no species restrictions for fishing in Pati Point Preserve, however, the fishing method is limited to hook-and-line from shore. Limited cultural take is permitted in Achang Reef Flat Preserve for seasonal runs of juvenile rabbitfish (mañahak) and scads (atulai). No fishing is allowed in Piti Bomb Holes and Sasa Bay Preserves.

The Department of Agriculture's Conservation Officers arrest over 40 people per year for fishing illegally in the marine preserves. Infractions range from buckets of sea cucumbers gleaned from the reef flat to large catches of parrotfish, surgeonfish, and other commercially important species taken from the fore reef slope

(DAWR, unpublished data). Despite these infractions, visual surveys suggest that the marine preserves are functioning as expected. Increases in fish density at Piti Bomb Holes and Achang Reef Flat Preserves of 113% and 115%, indicate that fish stocks are recovering in the preserves (See section on DAWR Marine Preserve Monitoring in the Coral Reef Ecosystem Monitoring Efforts and Resource Condition chapter for more detailed information). Surveys at comparison sites outside of the preserves have shown decreases of 29% (Asan/Cocos) and 4% (Cocos/Pago) during the same period of time (Gutierrez, 2004).

Reef Fisheries

A number of fishing methods are used on Guam including traditional methods such as hook-and-line, talaya (cast nets), spearfishing, and chenchulu (surround nets), and more controversial methods such as the use of mono-filament “throw-away” gill-nets and nighttime SCUBA spearfishing. Fishing is a popular activity in Guam and is monitored by the Guam Division of Aquatic and Wildlife Resources (DAWR). Creel surveys have been conducted since the early 1970s, with expanded data available for the past two decades. Creel surveys provide valuable insight into fishing activities on Guam and allow DAWR to estimate total harvest, total time spent fishing, and the catch per unit effort (CPUE), which provides insight into status of fish stocks. Creel surveys are divided into two categories, inshore fisheries and offshore fisheries. Inshore fisheries include shore-based fishing activity, usually involving nearshore casting, netting, and spearfishing. Offshore fisheries include boat-based fishing activities from small boats (12-48 feet) such as trolling, bottomfishing, and boat-supported spearfishing (Flores, 2003).

Table 4 shows the estimated inshore and offshore coral reef fisheries harvest and CPUE for 2002 and 2003. Among the inshore methods, hook-and-line resulted in the highest harvest for 2002, accounting for 33% of the total harvest. In 2003, snorkel spear was ranked as the top method for 2003 with 41% of the overall harvest. Although the overall hook-and-line harvest is high, this method had the lowest CPUE of all inshore methods for both years. In 2002, surround net and drag net produced the highest CPUE of all methods with 3.4 kg/g-hr and 3.3 kg/g-hr, despite a relatively low amount of effort (2,354 gear-hours and 501 gear-hours, respectively). In 2003, surround net CPUE decreased 32%. Harvest estimates for drag net could not be determined for 2003, as no interviews for this method were obtained.

The total harvest of reef fish using offshore methods was similar to the inshore catch for 2002, but exceeded inshore harvest for 2003. The top three methods for 2002 by harvest, bringing in over 75% of the total offshore reef fish catch, were bottom, SCUBA spear, and gill net. In 2003, snorkel spear took over the third spot, followed closely by gill net. The top three methods for 2003 brought in 77% of the total offshore reef fish catch. Although bottomfishing had the highest harvest, this method had the lowest CPUE of all offshore coral reef fisheries for both 2002 and 2003. In 2002, gill net produced the highest CPUE with 6.45kg/g-hr, despite a relatively low amount of effort (1,790 gear hours). This level decreased slightly in 2003 to a CPUE of 5.7 kg/g-hr with a slight drop in effort (1,566 gear hours). SCUBA spearfishing produced the highest CPUE of all offshore methods in 2003 with a CPUE of 5.72 kg/g-hr. This method was very effective, and produced approximately a quarter of the total offshore reef fish catch, while using a relatively low amount of effort (5,225 hours in 2002 and 5,205 hours in 2003).

Table 4. Estimated reef fish harvest and catch per unit effort (CPUE) for all inshore and offshore methods during 2002 and 2003. Reef fish harvest exceeded 100 metric tons in 2002 and 2003. Snorkel spearfishing had the largest catch with 22.8 m.t. in 2002 and 36.0m.t. in 2003, however, SCUBA spearfishing and gill-netting had higher CPUE in both years. Inshore data excludes seasonal runs of juvenile siganids and bigeye scads. *CPUE measures for bottom and trolling methods were calculated based on total catch including pelagic and deepwater species. Sources: Gutierrez, 2003, Flores, 2003, and DAWR unpublished data.

	2002					2003				
	INSHORE		OFFSHORE		TOTAL	INSHORE		OFFSHORE		TOTAL
METHOD	Harvest (kg)	CPUE (kg/gr-hr)	Harvest (kg)	CPUE (kg/gr-hr)	Harvest (kg)	Harvest (kg)	CPUE (kg/gr-hr)	Harvest (kg)	CPUE (kg/gr-hr)	Harvest (kg)
Snorkel Spear	12,808	0.81	9,982	1.37	**22,790**	25,844	1.5	10,201	1.96	**36,045**
Hook and Line	20,714	0.1	-	-	**20,714**	20,449	0.12	-	-	**20,449**
Bottom	-	-	18,840	0.44*	**18,840**	-	-	30,087	0.69*	**30,087**
Gill Net	6,053	0.41	11,553	6.45	**17,606**	5,875	0.42	8,924	5.7	**14,799**
SCUBA Spear	445	2	15,718	3.01	**16,163**	88	0.24	18,205	5.72	**18,293**
Cast Net	12,015	0.28	711	2.39	**12,726**	8,704	0.18	155	0.65	**8,859**
Surround Net	8,037	3.4	-	-	**8,037**	1,660	2.3	-	-	**1,660**
Trolling	-	-	2,136	1.55*	**2,136**	-	-	5,675	1.97*	**5,675**
Drag Net	1,643	3.3	-	-	**1,643**	-	-	-	-	**0**
Hooks and Gaffs	974	0.34	-	-	**974**	302	0.16	-	-	**302**
Jigging	-	-	757	1.1	**757**	-	-	905	1.1	**905**
Mix Spear	-	-	673	2.58	**673**	-	-	0	0	**0**
Spincasting	-	-	476	0.62	**476**	-	-	495	0.88	**495**
Atulai Jigging	-	-	227	0.99	**227**	-	-	802	0.99	**802**
Other Methods	431	0.14	-	-	**431**	712	0.16	-	-	**712**
Total	**63,120**	**0.21**	**61,073**	**1.34***	**124,193**	**63,634**	**0.24**	**75,449**	**1.67***	**139,083**

The top ten families harvested in 2002 and 2003 are shown in Table 5. Harvest composition varied from year to year, for example, Kyphosidae (rudderfish) accounted for 15% of the inshore catch for 2002, but was not a major component of the catch for 2003). Acanthuridae (surgeonfishes) were the most heavily fished inshore family in 2003 with 20% of the total inshore catch. Most of these families were targeted by hook-and-line, however, Kyphosidae were harvested primarily with cast net. Offshore harvest was dominated by the Lethrinidae (emperors) in both 2002 and 2003, with approximately 20% of the catch harvested primarily through bottomfishing. Other key target fish harvested primarily through bottomfishing techniques included Lutjanidae (snappers) and Serranidae (groupers). Acanthuridae, Scaridae (parrotfishes), and Labridae (wrasses) were often harvested using either SCUBA spear or snorkel spear. It is interesting to note that SCUBA spear was used to capture nearly 70% of the scarid harvest. Also, of special concern is the harvest of humphead wrasse (*Cheilinus undulatus*). This valuable species, now listed on Appendix II of the Convention on International Trade in Endangered Species (CITES), is targeted by fishermen using SCUBA spear with 789kg harvested by this method in 2002 and 1826 kg in 2003. This species made up nearly 60% of the total offshore Labridae catch in 2002 and over 75% of the total offshore Labridae catch in 2003.

Table 5. Estimated harvest of top ten families for inshore and offshore fisheries during 2002 and 2003. Inshore data excludes seasonal 'runs' of juvenile siganids and bigeye scads (Gutierrez, 2003, Flores, 2003, and DAWR unpublished data).

INSHORE				OFFSHORE			
2002		2003		2002		2003	
Family	Harvest (kg)	Family	Harvest (kg)	Family	Harvest (kg)	Family	Harvest (kg)
Kyphosidae (Rudderfishes)	9,465	**Acanthuridae** (Surgeonfishes)	12,691	**Lethrinidae** (Emperors)	13,598	**Lethrinidae** (Emperors)	11,632
Siganidae (Rabbitfishes)	8,773	**Carangidae** (Jacks)	9,699	**Acanthuridae** (Surgeonfishes)	9,329	**Serranidae** (Groupers)	10,737
Acanthuridae (Surgeonfishes)	7,786	**Siganidae** (Rabbitfishes)	5,640	**Scaridae** (Parrotfishes)	7,472	**Carangidae** (Jacks)	9,599
Carangidae (Jacks)	6,790	**Mullidae** (Goatfishes)	5,372	**Carangidae** (Jacks)	5,542	**Acanthuridae** (Surgeonfishes)	8,464
Lethrinidae (Emperors)	4,480	**Scaridae** (Parrotfishes)	4,302	**Serranidae** (Groupers)	2,983	**Scaridae** (Parrotfishes)	8,246
Mullidae (Goatfishes)	3,945	**Lethrinidae** (Emperors)	2,352	**Mullidae** (Goatfishes)	2,341	**Scombridae** (Mackerels)	3,431
Lutjanidae (Snappers)	2,712	**Diodontidae** (Porcupinefishes)	1,649	**Sphyraenidae** (Barracudas)	1,587	**Sphyraenidae** (Barracudas)	3,339
Serranidae (Groupers)	2,166	**Scombridae** (Mackerels)	1,307	**Lutjanidae** (Snappers)	1,509	**Lutjanidae** (Snappers)	3,087
Mugilidae (Mullets)	1,990	**Serranidae** (Groupers)	1,284	**Labridae** (Wrasses)	1,391	**Labridae** (Wrasses)	2,377
Belonidae (Needlefishes)	1,968	**Carcharhinidae** (Requiem Sharks)	1,258	**Siganidae** (Rabbitfishes)	1,389	**Carcharhinidae** (Requiem Sharks)	1,632

Invertebrates

Invertebrate harvest varied considerably during 2002 and 2003 for both inshore and offshore fisheries. The top five harvested invertebrate species for 2002 and 2003 are listed in Table 16.6. Inshore invertebrate harvest in 2003 increased 188% from 2002. The increase in invertebrate harvest in 2003 correlates with a shift in method; snorkel spear gear-hours and CPUE increased by 11% and 85%, respectively. Although octopus comprised the majority of the top five invertebrate species harvested in 2002 and 2003, harvest of the spiny lobster, *Panulirus pencillatus,* increased 245% between 2002 and 2003. The offshore invertebrate harvest decreased from 2002 to 2003 with catches of the top shell, *Trochus niloticus,* and *Panulirus pencillatus* decreasing 40% and 14% respectively over this time period. Conch harvest also decreased over this time period with over 1400 kg of conch (*Lambis lambis* and *Lambis truncata*) harvested in 2002 and no catch recorded in 2003. However, the harvest of venus clams (Veneridae), reef crab (*Zosimus aeneus*), and octopus did increase during this period.

Table 6. Estimated harvest of the top five invertebrate species during 2002 and 2003 Sources: Gutierrez, 2003 and DAWR unpublished data).

INSHORE				OFFSHORE			
2002		2003		2002		2003	
SPECIES	HARVEST (kg)	SPECIES	HARVEST (kg)	SPECIES	HARVEST (kg)	SPECIES	HARVEST (kg)
Octopus cyanea	1,052	Octopus cyanea	4,772	Trochus niloticus	1,525	Trochus niloticus	902
Panulirus penicillatus	572	Octopus other	3,105	Lambis lambis	1,224	Veneridae	635
Scylla serrata	508	Panulirus penicillatus	1,973	Panulirus penicillatus	289	Panulirus penicillatus	249
Octopus ornatus	383	Carpilus maculatus	145	Lambis truncata	218	Zosimus aeneus	235
Octopus other	359	Octopus ornatus	111	Zosimus aeneus	152	Octopus cyanea	219

Trade in Coral and Live Reef Species

In many areas, the harvest of coral reef species for aquariums and live food fish occurs at unsustainable levels, leading to a reduction in the abundance of the target species and possible ecosystem shifts caused by their loss. The impact of this type of harvest is lower in Guam than other parts of the Indo-Pacific, but collection for local use does occur. Local pet shops collect approximately 250 ornamental fish per month for the Guam aquarium trade (B. Tibbatts, pers. comm.). In addition, two local aquariums collect approximately 450 local reef fish each month for display in their facilities (L. Goldman, pers. comm.).

Guam's corals and live rock are protected by Public Law 24-21. UOGML is the only entity on the island permitted to harvest coral and live rock. UOGML's permit only allows harvesting in areas not designated as marine preserves and all surviving specimens must be returned to the area from which they were harvested. UOGML collected 1008 coral colonies in 2002 and 455 colonies in 2003 for research purposes. Harvested colonies included species of *Acropora, Alveopora, Favia, Goniastrea, Goniopora, Leptoria, Lobophyllia, Platygyra, Pocillopora, Porites,* and *Psammocora*. The colonies collected ranged in size from 2 cm x 2 cm to 40 cm x 20 cm (Amesbury, 2002; Amesbury, 2003; Smith, 2004).

Ships, Boats, and Groundings

Guam's Apra Harbor is the largest U.S. deepwater port in the Western Pacific and the busiest port in Micronesia. The harbor is shared by the Port Authority of Guam and the United States Navy. According to the Port Authority (http://www.netpci.com/~pag4, accessed 8/26/2004), the port handled approximately two million tons of cargo and serviced over 2000 vessels in 2002. These vessels are primarily fishing vessels, but also include fuel ships, container ships, tender ships, barges, and cruise ships. The U.S. Naval installation is home to a number of naval vessels including submarines and a submarine tender ship, two U.S. Coast Guard cutters, and is visited by numerous other vessels including aircraft carriers. The harbor also contains reefs with some of the highest coral cover on the island. Some reef areas have been dredged in the past and other areas (including patch reefs) may be dredged in the future as their growth impedes ship traffic and naval operations. They can also be damaged by anchors, groundings, and illegal vessel discharges.

Commercial ships are not the only concern. According to Bradley A. Hokanson, Boating Law Administrator at Guam Police Department (GPD) Special Programs Division, there are an estimated 3000 recreational vessels on Guam. Counting the approximately 2000 commercial vessels under 65 ft, there is an estimated total of 5000 vessels. Anchor damage from these vessels is a concern, due to the lack of operational mooring buoys around the island.

Ship groundings are inevitable due to the frequency of typhoon's affecting Guam. At this time, over 130 vessels are listed in NOAA's Abandoned Vessel Inventory database for Guam (http://response.restoration.noaa.gov/dac/vessels/vess_main.html, accessed 4/17/04). During a recent NOAA study, nine of the 31 vessels surveyed (29%) were located on coral reef, hardbottom, or lagoonal fauna (Helton et al., 2004). As these vessels deteriorate or are moved by storms they may impact the surrounding habitat. Because of limited funding for the removal of these vessels, most of them will remain a threat to the reefs. Navigational buoys also pose a problem as storm swells can drag them onto the reef damaging coral and other reef habitat. Such an incidence of this occurred in August 2004 when storm surge from Typhoon Chaba displaced the navigational buoys outside of Agat Marina (KUAM TV, http://66.129.67.220/news/11022.aspx, accessed 9/28/2004).

Marine Debris

Marine debris adversely impacts Guam's reefs through the destruction of habitat, entanglement and ingestion. According to the Guam Coastal Management Program (GCMP), the 2003 International Coastal Cleanup resulted in the collection of 924 bags of debris weighing 43,302 pounds from Guam's beaches and reefs, up from 7,172 pounds in 2002. Additionally, the Micronesian Divers Association (MDA) and the Guam Marine Awareness Foundation remove 5-10 bags of debris from local reefs each month (M. Barnett, pers. comm.).

