2. Seagrasses

This chapter should be cited as:
Coles, R, Smit, N, McKenzie, L, Roelofs, A, Haywood, M & Kenyon, R (2004). Seagrasses. In: National Oceans Office. Description of Key Species Groups in the Northern Planning Area. National Oceans Office, Hobart, Australia.

Monitoring seagrass ***Source:*** *Ports Corporation of Queensland*

Principal contributor:
Dr Rob Coles
Senior Principal Scientist
Northern Fisheries Centre
Queensland Department of
Primary Industries and Fisheries
PO Box 5396
Cairns QLD 4870
Ph: (07) 4035 0111
Fax: (07) 4035 4664
Rob.Coles@dpi.qld.gov.au

In cooperation with:
Neil Smit
Marine Scientist
Biodiversity Unit
Natural Systems Division
Department of Infrastructure,
Planning and Environment
PO Box 496
Palmerston NT 0831

Len McKenzie & Anthony Roelofs
Fisheries Biologists
Northern Fisheries Centre
Queensland Department of
Primary Industries and Fisheries
PO Box 5396
Cairns QLD 4870

Mick Haywood & Rob Kenyon
Marine Ecologists
CSIRO Division of Marine Research
PO Box 120
Cleveland QLD 4163

Species group name and description

The generic term seagrass is widely understood to include the group of flowering vascular plants that live in sea water or brackish water. They may be confused by non-specialists with some macro algae species and some freshwater vascular plants. There is debate regarding genera such as *Ruppia*. This is discussed in more detail in Short and Coles (2001). Recent taxonomic revisions of the species of *Zostera* and *Halophila* have led to some species change (Kuo 2000). The original names at the time of publication of this report have been used in this report.

Various common names are applied to species in the literature such as turtle grass, eelgrass and shoal grass. These names are not consistently applied among countries and in any case are not commonly used in northern Australia. We are not aware of any name for seagrass species used consistently by Indigenous groups. However coastal communities would almost certainly recognise the term 'dugong grass' as referring to the shallow subtidal and intertidal seagrasses.

Seagrasses are specialised marine flowering plants that have adapted to the nearshore environment of most of the world's continents. Most are entirely marine although some species cannot reproduce unless emergent at low tide or subject to fresh water inflow. Some 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.

Seagrass distribution has been described for most species (den Hartog 1970, Phillips & Menez 1988, Mukai 1993, Green & Short 2003). There is now a broad understanding of the global range of species and seagrass habitats. Areas where the global distribution is less well known include the Pacific Ocean reefs and islands, South America, the southern Atlantic, the Indian Ocean islands, the west African coast, and Antarctica.

Shallow subtidal and intertidal species distributions are better recorded than seagrasses in water greater than 10 m below mean sea level. 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).

Australian seagrass species distribution is well documented except for the northern tropical region (Butler & Jernakoff 1999). Recent initiatives such as the Torres Strait CRC and port monitoring programs (eg Rasheed et al. 2003) are addressing this for restricted areas but the majority of the north of Australia lacks recent seagrass distribution data.

There are 15 species of seagrass recorded in the Northern Planning Area (NPA):

Family **CYMODOCEACEAE** Taylor

- *Cymodocea rotundata* Ehrenb. & Hemp. Ex Aschers
- *Cymodocea serrulata* (R. Br.) Aschers. & Magnus
- *Halodule uninervis* (wide- & narrow-leaf) (Forsk.) Aschers.
- *Halodule pinifolia* (Miki) den Hartog
- *Syringodium isoetifolium* (Aschers.) Dandy
- *Thalassodendron ciliatum* (Forsk.) den Hartog

Family **Hydrocharitaceae** Jussieu

- *Enhalus acoroides* (L. *f*) Royle
- *Halophila decipiens* Ostenfeld
- *Halophila minor* (Zollinger) den Hartog
- *Halophila ovalis* (R. Br.) Hook f.
- *Halophila spinulosa* (R. Br.) Aschers. in Neumayer
- *Halophila tricostata* (Greenway)
- *Halophila ovata* Gaudichaud **
- *Thalassia hemprichii* (Ehrennb.) Aschers in Petermann

Family **ZOSTERACEAE** Drummortier

- *Zostera capricorni* Aschers

**Taxonomic revision now indicates this species is not present in the Torres Strait. Recent taxonomic revisions consider *H ovata* in the tropical Indo-western Pacific region to be a mis-identification of *Halophila minor*. The two species are not considered to co-occur in the same region (Kuo 2000).

In the Torres Strait the seagrass communities are a diverse array of complex assemblages with most combinations of the 11 species found recorded in the field (Long & Poiner 1997). There are large areas of reef platform seagrasses with communities consisting of the common reef associated species: *Thalassodendron ciliatum*, *Cymodocea rotundata*, and *Thalassia hemprichii*. Other species occur in small amounts with these species at some locations. These reef platform habitats are important as nursery grounds for commercial juvenile penaeid prawns (Turnbull & Mellors 1990). *Enhalus acoroides* is generally restricted to shallow subtidal and intertidal regions. It is the only seagrass species that must come to the water surface to pollinate. *Halophila spinulosa* is more common in deeper water (10 m and deeper).

2. Seagrasses

Published information on Torres Strait and Gulf of Carpentaria (GoC) seagrass is mostly in report form. The main distributional information is in Bridges et al. (1982), Long and Poiner (1997), Long and Skewes (1997), Long et al. (1997), Thomas et al. (1997), Rasheed et al. (1996; 2000; 2001; 2002; 2003) and Roelofs et al. (2001a; 2001b; 2003).

