Seagrasses

Pohnpei Island & Ahnd Atoll Marine Assessment

26 October – 3 November 2005

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Department Primary Industries & Fisheries

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EXECUTIVE SUMMARY

- This was the first detailed survey of seagrass resources surrounding Pohnpei Island and Ahnd Atoll, Pohnpei State, Federated States of Micronesia.
- The survey involved examination of 508 ground truth points and identified 260 individual meadows.
- 3 species of seagrass (*Cymodocea rotundata*, *Enhalus acoroides* and *Thalassia hemprichii*) were identified in the shallow waters surrounding Pohnpei Island, and 2 species at Ahnd Atoll (*Enhalus acoroides* was absent).
- 4,403.6 ±324.3 hectares (ha) of predominately intertidal and shallow subtidal seagrass meadows were mapped in the waters surrounding Pohnpei Island and Ahnd Atoll between 26 October and 3 November 2005.
- 21.3 ±11.8 hectares (ha) of seagrass was mapped in 8 meadows on the inner fringe of Ahnd Atoll.
- Most seagrasses were found in water less than 3m deep and meadows were monospecific or consisted of multispecies communities, with up to 3 species present at a single location.
- 21 seagrass meadow community types were identified based on species presence and proportion of cover.
- The dominant species encountered were *Enhalus acoroides* and *Thalassia hemprichii*.
- Seagrass distribution appears to be primarily influenced by the degree of wave action (exposure), water clarity and nutrient availability.
- Pohnpei's seagrass habitats can be generally categorised into six habitats: estuaries, sheltered fringing reef, exposed fringing reef, patch reef, barrier reef and atoll.
- Seagrass meadows in the region as a whole are in relatively healthy condition compared to many other regions globally.
- Coastal fringing mangrove communities appear to be generally intact, with only localised impacts.
- High sedimentation/turbidity in coastal waters, primarily the result of watershed runoff and marine extraction activity was identified as a major threat at some locations.
- Other impacts were similarly localised, and included soil erosion related to coastal agriculture (sakau plantations), sewage discharge (human and agriculture), industrial pollution, port/village infrastructure/dwellings and overfishing. Most of these impacts can be managed with appropriate environmental guidelines.
- Future recommendations include: establishing more protected areas, promoting seagrass conservation through development of education resource materials, and establishing a Micronesian monitoring program of seagrass ecosystem health.

INTRODUCTION & BACKGROUND

Pohnpei Island is the capital state of the Federated States of Micronesia (FSM) and lies approximately 5 degrees north of the equator, about halfway between Hawaii and Australia. Pohnpei State consists of the main island of Pohnpei, and the atolls Ngatik, Mokil, Oroluk, Ahnd (*aka* Ant or And), Kapingamarangi, Nukuoro, Pingelap and Pakin. Pohnpei is a volcanic high island which formed five million years ago. According to recent population estimates, there are about 30,000 people on Pohnpei Island. Of these, approximately 7,000 are concentrated in the urban centre of Kolonia. The majority of the population are subsistence farmers and fishers.

The marine habitats of Pohnpei Island include barrier reefs, lagoon patch reefs, inshore fringing reefs, seagrass meadows and mangrove forests. These habitats support a remarkable abundance of unique flora and fauna, some of which is found nowhere else on earth (Pohnpei-CSP 2002). The reefs around Pohnpei vary in condition, with coral cover ranging from 15% to more than 60% (Kelty & Kuartei 2004).

These marine environments also serve as the main source of all inshore fisheries and the most valuable socio-economic livelihood for local inhabitants. However, due to the small geographic scale of the shallow marine areas, the potential for loss is high and management action to preserve a sustainable economy in harmony with the natural resources on both land and its surrounding coasts is paramount (Micronesia 2002; Lindsay and Edward 2000).

To assist with management, the first important stage is to map the coral reefs, seagrass meadows and other benthic habitats with respect to location, type, distribution and abundance (percent cover). With support from the David & Lucile Packard Foundation and US Department of Interior, Office of Insular Affairs, the Conservation Society of Pohnpei has embarked on a program to provide detailed ecological information on Pohnpei's marine environments with the overall strategic objectives of strengthening protected area management both locally and regionally.

SEAGRASS MEADOWS

Seagrass meadows are a significant coastal habitat of Pohnpei. Seagrasses are a functional grouping of vascular flowering plants, which grow fully submerged and rooted in soft bottom estuarine and marine environments. Seagrass are among the few plants that have migrated back to the seas roughly 100 million years ago during the Cretaceous (den Hartog 1970; Larkum and den Hartog 1989). Seagrasses probably evolved from a freshwater hydrophyte (a plant adapted to growing in water or inundated soil) or saltmarsh-type primitive stock (den Hartog 1970).

Seagrasses can survive in a range of conditions encompassing fresh water, estuarine, marine, or hypersaline. There are relatively few species globally (about 60) and these are grouped into just 13 genera and five families. The greatest diversity of seagrasses occurs in the Indo-Pacific region. Global seagrass distribution has been described for most species (den Hartog 1970; Spalding *et al.* 2003). There is now a broad understanding of the range of species and seagrass habitats although shallow sub-tidal and intertidal species distributions are better recorded than seagrasses in water greater than ten metres below MSL. Surveying deeper water seagrass is time consuming and expensive and it is likely that areas of deepwater seagrass are still to be located (Lee Long *et al.* 1996).

Seagrasses rank as one of the major marine ecosystems on world terms. In the last few decades, seagrass meadows have received greater attention with the recognition of their importance in stabilising coastal sediments, providing food and shelter for diverse organisms, as a nursery ground for fish and invertebrates of commercial and artisanal fisheries importance, as carbon dioxide sinks and oxygen producers, and for nutrient trapping and recycling. Seagrass are rated the third most valuable ecosystem globally (on a per hectare basis) and the average global value for their nutrient cycling services and the raw product they provide has been estimated at US$19,004 ha^{-1} yr^{-1} (in 1994 dollars) (Costanza *et al.* 1997). This value would be significantly greater if the habitat/refugia and food production services of seagrasses were included.

Tropical seagrasses are also important in their interactions with mangroves and coral reefs. All these systems exert a stabilizing effect on the environment, resulting in important physical and biological support for the other communities. Seagrasses slow water movement, causing suspended sediment to fall out, and thereby benefiting corals by reducing sediment loads in the water. Worldwide there is a concern that seagrass meadows are being lost from coastal areas due to both natural and anthropogenic disturbances (Spalding *et al.* 2003).

SEAGRASSES OF POHNPEI

It is generally accepted that there are three species of seagrass (*Cymodocea rotundata, Enhalus acoroides* and *Thalassia hemprichii*) in the waters surrounding Pohnpei and two species (*Cymodocea rotundata* and *Thalassia hemprichii*) from Ahnd Atoll (Hodgson & McDermid 2000; Tsuda *et al.* 1977; Lobban *&* Tsuda 2003; McDermid & Edward 1999; Mukai and Aioi 1990; Green & Short 2003; Coles and Kuo 1995; Coles & Lee Long 1999). Although Mukai (1993) reported four to five seagrass species from Pohnpei (including *Thalassia hemprichii, Cymodocea rotundata, Cymodocea serrulata, Enhalus acoroides* and *Syringodium isoetifolium*), there are no validated records from herbarium collections or available scientific literature to support this.

In 1984 the US Army Corps of Engineers, Pacific Ocean Division conducted the first marine resource assessment of Pohnpei and mapped approximately 1,273 ha of seagrass in the intertidal and shallow subtidal waters (US Army Corps of Engineers 1985; hectare estimate from reconstructed GIS). Between 1994 and 1997, Hodgson & McDermid (2000) examined marine plants from 20 locations around Pohnpei and 11 at Ahnd Atoll. However, they only reported seagrass from 9 of the 31 sites examined.

In 2002, two Seagrass-Watch monitoring sites were established at the south-eastern reef flats at Nan Madol, and changes in the seagrass communities are being monitored (McKenzie *et al.*, 2006; Coles *et al.* 2005). Results indicate that the meadows appear to be in a fair condition, with little or no change between years (www.seagrasswatch.org).

Consequently, in 2005 a survey team was formed comprising local and international scientists to conduct a rapid ecological assessment of Pohnpei's marine life including coral reefs, reef fishes and seagrass meadows (Turak & DeVantier 2005). The primary goal of this survey was to provide a comprehensive inventory of seagrass species and to map their distribution around Pohnpei Island and Ahnd Atoll.

METHODOLOGY

Pohnpei Island is roughly 20km in diameter and has a land area of approximately 334 km^2 (Holthus 1985; Lindsay & Edward 2000). The island is surrounded by a complex reef and lagoon system. A deep lagoon encircles most of Pohnpei except along the southeast side where there is a continuous fringing reef platform. Numerous patch reefs of various sizes and shape and a few basalt islands with fringing reefs dot the lagoon.

The climate on Pohnpei is wet tropical, with an annual rainfall approaching or exceeding 5,000 mm on the coast and estimated to exceed 10,000 mm in upland areas. Temperature varies little throughout the year, averaging 27°C. Humidity is high, especially from May to October when the trade winds cease to blow. Tidal fluctuation on Pohnpei has a 0.7 m mean and 1.0 m diurnal range. Because of high rainfall, there are many significant perennial river systems on Pohnpei.

Pohnpei State includes 8 nearby smaller island and atolls, however apart from Ahnd Atoll these were outside the boundaries of the scope of the assessment and were not included in this report.

SURVEY STRATEGY

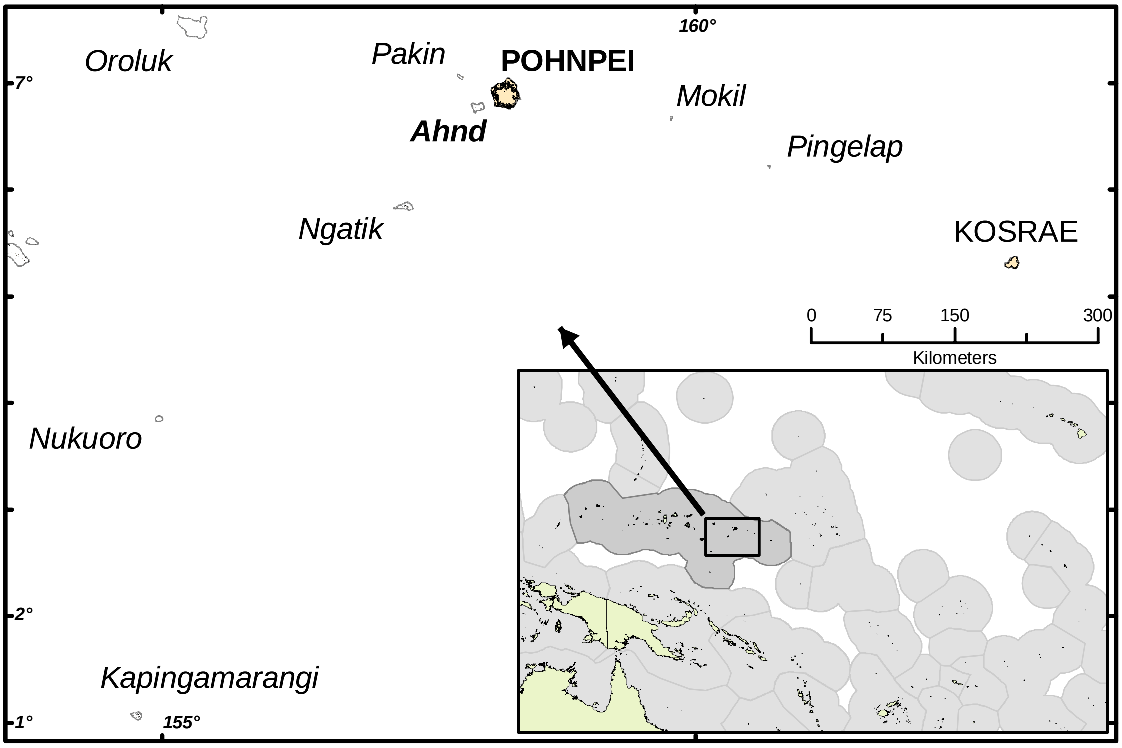
The survey focused on the main island of Pohnpei State, and included Ahnd Atoll (Figure 1). The survey was conducted from 26 October to 3 November 2005, and primarily focused on providing detailed information (distribution & abundance) on intertidal and shallow subtidal seagrass ecosystems in the region.

Intertidal and shallow sub-tidal areas were surveyed using a boats and free-diving. Benthos was examined at points which extended from the upper intertidal to depths beyond the outer edge of seagrass meadows (usually 5-6m). Some locations were surveyed at a lower intensity, with points >1 km apart, but sufficient to map and describe the major seagrass habitats.

DATA COLLECTION

Seagrass habitat characteristics including visual estimates of above-ground percentage cover (3 replicates of a 0.25 m^2 quadrat), species composition, % algae cover, sediment type were recorded at each point according to the Seagrass-Watch standard methodologies (McKenzie *et al.* 2001; www.seagrasswatch.org). A Global Positioning System (GPS) was used to accurately determine geographic location of sampling points (±5 m). Seagrass species were identified where possible according to Waycott *et al.* (2004) and voucher specimens were collected for taxonomic verification. Algae were identified into broad taxonomic groups in the field, although the taxonomic level extended to genus or species depending on the knowledge of the observer. Depths of survey sites were estimated by the diver and field descriptions of sediment type from hand or grab samples were recorded for each site: shell grit, rock gravel, coarse sand, sand, fine sand and mud.

FIGURE 1. Location of Pohnpei Island, Ahnd Atoll and the outlying atolls of Pohnpei State, Federated States of Micronesia.



Seagrass community types were determined by dominant seagrass species found within each meadow (Table 1) and their landscape structure (Figure 2). Seagrass habitat types were determined by species composition and physical attributes (i.e. intertidal or subtidal, coastal or fringing reef) influencing each seagrass community.

TABLE 1. Nomenclature for seagrass community types.

Community type	Species composition
Species A	Species A is 100% of composition
Species A with Species B	Species A is 60% of composition
Species A with Species B/Species C	Species A is 50% of composition
Species A/Species B	Species A is 50% - 60% of composition

FIGURE 2. Seagrass meadow patchiness categories used in the seagrass survey.

Isolated seagrass patches - The majority of area within the meadows consisted of unvegetated sediment interspersed with isolated patches of seagrass.

Aggregated seagrass patches - Meadows are comprised of numerous seagrass patches but still featured substantial gaps of unvegetated sediment within the meadow boundaries.

Continuous seagrass cover - The majority of area within the meadows was comprised of continuous seagrass cover interspersed with a few gaps of unvegetated sediment.

GEOGRAPHIC INFORMATION SYSTEMS (GIS)

A GIS of seagrass community distribution was created in ArcGIS® using the above survey information (see Appendix 1). A CD-Rom copy of the GIS with metadata has been archived at CSP offices and the original archived with the custodians (DPI&F) at the Northern Fisheries Centre, Cairns, Australia.

Errors in GIS maps include those associated with digitising and rectifying basemaps and with Global Positioning System (GPS) fixes for survey sites. The point at which divers estimated bottom vegetation may be up to 5 m from the point at which a GPS fix was obtained. These errors are considered to be within the errors associated with distance between survey sites.

In the survey, each seagrass meadow was assigned a qualitative mapping value, determined by the data sources and likely accuracy of mapping. Boundaries of seagrass habitat were interpreted using one or more of the following: seagrass data at each dive site, extent of habitat visible from the vessel, aerial photography, satellite imagery and bathymetry. Boundaries of meadows in intertidal depths were usually mapped with greatest reliability. Boundaries in sub-tidal depths were mapped with less reliability because of a) very gradual changes in habitat and b) poor underwater visibility. Estimates of reliability (R) (McKenzie *et al*. 2001) in mapping meadow boundaries ranged from 5 m to 15 m.

POHNPEI SEAGRASS MEADOWS & HABITATS

Three seagrass species were recorded/collected from the intertidal and shallow subtidal waters surrounding Pohnpei Island and Ahnd Atoll, between 26 October and 3 November 2005. They included:

Family **CYMODOCEACEAE** Taylor

Cymodocea rotundata Ehrenb. & Hemp. Ex Aschers

Family **HYDROCHARITACEAE** Jussieu

Enhalus acoroides (L. *f*) Royle

Thalassia hemprichii (Ehrennb.) Aschers in Petermann

Seagrass was present at 88% of ground truth points examined between 26 October and 3 November 2005 (Map 1). 4,403.6 ±324.3 hectares (ha) of seagrass was mapped in the intertidal and shallow subtidal waters surrounding Pohnpei Island and Ahnd Atoll. 260 individual meadows were identified and mapped from 508 ground truthed points.

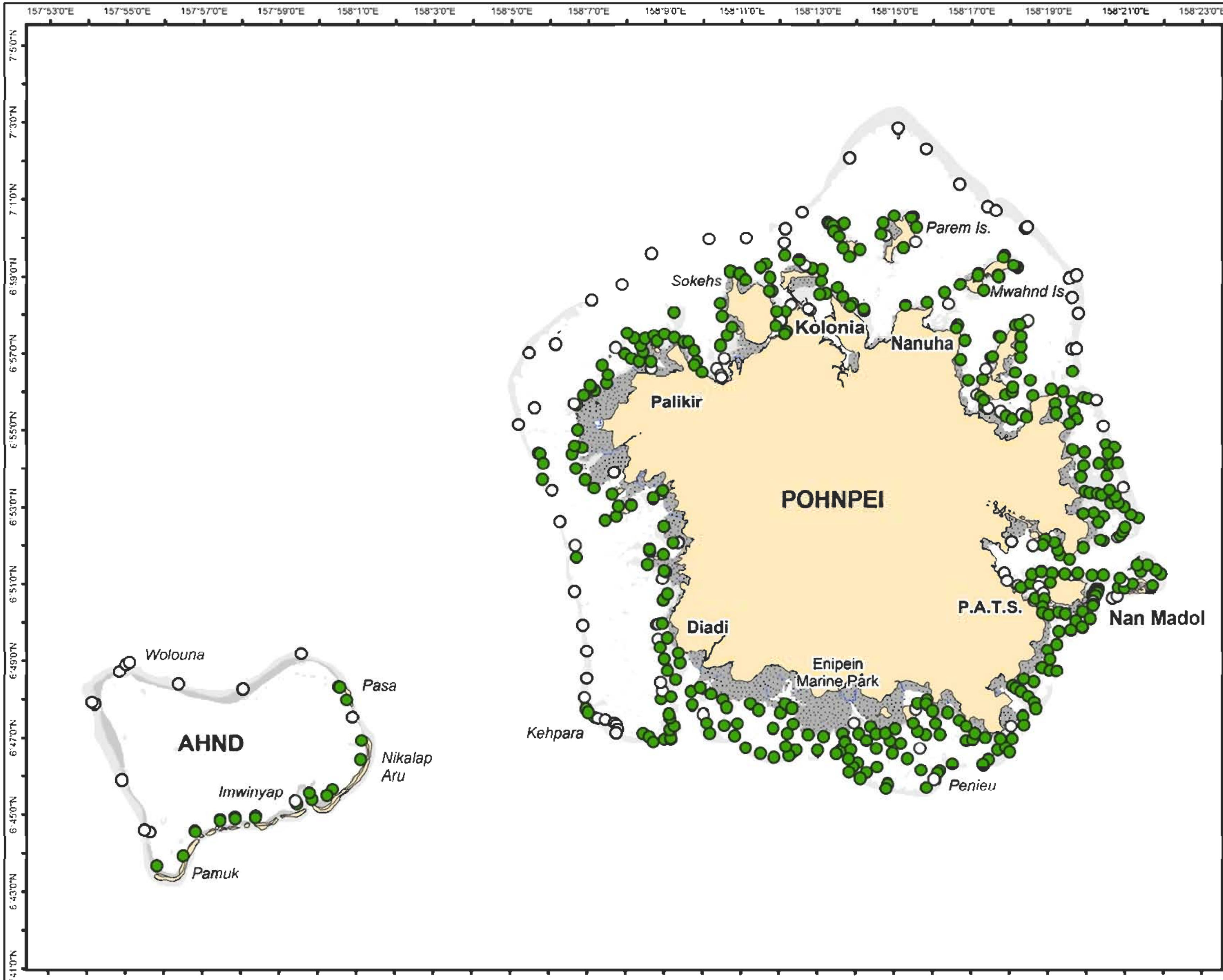
Plate 1.

Plate 2.

Extensive intertidal and shallow subtidal meadows were present around the entire island of Pohnpei. 21 seagrass meadow communities were identified, based on the relative composition of species present. Meadows were located predominately on fringing reef platforms (83% of area) and mostly continuous in landscape structure (62% of all meadow area) (Table 2). Dense stands of mangroves (*Rhizophora*) bordered the mainland side of fringing reefs, particularly on the south western side of the main island. Inside the reef crest of fringing reefs, *Thalassia* and *Cymodocea* meadows dominate (<1 m depth) on coarse sand, shell, reef substrate associated with *Halimedia*/*Padina* and turf algae. Aggregated patches of *Enhalus acoroides* dominated the landward edge of the fringing reefs, bordering the mangroves.

Seagrass meadows dominated by *Thalassia hemprichii* were the most common, comprising approximately 69% of area of all meadows encountered. The most dominant single seagrass community (36%) was *Thalassia hemprichii* dominated meadows with patches of *Enhalus acoroides*. Meadows of the greatest cover were generally dominated by *Cymodocea rotundata*, however the meadow with the highest cover (mean = 88.3%) was a relatively small *Enhalus acoroides*/*Thalassia hemprichii* meadow on the western side of Ros Island (Kitti).

Map 1. Seagrass ground truth sites - Pohnpei Island & Ahnd Atoll - 26 Oct - 03 Nov 2005



Legend

Ground truth sites

- Seagrass absent
- Seagrass present

Source: McKenzie, L.J. and Rasheed, M.J. (2006). Seagrasses: Pohnpei Island and Ahnd Atoll Marine Assessment: Technical report of survey conducted 26 October - 3 November 2005. (Seagrass-Watch, DPI&F, NFC, Cairns), 60pp.