Typically, the majority of marine debris comes from land-based sources. Beverage containers are the most common items picked up, but other items include appliances, batteries, car parts, and abandoned fishing gear. Over 100 nets were collected during the 2003 cleanup event, along with fishing line, crab and fish traps, buoys, and lures. In the past, fishing gear was composed of natural fibers, such as pineapple fiber and pago bark, and was susceptible to environmental degradation. However, since the 1950s, fishing gear has primarily been constructed with synthetic materials, such as nylon and polyethylene. Synthetic nets and fishing line can persist in the ocean for decades and can be transported for thousands of miles. DAWR reported that 35 additional nets were removed from coastal waters in 2002-2003. Typhoons are an additional source of debris and can blow objects as large as roofs onto the reefs. Although two powerful typhoons hit Guam in 2002, the debris from these storms appeared to be limited to smaller items such as beverage containers and palm fronds. In contrast, over 14 tons of debris, including tin roofing, auto parts, and dumpsters, were deposited on the reef in 1997 by Super Typhoon Paka (GCMP, 1998).

Aquatic Invasive Species

Aquatic invasive species can be defined as aquatic organisms that have been introduced, either intentionally or unintentionally, into new ecosystems resulting in harmful ecological, economic, and human health impacts, (http://www.invasivespecies.gov, Accessed 2/25/2005). Aquatic invasive species can be introduced to coral reef ecosystems through ships (due to ballast water discharges and hull fouling), aquaculture of non-native species, aquarium hobbyist, and marine debris. As the busiest port in Micronesia, invasive species from ships ballast discharge is of special concern. Because many species have a planktonic life stage, ballast tanks may carry bacteria, protists, dinoflagellates, diatoms, zooplankton, algae, benthic invertebrates such as mollusks, corals, sea anemones, and crustaceans, and fish (Lavoie et al., 1999; NRC, 1996).

Although Guam has spent considerable time and resources studying terrestrial invasive species, such as the brown treesnake, little work has been done on invasive marine species (Paulay et al., 2002). Paulay et al. (2002) attempted the first systematic survey of nonindigenous marine species in three study sites on Guam: Apra Harbor, Orote Point Ecological Reserve, and Haputo Ecological Reserve. They found a total of 85 nonindigenous species on Guam, recognizing that many taxa have yet to be surveyed. Of that total, they categorized 41 as introduced and 44 as cryptogenic. They found the majority of these species to be sessile (76%) and surmise that they primarily arrived via vessel hulls into Apra Harbor. Although further study is warranted, these nonindigenous marine species do not appear to be negatively impacting native species yet. Paulay et al. (2002) found that, although nonindigenous species were abundant on artificial substrates, they were relatively rare on natural reef bottoms.

Security Training Activities

Military bases and associated activities including exercises and training, daily operational procedures (i.e., construction, dredging and waste management), and personnel activities have the potential for adverse ecological impacts on coral reefs such as excessive noise, explosions and munitions disposal, oil and fuel spillage, wreckage and debris, breakage of reef structure, and non-native species introductions from ship bilge water or aircraft cargo (Coral Reef Conservation Guide for the Military, https://www.denix.osd.mil/denix/Public/ES-Programs/Conservation/Legacy/Coral/coral.html, accessed 2/25/05). DoD policy is to avoid adversely impacting coral reefs during military operations and ensure safe and environmentally responsible action in and around coral reef ecosystems, to the maximum extent practicable (DoD, 2000). However, exceptions to this policy can be made during time of war, national emergencies, or threats to national security, human health, and safety of vessels, aircraft, or platforms (Executive Order 13089, 1998). In Guam, DoD regularly carries out training exercises that impact coastal waters and adjacent reefs (U.S. Department of the Navy, 1998) Although attempts are made to minimize impacts by locating operations away from living corals, the explosions related to marine mine detection and demolition and the stress from landing craft have killed a limited amount of fish and invertebrates, and could threaten marine mammals and endangered sea turtles (DAWR, unpublished incident reports).

DoD has implemented a number of actions to comply with natural resource and environmental protection laws as well as developed programs to protect and enhance coral reef ecosystems. These programs include developing GIS planning tools, coral surveys to evaluate impacts from bombing exercises, assessments to determine the impact of amphibious training exercises on reef ecosystems, pollution and oil spill prevention programs, invasive species management and effective land management (DoD, 2000).

Other

The crown-of-thorns starfish, *Acanthaster planci*, continues to be affect Guam's reefs (Figure 10). This starfish feeds on several species of hard coral, including the reef building Acropora species. In the 1960s and 1970s aggregations consisting of hundreds of thousands of individuals caused large scale coral reef degradation throughout Micronesia (Colgan 1987). Randall (1973) reported that some coral communities in Guam were reduced to less than 1% coral cover during this period of infestation. While Guam has not had any large outbreaks of *A. planci* recently, aggregations of ~ 500 individuals have been documented (Bonito 2002). A study by Victor Bonito (2002) suggests that the feeding behavior of these aggregations may modify the coral community composition on Guam, as they prefer to feed on *Acropora, Montipora,* and *Pocillopora* species. The coral community at Tanguisson Reef was documented in 1981 and again in 2001. Comparison of the data suggests that preferential feeding on these species may have created a shift in the reef community towards *Porites, Favia*, and other non-preferred species.

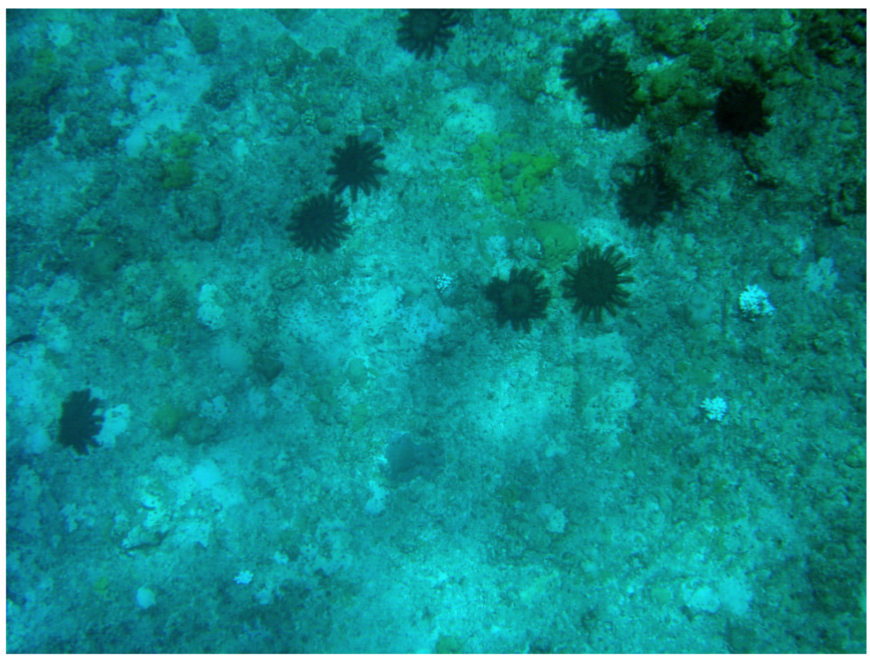

Figure 10. Crown of thorns starfish (*Acanthaster planci*) have impacted Guam's reefs in the pasts. Occasional, large aggregations are still observed near Tanguisson and Haputo. This group of starfish was located near Haputo. Source: D. Burdick, GCMP.

CORAL REEF ECOSYSTEM MONITORING EFFORTS AND RESOURCE CONDITION

A number of monitoring, research, and assessment activities are conducted on Guam. These include monitoring programs for communities associated with coral reefs, assessment of benthic habitat, and water quality. Table 7 describes all recent or ongoing studies related to Guam's coral reefs. Some of these studies are ongoing, while others have just started producing quantitative data. The studies with sufficient data will be discussed further in the next section.

Table 7. A number of coral reef monitoring, research, and assessment activities take place on Guam. A summary of each activity is listed in this table.

Activity	Agency	No. of Years	Funding	Objective	Data Collection	Fit in Larger Effort
Marine Preserve Monitoring	DAWR	2	NOAA - Coral Reef Monitoring Grant, Sportfish Restoration	Assess the effectiveness of Guam's Marine Preserves on Food Fish populations. Visual transects and interval counts are used to assess fish species. Some benthic baseline data has been collected but full-scale benthic monitoring is scheduled to start in 2006.	Every 1-2 years	Provides assessment of fisheries.
	University of Guam	2		Assess the effectiveness of Guam's Marine Preserves by looking at focal species abundance, population structure, and recruitment in preserves and adjacent control sites.		
Sedimentation	National Park Service	<1	Dept. of Interior	Assess the level of sedimentation occurring in the watershed included in the War of the Pacific National Park. Data collected includes total sediment, %organic, %carbonate, sediment size, water temperature, and light penetration. Benthic transect and coral recruitment should be added in near future. Goal of the project is to assess the impacts of wildland fire on sedimentation.	Monthly	Provides sedimentation data and effect on reefs.
Erosion	National Park Service	<1	Dept. of Interior	Land based monitoring of erosion rates in burned vs. non-burned areas. In addition erosion flumes are being used to assess possible badland mitigation techniques.	Weekly	Addresses the land based issues affecting reefs.
	University of Guam	1	EPA/NOAA	Monitoring sediment input in Fouha Bay to create a model of sediment flow and document corresponding changes in coral communities.	Weekly	Provide Water Quality Data affecting marine life.
Water Quality	Guam Environ. Protection Agency	>20	US EPA	GEPA 305b, Water Quality Report to Congress EMAP, Recreational Water Quality,	Biennially Weekly	Provides Water Quality Data affecting marine life
			NOAA/ US EPA	Denton et al. 1997, 1999, PCR Environmental, 2002 reports,	One time	
			Permittee	Monitoring wells, golf courses and restoration sites	Quarterly	
Benthic Habitat	NOAA Pacific Islands Fisheries Science Center - CRED	3	NOAA; Dept. of Interior	Document baseline conditions of the health of coral, algae, and invertebrates, refine species inventory lists, monitor resources over time to quantify possible natural or anthropogenic impacts, document natural temporal and spatial variability in resource community, improve our understanding of the ecosystem linkages between and among species, trophic levels, and surrounding environmental conditions.	Biannually	Provides long-term monitoring of coral reef ecosystem.
	US Navy	<1		Benthic assessments and establishment of long-term monitoring sites in Orote & Haputo ecological reserves.		Provides monitoring of Navy marine protected areas.

Fisheries Monitoring	Division of Aquatic and Wildlife Resources	>20	Sportfish Restoration	Conduct creel, participation, and boat-based surveys to obtain information including boating activity, fishermen participation, catch per unit effort, and species composition in order to monitor the health of the fisheries resources	Semi-weekly (on average)	Provides long term monitoring of fisheries resources.
Associated Biological Communities	Univerisity of Guam / DAWR	6	CRI Grants	Reef Check	Annually	Provides some long-term monitoring at a very broad level
	University of Guam			Assessment of *Acanthaster planci*	One time	Repeated survey from 1980s to assess change over time of benthic community
Recreational Impacts	University of Guam	1	Coastal Zone Management Grant	Assessment of recreational impacts of underwater activities in Cocos and Piti	One time	Provides an initial assessment of recreational impacts and suggests future courses of action

In addition to Guam's efforts, the NOAA research vessel Oscar Elton Sette initiated the Marianas Archipelago Reef Assessment and Monitoring Program (MARAMP) in 2003. The cruise lasted 39 days from 21 August to 28 September, 2003. The goals of the MARAMP include improving the understanding of coral reef ecosystems, evaluating and reducing adverse impacts, enhancing coral reef ecosystem-based fisheries management and conservation through cooperation with partners (federal and local agencies and non-governmental organizations), and providing scientific information needed to establish, strengthen, and manage MPAs (NOAA, Pacific Islands Fisheries Science Center, Coral Reef Ecosystem Division website http://www.nmfs.hawaii.edu/crd). The science team for the Guam leg (23-28 September) was comprised of staff from the NOAA Coral Reef Ecosystem Investigation Program, the Guam Division of Aquatic and Wildlife Resources, the National Park Service, and the University of Guam Marine Laboratory. They conducted a variety of ecological and oceanographic assessments, including the following (Figure 11):

*Benthic Habitat Mapping: multi-beam surveys, single beam QTC surveys, geodetic control, towed diver surveys, and TOAD towed camera surveys,

*Fish, Turtle, and Marine Mammal Surveys: belt transects, stationary point counts, towed diver surveys, roving diver surveys, and hydroacoustic surveys,

*Benthic Surveys (corals, other inverts, algae): belt transects, towed diver surveys, roving diver surveys, and TOAD towed camera surveys, and

*Oceanography: closely-spaced CTDs, drifters, subsurface temperature, ADCP transects, CREWS/SST buoys, current/wave moorings.

The MARAMP is intended to be a long-term monitoring program with research cruises scheduled bi-annually. The second cruise is scheduled to take place in October 2005 (Dr. R. Brainard, pers. comm.).

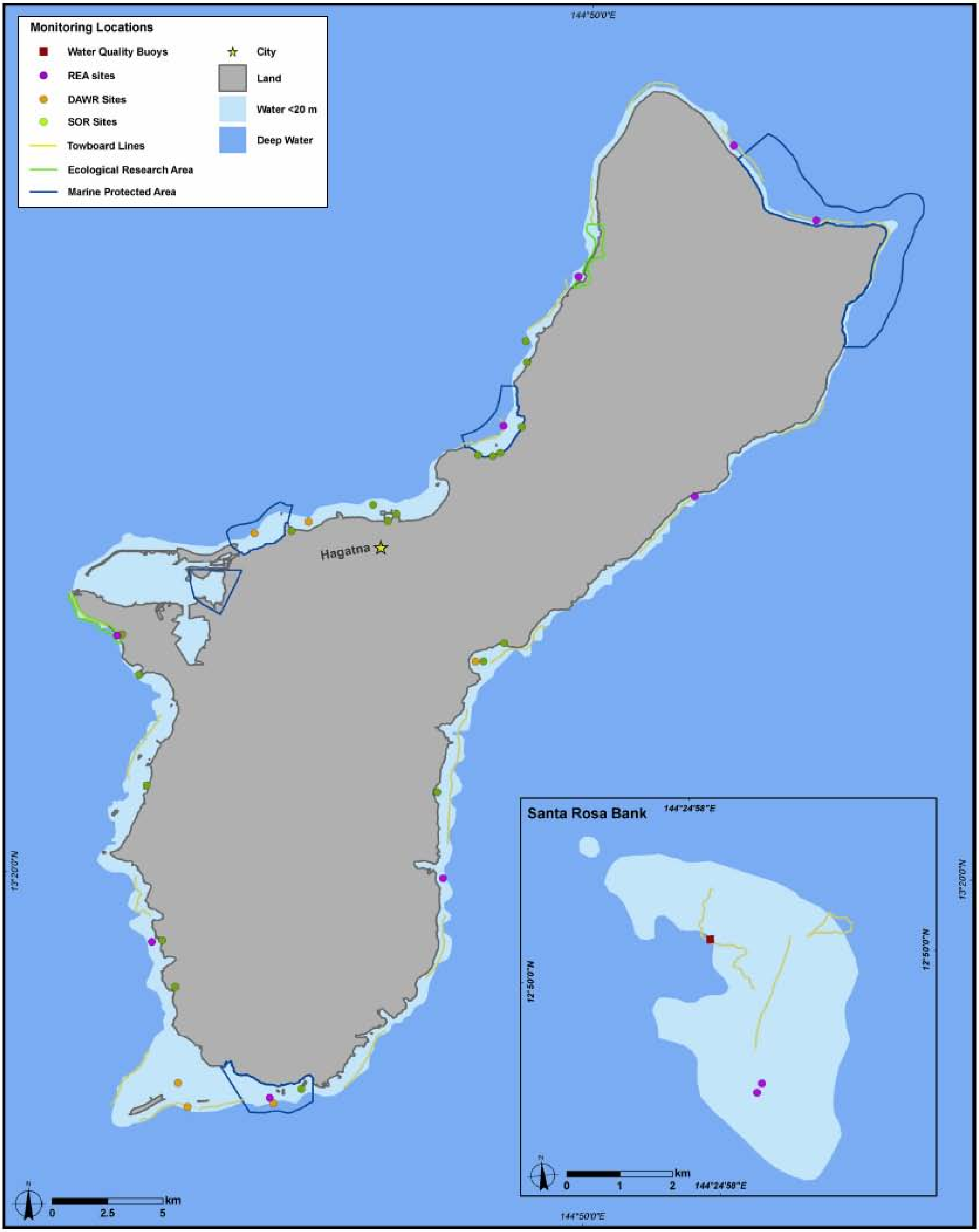

Figure 11. The locations of selected monitoring sites around Guam. Map: Waddell, 2005. Sources: DAWR; PIFSC-CRED.

