The State of Coral Reef Ecosystems of Palau

Sebastian Marino[1], Andrew Bauman[2], Joel Miles[2], Ann Kitalong[3], Asap Bukurou[4], Charlene Mersai[1], Eric Verheij[5], Ilebrang Olkeriil[6], Kliu Basilius[7], Patrick Colin[8], Sharon Patris[8], Steven Victor[1], Wayne Andrew[9], Joel Miles[2] and Yimnang Golbuu[1]

INTRODUCTION AND SETTING

This report is one of several that describe the status of Palau's coral reefs. In 2005, Golbuu et al. provided an overview of Palau's complex marine habitats stretching from Ngaruangel Atoll in the north to Helen Reef Atoll in the south. The overview also identified potential threats to Palau's coral reefs, including the Rock Islands south of the main island of Koror. In 2007, Kayanne et al. (2007) provided an overview of the different habitats in Palau. As in many other locations, Palauans face challenges in their efforts to protect their rich marine resources and continue to seek solutions that will mitigate threats from different sources.

Palau has an abundance of coral reef habitat types, as well as complex marine habitats associated with coral reefs including mangroves, seagrass beds, deep algal beds, mud basins, current swept lagoon bottoms and rich tidal channels. No description of Palau would be complete without mention of Palau's 70 famous marine lakes in the Rock Islands. According to Yukihira et al. (2007), the total area of coral reefs in Palau is approximately 525 km², which includes barrier reefs (264.7 km²), fringing reefs (194.8 km²) and atoll habitats (65.0 km²) with 1,457 patch reefs scattered throughout the lagoons. Figure 16.1 is a locator map with locations and reefs mentioned in this chapter. An effort to map Palau's benthic habitats using high resolution satellite imagery was completed by NOAA's Center for Coastal Monitoring and Assessment's Biogeography Branch (CCMA-BB) in 2007; the project classified marine habitats for 1,477.54 km^2 and estimated that coral reef and hardbottom areas cover 892 km^2.

Palau's rich marine environment plays an important role in generating income for Palau. Eco-tourism is perhaps the most economically important of these activities since over 80% of Palau's visitors come to dive among the coral reefs (Palau Visitors Authority, 2001).

1. Palau International Coral Reef Center
2. Office of Environmental Response and Coordination
3. The Environmental Inc
4. Palau Conservation Society
5 The Nature Conservancy
6. Koror State Government
7. Environmental Quality Protection Board
8. Coral Reef Research Foundation
9. Helen Reef Project

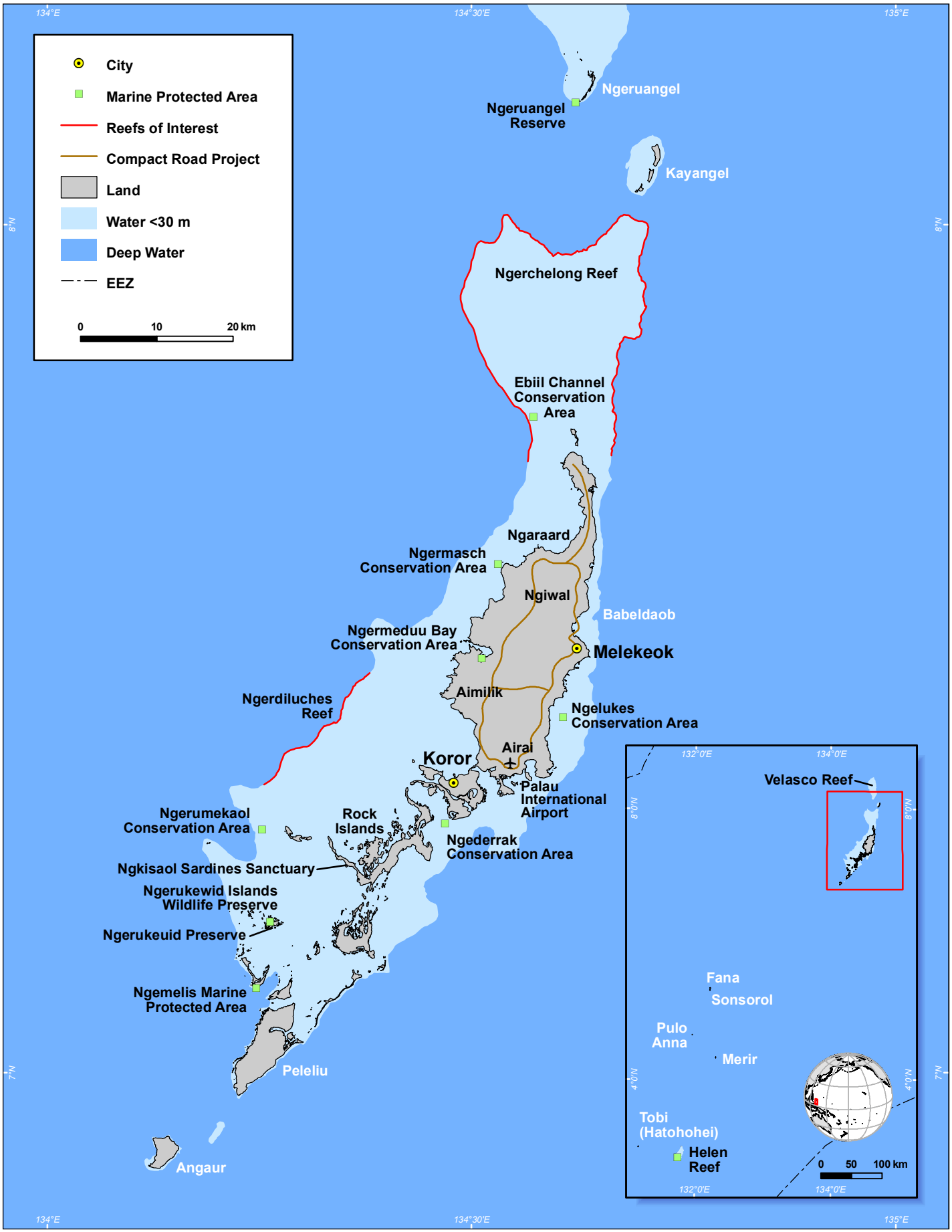

Figure 16.1. Map showing the locations of places mentioned in this chapter. Map: K. Buja.

ENVIRONMENTAL AND ANTHROPOGENIC STRESSORS

Climate Change and Coral Bleaching

Since the 1997-1998 El Niño event, which was described by Golbuu et al. (2005), Palau has not experienced any major bleaching events. However, there have been reports of localized bleaching in different parts of Palau that are believed to be related to human impacts.

Diseases

In the past several decades, the increasing prevalence of coral diseases worldwide has become one of the major threats challenging the resilience of coral reef communities (Harvell et al., 1999; Willis et al., 2004). In the Indo-Pacific, very little is known about the ecology and pathology of coral disease despite the fact that the region encompasses more than 80% of the earth's coral reefs (Bryant et al., 1998).

The first ecological surveys of coral disease prevalence on Palau reefs were carried out in January 2004 as part of the World Bank Global Environment Facility's Targeted Coral Reef Research Project. The purpose of the surveys was to identify and establish baseline information for coral disease at sites representative of the major habitat and community types in Palau. Results from these initial surveys indicate that the mean prevalence of coral disease was relatively low, affecting between 1 and 5.28% of colonies at six sites representative of protected, moderately exposed and exposed communities. A total of twelve diseases and syndromes were recorded from across thirteen reefs surveyed during preliminary site selection visits or disease prevalence surveys (Tables 16.1 and 16.2). Eight of these syndromes have been previously observed on Indo-Pacific reefs, in particular on the Great Barrier Reef (Willis et al., 2004). However, bleached patches, bleached spots, bleached stripe and yellow spot have not yet been recorded. At each of the six survey sites, approximately five to nine diseases or syndromes were observed. The greatest number of diseases or syndromes, nine, were recorded at the Malakal Harbor spawning site (Willis pers., comm.).

Table 16.1. Description of disease states and syndromes recorded on Palau reefs in January 2004. Source: Willis, pers. comm.

DISEASE STATE/SYNDROME	DESCRIPTION
Black Band Disease (BBD)	Cyanobacterial mat forming a band that is characteristically black in color.
Other Cyanobacteria (O. Cyano)	Cyanobacterial mat forming a band that may be red, rust, brown, dark green etc. in color.
Brown Band (BrB)	Band of ciliates on recently exposed skeleton immediately behind healthy tissue front that is brown when ciliate densities are high or tan or white when densities are low.
Skeletal Eroding Band (SEB)	Black band of ciliates (*Halofolliculina corallasia*) that may appear speckled at edge of band distal to live tissue front because of the ciliates' abandoned black loricae. Skeleton is commonly eroded.
White Syndrome (WS)	White band of recently exposed skeleton, narrower than a crown-of-thorns feeding scar and more regular than a *Drupella* feeding scar.
Bleached	Distinct paling of tissue in part or all of a coral colony, which in extreme cases appears white. Partial bleaching may involve irregular sections of colonies where paler tissues grade into normal colored tissues.
Bleached Patches	Moderate-sized areas of white tissue sharply demarcated from normal colored tissues. Areas often rectangular.
Bleached Spots	Small areas of white tissue sharply demarcated from normal colored tissues. Areas often circular.
Bleached stripe	Area of white tissue, sharply demarcated from normal colored tissue in a strikingly straight line. Only recorded on *Pachyseris speciosa*.
Patchy Necrosis	Areas where tissue is necrosing and lifting off skeleton. Necrotic areas generally surrounded by healthy tissue in locations distant from potentially competing organisms.
Yellow Spot	Areas of generally necrotic tissue surrounded by intact tissue that has a yellow tinge. Only seen on massive *Porites sp*.
Tumor	Raised, often spherical masses projecting above the surface of the colony. Only recorded on *Acropora* species, where they manifested as bleached neoplasms, which have few discernible polyp or corallite features.

Table 16.2. Diseases/syndromes recorded on and off of six transects in Palau in January 2004. Source: Willis pers. comm.

	NIKKO BAY SPAWNING	NIKKO BAY	MALAKAL HARBOUR SPAWNING	KELTARIR	WESTERN BARRIER NGATBANG	WESTERN BARRIER NGEREMLENGUI
Disease States Recorded on Transects						
Black Band Disease						
Brown Band Disease			x	x		
Skeletal Eroding Band	x	x	x	x	x	x
Other Cyanobacterial Infections	x	x	x	x	x	x
Bleached Spots	x	x	x	x	x	x
Bleached Patches	x	x	x	x	x	x
Bleached Stripe	x					
White Syndrome	x	x	x	x		
Patchy Necrosis	x	x				x
Yellow spot					x	
Tumours			x	x	x	
Disease States Recorded off Transects						
Black Band Disease			x			
Other Cyanobacterial infections	x (red)					
Yellow spot			x	x		

Tropical Storms

Tropical storms are common in Palau. The outer reef slope is much more susceptible to physical damage to corals from from tropical storm surge and large waves. Consequently, many of Palau's fore reefs are dominated by encrusting and massive forms of coral species (Golbuu et al., 2005). No directed studies have been conducted to quantify the effects of tropical storms on the coral habitats of Palau.

Since the last report, no major storms or typhoons have passed through Palau (Figure 16.2).

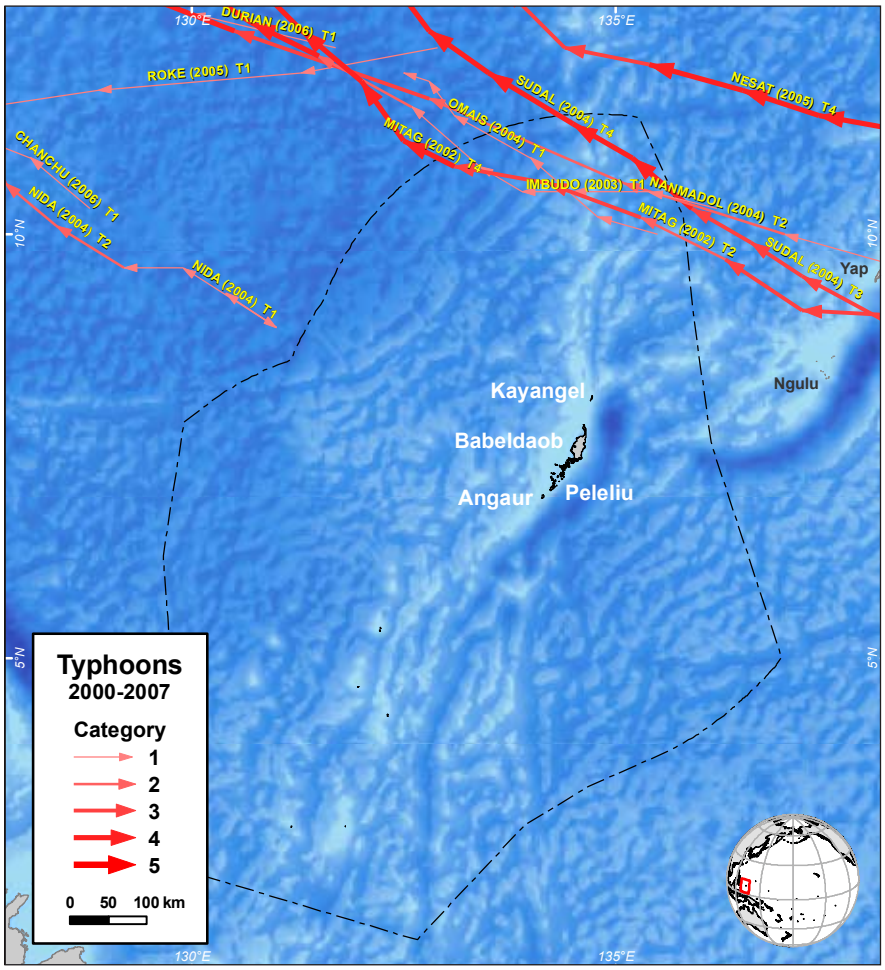

Figure 16.2. The paths, name, year and intensities of typhoons passing near Palau from 2000 to 2007. Map: K. Buja. Source: http://weather.unisys.com/hurricane/.

Coastal Development and Runoff

During the three-year period covered by this report, coastal development and runoff have increasingly become areas of concern. This reporting period has seen many changes regarding demographic shifts, permitting and construction, road building, sedimentation, land use and land use changes. Most of these changes are a result of the construction and completion of the compact road encircling Babeldaob Island, as well as the resulting move of the central government from Koror State to Melekeok State on Babeldaob.

Demographically speaking, Palau has seen a shift in population as people who once resided in Koror have increasingly moved back to their home villages and states in

Babeldaob. Since the central government officially opened for operations in October 2006, no census data has been collected to quantify this shift. Other concerns related to the return of numerous Palauans to Babeldaob include changes in land use, and to a lesser degree, construction and permitting. In addition to road building and resulting sedimentation, a large number of new residences have been constructed. Often this has required the construction of secondary roads for access.

The Environmental Quality Protection Board (EQPB) permitting process covers public and private projects such as housing projects, road constructions, hotels, docks, dredging and other large government infrastructure projects. Large commercial projects with significant environmental impacts are required to prepare to environmental impact assessments/ environmental impact statements in accordance with Palau's Environmental Quality Protection Act.

The EQPB reviewed and approved the Environmental Protection Plan (EPP) prepared and submitted by Daewoo prior to construction of the compact road. The EPP outlines the impacts and mitigation measures that the contractor needs to implement prior to and during construction of the road. In addition, EQPB's compact road inspector conducted regular monitoring of the contractor's work areas and facilities to ensure that the mitigation measures were properly implemented and in compliance with the EPP and EQPB permit and regulations.

Both the state governments and private contractors involved in secondary road construction are required to properly implement Erosion and Sedimentation Control Plans. These erosion controls, both temporary and permanent (such as silt tank, earth/rock berm, slope protection, hydroseeding) are measures necessary to prevent or minimize erosion problems in the area. Basic installation and maintenance procedures for erosion control structures are already in place at EQPB.

Measures are being undertaken to have all state access roads paved in the long term. Presently, with the exception of the compact road, all access roads in Babeldaob are unpaved and sediments are continually washed into streams and marine waters.