 The survey is a cooperative project of the Conservation Society of Pohnpei (CSP), Pohnpei Division of Marine Development, The Nature Conservancy, Queensland Department of Primary Industries & Fisheries and Seagrass-Watch. The survey was funded by Packard Foundation and US Department of Interior, Office of Insular Affairs.

Produced by Seagrass-Watch HQ, NFC, 2006.

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Queensland Government
Department of Primary Industries and Fisheries

Projection: WGS 1984 UTM Zone 57N

0 3 6 9
Kilometres

N

Along the parts of the coastline, which are protected by the outer barrier reef, the waters are generally more turbid and the size of the meadows dependent on the size of the fringing or patch reef. Much of the coast in these sheltered waters is fringed by dense mangroves and rivers which drain steep watersheds into the lagoon. The turbidity of the coastal waters may be a consequence of deforestation (e.g., sakau planting) activities. Although the seagrass meadows may be continuous and extend over entire platform, the general pattern seaward from the mangroves was *Enhalus acoroides* dominated, to *Cymodocea rotundata* dominated and then to *Thalassia hemprichii* dominate before the reef crest.

TABLE 2. Meadow categories, total area (hectares) and numbers of intertidal/shallow subtidal meadows for Pohnpei Island and Ahnd Atoll – October/November 2005.

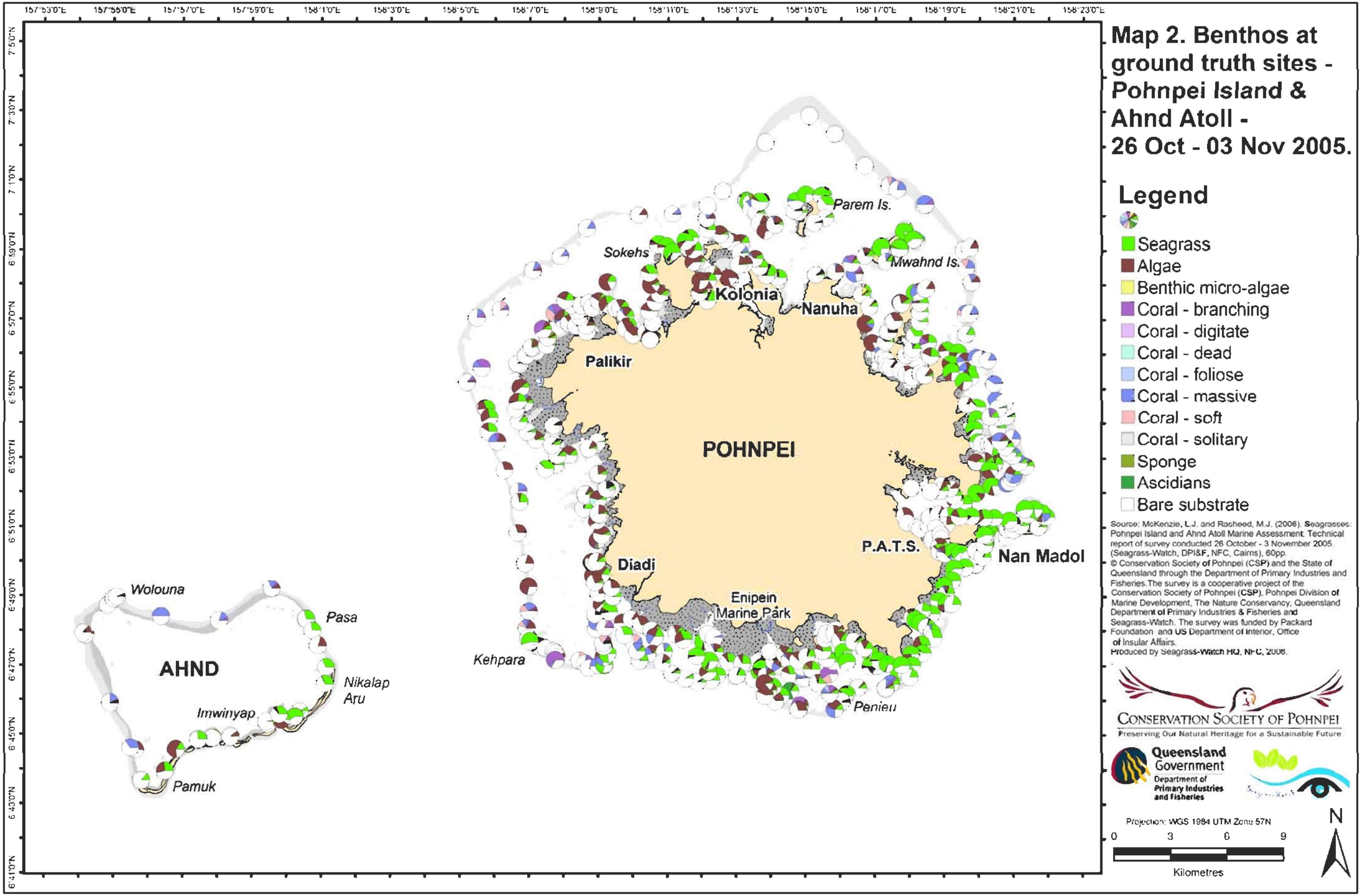
CATEGORY	Cover ±SE (range) (%)	Area in hectares (number of meadows) Isolated seagrass patches	Aggregated seagrass patches	Continuous seagrass cover	Total (ha)
C.rotundata	25.8 ±6.7 (12-37)			*5.4 (3)*	*5.4*
C.rotundata with *E.acoroides/T.hemprichii*	38.1 (9-60_			*67.9 (1)*	*67.9*
C.rotundata with *T.hemprichii*	36.3 ±4.9 (1-70)		*8.2 (1)*	*28.4 (6)*	*36.6*
C.rotundata with *T.hemprichii* & *E.acoroides*	36.8 ±4.3 (10-75)		*10 (2)*	*28.4 (5)*	*38.4*
C.rotundata with *T.hemprichii/E.acoroides*	34.1 ±4.8 (0-65)		*21.3 (4)*	*52.2 (6)*	*73.5*
C.rotundata/E.acoroides	37 (0-10)		*0.1 (1)*		*0.1*
C.rotundata/T.hemprichii	16.7 (13-22)			*7.2 (2)*	*7.2*
C.rotundata/T.hemprichii with *E.acoroides*	44.0 ±4.5 (25-60)			*53.2 (3)*	*53.2*
C.rotundata/T.hemprichii/E.acoroides	65 (60-70)		*2.4 (3)*	*3.4 (2)*	*5.8*
Enhalus acoroides	5.4 ±1.0 (0-35)	*41.9 (15)*	*215.2 (23)*	*118.1 (15)*	*375.2*
E.acoroides with *T.hemprichii*	11.6 ±3.1 (0-80)	*6.2 (1)*	*118.4 (20)*	*280.4 (18)*	*405*
E.acoroides with *T.hemprichii* & *C.rotundata*	13.3 (0-45)			*240.8 (1)*	*240.8*
E.acoroides/T.hemprichii	88.3 (85-90)			*0.9 (1)*	*0.9*
T.hemprichii	15.1 ±2.0 (0-80)		*619.8 (18)*	*398.9 (19)*	*1018.7*
T.hemprichii with *C.rotundata*	29.6 ±11.4 (0-90)		*13.2 (6)*	*23 (3)*	*36.2*
T.hemprichii with *C.rotundata/E.acoroides*	38.6 ±5.2 (6-80)		*26.7 (5)*	*241.1 (10)*	*267.8*
T.hemprichii with *E.acoroides*	25.0 ±3.0 (0-87)	*0.6 (1)*	*606.8 (33)*	*981.6 (22)*	*1589*
T.hemprichii with *E.acoroides* & *C.rotundata*	11.7 (2-30)			*45.9 (1)*	*45.9*
T.hemprichii with *E.acoroides/C.rotundata*	10.2 ±8.0 (0-25)			*82.9 (2)*	*82.9*
T.hemprichii/C.rotundata/E.acoroides	58.3 (55-60)			*3.2 (4)*	*3.2*
T.hemprichii/E.acoroides	20.4 ±9.6 (0-70)			*49.9 (3)*	*49.9*
Total		**48.7 (17)**	**1642.1 (116)**	**2712.8 (127)**	**4403.6**

Seagrass meadows do not generally grow in isolation, and are often an integral part of a complex ecosystem with connectivity to a number of other habitats, flora and fauna.

Macro-algae

Macro-algae were found to be abundant in approximately 5 locations around Pohnpei Island: *1.* adjacent to Kolonia and within Sokens Harbour; *2*. along the south western mangrove fringes of Kitti; *3*. the southern waters of Uh in the vicinity of Maramosok; *4*. from Mudokolos island to within the inlet in front of P.A.T.S. (Pohnpei Agriculture & Trade School), and; *5*. from the mouth of the Enipein River to Ros Island (Map 2).

Halimeda spp. was the most commonly encountered macro-algae and Chlorophyta. *Halimeda* dominated the algae species composition on the fringing reef platforms and patch reefs surrounding Pohnpei and the sandy lagoon of Ahnd Atoll. Patches of filamentous green algae were observed on the western side of Pohnpei, particularly associated with mangroves on both the barrier reefs and near mouths to rivers/creeks.


Map 2. Benthos at ground truth sites - Pohnpei Island & Ahnd Atoll - 26 Oct - 03 Nov 2005.
Legend
Seagrass
Algae
Benthic micro-algae
Coral - branching
Coral - digitate
Coral - dead
Coral - foliose
Coral - massive
Coral - soft
Coral - solitary
Sponge
Ascidians
Bare substrate
Source: McKenzie, L.J. and Rasheed, M.J. (2006). Seagrasses: Pohnpei Island and Ahnd Atoll Marine Assessment: Technical report of survey conducted 26 October - 3 November 2005. (Seagrass-Watch, DPI&F, NFC, Cairns), 60pp.
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Projection: WGS 1984 UTM Zone 57N
0 3 6 9
Kilometres
N
POHNPEI
Parem Is.
Mwahnd Is.
Sokehs
Kolonia
Nanuha
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Nan Madol
Diadi
Enipein Marine Park
Kehpara
Penieu
AHND
Wolouna
Pasa
Nikalap Aru
Imwinyap
Pamuk


Plate 3.

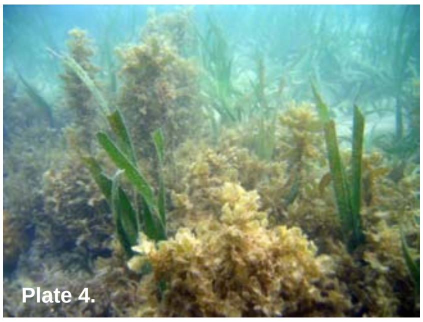


Plate 4.


Plate 5.

Phaeophyta (brown macro-algae) were also common. *Padina* spp. was the second most dominate macro-algal species encountered on the fringing reef platforms and patch reefs surrounding Pohnpei (Plate 3). As *Padina* was mainly associated with massive corals, it was less common on the sandy lagoon floor of Ahnd Atoll. Other common species of Phaeophyta observed included *Sargassum* spp., which were found mainly on fringing reefs adjacent to mangroves on the western side of Pohnpei (Plate 4). Of particular note, was an edible species locally called "noti", most abundant along the southern fringing and patch reefs.

Rhodophyta (red algae), in particular red calcareous, were relatively common on the barrier reefs in the Sokehs region and unidentified Benthic Micro-Algae (BMA) dominated on bare sandy areas, in particular the large sandy flats fringing reef north of Mudokolos Is. and the sandy lagoon of Ahnd Atoll..

The filamentous cyanobacterium *Lyngbya majuscula* was observed near the passages between the barrier reefs at Kepiduen Dawahk on the western side and Kepidautel in the south (Plate 5). Although *Lyngbya* occurs naturally, in some locations globally it is considered noxious, as blooms can smoother benthic habitats (including seagrass), depleting light and sediment oxygen. These toxic blooms can consequently result in death of seagrass and meiofauna (Garcia & Johnstone 2006).

Associated fauna

Branching and massive hard coral varieties were associated with all seagrass meadows around Pohnpei. Although no soft corals were observed within meadows, they did occur on large fringing reef platforms between Nan Madol and Rohi (Map 2).

Holothuria atra (lollyfish) were found in high densities in inshore shallow waters, particularly on large sand flats (Plate 6). The presence of *H. atra* was significantly higher when seagrass was present (Two sample T-Test, T=-8.72, d.f.=305.9, p<<0.01), however there does not appear to be a relationship between the abundance of *H. atr*a and the abundance of seagrass. The commercial holothurian *Holothuria scabra* (sandfish) was observed only in four meadows, all in the north west of Pohnpei – they included the *E. acoroides* dominated meadow adjacent to Paren Island, the large fringing reef of Nantuhtu, the fringing reef of Pohndauauk adjacent to

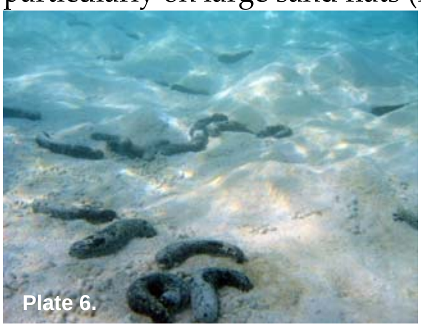


Plate 6.

the causeway and the large fringing reef adjacent to Kittialap. Apart from the fact that seagrass cover was not high in these meadows (generally <30%), there did not appear to be any preference in the seagrass species composition for *H. scabra*.

A number of economically important fish were observed inhabiting or transienting the seagrass meadows (particularly near the mangroves); these included groupers (e.g., *Lutjanus argentimaculatus, Lutjanus fulvus*), emperor (e.g., thumb-print emperor *Lethrinus harak*) (Plate 7), mullets (e.g., *Liza vaigiensis, Valamugil seheli*), rabbitfish (*Siganus* spp.) and goatfish (e.g., *Parupeneus barberinus*). More fish were associated with seagrass meadows in the southern region of Pohnpei between Rohi and Black Coral Island. Highest abundances were observed in the Rohi (inlet) area. Large schools of rabbit fish were also observed feeding amongst the isolated *Enhalus acoroides* patches along the mangrove edge near Pohnrakied (Kolonia)

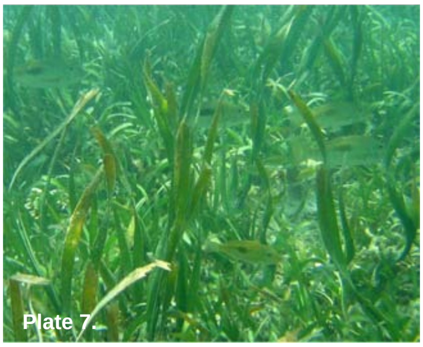


Plate 7.

The most unusual associated fauna that was observed, were large populations of the upside-down jellyfish *Cassiopea andromeda*, within the *Enhalus* dominated (*Thalassia* understory) meadows bordering the mangroves west of Sokehs Harbour and along the mangroves to Pahnak Pwetepwet (near Sekeren Iap village) in the south (Plates 8, 9 & 10). The greatest density was around Kiparalap. *Cassiopea* is commonly found in shallow mangrove swamps, mudflats, and seagrass meadows. Where found there may be numerous individuals with varying shades of white, blue, green and brown. They have a mild sting since they are primarily photosynthetic, but sensitive individuals may have a stronger reaction.

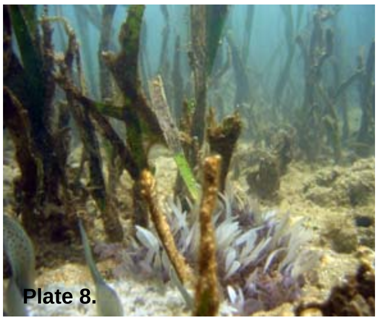


Plate 8.


Plate 9.

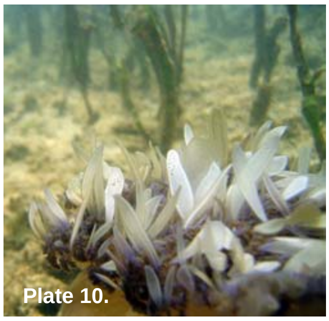


Plate 10.

Mangroves

Well developed mangrove forests were observed around Pohnpei and in some areas extended more than two kilometers from shore. The forests were characterised by channels bordered by large trees with a canopy height of up to 30 metres. Away from the channels, canopy height decreases markedly. Along the channels and toward the leeward edge of the mangrove forest, *Rhizophora stylosa* and *Sonneratia alba* tended to dominate. Other common tree species are *R. apiculata, Xylocarpus granatum, Lumnitzera littorea* and occasionally *Bruguiera gymnorrhiza*.

Turbid waters were observed at a number of locations spread around Pohnpei Island, mostly at the mouths of creeks and bordering the mangrove fringe. The highest turbidities were observed adjacent to all dredging/extraction sites and at other nearshore locations including: within the sheltered harbour in Madolenihmw, Maramosok (Uh), the waters surrounding Kolonia, Sokehs Harbour, Dauen Irendodi (west of Sokehs Harbour), along the south western coast of Kitti and adjacent to Enipein Marine Park (on dark sediment). Generally the highest turbidities were observed in the southern region of Sokehs (in the vicinity of Palikir), within the sheltered harbour in Madolenihmw and Maramosok (Uh).

POHNPEI ISLAND

Approximately 4,382 ±357 hectares (ha) of seagrass was mapped in the intertidal and shallow subtidal waters surrounding Pohnpei Island. Most (82.8%) seagrass meadows were located on fringing reef platforms, with only 16.5% and 0.7% located on barrier reef and patch reefs, respectively.

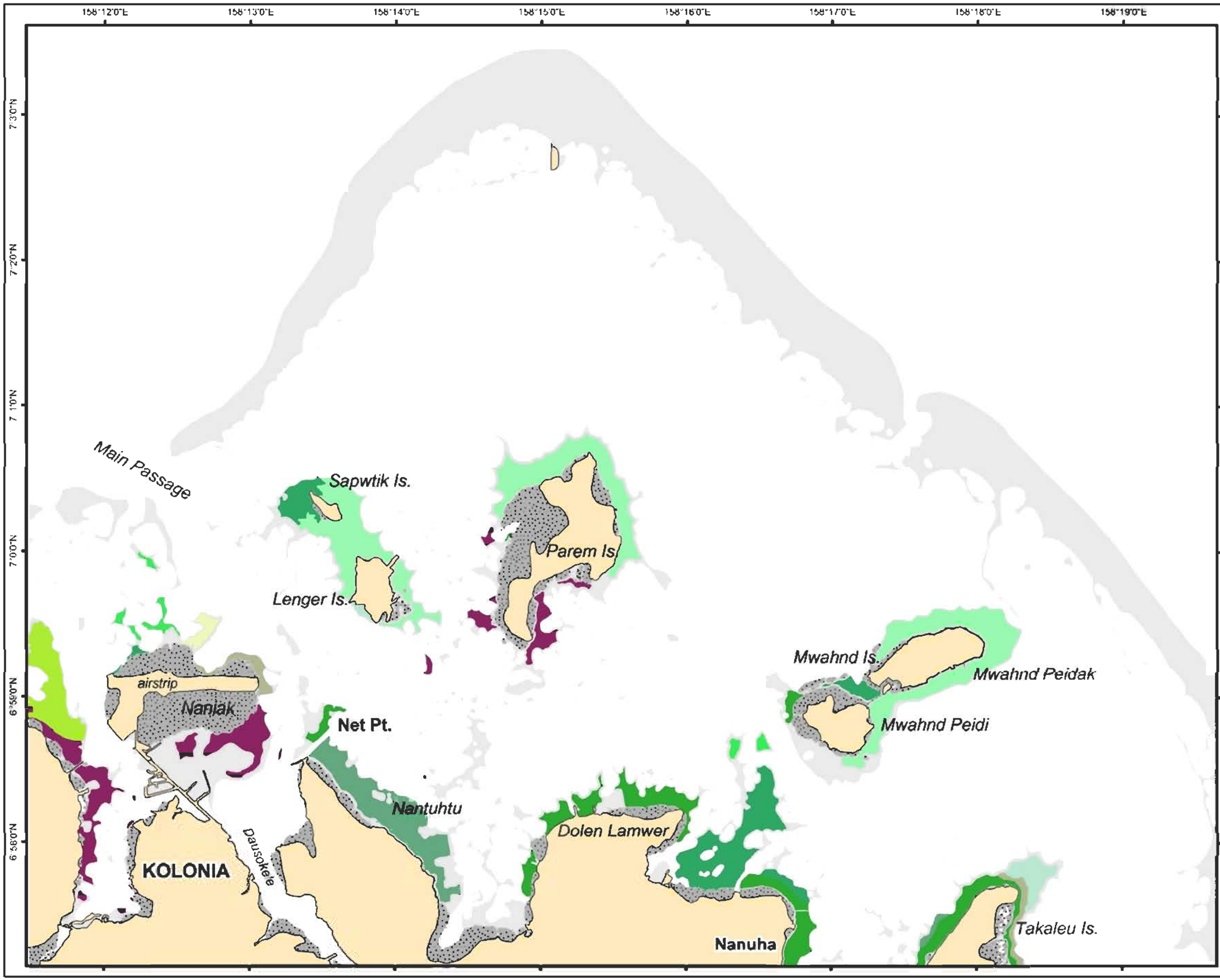
Nett Municipality

7 - 8% of the seagrass meadows surrounding Pohnpei where present within the boundaries of Net municipality. 336.8 ±27.8 hectares of seagrass was mapped in the municipality between 26 - 31 October 2005 (Map 3). 68% of seagrass meadows in the municipality were of continuous cover (Table 3) and located on large intertidal / shallow subtidal reef platforms. Most of the meadows (76%) were *T. hemprichii* dominated, of moderately high cover and often associated with *Halimeda* spp. and *Padina* spp., on coarse sand/shell substrates (<1m depth).