WATER QUALITY

Limited studies have been conducted on water quality indicators important to coral reefs. GEPA regularly monitors point source pollution and tests for *Enterrococcus* indicator bacteria on Guam's beaches, but there is limited information on parameters such as nutrient load, turbidity, or contaminants. This is expected to change in the near future with the implementation of GEPA's Environmental Monitoring and Assessment Program (EMAP).

GEPA Water Quality Sampling

GEPA samples coastal recreational waters at 39 stations around the island every week, testing for *Enterococcus* bacteria, according to U.S. EPA requirements. A public advisory is issued when instantaneous reading of bacteria exceeds 104 units per 100 ml of water. In fiscal year 2003, 27% of 2,028 samples exceeded these levels, resulting in 551 advisories. In 2002, GEPA weekly monitoring of the 39 stations resulted in 1,055 advisories (Table 8). Despite the apparent improvement in recreational water quality from 2002 to 2003, it is important to consider that water quality in 2002 was unusually poor with 51% of samples resulting in advisories. Previous years had rates similar to those observed in 2003. However, the validity of basing advisories on *Enterococcus* as a bacterial indicator of sewage pollution is questionable, since it exists in the tropical soils of Guam, independent of sewage pollution. Following rains and stormwater runoff, *Enterococcus* readings always increase in Guam's coastal recreational waters, as the bacteria wash out of the soil (Collins, 1995).

Table 8. Recreational Water Quality Summary of Enterococcus sampling in 2002-2003. Quarters are by fiscal year. Source: GEPA.

	NUMBER OF ADVISORIES PER QUARTER				TOTAL NUMBER OF
REGION	**1st**	**2nd**	**3rd**	**4th**	**ADVISORIES**
2002 Northern Subtotal	117	124	66	128	**435**
2002 Southern Subtotal	83	70	98	369	**620**
2002 Total	**200**	**194**	**164**	**497**	**1055**
2003 Northern Subtotal	76	29	63	78	**246**
2003 Southern Subtotal	81	26	77	121	**305**
2003 Total	**157**	**55**	**140**	**199**	**551**

According to PCR Environmental (2002 a, b, and c), freshwater springs in Tumon Bay discharge an estimated 17 million gallons of freshwater each day. In 2002, samples from eight of these springs were tested for a broad range of pollutants. Of 35 volatile organic compounds screened for, only methylene chloride was present in amounts exceeding drinking water standards (5 µ/L). Eight different organophosphate pesticide compounds and 25 carbamate pesticide compounds all showed no detection or levels below standards. Of 23 metals tested, including mercury, only one metal in one sample exceeded drinking water standards (Selenium at 0.0957mg/l, with standards at 0.05 mg/l). Despite meeting drinking water standards, the contaminants discharged by the freshwater springs may affect organisms found in the shallow marine waters of Tumon Bay(PCR Environmental, 2002 a, b, and c).

Other chemical and physical parameters of coastal waters were not tested regularly during 2002 and 2003 due to a shift to the new EMAP system, impacts from typhoons to the GEPA laboratory, and the need to prioritize increased testing of drinking water following the disasters. Previous years sampling of marine water quality by GEPA provided the following results.

From June 1997 to November 1998, 57 surface marine water quality samples were tested from San Vitores Beach, Dai Ichi Beach and Ypao Beach in the shallow waters of Tumon Bay (Table 9). In the rainy season of 2001 from July to October, GEPA took 89 surface water samples from sites throughout Tumon Bay (Table 10). Also, 30 samples from four surface water stations in Tumon Bay in the rainy season and the dry season from July to December 2001 were tested (Table 11).

Table 9. Summary of 57 water quality samples form Tumon Bay, 1997-98. Source: GEPA

	Temp (°C)	DO (mg/L)	pH	Sal. (ppt)	Secchi Disc - Horiz. (meters)	Enterococ. (CFU/ 100mL)	Total Susp. Solids (mg/L)	Turb. (NTU)	Cond. (mmho)	NO2-N (mg/L0. 000)	NO3-N (mg/L 0.000)	P-Tot (mg/L)	O-P (mg/L)	N P-Tot (mg/L)S
Mean	28.4	7.08	8.29	34	11.7	11.1	19.7	0.54	43.7	0.002	0.102	0.007	0.003	0.007
Med	28.4	7.35	8.3	35	11	1	20	0.41	42.7	0.001	0.046	0.007	0.002	0.007
Max	30.7	12.08	8.68	37	27	264	40	1.7	65.8	0.006	0.98	0.017	0.025	0.017
Min	26	2.76	7	30	3	1	4	0.15	33.2	0	0.003	0	0	0
Mode	27	7.4	8.5	35	11	1	20	0.3	#N/A	0	0.036	0	0.002	0

Table 10. Summary of 89 water samples from Tumon Bay, July to October 2001. Source: GEPA.

	Temp (°C)	DO (mg/L)	pH	Sal. (ppt)	Secchi Disc - Horiz. (meters)	Enterococ. (CFU/ 100mL)	Total Susp. Solids (mg/L)	Turb. (NTU)	Cond. (mmho)	NO2-N (mg/L) 0.000	NO3-N (mg/L) 0.000	P-Tot (mg/L)	O-P (mg/L)	N P-Tot (mg/L)S
Mean	30.5	6.63	8.2	34.4	0.12	0.33	48.7	0.003	0.077	0.037	0.003	0.003	0.007	0.003
Med	30.5	6	8.22	35	0.105	0.28	44.7	0.003	0.026	0.013	0.003	0.002	0.007	0.002
Max	32.5	11.8	8.71	35	0.463	1.5	431	0.008	0.99	0.321	0.011	0.025	0.017	0.025
Min	28.5	4.6	7.83	23	0.027	0.15	30.9	0.001	0.001	0.001	0.001	0	0	0
Mode	31	5.5	8.26	35	0.064	0.2	45.4	0.003	0.007	N/A	0.002	0.002	0	0.002

Table 11. Summary of 30 water quality samples from four locations in Tumon Bay, 2001. Source: GEPA.

	Temp (°C)	DO (mg/L)	pH	Sal. (ppt)	SiO2	Turb. (NTU)	Cond. (mmho)	NO2-N (mg/L) 0.000	NO3-N (mg/L) 0.000	NH4-N (mg/L) 0.000	O-P (mg/L)	O-P (mg/L)	N P-Tot (mg/L)S
Mean	29.82	6.55	8.19	34.8	0.104	0.998	50.78	0.003	0.0376	0.002	0	0.003	0.007
Med	29.75	6.29	8.21	35	0.093	0.425	52	0.003	0.0155	0.002	0	0.002	0.007
Max	32	9.14	8.39	35	0.18	16	53.2	0.008	0.155	0.002	0	0.025	0.017
Min	28	4.57	7.91	33	0.061	0.21	43.4	0.003	0.002	0.002	0	0	0
Mode	29.5	5.9	8.15	35	0.078	0.35	52	0.003	0.004	N/A	0	0.002	0

BENTHIC HABITATS

A number of studies have looked at benthic habitats in Guam's nearshore waters. These studies include studies sponsored by the U.S. Navy at two compensatory mitigation sites, Orote Peninsula and Haputo Ecological Reserve Areas (Amesbury et al., 2001; Paulay et al., 2001), a thesis study on the effects of *Acanthaster planci* infestations on coral community structure (Bonito, 2002), and Dr. Peter Vroom's initial interpretation of the macroalgae surveyed during the 2003 Oscar Elton Sette cruise to Guam (Vroom, in review).

Orote Peninsula Ecological Reserve Area

The Orote Peninsula ERA contains a diverse assemblage of habitats, including a highly exposed, current-swept point, a silty bay, intertidal fringing reefs, and deep, steep dropoffs and caves. To capture this diversity, the area was divided into 58 representative sub-zones (Figure 12). The area was examined using a manta tow and divided into 17 zones based on topography and bottom-type. These zones were then sub-divided based on depth. For the qualitative diversity surveys, divers surveyed each sub-zone recording all visible fish, macroinvertebrate, and coral species (Paulay et al., 2001).

Methods

For the quantitative surveys, ten permanent monitoring stations were established representing the main habitat types found in the ERA. Due to the steep fore reef topography in most of the study area, eight stations were located at the 15 m depth contour where the fore reef slope is less steep. The other two stations were located in Agat Bay, which has a more traditional fore reef slope and allowed for two stations at a depth of 5 m. At each monitoring station,

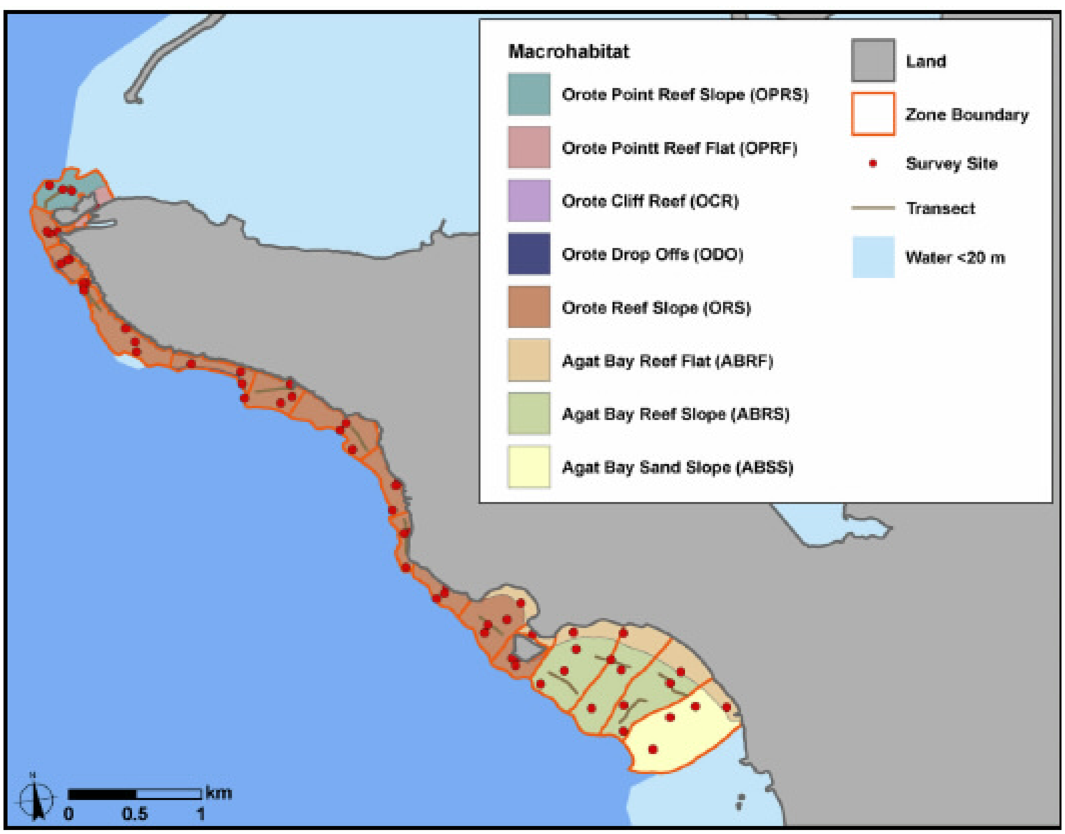

Figure 12. Macrohabitat zones, transect sites, and survey sites in the Orote Peninsula ERA. Map: Waddell, 2005. Source Paulay et al., 2001.

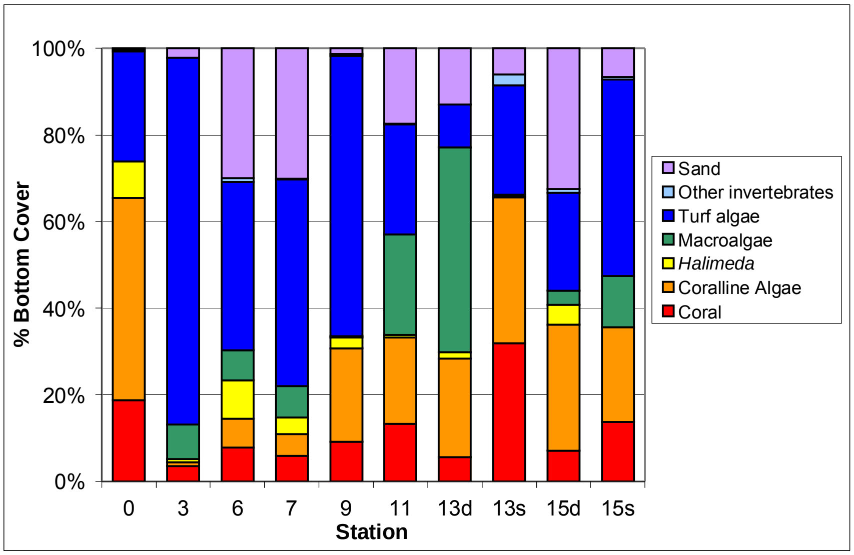

Figure 13. The relative composition of each benthic cover class at 10 stations in the Orote ERA. Coral cover was relatively low. Percent coral cover ranged from 4 to 19%, except at one site dominated by *Porites rus,* which had 32% cover. Other cover types included turf algae, macroalgae, *Halimeda*, and coralline algae. Source: Paulay et al., 2001.

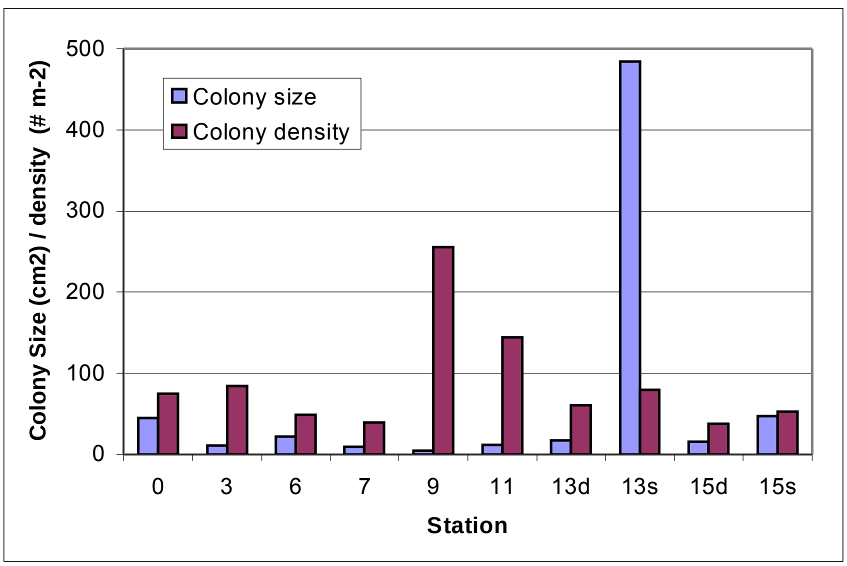

Figure 14. Coral demographics at 10 stations in the Orote ERA. Colony density was greater than colony size at all but one site. Source: Paulay et al., 2001.

five 50 m transects laid end to end (5-10 m apart) were used to survey an area approximately 270-290 m long. Four types of surveys were conducted along each transect: 1) a benthic cover survey, 2) a coral population survey, 3) a fish survey, and 4) a macroinvertebrate survey.

Quantitative surveys used both the video protocol recommended by English et al. (1997) and point quarter methods used by Birkeland and Lucas (1990). For the video transects, the camera was held 25 cm away from the bottom to record a 25 cm swath along each transect. Five points from 60 equally spaced frames were analyzed for each transect, providing a total of 1500 points per station. The point quarter method was used to survey one to three transects at each station. Sixteen points were haphazardly selected on each transect. The distance to the center of the closest coral colony center, the length and width of the colony, and the species were recorded in each quadrant.

Results and Discussion

During these surveys 1252 species of marine animals were reported, including 156 species of scleractinian corals. Two of the coral species documented (*Leptoseris n. sp.* and *Favia rotundata*) were new records for Guam. Coral cover was relatively low at most Orote stations surveyed, ranging between 4 and 19%. One site dominated by *Porites rus* had 32% coverage. Bottom cover varied across the study area (Figure 13), and included coral, coralline algae, the green algae *Halimeda*, other macroalgae, turf algae, other invertebrates and sand. Coral demographics also varied by site with colony size exceeding colony density at only the site dominated by *Porites rus* (Figure 14).