The extensive intertidal banks along the GoC coast have seagrass meadows that are a mixture of *Halodule* and *Halophila* species. *Syringodium isoetifolium* and *Cymodocea serrulata* are common subtidally and *Halophila ovalis* and *Halophila spinulosa* further offshore (Poiner et al. 1989). Published information for the GoC except in report format is now over 15 years old.

Distributional information and some ecological comment is in Coles and Lee Long (1985), Poiner et al. (1987), Rasheed et al. (1996), Kenyon et al. (1997), Loneragan et al. (1998), Kenyon et al. (1999), Sheppard et al. (2001), Rasheed et al. (2000; 2001; 2002; 2003), Roelofs et al. (2001a and 2001b) and Coles et al. (in prep). Some recent information on seagrass distribution has been collected for the Macarthur River region (south western Gulf) (Smit pers. comm. 2003).

Little information on species is available for the Northern Territory (NT) coast outside the GoC. Dugong distribution will provide some information (Elliot et al. 1979, Saalfeld 2002). Green and Short (2003) have polygon information for the NT coast that to the best of our knowledge is unverified.

Status

None of the seagrass species in the planning area is listed as threatened or endangered. *Halophila tricostata* is the least common of the 15 species and is endemic to northern Australia. *Thalassodendron ciliatum* is found almost entirely on reef platforms and exposed reef edges and so has a very limited distribution in the area.

Seagrasses are protected in Queensland waters by provisions of the *Queensland Fisheries Act 1994*. Intentional damage to seagrasses can only occur if a permit has been issued. Exemptions are available for small collections for research and for maintenance of infrastructure. The *NT Fisheries Act 1988* provides for the control of harvesting of aquatic life and for the protection of fish habitat (including seagrasses).

Marine protected areas exist under state laws but include few if any seagrass areas. Restrictions on the use of certain fishing gear (eg trawl fishing in most of the Torres Strait and from Mornington Island to Groote Eylandt, 2 nautical miles to seaward from the low tide line including embayments) would indirectly protect seagrass meadows.

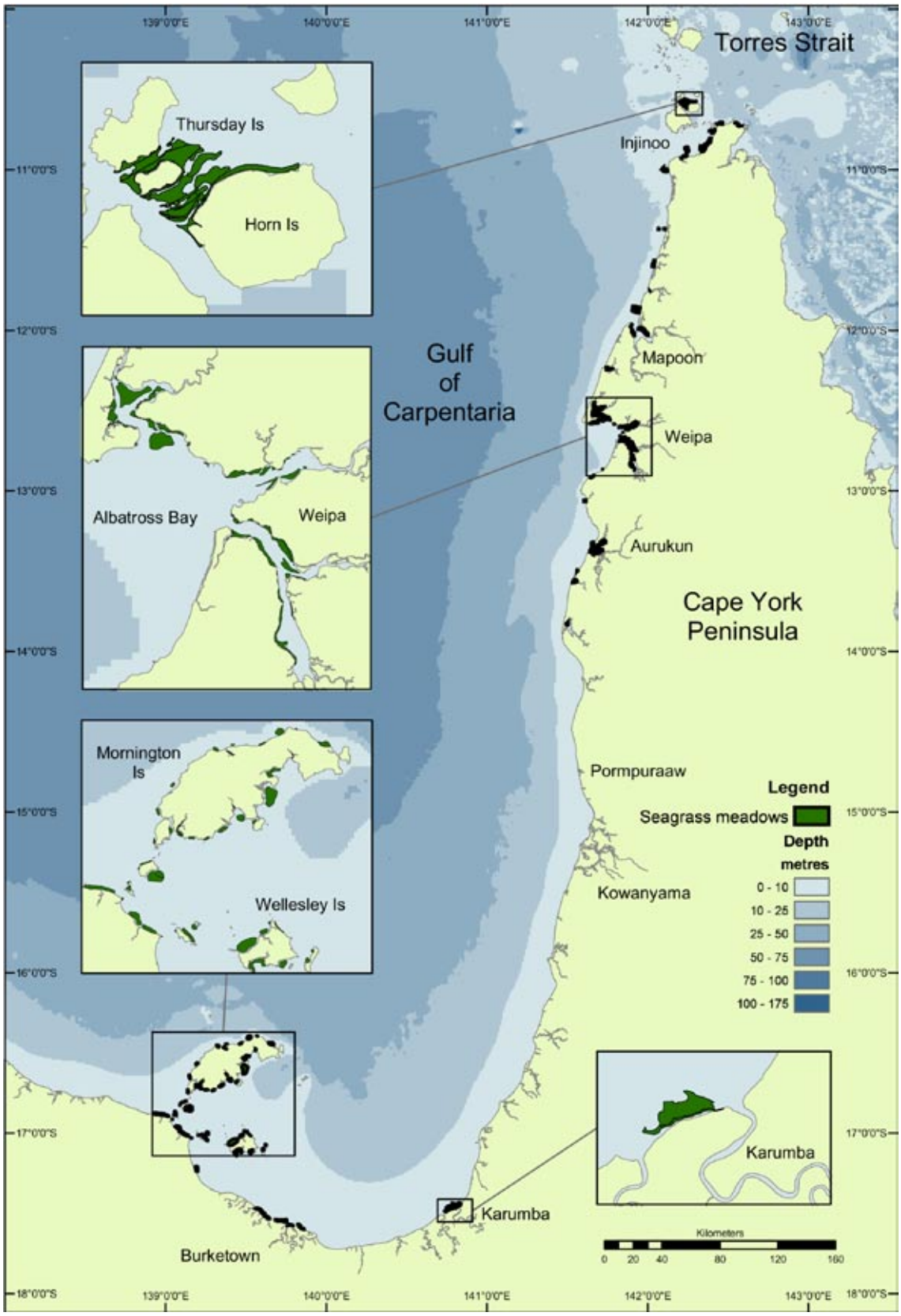
A small amount of seagrass is outside state waters and comes under Commonwealth jurisdiction. We are not aware of any specific protection given to seagrass in the NPA by Commonwealth legislation, though the *Environment Protection and Biodiversity Conservation Act 1999* requires that a person must not take in a Commonwealth marine area an action that has, will have or is likely to have a significant impact on the environment. This would include any significant impact on seagrass beds.