Coastal Pollution

There are quite a few point source pollution sources in Palau. Major industries in coastal areas that contribute marine pollution and coastal area degradation include fishing companies and hotels. Fishing companies discharge brine, oil and trash such as fishing lines, trash and sewage from ships moored at their docks.

There are roughly ten fueling stations that are near, if not adjacent to, the water. No reports of adverse problems have been reported due to major spills of oil or other pollutants from these stations. Still, the cumulative effects of small spills may damage nearby coral reefs and marine life.

There are also challenges related to the Koror State landfill and pollution of nearby waters from contaminated leachate. Work is ongoing to rehabilitate the M-Dock Landfill through construction of a new anaerobic sanitary landfill.

The public sewer system that exists in Palau is over 25 years old and has deteriorated due to a lack of maintenance. Sewage overflows are reported by the public at least twice per week. This affects water quality in the immediate vicinity of the overflow by contaminating the area with bacteria, which adversely affects the water quality and increases the concentrations of nitrates and phosphates. Plans are underway by the Ministry of Resources and Development to upgrade the whole system by improving the major pump stations at the Capital Improvement Project (CIP) and Malakal.

Improper farming methods and unplanned road construction are some of the common sources of coastal pollution (Victor et al., 2004). One of the challenges that the EQPB faces is regulating earthmoving activities that have not been permitted. When these activities take place without control measures in place, implementation of corrective measures are often lengthy and costly.

Tourism and Recreation

Tourism remains the primary source of revenue for Palau and the government is pursuing an approach to attract higher-income tourists to Palau. Local governments and communities see the potential of tourism as a continued source of income generation. In 2005, 80,578 tourists visited Palau, while 82,397 visited in 2006 (Tables 16.3 and 16.4). This steady increase of visitors to Palau could represent a serious threat to the marine environment and coral reef areas, but Palauans are taking action to prevent some damage. In 2006, Peleliu State placed more mooring buoys around the island at known dive sites to minimize damage to the coral reefs. In addition, the introduction of a sea anemone (*Aiptasis* sp.*)* into Jellyfish Lake in 2003 prompted Koror State to take precautionary measures and amend the Rock Island Use Act of 1997. The amendment established zoning for the Rock Islands and created a new fee schedule to help mitigate impact at sensitive tourist sites.

Many communities on the big island of Babeldaob are taking advantage of the increase in tourism and the opening of the new road to develop land-based activities for visitors. In 2007,a river boat tour business began operations in Ngchesar State on the big island of Babeldaob. There has also been an increase in the number of tourists visiting waterfalls and other historical sites on Babeldaob Island. Still, the vast majority of visitors to Palau come to dive, snorkel and visit the famous Rock Islands.

Table 16.3. 2005 visitor breakdown by country of origin. Source: PVA.

	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
AUS / NZ	72	46	42	95	65	80	94	61	83	87	44	49	818
GERMANY	80	104	110	55	46	22	26	17	16	47	51	32	606
GUAM	228	231	344	200	289	288	477	200	170	177	237	171	3,012
HONG KONG	16	108	58	47	71	24	132	455	82	278	39	77	1,387
ITALY	26	22	40	23	22	3	8	68	4	2	19	47	284
JAPAN	3,003	2,829	2,605	1,673	1,621	834	2,233	2,841	2,630	1,447	1,570	2,995	26,281
KOREA	1,292	471	18	25	19	31	27	33	6	29	22	196	2,169
MICRONESIA	209	128	140	104	160	223	716	128	95	104	201	84	2,292
PHILIPPINES	76	38	79	66	68	58	68	66	43	70	82	62	776
PRC CHINA	49	44	16	20	24	22	38	39	8	38	16	22	336
ROC TAIWAN	2,755	2,999	2,469	3,134	2,846	3,116	3,871	3,667	2,752	2,388	2,121	1,983	34,101
RUSSIA	37	42	23	17	15	1	-	-	-	80	43	10	268
SWITZERLAND	27	11	40	25	18	7	2	6	5	19	15	13	188
UNITED KINGDOM	21	16	42	7	27	27	14	19	14	42	23	40	292
US MAINLAND	564	610	518	494	375	453	463	292	306	424	538	495	5,532
OTHER EUROPE	72	82	70	82	3	41	55	47	23	56	71	49	651
OTHERS	54	97	85	90	134	77	737	48	23	80	114	46	1,585
TOTAL	**8,581**	**7,878**	**6,699**	**6,157**	**5,803**	**5,307**	**8,961**	**7,987**	**6,260**	**5,368**	**5,206**	**6,371**	**80,578**

Table 16.4. 2006 visitor breakdown by country of origin. Source: PVA.

														FY'06 YTD**
	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL	vs. FY'05 YTD**
AUS / NZ	52	28	46	75	92	34	82	23	50	50	36	28	596	-27.14%
GERMANY	43	89	112	66	28	10	7	24	20	21	47	47	514	-15.18%
GUAM	170	176	158	218	107	197	239	185	195	86	134	174	2,039	-32.30%
HONG KONG	62	11	20	69	22	18	22	23	34	40	11	60	392	-71.74%
ITALY	29	72	43	34	4	2	11	55	3	28	21	42	344	21.13%
JAPAN	2,898	2,876	3,070	1,684	1,423	772	2,318	2,905	2,793	1,530	1,441	3,182	26,892	2.32%
KOREA	920	1,207	240	729	1,173	1,334	1,336	1,069	181	1,145	1,064	1,358	11,756	442.00%
MICRONESIA	52	85	96	106	128	93	393	82	91	81	92	138	1,437	-37.30%
PHILIPPINES	50	53	65	233	173	147	94	137	120	135	77	146	1,430	84.28%
PRC CHINA	43	16	18	50	54	8	20	30	30	42	18	57	386	14.88%
ROC TAIWAN	2,084	2,877	2,641	2,393	2,293	2,354	2,821	2,652	2,152	2,317	1,781	2,084	28,449	-16.57%
RUSSIA	40	9	21	63	31	2	4	-	4	52	81	9	316	17.91%
SWITZERLAND	18	13	27	20	9	3	6	4	13	19	31	22	185	-1.60%
UNITED KINGDOM	19	25	36	40	12	20	13	11	20	9	14	20	239	-18.15%
US MAINLAND	464	596	640	721	498	462	566	331	274	381	597	392	5,922	7.05%
OTHER EUROPE	54	86	86	92	21	8	38	42	30	81	71	56	665	2.15%
OTHERS	52	34	55	94	93	43	141	53	78	51	74	67	835	-47.32%
TOTAL	7,050	8,253	7,374	6,687	6,161	5,507	8,111	7,626	6,088	6,068	5,590	7,882	82,397	2.26%

**FY06/MO versus FY05/MO=FISCAL 2006 MONTHLY versus FISCAL 2005 MONTHLY.*
***YTD stands for year to date*

Fishing

Inshore Fisheries Production

The fishery industry in Palau is a dynamic, multi-species industry involving individual fishers feeding their families, providing food for traditional customs and selling to commercial markets, restaurants and selective buyers for export. Between 1989 and 1998, Palau's total inshore fisheries production was estimated at 2,155 metric tons (mt) from 1,000 fishers with 800 boats (TEI, 1999). An estimated 400 mt (19%) was exported either directly by the fishers, residents or through retailers and wholesalers. An estimated 1,715 mt (81%) was consumed locally (TEI, 1999; PCS, 2000). Palau's reef yield was estimated at one million metric tons of fish and invertebrates over the span of 100 years (TEI, 1999). This value is based upon an average total production of 1,800 mt/km^2 for a total reef and lagoon area of 1,706 km^2. The total maximum yield from the reefs between the periods of 1992 to 1997 and 1998 to 2001 showed a decline in yield for nine states: Aimeliik,

Airai, Angaur, Ngaraard, Ngarchelong, Ngardmau, Ngatpang, Ngchesar and Ngiwal. This decline may be attributed to several factors including the presence of large-scale pulse fishing operations, coral bleaching, loss of habitat and sedimentation from land based activities. New management regulations through the 1994 Marine Protection Act may also explain the decline in specific fisheries (TEI, 2003).

The 1994 Marine Protection Act
The 1994 Marine Protection Act was established to better manage the local fisheries. Specific management tools described in this Act include: bans on export of certain species (e.g., mangrove crab, specific species of sea cucumber); closed harvest seasons (the rabbitfish, *S. fuscescens* and groupers, *Epinephelus* and *Plectropomus* spp.); size limits (*Cheilinus*, *Bolbometopon*, crabs, lobsters); and mesh size limits for nets and permit requirements for aquaculture and aquarium trade ventures. Legislative attempts to implement complete bans on certain species and extend moratoriums of endangered species have been met with limited success.

Annual Variation in Production
Annual variation in landing for any given fishery is complex in nature. Cyclic patterns based upon climate conditions and good recruitment years may occur. Seasonal closures during peak spawning may also be peak fishing periods and thus reduce landings (such as the 1994 Marine Act). Overfishing and pollution may alter important marine habitats and reduce catch rates. Lack or loss of data from a major fish market may be a factor causing variability as well. All these factors may in part explain annual variations in landings for a specific fishery such as the mottled spinefoot (*Siganus fuscescens)*.

Mangrove Crab
Mangrove crab (*Scylla serrata*) is the top crustacean sold commercially. From 1989 to 1998, the mean annual production averaged at 24 mt with yields of 0.5 mt/km². (TEI, 2003) The mangrove crab fishery peaked in the early 1990s when a commercial venture in Ngatpang State was in full production. In 1994, the Marine Protection Act 27 Palau National Code Annotated 1204 was enacted and imposed a minimum size limit of six inches across the carapace and a ban on their export. The following few years showed a decline in sales that may reflect a decrease in export sales. In 1998, domestic market sales increased but there was a trend of steady decrease over the next seven years (BMR, 2005). Ecological, economical and social studies are needed to understand the dynamics of a given fishery.

Trochus
For the past 100 years, *Trochus niloticus* has been the top mollusk collected in Palau. However, over the past decade, the average annual landing of *Trochus* is at 200 mt. Management has consisted of size limits, sanctuaries, three-year moratoriums, a short (one-month) harvest season and a very specific export market. Such protective multi-pronged management approaches should be implemented for other marine resources.

Market Survey Data
In the 1970s, the Palau Federation of Fishing Association (PFFA) was the main distributor of fish both locally and internationally. PFFA was government-operated, which helped make data collection more efficient and complete. Over the years, fish distribution has become less centralized and smaller markets experience shifts in sales based upon the fisher's preference and the buyer's incentives. These markets are not required by law to provide information to Palau's Bureau of Marine Resources (BMR). Consequently, sales are reported based upon price categories and not individual species of fish. Over the last three decades, the quality of data has varied and the percentage of market information captured has varied from 30 to 85%. Often data is outdated or non-existent for many species. More studies are needed to implement appropriate management strategies for specific species.

Data Collection
In the past decade, the BMR has set up a data collection program to track fish exports at the species level; this program provides the most reliable source of information for exported fish. The purposes of collecting data is to determine relative abundance of a resource, develop effective management tools for both the informal and commercial fishery and draft legislation to guide the implementation of effective management practices. The BMR requires that all exporters submit a report with detailed information on the name, number and weight of all fish and invertebrate species and other organisms being exported by air. In addition the BMR collects data from local fisheries markets. Unfortunately, nearly 33% of species are lumped into the "assorted fish" category that is based on price. Market data is also being collected to track sales to hotels, restaurants and individuals in the communities. Maintaining a database and archiving data is critical to look at a long-term trends in a given fishery. Example results from these efforts are provided in Tables 16.5 and 16.6.

Fisheries Management
The goal of any fisheries management strategy is to sustain a resource over time. Resource studies are needed in order to assess the efficacy of management actions and determine what management approaches are most effective. Banning exports, setting size limits and implementing closed seasons in an effort to manage specific resources requires studies before, during and after a restriction to establish baseline data. From there, the consequences activities have on the resource can be studied. Setting restrictions on one resource can also shift fishing pressure to another species that must also be monitored. Parrotfish, (*Bolbometopon muricatum*, kemedukl), groupers (*Epinephelus* spp.) and rabbitfish (*Siganus fuscescens*) were top commercial species between 1992 and 2005 (BMR, unpub. data). However, a ban on commercial sale of parrotfish and closures during the spawning seasons for groupers and rabbitfish *have* shifted fishing effort toward fish for which there are no restrictions, such as bluespine unicornfish (*Naso unicornis)*. Bluespine unicornfish

Table 16.5. 2000-2004 fisheries landing data by state. Source: Palau Department of Planning and Statistics.

State	Year	Reef fish (lbs)	Reef Fish Value	Tuna and Mackerel (lbs)	Tuna and Mackerel Value	Crabs (lbs)	Crabs Value	Lobster (lbs)	Lobster Value	Trochus (lbs)	Trochus Value
Aimeliik	2000	2636	$3,401.00			137	$481.00			509	$509.00
	2001	2856	$3,650.00			197	$763.00				
	2002	9301	$12,245.00	97	$49.00	47	$186.00	77	$296.00		
	2003	4070	$5,170.00	156	$203.00	164	$956.00				
	2004	111180	$14,805.00	19	$21.00	216	$1,213.00				
Airai	2000	730	$949.00	171	$167.00	3031	$12,003.00			740	$740.00
	2001	2431	$3,010.00	224	$246.00	3221	$12,946.00	2	$8.00		
	2002	9797	$12,594.00	425	$375.00	2390	$14,365.00	35	$124.00		
	2003	43416	$58,768.00	747	$971.00	1596	$7,928.00	436	$1,679.00		
	2004	46993	$67,667.00	294	$354.00	1607	$9,423.00				
Angaur	2000	235	$235.00			18	$61.00			1549	$1,549.00
	2001	1275	$1,477.00			77	$308.00	27	$100.00		
	2002	4449	$5,657.00	133	$133.00			14	$45.00		
	2003	43416	$58,768.00	747	$971.00	1596	$7,928.00	436	$1,679.00		
	2004										
Kayangel	2000	2187	$2,368.00							41761	$41,761.00
	2001	1162	$1,335.00	498	$548.00			37	$134.00		
	2002	2876	$3,467.00	1015	$1,063.00						
	2003	261	$287.00	99	$109.00						
	2004	22487	$26,670.00	214	$246.00			3	$15.00		
Koror	2000	200209	$263,851.00	2302	$2,380.00	3455	$12,411.00	491	$1,882.00	229351	$231,210.00
	2001	179250	$221,453.00	6876	$6,972.00	4036	$15,480.00	853	$3,052.00		
	2002	259374	$346,813.00	7347	$5,682.00	2221	$8,892.00	1844	$6,609.00		
	2003	275477	$375,047.00	18671	$20,791.00	2129	$10,594.00	1185	$4,208.00		
	2004	228300	$310,053.00	12540	$14,495.00	2964	$17,831.00	29	$109.00		
Melekeok	2000	57	$74.00							10782	$10,782.00
	2001	5430	$6,302.00	54	$59.00			32	$120.00		
	2002	11594	$12,693.00			22	$88.00				
	2003	16151	$20,013.00	2060	$2,415.00			41	$156.00		
	2004	10566	$13,105.00	717	$932.00						
Ngatpang	2000	16931	$16,605.00			1005	$3,948.00	30	$94.00	3489	$3,489.00
	2001	12206	$13,046.00	190	$162.00	255	$982.00	26	$81.00		
	2002	22139	$27,004.00	483	$531.00	788	$3,161.00				
	2003	10403	$13,423.00	5	$72.00	401	$1,817.00				
	2004	13324	$16,232.00	159	$207.00	168	$979.00				
Ngiwal	2000	819	$1,081.00							3591	$3,591.00
	2001	3974	$5,192.00			378	$1,432.00	48	$168.00		
	2002	2427	$3,068.00	142	$107.00	1010	$4,302.00	23	$90.00		
	2003	1331	$1,731.00			456	$2,379.00	2	$8.00		
	2004	272	$366.00	329	$428.00	459	$2,600.00				
Ngerchelong	2000	6941	$7,604.00			248	$990.00	4	$16.00	36269	$36,269.00
	2001	16479	$18,105.00	502	$542.00	1091	$4,349.00	13	$50.00		
	2002	37013	$49,517.00	615	$557.00	850	$3,390.00	25	$98.00		
	2003	6227	$7,889.00	25	$33.00	26	$132.00				
	2004	6991	$87,723.00			26	$155.00				

Table 16.6. 2000-2004 fish survey (continued). Source: Palau Department of Planning and Statistics.