Haputo Ecological Reserve Area

The Haputo ERA is located along the northwest coast of Guam, from just south of Haputo Beach to just north of Double Reef. This area is bounded by narrow, supratidal benches or unprotected rock faces, however, the study area contains two small, localized reef flats near Haputo Beach and Double Reef. Double Reef, an incipient barrier reef, is a unique feature in this area that creates highly heterogeneous habitat, including a distinct backreef community. Unlike the Orote Peninsula ERA, this study area lacked large-scale transitions along the shore, thus 31 sites were distributed evenly along the coast and along the depth gradient for the qualitative surveys (Figure 15). The fauna at each site were surveyed for at least one hour by a team of 4 or 5 divers. Two divers focused on corals and fish, which were surveyed during 30 minute timed diversity surveys. Two to three divers surveyed both exposed and cryptic macroinvertebrates.

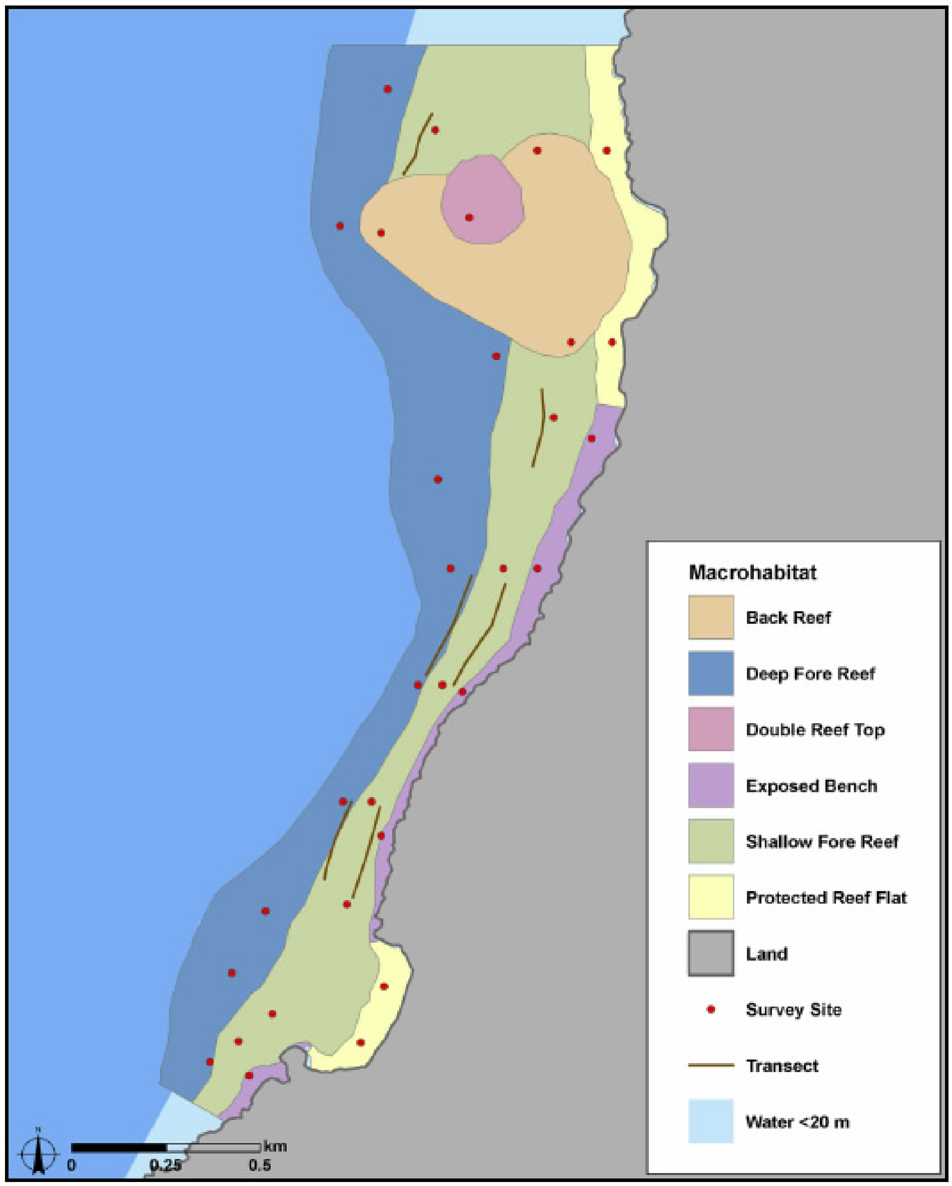

Figure 15. Macrohabitat zones, transect sites, and survey sites in the Haputo ERA. Map: Waddell, 2005. Source: Amesbury et al., 2001.

Methods

For the quantitative surveys, six permanent monitoring stations were established in areas that provided relatively homogeneous benthic communities and maximal geographic coverage within the study area. Three stations were set at 8 m and three were set at 15 m. At each station five 50 m transects were laid end to end (5-10 m apart) covering an area 270-290 m long. If there was not sufficient homogeneity for 250+m of transects, two groups of 2-3 transects were laid with the second group placed 10 m seaward of the first. Four types of surveys were conducted along each transect: a benthic cover survey, a coral population survey, a fish survey, and a macroinvertebrate survey. Quantitative surveys followed the same protocols discussed in the previous section.

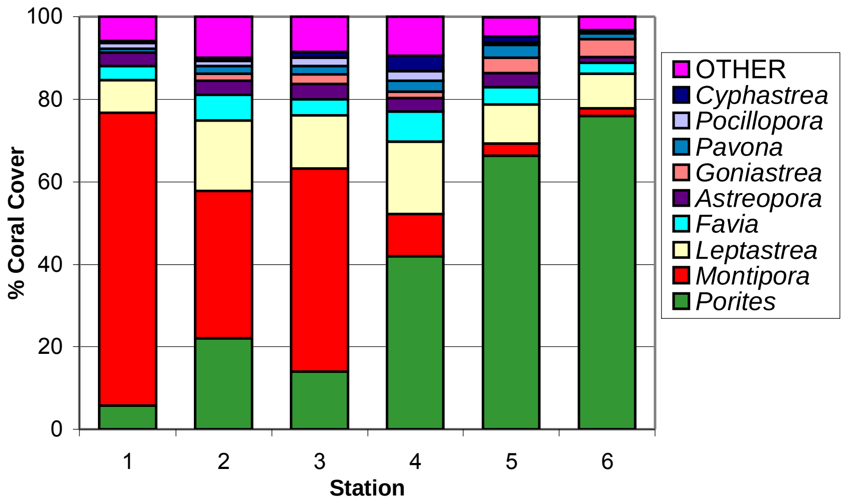

Figure 16. Over 150 species of scleractinian coral were documented in the Haputo ERA. Coral cover was dominated by *Montipora* and *Porites* at most of the six sites. Source: Amesbury et al., 2001.

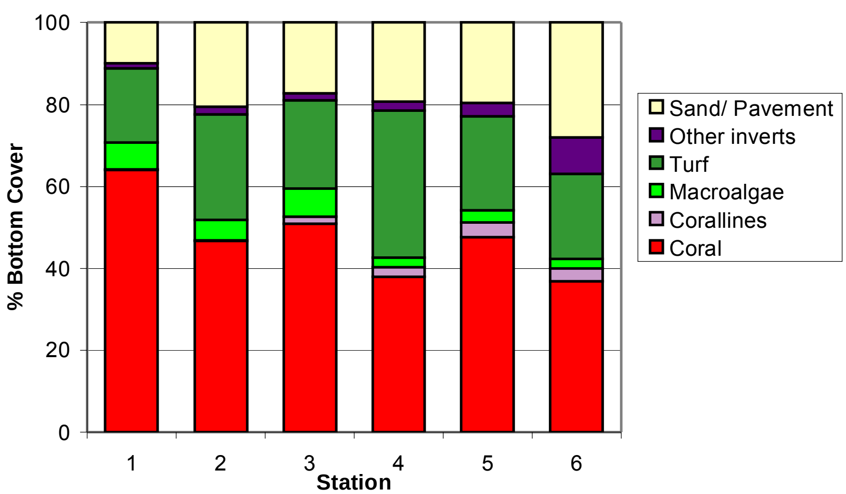

Figure 17. Bottom cover within the Haputo ERA. Corals encompass 37-64% of bottom cover at the six sites. Other cover included turf algae, macroalgae, and coralline algae. There was a high incidence of *Terpios hoshinota,* the coral-killing sponge at site 6. Source: Amesbury et al., 2001.

Results and Discussion

During these surveys, 944 species of marine animal, including 154 species of scleractinian corals, were recorded. The quantitative studies indicated that coral cover was relatively high at most Haputo stations surveyed, ranging between 37-64%. This is higher than most locations in Guam's waters. *Montipora* and *Porites* were the dominant corals at all stations (Figure 16). *Montipora* was common at the shallow stations (1-3), but *Porites* dominated in deeper stations (4-6). Station 1 had 64% coral coverage, which was dominated by a diverse assemblage of *Montipora* colonies. In general, the data from this area suggest that the coral communities are thriving. Bottom cover varied across the study area (Figure 17), and included coral, coralline algae, macroalgae, turf algae, other invertebrates and sand/pavement. Corals were the dominant cover, followed by turf algae. It is interesting to note that *Terpios hoshinota,* the coral-killing sponge, was an important cover at Station 6 (coded as other invertebrates).

Effects of *Acanthaster planci* on Coral Community Structure

Tanguisson Reef has been studied since the early 1970s, when Randall (1973) monitored the recovery from a 1967 outbreak of *Acanthaster planci*. The study indicated that coral coverage increased after the infestation through new coral recruitment and growth of existing corals. By 1980-81, the coverage of corals had increased until it was similar to neighboring reefs unaffected by the outbreak (Colgan 1981a, 1981b; Colgan, 1987). This study also indicated that the community was dominated by *Acropora* and *Montipora* species. Since that time, a number of smaller *A. planci* outbreaks have been reported. Bonito and Richmond (submitted) studied the community again in 2001 to determine if the community structure had changed since the 1980s.

Methods

Tanguisson Reef is located on the northwest coast of Guam and can be divided into three physiographic zones. The reef front is a well-developed spur and groove system in depths of 1-6 m and ranges in width from 50 m to 70 m. Relief in this area can be greater than 3 m, but tapers off at the end of this zone. The submarine terrace covers areas that are 6 m to 18 m in depth. This zone has lower relief and ranges from 40 to 110 meters in width. It is followed by the seaward slope, which ranges from 18 m to 40 m in depth. This zone has an intermediate relief of 1-2 m.

Transects in the 1970s and 1980s were laid perpendicular to shore across the reef to a depth of 33 feet. In 1970, 1971, and 1974, Randall (1973) used a quadrat method at 10 m intervals along each transect (Jones et al 1976). This method measured the width and length of each colony at least 50% within the quadrat, and recorded the growth form of each colony. This information was used to determine the live coral cover, colony abundance, small colony abundance, and species frequency. Colgan resurveyed the transects in 1980 using the point-quarter method at 2 m intervals and in 1981 using the quadrat method. The most recent study in 2000 and 2001 used the quadrat method used by Randall in the 1970s, however, the original transects could not be located. Twenty stations were sampled on the reef front, 22 on the submarine terrace, and 15 on the seaward slope. Three additional dives were conducted in each zone to assess overall species richness.

The researchers also studied the feeding preferences of *A. planci* on northwestern reefs. Twelve sites were chosen on the western side of the island. At each site, coral species abundance was surveyed and the site was searched for *A. planci*. Researchers recorded the number of *A. planci* present and the number of freshly eaten colonies of each coral species.

Results and Discussion

The researchers found that *A. planci* preferentially feed on *Acropora, Montipora,* and *Pocillopora* species. *Astreoopora, Cyphastrea, Goniastrea, Pavona,* and *Stylophora* were considered medium-preference corals.

Acanthastrea, Favia, Favites, Galaxea, Goniopora, Leptastrea, Leptoseris, Millepora, Platygyra, Porites, Psammocora, and *Stylocoeniella* were considered non-preferred corals. They observed that diet depended on relative abundance of corals. If the preferred species were relatively abundant, they were the predominant food source, while medium-preference corals were eaten when preferred species were not abundant. Non-preferred corals were only eaten when the others were relatively rare.

Colgan's study in 1980-81 found that the submarine terrace was dominated by several species of *Montipora*. *Acropora* and *Montipora* species were the second and third most dominant species in the reef front and seaward slope. The newest survey of this area found that *Porites* is now the dominant genus on the submarine terrace and seaward slope, with only negligible contributions from *Montipora* and *Acropora*. The reef front is now dominated by other genera and *Acropora* is only an insignificant contributor. This study found no change in total percent coral cover on the submarine terrace and a slight decrease on the seaward slope. The researchers suggest that this change in community composition may be due to feeding by *A. planci*, as non-preferred corals had significantly greater cover than preferred or medium-preference corals on the seaward slope and the submarine terrace. Non-preferred corals are the most abundant in all zones. Preferred corals increased slightly in cover and abundance on the reef front, but not as much as the other preference groups.

This study suggests that large scale changes in the coral communities at Tanguisson Reef over the last twenty years may have been driven by selective feeding by *A. planci*. The study also identifies seasonal algal blooms as an additional stressor that may impact the settling of larvae produced by *Acropora, Montipora,* and *Pocillopora* species that spawn in the summer. This combination of effects seems to be exacerbated by nutrient influx into Guam's coastal waters and depletion of herbivorous fish stocks due to overfishing. Nutrient influx may be directly affecting the survivorship of *A. planci* larvae, which are dependent on planktonic food supply and can directly assimilate dissolved organic matter. Declines in the herbivorous fish stocks may impact larval settling of corals as algal blooms cover most of the suitable substrate during the summer months when these species spawn. Better land management is suggested as the best means to protect Guam's reefs from future shifts in coral communities.

Algal Communities

Guam's algal communities were surveyed by Dr. Peter Vroom as a part of the MARAMP in September 2003, using a rapid ecosystem assessment (REA) protocol developed specifically for remote island ecosystems (Preskitt et al., 2004). One component of this protocol, a rapid method of analysis using presence/absence and ranked data, was employed for this preliminary assessment (Vroom, in review). These data provide information on prevalence and relative abundance of algae in Guam at the genus level. Prevalence was defined as the percentage of quadrats in which a genus occurs at each site and relative abundance was defined as the abundance of a genus (e.g., the rank) in relation to other algal genera occurring in the same quadrat (Vroom, in review).

Methods

Benthic REAs were conducted at 9 sites around Guam, including 1 site on Santa Rosa Bank, just southeast of Guam. Three 25 m transect lines were set in a single-file row at a constant depth, with each transect separated by 10 m. Ranked abundance of algal genera was collected from a total of 12 quadrats (0.18 m^2) at each site (1 being the most abundant, 2 being the next most abundant, etc.; Vroom et al., submitted). Additionally, samples of macroalgae present within each quadrat were collected as voucher specimens (Preskitt et al., 2004).

Results and Discussion

According to Vroom (in review), algae from 28 genera or functional groups (i.e., crustose coralline algae, upright branched coralline algae, turf algae, cyanophytes) were found in quadrats at sites sampled around Guam and Santa Rosa Bank. In addition to the functional groups of turf, cyanophytes, branched coralline and crustose coralline algae, the most prevalent genera found around Guam included *Halimeda* and *Neomeris* (green algae), *Padina* (brown algae), and *Trichleocarpa* and an unknown gelid rhodophyte (red algae). At the Santa Rosa site, species in the genera *Dictyosphaeria, Halimeda, Udotea,* and the species *Microdicyton okamurai* Setchell, (green algae), were most prevalent. Turf and the gelid rhodophyte were also extremely prevalent. Relative abundance of genera was similar among sites.