Habitat and distribution

Seagrasses are common in most parts of the Torres Strait and occur in dense and extensive meadows in areas such as Thursday Island Port and on some reef platforms. Surveys of the open waters of Torres Strait have estimated 13 425 km² of seagrass habitat. Seagrass communities occur across the open seafloor, on reef flats and subtidally adjacent to continental islands. A line of large reefs runs northwards from Cape York, including the Warrior Reefs with extensive seagrass-covered reef platforms. Mixed species occur on these platforms, most commonly of the genera *Halodule*, *Thalassia*, *Thalassodendron* and *Cymodocea*. These reef platform habitats are important as nursery grounds for commercial juvenile penaeid prawns (Turnbull & Mellors 1990).

In the Torres Strait *Enhalus acoroides* is generally restricted to shallow subtidal and intertidal regions. The large expanses of open water bottom are covered with either sparsely distributed *Halophila* or mixed species (*Halodule*, *Thalassia* and *Syringodium*) communities. Lush *Halophila ovalis* and *Halophila spinulosa* communities are also found in the deep waters (greater than 30 m) of the south-western Torres Strait. *Halophila spinulosa* is more common in deeper water (10 m and deeper).

Figure 2.1: *Distribution of seagrass in the eastern Gulf of Carpentaria* ***Source:*** *Marine Ecology Group, QDPIF*



2. Seagrasses

The northern tip of Cape York also has extensive coastal seagrass meadows. Seagrasses have been recorded to 15 m off Bamaga and are likely to occur deeper.

Seagrasses in the GoC are less extensive than Torres Strait, covering about 900 km² of seabed in the 1980s. They are mostly restricted to the littoral zone around the periphery of the Gulf, probably because of more turbid waters restricting light to deeper sediments. Recently, *Halophila spinulosa* and *Halophila ovalis* have been found growing in areas to the west of Mornington Island (16° 24_ S, 138° 39_ E) in about 20 m of water (Rob Kenyon pers. obs.), indicating that seagrass may grow at depths and in areas not surveyed by Poiner et al. (1987) and Coles et al. (2001). Surveys in this area are ongoing. The extent and temporal stability of such seagrass meadows throughout the region is largely unknown and requires investigation.

Moving down the western shore of Cape York, seagrasses are largely restricted to bays and inlets south as far as the Kirke and Love Rivers. The Embley and Hey Rivers at Weipa have the most extensive intertidal *Enhalus* beds in the western Gulf. No seagrass has been recorded in the coastal area between Cape Keerweer and the Norman River mouth (Karumba), over 400 km of coastline.

Seagrass bed near Karumba
Source: *Marine Ecology Group, QDPIF*

Along the exposed southern coast west of Karumba seagrass meadows are a mixture of *Halodule* and *Halophila* species. *Syringodium isoetifolium* and *Cymodocea serrulata* are common subtidally and *Halophila ovalis* and *Halophila spinulosa* further offshore (Poiner et al. 1989, Poiner & Peterken 1995, QDPIF unpublished data). These meadows occur patchily along the southern coast, becoming more extensive further westward, with substantial meadows west of the Wellesley Islands. From the Sir Edward Pellew Islands to Maria Island and adjacent to the Rose River, seagrass communities form a mostly continuous coastal meadow (Poiner et al. 1987). Shallow water areas in parts of the south-western Gulf were remapped in 2000 (Hemple & Smit 2000) and areas between the Limmen Bight and Bing Bong and the McArthur River system are considered to be among the top four important dugong sites in Australia (Smit pers. comm.). Seagrass is also found in patches up the estuaries of many rivers and creeks along the NT GoC coast and has been reported in Port Bradshaw, two hours drive south of Gove between Gove and Blue Mud Bay (mainly *Halophila* and *Halodule* species) (Smit pers. comm.).

Seagrass species dominating meadows adjacent to the mainland coast are considered to be pioneering or early colonists (*Halophila* and *Halodule* species) in intertidal areas or areas with environmental stress (eg high turbidity). Subtidally on the open coasts of the western GoC, meadows may be climax species such as *Syringodium isoetifolium* and *Cymodocea serrulata*. Very little is known of the seagrass communities in waters greater than 10 - 15 m depth. Species which are more common in deeper waters (10 m and deeper) such as *Halophila decipiens* are present in the Gulf and could at times form meadows in deeper water. *Halophila tricostata*, also a deepwater species and endemic to northern Australia, has been found in isolated patches as far south as Port Musgrave.