State	Year	Reef fish (lbs)	Reef Fish Value	Tuna and Mackerel (lbs)	Tuna and Mackerel Value	Crabs (lbs)	Crabs Value	Lobster (lbs)	Lobster Value	Trochus (lbs)	Trochus Value
Ngaraard	2000	92309	$92,331.00	6556	$5,308.00	6406	$23,621.00	888	$3,207.00	72344	$728,119.00
	2001	3637	$4,472.00			90	$358.00	121	$449.00		
	2002	6881	$9,277.00			391	$1,574.00	19	$74.00		
	2003	2993	$4,169.00			726	$3,597.00	20	$80.00		
	2004	8630	$11,758.00			379	$2,011.00				
Ngarmlengui	2000	92309	$92,331.00	6556	$5,308.00	6406	$23,921.00	888	$3,207.00	72344	$72,819.00
	2001	32374	$33,983.00	2849	$2,957.00	7195	$26,833.00	613	$1,868.00		
	2002	25129	$32,103.00	948	$709.00	2703	$11,434.00	145	$573.00		
	2003	22329	$244,011.00	3237	$3,896.00	1362	$5,663.00	105	$324.00		
	2004	25321	$29,545.00	3965	$4,801.00	1510	$7,312.00	80	$309.00		
Ngchesar	2000	2254	$2,876.00	226	$233.00	24	$96.00			943	$943.00
	2001	9271	$11,731.00	1139	$1,215.00	369	$1,434.00				
	2002	4360	$5,514.00	161	$139.00	340	$1,358.00	52	$208.00		
	2003	922	$1,228.00	126	$102.00	371	$1,926.00				
	2004	545	$629.00			141	$817.00				
Ngardmau	2000	12858	$16,772.00			215	$850.00	18	$85.00	4341	$4,402.00
	2001	8646	$11,207.00			128	$504.00	56	$233.00		
	2002	14581	$20,479.00			297	$1,195.00	92	$346.00		
	2003	13427	$18,253.00			724	$3,514.00	96	$369.00		
	2004	19006	$25,739.00			946	$5,592.00				
Peleliu	2000	26443	$27,543.00	1471	$1,388.00	23	$92.00			46299	$46,360.00
	2001	37247	$48,043.00	1242	$1,024.00	283	$1,130.00	98	$386.00		
	2002	22784	$24,753.00	1604	$1,440.00	114	$456.00				
	2003	18231	$19,471.00	4070	$3,510.00	21	$84.00	20	$76.00		
	2004	16332	$17,295.00	1029	$875.00	25	$149.00				
Unkown	2000	1585	$2,126.00			41	$205.00				
	2001	949	$967.00			31	$124.00				
	2002	1418	$1,999.00	102	$58.00	93	$371.00	9	$36.00		
	2003	92	$92.00								
	2004	219	$241.00								

has been the top commercial species for the past decade, and visual inspections of commercial landings of Bluespine unicornfish included many undersized fish (TEI, 1999). During a survey of subsistence activities in the Rock Islands, many respondents (49%) felt that current restrictions were ineffective due to poor enforcement or monitoring of catches to control the size of fish taken. Most (68%) felt that there are species that are threatened and not currently protected including the *N. unicornis* and *B. muricatum* (Matthews, 2004). It is recommended that further studies be conducted to determine the status and distribution of Palau's population of *N. unicornis*.

Seasonal closures may also concentrate fishing activity. Export data shows an increased level of fishing during pre and post closure periods that may be causing a greater impact than the closure itself (BMR database). Managers recommend extending closures if a resource continues to decline. Another management tool is to implement protected areas, but more data is needed in Palau to determine if protected areas are effective and how to regulate uses within protected area boundaries. In a multi-species fishery, it is difficult to integrate species' life histories with size limits, seasonal closures and protect habitats, which underscores the need for consultation with key stakeholders. In Palau, stakeholders are easily identified through the BMR database, which lists the fishers that sell or export fisheries resources. These individuals are potential collaborators in research to better understand life histories, behavior and habitats of a given resource.

Adaptive Management

Fisheries management needs to be adaptive to changes in the natural and social environment for each resource in question. Active participation with the people most dependent upon that resource is critical. Traditional ecological knowledge in combination with sound scientific methodologies may help sustain small scale fisheries within each state. Education and awareness within communities about their resources and how to best manage and sustain them is ongoing in Palau. Decision makers need information from ongoing studies that evaluate the status of key commercial species. Monitoring programs need to include periodic habitat and market surveys to determine relative population densities and collect length

and weight data to assess changes in the population structure and determine if populations are sustainable. Surveys need to be adapted to the life histories of the resource in question. One time surveys during the day provide information but we must be cautious how this information is interpreted and extrapolated. The outcome may result in a modification of management that in fact was neither necessary nor appropriate. Ongoing educational programs are needed to disseminate new information and promote a healthy exchange of information and mutual trust between the managers and the stakeholders. Stakeholders need to know why resource limitations are being implemented and if the management approach is working before they will support and assist in programs for a resource they depend on for a living. Feedback is crucial once a management strategy is implemented to determine gaps or unanticipated impacts as a result of that strategy.

Aquaculture

Aquaculture has been promoted for decades, yet a cost-benefit analysis of this activity has shown that it is unsustainable in Palau and would require large financial subsidies, in the form of equipment, trained personnel, marketing and supplies, for long-term maintenance. If it is national policy to support and promote aquaculture, an effective mechanism to implement and sustain aquaculture is needed. This mechanism needs to include a phasing out of subsidies and a long-term commitment to the aquaculture community to maintain and train local farmers. Stakeholders need to work with the BRM to provide data and monitoring. A commercial venture needs to devote a percentage of the profits towards the cost of restocking juvenile clams and fish species. States that are currently receiving national funds for aquaculture need to have Palauans working on site. It is important that skills are transferred and states commit funds and human resources to programs. Another issue is the loss of habitat for aquaculture. The reefs and mangroves provide natural services. Loss of mangroves and reefs make coastal communities more vulnerable to storms and wind. Site selection and cost-benefit are critical factors as well as long-term commitment.

Vulnerable Marine Species Conservation Program

The BMR has established the Vulnerable Marine Species Conservation Program for the endangered crocodile, turtles and dugong. The Endangered Species Act (Title 24 Palau National Code, Chapter 10) and Protected Sea Life Act (Title 24 Palau National Code Chapter 12) prohibit the harvest of dugong and crocodile and restrict turtle harvest to certain months of the year. Dugongs (*Dugong dugon*) and its habitat are protected by law. Joshua Eberdong, the Vulnerable Marine Species conservation program Coordinator at BMR, directed the flight paths for dugong surveys based on surveys conducted by The Nature Conservancy (TNC) and other scientists in 1977/1978, 1983, 1991, 1998 and 2003. In September 2007, a total of 27 dugongs (18 adults and nine calves) were spotted around Malakal Harbor and the Rock Islands. Two days later, two adult dugongs and one calf were seen on the west coast of Babeldaob (J. Eberdong and S. Klain pers. comm.; A. Kitalong pers. obs. 2007). The aerial coverage of the 2007 surveys was less than the 2003 aerial survey in which 27 individuals, 20 adults and seven calves were observed. Palau's salt water crocodile (*Crocodylus porosus*) is the only population that occurs within Micronesia. The last official survey was in 2003 and the population was estimated to be 500 to 750 non-hatchling individuals (Brazaitis et al., 2003). Crocodile monitoring and tagging is ongoing. Nuisance crocodiles are trapped and relocated to other locations within a state.

Hawksbill (*Eretmochelys imbricata*) and green turtles (*Chelonia mydas*) maintain resident and nesting populations in Palau. During 2004 and 2005, nesting green turtles were tagged at Hatohobei at Helen Reef Islet (40) and Sonsorol at Merir Islands (36). A total of 581 green turtle nests were recorded in Sonsorol (331), Hatohobei (232), Kayangel (7) and Ngarchelong (11). During 2004 and 2005, 66 hawksbill nests were found in Angaur, Peleiu, Koror, Ngaraard, Ngarchelong and Kayangel. Evidence of poaching was present for 36% of the nests (Kitalong and Eberdong, 2006). Management of turtles included size limits, closed seasons, head starting, tagging and monitoring of beaches. Head starting was discontinued because it was considered unsustainable. Conservation and monitoring are currently underway. A similar concern of increased hunting pre and post closure may have a negative impact that outweighs the closure. Enforcement and increased fines has been recommended in two national workshops. Traditionally, large species were caught in small numbers for very important customs. The Helen Reef community decided to close its turtle fishery for several years. However, this ban put increased harvesting pressure on the Sonsorol turtles. A collaborative approach with communities sharing a similar resource is recommended. Currently the capture of turtles has been excessive for both traditional and non-traditional celebrations. The women in Palau want a long-term ban on the harvest of turtle, especially hawksbill. The traditional money is made from the hawksbill shell and its value is based on size and quality of shell. The women have seen a decline in size over time. Regional collaboration is required as two green turtles with tracking devices are currently foraging in Indonesia.

Trade in Coral and Live Reef Species

Marine ornamental trade continues to be a growing business around the world. The popularity of home aquaria that mimic coral reef ecosystems has made the live fish and marine invertebrate trade an attractive business venture (Golbuu et al., 2005). However, since the 2005 edition of this report, there has been a significant reduction in the volume of live fish, coral and other organisms exported for the aquarium trade from Palau. The only live fish and marine invertebrate trade business in Palau, Belau Aquaculture, was closed down in 2006. During this same year, a private business dealing in live fish food trade was launched. This business targeted live groupers and napoleon wrasses. The employees either fished or bought live fish from local fishermen. It was not long before the business ran into some legal problems, which lead to its closure. Although the company operated for just over six months, there was no data available on their exports.

Ships, Boats and Groundings

Four major ship groundings have occurred in Palau since the last status report. In late October 2005, the USNS *Niagara Falls*, a 176 m long "Combat Stores Ship" with a draft of 8 m and operated by the Military Sea Lift Command, grounded on a reef 1.5-2 m deep bordering the main shipping channel while departing Palau (Figure 16.3). The vessel remained aground for two days; its forward portion resting on the reef while its stern was in deeper water of the channel. It was finally able to back off the reef at high tide on November 1, 2005. After an underwater inspection revealed no significant damage to the hull, the ship was able to steam away under its own power.

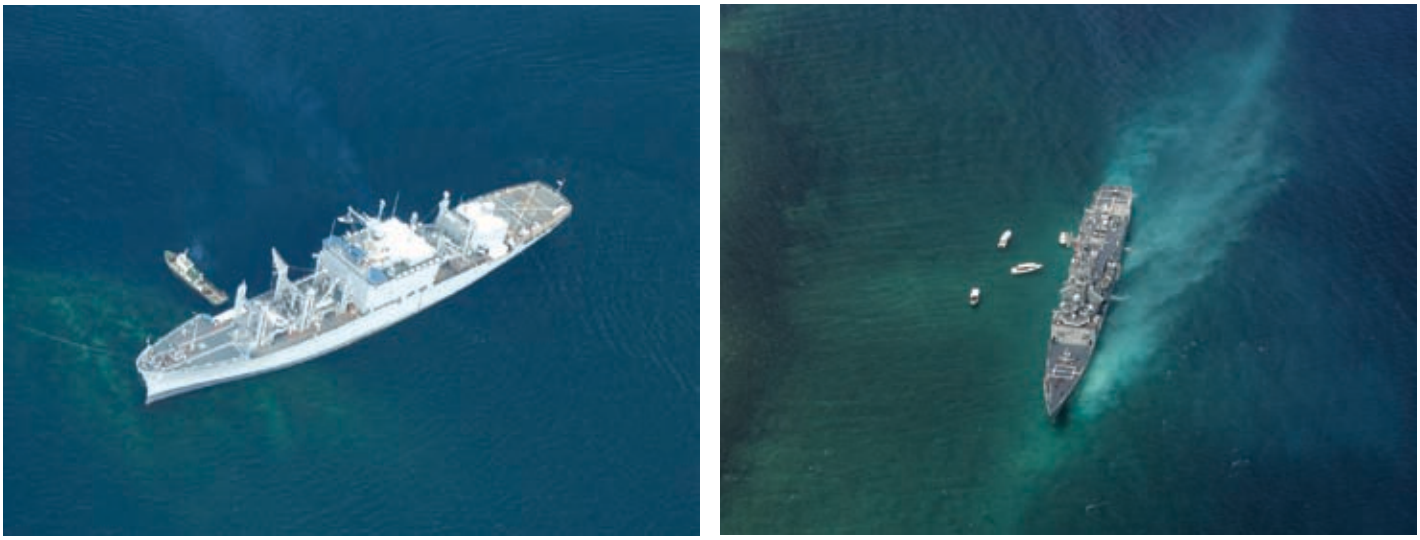

Figure 16.3. Vessels recently grounded on Palau's reefs include the USNS Niagra Falls (left) and Taiwan Naval Frigate 1103 (right). Photos: CRRF.

The grounding damaged an area of about 875 m^2 of channel edge reef with high cover of coral, particularly table *Acropora* spp. (Colin, 2006). About 350 m^2 of reef were crushed and compressed under the hull while an additional 85 m^2 had broken reef structure and debris berms which were produced when the ship plowed into the reef. A small down slope movement of debris occurred on the channel slope. The grounding triggered a bleaching event among corals within 10-15 m of the hull covering an area of over 300 m^2, probably due to thermal discharges from the ship's generators or engines while grounded. The ship left a large amount of copper-based bottom paint on the site. Virtually 100% of bleached coral colonies, primarily tabulate *Acropora* spp., died following this event. A follow-up study 14 months later (Colin, 2007) found no recovery of the site as a coral reef. Not a single coral recruit occurred in the area of reef crushing, suggesting that the toxins from remaining bottom paint may be inhibiting reestablishment of many organisms. Colin (2007) reexamined the site of a similar grounding in 1997, that of the container ship M/V *Kyowa Violet* (Colin, 1997), and found only minor recovery of that site after almost ten years.

The second major grounding was that of the Taiwanese Naval Frigate 1103 (*Cheng Ho*), a 138 m vessel with a draft of 8.6 m, which struck a reef while entering the main shipping channel (West Channel) of Palau on March 20, 2006 (Figure 16.3). The vessel went aground in 4-5 m of water on the outer slope of the barrier reef as it transited to the channel proper. It remained a ground for two days and was pulled from the site by another Taiwanese naval vessel at high tide.

The vessel grounded in a wave-exposed area where little coral occurs above 6 m depth, so the ship caused minimal damage to reefs. It is estimated less than 50 coral colonies of any size were damaged by the grounding. The reef structure is very solid and no crushing of reef framework occurred. The single, variable pitch propeller of the vessel continued to turn after the ship's bow hit the reef and dug a 1.5 wide by 0.5 m deep groove 20 m in length through the reef limestone as the stern slewed towards the reef. Its blades were finally ripped from the hub and the hub's lubricating oil was released. This quickly dissipated to sea on the outgoing tide. No other discharges occurred from the ship.

A follow up examination of the site six months later found minimal damage to the reef. After the benthic algal film reestablished itself, the site was very difficult even to identify underwater. Some of a limited number of corals damaged could still be easily identified, but overall the site was not significantly affected.

The third major grounding was that of a long-liner fishing vessel (Figure 16.4); the grounding occurred on September 23, 2006. Although this was the first major grounding of a long-liner fishing vessel recorded in this area, the size of the vessel was not recorded. The location of the grounding is at 07°15.896 N, and 134° 3.018 E on the Uchelbeluu Barrier Reef. The ship first came into contact with the reef on the fore-reef area at about 5 m depths. During the grounding, there were strong waves that may have pushed the vessel over the reef crest. Since the strong waves continued for sometime, it further pushed the vessel to the back reef on the lagoon side where it sat exposed during low tide (PICRC, 2006)

On November 10, 2006, the Palau International Coral Reef Center Research (PICRC) staff conducted a rapid assess-

ment of the grounding site. No assessment had been done to describe reef condition before the grounding. As a result, post-grounding results collected over one month after the ship ran aground are the only available data on this reef. Using the line intercept method, coral cover at 3 m depth at the grounding site was determined to be at 34.1 %. The dominant coral species was encrusting *Montipora* (12.1%), followed by *Acropora* (10.8%). About 54% of the surveyed area was hard carbonate substrate (PICRC, 2006).