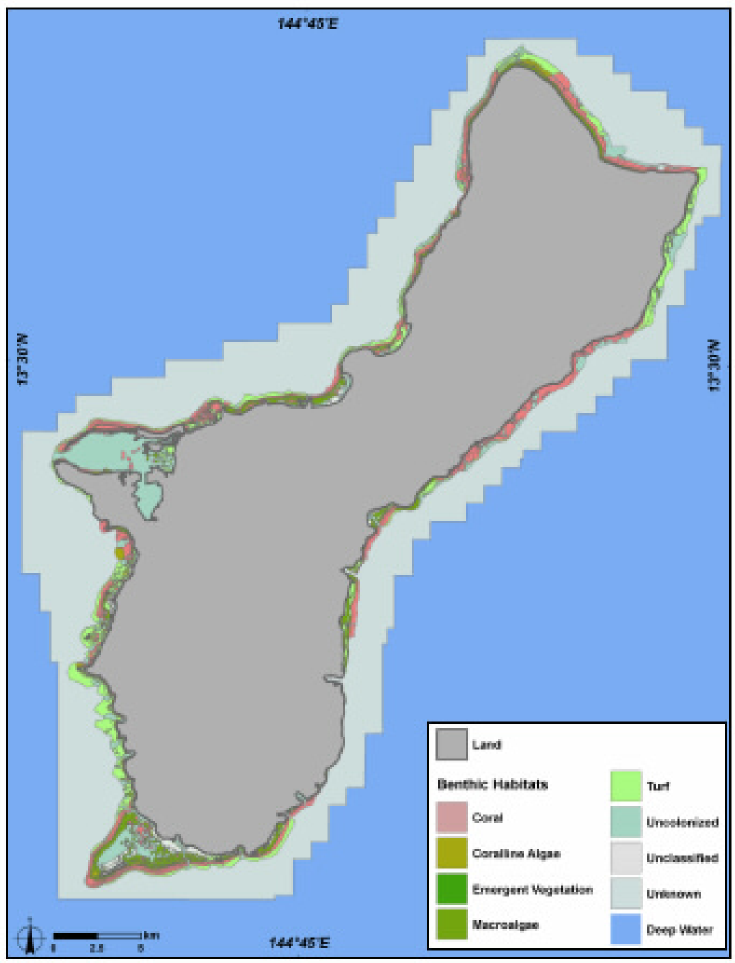

Figure 18. Nearshore benthic habitat maps were developed in 2004 by CCMA-BT based on visual interpretation of IKONOS satellite imagery. For more info, see: http://biogeo.nos.noaa.gov. Map: Waddell, 2005.

Benthic Habitat Mapping

The Biogeography Program, part of NOS's Center for Coastal Monitoring and Assessment, initiated a nearshore benthic habitat mapping program for Guam, American Samoa and CNMI in 2003. IKONOS Satellite imagery was purchased from Space Imaging for all three jurisdictions, which was used to delineate habitat polygons in a Geographic Information System (GIS). Habitat polygons were defined and described according to a hierarchical habitat classification system consisting of 18 distinct biological cover types and 14 distinct geomorphological structure types. The project, which was completed in 2004, mapped 104.7 km^2 of nearshore habitat in the islands and produced a series of 42 maps that are currently being distributed as a print atlas, a CD-ROM, and on-line at: http://biogeo.nos.noaa.gov/products/us_pac_terr/. The benthic habitat maps for Guam are depicted in Figure 18.

ASSOCIATED BIOLOGICAL COMMUNITIES

Many recent studies on Guam have examined the biological communities associated with coral reefs. The most detailed studies have examined the fish communities. These include the marine preserve monitoring by DAWR (Gutierrez, in prep.) and Dr. Mark Tupper of the University of Guam Marine Laboratory (in prep). The U.S. Navy-sponsored studies at Orote Peninsula and Haputo Ecological Reserve Areas discussed in the previous section also examined fish communities at the survey sites, as well as macroinvertebrate populations. Preliminary data for fish communities collected during the MARAMP are included below, however, data for other communities are not yet available.

DAWR Marine Preserve Monitoring

In 1997, Guam established five marine preserves around the island amounting to 11.8% of Guam's shoreline. DAWR sampled the fish populations in two of the preserve areas and suitable control sites prior to the start of full enforcement on January 1, 2001, and have since monitored the fish communities at these sites to determine the effectiveness of the preserve system. These studies focus on the fish species targeted for consumption and indicator species such as butterflyfish.

Methods

The Piti Bomb Holes Preserve and the Achang Reef Flat Preserve are the experimental sites for the stock assessment surveys. Cocos Lagoon and the Asan fore reef slope serve as the control sites for the Piti Bomb Holes Preserve, while Pago Bay reef flat and Cocos fore reef slope serve as the control sites for the Achang Reef Flat Preserve.

Prior to full enforcement in 2001, 66 permanent belt transects (50m x5m) were surveyed on the reef flats and fore reef slopes of two preserve sites, Piti Bomb Holes Preserve and Achang Reef Flat Preserve, and three control sites, Asan Bay, Cocos Lagoon, and Pago Bay. Two sets of transects were placed on the fore reef slope at the 20, 30, 40, and 50 foot depth contours. Eight transects were placed on the reef flat at each site representing distinct microhabitats (seagrass, coral/algal/ rubble, and sandy bottom).

Fish communities were surveyed using two different visual survey techniques along each transect. Density was assessed using a visual fish census along a strip transect. Two fish counters followed the 50 m long permanent transect, each counting all target fish within 2.5m of their side of the transect. All target fish within this 250 m^2 area were scored on data sheets based on their species and size class. Three size classes were used based on the fork length of the fish (<15 cm, 15 cm-30 cm, >30 cm). The strip transect method was complemented by a timed visual survey in the same area. At each site, fish counters recorded the species and size class of all fish encountered in the area during a 30 minute interval.

Fish surveys were conducted at all sites prior to full enforcement of the preserves and then repeated within two years. Because of poor weather conditions and lack of a boat, only four transects on the fore reef slope of Achang Reef Flat Preserve were repeated (one at each depth of 20, 30, 40 and 50 ft). Data were analyzed using Statview 4.5 for PC published by Abacus Concepts Inc. A two-tailed paired t-test (Sokal and Rohlf, 1995) was used to compare fish densities and diversity over time within each study site. The Shannon diversity index was used to calculate an index number for species diversity and evenness at each site for both pre- and post-implementation data. A higher index number indicates greater diversity. When the assumptions of analysis of variance (ANOVA) were not met, even after transformations, a nonparametric test was conducted (Sokal and Rohlf, 1995).

Results and Discussion

The data from the belt transect surveys suggests that fish stocks in the preserve areas are starting to recover, while some non-preserve areas were still declining. Data also indicate that within the Piti Bomb Holes Preserve and Achang Reef Flat Preserve, there were significant increases of 113% ($p<0.001$) and 115% ($p<0.001$)respectively, in the total number of individuals within the transects after the preserves were implemented (Figure 19). At the non-preserve control sites, there were significant to minor decreases were detected (29% at Asan/Cocos ($p<0.005$) and 4% at Cocos/Pago ($p>0.05$)) in the total number of individuals within the transects (Figure 20).

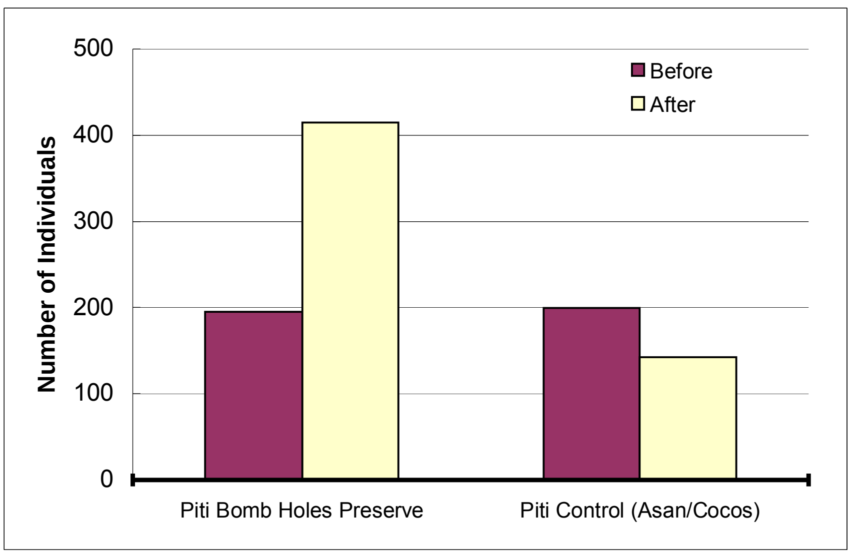

Figure 19. Prior to full enforcement, DAWR counted 195 individuals within sixteen transects in the Piti Bomb Holes Preserve. After two years, this number had increased by 113% to 415 individuals, a significant increase ($P < .001$). At the control sites for the Piti preserve, Cocos Lagoon and Asan Bay, the number of individuals decreased from 199 prior to full enforcement of the preserves to 142 two years later. This was a significant decrease of 29% ($P<0.005$). Source: Gutierrez, 2003.

The largest increase appeared to be in the smallest size class. There were significant increases of 123% and 138% within the Piti Bomb Holes Preserve ($p<0.001$) and Achang Reef Flat Preserve ($p<0.001$) for individuals < 15 cm after the preserves were implemented. In the non-preserve areas, there were significant to minor decreases of 27% at Asan/Cocos ($p<0.001$) and 5% at Cocos/Pago ($p>0.05$) for individuals < 15 cm during the same period. For larger fish (>15 cm - <30 cm), results were more variable, with an increase of 44% within the Piti Bomb Holes Preserve after implementation and a 10% decrease in the Achang Reef Flat Preserve. However, in the non-preserve areas, there were decreases of 75% (Asan/Cocos) and 33% (Cocos/Pago) in the number of individuals between >15 cm and <30 cm, during the same period of time.

Timed interval surveys indicated that the number of species observed at the study sites after implementation increased by 14% within the Piti Bomb Holes Preserve and 3% at the Asan/Cocos control sites. During the study period, diversity increased significantly (38%) in the Piti Bomb Holes Preserve. Although diversity increased in the Asan/Cocos control sites, the increase was not significant (3%). Diversity indices have not yet been calculated for Achang Reef Flat Preserve and the Pago/Cocos control sites.

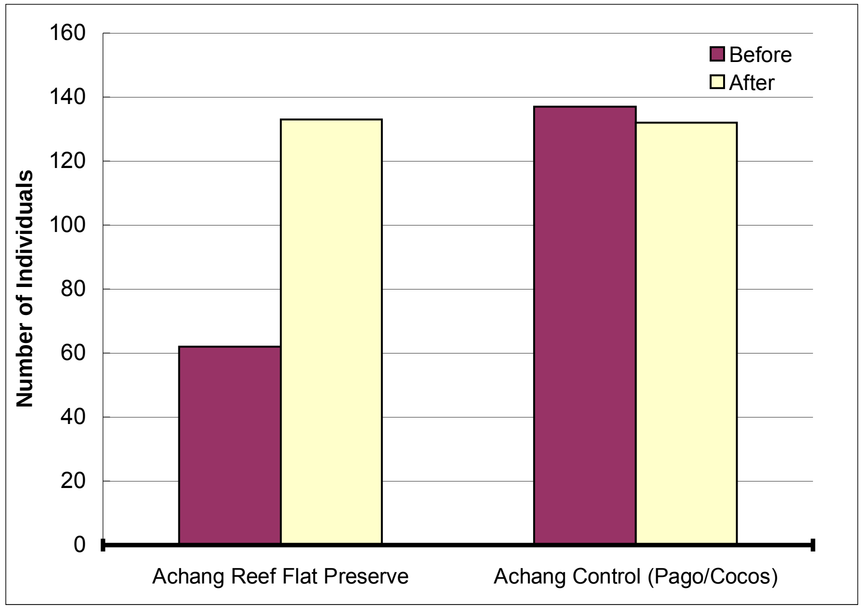

Figure 20. In baseline surveys at Achang Reef Flat Preserve, 62 total individuals were counted within sixteen transects. Two years later, DAWR counted 133 individuals within the same transects. This was a significant increase of 115% in the total number of individuals (P<0.001). Surveys at the control sites for this preserve, Pago Bay and Cocos Lagoon, did not show a significant change in the number of individuals during this time period (P>0.05). Source: Gutierrez, 2003.

After only two years of implementation, there have been significant increases in fish density within the preserves. The majority of fish recruiting into the preserves are smaller than 15 cm. Within the non-preserve areas, fish density has remained the same or has decreased significantly, within the same period of time. Preliminary data show that larger size fish (>15 cm) are being observed within the preserve while their numbers are decreasing within the non-preserve areas. Within one preserve, diversity also increased significantly.

UOGML Marine Preserve Effectiveness

The University of Guam Marine Laboratory is also involved with assessing the effectiveness of the marine preserves. Dr. Mark Tupper (in prep) studied the effectiveness of three marine preserves: Achang Reef Flat, Piti Bomb Holes, and Tumon Bay. These sites were compared to adjacent, unmanaged control sites: Cocos Lagoon, Asan Bay, and Agana Bay, respectively. The biophysical indicators chosen for this study were: focal species abundance, population structure, and recruitment.

Focal Species Abundance

Focal species abundance was determined for four species: bullethead parrotfish (*Chlorurus sordidus*), yellowstripe goatfish (*Mulloidichthys flavolineatus*), orangespine unicornfish (*Naso lituratus*), and bluespine unicornfish (*Naso unicornis*). Two sites were chosen within each of the three marine preserves studied and within each of the three control sites. All sites were near the edge of the reef flat at depths of 2-5 m. Four replicate 50 m x 2 m transects were surveyed at each site to determine the density of each species per 100 m^2 area. The results were analyzed using a nested ANOVA. Location and status were used as model factors with location nested within status.

Densities for all four species were significantly higher in the MPAs than in the control sites, and at some sites were an order of magnitude higher in the preserves (Figure 21). Further analysis indicated that there were also significant differences among the preserve sites and among the control sites. Density of *Chlorurus sordidus* was highest at Piti Bomb Holes Preserve, possibly due to fish feeding by divers and snorkelers. *Mulloidichthys flavolineatus* density was five to nine times higher in the preserves than in the control sites, with the highest density documented in Tumon Bay. Achang Reef Flat Preserve had the highest densities of *Naso lituratus* and *Naso unicornis*.

Focal Species Population Structure

Population size structure was determined by counting fish and estimating their fork length in situ. As described in the previous section, fish were surveyed on four replicate 50 m x 2 m transects. Eight size classes were used for size estimation: 10-12.5 cm, 12.5-15 cm, 15-17.5 cm, 17.5-20 cm, 20-22.5 cm, 22.5-25 cm, 25-27.5 cm, and 27.5-30 cm. Fish less than 10 cm were not counted. These small transects did not provide enough data, so the method was modified to use a single 100 m x 4 m transect. However, this prevents statistical comparison between sites. The results indicated that *C. sordidus*, particularly the larger size classes, were more abundant at all preserve sites than control sites. *M. flavolineatus* were more abundant in the preserves than the control sites; however, small-medium sized *M. flavolineatus* were less abundant in Achang Reef Flat Preserve than at the control sites in Cocos Lagoon. The length and abundance data were used to determine the spawning biomass (the weight of the spawning adult fishes per unit area). The length data were used to estimate weight values using published length-

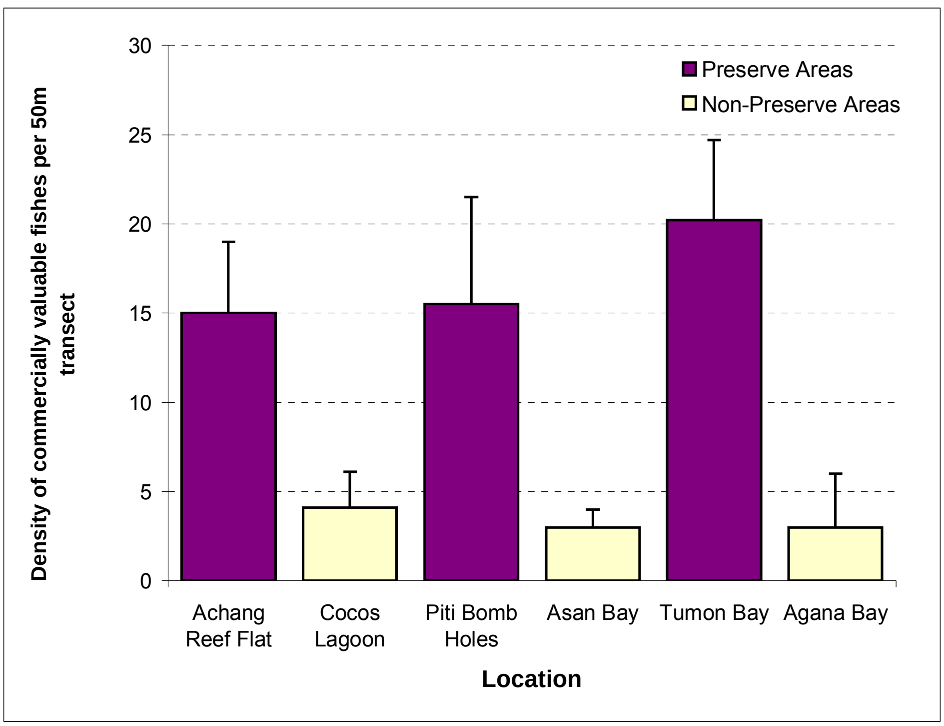

Figure 21. In 2002-2003, two years after full enforcement began, the density of commercially valuable food fish along a 50m transect was examined in both marine preserve and non-preserve sites. Food fish density was noticeably greater in preserve sites. Source: Tupper, 2004.

weight regressions. Biomass for *C. sordidus* and *M. flavolineatus* was significantly higher in the preserve sites than the control sites (nested ANOVA, F=8.49, p=0.006, F=15.7, p<0.001).