TABLE 3. Meadow categories, total area (hectares) and numbers of intertidal/shallow subtidal meadows within Net Municipality – October 2005.

CATEGORY	Cover ±SE (range) (%)	Area in hectares±R (ha)			Total±R (ha)
		Isolated seagrass patches	Aggregated seagrass patches	Continuous seagrass cover	
C.rotundata with *T.hemprichii*	14.3 (1-32)		8.2±0.9		8.2 ±0.9
C.rotundata with *T.hemprichii/E.acoroides*	8.2 ±6.5 (0-20)		10.1 ±1.6		10.1 ±1.6
E.acoroides	9.4 ±0.1 (0-35)	23.1±3.5	33.9 ±2.8		57 ±6.4
E.acoroides with *T.hemprichii*	8.2 (4-15)		6.1 ±1.1		1.8 ±0.4
T.hemprichii	0.3 (0-1)		1.8 ±0.4		8.1 ±1.9
T.hemprichii with *C.rotundata*	11.5 (0-28)		8.1 ±1.9		8.1 ±1.9
T.hemprichii with *C.rotundata/E.acoroides*	37.9 ±17.1 (7-75)		1.9 ±0.6	19.6 ±1.5	21.5 ±2
T.hemprichii with *E.acoroides*	18.1 ±5.5 (0-75)		14.5 ±2	130 ±7.3	144.5 ±9.3
T.hemprichii with *E.acoroides/C.rotundata*	18.1 ±3.9 (2-25)			79.3 ±4.2	79.3 ±4.2
Total		**23.1 ±3.5**	**84.8 ±11.3**	**228.9 ±13**	**336.8 ±27.8**

The lagoon in this municipality is up to 10 km wide. The landward (Pohnpei Island) edge was dominated by *T. hemprichii* with *C. rotundata* and some *E. acoroides* closer to shore (mean quadrat cover 10-18%, coarse sand/shell sediments). Most meadows covered entire fringing reef platforms (e.g., Nantuhtu) and smaller patch reefs. Inside the protected inlets adjacent to Kolonia, turbidity is higher, and the *E. acoroides* dominated meadows were scattered along the bordering mangroves.



Map 3. Seagrass distribution and community types within Nett & Uh, Pohnpei Island - 26-31 October 2005

Legend

- C.rotundata
- C.rotundata with E.acoroides/T.hemprichii
- C.rotundata with T.hemprichii
- C.rotundata with T.hemprichii and E.acoroides
- C.rotundata with T.hemprichii/E.acoroides
- C.rotundata/E.acoroides
- C.rotundata/T.hemprichii
- C.rotundata/T.hemprichii with E.acoroides
- C.rotundata/T.hemprichii/E.acoroides
- E.acoroides
- E.acoroides with T.hemprichii
- E.acoroides with T.hemprichii and C.rotundata
- E.acoroides/T.hemprichii
- T.hemprichii
- T.hemprichii with C.rotundata
- T.hemprichii with C.rotundata/E.acoroides
- T.hemprichii with E.acoroides
- T.hemprichii with E.acoroides and C.rotundata
- T.hemprichii with E.acoroides/C.rotundata
- T.hemprichii/C.rotundata/E.acoroides
- T.hemprichii/E.acoroides

Source: McKenzie, L.J. and Rasheed, M.J. (2006). Seagrasses: Pohnpei Island and Ahnd Atoll Marine Assessment: Technical report of survey conducted 26 October - 3 November 2005 (Seagrass-Watch, DPI&F, NFC, Cairns), 60pp.
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Kilometres

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Plate 11.


Plate 12.


Plate 13.


Plate 14.

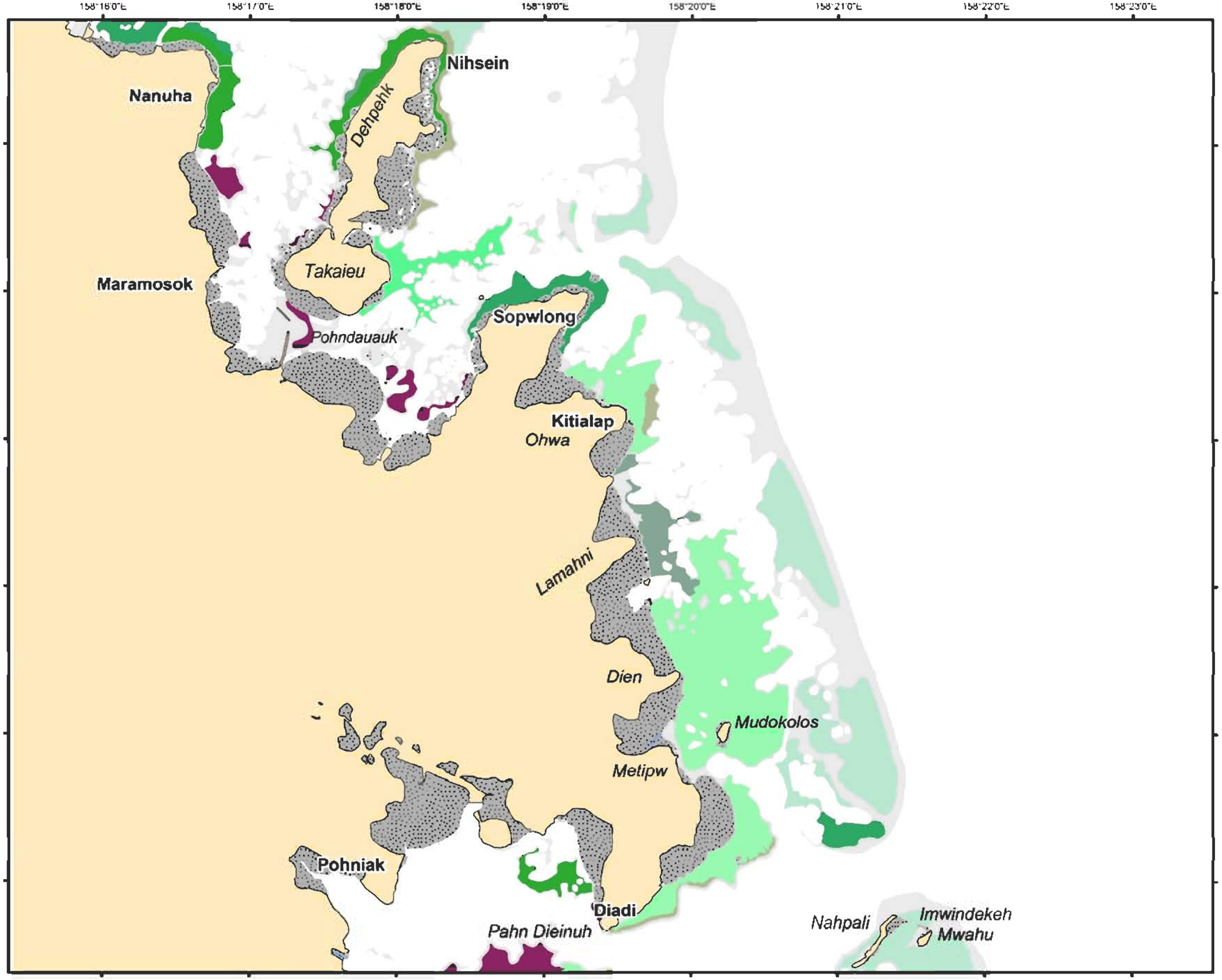
Toward mid-lagoon, larger continuous meadows were found covering the fringing reef platforms of the high lagoon islands of Sapwtik, Lenger, Parempei, Mwahnd Peidak and Mwahnd Peidi. Although the meadows were near continuous in landscape structure, there were distinct species compositional changes across the meadow from the shore to the reef crest. Nearshore, generally bordering mangroves, the meadow was dominated by *E. acoroides*, but often with a mixed *C. rotundata* and *T. hemprichii* understory. Moving seaward, the meadow changed to *C. rotundata* dominated (Plate 11), which changed to *T. hemprichii* dominated closer to the fringing reef crest (Plate 12). In the *C. rotundata* and *T. hemprichii* dominated areas, isolated patches of *E. acoroides* sometimes occurred.

On the western shores of Parem Island, the sediments are very dark and contain a large component of mud. Bordering the mangroves are isolated – aggregated *E. acoroides* meadows. A large continuous *T. hemprichii* with *E. acoroides* meadow surrounded Parem Island covering the entire fringing reef platform (Plate 13), similar to Sapwitik and Lenger Islands. On the eastern side of Parem Island, the reef-flat is well protected behind the reef crest, and the canopy of *E. acoroides* plants was relatively high and the leaves covered by epiphytes (Plate 14).

No seagrasses were found on the outer barrier reefs.

<u>Uh Municipality</u>

Approximately 10% of the seagrass meadows surrounding Pohnpei where present within the boundaries of Uh municipality (Table 4, Maps 3 & 4). 441.1 ±39.9 hectares of seagrass was mapped in the municipality between 26-29 October 2005. 78% of seagrass meadows in the municipality were of continuous cover (Table 4) and located on large intertidal / shallow subtidal reef platforms. Most of the meadows (62%) identified were *Thalassia* dominated communities (<1m depth). Seagrass cover was generally <35% on coarse sand/shell substrates.



Map 4. Seagrass distribution and community types within Uh & Madolenihmw, Pohnpei Island - 26-31 October 2005

Legend

- C.rotundata
- C.rotundata with E.acoroides/T.hemprichii
- C.rotundata with T.hemprichii
- C.rotundata with T.hemprichii and E.acoroides
- C.rotundata with T.hemprichii/E.acoroides
- C.rotundata/E.acoroides
- C.rotundata/T.hemprichii
- C.rotundata/T.hemprichii with E.acoroides
- C.rotundata/T.hemprichii/E.acoroides
- E.acoroides
- E.acoroides with T.hemprichii
- E.acoroides with T.hemprichii and C.rotundata
- E.acoroides/T.hemprichii
- T.hemprichii
- T.hemprichii with C.rotundata
- T.hemprichii with C.rotundata/E.acoroides
- T.hemprichii with E.acoroides
- T.hemprichii with E.acoroides and C.rotundata
- T.hemprichii with E.acoroides/C.rotundata
- T.hemprichii/C.rotundata/E.acoroides
- T.hemprichii/E.acoroides

Source: McKenzie, L.J. and Rasheed, M.J. (2006). Seagrasses Pohnpei Island and Ahnd Atoll Marine Assessment: Technical report of survey conducted 26 October - 3 November 2005 (Seagrass-Watch, DPI&F, NFC, Cairns), 60pp.

 The survey is a cooperative project of the Conservation Society of Pohnpei (CSP), Pohnpei Division of Marine Development, The Nature Conservancy, Queensland Department of Primary Industries & Fisheries and Seagrass-Watch. The survey was funded by Packard Foundation and US Department of Interior, Office of Insular Affairs.

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0 0.8 1.6 2.4
Kilometres

TABLE 4. Meadow categories, total area (hectares) and numbers of intertidal/shallow subtidal meadows within Uh Municipality – October 2005.

CATEGORY	Cover ±SE (range) (%)	Area in hectares±R (ha)			Total±R (ha)
		Isolated seagrass patches	Aggregated seagrass patches	Continuous seagrass cover	
C.rotundata with *T.hemprichii/E.acoroides*	30.6 ±2.5 (23-43)			22.3 ±3.5	22.3 ±3.5
E.acoroides	4.5 ±0.1 (0-12)	9 ±1.6	13.9 ±1.4		22.9 ±3
E.acoroides with *T.hemprichii*	16.9 ±0.5 (0-80)		48.2 ±5.1	73.7 ±7.2	121.9 ±12.3
T.hemprichii	13 ±4 (2-25)		18 ±1.3	18.2 ±1.2	36.3 ±2.4
T.hemprichii with *C.rotundata*	12 (10-15)		5 ±0.7		5 ±0.7
T.hemprichii with *C.rotundata/E.acoroides*	33.9 ±12.8 (11-80)			88 ±5.5	88 ±5.5
T.hemprichii with *E.acoroides*	29.6 ±8.6 (2-80)		2.9 ±0.7	92.4 ±5.2	95.3 ±5.9
T.hemprichii with *E.acoroides* & *C.rotundata*	11.7 ±4.7 (2-30)			45.9 ±5.8	45.9 ±5.8
T.hemprichii with *E.acoroides/C.rotundata*	2.2 ±0.8 (0-4)			3.6 ±0.7	3.6 ±0.7
Total		**9 ±1.6**	**88 ±9.2**	**344.1 ±29**	**441.1 ±39.9**


Plate 15.

Inside the protected inlets (particularly adjacent to Maramsoko) the turbidity was high, the sediments were fine silts and the meadows were aggregated. In these habitats, the seagrasses were dominated by *E. acoroides*, particularly associated with massive hard corals (Plate 15). Along the eastern side of Takaieu Island, the fringing reef is complex in structure, and seagrass covered all sheltered areas which supported sediment deep enough (~5cm) for plants to take root. The meadows were dominated by *E. acoroides* in a 5-25m band that bordered the mangroves. Beyond this band, the meadows were more *T. hemprichii* or *C. rotundata* dominated. On several sites, significant amounts of freshwater were found flowing and mixing with the surface layers.

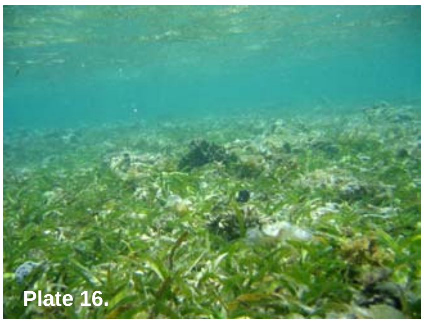


Plate 16.

Similar to Net Municipality, the lagoon in this region of Pohnpei is wide (6-7 km). The fringing reef platforms around the shores of Pohnpei Island were almost entirely covered with aggregated *E. acoroides* and *T. hemprichii* dominant meadows on coarse sand/shell. On the wider platforms and patch reefs, *T. hemprichii* was more dominant.

Larger continuous meadows covered the fringing reef platforms of the Mwahnd Island in the mid lagoon region, similar to Parem Island. These meadows were near continuous, dominated by *E. acoroides* inshore, *C. rotundata* mid platform and *T. hemprichii* closer to the reef crest (Plate 16). Isolated patches of *E. acoroides* sometimes occurred in the *C. rotundata* and *T. hemprichii* dominated areas (Plate 17).

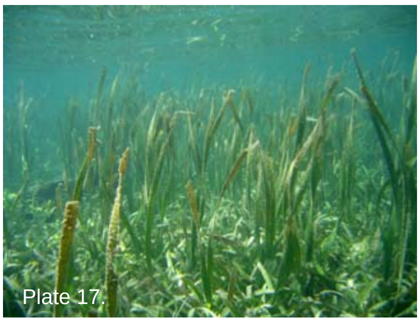


Plate 17.

Madolenihmw Municipality

The greatest area of seagrass meadows (~42%) surrounding Pohnpei where present within the boundaries of Madolenihmw municipality (Maps 3, 4 & 5). This is a consequence of the extensive fringing reef platforms within this municipality. 1,819.6 ±117.7 hectares of seagrass was mapped in the municipality between 27 October and 3 November 2005. Approximately half the seagrass meadows in the municipality were of continuous cover (Table 5) and located on large intertidal / shallow subtidal reef platforms. Most of the meadows (84%) identified were *Thalassia* dominated (<1m depth). Seagrass cover was high, generally between 30-60%, on coarse sand/shell substrates.

In the north around Sopwlong, near continuous *T. hemprichii* dominated meadows with *C. rotundata* cover the fringing reefs. In the sheltered bay between Sopwlong and Kitialap, the meadow has more *E. acoroides*, however turbidity was high due to dredging/extraction activity (Plate 18). Sediments were very fine and calcareous, and the leaves of *E. acoroides* were heavily epiphytised (Plate 19). On the most eastern extent of the fringing reef, the meadow was similar in species composition, however the epiphytes were significantly less and more massive hard corals were present (Plate 20). On the barrier reef, aggregated patches of *T. hemprichii* (<10% cover) were scattered over large areas up to the reef crest (Plate 21).


Plate 18.

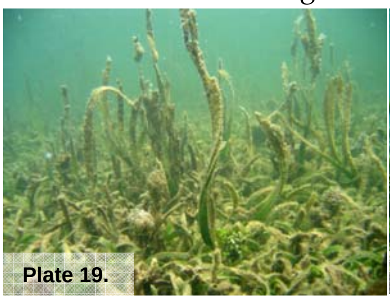


Plate 19.

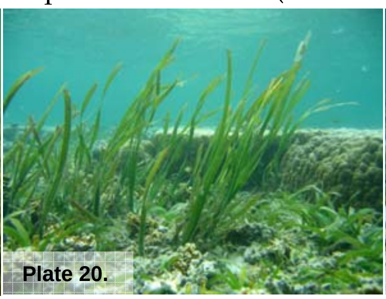


Plate 20.

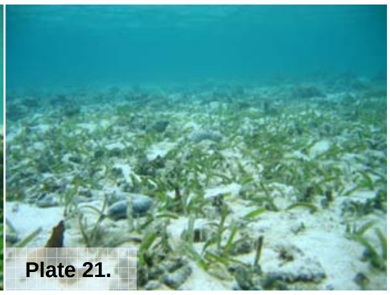
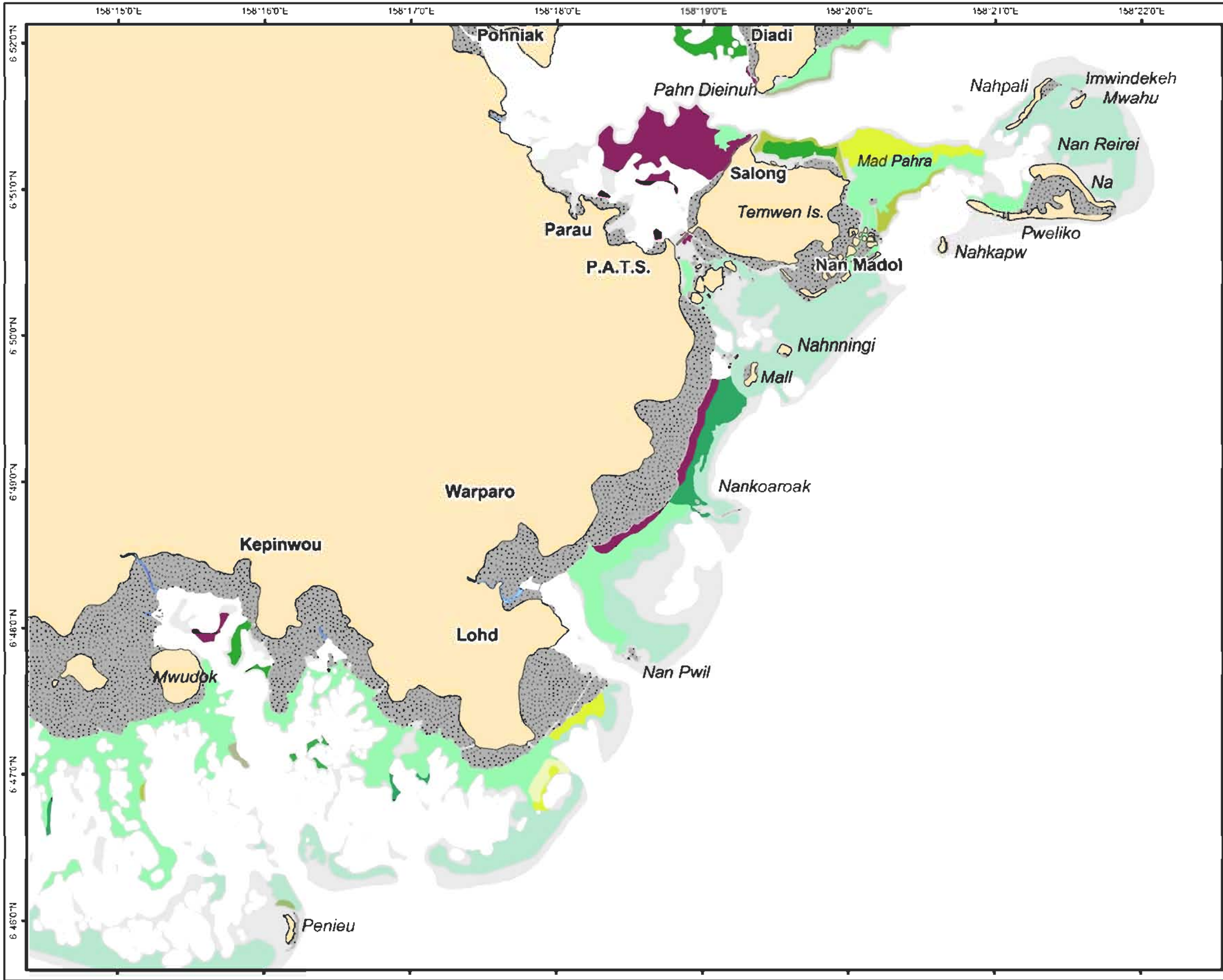


Plate 21.

TABLE 5. Meadow categories, total area (hectares) and numbers of intertidal/shallow subtidal meadows within Madolenihmw Municipality – October/November 2005.