GoC reef flat communities are dominated by *Thalassia hemprichii*. Meadows in estuaries and sheltered bays are mostly of the genera *Halodule*, with some *Cymodocea* and *Enhalus*.

Seagrass distribution and abundance in the inlets and bays of the GoC was last mapped extensively in 1986 (Poiner et al. 1987, Coles et al. 2001). Long-term studies of change in population density and structure associated with port activities have been carried out in Weipa, Karumba and Kirke River and these studies suggest that the distribution of seagrass is still similar

to that of the 1980s but is highly seasonal with declines associated with flooding during the wet season (Roelofs et al. 2001a, Rasheed et al. 2001).

Some recent mapping has taken place in the Macarthur River region (Smit pers. comm. 2003).

Sediments throughout the southern GoC are predominately fine muds, and these are easily resuspended due to the shallow bathymetry resulting in increased turbidity, which restricts seagrass distribution and growth and may lead to seasonal and inter-annual variability in the extent of seagrass meadows.

Anecdotal evidence from the presence of Dugong populations and from unverified database entries suggests that seagrasses extend along the shallow waters of the top of the NT. A port baseline survey for introduced marine pests conducted within the Port of Gove, Nhulunbuy, did detect *Halophila decipiens* from a number of sites within Catalina Bay and adjacent to shipping berths in the Port (Neil et al. 2003).

Our understanding of seagrass flowering, asexual reproduction and timing of flowering and seed production is quite poor. Available information is summarised in Short and Coles (2001).

Significance of the species group in the Northern Planning Area

Seagrasses are a key habitat type in the NPA. They are important for stabilising coastal sediments, providing food and shelter for diverse organisms, as a nursery ground for shrimp and fish of commercial importance, and for nutrient trapping and recycling (Coles et al. 2003). The marine mammal *Dugong dugon* and the green sea turtle *Chelonia mydas* feed directly on seagrasses. Traditional Australian communities use both animals for food and ceremonies.

In the open mud flats of the GoC seagrass meadows and adjacent mangrove forests may provide the only three-dimensional habitat for fish and shrimp to shelter from predation.

Seagrass beds have been specifically identified as juvenile habitat for penaeid shrimps in the eastern Torres Strait (Turnbull & Mellors 1990) and in the GoC (Coles & Lee Long 1985; Loneragan et al. 1998; Coles et al. (in prep.)). Major trawl fisheries are based on these shrimp stocks.

The importance of seagrass meadows as structural components of coastal ecosystems has resulted in new research interest being focused on the biology and ecology of seagrasses and on the methods for mapping, monitoring and protection of critical seagrass habitats. Better camera systems, remote sensing, GPS positioning, and methods of measuring seagrass health such as PAM fluorometry, have improved our ability to map and monitor seagrass communities.

Impacts/threats

Torres Strait region

- Widespread dieback of seagrasses has been reported in the central and northern regions of the Torres Strait. More than 1400 km² of seagrass was lost between 1989 and 1993. There is anecdotal evidence of earlier dieback incidents in the 1970s (Long et al. 1997). It is possible this is a natural cyclical event but that has not been determined.
- Infrastructure works in the region have been permitted in seagrass areas with some small losses (eg Coles 1998).
- Seagrass exposed at low tide is likely to be threatened by climate change (*State of the Environment Report, Queensland, 2003*).
- The Torres Strait shipping lanes have been identified as high risk and port and shipping accidents could have a major impact on seagrass meadows.
- There is a risk of introduced marine pests in the Torres Strait, some of which could have an impact on coastal seagrasses.

Gulf of Carpentaria

- Major port and shipping activities at Weipa and Karumba and Macarthur River are potential threats to regional seagrasses.
- Cyclone-induced erosion has caused large loss of seagrasses (183 km²) in the southern Gulf (Poiner et al. 1989) and an increase in cyclone activity with climate change could result in the loss of extensive intertidal meadows in this region.
- There is anecdotal evidence of seagrass dieback in the southern GoC in 2002 but insufficient data is being collected on seagrass to confirm this (Kwan & Bell 2003, Smit pers. comm. 2003).
- Minor/moderate (loss of 19 hectares) port activity at Macarthur River and Groote Eylandt may have an impact on regional seagrass meadows.
- Future land-based threats to the Gulf region seagrass may arise from increased levels of extractive mining and the development of pastoral areas

for horticulture. These activities can greatly increase the amount of sediment/turbidity and pollutants associated with runoff produced after the monsoon rains.

- Projects are being developed or extended for ecotourism, pearl leases and aquaculture and these may have an impact on coastal seagrass meadows.

Northern Territory (outside the Gulf of Carpentaria)

- Port and shipping activity at Gove and nearby may have an impact on regional seagrasses.
- There is a low level risk of introduced marine pests affecting coastal seagrasses.
- A holothurian (bêche-de-mer) aquaculture project is proposed west of Gove with a grow-out proposal for seagrass meadows.

There is insufficient information on seagrass meadows in this region from which to fully determine likely impacts and threats.

Information gaps

The only recent data collection on seagrasses in the NPA has been in ports (Thursday Island, Skardon, Weipa, Macarthur River and Karumba) or specific locations such as the Kirke River. Some information is being collected in the Torres Strait by CSIRO and QDPI and this data collection will increase with the start of the Torres Strait CRC.