Figure 16.4. Long liner on its side at Uchelbeluu. Photo: PICRC.

The impact of the grounding was difficult to determine. While there was some obvious damage to the reef, which may have occurred as a result of vessel removal, based on the assessment and observations made by PICRC staff, it appeared that the ship grounding caused little damage to live coral. The major damage caused by the ship was to the reef structure, particularly on the reef crest and the back reef. Broken corals that were still attached to the reef have shown signs of recovery. Dislodged colonies that had not died will eventually succumb if they are not stabilized (PICRC, 2006).

Toward the end of December 2006, the last grounding included in this report occurred on the southeastern part of Helen Reef, the southernmost part of Palau (Figure 16.5). The grounded vessel was a fishing boat owned by one of the long-line fishing companies operated in Palau. The position of the grounding was 2°49.16N, 131°46.89E.

Figure 16.5. Long liner at Helen Reef. Photo: Helen Reef Resource Management Program.

The size of the vessel was not stated, but some information on the extent of the damage caused by the grounding was reported. The inner reef structure at the grounding site is very solid with little coral growth. Therefore coral damage on the reef flat was minimal. However, there was visible damage to benthic habitats from the anchor and propeller. The extent of damage on the outer reef area was not assessed due to the presence of big waves and rough water. A few hours after the grounding occurred, the boat caught on fire. Approximately 70-80% of the vessel was destroyed by this fire. There was no obvious sign of an oil spill from the vessel. The Hatohobei State Rangers retrieved a large bundle of tangled up fishing line on the reef flat near where the vessel ran aground. It is believed that this line was thrown overboard by the crew in an attempt to lighten the vessel so that it could be floated off of the reef.

Marine Debris

Marine debris is common in Palau. It can be found on the beaches around the country. EQPB annually organizes an Earth Day Program which includes a debris removal activity by volunteers who collect trash from both the shores and the water. Koror State also has been active in organizing and implementing Rock Island beach cleanups. Since Palau is a country that relies heavily on importation of goods from neighboring countries, it is hard to determine if debris originated locally or from outside of Palau.

Debris in the form of fishing lines and fishing nets are also commonly sighted in Palauan waters (Figure 16.6). In April 2005, gill nets belonging to an unlicensed fishing boat were reported tangled at 10-20 m depth on the reef edge in Hatohobei Island. Fortunately, the patrol boat from Marine Law Enforcement was in the area and was able to remove the gill nets. The four gill nets recovered contained five turtles that had been caught in the net. Fortunately, damage to the surrounding coral reef was minimal (Tervet, 2005).

In late December 2006 at Helen Reef, a bundle of fishing line was retrieved by state rangers from the reef flat after the rangers rescued the crew from a grounded vessel. Since currents in the area were moving swiftly towards the outer reef edge, some of the fishing lines may have been washed out to sea by the current.

Aquatic Invasive Species

In July 2007, the National Invasive Species Committee (NISC) hosted a week-long training on detection and response to invasive species in Palau's marine environment. Participants represented national and state government agencies, marine protected areas, non-governmental organizations (NGOs), and the private sector. The participants developed recommendations to enable Palau to respond to the threat of marine invasives. These recommendations have been taken up by the NISC.

Figure 16.6. Fishing net on the reef. Photo: Marine Law Enforcement.

The week was devoted to training in survey design and methodology for Palau's Marine Invasives Survey Team, and included hands-on surveying in the field, as well as training in laboratory techniques for sorting and identifying marine invasives. High-risk sites in Malakal Harbor were selected for the training. As a result of this training we now have a 17-member team of divers and support personnel representing national government agencies, state governments, non-governmental agencies, and dive tour companies.

The training was conducted by two experts from Australia, Dr. Chad Hewitt and Dr. Marnie Campbell. It is a priority project of the NISC, with funding from the Republic of China-Taiwan under Operation Counter-Invasion. Additional support was provided by the World Conservation Union, International Union for the Conservation of Nature and Natural Resources, the Marine Bio-security Education Consortium and the Australian Maritime College. In-kind support was provided by local NGO's, state and national government agencies and the private sector.

This workshop and training survey are Palau's first steps to gather baseline information on marine invasive species, and to develop policies and procedures to prevent and control them. It comes as the result of nearly two years of efforts by the NISC to start addressing invasive species in the marine environment, often forgotten compared to their terrestrial counterparts. A report on the findings of the survey and training will be produced before the end of 2007, and will be shared with participants as well as with the public.

Although a comprehensive survey has not been conducted for marine/aquatic invasive species in Palau, several marine invasive species have been identified here (P. Colin, pers. obs.). At present it appears that none of these species are having a quantifiable effect on fisheries or the marine tourism industry, but marine invasive species do have the potential to become a serious problem in Palau, as they have in other Pacific Islands. NISC considers a complete baseline survey of Palau's ports and other high-risk areas a high priority need and is actively seeking funding to complete this survey.

Most marine invasive species in Palau come from a small group of marine invertebrates probably introduced as fouling on ship's hulls or from ballast water pumped out in harbors. Relatively little baseline information exists describing marine invertebrates that are invasive species in Palau. Major groups include ascidians or tunicates (Phylum Chordata, Subphylum Urochordata); hydroids and other cnidarians (Phylum Cnidaria); molluscs (Phylum Mollusca); sponges (Phylum Porifera); bryozoans (Phylum Ectoprocta); and other small groups (P. Colin, pers. obs.).

Given Palau's reliance on imports, there is always the potential for more introductions of marine organisms from ships. For this reason, approaches for controlling marine invasive species should focus on the prevention of introduction and early detection.

Presently only one marine invasive species has the potential for becoming a "pest" organism in Palau, and this is the hydroid, *Eudendrium carneum*. This particular hydroid is a rapidly growing species, which has been found growing in at least three channels of Palau. *E. carneum* prefers rocky substrates with particularly high currents, and often forms a tangle of branches that tend to accumulate sediment, making it a fairly unattractive "weed". As with any marine invasive species, *E. carneum* has the potential to spread throughout rocky marine environments of Palau. *E. carneum* could potentially interfere with the feeding of bottom grazers, such as parrotfishes and surgeonfishes, which scrape algae from rock surfaces. In addition, masses of *E. carneum* tend to make rocky surfaces on the reef less visible and the reef look dirty. At present, the current knowledge on the status and distribution of *E. carneum* in Palau is very limited. It would be useful to survey the extent of its distribution at regular intervals.

Invasive Species of Palau's Marine Lakes

As of 2006, there are three known non-indigenous, invasive species in Ongeim'l Tketau (OTM), also known as Jellyfish Lake: a sea anemone in the genus *Aiptasia*, its symbiotic strain of zooxanthellae, and a sponge belonging to the genus *Haliclona*. It is uncertain where the *Aiptasia* sp., its zooxanthellae (clade E) and the *Haliclona* sp. originated.

The Sea Anemone Aiptasia *sp.*

Relatively small patches of *Aiptasia* sp. were first observed in November 2003 at the foot of the dock where visitors enter the lake. Since then, annual surveys have documented the progress of the invasion eastward along both the north and south shorelines (Figure 16.7). Metrics such as patch area, degree of continuity and density decrease with increasing distance from the original site of introduction. The invasion appears to proceed in a somewhat saltatory fashion with new clusters appearing at points many linear meters ahead of areas of nearly continuous coverage (Figure 16.7). These new colonies can grow quickly. One colony more than doubled in number every month for three months. Their ability to reproduce via pedal laceration likely explains its rapid expansion.

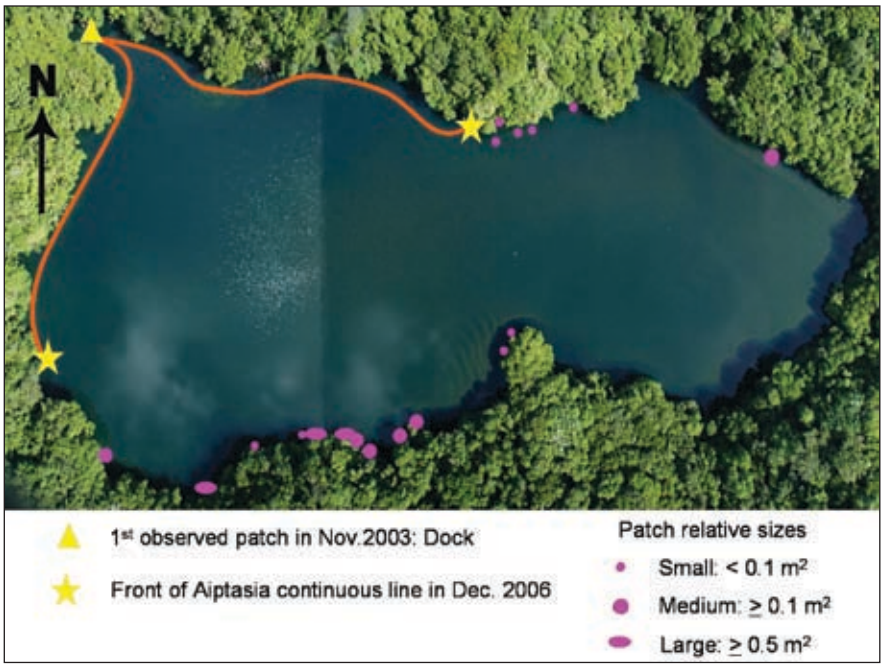

Figure 16.7. Aiptasia *sp. distribution in Jellyfish Lake in December 2006. Furthest extent of the dense line of* Aiptasia *sp. indicated by orange line and yellow stars. Dots of different sizes represent isolated patches found outside of the continuous dense line. Photo: Coral Reef Research Foundation.*

In OTM, *Aiptasia* sp. appear able to establish on any sufficiently hard substrate (Figure 16.8), including mud, rock, mussel shells, algal bottoms, dead leaves and tree falls. The lower boundary of their depth distribution appears to be at least partially limited by available substrate. However, other factors, including light availability and oxygen levels may also contribute. Light availability does not seem to strongly influence its distribution at shallow depths despite its symbiont's need for sunlight. Well developed patches can be found in light limited areas. Temperature may be an important factor influencing abundance and distribution and their rate of spread as well. Qualitative evidence suggests that anemones bleach during warmer conditions.

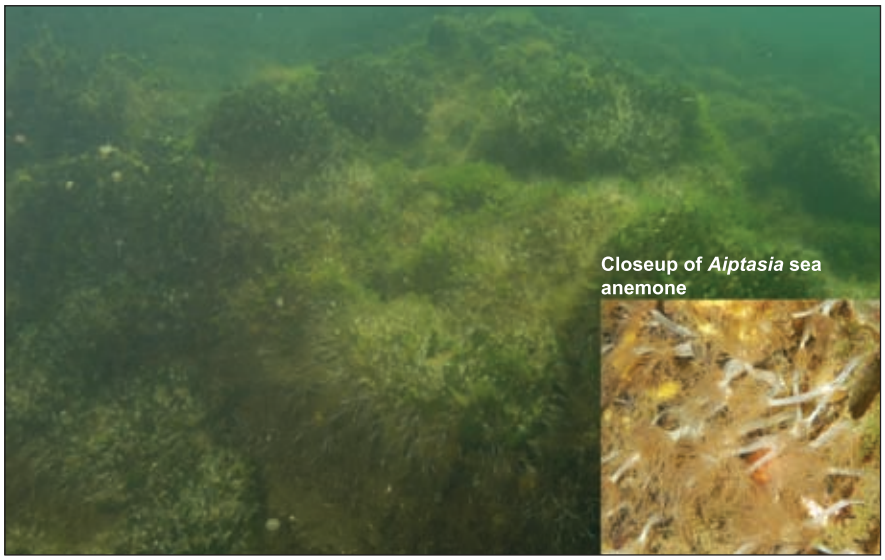

Figure 16.8. Typical invasive sea anemone patch (mottled brown and white patch among green algae) found along the shallow slope in the west basin of the lake. Inset: Aiptasia *sea anemone with the characteristic light brown tentacles and white column. Photo: Coral Reef Research Foundation.*

Currently, no quantitative data exist to describe the impact *Aiptasia* sp. is having on the ecosystem. However, it is clear from direct observation that *Aiptasia* sp. is a thriving competitor for space and can heavily alter benthic diversity (Figure 16.9). Mangrove root and shallow water communities that were once dominated (in terms of both space and numbers) by algae or diverse assemblages of invertebrates are now dominated by invasive anemones. Despite previous experimental eradication of isolated patches, measures to counter the invasion have not been established.

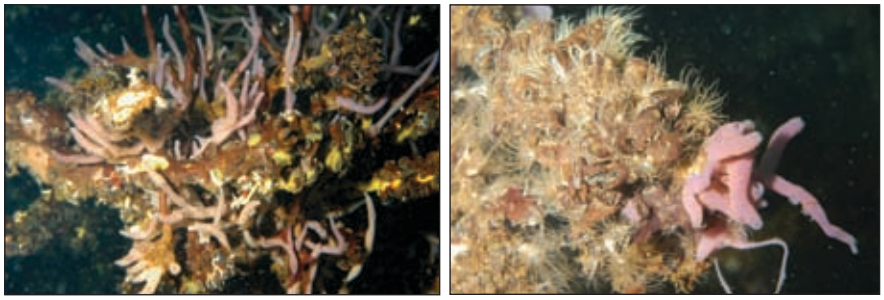

Figure 16.9. Qualitative impact of Aiptasia *sp. on benthic diversity. Uncolonized tree fall (left). Community composed of diverse invertebrates, dominated by sponges and mussels. Colonized tree fall (right). One species of sponge and mussel can be seen among the dense cover of* Aiptasia *sp. Photos: Coral Reef Research Foundation.*

Clade E Symbiodinium Zooxanthellae
DNA testing conducted in 2006 indicated that the invasive sea anemone harbors a clade of zooxanthellae (clade E *Symbiodinium*) that differs from the clade of zooxanthellae that is symbiotic with the lake's *Mastigias medusae* (clade C *Symbiodinium*). Thus, it is very likely that the symbiont was introduced into the lake in partnership with the sea anemone and constitutes a second invasive species. As with its anemone host, it is unclear what impact, if any, the introduced *Symbiodinium* will have beyond enabling sea anemone proliferation. However, because *Mastigias* also harbor zooxanthellae, it is possible that the non-native *Symbiodinium* could become established in *Mastigias*. It is not possible at this time to predict what effect, if any, such an event might have on the jellyfish's ecology but temperature and light tolerances do differ among *Symbiodinium* clades.

The Sponge Haliclona *sp.*
Although *Haliclona* sp. (Chalinidae, Haplosclerida) was first recognized as a non-indigenous species in OTM in June 2005, photographic evidence indicates that it was present in 2001. Due to striking similarities in color and morphology, *Haliclona* sp. can easily be mistaken for the lake's native *Dragmatella* sp. (Desmacellidae, Poecilosclerida). Consequently, its status as a non-native in OTM only became apparent after a broader survey of invertebrate diversity was conducted in 13 of Palau's marine lakes.

The sponge's exact identification (to species level) and its origin are still unknown, but it appears to characteristically and exclusively inhabit well connected marine lakes, which are environmentally very similar to the lagoon where the species also appears to occur naturally. Its status as a non-native in OTM is also supported by its spatial distribution, which is currently restricted to the extreme western edge of the lake near the dock and through the entrance channel where visitors enter the lake. Here several large patches, much larger than those formed by any native species, occur between 0.5 and 6 m depth along the northern side of the entrance channel. The effect this species is having and will have on the lake is unknown Figure 16.10.