CATEGORY	Cover ±SE (range) (%)	Area in hectares±R (ha) Isolated seagrass patches	Aggregated seagrass patches	Continuous seagrass cover	Total±R (ha)
C.rotundata	36 (35-37)			1.8 ±0.3	1.8 ±0.3
C.rotundata with *T.hemprichii*	42.3 (40-45)			10.1 ±1	10.1 ±1
C.rotundata with *T.hemprichii* & *E.acoroides*	36 ±2.5 (10-75)		10 ±2.1	9.2 ±1.5	19.3 ±3.5
C.rotundata with *T.hemprichii* & *E.acoroides*	40.5 (25-65)		11.1 ±3.1	7.7 ±0.8	18.8 ±3.9
C.rotundata/T.hemprichii with *E.acoroides*	44 ±1.8 (25-60)			53.2 ±4.2	53.2 ±4.2
E.acoroides	7.7 ±0.3 (0-30)	9.4 ±1.7	105.2 ±5.9	24.1 ±3.4	138.8 ±11
E.acoroides with *T.hemprichii*	14.8 ±1.7 (0-50)	6.2 ±0.8	19.7 ±2.1	16.5 ±1.6	42.5 ±4.6
T.hemprichii	20.1 ±3.5 (0-80)		375.9 ±19.1	331 ±19.5	706.9 ±38.6
T.hemprichii with *C.rotundata/E.acoroides*	41.8 ±3.1 (6-70)		21 ±1.2	81.2 ±7.1	102.2 ±8.3
T.hemprichii with *E.acoroides*	35 ±8.4 (0-87)		256.6 ±8.8	421.8 ±29.1	678.4 ±37.9
T.hemprichii/C.rotundata/E.acoroides	58.3 (55-60)			3.2 ±0.9	3.2 ±0.9
T.hemprichii/E.acoroides	35 ±15.9 (5-70)			44.6 ±3.6	44.6 ±3.6
Total		**15.6 ±2.4**	**799.5 ±42.3**	**1004.4 ±73**	**1819.6 ±117.7**



Map 5. Seagrass distribution and community types in Madolenihmw, Pohnpei Island - 26 Oct - 3 Nov 2005

Legend

- C.rotundata
- C.rotundata with E.acoroides/T.hemprichii
- C.rotundata with T.hemprichii
- C.rotundata with T.hemprichii and E.acoroides
- C.rotundata with T.hemprichii/E.acoroides
- C.rotundata/E.acoroides
- C.rotundata/T.hemprichii
- C.rotundata/T.hemprichii with E.acoroides
- C.rotundata/T.hemprichii/E.acoroides
- E.acoroides
- E.acoroides with T.hemprichii
- E.acoroides with T.hemprichii and C.rotundata
- E.acoroides/T.hemprichii
- T.hemprichii
- T.hemprichii with C.rotundata
- T.hemprichii with C.rotundata/E.acoroides
- T.hemprichii with E.acoroides
- T.hemprichii with E.acoroides and C.rotundata
- T.hemprichii with E.acoroides/C.rotundata
- T.hemprichii/C.rotundata/E.acoroides
- T.hemprichii/E.acoroides

Source: McKenzie, L.J. and Rasheed, M.J. (2006). Seagrasses: Pohnpei Island and Ahnd Atoll Marine Assessment: Technical report of survey conducted 26 October - 3 November 2005. (Seagrass-Watch, DPI&F, NFC, Cairns), 60pp.

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N

0 0.8 1.6 2.4

Kilometres

South of Kitialap, the fringing reef platforms becomes quite extensive in size, up to 3km in width (Map 4), and covered with very sparse/aggregated patches of *T. hemprichii* on coarse sand, with isolated *E. acoroides* plants. In some areas, particularly when bioturbation was high, *H. atra* abundance was very high. Large colonies of branching corals bordered the seaward edges of the fringing reef, and this provided sufficient protection from wave action for *T. hemprichii* plants (Plate 22).


Plate 22.

Near Mudokolos Island, the fringing reef crest meets the ocean (the barrier reef no longer exists). To provide safe passage for boats, an access channel has been cut through the reef platform. *E. acoroides* did not extend seaward beyond this channel.

South of this region, a large break in the fringing reef provides a deep water channel leading into a natural harbour, with Diadi and Salong at it's mouth. Within the harbour, the waters are very turbid and seagrass was absent from the mud/silt banks. The only large meadows within the harbour were closer to the mouth. These meadows were dominated by very long leaved *E. acoroides* with *T. hemprichii* understory, particularly adjacent to Temwen Island (Plate 23).


Plate 23.

Outside the harbour on the northern shores of Temwen Island, the seagrass meadows were very extensive and continuous in structure (Map 5). These meadows formed part of an extensive reef platform, that includes Nan Madol and islands of Nahpali, Imwindekeh and Pwelikois. The gross topography of the meadow is set by the underlying reef platform that slopes gently upward from the seaward margin to the mangrove-lined shore. The type of seagrass community is dependent on exposure to waves and currents. In the sheltered areas of the reef flat, within the ruins of Nan Madol and on the lee of islands, the meadows are dominated by *E. acoroides* with an understory of *T. hemprichii* (Plate 24). On the more exposed reef flats, the meadows are dominated by *T. hemprichii* and *C. rotundata*, with an occasional isolated *E. acoroides* plant (generally shorter leaves than the sheltered areas).


Plate 24.

On the large exposed fringing reefs south of Nan Madol, the seagrass communities depend on the presence of islands, and the level of water movement. Short leaved T. hemprichii plants are scattered across the intertidal reef platform (Plate 25),

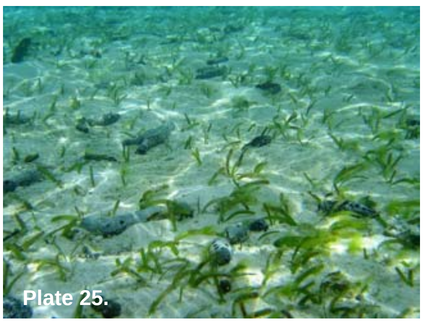


Plate 25.

and associated with high numbers of H. atra. The seagrass meadows, although extensive (<35% cover), are structurally a lot shorter – possibly a consequence of exposure to greater wave action and currents.

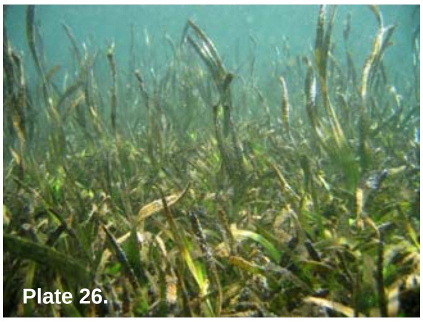


Plate 26.

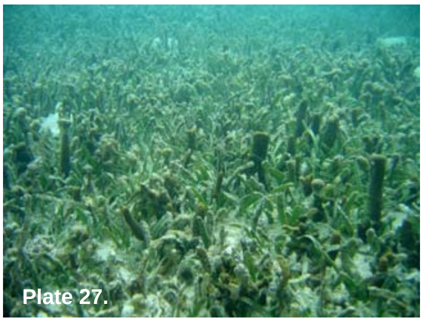


Plate 27.

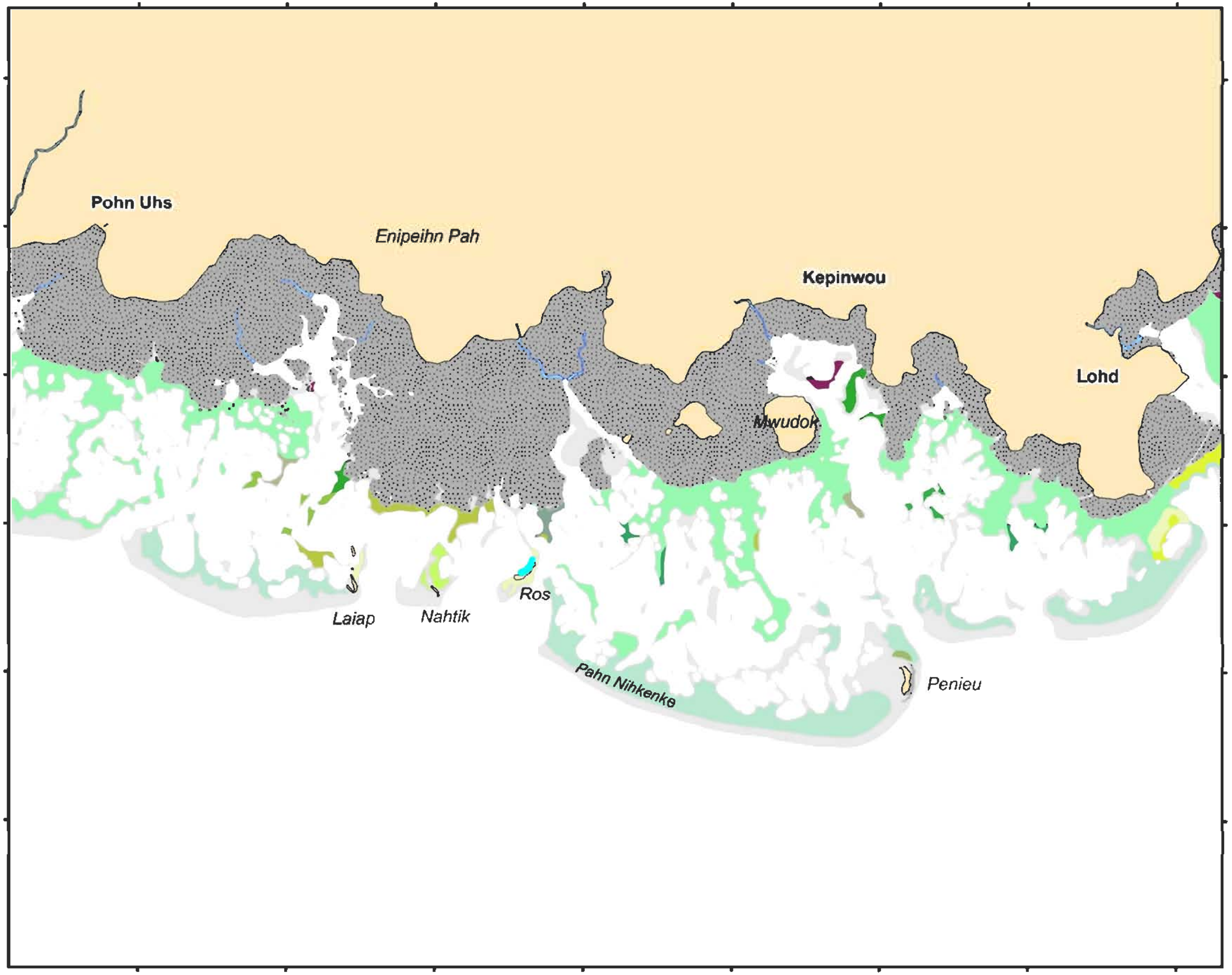
South of Mall island, the meadows are denser (>50% cover) and include a greater composition of *E. acoroides* and *C. rotundata*. *T. hemprichii* is often scattered across the reef-flat, and the occasional *E. acoroides* plant is present within the protected environments of *Porites* corals. Shoreward the meadows become more continuous forming a distinct meadow dominated by *T. hemprichii* / *C. rotundata* with *E. acoroides*, often adjacent to mangroves (*Rhizophora*) (Plate 26). *E. acoroides* plants are generally confined to the very shoreward portion of the reef (5-10m wide), often in highly turbid waters, and high epiphytes. Here the wave action is much less. These areas also often have high amounts of macroalgae (*Caulerpa* and *Halimeda*), benthic micro-algae, and sponges (Plate 27).

Kitti Municipality

Although Kitti is the largest municipality on Pohnpei in area, only approximately 26% of the seagrass meadows surrounding Pohnpei where present within the municipal boundaries. 1,157.7 ±103.9 hectares of seagrass was mapped in the municipality between 1 October and 2 November 2005. 66% of the seagrass meadows in the municipality were of continuous cover (Table 6) and located on large intertidal / shallow subtidal reef platforms. Approximately half of the meadows (54%) identified were *Thalassia* dominated communities (<3m depth). Seagrass cover was highly variable, but generally <40%. Substrates also varied greatly from coarse sand/shell to fine mud/silt.

Although the southern region of Kitti is protected by a series of barrier reefs with significant passages separating them, the lagoon is not a simple structure. Fingers of fringing reefs extend for the dense mangrove shores across nearly the entire lagoon (1-3km) (Map 6). This intermingling of sheltered fringing reefs, patch reefs and barrier reefs gives a complex structure to the region. The extensive mangrove forests, seagrass meadows and coral reefs provide a diversity of estuarine habitats.

Seagrass meadows cover nearly all fringing, patch and landward portions of barrier reefs (Maps 6 & 7) in this region. Most meadows are dominated by *T. hemprichii* with isolated patches of *E. acoroides* and often associated with the macro-algae *Caulerpa racemosa, Halimedia cylindrical* and *Halimedia opuntia*.



Map 6. Seagrass distribution and community types in Kitti, Pohnpei Island - 26 Oct - 3 Nov 2005

Legend

- C.rotundata
- C.rotundata with E.acoroides/T.hemprichii
- C.rotundata with T.hemprichii
- C.rotundata with T.hemprichii and E.acoroides
- C.rotundata with T.hemprichii/E.acoroides
- C.rotundata/E.acoroides
- C.rotundata/T.hemprichii
- C.rotundata/T.hemprichii with E.acoroides
- C.rotundata/T.hemprichii/E.acoroides
- E.acoroides
- E.acoroides with T.hemprichii
- E.acoroides with T.hemprichii and C.rotundata
- E.acoroides/T.hemprichii
- T.hemprichii
- T.hemprichii with C.rotundata
- T.hemprichii with C.rotundata/E.acoroides
- T.hemprichii with E.acoroides
- T.hemprichii with E.acoroides and C.rotundata
- T.hemprichii with E.acoroides/C.rotundata
- T.hemprichii/C.rotundata/E.acoroides
- T.hemprichii/E.acoroides

Source: McKenzie, L.J. and Rasheed, M.J. (2006). Seagrasses: Pohnpei Island and Ahnd Atoll Marine Assessment: Technical report of survey conducted 26 October - 3 November 2005. (Seagrass-Watch, DPI&F, NFC, Cairns), 60pp.
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Kilometres

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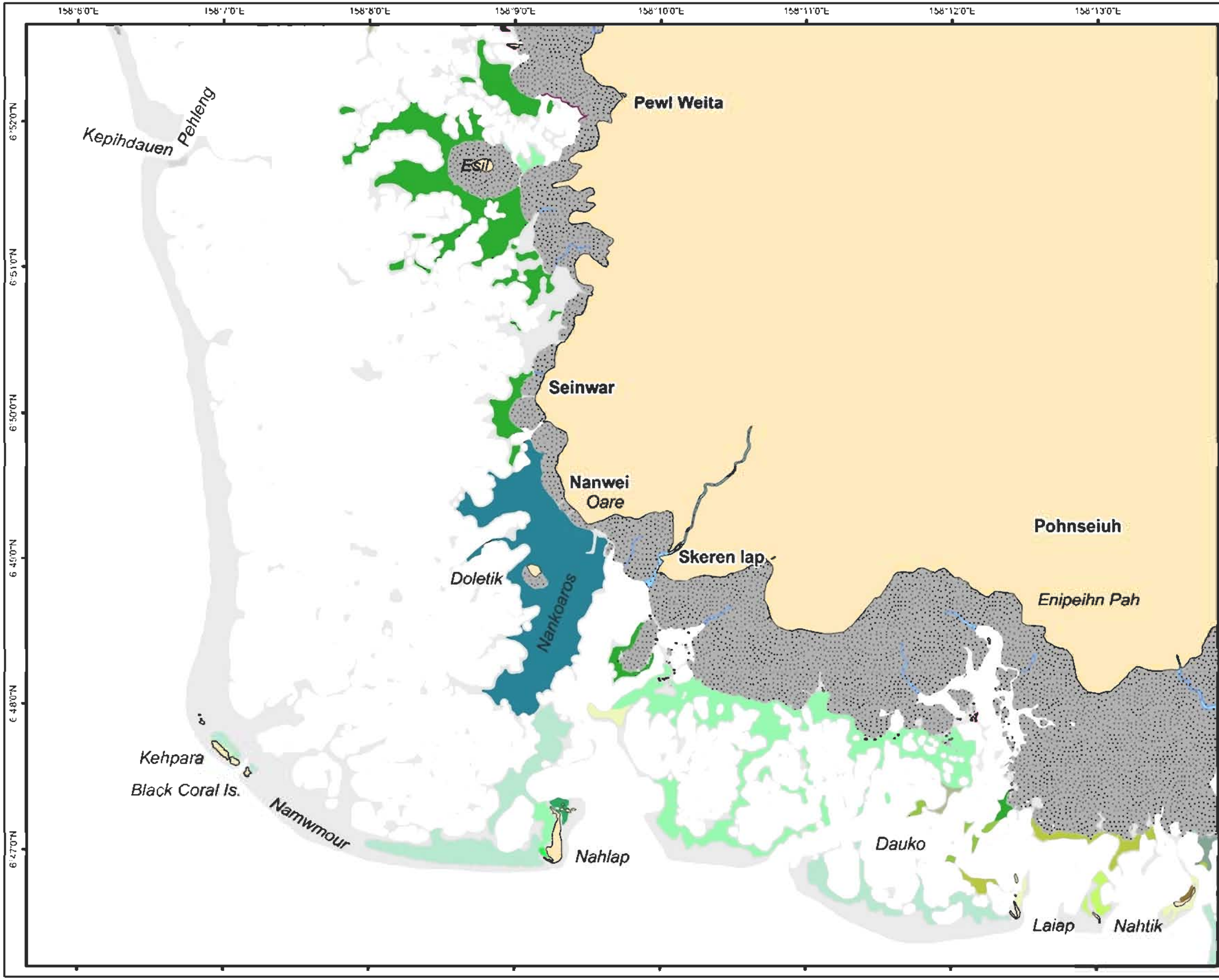

Map 7. Seagrass distribution and community types in Kitti, Pohnpei Island - 26 Oct - 2 Nov 2005

Legend

- C.rotundata
- C.rotundata with E.acoroides/T.hemprichii
- C.rotundata with T.hemprichii
- C.rotundata with T.hemprichii and E.acoroides
- C.rotundata with T.hemprichii/E.acoroides
- C.rotundata/E.acoroides
- C.rotundata/T.hemprichii
- C.rotundata/T.hemprichii with E.acoroides
- C.rotundata/T.hemprichii/E.acoroides
- E.acoroides
- E.acoroides with T.hemprichii
- E.acoroides with T.hemprichii and C.rotundata
- E.acoroides/T.hemprichii
- T.hemprichii
- T.hemprichii with C.rotundata
- T.hemprichii with C.rotundata/E.acoroides
- T.hemprichii with E.acoroides
- T.hemprichii with E.acoroides and C.rotundata
- T.hemprichii with E.acoroides/C.rotundata
- T.hemprichii/C.rotundata/E.acoroides
- T.hemprichii/E.acoroides

Source: McKenzie, L.J. and Rasheed, M.J. (2006). Seagrasses: Pohnpei Island and Ahnd Atoll Marine Assessment. Technical report of survey conducted 26 October - 3 November 2005. (Seagrass-Watch, DPI&F, NFC, Cairns). 60pp.

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Kilometres

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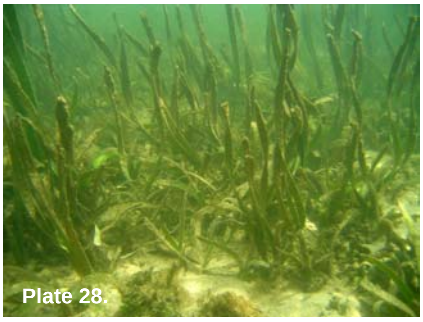


Plate 28.

In the estuaries and close to shore along the edge of the mangroves, the water clarity is poor and epiphyte abundance high. In these locations, such as near the mouth of the Enipein River, *E. acoroides* dominates (Plate 28). On the longer fingers of fringing reef, the waters are clearer and the meadows are dominated by *T. hemprichii* with isolated patches of *E. acoroides*.

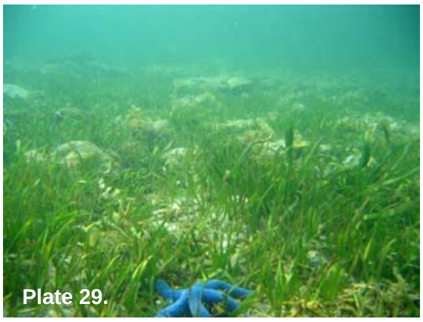


Plate 29.

On the edge of the passages through the barrier reefs, dense *C. rotundata* meadows occur. Also, in areas where the mangroves are close to the barrier reef and opposite a passage, *C. rotundata* meadows dominant in the clearer waters (Plate 29). On the leeward portion of the barrier reefs, meadows of *T. hemprichii* dominate (Plate 30).

Plate 30.

North-west of Skeren Iap, the nearshore fringing reef meadows became more dominated by *E. acoroides* with an understory of *T. hemprichii* (Map 7) (Plate 31). The most extensive meadow was across Nankoaros. Although covers ranged from 0-45%, mean cover was approximately 13%. Along the western shores of Pohnpei, the meadows were similar in species composition and structure. Between Pwel Weita and Palikir, the nearshore water were very turbid, sediments contained a greater component of mud and epiphytes more abundant (Plate 32).