Most other data for the region dates from the late 1980s or earlier and its value for input into a planning process is difficult to assess.

Detailed density, growth and reproduction data on species such as *Halodule uninervis*, *Halophila ovalis*, *Syringodium isoetifolium* and *Cymodocea serrulata* exist in CSIRO Marine Research databases. These data were collected during bi-monthly surveys at Groote Eylandt during the 1980s, but have not been analysed.

There is sufficient anecdotal evidence of seagrass losses or large time-scale cyclical change and consequent detrimental effects on large herbivore populations for this to be a matter of concern[1].

There is almost a complete lack of information in the planning area outside the Torres Strait on the distribution of seagrass deeper than about 15 m. Except for the ports monitoring program information, the shallow water information is either too old or too imprecise to be of much value for management purposes.

Proposed actions

Mapping needs

- Thursday Island to Mapoon – available data is quite old and broad-scale. The data needs to extend seaward to take in the main shipping route and include islands.
- Wellesley Islands (Mornington Island) – data are quite historic (1984) and there has been some concern over the past 12 months that the poor condition of sea turtles and dugong may be a consequence of poor habitat nutritional quality. Original maps were of low precision and re-mapping is needed.
- Western Gulf & Groote Eylandt – broad-scale mapping is mostly late-1980s and prior to accurate satellite-based position fixing and requires remapping in a consistent fashion. (Wellesley Islands to the Sir Edwin Pellew (Vanderlin Islands) were last mapped in 1984, prior to accurate satellite-based position fixing; Sir Edward Pellew Islands to Rose River was mapped in 1995 (though not published); Groote Eylandt/Blue Mud Bay was last mapped in the 1980s, prior to accurate satellite-based position fixing).
- Nhulunbuy to Goulburn Islands – little or no detailed information or consistent ground-based mapping on habitats from this area exists as far as we are aware and a baseline habitat map of seagrass would assist planning.
- Recent reports of central Gulf reefs and records of seagrass at depths of 20 m in the less turbid south-west Gulf have emphasised our lack of any data much below 15 m (and emphasise how little is really know about seagrass distribution in this region). Some deeper water surveys for seagrass habitat are required.

[1] *See Chapter 10 'Dugon" for further dicussion on this point*

Ecological/process studies

- There have been reports from the southern GoC of turtle 'thinning' with black fat (high chlorophyll remaining in mesenteric tissue), and a high occurrence of floating turtles (this is due to obstructed digestive tract) particularly in southern Mornington Island waters. Also, there are reports of emaciated dugong with 'bubbly' fat, depleted stocks of bêche-de-mer (Holothurians) and a significant increase in filamentous algae. The Indigenous communities in the area are of the opinion that all these impacts are a consequence of Pasminco mining in the Karumba region. The concerns about these consequences of development are shared by communities in the south western Gulf (Smit pers. comm. 2003). We have little information on the quality of the seagrass as food and the relationship between the seagrass and algae communities and how this may affect grazing populations. Nutritional studies and studies of short and long-term change are required. Some ecological network analysis studies in the southern GoC would be desirable.
- Water quality information is patchy and generally specific to those estuaries used as ports. More coordinated water quality monitoring would be valuable.

Discussion

The seagrass habitats of this region are extremely valuable for endangered species and for commercial fisheries. They are a major component of the coastal habitat.

Despite this there is no coordinated ongoing monitoring and little recent published work in the scientific literature. Detailed studies are being conducted for port and fisheries monitoring but this information mostly remains in report format. Large areas of the coast have not been mapped sufficiently (or at all) and most of the potential dugong food resource in waters deeper than 15 m has not been mapped at all.

There are worrying anecdotal reports of possible dieback of seagrass in the southern GoC and effects on dugong and turtle populations but no way of verifying these at present.

This is an unsatisfactory situation from a management point of view. Data from the Torres Strait is presently being collated in a process to make all Torres Strait Fisheries Scientific Advisory Committee reports available on CD. A similar process for seagrass information/ reports in the remainder of the NPA would be highly desirable. There is potential for future catchment development and land uses to affect water quality. With the present status of information it would be difficult to assess the risk to the region's seagrasses.

Re-mapping to modern standards of precision and metadata is also essential if management or planning decisions are to be based on seagrass distribution.

Key references and current research

Most seagrass work in the NPA is undertaken by the Queensland Fisheries Service, Northern Fisheries Centre.

Species distributions for the Torres Strait and Queensland GoC are available in GIS format. Torres Strait information is held by CSIRO Marine Laboratory. The Queensland GoC maps are available on http://chrisweb.dpi.qld.gov.au/chris/ or on disk from the Northern Fisheries Centre with appropriate data contracts. Some preliminary satellite and aerial image analysis is available for the Pellew Bioregion in the NT.

More general GIS information (some unverified) is available on the IMAP system hosted by UNEP. See http:www.unep-wcmc.org.

A full list of data sets, descriptions, and references are in Table 2.1.

References (Key references are highlighted)

Bridges, KW, Phillips, RC & Young, PC (1982). Patterns of some seagrass distributions in the Torres Strait, Queensland. *Australian Journal of Marine and Freshwater Research*. 33: pp.273-283.

Butler, A & Jernakoff, P (eds) (1999). *Seagrass in Australia*. CSIRO Publishing, Melbourne, Australia.