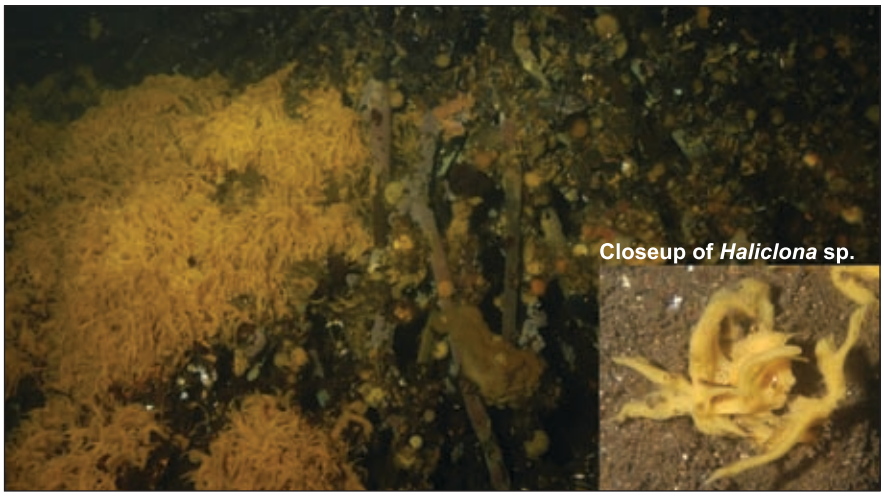

Figure 16.10. Non-native Haliclona *sp. colony near the dock from which tourists enter the lake. Inset: Non-native* Haliclona *sp. is easily mistaken for the native* Dragmatella *sp. Photo: Coral Reef Research Foundation.*

Security Training Activities
Since the last report, security training activities continued to be non-existent in Palau.

Offshore Oil and Gas Exploration
Since the last report, there has not been any oil extraction in and around Palau. However, in the past four years, oil exploration has been carried out in the northern Velasco Reef. On the southern end of Velasco Reef is a conservation area. An agreement on oil exploration and extraction has been signed by the leaders of Kayangel State that owns the Velasco Reef as well as four other outlying states in the south (Peleliu State, Angaur State, Sonsorol State and Hatohobei State). In 2006, the oil company carried out an environmental assessment (EA) in Velasco Reef as required by the EQPB, which is still under review. To date, this is the only EA that been carried out and submitted for review.

CORAL REEF ECOSYSTEMS—DATA-GATHERING ACTIVITIES AND RESOURCE CONDITION

A multi-level effort by different government and non-government agencies contributes to the general understanding of coral reef ecosystems and marine life in Palau. Table 16.7 provides a general understanding of the effort undertaken by various agencies and organizations. Figure 16.11 depicts the location of ongoing monitoring activities throughout Palau.

Table 16.7. Monitoring and assessment activities in Palau.

AGENCY	PLANNING/ MANGEMENT	RESEARCH	MONITORING	EDUCATION /OUTREACH	TRAINING	ENFORCE-MENT	YEAR EST.
Bureau of Natural Resources and Development	X	X	Ngermeduu Bay, Clam export and fish market		X	X	1990
Coral Reef Research Foundation		X	Temperature, marine lake				1998
Environmental Quality Protection Board			Water quality	X		X	1992
Helen Reef Resource Management Board	X		MPA	X	X	X	2000
Koror State Department of Conservation and Law Enforcement	X	X	Marine lakes, Rock Island, MPA				1994
Palau Conservation Society	X		MPA's	X	X		1996
Palau International Coral Reef Center		X	Fish, coral MPA's, watersheds				2001
The Nature Conservancy	X	X	MPA Network	X	X		2003

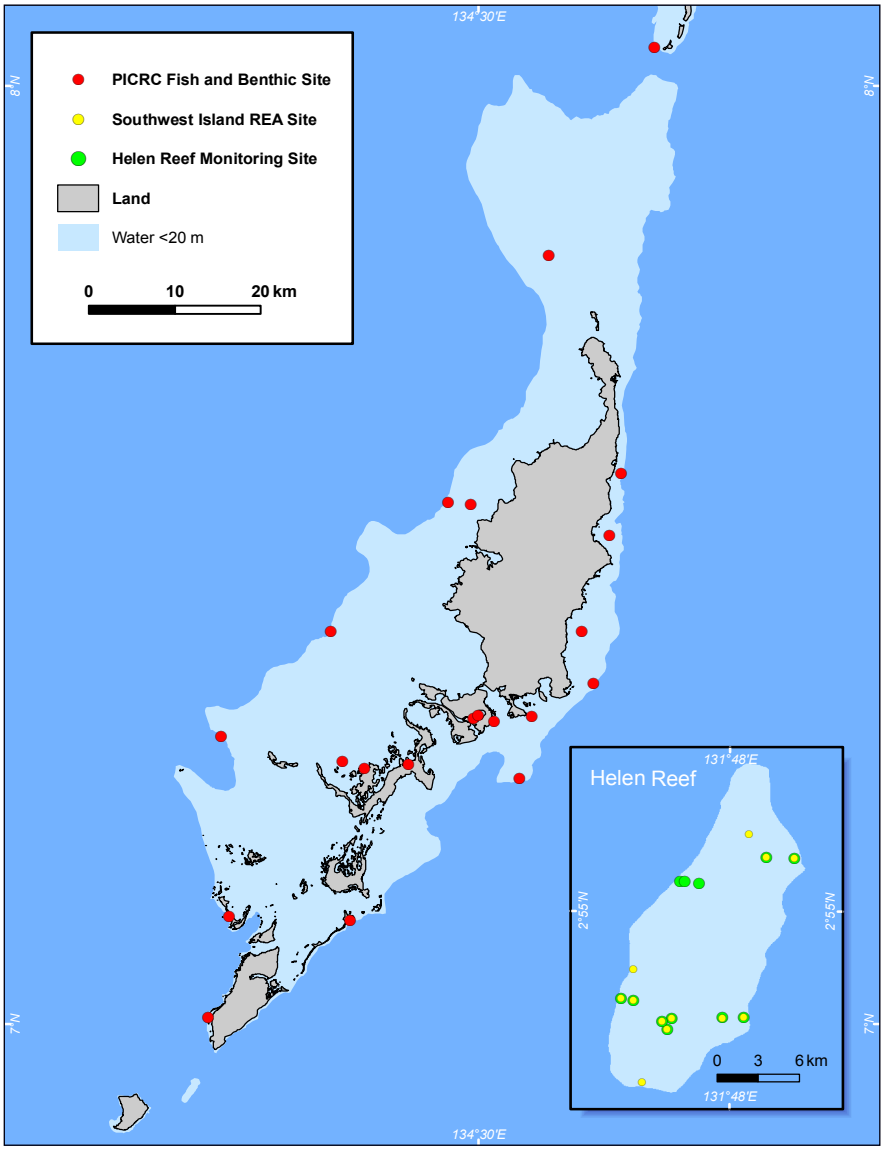

Figure 16.11. Map of monitoring locations in Palau. Map: K. Buja.

WATER QUALITY AND OCEANOGRAPHIC CONDITIONS

The Environmental Quality Protection Board of Palau (EQPB) conducts monthly water quality monitoring of marine waters around most of Palau. Turbidity, pH, salinity, dissolved oxygen, fecal coliform and temperature are collected monthly at 40 permanent sites (Figure 16.12). Sampling sites were selected because they are either a popular recreational site or in close proximity to a sewage substation. Results from the monitoring program are added to a database that dates back to 1992. Figure 16.12 shows the average monthly values for each parameter tested, with the exception of the month of April. In 2006, fecal coliform bacteria averages throughout the nearshore marine waters in Palau were well below the safe recreational water standards set for by the EQPB. In addition, turbidity, pH, temperature, dissolved oxygen and salinity levels were within the set standards.

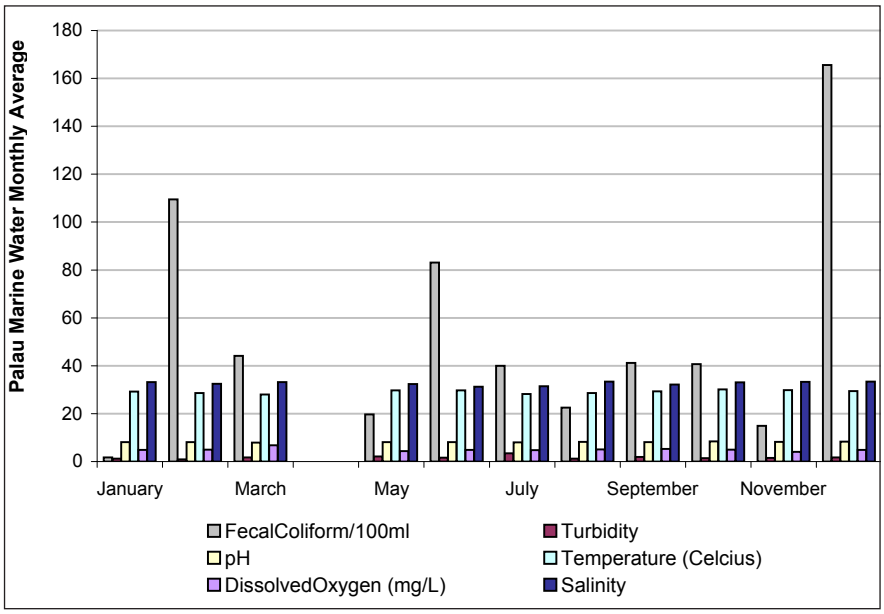

Figure 16.12. Comprehensive water quality graph for Palau in 2006. Source: EQPB.

EQPB issues an "unsafe for swimming" warning when the fecal coliform count at a site exceeds 200 bacteria per 100 mL. For the most part, the 40 sites sampled monthly have had fecal coliform counts less than this threshold. However, in February, June and December of 2006, at least a quarter of monitoring sites had fecal coliform counts near 200 bacteria per 100 mL.

Figure 16.13 shows the monthly averages in 2006 for turbidity levels, which is measured in nephelometric turbidity units (NTU). The highest averages were in the month of July, which corresponds with the rainy season. Average monthly pH levels ranged from 7.9 to 8.4, which fall within the marine water quality standards for Palau. In 2006, the average turbidity was below 2 NTU, except in May and July when it exceeded 2 NTU (Figure 16.13). The increase in turbidity in May and July could be the result of increased earth moving activities or more rain during those months.

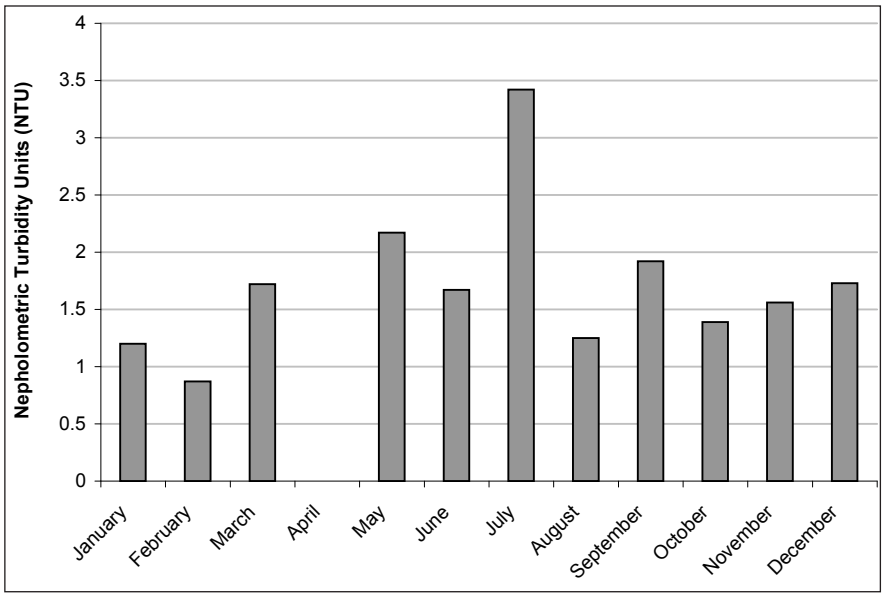

Figure 16.13. Average turbidity levels in Palau water in 2006. Source: EQPB.

No major shifts in average monthly temperature were recorded for 2006. Dissolved oxygen levels were just within the lowest acceptable limits for Palau. Temperature, pH and dissolved oxygen are shown in Figure 16.14. Average salinity levels in June and July show rainy season impacts. Table 16.8 summarizes the water quality data for 2006.

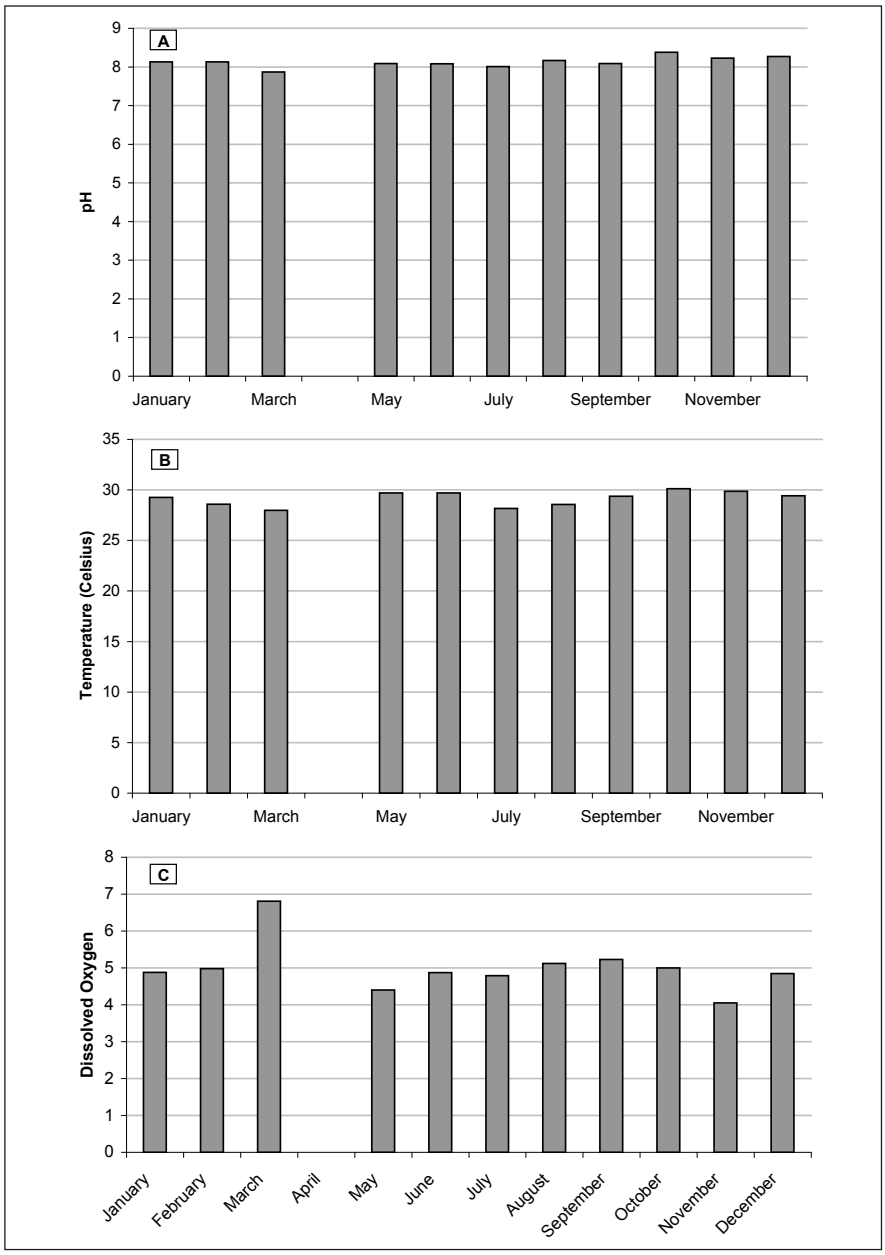

Figure 16.14. (a) Average pH levels in Palau waters in 2006; (b) Average temperature (˚C) levels in Palau water in 2006; (c) Average dissolved oxygen (mg/L) levels in Palau water in 2006. Source: EQPB.

Table 16.8. Monthly averages of 2006 water quality data for various parameters. Source: EQPB.