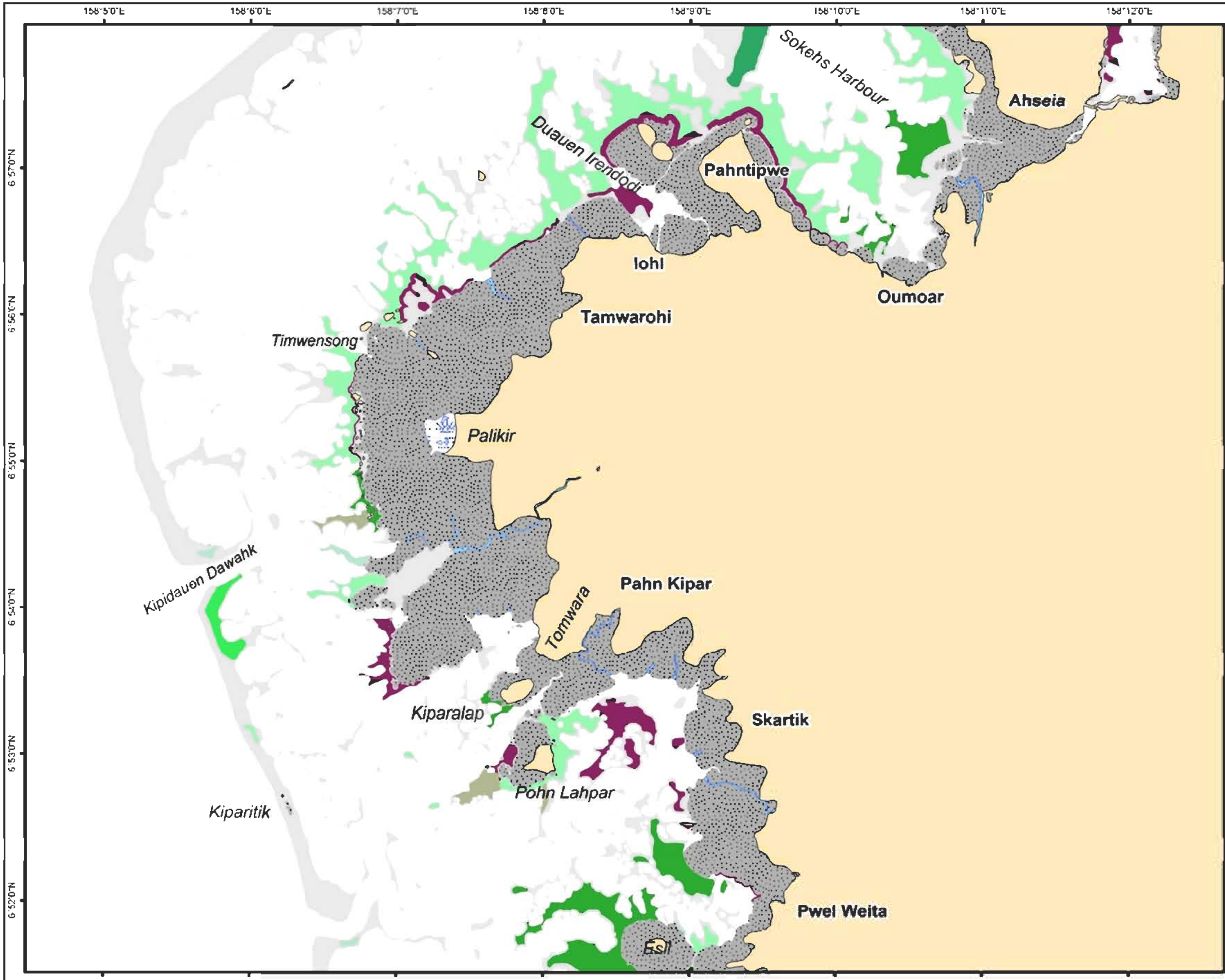
Plate 31.

North of Kehpara Islands, a near continuous barrier reef protected the main lagoon. The only seagrass meadows present on the barrier reefs were either sheltered by small vegetated islands, or on the inner mouths of passages (Maps 7 & 8). A *T. hemprichii* and *C. rotundata* meadow inside Kipidauen Dawahk although reasonably abundant (~30% cover), had significant amount of *Lyngbya* associated (Plate 33).

Plate 32.

Plate 33.

Map 8. Seagrass distribution and community types in Sokehs, Pohnpei Island - 26 Oct - 2 Nov 2005



Legend

- C.rotundata
- C.rotundata with E.acoroides/T.hemprichii
- C.rotundata with T.hemprichii
- C.rotundata with T.hemprichii and E.acoroides
- C.rotundata with T.hemprichii/E.acoroides
- C.rotundata/E.acoroides
- C.rotundata/T.hemprichii
- C.rotundata/T.hemprichii with E.acoroides
- C.rotundata/T.hemprichii/E.acoroides
- E.acoroides
- E.acoroides with T.hemprichii
- E.acoroides with T.hemprichii and C.rotundata
- E.acoroides/T.hemprichii
- T.hemprichii
- T.hemprichii with C.rotundata
- T.hemprichii with C.rotundata/E.acoroides
- T.hemprichii with E.acoroides
- T.hemprichii with E.acoroides and C.rotundata
- T.hemprichii with E.acoroides/C.rotundata
- T.hemprichii/C.rotundata/E.acoroides
- T.hemprichii/E.acoroides

Source: McKenzie, L.J. and Rasheed, M.J. (2006). Seagrasses: Pohnpei Island and Ahnd Atoll Marine Assessment: Technical report of survey conducted 26 October - 3 November 2005. (Seagrass-Watch, DPI&F, NFC, Cairns), 60pp.

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Kilometres

TABLE 6. Meadow categories, total area (hectares) and numbers of intertidal/shallow subtidal meadows within Kitti Municipality – October/November 2005.

CATEGORY	Cover ±SE (range) (%)	Area in hectares±R (ha)			Total±R (ha)
		Isolated seagrass patches	Aggregated seagrass patches	Continuous seagrass cover	
C.rotundata with *T.hemprichii*	38.1 ±0.1 (28-70)			14.1 ±2.5	14.1 ±2.5
C.rotundata with *T.hemprichii* & *E.acoroides*	37.5 ±0.6 (13-55)			19.1 ±3.4	19.1 ±3.4
C.rotundata with *T.hemprichii/E.acoroides*	42 (25-60)			16.1 ±2.2	16.1 ±2.2
C.rotundata/E.acoroides	3.7 (0-10)		0.1 ±0.05		0.1 ±0.05
C.rotundata/T.hemprichii	16.7 (13-22)			7.2 ±1.1	7.2 ±1.1
C.rotundata/T.hemprichii/E.acoroides	65 (60-70)		2.4 ±0.7	3.4 ±0.7	5.9 ±1.4
E.acoroides	4.1 (0-10)	0.4 ±0.2	1.6 ±0.9	38.5 ±4.8	40.5 ±5.9
E.acoroides with *T.hemprichii*	7.8 ±2.4 (0-30)		8.9 ±1.8	183 ±16.6	190.2 ±18.4
E.acoroides with *T.hemprichii* & *C.rotundata*	13.3 ±4.8 (0-45)			240.8 ±8.2	240.8 ±8.2
E.acoroides/T.hemprichii	88.3 (85-90)			0.9 ±0.3	0.9 ±0.3
T.hemprichii	9.4 ±1 (0-29)		220.5 ±12.8	38.9 ±5.2	259.4 ±17.9
T.hemprichii with *C.rotundata*	83.3 (75-90)			0.8 ±0.2	0.8 ±0.2
T.hemprichii with *C.rotundata/E.acoroides*	43.9 (15-80)		3.9 ±1	3.7 ±0.7	7.6 ±1.7
T.hemprichii with *E.acoroides*	20.9 ±4.3 (0-85)		162.3 ±17.5	187.3 ±21.7	349.6 ±39.3
T.hemprichii/E.acoroides	13.2 (0-35)			5.3 ±1.1	5.3 ±1.1
Total		**0.4 ±0.2**	**397.7 ±34.8**	**759.6 ±68.9**	**1157.7 ±103.9**

Sokehs Municipality

Approximately 14% of the seagrass meadows surrounding Pohnpei where present within the boundaries of Sokehs municipality.

627.2 ±68.2 hectares of seagrass was mapped in the municipality between 31 October and 2 November 2005. 57% of the seagrass meadows in the municipality were of continuous cover (Table 7) and located on sheltered intertidal / shallow subtidal reef platforms. 63% of the meadows identified were *Thalassia* dominated (<2m depth). Seagrass cover was highly variable, but generally <25%. Substrates varied from coarse sand/shell to fine mud/silt. No seagrass was present on the barrier reefs in Sokehs municipality.

Between the border with Kitti and Sokehs harbour, nearshore fringing reef meadows were similar in species composition and structure, dominated by *T. hemprichii* with isolated *E. acoroides* plants (Maps 8 & 9). Immediately adjacent to the mangroves, was a narrow band (5-20m) of aggregated *E. acoroides* patches, mean cover of approximately <10%. The nearshore waters were also very turbid, sediments contained a greater component of mud and epiphytes were more abundant. *E. acoroides* plants in these very turbid and muddy locations were generally associated with massive corals.

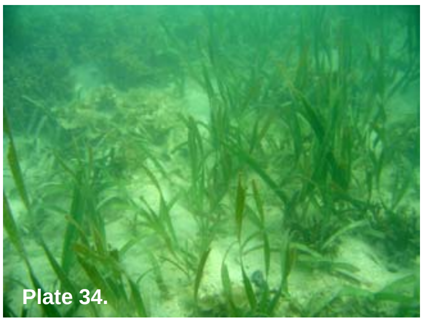
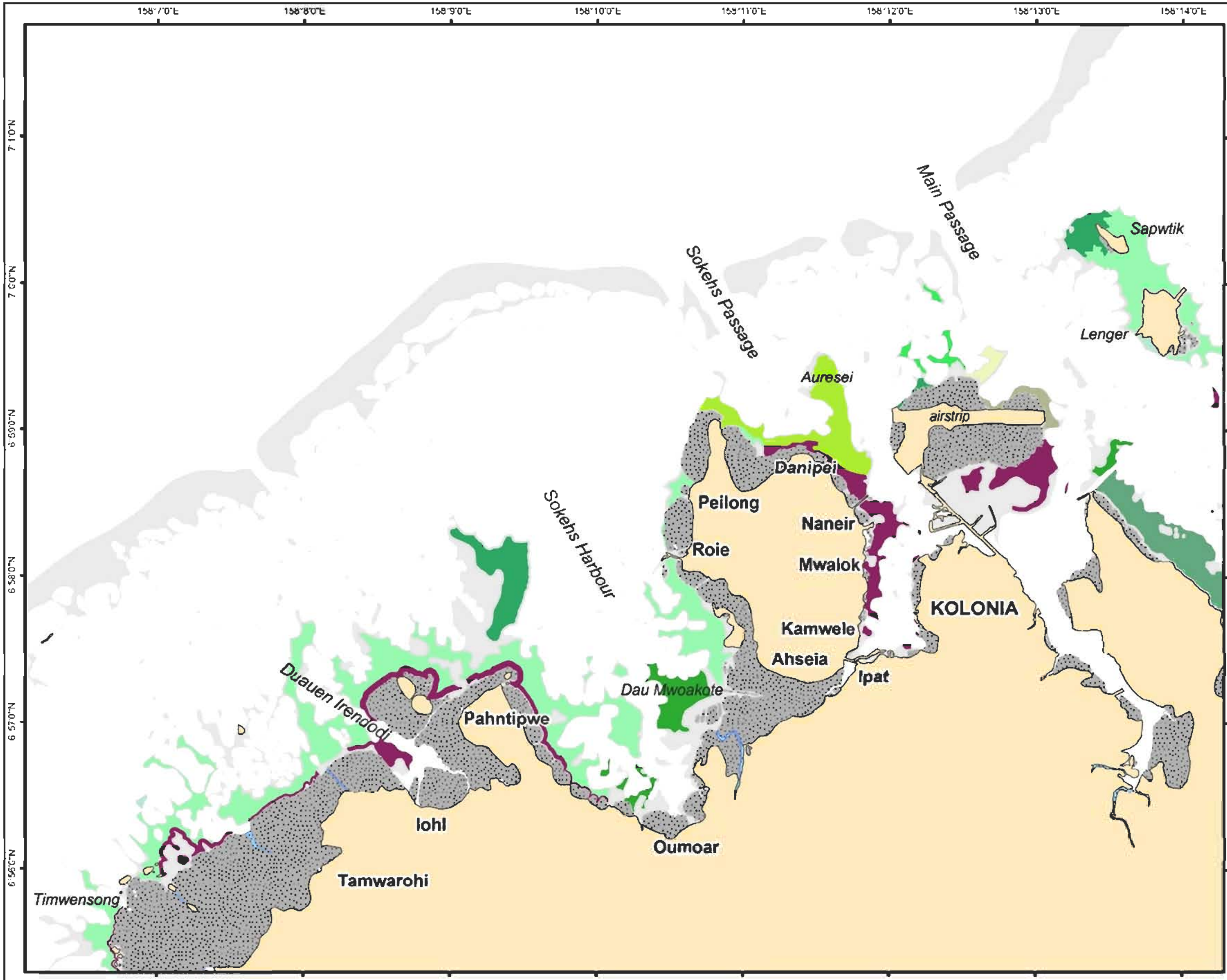


Plate 34.

On the outer edges of the fringing reefs, water clarity was better, seagrass communities were more continuous in structure, and often associated with *Sargassum* and *Halimedia opuntia* on coarse sand/shell/rubble substrates (Plate 34).



Map 9. Seagrass distribution and community types in Sokehs, Pohnpei Island - 26 Oct - 3 Nov 2005

Legend

- C.rotundata
- C.rotundata with E.acoroides/T.hemprichii
- C.rotundata with T.hemprichii
- C.rotundata with T.hemprichii and E.acoroides
- C.rotundata with T.hemprichii/E.acoroides
- C.rotundata/E.acoroides
- C.rotundata/T.hemprichii
- C.rotundata/T.hemprichii with E.acoroides
- C.rotundata/T.hemprichii/E.acoroides
- E.acoroides
- E.acoroides with T.hemprichii
- E.acoroides with T.hemprichii and C.rotundata
- E.acoroides/T.hemprichii
- T.hemprichii
- T.hemprichii with C.rotundata
- T.hemprichii with C.rotundata/E.acoroides
- T.hemprichii with E.acoroides
- T.hemprichii with E.acoroides and C.rotundata
- T.hemprichii with E.acoroides/C.rotundata
- T.hemprichii/C.rotundata/E.acoroides
- T.hemprichii/E.acoroides

Source: McKenzie, L.J. and Rasheed, M.J. (2006). Seagrasses: Pohnpei Island and Ahnd Atoll Marine Assessment: Technical report of survey conducted 26 October - 3 November 2005. (Seagrass-Watch, DPI&F, NFC, Cairns), 60pp.

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0 0.8 1.6 2.4
Kilometres

N

TABLE 7. Meadow categories, total area (hectares) and numbers of intertidal/shallow subtidal meadows within Sokehs Municipality – October/November 2005.

CATEGORY	Cover ±SE (range) (%)	Area in hectares±R (ha) Isolated seagrass patches	Aggregated seagrass patches	Continuous seagrass cover	Total±R (ha)
C.rotundata with *E.acoroides/C.rotundata*	38.1 ±6.2 (9-60)			67.9 ±4.2	
C.rotundata with *T.hemprichii/E.acoroides*	22.3 (15-27)			6.1 ±1	
E.acoroides	8.8 ±3.7 (0-12)		60.5 ±12.1	55.4 ±7.1	116 ±19.3
E.acoroides with *T.hemprichii*	8.1 (4-12)		37.4 ±3.5	6.8 ±1.9	44.2 ±5.4
T.hemprichii	20.8 (7-35)		0.9 ±0.2	5.5 ±1.1	6.4 ±1.4
T.hemprichii with *C.rotundata*	27.2 ±1.2 (23-35)			16.7 ±1.5	
T.hemprichii with *C.rotundata/E.acoroides*	16.7 (15-18)			48.6 ±2.3	
T.hemprichii with *E.acoroides*	19.5 ±3.2 (0-75)	0.6 ±0.4	170.6 ±18.4	150.2 ±14.3	321.4 ±33.1
Total			**269.5 ±34.3**	**357.1 ±33.5**	**627.2 ±68.2**


Plate 35.

Within Sokehs Harbour, the *T. hemprichii* with *E. acoroides* meadows on the western side were often associated with extensive *Halimeda* spp. beds, on coarse sand/shell substrates (Map 9) (Plate 35). However the very southern reaches of the harbour were barren of any marine flora, and substrates were heavily silted.


Plate 36.

On the eastern side of the harbour, the mangrove forests were much larger and the seagrass meadows sparse (<10% cover), generally occurring in aggregated patches. The brown algae *Padina* was abundant, and the substrate was coarse sand/shell/ with a significant mud component (Plate 36). A large *E. acoroides* dominated meadow covered the intertidal mud bank adjacent to Dau Mwoakote.

On the large intertidal fringing reef adjacent to Sokehs Rock, opposite Sokens Passage, was a dense (~40%) *C. rotundata* with *E. acoroides / T. hemprichii* meadow on coarse sand / shell (Plate 37). Inshore was a narrow (<50m) continuous *E. acoroides* meadow of low cover (<5%) which bordered the mangroves. This inshore meadow extended east around Sokehs and down into the inlet to near Kamwele. Within the inlet the meadows were monospecific and more aggregated or isolated in places (Plate 38). The sediments were also a lot finer, mainly sand with a significant component of mud. A few isolated *E. acoroides* plants were found scattered around the causeways and marinas of Kolonia.


Plate 37.

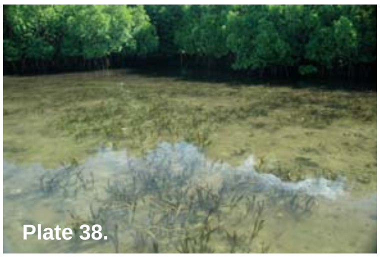


Plate 38.

AHND ATOLL

21.3 ±11.8 hectares (ha) of seagrass was mapped in 8 meadows on the sandy nearshore edge of Ahnd Atoll on the 28 October 2005 (Map 10). *C. rotundata* and *T. hemprichii* were the only seagrass species present.

Plate 39.

Seagrass meadows were generally long, narrow (25-50m) and only present adjacent to vegetated islands. The monospecific *C. rotundata* meadow adjacent to Pasa Island was continuous in structure and near homogeneous in cover (~30%) (Plate 39).

The widest and densest meadow (~50% cover) on the atoll was on the eastern side of Tauenai Passage. This *C. rotundata* with *T. hemprichii* meadow was in a well sheltered region, which was evident on the structure of the plants as the leaves were very long (Plate 40). The meadows were also associated with *Porites* colonies on coarse sand/shell (Plate 41).

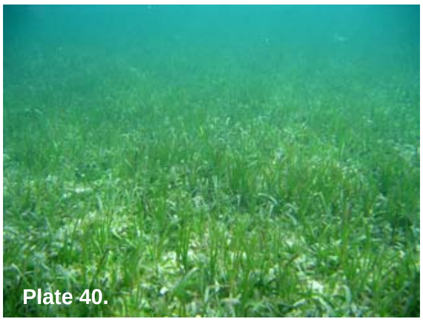


Plate 40.

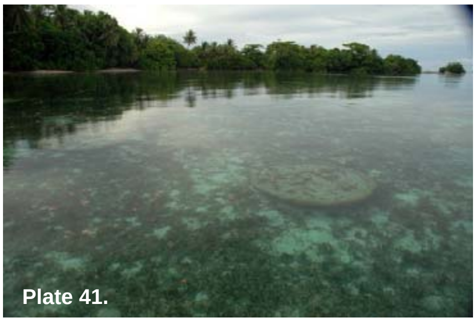
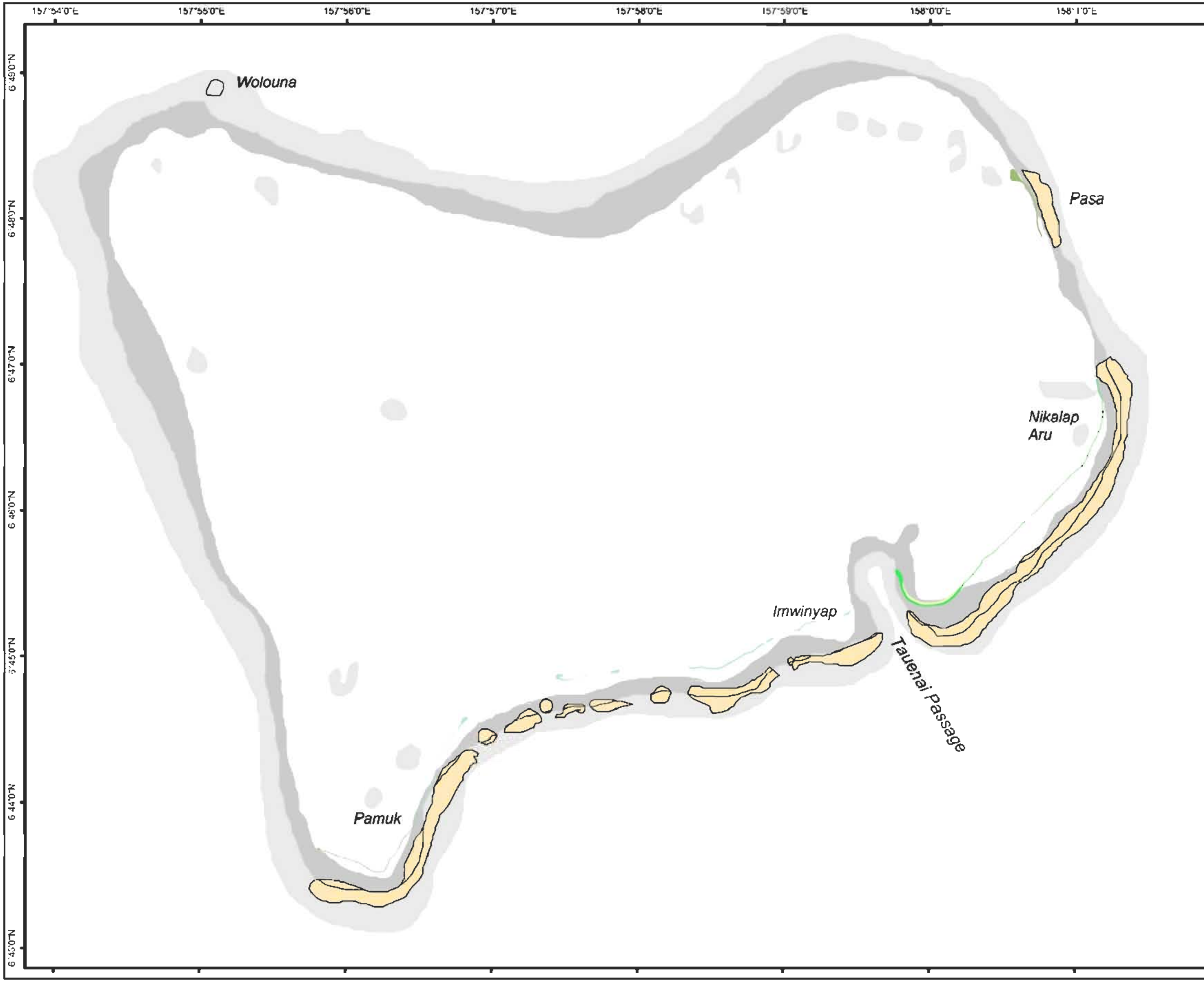


Plate 41.