Coles, RG (1998). *Proposed Pontoon at Engineer's Wharf, Thursday Island – Review of Environmental Factors (seagrasses and other benthic habitats)*. Report to Queensland Department of Main Roads. QDPIF, NFC, Cairns, Australia.

Coles, RG & Lee Long, WJ (1985). Juvenile prawn biology and the distribution of seagrass prawn nursery grounds in the south-eastern Gulf of Carpentaria. In: Rothlisberg, P, Hill, DJ & Staples DJ (eds). *Second Australian National Prawn Seminar, Cleveland*. Cleveland, Australia. NPS2. pp. 55-60.

Coles, RG, McKenzie, LJ & Yoshida, RL (2001). *Validation and GIS of seagrass surveys between Cape York and Tarrant Point– October/November 1986*. CD Rom. QDPIF, Cairns.

Coles RG, McKenzie, LJ & Campbell, S (2003). The seagrasses of eastern Australia. In: Green, EP & Short, FT (eds) *The World Atlas of Seagrasses: present status and future conservation*. University of California Press. pp. 119-133

Coles, RG, McKenzie, LJ, Bibby, J, Lee Long, WJ & Mellors, JE (in prep). *Surveys of Seagrass Meadows and Juvenile Prawn Populations in the Eastern Gulf of Carpentaria: Mornington Island region (March - September 1984) and Cape York to Tarrant Point (October - November 1986)*. QDPIF Information Series. Brisbane.

den Hartog, C (1970). *The Sea Grasses of the World*, North-Holland Publication Co., Amsterdam, Holland.

Elliott, M, Marsh, H, Heinsohn, GE & Gardner, BR (1979). Dugongs in the Northern Territory of Australia. *Environmental Conservation*., No. 6. p277.

Green, EP, Short, FT (eds) (2003) *The World Atlas of Seagrasses: present status and future conservation*. University of California Press.

Hempel, C & Smit, N (2000). Preliminary coastal and marine habitat mapping in the Gulf of Carpentaria using satellite and aerial remote sensing techniques. In: Smit, N (ed). *Identification and trialing of rapid and effective sampling methodologies for mapping marine substrates and habitats in the Northern Territory*. Technical Report No 67 (2000), Parks and Wildlife Commission of the Northern Territory, DIPE, Darwin, NT, Australia.

Kenyon, R, Conacher, CA & Poiner, IR (1997). Seasonal growth and reproduction of *Enhalus acoroides* (L.f.) Royle in a shallow bay in the western Gulf of Carpentaria, Australia. *Australian Journal of Marine and Fresh Water Research*, 48, pp. 335–42.

Kenyon, R, Burridge, C & Poiner, I (1999). *Impact of the Macarthur River Project Mine Transhipment Facility on the Marine Environment: Post-construction - 3 survey*. CSIRO Marine Laboratories Report. CSIRO, Division of Fisheries, Marine Laboratories, Cleveland, Australia.

Kirkman, H (1997)]. *Seagrasses of Australia*. Australia: State of the Environment. Technical Paper Series (Estuaries and the Sea). Department of the Environment, Canberra, Australia.

Kuo, J (2000). Taxonomic notes on *Halophila ovata and Halophila minor. Biologia Marina Mediterranea*. 7(2): pp. 79–82.

Kwan, D & Bell, I (2003). *Response to community concerns about green turtle (Chelonia mydas) and dugong (Dugong dugon) in waters adjacent to the Wellesley Group of islands in the Gulf of Carpentaria*. Report to the Mornington Shire Council (unpublished).

Lee Long, WJ, Coles, RG, McKenzie, LJ (1996). Deepwater seagrasses in Northeastern Australia - How deep? How meaningful? In: Kuo, J, Phillips, RC, Walker, DI & Kirkman, H (eds) *Seagrass Biology*. Proceedings of an International Workshop. Sciences UWA. pp. 41–50.

Loneragan, NR, Kenyon, RA, Staples, DJ, Poiner, IR & Conacher, C (1998). The influence of seagrass type on the distribution and abundance of postlarval and juvenile tiger prawns *(Penaeus esculentus* and *P. semisulcatus)* in the western Gulf of Carpentaria, Australia. *Journal of Experimental Marine Biology and Ecology*, 228(2), pp. 175–195.

Long. BG & Poiner, IR (1997). *The Seagrass Communities of Torres Strait, Northern Australia*. Final report to TSFSAC 26. CSIRO Division of Marine Research, Cleveland, Australia.

Long, BG & Skewes, T (1997). *Influence of Land Runoff on the Distribution and Abundance of Seagrass on the Reefs in Torres Strait*. Final report to TSFSAC 26. CSIRO Division of Marine Research, Cleveland, Australia.

Long, B, Skewes, T, Thomas, M, Isdale, P, Pitcher, R & Poiner, I (1997). *Torres Strait Seagrass Dieback*. Final report to TSFSAC 26. CSIRO Division of Marine Research, Cleveland, Australia.

Mukai, H (1993). Biogeography of the topical seagrasses in the Western Pacific. *Australian Journal of. Marine and Freshwater Research*. 44. pp. 1–17.

Neil, KM, Hilliard, RW, Stafford, HS, Sheaves, J & Wiebkin, A (2003). *Port Baseline Survey for Introduced Marine Pests: Port of Gove*. Report to Alcan Gove Pty Limited prepared by CRC Reef Research Centre, Townsville, and URS Australia, Perth, Australia.

Phillips, RC & Menez, EG (1988). *Seagrasses*. Smithsonian Institution Press, Washington, D.C.