Recruitment Success

Two aspects of recruitment were studied: settlement and recruitment. Four replicate 25 m x 2 m transects were used to enumerate newly settled fish in March 2002. *C. sordidus* were recorded as newly settled if they were 10-15 mm long. *M. flavolineatus* were recorded as newly settled if they were 6-7 mm long. *C. sordidus* had the highest settlement in Cocos Lagoon, however, overall mean settlement was higher in the preserves than the control sites (nested ANOVA, F=4.1, p<0.01). *M. flavolineatus* settlement was similar across all sites with no significant differences between preserve areas and the control sites (nested ANOVA, F=0.04, p=0.840).

Transects were revisited three months later to determine the survival rates of the settled fish. For the second visit *C. sordidus* 25-50 mm long and *M. flavolineatus* 90-120 mm long were recorded (the expected length for the previously recorded settlers). The pattern of recruitment changed during the three months that elapsed between surveys. Despite the high settlement in Cocos Lagoon, the second survey indicated that recruitment success was 50% less than in the Achang Reef Flat Preserve. In general, *C. sordidus* recruitment in the marine preserves was significantly higher than in the control sites (nested ANOVA, F=64.8, p<0.001). *M. flavolineatus* recruited less successfully in the control sites, despite similar settlement (nested ANOVA, F=9.5, p=0.004). This was expected due to fishing pressure on newly-settled *M. flavolineatus* in the control sites.

Discussion

The results of this study suggest that the marine preserves in Guam have a positive effect on local reef fish populations. Species abundance for four species indicated significant differences between protected areas and adjacent control sites. Large sizes of *C. sordidus* and *M. flavolineatus* were more common in the preserve areas; however, smaller sizes were more abundant in some of the control sites. Spawning mass was significantly higher in the marine preserves than in the control sites indicating that the marine preserves may function as “egg banks” and provide higher production potential.

Orote Peninsula ERA Fish and Macroinvertebrate Surveys

As described in the above section on benthic habitat, the US Navy sponsored biodiversity studies and baseline reef monitoring surveys at Orote Peninsula ERA (Paulay et al., 2001). Both qualitative biodiversity surveys and quantitative baseline monitoring were conducted for fish and macroinvertebrates.

Methods

Fish and macroinvertebrates were qualitatively surveyed at a site in each of the subzones identified in the study. At least one diver surveyed each category for the duration of one dive. Deep dives occurred at a depth of 27-30 m for 25 minutes, deeper dives were shorter (at least 10-15 minutes), and all other dives were 40 minutes or longer.

Fish surveys were conducted along the three central transects (50m x 5m) laid out for the benthic surveys described above. Quantitative surveys were conducted following the methods described in English et al (1997). The fish surveyor started the transect at least 10 minutes after the transects were laid and before any other surveyor. Large fish within 2.5 m of the transect and within 5 m of the bottom were recorded first. For highly abundant fish, a logarithmic scale was used for estimates of abundance. Abundance statistics were calculated for species, family, and total population at each station. The Shannon-Weiner diversity index and the number of species encountered were also calculated for each station.

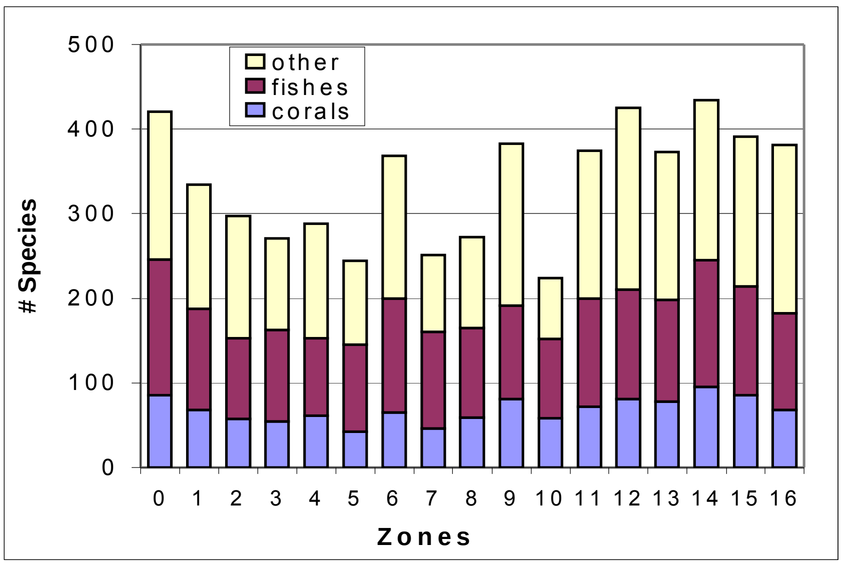

Figure 22. 1252 species were recorded during the diversity survey at Orote ERA. Species richness varied greatly between subzones. Source: Paulay et al 2001.

Quantitative surveys of macro-invertebrates were conducted along all five belt transects (50m x 1m). Surveys included all large, exposed macrofauna. The primary taxa studied were larger mollusks and echinoderms, as cryptic fauna and small species could not be effectively sampled. Abundance was recorded in five 10 m^2 quadrats per transect, which were lumped into 50 m^2 quadrats for analysis. The mean and standard deviation were calculated for each of the transects.

Results and Discussion

The survey recorded 1252 species of marine animals. This included only the exposed macrofauna identified during the limited dives. Fish recorded included 339 species, approximately 37% of the 920 known species from Guam. Macroinvertebrates accounted for 657 species encountered during the qualitative surveys. Diversity appears to be related to habitat, with areas such as the reef flat between Neye Island and the coast, and the patch reefs in North Agat Bay, exhibiting high levels of diversity. In general, diversity declines from Orote Point southeastward and then increases again in the Agat area (Figure 22).

The quantitative surveys were conducted at 10 stations. Orote fore reef sites had a higher abundance of fish than Agat Bay. Twenty-five fish families were recorded during the quantitative studies. The most abundant family was the Pomacentridae (69%) followed by the Acanthuridae (10.2%), Labridae (4.4%), Chaetodontidae (3.8%), Scaridae (3.2%), and Balistidae (2.2%), while all other fish species comprised 7.2% (Figure 23).

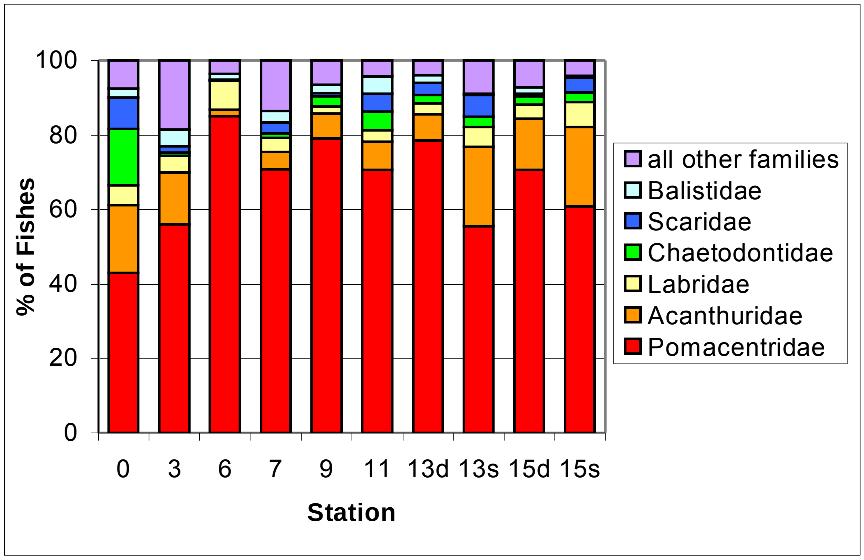

Figure 23. Fish family composition in the Orote ERA. The quantitative surveys identified 25 fish families, however, the community was dominated by six families, most notably Pomacentridae, which dominated every site. Source: Paulay et al 2001.

During the quantitative surveys, a total of 26 species of macroinvertebrates were identified. This included 19 echinoderms, 6 mollusks, and 1 crustacean. The maximum number of species observed at a single station was 13, with the highest diversity occurring towards Agat Bay (Figure 24). These surveys only captured the large, diurnal, exposed species and did not capture the many cryptic and nocturnal species resident at these areas. The most commonly encountered species were: echinoids *Echinostrephus aciculatus* and *Echinothrix* spp, the giant clam *Tridacna maxima*, and the sea cucumber *Holothuria edulis*.

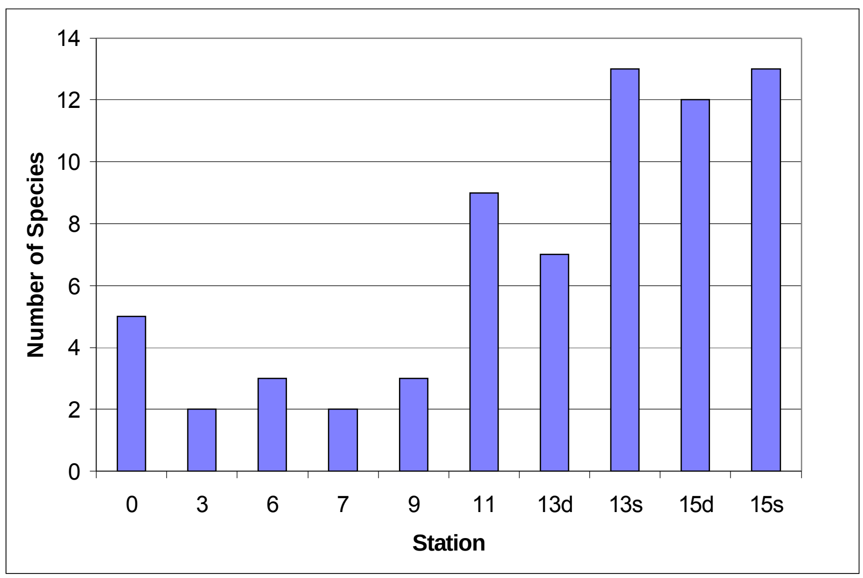

Figure 24. Macroinvertebrate communities varied greatly over the study sites with the highest diversity documented in the southern sites. Species include 19 echinoderms, 6 mollusks, and 1 crustacean. Cryptic species were not included in the survey. Source: Paulay et al 2001.

The study indicates that diversity and species composition of the Orote Peninsula reefs are strongly influenced by physical factors such as wave exposure, currents, riverine influence, and bottom topography. A number of unique micro and macrohabitats exist in this area with very different assemblages found within each. The researchers indicate that Blue Hole, the Orote Boulder Fields, and the Orote Point Reef Slope were biologically important due to unique species and high biodiversity.

Haputo ERA Fish and Macroinvertebrate Surveys

As described in the above section on benthic habitat, the US Navy sponsored biodiversity studies and baseline reef monitoring surveys at Haputo Peninsula ERA (Amesbury et al., 2001). Both qualitative biodiversity surveys and quantitative baseline monitoring were conducted for fish and macroinvertebrates.

Methods

Fish and macroinvertebrates were qualitatively surveyed at each of the sites identified in the study using timed surveys (30 minutes) to assess fish diversity and abundance and a timed search (1 hour) for large macroinvertebrates. The survey team followed the same methodology described in the Orote section above for fish, but used 2 m-wide transects for macroinvertebrates.

Table 12. A comparison of biodiversity between the Orote ERA and the Haputo ERA indicated that both areas exhibited similar coral species richness, but different levels of fish and invertebrate species richness. Source: Amesbury et al 2001.

SURVEY AREA	CORALS	OTHER INVERTEBRATES	FISHES
Orote-Agat	156	757	339
Haputo-Double Reef	154	583	207
Ratio	1.01	1.3	1.64

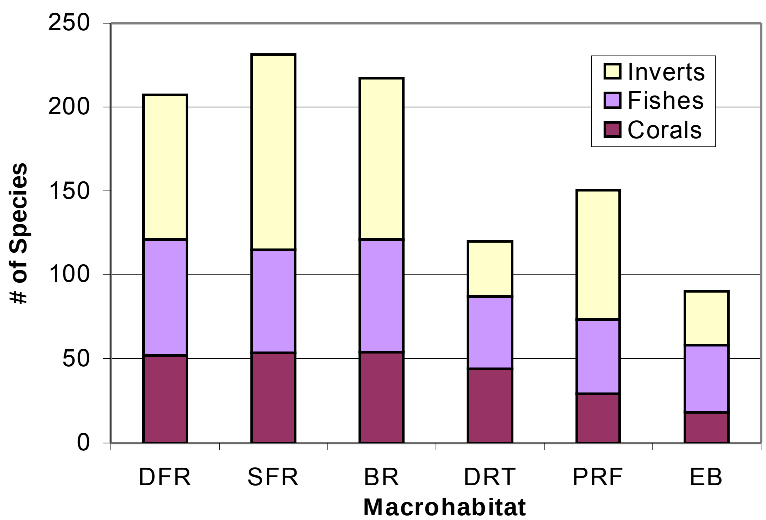

Figure 25. Species richness varied greatly between microhabitats in the Haputo ERA. The graph shows the mean number of species per site of six surveyed macrohabitats: Exposed Bench (EB), Protected Reef Flat (PRF), Double Reef Top (DRT), Back Reef (BR), Shallow Fore Reef (SFR), and Deep Fore Reef (DFR). Source: Amesbury et al 2001.

Results and Discussion

This survey recorded 944 species of marine animals. This included only the exposed macrofauana identified during the limited dives. Fish recorded included 207 species, approximately 22% of the 920 known species from Guam. Macroinvertebrates accounted for 583 species encountered during the qualitative surveys. A comparison of surveyed biodiversity between Orote and Haputo showed some interesting results (Table 12). Researchers identified a similar number of corals at the two sites; however, they found more species of fish and invertebrates at Orote than at Haputo sites. The researchers noted that while the corals are thriving at Haputo, the fish community is not. Large piscivores and herbivores were rare.

The researchers also noted differences between the six macrohabitats identified in the survey. The fore reef sites are more diverse than the shallow sites. The shallow sites had fewer coral, fish, and other invertebrate species, than the medium to deep macrohabitats (Figure 25).

The quantitative surveys were conducted at six stations. Twenty-one fish families were recorded during the quantitative studies. The most abundant family was the Pomacentridae (74%) followed by the Acanthuridae (10.1%), Labridae (6.7%), Lethrinidae (3.1%, *Gnathodentex aurolineatusa* only), Gobiidae (2.7%), Scaridae (1.2%) and Chaetodontidae (1.1%), while all other fish species comprised 3.4% (Figure 26).