These atoll islands not only provided significant protection from waves and storms, but possibly significant nutrients. However, no seagrass was found near Wolouna Island which is a large rookery/sanctuary for the White-capped Black Noddy (*Anous minutus*) and Red Footed Booby (*Sula sula*). The absence of seagrass appears a consequence of insufficient sediment depth for seagrass plants to take root.

TABLE 8. Meadow categories, total area (hectares) and numbers of intertidal/shallow subtidal meadows within Ahnd Atoll – October 2005.

CATEGORY	Cover ±SE (range) (%)	Area in hectares±R (ha)			Total±R (ha)
		Isolated seagrass patches	Aggregated seagrass patches	Continuous seagrass cover	
C.rotundata	20.8 ±0.4 (12-32)			3.6 ±2.8	3.6 ±2.8
C.rotundata with *T.hemprichii/E.acoroides*	44.7 ±13.7 (25-65)			4.2 ±4	4.2 ±4
T.hemprichii	10.5 ±7.4 (0-35)		2.7 ±1.2	5.3 ±3	8 ±4.2
T.hemprichii with *C.rotundata*	31.8 ±9.8 (0-60)			5.4 ±4.6	5.4 ±4.6
Total			**2.7 ±1.2**	**18.6 ±14.5**	**21.3 ±15.7**



Map 10. Seagrass distribution and community types at Ahnd Atoll - 28 October 2005

Legend

- C.rotundata
- C.rotundata with E.acoroides/T.hemprichii
- C.rotundata with T.hemprichii
- C.rotundata with T.hemprichii and E.acoroides
- C.rotundata with T.hemprichii/E.acoroides
- C.rotundata/E.acoroides
- C.rotundata/T.hemprichii
- C.rotundata/T.hemprichii with E.acoroides
- C.rotundata/T.hemprichii/E.acoroides
- E.acoroides
- E.acoroides with T.hemprichii
- E.acoroides with T.hemprichii and C.rotundata
- E.acoroides/T.hemprichii
- T.hemprichii
- T.hemprichii with C.rotundata
- T.hemprichii with C.rotundata/E.acoroides
- T.hemprichii with E.acoroides
- T.hemprichii with E.acoroides and C.rotundata
- T.hemprichii with E.acoroides/C.rotundata
- T.hemprichii/C.rotundata/E.acoroides
- T.hemprichii/E.acoroides

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Kilometres

MPAs

Plate 42.

There are nine Marine Protected Areas (MPAs) located around Pohnpei which are conserved under the Pohnpei State Marine Sanctuary and Wildlife System, pursuant to State Lax No. 4L-115-99 (Plate 42). These are present in all municipalities with the exception of Sokehs.

Less than 5% of the total seagrass area surrounding Pohnpei is located within MPAs (Table 9). 12 of the 21 meadow types identified for Pohnpei and Ahnd Atoll occur within MPAs (Table 9).

TABLE 9. Meadow categories and total area (hectares) within Pohnpei MPAs.

CATEGORY	MPA	Total (ha)
C.rotundata with *T.hemprichii*	Enipein, Kehpara	1.37
C.rotundata with *T.hemprichii* & *E.acoroides*	Enipein	12.80
C.rotundata with T.hemprichii/E.acoroides	Dehpehk	16.58
C.rotundata/T.hemprichii	Nahtik	7.24
E.acoroides	Pwudoi	1.58
E.acoroides with *T.hemprichii*	Dehpehk, Enipein, Pwudoi	39.18
E.acoroides/T.hemprichii	Enipein	0.04
T.hemprichii	Dehpehk, Kehpara, Namwen Na, Namwen Nahnningi, Pwudoi	37.69
T.hemprichii with *C.rotundata/E.acoroides*	Sapwitik	19.61
T.hemprichii with *E.acoroides*	Dekehos, Enipein, Namwen Na, Pwudoi, Sapwitik	42.88
T.hemprichii with *E.acoroides* & *C.rotundata*	Dehpehk	4.27
T.hemprichii/E.acoroides	Enipein	5.07
Total		**188.31**

Seagrass communities not represented within an MPA (Table 10) include:

- *C. rotundata* – these are monospecific meadows which are only found at Ahnd Atoll (Map 10).
- *C. rotundata* with *E. acoroides/T. hemprichii* – this meadow is located on the large intertidal bank in front of Sokehs rock, opposite Sokehs Passage and the loading wharves (Map 9).
- *C. rotundata/E. acoroides* – this is a small meadow adjacent to the large *Thalassia* meadows at Pahn Nihkehke (Map 6).
- *C. rotundata/T. hemprichii* with *E. acoroides* - these meadows occur on the fringing reef platform adjacent to Lohd Pa and north of Nan Madol (Map 5)
- *C. rotundata/T. hemprichii/E. acoroides* - these meadows occur on the patch reefs at Dauko, adjacent to Enipein marine park (Map 7)
- *E. acoroides* with *T. hemprichii & C. rotundata* – this is a large meadow on the fringing reef platform of Nankaoros in Kitti (Map 7).
- *T. hemprichii* with *C. rotundata* – these occur as: a large meadow on the shallow sandy lagoon fringing the eastern shores of Ahnd Atoll (Map 10); on the barrier reef on southern mouth of Kepidauen Dawahk (channel) (Map 8); on the northern fringing reef flat adjacent to the airport (Map 3); on the patch reef between Mwahnd Peidi (island) and Dekehn Awak (mainland) (Map 3); and as a dense continuous meadow on the southern end Nahlap (southern Kitti), protected by shingle, up to the mangroves (Map 7).

- *T. hemprichii* with *E. acoroides*/*C. rotundata* - these include: the large meadow scattered across the reef flat at Nantuhtu; south of Net Point (Kitti); and Seaward edge of the meadow on the fringing reef flat along the northern shores of Dehpehk (Uh) (Map 3)
- *T. hemprichii*/*C. rotundata*/*E. acoroides* – these are four meadows located on patch reefs in Rohi (Madolenihmw) (Map 6).

TABLE 10. Meadow categories and total area (hectares) within Pohnpei MPAs.

CATEGORY	Area (*ha*)	Location (*number of meadows*)
C.rotundata	5.4	Ant (3)
C.rotundata with *E.acoroides/T.hemprichii*	67.9	Sokehs (1)
C.rotundata/E.acoroides	0.1	SE Kitti (1)
C.rotundata/T.hemprichii with *E.acoroides*	53.2	Madolenihmw (3)
C.rotundata/T.hemprichii/E.acoroides	5.8	SE Kitti (5)
E.acoroides with *T.hemprichii & C.rotundata*	240.8	Kitti (1)
T.hemprichii with *C.rotundata*	36.2	Ant (1), Kitti (1) Sokehs (1), Nett (4), Uh (2)
T.hemprichii with *E.acoroides/C.rotundata*	82.9	Nett (1), Uh (1)
T.hemprichii/C.rotundata/E.acoroides	3.2	Madolenihmw (4)

DISCUSSION

This survey was the first detailed assessment of seagrasses in the waters surrounding Pohnpei Island and Ahnd Atoll. Most of Pohnpei's seagrasses are found in water less than 3m deep and meadows were monospecific or consisted of multispecies communities, with up to three species present at a single location. The number of seagrass species identified is within the range expected and the species are all typical of coral reef flat communities in the western Pacific (Coles *et al*. 2003a).

In 1984 the US Army Corps of Engineers, Pacific Ocean Division mapped approximately 1,273 ha of seagrass in the intertidal and shallow subtidal waters surrounding Pohnpei Island. The current survey mapped more than three times the area of seagrass within the same survey area. It is difficult to interpret the present results when compared with those collected 21 years ago by US Army Corps. In 1984, the survey was designed as a resource inventory and not a detailed assessment and mapping exercise. Only 86 points were examined during a field survey over six weeks in April and May 1984, and much of the mapping was assisted by colour aerial photography (1984). Although we cannot rule out some expansion in seagrass area since 1984, however it would be possibly erroneous to attribute the entire difference between the surveys to a significant increase in the area of seagrass. Despite this, some patterns in distribution have remained remarkably similar. Seagrasses in both surveys were predominantly on the extensive intertidal and shallow subtidal banks that fringe the Island.

No deepwater seagrasses have been previously reported from Pohnpei and none were found in the present study, although the seabed was only examined to a maximum depth of 10 m. Deep water seagrasses occur at subtidal depths greater than 10 m, and are restricted to where high water clarity allows sufficient light penetration for photosynthesis (Lee Long *et al.* 1993). However seagrass species which are adapted for deep water are restricted to the genus *Halophila* (Lee Long *et al.* 1993, Lee Long *et al.* 1996), which have only been reported from Palau and Yap (Kock and Tsuda 1978; Bridges and McMillan, 1986).

Seagrasses of Pohnpei and Ahnd Atoll are all structurally large species and distribution appears to be primarily influenced by the degree of wave action (exposure), water clarity and nutrient availability. Seagrasses of Pohnpei and Ahnd Atoll are influenced by pulses of sediment laden, nutrient rich freshwater, resulting from high volume seasonal rainfall. In general, seagrass growth is limited by light, disturbance and nutrient supply, and changes to any or all of these limiting factors may cause seagrass decline.

The seagrasses of Pohnpei and Ahnd Atoll can be generally categorised into six main habitats (Table 10), some similar to those other tropical locations (see Carruthers *et al.* 2001). In their natural state, these habitats are characterised by very low nutrient concentrations, are primarily phosphorus limited and are influenced by seasonal and episodic coastal runoff.

Table 11. Summary of seagrass habitats of Pohnpei and Ahnd Atoll.

Habitat	Limiting factor	Seagrass species	Feature/threats
Estuary/inlet	Terrigenous runoff	*Enhalus acoroides*	Highly productive Low density, low diversity Often associated with mangroves High salinity variations High temperature intertidally Highly threatened by runoff
Sheltered Coastal Fringing reef	Terrigenous runoff	*Cymodocea rotundata* *Enhalus acoroides* *Thalassia hemprichii*	Highly productive High density Diverse Important for fisheries Supports macro-grazers Threatened by development & extraction activities
Exposed Coastal Fringing reef	Physical disturbance Low nutrients	*Cymodocea rotundata* *Enhalus acoroides* *Thalassia hemprichii*	Shallow unstable sediment Variable physical environment High light
Patch Reef *(e.g., isolated)*	Low nutrients Bioturbation	*Cymodocea rotundata* *Enhalus acoroides* *Thalassia hemprichii*	Temperature variation High light
Barrier Reef	Physical disturbance Low nutrients	*Thalassia hemprichii*	Shallow unstable sediment Variable physical environment Little studied Least threatened
Atoll	Low nutrients	*Cymodocea rotundata* *Thalassia hemprichii*	Little studied Least threatened

Each of these six habitat types has a number of dominant processes that influence seagrass growth, survival, and seagrass community biodiversity. The seagrasses of these habitats also contain different life history strategies, which provide some insight into the dynamic but variable physical nature of Pohnpei's seagrass habitats. The species present in the different habitats reflect the observed physical and biological impacts, suggesting that reef and coastal environments are particularly variable and dynamic, while estuarine habitats have stable areas but are extremely harsh. Of these seagrass habitat types in Pohnpei, both estuarine and sheltered (coastal) fringing reef seagrass habitats are of primary concern with respect to water quality due to their location immediately adjacent to catchment inputs.

Many of these habitats are rarely in isolation of each other. For example, if transects were run from Pohnpei Island to the edge of the outer reef crest in the north, east and south (Figure 3), they would encompass examples of five of these seagrass habitats (Figures 4, 5 & 6).

FIGURE 3. Location of transects around Pohnpei Island which encompass all the seagrass habitat types (*with the exception of atoll*).

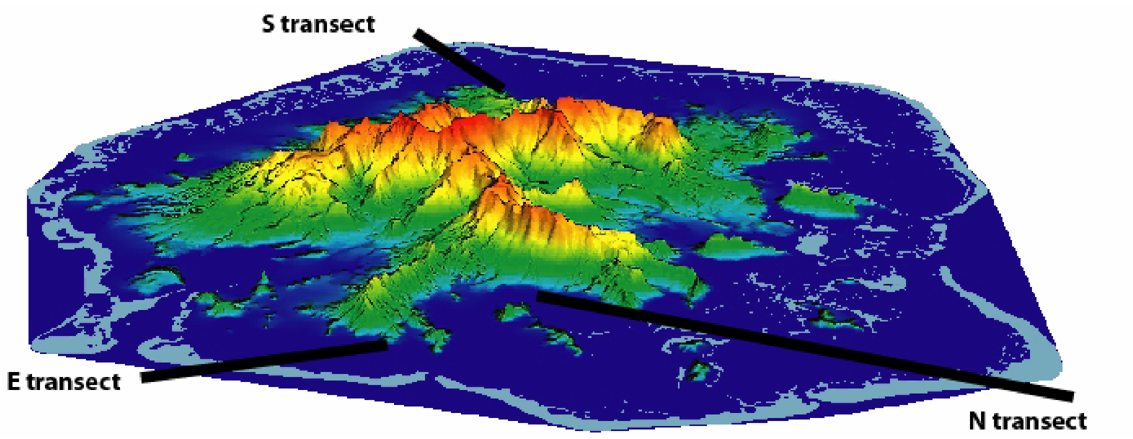


FIGURE 4. N transect, in the northern region of Pohnpei, showing seagrass habitat types and major impacts.

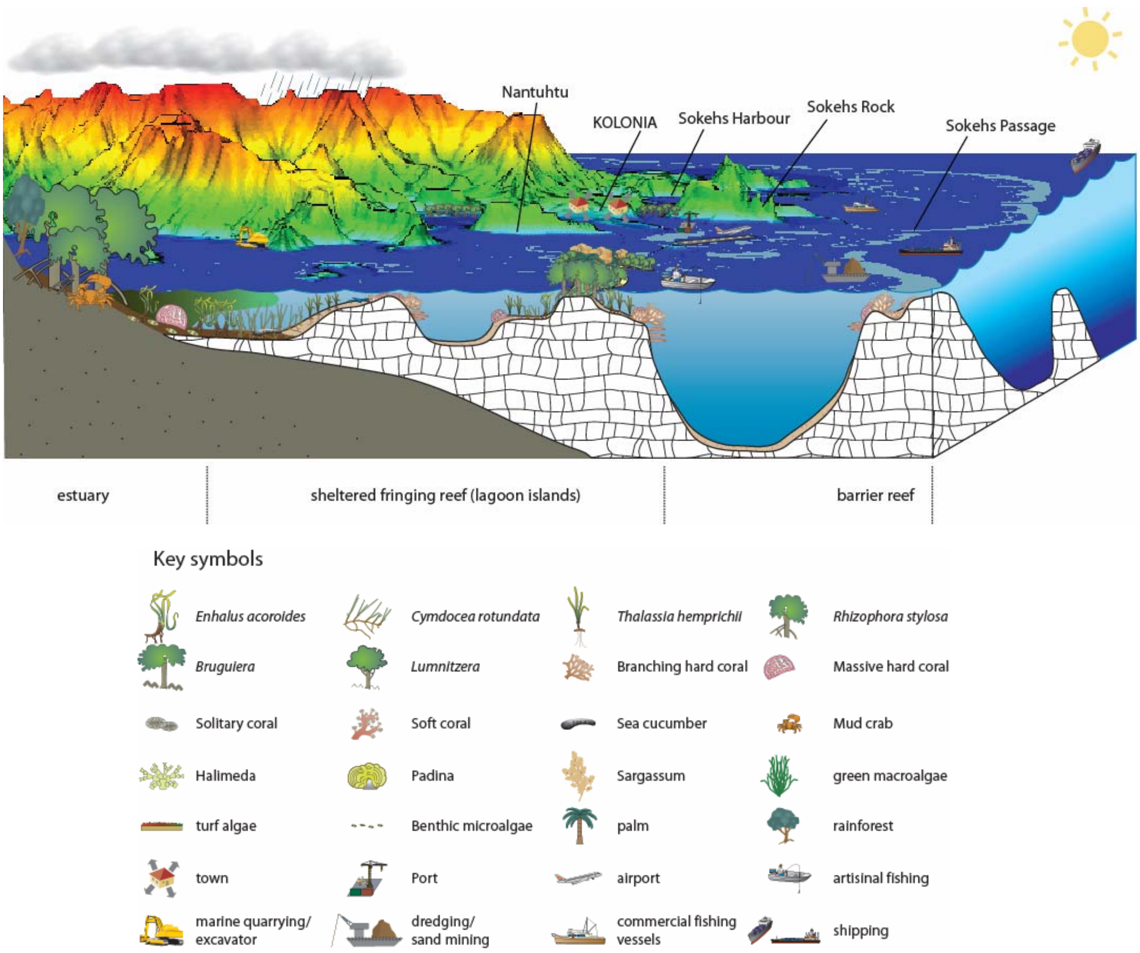


FIGURE 5. S transect, in the southern region of Pohnpei, showing seagrass habitat types.

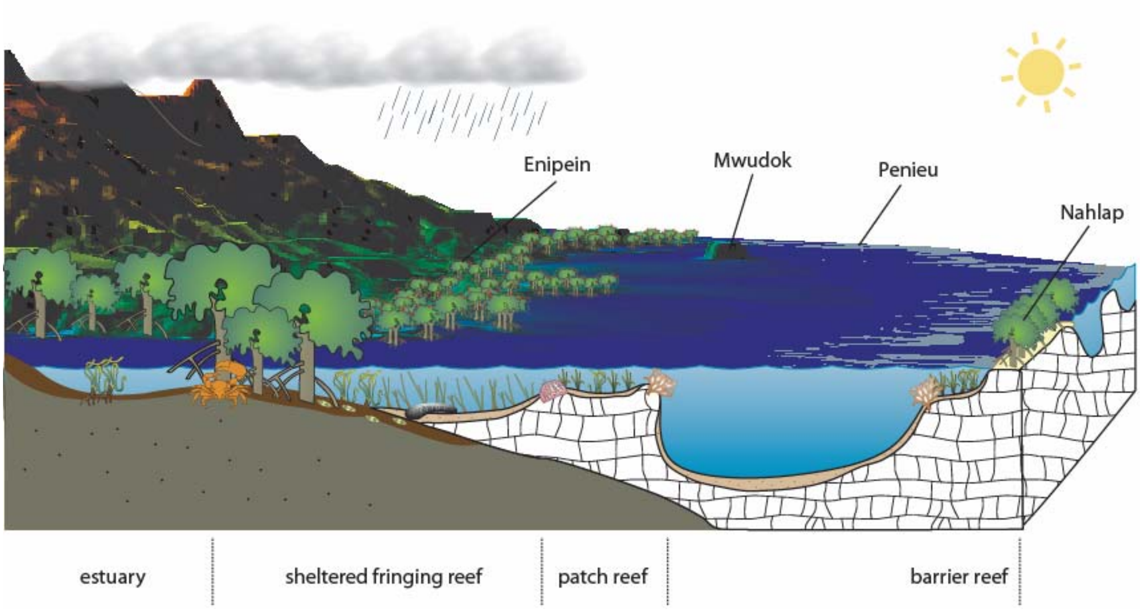
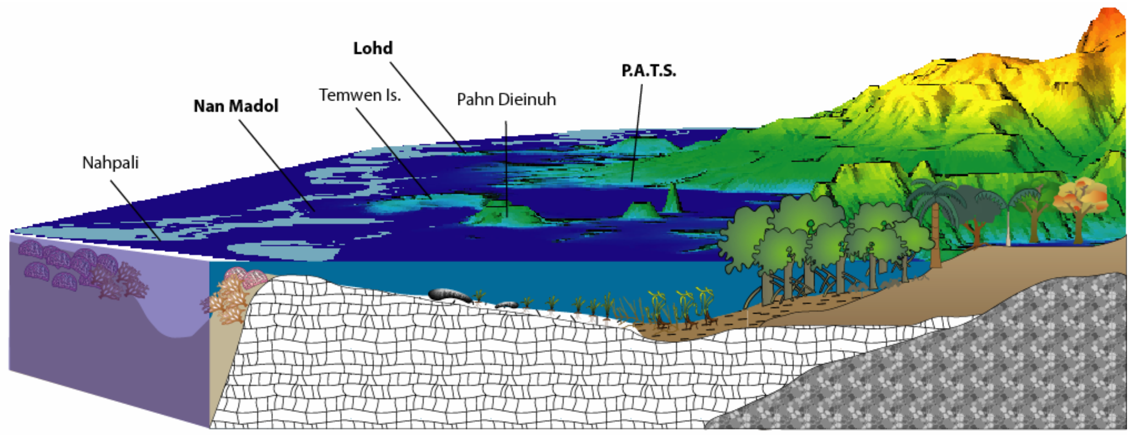


FIGURE 6. E transect, in the eastern region of Pohnpei, showing seagrass habitat types.