Poiner, IR, Walker, DI & Coles, RG (1989). Regional Studies – Seagrass of Tropical Australia. In: Larkurn, AWD, McComb, AJ & Shepherd, SA (eds). *Biology of Seagrasses*. Elsevier, Amsterdam, New York.

Poiner, IR, Staples, DJ & Kenyon, R (1987). Seagrass Communities of the Gulf of Carpentaria. *Australian Journal of Marine and Fresh water Research*. 38. pp. 121–131.

Poiner, IR & Peterken, C (1995) Seagrasses. In: Zann, LP (Comp.) *State of the Marine Environment Report for Australia*: The marine environment. Technical annex 1. Department of the Environment, Sport and Territories, Canberra. http://www.ea.gov.au/coasts/publications/somer/annex1/seagrasses.html

Rasheed, MA & Thomas, R (2000). *Port of Karumba Long Term Seagrass Monitoring, Progress Report – October 2000*. Report to the Ports Corporation of Queensland. QDPI. Cairns, Australia.

Rasheed, MA & Thomas, R (2002). *Port of Karumba Long Term Seagrass Monitoring, Progress Report - October 2001*. Report to the Ports Corporation of Queensland. QDPI. Cairns, Australia.

Rasheed, MA & Thomas, R (2003). *Port of Karumba Long Term Seagrass Monitoring, Progress Report - October 2002*. Report to the Ports Corporation of Queensland. QDPI. Cairns, Australia.

Rasheed, MA, Lee Long, WJ, McKenzie, LJ, Roder, CA, Roelofs, AJ & Coles, RG (1996). *Port of Karumba Seagrass Monitoring, Baseline Surveys - Dry-Season (October) 1994 and Wet-Season (March) 1995*. Ecoports Monograph Series No 4. Ports Corporation of Queensland, Brisbane, Australia.

Rasheed, MA, Roelofs, AJ, Thomas, R & Coles, RG (2001). *Port of Karumba Seagrass Monitoring - First 6 Years*. EcoPorts Monograph Series No 20. Ports Corporation of Queensland, Brisbane, Australia.

Rasheed, MA, Thomas, R, Roelofs, A & Neil, K (2003). *Seagrass, benthic habitats and targeted introduced species of the Ports of Thursday Island: March 2002*. QDPI Information Series. QDPI, Cairns, Australia.

Roelofs, AJ, Rasheed, MA & Thomas, R (2001a). *Port of Weipa Seagrass Monitoring Baseline Surveys, April & September 2000*. Ecoports Monograph Series No 21. Ports Corporation of Queensland, Brisbane, Australia.

Roelofs, AJ, Rasheed, MA & Thomas, R (2001b). *Port of Weipa Seagrass Monitoring Surveys, April and September 2001*. Interim Report to the Ports Corporation of Queensland, Brisbane, Australia.

Roelofs, AJ, Rasheed, MA & Thomas, R (2003). *Port of Weipa Seagrass Monitoring, 2000 – 2002*. EcoPorts Monograph Series No.22. Ports Corporation of Queensland, Brisbane, Australia.

Saalfeld, K (2002). *Draft management program for the Dugong (Dugong dugon) in the Northern Territory of Australia*. Parks and Wildlife Commission, Darwin, Australia.

Short, FT & Coles, RG (eds) (2001). *Global Seagrass Research Methods. Elsvier Science BV, Amsterdam.*

Sheppard, R, Rasheed, M & Helmke, S (2001) *Kirke River - Fisheries Resources Assessment - August 1999*. QDPI Information Series QI00086. Cairns, Australia.

Thomas, M, Long, B & Taranto, T (1997). *Mapping Shallow Water Seagrass with Landsat TM Satellite Data in Torres Strait*. Final report to TSFSAC 26. CSIRO Division of Marine Research, Cleveland, Australia.

Turnbull, C & Mellors, J (1990). Settlement of juvenile Penaeus esculentus (Haswell 1978) on nursery grounds in the Torres Strait. In: Mellors, JE (ed). *Torres Strait prawn project: A Review of Research 1986-88*. QDPI Information Series QI90018. pp. 29–38.

Current Research/Relevant Information

Burridge, C, Kenyon, R & Poiner, I (1994). *Impact of the Macarthur River Project Mine Transhipment Facility on the Marine Environment: Pre-construction survey*. CSIRO Marine Laboratories Report. CSIRO, Division of Fisheries, Cleveland, Australia.

Coles R.G and Fortes M.D (2001). Seagrass Protection Policy. In Short F.T and Coles R.G (eds)(2001) Global Seagrass Research Methods. Elsevier Science BV, Amsterdam. pp 445-464.

Coles, R. G. And Kuo, J, (1995). Marine and Coastal Biodiversity in the Tropical Island Pacific Region. Volume 1: Species Systematics and Information Management Priorities. Pacific Science Association/east West Centre, Honolulu, Hawaii.

Coles, RG & Lee Long, WJ (1999). Seagrasses. In: Pacific Science Association/ East West Centre. *Marine/Coastal Biodiversity in the Tropical Island Pacific Region:* Volume 2. Population, Development and Conservation Priorities Workshop Proceedings. Honolulu, Hawaii.

Coles, RG, Lee Long, WJ, McKenzie, LJ, Roelofs, AJ & De'ath, G (2000) Stratification of seagrasses in the Great Barrier Reef World Heritage Area, Northeastern Australia, and the implications for management. *Biol. Mar. Medit.*. 7(2): pp. 345–348.