MONTH	FECALCOLIFORM (per 100 ml)	TURBIDITY	PH	TEMPERATURE (˚C)	DISSOLVED OXYGEN (mg/l)	SALINITY
January	1.75	1.2	8.13	29.27	4.88	33.15
February	109.5	0.87	8.13	28.59	4.98	32.46
March	44.1	1.72	7.87	27.97	6.81	33.2
April	0	0	0	0	0	0
May	19.65	2.17	8.09	29.71	4.4	32.32
June	83.08	1.67	8.08	29.69	4.87	31.24
July	40	3.42	8.01	28.17	4.79	31.43
August	22.57	1.25	8.17	28.57	5.12	33.34
September	41.21	1.92	8.09	29.37	5.23	32.14
October	40.72	1.39	8.38	30.13	5	33.06
November	14.93	1.56	8.23	29.87	4.05	33.28
December	165.59	1.73	8.27	29.42	4.85	33.36

BENTHIC HABITATS

Coral Ecosystem monitoring by the PICRC began in 2001 and has continued to the present. It started with the establishment of 14 permanent monitoring sites in 2001. Two more sites were added in 2002 and five were added in 2005. Currently, there are 21 permanent monitoring sites. Video transects are utilized to survey benthic habitats (Golbuu et al., 2005; Golbuu et al., 2007a; Golbuu et al., 2007b) and five 50 x 5 m belt transects are used for fish surveys (Golbuu et al., 2005). Coral recruitment surveys were also conducted using 0.30 x 10 m belt transects (Golbuu et al., 2005; Golbuu et al., 2007a; Golbuu et al, 2007b). Figure 16.15 shows coral cover on reefs around Palau in 2001, 2002 and 2005 at four different habitats.

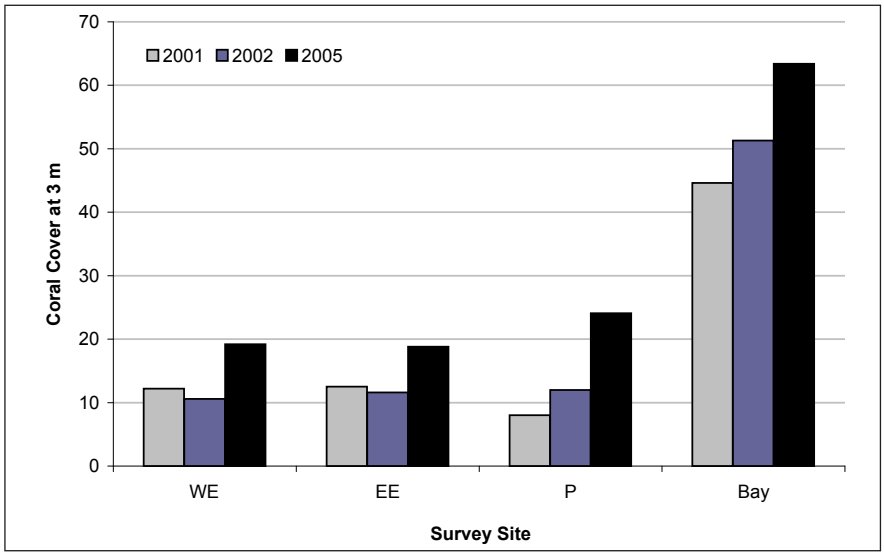

Figure 16.15. Average coral cover at four habitat types found in Palau at 3 m depth: western exposed reefs (WE), eastern exposed reefs (EE), patch reefs (P) and reefs around the rock islands (Bay). Source: Golbuu et al., 2007b.

Before the 1998 bleaching event, Palau coral reefs were generally in good condition with high coral cover. After the 1998 bleaching, coral cover was reduced at most sites around Palau (Golbuu et al., 2007a; Table 16.9). The largest reduction in coral cover caused by the bleaching was found at the western slopes of the northern lagoon where coral cover dropped from 60-70% to 15%; coral cover in the Southern Lagoon dropped from 50-70% to 14-23% over the same period (Golbuu et al., 2007).

Table 16.9 shows coral cover at different regions of Palau as recorded by the 1992 Rapid Ecological Assessments (REAs; Maragos et al., 1994), the 2001-2003 Spot Checks, the 2005 surveys of the permanent sites from the PICRC long-term monitoring programs, and other studies.

Table 16.9. Coral cover at different regions of Palau as recorded by the 1992 Rapid Ecological Assessments (Maragos et al., 1994) the 2001-2003 Spot Checks, the 2004/2005 surveys of the permanent sites from the PICRC long-term monitoring programs, and other studies. Source: Golbuu et al., 2007a.

LOCATION	1992 REA (RANGE)	2001–2003 SPOT CHECKS (MEAN ± SE)	2004/2005 SURVEYS (MEAN ± SE)	OTHERS (RANGE)
Kayangel	20 – 25	30 ± 4	25 ± 3	
Northern Lagoon: Barrier- NE slopes Barrier- W slopes Patch	10 60 – 70 N/A	13 ± 2 15 ± 2 20 ± 6	NA NA 26 ± 6	
West Babeldaob: Barrier Channels Patch Fringing	N/A 50 – 70 50 33-50	23 ± 2 14 ± 2 20 ± 3 33 ± 6	28 ± 4 NA 10 ± 2 NA	17 – 35 (*Golbuu, 2000*)
East Babeldaob : Barrier Patch Fringing	50 or more NA 10-50	14 ± 2 NA 22 ± 3	33 ± 8 8 ± 3 16 ± 2	10 – 30 (*PCS, 1999*)
Southern Lagoon: Barrier Channels Channel-Ngerumekaol Patch Fringing	50 25 – 50 52 N/A N/A	17 ± 2 N/A 23 ± 5 35 ± 5 39 ± 5	27 ± 2 NA NA NA 48 ± 3	23 (*Golbuu et al., 1999*)

From 2001 to 2005, coral cover on the reefs of Palau generally increased at both 3 and 10 m depths with the highest rate of increase found on Bay reefs (Golbuu et al., 2007b; Figures 16.15 and 16.16). Coral cover at deeper sites (10 m) generally increased 4% more than at shallower sites (3 m; Golbuu et al., 2007a). Overall, the increase in coral cover over this period averaged 2.9% per year (Golbuu et al., 2007a).

Coral recruitment was variable between the years with the highest recruitment rate recorded in 2002 (Golbuu et al., 2007a). Among the different sites, west exposed sites had the highest rate of recruitment at 10 m depth (Figures 16.17). There are no relationships with recruitment and coral cover (Golbuu et al., 2007b)

Generally coral reefs in Palau are recovering well from the 1998 bleaching event. Recovery is dependent on both remnant populations that survived the 1998 bleaching as well as on recruitment (Golbuu et al, 2007b).

Benthic Habitat Mapping

In November 2007, NOAA's CCMA-BB released benthic habitat maps covering 2,450 km^2 (946 mi^2) of nearshore marine habitats in Palau (Figure 16.18). Summary data indicate that about 35% of the area mapped contains live coral cover and that significant areas are covered by macroalgae, crustose calcareous algae, and sand. Deep lagoon areas were not able to be mapped since the seafloor was not visible in the IKONOS satellite imagery that was used to develop the maps.

The mapping effort was requested by Palau to support development of local monitoring programs and help resource managers evaluate the effectiveness of Palau's system of marine reserves and help identify areas in which additional (MPAs) can be established. Access to the source imagery and various map products is available at: http://ccma.nos.noaa.gov/products/biogeography/palau/welcome.html.

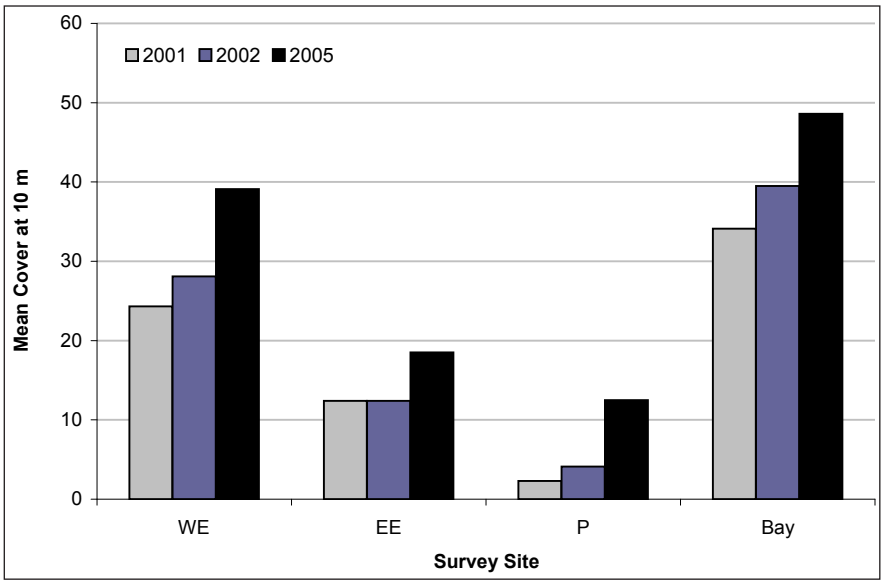

Figure 16.16. Average coral cover at four habitat types found in Palau at 10 m depth. Western exposed reefs (WE), eastern exposed reefs (EE), patch reefs (P) and reefs around the rock islands (Bay). Source: Golbuu et al., 2007b.

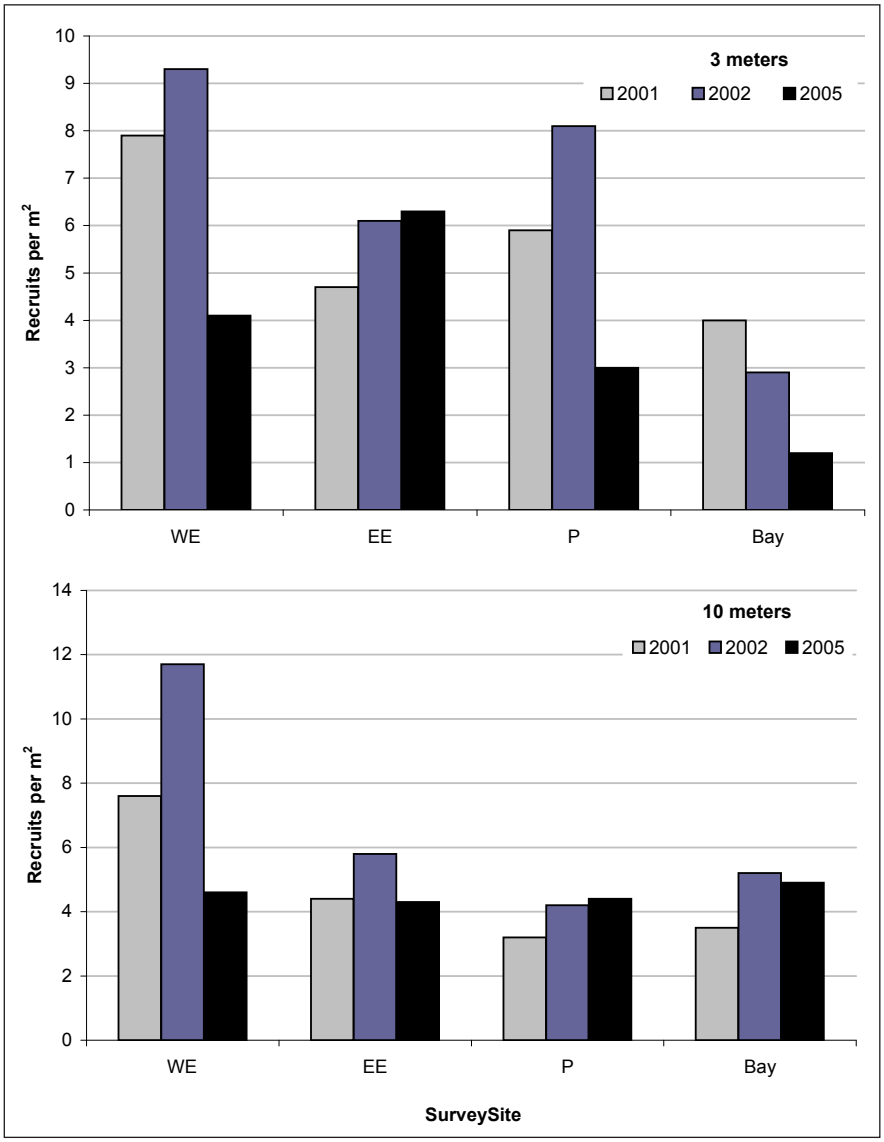

Figure 16.17. Average coral recruitment by habitat type at 3 m (top) and 10 m (bottom) depth. Source: Golbuu et al., 2007b.

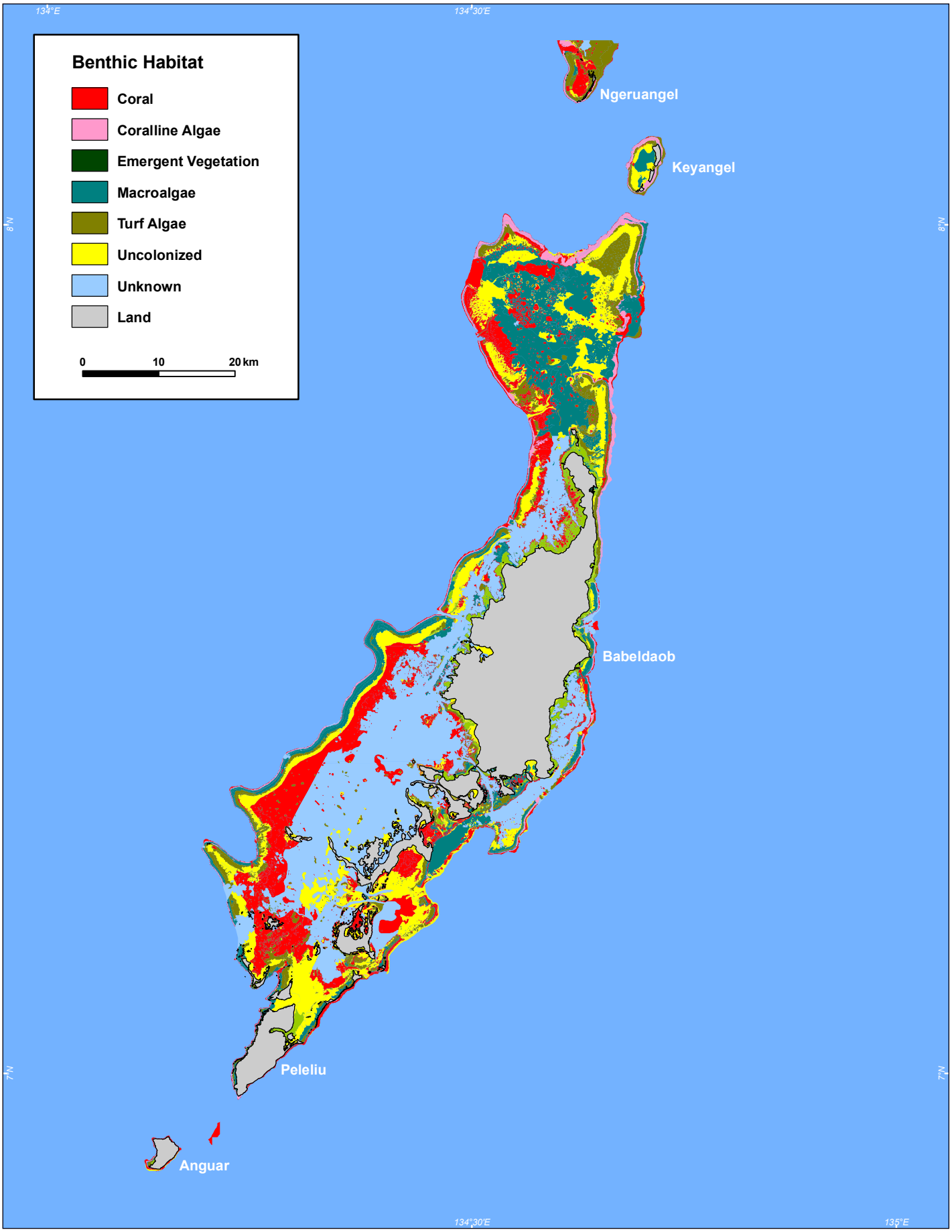

Figure 16.18. Benthic habitats of Palau as classified by NOAA. Detailed habitat classes have been aggregated to major classes. Data: http://ccma.nos.noaa.gov/products/biogeography/palau/welcome.html. Map: K. Buja.