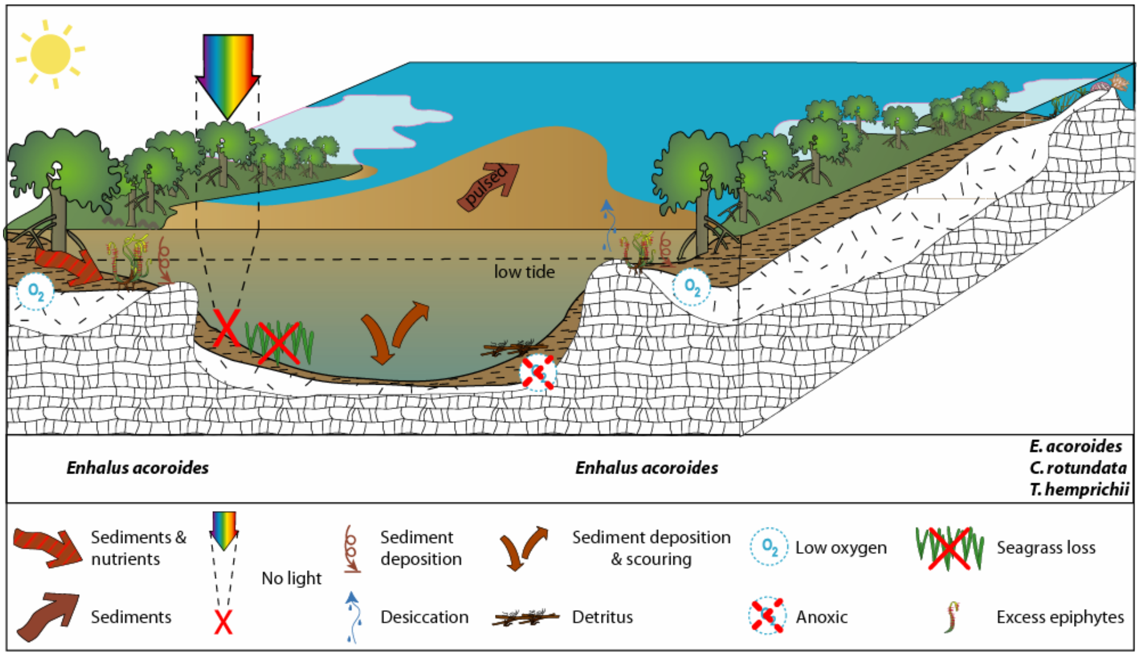
Using the previous figures as a basis, six conceptual models are discussed detailing the major features and processes within each habitat type. Icons used are constant throughout the models, however differences in the specifics of those processes within a particular habitat are detailed in the text.

POHNPEI STATE'S SEAGRASS HABITATS

Estuary/inlet

Estuary habitats can be subtidal or intertidal, contain only one or two seagrass species, and are possibly highly productive. In Pohnpei, these habitats are closely associated with mangrove forests, characterized by fine sediments and prone to high sedimentation and anoxic conditions (Figure 7). The dominant influence of estuary habitats is terrigenous (from the land) runoff from seasonal rains. Increased river flow results in higher sediment loads which combine with reduced atmospheric light to create potential light limitation for seagrass (McKenzie 1994). Estuary habitats also have higher loadings of micro and macro-algal epiphytes than other seagrass habitats. Associated salinity fluctuations and scouring make estuary and inlet habitats a seasonally extreme environment for seagrass growth.

FIGURE 7. Model of Estuary habitat – major control is pulsed terrigenous runoff: general habitat and seagrass meadow processes.



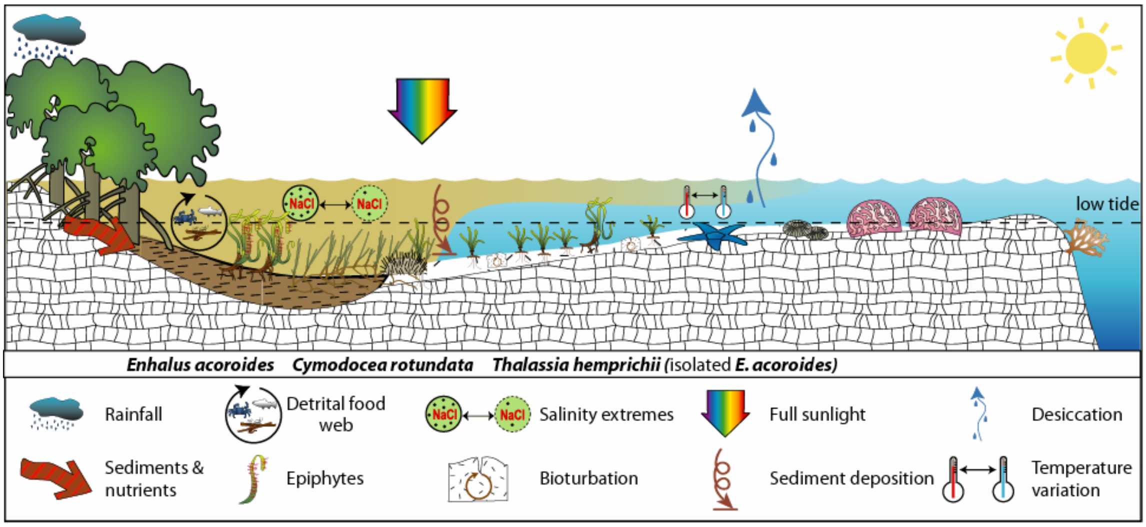
Watersheds from where water originates to estuary habitats often support a large range of land uses, which result in increased sediment and nutrient inputs (Spalding *et al.* 2003). Intertidal seagrasses show variable resilience to light reduction resulting from pulsed turbidity events. Ocean flushing and tidal exchange can moderate both nutrient and sediment input to these habitats.

*Enhalus acoroide*s was typically found in estuarine locations, often adjacent to dense mangrove forests. *E. acoroides* is a slow turnover, persistent species with low resistance to perturbation (Bridges *et al.* 1981; Walker *et al.* 1999), suggesting that there are some coastal habitats that are quite stable over time. It is predicted that removal of a 1m^2 area from a meadow would take more than 10 years for full recovery (Rollon *et al.* 1998). However, *E. acoroides* has been reported to be tolerant of high temperatures and low salinities experienced in the nearshore intertidal environments of Micronesia (Bridges & McMillan 1986). *E. acoroides* can also withstand burial due to their morphology (Duarte *et al.* 1997). All other species in Pohnpei are unlikely to withstand burial (Bach *et al.* 1998; Duarte *et al.* 1997).

Sheltered Coastal Fringing reef

Sheltered coastal fringing reef habitats are both subtidal, intertidal and as with all fringing reef habitats on Pohnpei, support the most diverse seagrass assemblages. These seagrass meadows are also highly productive and provide important nursery grounds for fisheries. The sediments in these locations are relatively stable, although bioturbation may restrict seagrass growth and distribution in some localities. A dominant influence of sheltered coastal fringing reef habitats is terrigenous (from the land) runoff from seasonal rains, similar to the adjacent estuary habitats (Figure 8).

FIGURE 8. Model of sheltered coastal fringing reef habitat – major control is pulsed terrigenous runoff, salinity and temperature extremes: general habitat and seagrass meadow processes.



Episodic terrigenous runoff events result in pulses of increased turbidity, nutrients and a zone of reduced salinity in nearshore waters. Seagrasses, especially structurally large species (*Thalassia, Enhalus, Cymodocea*), affect coastal and reefal water quality by absorbing nutrients and trapping sediments acting as a buffer between catchment inputs and reef communities. Seagrasses have the ability to act as a bio-sink for nutrients, sometimes containing high levels of tissue nitrogen and phosphorous.

*Enhalus acoroide*s was found across the sheltered reef platforms, but was more common along the nearshore mangrove fringe. The nearshore region of the reef platform is relatively stable, and possibly more similar to estuarine habitats. *C. rotundata* is more sensitive to siltation than *E. acoroides* (Terrados *et al.* 1998) which most likely explains its absence on the shoreward part of the meadow. On the outer regions of the reef platform, the sediments are often more mobile, ad bioturbation greater. Intertidal environments also have high variations in temperature and may be exposed at low tide. *Thalassia* and *Cymodocea* dominate these areas, as they are seen as intermediate genera that can survive a moderate level of disturbance (Walker *et al*. 1999).

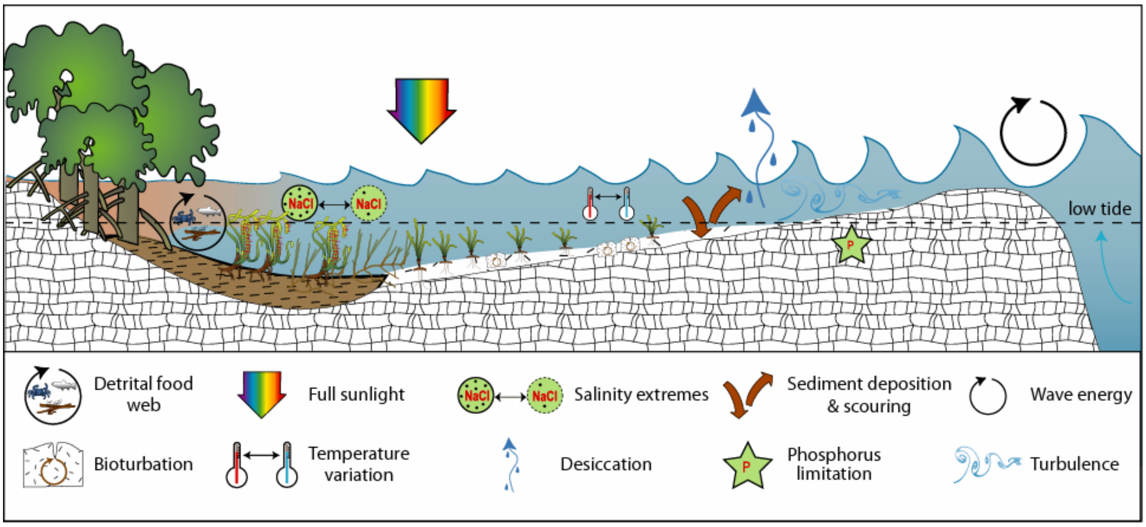
On the intertidal reef platforms the presence of pooling water at low tide prevents drying out and enables seagrass to survive tropical summer temperatures which would otherwise cause seagrasses to desiccate (Stapel *et al.* 1997). It was also noted, that canopy heights were greater in the nearshore sheltered locations, possibly a consequence of the pooling water. Low tide exposure in this region close to the equator can lead to UV-B radiation damage to leaves (Short & Neckles 1999), reducing their length. The increased canopy height may also result from the muddier sediments providing a more conducive environment for seagrass growth on the shoreward side. Muddier sediments may also explain the greater abundance of seagrasses on the shoreward side and the change in species composition between areas of fine silty sediments and coarse sand dominated sediments.

In Pohnpei, sheltered coastal fringing reef habitats are closely associated with mangrove forests. The physical and biological connectivity between these habitats is of high importance to support the detrital food chains and the productive faunal communities. Although macro-grazers are generally an important feature in structuring seagrass communities (Duffy *et al.* 2003), on Pohnpei however, this was not particularly evident. No macro-grazers, such as green sea turtles (*Chelonia mydas*) (Lanyon *et al.* 1989) were observed, although there are reports in the literature of their abundance and utilization on Pohnpei (Buden & Edward 2001).

Exposed Coastal Fringing reef

Exposed coastal fringing reef-platform habitats are both subtidal and intertidal and similar to sheltered environments, support diverse seagrass assemblages. Physical disturbance from waves and swell and associated sediment movement primarily control seagrass growing in these habitats (Figure 9).

FIGURE 9. Model of exposed coastal fringing reef habitat – major control disturbance: general habitat and seagrass meadow processes.



Shallow unstable sediment, fluctuating temperature, and variable salinity in intertidal regions characterize these habitats. Nutrient concentrations are generally low in reef habitats; however intermittent sources of nutrients are added by seasonal runoff. The primary limiting nutrient for seagrass growth in carbonate sediments of these reefs would be Phosphate (Short *et al.* 1990; Fourqurean *et al.* 1992; Erftemeijer & Middelburg 1993). Tight nutrient recycling strategies of *T. hemprichii* (e.g., the location of nitrogen in the rhizomes) aids in survival in the nutrient-poor reef habitat when leaves are shed due to desiccation stress (Stapel *et al.* 1997).

Episodic events such as cyclones or storms can have severe impacts at local scales, making this a dynamic and variable habitat. Sediment movement due to prevalent wave exposure creates an unstable environment where it is difficult for seagrass seedlings to establish or persist. Succession or recolonization after extreme loss has been suggested to be directional and modified by small-scale perturbations, resulting in patchiness in seagrass distributions (Birch and Birch 1984). The end result of this successional process, however, varies with geographic location.

Water flow affects almost all biological, geological and chemical processes in seagrass ecosystems at scales from the smallest (physiological and molecular) to the largest (meadow wide). The pollination of seagrass flowers depends on currents and the turbulence around these reproductive structures to transport pollen between male and female flowers (Ackerman 1986, Ackerman 1997). Similarly, without current flows, vegetative material and seeds will not be transported to new areas, and species will not be exchanged between meadows. Factors such as the photosynthetic rate of seagrasses depend on the thickness of the diffusive boundary layer (Koch 1994) that is determined by current flow, as is the sedimentation rate. Both influence growth rates of seagrass, survival of seagrass species and overall meadow morphology. Some fauna (Murphey & Fonseca 1995) and attached epiphytic algae found in seagrass meadows survive because of the low current environments created by the presence of the vegetation.

*Enhalus acoroide*s was typically found in sheltered locations, often adjacent to dense mangrove forests. *E. acoroides* differs in that pollination occurs above water and the plant must be able to extend above the water surface to sexually reproduce. Pollen movement could be disrupted by wave action and a strong current so this species is more likely to occur where water pools and is commonly found abutting mangrove forests in the Pacific islands. *C. rotundata* and *T. hemprichii* will colonise exposed reefs and are found in areas of high current. It is common in locations such as Torres Strait (Coles *et al.* 2003b) and the Great Barrier Reef (Lee Long *et al.* 1993) where strong currents occur.

Disturbance from waves can have a significant influence of seagrass community type and morphology. For example, Coles *et al.* (2005) demonstrated that a semi-permeable causeway at Nan Madol provided shelter and had significant influence on seagrass abundance and species. The change in species composition from *E. acoroides* dominated community in sheltered muddy sediments to *C. rotundata* or *T. hemprichii* dominated communities in the exposed sand sediments is consistent with observed seagrass community changes along siltation gradients in south-east Asia (Terrados *et al.* 1998).

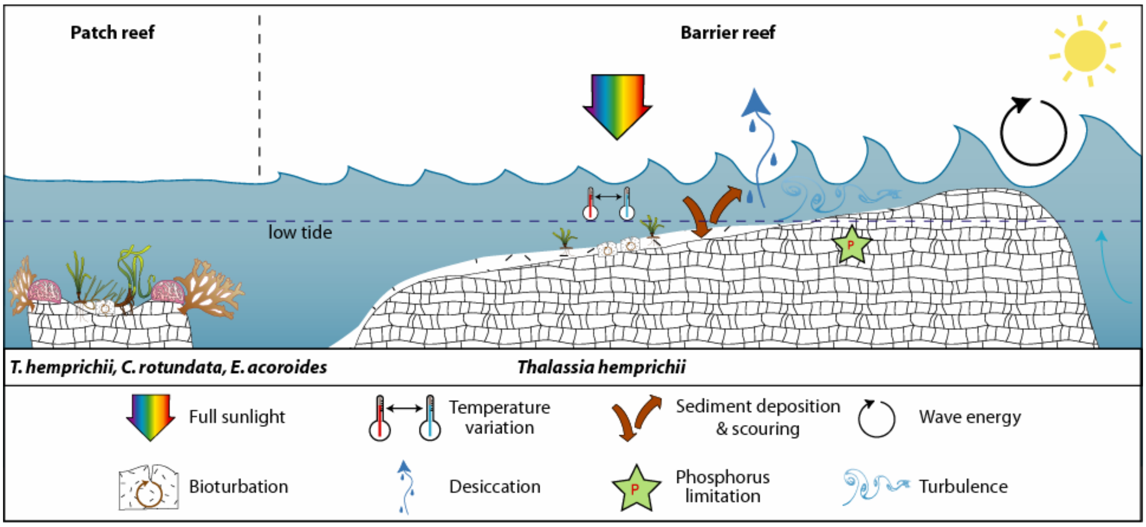
Reef seagrass communities also have unique faunal interactions. Bioturbation by shrimps can be so prevalent in some reef environments as to prevent seagrass growth (Ogden & Ogden 1982). A region of bare sand often separates coral heads from seagrass meadows, previous research suggests this is maintained by parrotfish and surgeonfish associated with the coral (Randall 1965).

Barrier Reef & Patch Reef

Barrier and Patch reef habitats are both subtidal and intertidal and differ significantly in level of disturbance, but are similar in nutrient limitations. Low nutrient availability characterises reef habitats (Stapel *et al*. 1997). The physical and biological processes with determine the seagrass communities on barrier reefs, are similar to exposed fringing reef platforms. Physical disturbance from waves and swell and associated sediment movement primarily control seagrass growing on barrier reef habitats (Figure 10).

Nutrient concentrations are generally low in reef habitats. Carbonate sediments vary in the primary limiting nutrient at different geographic locations around the world (Short *et al*., 1990; Fourqurean *et al*., 1992; Erftemeijer & Middelburg, 1993), however it is most likely Phosphate in Pohnpei habitats. On barrier reefs, seagrass species are generally limited to *T. hemprichii* due to it's tight nutrient recycling strategies.

FIGURE 10. Model of barrier and patch reef habitats – major control disturbance & nutrients: general habitat and seagrass meadow processes.



The only seagrass meadows located on barrier reefs were on the leeward side of vegetated islands, or when the back reef was large. *T. hemprichii* appears the only seagrass species which is able to tolerate the shallow sediment depths, high temperatures and strong currents. At some locations, bioturbation by shrimps and polychaete worms was so prevalent, it possibly prevented seagrass growth (Ogden & Ogden, 1982).

Patch reefs conversely, are less disturbed by water action. Although currents may be high due to their proximity to passages between the barrier reefs, the encircling reef crest affords significant protection. Also, most patch reefs do not appear to be intertidal, but rather shallow subtidal habitats. During low tides, water movement may be slowed, but temperatures may not be significantly elevated. Sediments on patch reefs are predominately coarse carbonate sands and shells. The seafloor also generally contains significant abundance of branching and massive hard corals, and the occasional soft coral. These relatively calm and sheltered habitats support all three seagrass species found on Pohnpei. The sheltered environment also supports abundant communities of burrowing shrimps, which in some locations are so extensive that the bioturbation limits the ability of seagrass seeds to settle and colonize.

Atoll

Atolls include both subtidal and intertidal seagrass habitats. These environments have excellent water clarity. The sediments in these locations can be relatively stable, although bioturbation may restrict seagrass growth and distribution. The physical and biological processes which determine the seagrass communities on atolls, are similar to fringing reef platforms. Seagrasses are only found adjacent to vegetated sand cays/ islands which fringe the atoll (Figure 11). A dominant influence is nutrient availability, shelter from waves / swell and sediment availability/depth (Figure 12).

Thalassia and *Cymodocea* dominate these areas, as they are seen as intermediate genera that can survive a moderate level of disturbance and able to tolerate nutrient poor sediments (Walker *et al.*, 1999).

FIGURE 11. Diagrammatic representation of seagrass habitats on Ahnd Atoll.

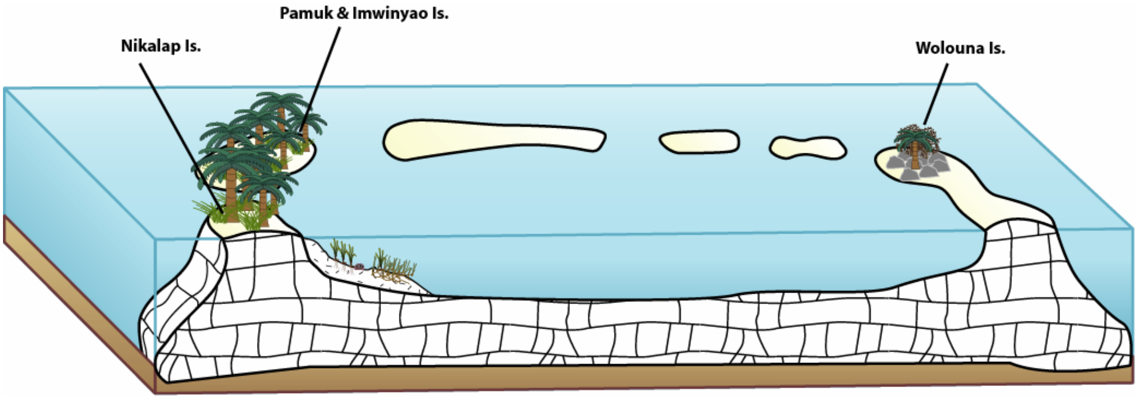
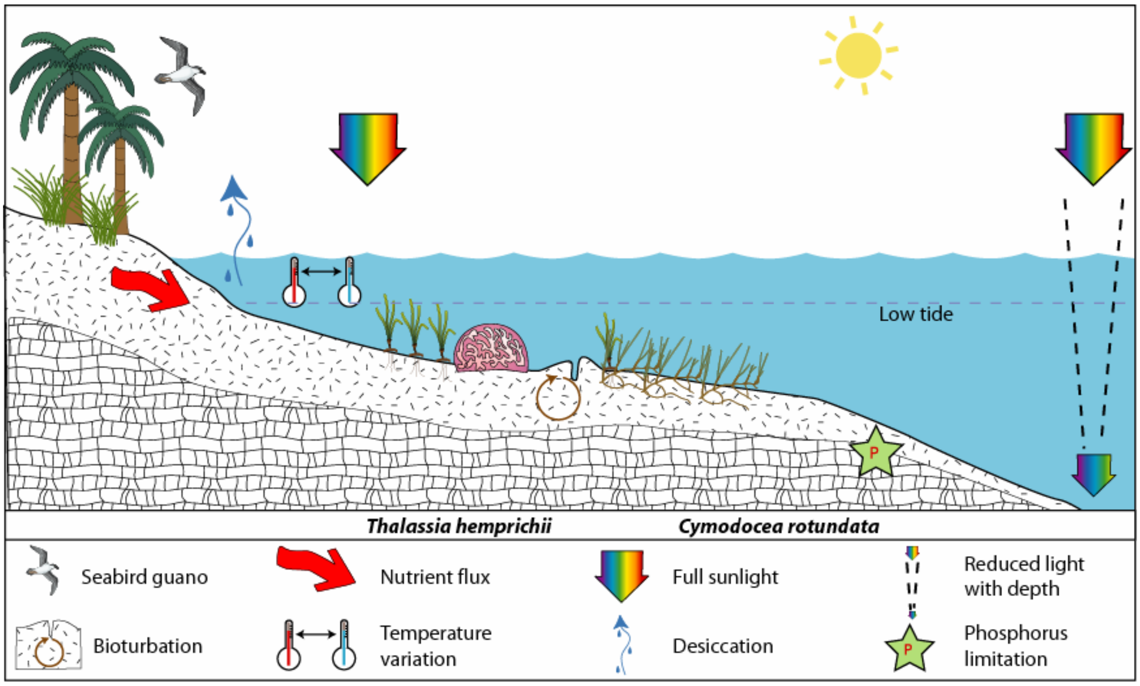


FIGURE 12. Model of atoll habitats – major control disturbance & nutrients: general habitat and seagrass meadow processes for sheltered sandy section of lagoon.