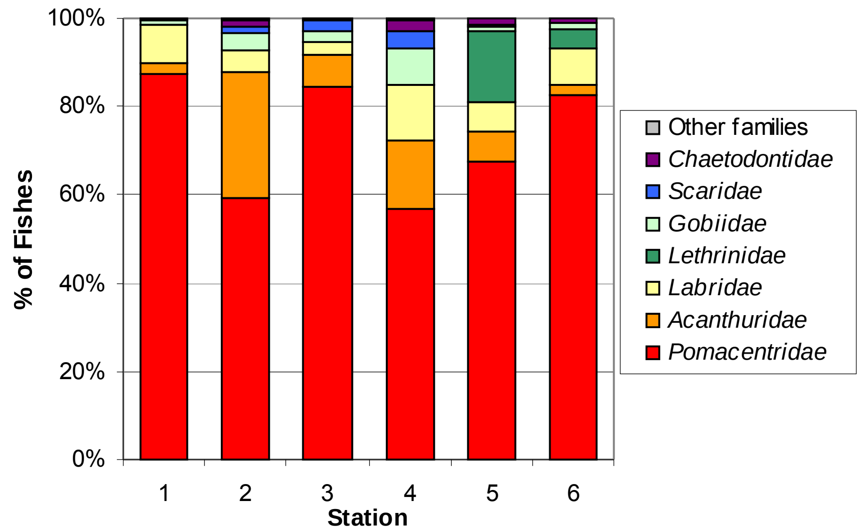

Figure 26. Quantitative surveys at Haputo ERA indicate that the fish community is dominated by 7 families. Large piscivorous and herbivorous fish were rare and of low diversity. Source: Amesbury et al 2001.

During the quantitative surveys a total of 24 species of macroinvertebrates were identified. This included 16 echinoderms and 8 mollusks. The maximum number of species observed at a single station was 13, with the highest diversity occurring in the shallow stations (1-3) (Figure 27). The most commonly encountered species were sea urchins in the genera *Echinometra* and *Echinostrephus*. Giant clams *Tridacna maxima*, were found at five of the six sites, but were less common than sea urchins.

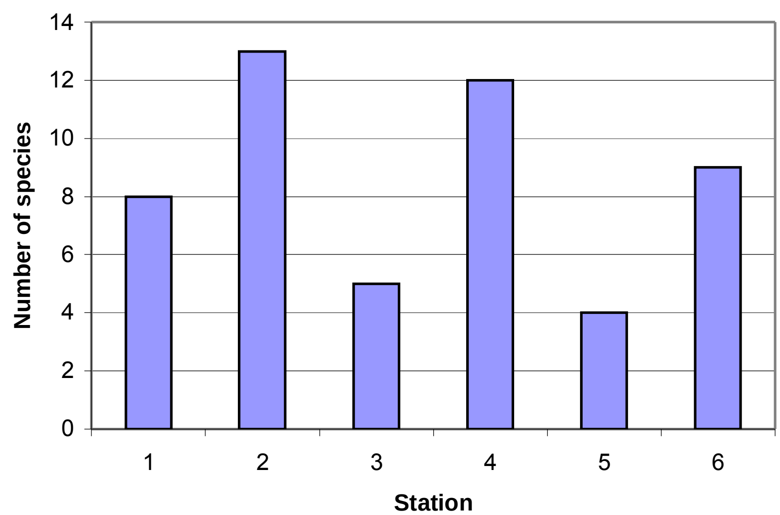

Figure 27. Number of macroinvertebrate species in the Haputo ERA. Communities varied greatly across the six study sites. Species recorded in the quantitative surveys include 16 echinoderms and 8 mollusks. Cryptic species were not included in the survey. Source: Amesbury et al 2001.

The study indicated that while corals were thriving, the fish targeted by the local fisheries were less diverse and less abundant than expected. The low abundance of large individuals of these species suggests that overfishing may also be a problem in this area.

MARAMP Fish Surveys

Fish surveys were directed by Dr. Robert Schroeder in September 2003 as part of the Guam leg of the MARAMP. Objectives of the surveys included: creating a fish baseline to measure MPA effectiveness; monitoring size-frequency assemblages; assessing the status of target, indicator or keystone species; assessing response by fish community to possible ecosystem impacts (e.g., overfishing, habitat damage, sedimentation, prey size changes); and assessing species composition and diversity, by area and effectiveness of temporal monitoring of managed areas (Schroeder, unpublished report).

Methods

Fish were surveyed around the island of Guam and at Santa Rosa Bank. Schroeder and his team conducted several types of surveys including: 1) Rapid Ecological Assessments (REA) to document species diversity at a site; 2) Belt Transects (BLT) to estimate densities of relatively small-bodied and abundant fishes; 3) Stationary Point Counts (SPC) to estimate densities of relatively larger (>25 cm Total Length [TL]) and more mobile fish species; and 4) Towed-Diver/Video Surveys (TDVS) to estimate densities of relatively large-bodied (>50 cm TL), wide-ranging fishes over a broad-spatial scale, in conjunction with a towed-diver/habitat video. Fish length-class was estimated for all quantified fishes to provide an estimate of numerical size structure and biomass density by taxa.

Results and Discussion

Schroeder (unpublished report) provided the following preliminary results. Data from 11 belt transects showed that large fish (>20 cm) were not abundant, averaging about 2 /100 m^2 (compared with over 14 /100 m^2 at Uracas and Maug, the two northernmost islands in the Mariana Chain). Results from 11 SPC surveys were similar. Medium-size fish were only common along the N and NE sides of the island. Densities of larger fish (>50 cm TL) from towboard surveys were also quite low for both Guam and Santa Rosa (less than 0.1 /100 m^2). No sharks were observed by the fish census team, although the fish tow-team did see black-tip and white-tip sharks. About 232 species were sighted during the five-day survey. Few juvenile fish were present, unlike the northernmost Mariana Islands, where recruitment for several species was higher. The highest diversity of fish was found at Jinapsan Beach on the Northern tip of Guam. Common species observed included brown surgeonfish (*Acanthurus nigrofuscus*), red ribbon wrasse (*Thalassoma quinquevittatum*), bullethead parrotfish (*Chlorurus sordidus*), and orangespine unicornfish (*Naso lituratus*).

Guam sustains a large human population and its waters are heavily fished. Habitat damage and loss may also contribute to these preliminary findings on the status of coral reef fish assemblages. Ongoing analysis of the 2003 data, together with planned biennial monitoring, should help determine the effectiveness of Guam's recently established MPAs, as well as provide the scientific basis for other management initiatives.

Overall Condition/ Summary of Analytical Results

Guam's northern reefs are generally in better condition than those affected by erosion and sedimentation in the south, due to the primarily limestone composition of northern Guam. Coral cover and diversity are generally highest in an area beginning roughly at Falcona Beach on the northwest coast, continuing clockwise around the northern coast, and extending down to Pagat Point on the eastern side of the island (Figure 28). The areas between Tanguisson Point and Falcona Beach also have high coral cover and diversity; however, they are heavily fished and have higher recreational use than the reefs to the north (Amesbury et al., 2001).

The eastern reefs along the central and southern portions of the island are heavily affected by sedimentation and freshwater runoff near the mouths of rivers draining Guam's largest watersheds, especially during the rainy season. However, some very diverse and relatively healthy reefs lie adjacent to these heavily impacted spots; in particular, the fore reef slopes off of Achang Reef Flat Marine Preserve and the south side of Cocos Lagoon. Most of the fringing reefs along the southwestern shores are in poor to fair condition, again depending on their proximity to river mouths. Water quality impacts caused by coastal development, wildland arson, and runoff are a serious concern in these areas; however, there are limited water quality data available. GEPA, DAWR,

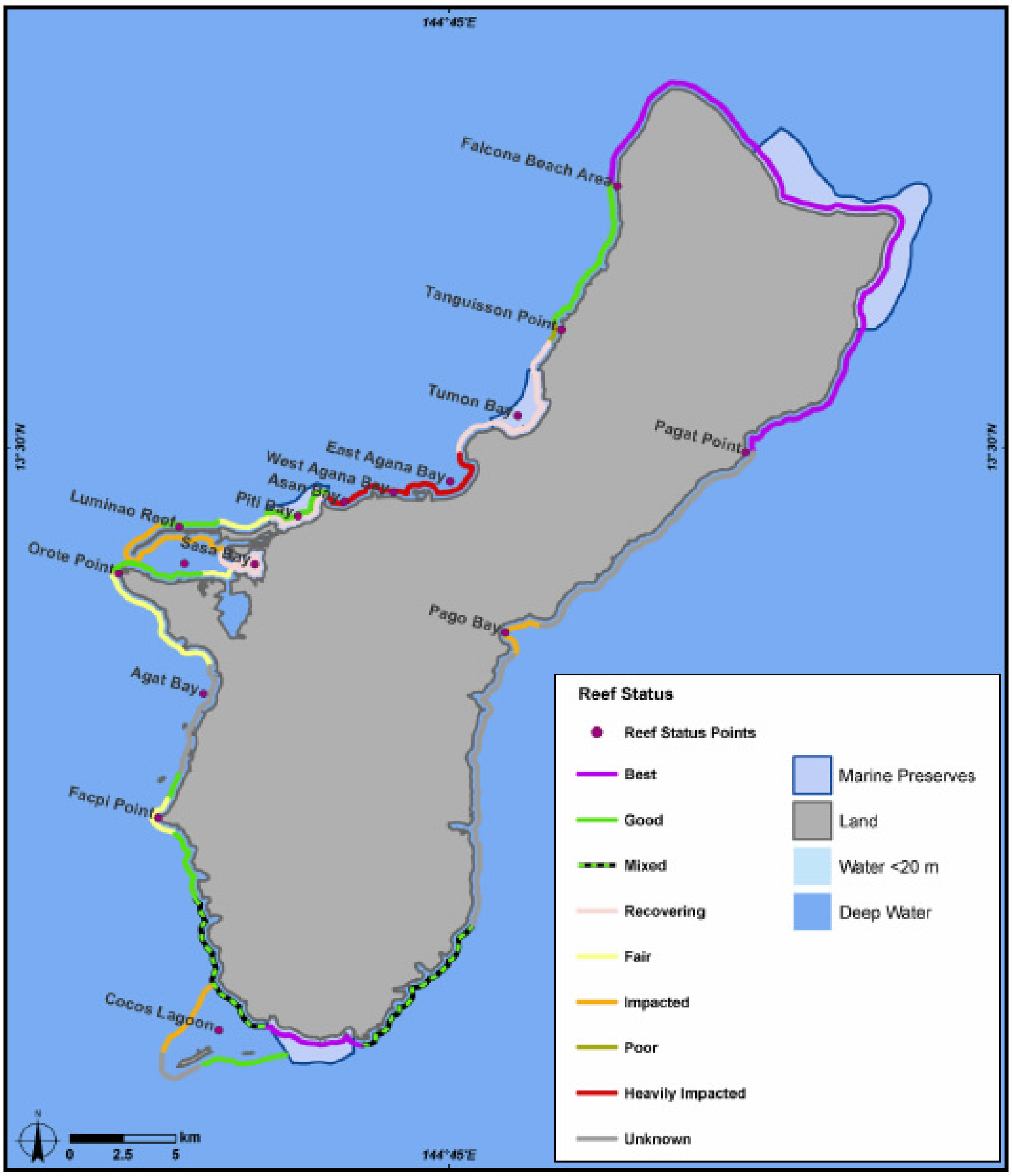

Figure 28. Summary map showing the overall condition of Guam's coral reef ecosystems. Map: Waddell, 2005. Source: DAWR.

and UOGML hope to address this issue, with future monitoring efforts such as increasing water quality monitoring and studying sedimentation of southern reefs in conjunction with upland restoration projects.

Although Apra Harbor is home to the busiest port in Micronesia, a large Navy Base, and numerous recreational facilities, it contains both patch and fringing reefs with some of the highest coral cover on the island (i.e., Jade Shoals, Western Shoals, and Finger Reef). Both hawksbill and green sea turtles frequently forage in the protected waters of the harbor, and the extensive mangroves of Sasa Bay Marine Preserve are also located there. However, corals and reefs near the northeastern part of the harbor have been impacted by thermal discharges from the Guam's main power generation facilities (G. Davis, pers. comm.). The reefs from Orote Point south to Agat include many different microhabitats that provide habitat for a diverse assemblage of reef organisms. The fishing advisory for the areas near the Orote Dump has acted as a de facto fishing preserve, allowing some stocks to rebound from fishing pressure. Chemicals leaching from the dumpsite do not appear to have significantly impacted the resources (Paulay et al., 2001).

Several large bays, Piti, Asan, West and East Agana, and Tumon, are located along the central western coastline; an area that experiences calm conditions for most of the year. According to Gutierrez (2004) and Tupper (2004), Asan Bay is heavily impacted by fishing, and fish stocks have decreased in this area since monitoring began in 2001. Piti and Tumon Bays were selected to be marine preserves due to their wide diversity of habitat types. Since full implementation of the preserves in January 2001, increases in herbivorous fish densities appear to have better controlled the growth of palatable macroalgae in the two preserves, resulting in healthier looking reefs (T. Leberer, pers. obs.). A study to assess algal abundance and composition in relation to herbivore stocks in- and outside marine preserves has been proposed for funding for the fiscal year 2005.

The overall scarcity of reef fish, especially larger individuals, despite the persistence of some relatively healthy and diverse coral communities around the island is a serious concern (Schroeder, unpublished report). The exceptions to this are within the marine preserves, where significant increases in fish density and diversity have been seen (Gutierrez, 2004). Continued fish and habitat assessment surveys within Guam's marine preserves will provide an effective means to monitor their status. In addition, two recently funded projects are attempting to assess the amount of spillover occurring into areas adjacent to the marine preserves, both from larval recruitment and adult migration. This information is crucial for Guam's resource managers, to help determine whether current marine protected areas are an effective management tool for restoring depleted coral reef fishery resources island-wide.

CURRENT CONSERVATION MANAGEMENT ACTIVITIES

Guam recognizes the important benefits that coral reefs provide, and has developed a diverse assortment of laws, regulations, permits, policies, plans and education programs to serve as mechanisms for management of human activities that impact Guam's coral reefs (Gawel, 1999). Many of these, such as the Environmental Impact Assessment requirements, were not created specifically to protect coral ecosystems but now serve that purpose. Guam continues to expand and improve its management activities to address the threats identified above.

This process has been facilitated by the creation of the Guam Coral Reef Initiative Coordinating Committee (GCRICC) by Executive Order 97-10 in 1997. This committee prioritized the 13 threats identified in the National Coral Reef Action Strategy and selected the top five on which to focus for the next three years. By February 2003, the GCRICC had identified local navigators and drafted local action strategies (LAS) for the prioritized focus areas of land-based sources of pollution, fisheries management, outreach and education, recreational misuse and overuse, and climate change and coral bleaching. These local action strategies have provided a guiding framework for local resource agencies and have facilitated improved management

Current Conservation Management Activities in Guam

Land-Based Sources of Pollution

- Guam Seashore Protection Plan
- Soil Erosion and Sediment Control Regulations of 2000
- GEPA enforcing Section 401 and NPDES permits
- Watershed Restoration (DoAg)
- Watershed Planning Group
- Permit Conditions to Limit disturbance during coral spawning (DPW/GEPA)

Fisheries Management

- Marine Preserve Areas (DAWR)
  - Enforcement
  - Education
  - Monitoring
- Creel Surveys (DAWR)
- School Presentations

Lack of Public Awareness

- Coral Awareness Campaign
  - Video
  - PSAs
  - Hotel Tent Cards
  - Coloring Books
- Island Pride Campaign
  - Trash Collections
  - Tree Planting
  - Snorkeling

Recreational Overuse & Misuse

- Informational campaign for Tumon Bay (GCMP/GVB)
- Beach Cleaning Permit Conditions (GVB)
- Eco-Permit for Marine Preserves (DAWR)

Figure 29. The Local Action Strategies developed by Guam's Coral Reef Initiative Coordinating Committee include: Land-Based Sources of Pollution, Lack of Public Awareness, Recreational Misuse and Overuse, Fisheries Management. The fifth, Coral Bleaching/Global Warming, is still under development.

and coordination between agencies. Current conservation management activities can be grouped according to the threat that they address (Figure 29).

The LAS process has also served to broaden the network of stakeholder groups working on coral reef issues. Members of the Guam Watershed Planning Committee (WPC), a group of local, federal, and non-governmental agencies involved primarily with watershed restoration, have become involved in the LAS development and members of the GCRICC now participate in the WPC. In addition, the University of Guam Marine Laboratory and Water and Environmental Research Institute, guided by the needs of the local natural resource agencies, have shifted much of their focus toward management-driven research. Recently, another crucial stakeholder group has been engaged. The Guam Visitors Bureau and the tourism industry are now working with the natural resources agencies to market Guam's coral reefs, and in particular the marine preserves, to the 1 million visitors that come to our island yearly. This new awareness of the economic value of our coral reef resources is beginning to create a sense of stewardship in the industry, absent during the economic boom of the 1980s and recession of the 1990s.