ASSOCIATED BIOLOGICAL COMMUNITIES

Fish

Fish surveys were conducted at permanent monitoring sites using visual census techniques on five, 5 x 50m belt transects (Golbuu et al., 2005).

Fish abundance increased in 2004 in all the sites at 3 m and west exposed and patch reef sites at 10 m (Figures 16.19). East exposed sites and bay reefs did not have significant increases in 2005 (Figure 16.19). For the habitats with different exposures, west exposed sites has the highest number of fish, followed by east exposed and path reefs. Bays had the lowest number of fish. Fish abundance at west exposed sites in 2004 were higher at 10 m than at 3 m, while east exposed patch and bay reefs showed a different pattern with higher abundance at shallower water (Figures 16.19).

Despite fishermen's concerns that there is a decrease in fish as a result of their increased fishing effort, fish data shows a general increase in 21 fish species at selected monitoring sites. The data as presented are total fish population of these selected species. There exists an inability to conduct analysis to determine which species are increasing and which ones are decreasing.

The Palau Marine Protection Act of 1994 puts size, exports and seasonal restrictions on certain commercially important reef fish species, such as groupers, rabbit-fish, napoleon wrasse and humphead parrotfish. In 2006, Palau instituted a total ban on the collection of napoleon wrasse until some sort of assessment is done to provide recommendation on the status of this species.

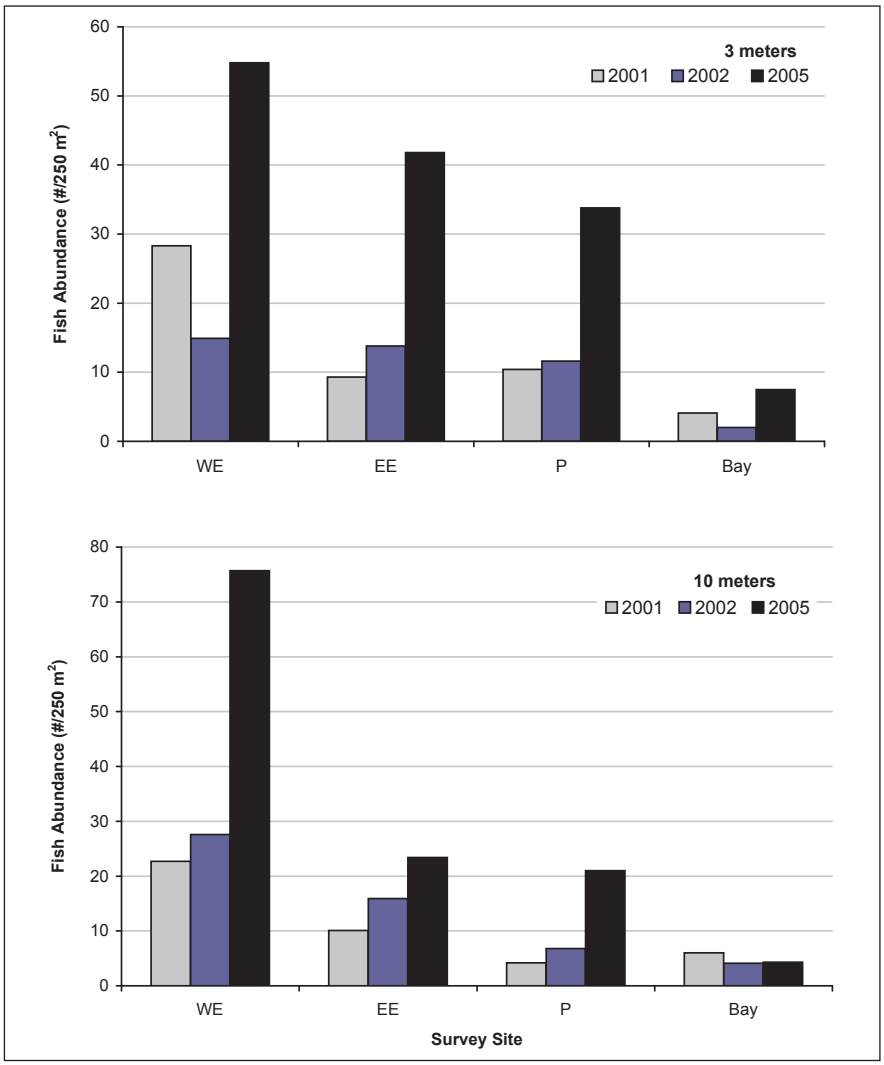

Figure 16.19. Average fish abundance at five habitat types at 3 m depth (top) and 10 meters (bottom). WE=west exposed; EE=east exposed; P=protected. Source: Golbuu et al., 2007a.

There is a lack of baseline data to permit the determination of whether there is indeed a decline in fish populations at the species level. However, despite all these management efforts at the policy level and at community level to establish MPA's, fishermen are still concerned over a decrease in fish populations.

Invertebrates

Invertebrates were only added to monitoring activities in 2007; no data are available for this report, but results will be presented in the next report. There is a general consensus that most commercially important invertebrates on the reefs are declining due to over-harvesting. Despite restricted export under the 1994 Marine Protection Act, giant clams (*Trochus* spp.) have experienced a decline. There is a government effort in providing seedlings to interested individuals to raise clams and there are many clam farm in existence throughout Palau on the inter-tidal reefs flats. There hasn't been any assessment to determine whether there are possible negative environmental impacts on the reefs of these activities.

CURRENT CONSERVATION MANAGEMENT ACTIVITIES

The Palau Ministry of Resources and Development (MRD) has overlapping jurisdiction with each of Palau's 16 state governments for all marine areas within 12 nm of the high tide watermark. Various governmental and NGOs have conducted research and monitoring projects to aid in the management of Palau's coral reef ecosystems. National and state agencies, in coordination with locally based NGOs, have put a variety of management tools in place to address issues such as fishing, recreational use, and land-based sources of pollution in order to protect the marine resources of Palau.

Marine Protected Areas

MPAs have been established throughout Palau by states and local communities to provide protection for marine resources (Table 16.10). Several more of these protected areas have been designated over the years, thereby providing

Table 16.10. Marine Protected Areas of Palau. Source: PICRC and PCS.

MPA	YEAR	PROTECTED HABITATS	AUTHORITY	RESTRICTIONS
Ngerukuid Preserve	1956 1999	Lagoon, patch reef, limestone islands	National Government, Koror State Government	No entry
Ngerumekaol Spawning Area	1976 1999	Reef channels, barrier reef, lagoons	National Government, Koror State Government	No fishing
Ngaraard Beach Conservation Area	1990	Patch reefs, lagoon, beach, seagrass beds	Ngaraard State Government	No fishing
Airai Mangrove Conservation Area	1994	Mangrove, fringing reef	Airai State Government	Subsistence fishing and educational uses only
Ngaraard Mangrove Conservation Area	1994	Mangrove, fringing reef	Ngaraard State Government	Subsistence fishing and educational uses only
Ngemelis Island Complex	1995 1999	Lagoon, patch reefs, barrier reef, limestone islands	Koror State government	No fishing; no operation of motor boat between island complex
Ngeruangel Preserve	1996	Atoll, patch reefs, lagoon	Kayangel State Government	No entry without permit
Ngeream Conservation Area	1997	Limestone island, mangrove, fringing reef	Airai State Government	Subsistence fishing and educational uses only
Melekeok Management Area	1997	Fringing reef	Melekeok State Government	No net fishing
Ngkisaol Sardine Sanctuary	1999	Mangrove, patch and fringing reefs	Koror State Government	No take
Ebiil Conservation Area	2000	Channel, patch reefs, lagoons, barrier reef	Ngarchelong State Government	No entry
Ngermeduu Bay	2000	Mangroves, mudflats, seagrass beds, fringing reefs, reef channel	National Government, Aimeliik, Ngatpang and Ngaremlengui State Governments	Subsistence fishing and educational uses only
Helen Reef Reserve	2001	Atoll, patch reefs, lagoon, channel	Hatohobei State Government	No entry
Ngederrak Reef Area	2001 2005	Seagrass beds, lagoon	Koror State Government	No entry for motorized watercraft
Teluleu Seagrass Conservation Area	2001	Seagrass bed	Peleliu State Government	No entry
Ngelukes Conservation Area	2002	Patch reef, seagrass beds	Ngchesar State Government	No entry
Ngerkebesang Conservation Zone	2002	Beach, fringing reef	Koror State Government	No take
Imul Mangrove Conservation Area	2002	Mangrove, fringing reef	Aimeliik State Government	No take
Ngchesechang Mangrove Conservation Area	2002	Mangrove, fringing reef, reef channel	Airai State Government	Subsistence fishing and educational uses only
Ngermasech Reef Conservation Area	2003	Seagrass beds, fringing reefs	Ngardmau State government	No entry
Ngatpang Fish Conservation Area	2004	Mangrove, fringing reef	Ngatpang State Government	No entry
Ngatpang Clam Conservation Area	2004	Patch reef	Ngatpang State Government	No entry
Ngatpang Crab Conservation Area	2004	Mangrove	Ngatpang State Government	No entry
Ileaklbeluu Conservation Area	2005	Patch reef	Ngardmau State Government	No entry
Angaur State Conservation Zone	2005	Fringing reef	Angaur State Government	No fishing, except on reef slope (spear fishing only)
Medal a Ngerang Management Area (Ngerang Clam Farm)	1999	Seagrass bed, fringing reef	Melekeok State Government	No clam harvest
Airai Reef Conservation Area	2005	Mangrove, fringing reef	Airai State Government	No entry
Ngerchebal Island Wildlife Conservation Area	2006	Volcanic island, patch reefs	Aimeliik State Government	No entry
Oikull Mangrove Conservation Area	2002	Mangrove, channel	Airai State Government	Subsistence and educational uses only
Bkulengriil Conservation Area	2006	Fringing reef, seagrass bed, mangrove	Ngaremlengui State Government	No fishing

protection for a greater percentage of coral reef ecosystems. In 2007, there were 31 MPAs, covering more than 40% of Palau's nearshore marine area.

Most of Palau's MPAs have been designated by the states and management of these areas falls under the authority of the local governments. In addition, there are MPAs designated by the national government for the purpose of protecting biodiversity and significant habitats. The designation of a MPA by the local governments is initiated by the implementation of a traditional moratorium, or 'bul', on the area, prohibiting all use for a restricted time period (usually one to three years). The majority of these MPAs were designated to address local concerns related to decreased commercial reef fish populations. The Palau Conservation Society (PCS) and TNC have been working in partnership with state governments to implement community-level monitoring and management programs within the MPAs and to produce management plans that will take effect after the moratorium period has expired. In the last several years, more of these MPAs have also been designated through legislation by the state governments to provide a legal basis for management action.

Helen Reef Management Area

Helen Reef is a large, biologically-significant atoll located in the remote Southwest Islands of Palau with a reef size of 163 km². It is the traditional fishing ground for the Hatohobei people who have depended on Helen Reef as an important source of food for many generations. In recent decades, foreign poaching and overfishing have threatened the biological health of the Reef.

In response to these challenges, the people and the state of Hatohobei made attempts to protect and better manage Helen Reef's resources, including the formation of the Helen Reef Resource Management Program and the enactment of state legislation declaring the area a marine reserve and protected area. Since the inception of the Program in 1999, community members from Hatohobei State have been successful in protecting the reef from outside poachers and overfishing. A community monitoring, surveillance and enforcement program has been implemented since 2002 and a new management plan has recently been developed to address ongoing management and project sustainability (Andrew, 2007). Tables 16.11 and 16.12 provide more information about the locations and objectives of monitoring work at Helen Reef.

Table 16.11. Location of study sites and objectives for quantitative survey design combined for fishes, corals and macroinvertebrates. Source: Helen Reef Project.

LOCATION	SITE #	GENERAL DESCRIPTION	STANDARD HANDHELD GPS READING
Northeast	30(/18)	(a) Transects on the outer reef slope started approximately 250 m north of the point were Site 30 was located and ran in a southerly direction. (c) Transects on the inner reef slope commenced at approximately the same latitude (in the vicinity of 1992 Site 18) and ran in a southerly direction.	(a) 2° 57.13' N; 131° 50.54' E (c) 2° 57.17' N; 131° 49.44' E
Southeast	29	(a) Transects on the outer reef slope started approximately 250 m north of the point were 1992 Site 29 was located and ran in a southerly direction. (c) Transects on the inner reef slope were done on the lagoon side of a bar reef parallel to the inner reef slope north of 1992 Site 23 and ran in a southerly direction.	(a) 2° 50.72' N; 131° 48.58' E (c) 2° 50.70' N; 131° 47.72' E
Northwest	15(/16)	(a) Transects on the outer reef slope started directly adjacent to the stern of the big shipwreck on the NW side and ran in a northerly direction. (b) Transects on the reef flat started approx 150m from the wreck where the two upright stern masts lined up forming a line perpendicular to the long axis of the ship and ran in a northerly direction. (c) Transects on the inner reef slope also commenced where the two upright stern masts lined up forming a line perpendicular to the long axis of the ship and ran in a southerly direction.	(a) 2° 56.17' N; 131° 46.05' E (b) 2° 56.20' N; 131° 46.24' E (c) 2° 56.12' N; 131° 46.79' E
Southwest	21	(a) There were no obvious reef features at this site. Transects on the outer reef slope commenced at the GPS location and proceeded in a northerly direction. (b) Transects on the reef flat were located approximately 150m from the outer reef slope site. To avoid large expanses of sand flat, one transect ran in a northerly direction and the remaining four ran in a southerly direction. An additional macroinvertebrate survey was conducted nearer to the outer reef slope from this area in a depth of 2m. (c) Transects on the inner reef slope commenced directly across from the outer reef slope site.	(a) 2° 51.46' N; 131° 43.75' E (b) n/a (c) 2° 51.40' N; 131° 44.24' E
Patch reefs	22	Three patch reefs were surveyed on the reef slope for both fish, corals and macroinvertebrates: (a) Site 22a (P22 in figures) – 1 transect on east side (b) Site 22b (P2 in figures) – 2 transects on east side (c) Site 22c (P3 in figures) – 2 transects on east side	(a) 2° 50.66' N; 131° 45.73' E (b) 2° 50.22' N; 131° 45.57' E (c) 2° 50.53' N; 131° 45.35' E

Table 16.12. Summary of 1992 Southwest Island REA survey sites (from Maragos et al., 1994). Repeated in 2000. Source: Helen Reef Project.

2000 SITE NAME	1992 SITE NAME	FISH	MACRO INVERTEBRATES	BENTHIC VIDEOS	CORAL RECRUITMENT	2000 HANDHELD GPS READING
9 North	9	X	X	X	X	2° 52.6583' N; 131° 44.23' E
10	10	X	-	-	-	-
11	Near 11	X	-	-	X	2° 58.11' N; 131° 48.75' E
--	12	-	-	-	-	-
--	13	-	-	-	-	-
--	14	-	-	-	-	-
15 inside	15/16	X	X	X	X	2° 56.12' N; 131° 46.79' E
--	17	-	-	-	-	-
19	19	X	-	-	-	-
20	20	X	-	-	-	-
21 inside	21	X	X	X	-	2° 51.40' N; 131° 44.24' E
21 (outside)	-	X	X	X	X	2° 51.46' N; 131° 43.75' E
22a 22b 22c	22 (Expanded to include 3 patch reefs)	X	X	X	X	**22a:** 2° 50.66' N;131° 45.73' E **22b:** 2° 50.22' N;131° 45.57' E **22c:** 2° 50.53' N;131° 45.35' E
-	23	-	-	-	-	-
24	24	X	-	-	-	-
25	**25**	**X**	-	**X**	-	-
--	262	-	-	-	-	-
--	27	-	-	-	-	-
28	28	X	-	-	-	2° 48.08' N; 131° 44.56' E
29 (outside)	29	X	X	X	X	2° 50.72' N; 131° 48.58' E
29 (inside)	-	X	X	X	X	2° 50.70' N; 131° 47.72' E
30 (outside)	30	X	X	X	X	2° 57.13' N; 131° 50.54' E
30 (inside)	18	X	X	X	-	2° 57.17' N; 131° 49.44' E

Management of the Northern Reef

The Northern Reef encompass an area, approximately 200 km², of enclosed reefs and lagoons situated between the land masses of Ngerchelong State, on the main island of Babeldoab and Kayangel State, the northernmost atoll in the archipelago. This complex system of reefs is known throughout Palau for its rich marine biodiversity and spawning aggregations. As such, the Northern Reef has seen an increase in fishing activity, not only by fishermen from those two states, who own the resources but from other states throughout Palau. This mounting fishing pressure prompted Ngerchelong State to request that PCS conduct a baseline biological survey of the area. Results are presented in Tables 16.13 and 16.14.