The nearshore region of the sandy lagoon adjacent to the vegetated sand cays/ islands is relatively stable. Canopy heights were greater in the subtidal nearshore locations, possibly a consequence of the sheltered environment. In the intertidal areas, only *T. hemprichii* was present, and the leaves were very short. Low tide exposure in this region close to the equator can lead to UV-B radiation damage to leaves (Short & Neckles 1999), reducing their length.

This type of seagrass distribution appears generally typical of atolls. For example, seagrasses meadows in the atolls of Lakshadweep (India) are mainly confined to the leeward side of lagoons, generally occurring in long stretches along the shores and confined to depth of up to 3 m (Jagtap 1998; Untawale & Jagtap 1984). Apart from protection from waves, Jagtap (1998) concluded that this pattern of distribution was highly correlated with sufficient depth of well sorted sediments.

The presence of seagrass on the sandy sediments behind the sandy cays/islands is also possibly a consequence of restricted nutrient transport. Nutrients, particularly phosphate, on the atoll would be limited due to the carbonate content of the sediments.

Nutrients from the decomposition of vegetation and seabird guano (high in phosphate) would flow/flux into the adjacent marine waters from the water table (rainfall). Due to water currents, the distance the nutrients would be available to benthic plants may be restricted to <100m. Other factors restricting seagrasses would be sufficient sediment depth and possible light limitation in the deeper waters of the lagoon.

In the Maldives, nutrient limitation (total phosphorus) was shown to restricted seagrass distribution and abundance in several atolls (Miller & Sluka 1999). Consequently, chronic nutrient enrichment (for either traditional fishing village waste or seabirds) is known to result in increased seagrass production and standing crop, and, over a longer time scale, a shift in species composition (Miller & Sluka 1999; Powell et al., 1991; Fourqurean et al., 1995)

On the outer regions of the reef atoll, the sediments can be very shallow, and often more mobile. These environments are similar to barrier reef habitats. Intertidal environments also have high variations in temperature and may be exposed at low tide.

Atoll habitats in Pohnpei are possibly the least threatened seagrass community. However they are little studied and therefore assessing change in this habitat is extremely valuable.

ASSOCIATED FAUNA

As many as 154 species of fish and invertebrates feed directly on seagrass tissue and many more feed on epiphytic algae or shelter from predation amongst seagrass leaves (Klumpp *et al.* 1989). For example, Benstead *et al.* (2006) demonstrated using stable isotope signatures ($\delta^{13}C$ and $\delta^{34}S$) that the importance ranking of organic matter sources to consumers (fish and crabs) from four estuaries on Kosrae (FSM) was seagrasses > seagrass epiphytes > marine particulate organic matter > mangrove forest > freshwater swamp-forest. However, it is generally the habitat value of seagrass meadows, in particular fisheries, for which seagrasses are important.

Seagrass meadows are important shallow coastal-water nurseries for the growth and survival of many marine fishes (Jackson *et al*., 2001; Nagelkerken *et al.*, 2002). Generally the most abundant fishes in seagrass meadows of intertidal reef flats of Micronesia are Gobiidae, Labridae and Scaridae (Nakamura & Sano 2004). Approximately 15% of fish species (approximately half the individuals) inhabiting intertidal seagrass meadows dominated by *E. acoroides* (including *T. hemprichii*, *Syringodium isoetifolium* and *C. rotundata*) in the Ryukyu Islands, also spend some part of their life on coral reefs (Nakamura & Sano 2004). They utilized the seagrass meadow as an important juvenile habitat. Sometimes seagrass meadows are used as part of the adult habitat as well as the juvenile habitat.

The emperors (Lethrinidae) are prominent fishes, found principally as adults along shallow coral reef habitats of the subtropical and tropical Indo-Pacific region (Grandcourt *et al.,* 2006), and are an important component of reef-based fisheries throughout their range. In the present survey, schools of *Lethrinus harak* were often observed, particularly in the seagrass meadows on the sheltered fringing reef platform in southern Pohnpei. Their diet mainly comprises molluscs, crustaceans, and polychaete worms. It is likely that juveniles settle into seagrass meadows at the end of their pelagic larval phase on the basis of chemical cues. For example, juveniles

L. nebulosus can select a seagrass meadow habitat (60% *T. hemprichii*, and 40% *Zostera japonica*/*S. isoetifolium*/*C. rotundata*) on the basis of chemical cues, when settling into its first benthic habitat at the time of metamorphosis (Arvedlund & Takemura 2006). It is unknown how long *Lethrinus* spp. juveniles remain in seagrass meadows, however some research reported that they stayed almost exclusively over shallow-water (≤7 m) seagrass areas until "at least 80 mm" (Wilson 1998).

Juveniles of some species of coral reef fish shelter in the mangroves during the day and forage in the seagrass at night (Cocheret de la Morinie`re *et al.* 2002; Faunce & Serafy 2006; Nagelkerken & van der Velde 2004b). Reef-fish species using mangroves and seagrass can be further divided into two groups (Nagelkerken & van der Velde 2004a). One group shelter in mangroves during the day and at night feed primarily in the mangroves and use seagrass only as a secondary feeding habitat. The other group feeds and shelters only in seagrass, both day and night (Nagelkerken & van der Velde 2004a). A study in the Caribbean found that the species richness of juvenile coral fish was greater in seagrass meadows adjacent to mangrove forests than in seagrass meadows in bays without mangroves (Nagelkerken *et al.* 2001). Other work there shows movements between seagrass and mangroves at different times of the day (Cocheret de la Morinie`re *et al.* 2002). Over longer periods, grey snapper (*Lutjanus griseus*) show ontogenetic shifts in habitat utilisation, foraging in the prop root fringe of mangroves as juveniles and in adjacent habitats including seagrass as adults (Thayer *et al*. 1987).

Although not observed during this survey, sea turtles are considered an important component of Micronesian coastal and nearshore habitats, including seagrasses. The distribution and status of sea turtles at many Pacific island localities has yet to be determined but is of concern as continuing human expansion and coastal development throughout the region has great potential to negatively impact local sea turtle populations through increased harvests, incidental catch, and the degradation of nesting and critical nearshore and pelagic habitats (see Lutcavage *et al.* 1997, Bjorndal 1997). The lack of specific island and archipelago information hinders efforts to understand not only local, but also the large-scale regional dynamics of turtle populations, and reduces the ability to effectively plan development and human activities to minimize impacts and to manage sustainable utilization of turtles as a resource.

THREATS

Reef and marine degradation in the Federated States of Micronesia (FSM) region is attributed to various natural and anthropogenic disturbances, including: storm and wave action (particularly those resulting from typhoons), increased seawater temperature (El-Nino Southern Oscillation), freshwater runoff, soil erosion related to inappropriate / unregulated land clearing (e.g., sakau crops, logging), development activities (e.g., road construction, port/village infrastructure/dwellings), boat anchoring, marine quarrying / dredging, sewage discharge (human and agriculture), industrial pollution and over fishing (Lindsay and Edward 2000; Hasurmai *et al.* 2005; Kelty *et al.* 2004). Apart from climate change, these impacts are mostly localized and would have occurred post World War Two.

Increased sedimentation, particularly to coastal and nearshore marine communities was observed at several locations around Pohnpei. The greatest impacts appear from road construction without sufficient sediment-stabilisation mitigation, clearing for infrastructure and cash crops (e.g., sakau), and dredging/coral mining nearshore and in the lagoon for sand and fill. Victor *et al* (2005) reported that the coral reefs on the southern coast are silting as a result of sediment discharged from Enipein watershed after heavy rain events. They attributed the high sedimentation rate to poor farming and land-use practices in the upland areas.

The presence of particulates in the nearshore waters (from terrigenous soils in run-off and sediments in dredge spoils) and resuspension from climatic events, results in reduced photosynthetic capability of seagrass, a consequence of reduced water clarity and nutrient enrichment. Although seagrass meadows trap and store both sediments and nutrients (Hemminga & Duate 2000), seagrasses have a high minimum light requirement, which results in susceptibility to altered water clarity (Dennison e*t al* 1993).

Elevated nutrients can lead to a loss in seagrass by limiting light. Chronic increases in dissolved nutrients can leading to proliferation of algae reducing the amount of light reaching the seagrass (e.g. phytoplankton, macroalgae or algal epiphytes on seagrass leaves and stems) or chronic and pulsed increases in suspended sediments and particles leading to increased turbidity (Schaffelke *et al.* 2005). Eutrophication of shallow estuaries and lagoons can also lead to the proliferation of bloom-forming "ephemeral" macroalgae shading seagrass populations and eventually in displacing seagrasses as the dominant benthic autotrophs (McGlathery 2001). High epiphyte and macro-algal abundance was observed at several locations around Pohnpei, most adjacent to villages and towns, but also in estuaries.

Dredging and coral mining have caused significant impacts on nearshore habitats around Pohnpei. On land quarrying would be a suitable and viable alternate, and this has been identified by Maharaj (2001).

Over fishing and destructive fishing practices can threaten seagrasses. Most of the marine fish species recorded for the FSM are reef-associated (873 of 1,125) (Myers & Donaldson 2003). There are few catch and export data, but some market information suggests that the fisheries may be substantial. The gross value output of FSM fisheries was estimated at US$86.4 million in 1998, and while commercial export has the greatest impact on FSM fisheries, over-fishing by foreign vessels has also been documented. Destructive fishing practices, including the use of explosives taken from the wrecks, have caused local damage, but better assessments of fisheries resources within the FSM are needed.

Most of these localized impacts can be managed with appropriate environmental guidelines, however climate change and associated increase in storm activity, water temperature and/or sea level rise has the potential to damage seagrasses in the region or to influence their distribution. Sea level rise and increased storm activity could lead to large seagrasses losses.

PROTECTION

Since 2000, the Conservation Society of Pohnpei has implemented a program to conserve Pohnpei's marine biodiversity through a network of community-based Marine Protected Areas (MPAs). The network of five MPAs includes Sapwitick/Lenger, Kehpara, Nahtik, Dekehos and Dehpehk. An additional two MPAs were delineated at Namwen Na and Kisin Namwen Nahningih in May 2005.

The primary goal of any network is to establish and manage a Comprehensive, Adequate and Representative system of MPAs to contribute to the long-term ecological viability of marine systems, to maintain ecological processes and systems, and to protect Pohnpei's biological diversity at all levels.

A number of secondary goals (Baker 2000) can also be designed to be compatible with the primary goal:

- To promote the development of MPAs within the framework of integrated ecosystem management;
- To provide a formal management framework for a broad spectrum of human activities, including recreation, tourism, shipping and the use or extraction of resources, the impacts of which are compatible with the primary goal;
- To provide scientific reference sites;
- To provide for the special needs of rare, threatened or depleted species and threatened ecological communities;
- To provide for the conservation of special groups of organisms, e.g. species with complex habitat requirements or mobile or migratory species, or species vulnerable to disturbance which may depend on reservation for their conservation;
- To protect areas of high conservation value including those containing high species diversity, natural refugia for flora and fauna and centres of endemism;
- To provide for the recreational, aesthetic and cultural needs of indigenous and non-indigenous people.

Currently there is no legislation in FSM that specifically stipulates that the function of seagrass ecosystems should be maintained. However, seagrasses do not exist in nature as a separate ecological component and are often closely linked to other community types. Associations are likely to be complex interactions with mangrove communities, algae beds, salt marshes, and coral reef systems. Worldwide, many management actions to protect seagrasses have their geneses in the protection of wider ecological systems or are designed to protect the overall biodiversity of the marine environment. The protection of seagrass habitat for species listed as threatened or vulnerable to extinction (e.g., green turtle), and their importance as habitat for juvenile fish and crustaceans which form the basis of economically valuable subsistence and/or commercial fisheries, have become motivating factors for the protection of seagrasses.

Coles and Fortes (2001) recommended three approaches to protection of seagrass resources: a prescriptive legal approach; a non-prescriptive broad based approach ranging from planning processes to education; and a reactive approach designed to respond to a specific issue such as a development proposal. These may overlap and be used simultaneously in many cases.

Prescriptive management of seagrass issues can range from local to statewide. Protection is often strongest at the village or district level by Government supported agreements or through local management level (Coles and Fortes 2001). At a village level, successful enforcement is very dependent on community support. While there is no international legislation that specifically protects seagrass, there are international conventions that recognise the importance of wetlands and coastal areas (IUCN 1994), such as the Ramsar Convention on Wetlands. In some cases, seagrass meadows have been inadvertently protected because they are located within protected areas.

There are also a number of features to consider when designing MPAs for fish and seagrass. For example, small meadows of seagrass can have greater fish species richness than larger meadows and both patchy and uniform meadows should also be included within a network because they were found to have different assemblages of fish (Jelbart and Ross 2003, Jelbart *et al.* 2006a). Meadows from all habitats should be included to ensure the protection of all fish species. The protection of adjoining mangrove and coral habitat as well as seagrass habitat is recommended, because meadows proximal to mangrove have significantly greater species richness than meadows without adjoining mangrove. The proximity of seagrasses to other critical habitats such as mangroves and coral reefs, facilitates trophic transfers and cross habitat utilization (Jelbart *et al.* 2006b). In the case of some coral reef fish, this provides an energy subsidy that may be essential in maintaining abundance of these fish species (Valentine & Heck 2005)

Non-prescriptive methods of protecting seagrasses generally have a strong extension and/or education focus. Providing information is important as it encourages and enables individuals to voluntarily act in ways that reduce impacts to seagrasses. Actions in response to such information could range from being more aware of the down-stream effect of poor agricultural practices to lobbying politicians for stronger sanctions against decisions that lead to seagrass loss. Non-prescriptive methods range from simple explanatory guides to complex industry codes of practice developed in negotiation with the industry in question (Coles and Fortes 2001).

Reactive processes generally occur in response to a perceived operational threat such as a coastal development proposal. Reactive processes can also include risk management plans that identify areas of seagrass to be protected in the event of an impact (e.g., oil spill or ship grounding). Reactive processes are generally identified in environmental impact statements (EIS), which also propose strategies (e.g., redesign, response, or by reducing future risk) to minimise the effect of a development or structure on the coastal environment including seagrasses. The combination of project redesign in response to EIS information and reactive environment management systems can provide enormous improvements to coastal seagrass protection.

MONITORING

Seagrasses can be effective biological sentinels or "coastal canaries", as widespread seagrass loss signals important negative changes in coastal ecosystems. To provide an early warning of change, long-term monitoring sites have been established at Nan Madol as part of Seagrass-Watch, Global Seagrass Monitoring Network (www.seagrasswatch.org McKenzie *et al.* 2006; McKenzie *et al.* 2000). The program has monitoring sites in Kosrae and hopes to expand to include other states of FSM. Seagrass-Watch results alone may not answer every question. Fisheries science assistance may be necessary to fully understand impacts of change in seagrasses on local food webs. Seagrass-Watch does, however, provide a simple and rapid method of quantifying seagrass meadow characteristics and this can be used as a surrogate for monitoring impacts on broader marine biodiversity. The Seagrass–Watch monitoring method can provide useful information sufficient to influence decision making in the coastal zone in ways that may have an enormous long-term beneficial outcome. By working with both scientists and local communities, it is hoped that many anthropogenic impacts on seagrass meadows which are continuing to destroy or degrade these coastal ecosystems and decrease their yield of natural resources can be avoided.

RECOMMENDED ACTIONS

- Promote seagrass and mangrove conservation in the Micronesian islands as they have had a low priority in conservation programs in the region.
- The inclusion of Ahnd Atoll into the states MPA program would aid in conservation.
- Additional Seagrass-Watch monitoring sites established to serve as an early warning of decline and scientific reference;
- More protected areas to be established, to ensure that examples of seagrass ecosystem remain in the FSM for use by future generations
- Seagrass conservation values need to be enhanced by development of education resource materials, to be used in schools and community groups
- A Pacific Island monitoring program of seagrass ecosystem health needs to be established. This could be linked to existing region/global monitoring programs (e.g., Seagrass-Watch, www.seagrasswatch.org) for monitoring climate change/sea level rise impact.
- Studies on importance, ecology, and population dynamics of subsistence fisheries which seagrass ecosystems support

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APPENDIX 1. METADATA FOR GIS DATASETS

[Compliant with ANZLIC Guidelines, Table 1: Core Elements]

Category	Element	Detail/Comment
Dataset	Title	Pohnpei REA sites
	Custodian	Department of Primary Industries & Fisheries
	Jurisdiction	Pohnpei State, Federated States of Micronesia
Description	Abstract	Pohnpei Island and Ahnd Atoll seagrass ground truthed sites surveyed 26 October – 03 November 2005.
	Search Words	Seagrass, Micronesia, MPA
	Geographic Extent	Pohnpei Island & Ahnd Atoll; Pohnpei State; Federated States of Micronesia.
Currency	Origin Date	October 2005
	Ending Date	August 2006
Status	Progress	Currently in general usage
	Projection	Latitude/Longitude
	Datum	WGS84 UTM Zone 57N
	Scale	1:100
	Maintenance, Update Frequency	Completed
	Stored Data Format	Digital ArcGIS shapefile
	Available Format Type	Digital ArcGIS shapefile and export
	Access Contraint	Files are not to be copied or distributed to third parties. Files to be deleted after use.
Quality	Lineage	Derived from visual assessment of the seabed by diving on points out from the coastline. Source: McKenzie, L.J. and Rasheed, M.J. (2006). Seagrasses: Pohnpei Island and Ahnd Atoll Marine Assessment: Technical report of survey conducted 26 October – 3 November 2005. (Seagrass-Watch HQ, DPI&F, Cairns). 60pp.
	Positional Accuracy	A Global Positioning System (GPS) was used to accurately determine geographic location of sampling sites (±5 m).
	Attribute Accuracy	Contains pecentage cover of seagrass and other benthos in a 50cmx50cm quadrat. Information finalized. Codes for seagrass species names are: EA = *Enhalus acoroides*, CR = *Cymodocea rotundata*, TH = *Thalassia hemprichii* updated. Meadow habitat and community types are listed in the source publication. Information finalized.
	Logical Consistency	Attributes are standradised.
	Completeness	All sites examined 26 October – 03 November 2005.are represented. Seagrass abundance can change seasonally and between years, and users should ensure that they make appropriate enquires to determine whether new information is available on the particular subject matter.
Contact Information	Organisation	Department of Primary Industries & Fisheries, Queensland
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Metadata	Metadata Date	29.08.2006
Additional Metadata		

Category	Element	Detail/Comment
Dataset	Title	Pohnpei REA meadows
	Custodian	Department of Primary Industries & Fisheries
	Jurisdiction	Pohnpei State, Federated States of Micronesia
Description	Abstract	Pohnpei Island and Ahnd Atoll seagrass meadows surveyed 26 October – 03 November 2005.
	Search Words	Seagrass, micronesia, MPA
	Geographic Extent	Pohnpei Island & Ahnd Atoll; Pohnpei State; Federated States of Micronesia.
Currency	Origin Date	October 2005
	Ending Date	August 2006
Status	Progress	Currently in general usage
	Projection	Latitude/Longitude
	Datum	WGS84 UTM Zone 57N
	Scale	1:100
	Maintenance, Update Frequency	Completed
	Stored Data Format	Digital ArcGIS shapefile
	Available Format Type	Digital ArcGIS shapefile and export
	Access Contraint	Files are not to be copied or distributed to third parties. Files to be deleted after use.
Quality	Lineage	Derived from visual assessment of the seabed by diving on points out from the coastline. Source: McKenzie, L.J. and Rasheed, M.J. (2006). Seagrasses: Pohnpei Island and Ahnd Atoll Marine Assessment: Technical report of survey conducted 26 October – 3 November 2005. (Seagrass-Watch HQ, DPI&F, Cairns). 60pp.
	Positional Accuracy	A Global Positioning System (GPS) was used to accurately determine geographic location of sampling sites (±5 m).
	Attribute Accuracy	Contains pecentage cover of seagrass and other benthos in a 50cmx50cm quadrat. Information finalized. Codes for seagrass species names are: EA = *Enhalus acoroides*, CR = *Cymodocea rotundata*, TH = *Thalassia hemprichii* updated. Meadow habitat and community types are listed in the source publication. Information finalized.
	Logical Consistency	Attributes are standradised.
	Completeness	All meadows examined 26 October – 03 November 2005.are represented. Seagrass abundance can change seasonally and between years, and users should ensure that they make appropriate enquires to determine whether new information is available on the particular subject matter.
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Metadata	Metadata Date	29.08.2006
Additional Metadata		

This was the first detailed survey of seagrass resources surrounding Pohnpei Island & Ahnd Atoll, Pohnpei State, Federated States of Micronesia.

4,400 hectares of seagrass were mapped in the intertidal and shallow subtidal waters surrounding Pohnpei Island & Ahnd Atoll.

Three species of seagrass (*Cymodocea rotundata, Enhalus acoroides* and *Thalassia hemprichii*) and 21 seagrass meadow community types were identified.

Seagrass distribution appears to be primarily influenced by the degree of wave action (exposure), water clarity and nutrient availability. Pohnpei's seagrass habitats can be generally categorised into six habitats: estuary, sheltered fringing reef, exposed fringing reef, patch reef, barrier reef and atoll.

Seagrass meadows in the region are in a relatively healthy condition compared to many other regions globally.