Land-Based Sources of Pollution

Guam identified land-based sources of pollution as its number one priority focus area in 2002 and local and federal stakeholders have developed a 3 year local action strategy to address this threat. This is also the most difficult threat to address as it involves a large number of stakeholders. This is complicated by the lack of cooperation from some key government of Guam agencies.

One of the most effective outlets has been the Guam Watershed Planning Committee strengthened by Executive Order 2004-04. This committee is carrying out a comprehensive watershed planning process to address pollution in each individual Guam watershed, through assessing pollution, determining Total Maximum Daily Loads for particular pollutants in the watershed and potential sources, and then initiating projects to control or prevent the pollution. In addition, Guam's Clean Marina Advisory Committee has developed an Action Plan identifying specific projects to manage nonpoint source pollution at Guam's marinas.

This is complemented by recent revisions to the Soil Erosion and Sediment Control Regulations in 2000. These are applied through clearing and grading permits, which are processed through the Department of Public Works and GEPA. These permits provide protection during coral spawning periods by limiting activities during these times. One of the major topics of Guam's upcoming 2005 Land Use Conference will be control of pollution, especially stormwater runoff, through better land use planning. A Manual for Stormwater Management is being produced for Guam in 2004, and recently GCMP funded a workshop, for contractors and builders on the Guam Soil Erosion and Sediment Control Regulations, under GEPA oversight. To address the illegal burning of natural grasslands on mountain slopes carried out by deer hunters, an anti-arson campaign coordinator will be funded in 2005. In the meantime, FSRD, NRCS, and UOG are working to restore badlands using erosion control fabric and nitrogen-fixing plants and trees such as acacia (Figure 30).

Figure 30. Erosion control fabric and nitrogen fixing acacia trees are being used in an attempt to re-vegetate lands damaged by wildfires in southern Guam. Source: Forestry and Soil Resources Division

The Guam EPA has a number of permit processes in effect to limit the impacts of non-point source pollution. Landfills, including construction material hardfills, must receive GEPA permits and be designed to protect all waters from polluting discharges. A new landfill for receiving public solid waste is being planned and its site will be determined in 2004, with its construction following an accelerated schedule determined by a U.S. Court ordered Consent Decree. Baseline monitoring is being done to assess the impacts of leachate polluting the coastal and river waters below Guam's old landfill, which must be closed when the new one is operable. In addition, injection of stormwater runoff through dry wells is regulated by the GEPA Underground Injection Control (UIC) permits, to prevent pollution entering groundwaters and subsequently being discharged to beaches and reefs. The GEPA Water Resources staff also requires golf courses to monitor the quality of their ground water through monitoring wells. GEPA also locally administers the Water Quality Certification (Section 401) and National Pollutant Discharge Elimination System (NPDES) permits for the U.S. EPA. Through its Water Pollution Control Program in coordination with its Environmental Planning and Review Division, GEPA is responsible for certifying all permit applications, recommending the conditions and abatement schedules for each permit, and providing oversight for the implementation and compliance with the conditions. All permittees are routinely monitored by the GEPA staff to verify compliance with applicable permit requirements and compliance schedules. The Guam Waterworks Authority (GWA), with responsibility over public water supply and wastewater systems, is restructuring and improving its facilities and operations in response to U.S. District Court Stipulated Orders. Activities that must be carried out include improving the Northern and Agana Sewage Treatment plants and building new deeper outfalls for both, to meet NPDES requirements.

These improvements to Guam's sewage systems involve major expenses that are far beyond GWA's current budget, costing well over forty million dollars. These costs and similar high unbudgeted costs for public facilities for stormwater management and solid waste pollution control are not only a Guam problem, but are also shared with other U.S. island territories and commonwealths that are members of the U.S. Coral Reef Task Force. At its October 2003 meetings, the Task Force passed a Pacific Islands Water Quality Resolution, directing its attention to seeking a solution to funding the capital improvement needs to provide the infrastructure necessary to manage water pollution to protect islands' coral reefs. Guam's estimate for basic funding for these projects totals close to a hundred million dollars. Pacific Islands members of the Task Force await urgent action on this resolution.

The Guam Seashore Protection Commission (GSPC) has review and approval authority over construction projects proposed within the area from 10 meters inland of the mean high tide mark out to a depth of 60 ft (an area defined in law as the "seashore reserve"). The Application Review Committee, comprised of a large number of Government of Guam agencies, reviews all project applications, identifying potential impacts. Their comments are submitted to a 7- member commission, appointed by the Governor, for consideration of approval or rejection.

Presently, the Guam Seashore Reserve Plan Task Force, comprised of several Government of Guam agencies, is developing the Guam Seashore Reserve Plan to better guide the decisions of the GSPC. The plan will limit development in the areas designated as the Seashore Reserve. Zones are designated that will determine what types of development, if any, are allowed. The zones were determined based on sensitivity of areas adjacent to the shoreline and the effects of development on the coral reefs. While this task is taking longer than desired, the end product should help Guam make good decisions about future development along its coasts.

In addition to local activities, the Department of Defense (DOD) has started restoration activities on DOD base sites, cleaning up scores of old dumps and hazardous or toxic pollutants with impacts on the coastal waters of Guam. Contaminated sites, including ammunition dumps on coral reefs that were formerly used by the military but are not on current DOD property, are being identified through the Department of Defense and State/Territorial Memorandum of Agreement program with GEPA, which is the first step to their cleanup.

Fisheries Management

A three-year local action strategy for coral reef fishery management focusing on increasing the effectiveness of Guam's marine preserves was developed by the Division of Aquatic and Wildlife Resources and reviewed by fishermen, resource managers, and other stakeholders. The strategy addressed three main issues: lack of enforcement and prosecution, lack of public awareness and support, and the need to assess the effectiveness of the preserves in increasing reef fish stocks. Specific management actions proposed to address these issues include the purchase of vehicles, a vessel, and equipment for conservation officers, implementing a reserve officer program to expand enforcement coverage, hiring of a natural resource prosecutor, implementing a multi-media education and outreach campaign, and funding studies that focus on assessing fish biomass increases and spillover effects.

This has been one of the more successful strategies for Guam. A number of the tasks have been accomplished: the conservation officers have purchased new vehicles and equipment to facilitate better enforcement, the GCRICC has continued education efforts at all levels, from elementary to the territorial legislature and administration, monitoring programs are underway in three preserves, and the legislature recently passed Public Law 27-87 which requires a permit for certain non-fishing activities in the preserves. In addition, GCRICC is in the process of hiring a natural resource prosecutor to be based in the Attorney General's Office and DAWR is working on a citation system for marine preserve violators.

Guam has statutory laws (5 GCA, Chapter 63) that regulate the taking of coral and identify penalties for damage inflicted on corals, when an individual is in the act of fishing. Coral can be taken only under a permit issued by the Department of Agriculture. The law has provisions for both personal and commercial take but limits such permits to five days and requires that specific collecting locations be identified. However, no personal or commercial permits have been issued since 1982. UOGML has been issued a collection permit for scientific research. This same title also regulates fishing net mesh sizes used in coastal waters and the use of illegal chemicals and explosives for fishing. In addition, the legislature also delegated the authority and responsibility of management and oversight for all aquatic and wildlife resources to the Department of Agriculture. In 1997, the Department of Agriculture's Division of Aquatic and Wildlife Resources used its regulatory authority to amend and expand the existing fishing regulations. Title 16 includes size and gear restrictions for aquatic fauna. Also contained in these regulations is the creation of the marine preserves. The penalty for violating both statutes and regulations is a petty misdemeanor, with a fine of up to $500. Currently DAWR is in the process of converting the misdemeanor penalties to a magistrate court system that could be used to issue citations instead of requiring a court hearing to collect penalties.

Lack of Public Awareness

In 2003, as part of its Education and Outreach Local Action Strategy, the GCRICC launched a multi-media, coral reef awareness campaign featuring a clownfish character in an educational video for use on incoming flights, movie theater slides, hotel room tent cards, coloring books, advertisements, and streetside banners (Figure 32). A contest seeking a name for the clownfish character was held in conjunction with Earthweek activities from April 17-24, 2004. The contest was open to children island-wide. The Environmental Education Committee selected the top 10 out of over 600 total entries. On April 24, at the Earthweek Island Pride Festival, the public voted for Professor Kika Clearwater as the favorite name.

GCRICC members have also teamed up for the Island Pride Campaign. This program combines educational and environmental activities with fun events to teach children to love the island's resources and instill a sense of stewardship. Events have included the 2004 Earthweek festival, a trash collection and snorkel tour at Tumon Bay Marine Preserve, a trash collection and kid's fishing derby at the War in the Pacific National Park, and a tree-planting at Paseo combined with the Fishermen's Festival at the Guam Fishermen's Cooperative. The events have been a great success attracting families from all over the island. The campaign has also strengthened ties among the GCRICC members and the Guam Visitor's Bureau (GVB), and the private sector which have helped sponsor these events.

Figure 31. Professor Kika Clearwater is Guam's new ambassador for the reefs. She is featured in a multimedia Coral Reef Awareness Campaign that includes billboards, print ads, public service announcements, tourism literature, and an upcoming video to be shown on all flights to Guam. Source: GEPA.

Recreational Misuse and Overuse

The GCRICC decided that Recreational Misuse and Overuse were serious threats to Guam's coral reefs. With jet skis, recreational boaters, scuba divers and snorkelers all using the reef zone, the impacts can multiply. The committee decided that it is important to address these issues before they cause severe damage to the reefs. While this strategy is still being developed through meetings with stakeholders, positive steps have already been taken to limit recreational impacts in the marine preserves. Public Law 27-87 was passed in May 2004, creating a marine preserve eco-permitting system to be administered by

DAWR, which will address non-fishing activities occurring in Guam's marine preserves. Currently DAWR is working with a large group of stakeholders to draft the rules and regulations for this new permitting system.

Other actions have worked to limit the impact of recreational watercraft. The impacts of jet skis have been addressed through the Recreational Water Use Master Plan, which currently limits these watercraft to three locations within reef areas: East Agana Bay, Apra Harbor, and Cocos Lagoon. A study to examine the impacts of these jet skis is scheduled to begin in 2004. In 1999, DAWR installed 35 Shallow Water Mooring Buoys at popular sites on the western side of the island and in Apra Harbor. The goal of these buoys was to avoid anchor damage from recreational boaters and fishermen. Due to storms, theft, and age only 7 of these buoys are still in the water. DAWR did not have the manpower to replace these buoys, so they have teamed up with the Guam Marine Awareness Foundation to replace the missing buoys. DAWR will acquire the buoys and GMAF will use volunteer divers to install them. Current plans are to have 24 SWMs operational by the end of 2004, with additional buoys to follow.

GVB, in association with GCMP, is launching a new campaign to educate tourists about Tumon Bay's unique habitat and diverse assemblage of marine creatures. The project will include three educational kiosks placed in Northern, Central, and Southern Tumon Bay, which will be accompanied by underwater guides. The goal is to reduce the impacts of recreational activities by educating divers about the resources and how they can prevent damage. GVB has also assisted with the incorporation of changes for beach cleaning permits in the tourist areas of Tumon and East Agana Bay. These included: 1) requiring contractors to find ways to shake out as much sand and dead coral as possible from algae and place the sand and dead coral back onto the beach and 2) implementing an adopt-a-beach program, in which hotels would manually rake the algae from the beach in front of their property. Unfortunately, not all changes have currently been implemented. However, GVB is again consulting with DAWR in developing a new Request for Proposals for beach cleaning and maintenance of Tumon and Agana Bays for 2004.

Climate Change and Coral Bleaching

This strategy has had the least development, as it is the most difficult to solve at the local level. Addressing the issue of climate change requires policy at the national and international level. Locally, current management efforts focus on addressing additional anthropogenic stresses on coral reefs such as overfishing and land-based sources of pollution through the development and implementation of 3 year local action strategies. Outreach and education efforts include the development of posters, pamphlets, PSAs, and videos addressing the importance of coral reefs and ways to better protect them. One of the greatest challenges facing resource managers in Guam is the reality that, given current regulatory processes, management decisions cannot happen in as timely a manner as that dictated by a bleaching event.

At the 10th U.S. Coral Reef Task Force Meeting in CNMI and Guam, the steering committee was directed to consider the opportunities to include mass coral bleaching in natural disaster relief efforts. Task Force members endorsed a resolution to address emergency response for environmental impacts of natural disasters. Federal members of the Task Force, as appropriate, were also directed to engage the states, territories and commonwealths of the United States and the Freely Associated States in developing partnership response plans for environmental impacts to coral reef ecosystems from natural disasters, and developing strategies to support implementation of the plans.

While natural disasters can not be managed, responses can be. A Hazard Mitigation Plan is currently being developed for Guam. The intent of the plan is not only to reduce the damages caused by natural disasters to buildings and infrastructure, but also to protect the environment by limiting the effect of flooding to property and subsequent depositing of debris on Guam's coral reefs. Better protection of coral reefs and other natural resources from impacts of Guam's frequent natural disasters is also being sought through development of a Guam Environmental Emergency Response Plan. This plan will provide appropriate steps for government agencies to take after a natural disaster has occurred, for conducting both damage assessments and debris removal efforts.

OVERALL CONCLUSIONS AND RECOMMENDATIONS

The health of Guam's coral reefs vary significantly. Reefs unaffected by sediment and nutrient loading, such as those in the northern part of the island and in between river outflows in the south, have healthy coral communities. Guam's reefs have been spared from large scale bleaching events and coral diseases, prevalent in so many parts of the world. Unfortunately, a number of Guam's reefs are impacted by land-based sources of pollution and heavy fishing pressure. Sedimentation, algal overgrowth due to decreased fish stocks, and low recruitment rates of both corals and fish are important issues that must be addressed.

The GCRICC has made great strides in identifying ways to understand and address these issues, from funding watershed restoration efforts, to innovative education and outreach, expanded monitoring, and increased support of the five marine preserves. Working groups have been created for each of the five local action strategies: land-based sources of pollution, fisheries management, outreach and education, recreational misuse and overuse, and climate change and coral bleaching.

Although Guam has made a great deal of progress in the past two years in terms of coral reef protection, monitoring, and public outreach, many challenges still remain. Wildland arson is still a problem in many watersheds in Southern Guam. Sewage treatment facilities in Toguan, West Agana, and Tanguisson discharge primary treated wastewater into coastal waters of 60 ft. or less. Leaks from aging infrastructure and an increase in impervious surfaces, especially near the coast, have exacerbated the problem of stormwater runoff. In response to the Pacific Water Quality Resolution passed by the U.S. Coral Reef Task Force at their 10th Meeting in CNMI and Guam in October 2003, the GCRICC asked the GEPA to compile a list of priority capital improvement projects that would have direct implications for improved water quality and subsequent coral reef ecosystem health. The estimated cost of the eight projects totals more than $90 million and includes such infrastructure improvements as closing the island's municipal dump and replacing it with a fully functioning landfill, renovating and expanding several sewage treatment plants (including extending their ocean outfalls), and eliminating the discharge of stormwater into Tumon and Agana Bays.

Gaps in Guam's monitoring efforts have been identified and will begin to be addressed in the next few years. However, despite the presence of the University of Guam (in particular the Marine Laboratory and Water and Environmental Research Institute), Guam still suffers from a lack of capacity to fully implement all of these monitoring gaps. The lack of capacity is not entirely due to a lack of available manpower. For example, Guam would benefit greatly from a more streamlined and stable federal grant process for coral reef efforts, in order to secure contractual monitoring assistance (i.e., three year block grants). Local resource agencies would also be better served in their partnerships with such valuable federal programs, such as the NOAA Rapid Ecosystem Assessment research cruises, by a faster turnaround time on data availability and analysis. In addition, although federal sources of funding have been utilized to support enforcement efforts, local support for additional full time conservation officers is still nonexistent. To rectify this, local resource agencies have spent a great deal of time recently to escort local policymakers and members of the private sector on snorkel tours of the marine preserves in order to convince them of the value of our reef resources to the whole island. A new economic valuation study commencing in the fiscal year 2005 will also provide an effective means to garner support for coral reef protection. With successes like the recently launched Island Pride campaign, there is certainly reason to hope for an increased awareness of the value of coral reefs to the people of Guam.

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