Table 16.13. Species surveyed at Northern Reefs, Palau. Source: PCS.

	Bumphead parrotfish	Humphead wrasse	Orange-spine unicornfish	Blue-Spine unicornfish	Red snapper	Humpback snapper	Squaretail grouper	Camouflage grouper	*Epinephelus fuscoguttatus*
Number of fish counted	907	168	1661	245	1,715	6,230	177	222	9
Density (#/ km²)	14.9	2.8	27.4	4.0	28.3	102.6	2.9	3.7	0.1

Table 16.14. Family groups surveyed at Northern Reefs, Palau. Source: PCS.

	Parrotfish	Surgeonfish	Rabbitfish	Emperors	Sweetlips	Sharks	Turtles
Number of fish counted	3,804	2,709	708	428	395	48	19
Density (#/ km²)	62.7	44.6	11.7	7.1	6.5	0.8	0.03

In August of 2006, PCS collaborated with Coral Reef Research Foundation (CRRF) and Ngerchelong State conservation officers to complete a marine biological resource survey of the Northern Reefs. The main objective of this survey was to document the general condition of the area in terms of fish abundance and distribution (Tables 16.13 and 16.14) and substrate coverage. The secondary objective was to map potential scuba diving/snorkeling locations, sport fishing sites and other recreational areas for tourism to increase economic development for the two states in the future. The results are currently being analyzed and will be presented to Ngerchelong and Kayangel States for use in management of the area.

Protected Area Network Act

The Protected Areas Network (PAN) Act of 2003 aims to support Palauan state government efforts to protect marine resources. This law creates a nationally sanctioned framework by which NGOs and local governments can coordinate marine reserve conservation initiatives through a system of protected areas, which collectively preserve marine biodiversity. It is hoped that the PAN Act will encourage the designation of new MPAs by state governments. Until recently, state governments have designated MPAs, but there was no system for collaboration and support from the national government in identifying appropriate areas or designating and maintaining these resources. A PAN coordinator was appointed to facilitate the implementation of this law. With technical assistance from TNC in the form of a PAN counterpart, the state governments will have access to technical expertise and financial resources that are often lacking at the local level to properly develop MPAs. Recently, the PAN office finalized the drafting of the regulations, which are a requirement under the PAN Act and a precondition for nominating sites for the PAN. In February 2007, the Minister of Resources and Development signed the regulations, and the PAN office has started to assists the states in nominating existing sites for the PAN.

The results of the sustainable financing study, which was completed in 2005/2006, formed the basis for the ongoing revision of the PAN Act to ensure sustainable financing of the PAN. The draft revised PAN Act also ensures that traditionally designated areas are eligible for inclusion. In addition, the revised Act also recognizes that the PAN represents the implementation of the Micronesia Challenge in Palau. The revised PAN Act is currently under consideration by the House of Delegates.

Micronesia Challenge

In March 2006, at the Eighth Conference of the Parties to the Convention on Biological Diversity (CBD), the leaders of the five political entities of Micronesia (Palau, Federated States of Micronesia, Marshall Islands, Northern Mariana Islands and Guam) launched the Micronesia Challenge: a shared commitment to “effectively conserve at least 30% of the nearshore marine and 20% of the forest resources across Micronesia by 2020.” This commitment will contribute to global and national targets set out in the Millennium Development Goals, Johannesburg Plan of Implementation for the World Summit on Sustainable Development, Mauritius Strategy for Small Island Developing States, U.S. Coral Reef Task Force National Plan of Action and relevant Programmes of Work of the CBD. In order to implement the Micronesia Challenge, leaders, resource managers, community representatives and technical experts from around the region participated in a planning meeting in Palau in December 2006. The objectives of the meeting included: designating regional coordinating and fundraising mechanisms; establishing sustainable financing mechanisms; developing a clear understanding of the terms of the Micronesia Challenge; establishing key targets and milestones to measure progress region-wide; identifying additional skills and knowledge that will be required for successful implementation; and developing a plan for expanding communication and interaction with local communities and traditional leadership. The Micronesia Challenge provides a once-in-a-generation opportunity to significantly “ramp up” biodiversity conservation efforts in Micronesia. In light of this, a team of key regional, international and U.S. federal agency partners has been formed to assist jurisdictions on their implementation efforts.

MPA Effectiveness

PICRC is currently conducting research to assess the efficacy of several MPAs in Palau. In 2007, TNC was invited to assess the effectiveness of the Rock Islands Southern Lagoon management plan three years after its implementation. Additionally, TNC along with PICRC conducted a day long workshop to underscore the importance of considering management efficacy during the initial stages of plan development. In the future, MPAs will be selected based on the level of management, geographic distribution, size, the protection time frame, and willingness of managers and community members to be evaluated. Ultimately, the objective is to improve the management of MPAs in Palau, thereby making MPAs more effective in meeting their goals and objectives.

PCS, in partnership with TNC, has also established several monitoring sites in four community-designated MPAs in Babeldaob. The monitoring program tracks the abundance of locally important fish and invertebrate species (Table 16.15).

Other Management Tools

The Palau BMR has deployed fish aggregating devices in territorial waters around Palau in order to take fishing pressure off the reefs and promote a shift to pelagic fisheries. Mooring buoys have been installed throughout the state of Koror as a management tool to decrease recreational impacts on coral reefs. Mooring buoys are well used by dive operators, recreational fishers and boaters. Outside MPAs and other managed areas with very specific regulations, fishing is nationally regulated. Size restrictions exist for lobster. Recently the government enacted a bill fully protecting the humphead wrasse and bumphead parrotfish. The harvest of grouper is restricted to non-peak spawning months and the season is well established. Additionally, the commercial export of reef fish and crustaceans is prohibited. Other restrictions are in

Table 16.15. Community-designated Conservation Areas. Source: PICRC.

MARINE PROTECTED AREA	STATE GOVERNMENT	INDICATORS
Ngelukes Conservation Area	Ngchesar State	Reef fish and invertebrate species abundance (rabbitfish, snappers, surgeonfish, giant clams and sea cucumbers)
Ngermasech Conservation Area	Ngardmau State	Reef fish and invertebrate species abundance (rabbitfish, snappers, surgeonfish, giant clams and sea cucumbers)
Ebiil Channel Conservation Area	Ngarchelong State	Abundance of groupers at spawning aggregation sites
Ngaruangel Reserve	Kayangel State	Fish abundance, occurrence of nesting sea turtle and sea bird populations

place, such as a closed season on harvesting sea turtles and full protection for dugongs in Palau.

Regional Collaboration

For the past three years, PICRC, through the support of NOAA and Japan International Cooperative Agency, has conducted coral reef monitoring training for all of the Freely Associated States (Republic of Palau, Federated States of Micronesia and The Marshall Islands)

From 2005 to 2007, NOAA's Coral Reef Conservation Program and PICRC collaborated with local, regional, and international organizations to build capacity in coral reef ecosystem monitoring in the Freely Associated States of Micronesia. Micronesia is one of the most diverse and resilient coral reef regions in the world and arguably one of the better investments for coral reef conservation. A bottom-up approach was emphasized, focusing on relationship-building and skill development over three years. Forty-three members of Micronesia's governmental regulatory agencies (e.g., Marine Resources Division and Environmental Protection Agencies), local NGOs, and academic institutions were trained over three summers in coral and fish taxonomy, reef sampling methods, experimental design, statistical analyses, database management and reporting. Through continued support from NOAA's National Coral Reef Ecosystem Monitoring Program, the states of Chuuk, Kosrae, Palau, Pohnpei, and Yap and the Republic of Marshall Islands are now beginning to implement a standardized monitoring protocol to monitor their coral and fish resources. This type of monitoring program, combined with traditional management practices in Micronesia, will provide long-term ecosystem-based management in this coral reef setting.

OVERALL CONCLUSIONS AND RECOMMENDATIONS

Efforts to assess biological and physical aspects of coral reef ecosystems and marine resources in Palau have improved since 2005 edition of this report. Since social, cultural, economic and political factors were identified as extremely important to the success of management strategies, PICRC has taken the lead in coral reef monitoring in and around MPAs. PCS has implemented complementary efforts and leads efforts to assess fish abundance in all the MPAs at the request of communities around Palau. Different organizations are also taking part in both the biological and physical assessment of the reefs and marine resources around Palau.

As Golbuu et al. stated in the 2005 report, the importance of improving communication among the different agencies and groups that are involved in coral reef monitoring, management and conservation at all levels should be considered. To eliminate duplication of work in each community and the resulting frustration by community members, collaboration among agencies and organizations should be improved.

REFERENCES

Andrew, W. 2007. Long-term Monitoring at Helen Reef Atoll, Palau. pp 51-58. In: H. Kayanne, M. Omuri, K. Fabricius. E. Verheij, P. Colin, Y. Golbuu, and H. Yukihira (eds.). Coral Reefs of Palau. Palau International Coral Reef Center. Koror, Palau. 231 pp.

Brazaitis, P.J., J. Eberdong, and P.J. Brazaitis. 2003. The Saltwater Crocodile, *Crocodylus porosus*, in the Republic of Palau. A special report to the U.S. Fish and Wildlife Service and The Nature Conservancy. 23 pp.

Bryant, D., L. Burke, J. McManus, and M. Spalding. 1998. Reefs at Risk: A map-based indicator of threats to the world's coral reefs. World Resources Institute. 56 pp.

Bureau of Marine Resources. 2005. Draft Report. Palau Ministry of Resources and Development. Koror, Palau. 32 pp.

Bureau of Marine Resources. Unpublished database. Palau Ministry of Resources and Development. Koror, Palau.

Colin, P.L. 1997. Report of visit to the location of the grounding of the container ship Kyowa Violet, Ngeremlengui State, Republic of Palau, August 4, 1997. Report to Palau Environmental Quality Protection Board. Koror, Palau. 4 pp.

Colin, P.L. 2006a. Preliminary report on reef damage due to the grounding of the USNS Niagara Falls, Ngatpang State, Republic of Palau. Report to Ngatpang State Government, Republic of Palau. 10 pp.

Colin, P.L. 2006b. Preliminary report on reef damage due to the grounding of Tawinese naval frigate 1103 on a coral reef, Ngatpang State, Palau. Report to Ngatpang State Government, Republic of Palau. 5 pp.

Colin, P.L. 2007. Update (January 2007) on the October 2005 Grounding of the USNS Niagara Falls, Ngatpang State, Republic of Palau. Report to Ngatpang State Government, Republic of Palau. 8 pp.

Eberdong, J. Bureau of Marine Resources, Ministry of Resource and Development. Koror, Palau. Personal communication.

Golbuu, Y. 2000. Status of Coral Reefs of Palau. PCC-CRE Publication 19/00. Palau Community College. Koror,Palau, 54 pp.

Golbuu, Y., G. Mereb, D. Uehara, A. Bauman, and J. Umang. 1999. Biological survey at Ngerumekaol, Koror State, Republic of Palau. PCC-CRE Publication 17/99. Palau Community College. Koror, Palau. 23 pp.

Golbuu, Y., A. Bauman, J. Kuartei, and S. Victor. 2005. The State of Coral Reef Ecosystems of Palau. pp. 488-507. In: J.E. Waddell (ed.). The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005. NOAA Technical Memorandum NOS NCCOS 11. 522 pp.

Golbuu, Y., K.E. Fabricius, and K. Okaji. 2007a. Status of Palau's coral reefs in 2005, and their recovery from the 1998 bleaching event. pp. 40-50. In: H. Kayanne, M. Omuri, K. Fabricius. E. Verheij, P. Colin, Y. Golbuu, and H. Yukihira (eds.). Coral Reefs of Palau. Palau International Coral Reef Center. Koror, Palau. 231 pp.

Golbuu, Y., S. Victor, L. Penland, D. Idip Jr., C. Emaurois, K. Okaji, H. Yukihira, A. Iwase, and R. van Woesik. 2007b. Palau's coral reef show differential habitat recovery following the 1998-bleaching event. Coral Reefs 26: 319-322.

Harvell, C., K. Kim, J. Burkholder, R. Colwell, P. Epstein, D. Grimes, E. Hofmann, E. Lipp, A. Osterhaus, R. Overstreet, J. Porter, G. Smith, and G. Vasta. 1999. Emerging marine diseases: Climate links and anthropogenic factors. Science 285(5433): 1505-1510.

Kayanne, H., M. Omori, K. Fabricius, E. Verheij, P. Colin, Y. Golbuu, and H. Yukihira (eds.). 2007. Coral Reefs of Palau. Palau International Coral Reef Center. Koror, Palau. 231 pp.

Kitalong, A. and J. Eberdong. 2006. Palau Marine Turtle Conservation and Management Project. Palau Bureau of Marine Resources. Koror, Palau. 69 pp.

Klain, S. Bureau of Marine Resources, Ministry of Resource and Development. Koror, Palau. Personal Communication.

Maragos, J.E., C. Birkeland, C. Cook, K. Des Rochers, R. Di Rosa, T.J. Donaldson, S.H. Geermans, M. Guilbeaux, H. Hirsh, L. Honigman, N. Idechong, P.S. Lobel, E.Matthews, K.J. McDermid, K.Z. Meier, R. Myers, D. Otobed, R.H. Richmond, B. Smith, and R. Smith. 1994. Marine and Coastal Areas Survey of the Main Palau Islands: Part 2 Rapid Ecological Assessment Synthesis Report. Prepared by CORIAL and The Nature Conservancy. 125 pp.

Matthews, L. 2004. Subsistence Fishing Activities in the Rock Islands. Palau Conservation Society. PCS Report No. 2004-01.

Palau Conservation Society. 1999. Resource surveys of Ngemai Reef, Ngiwal, 1997-1998. PCS Report 99-01. 16 pp.

Palau International Coral Reef Center. 2006. Rapid Assessment of ship grounding (Kamaneka 212) at Techeraech Reef on Uchelbuu Barrier Reef. Palau International Coral Reef Center. Koror, Palau.

Palau Visitors Authority. 2001. Comprehensive exit survey analysis report. Palau Visitors Authority Report. 45 pp.

Ridep-Morris, A. 2004. Coastal Fisheries National Report for the Republic of Palau.

Tervet, I. 2005. Operation Big Eye - Marine Law Enforcement Report. Republic of Palau.

The Environmental, Inc. (TEI). 1999. Palau Inshore Fisheries Profile TEI Publication #0499 26 pp.

The Environmental, Inc. (TEI). 2003. Resource Use Study. Office of Environmental Response and Coordination.

The Palau Conservation Society. 2000. Profiles of Palau's Inshore Fisheries, 1989-1998. 28 pp.

Victor, S., Y. Golbuu, E. Wolenski, and R.H. Richmond. 2004. Fine Sediment Trapping in Two Mangrove-Fringed Estuaries Exposed to Contrasting Land-Use Intensity, Palau, Micronesia. Wetlands Ecol. Manage. 12: 277-283.

Willis, B. James Cook University, Townsville, Australia. Personal Communication.

Willis, B.L., C.A. Page, and E.A. Dinsdale. 2004. 3. Coral disease on the Great Barrier Reef. pp. 69-104. In: E. Rosenberg and Y. Loya (eds.). Coral Health and Disease. Springer, Berlin, Heidelberg, New York. 488 pp.

Yukihira, H., K. Shimoike, Y. Golbuu, T. Kimura, S. Victor, and H. Ohba. 2007. Coral Reef Communities and Other Marine Biotopes in Palau. pp. 10-29. In: H. Kayanne, M. Omuri, K. Fabricius. E. Verheij, P. Colin, Y. Golbuu, and H. Yukihira (eds.). Coral Reefs of Palau. Palau International Coral Reef Center. Koror, Palau. 231 pp.