Coles, R. G., L. J. McKenzie, et al. (In prep). Surveys of seagrass meadows and juvenile prawn populations in the eastern Gulf of Carpentaria: Wellesley Islands region (March - September 1984) and Cape York to Tarrant Point (October - November 1986), QDPI, Cairns, Australia.

Coles, RG, McKenzie, LJ & Campbell, SJ (2002). The seagrasses of eastern Australia. In: Green, EP; Short, FT & Spalding, MD. (eds) *The World Atlas of Seagrasses: present status and future conservation*. University of California Press. pp. 131–147.

Coles, RG, McKenzie, LJ, Campbell, SJ, Fortes, M & Short, FT (2002). The seagrasses of the western Pacific islands. In: Green, EP; Short, FT & Spalding, MD (eds) *The World Atlas of Seagrasses: present status and future conservation*. University of California Press. pp. 177–186.

Haynes, D, Ralph, P, Prange, J & Dennison, W (2000). The effect of the herbicide Diuron on Photosynthesis in three species of tropical seagrass. *Marine Pollution Bulletin*. 41. pp. 288–293.

Kenyon, R., Poiner, I, and Burridge, C. (1995). *Impact of the Macarthur River Project Mine Transhipment Facility on the Marine Environment: Post-construction survey*. CSIRO Marine Laboratories Report. CSIRO, Cleveland, Australia.

Kenyon, R, Burridge, C & Poiner, I (1996). *Impact of the Macarthur River Project Mine Transhipment Facility on the Marine Environment: Post-construction - 2 survey*. CSIRO Marine Laboratories Report. CSIRO. Cleveland, Australia.

Lee Long, WJ, Coles, RG & McKenzie, LJ (2000). Issues for Seagrass Conservation Management in Queensland. *Pacific Conservation Biology*. 5: pp. 321–328.

Marsh, HE (1989). Mass stranding of Dugongs by a tropical cyclone in northern Australia. *Marine Mammal Science*. 5. pp. 78–84.

Moir, CM (2002). *Uptake and homeostasis of heavy metals by seagrass species in the Gulf of Carpentaria, Australia*. PhD Thesis. Charles Darwin University, Darwin, Australia.

Munksgaard, NC & Parry, DL (2000). Anomalous lead isotope ratios and provenance of offshore sediments, Gulf of Carpentaria, northern Australia. *Australian Journal of Earth Sciences*. 47. pp. 771–777.

Munksgaard, NC & Parry, DL (2001). Trace metals, arsenic and lead isotope ratios in dissolved and particulate phases of north Australian coastal and estuarine seawater. *Marine Chemistry*, 75, pp. 165–184.

Munksgaard, NC & Parry, DL (2002). Metals, arsenic and lead isotopes in near-pristine estuarine and marine coastal sediments from northern Australia. *Marine and Freshwater Research*. 53. pp. 719–729.

Munksgaard, NC, Moir, CM & Parry, DL (2002). Bio-monitoring using lead isotope ratios in seagrass and oysters. *Marine Science and Technology Journal*. 36 (1). pp. 52–54.

Munksgaard, NC, Lim, K & Parry, DL (2003). Rare earth elements as provenance indicators in north Australian estuarine and coastal sediments. *Estuarine, Coastal and Shelf Science*. 57. pp. 399–409.

Poiner, IR, Conacher, CA, Loneragan, NR, Kenyon, RA & Somers, I (1993). *Effect of cyclones on seagrass communities and penaeid prawn stocks of the Gulf of Carpentaria*. CSIRO Marine Laboratories Report. CSIRO, Cleveland, Australia.

Preen, AR, Lee Long, WJ & Coles, RG (1995). Flood and cyclone related loss, and partial recovery, of more than 1,000 km^2 of seagrass in Hervey Bay, Queensland, Australia. *Aquatic Botany*. 52. pp. 3–17.

Short, FT, Coles, RG & Pergent Martini, C (2001). Global Seagrass Distribution. In: Short, FT & Coles, RG (eds) (2001). *Global Seagrass Research Methods*. Elsvier Science BV. Amsterdam. pp. 5–30.

Thomas, M, Lavery, P & Coles, RG (1999) Monitoring and Assessment of Seagrass. In: Butler, A & Jernakoff, P (eds). *Seagrass in Australia*. CSIRO, Melbourne, Australia.

Walker, DI & Prince, RIT (1987). Distribution and Biogeography of seagrass species in the northwest coast of Australia. *Aquatic Botany*. 29(1). pp. 19–32.

2. SEAGRASSES

Table 2.1: *Seagrasses Mapped in Northern Planning Region*

Region	Location Surveyed	Scale	Date	Citation	GIS / other Status	Proprietor
Queensland Gulf of Carpentaria	Tarrant Pt – Cape York	Broad	Nov 1986	Coles et al. (in prep.)	Validated	QDPI/FRDC
	Mornington Island	Broad Broad	Mar 1984 Sept 1984	Coles & Lee Long 1985 Coles et al. (in prep.)	In prep In prep	QDPI
	Karumba	Fine Fine Fine Fine Fine Fine Fine Fine Fine Fine Fine Fine Fine Fine Fine	Oct 1994 Mar 1995 Oct 1995 Mar 1996 Oct 1996 Mar 1997 Oct 1997 Mar 1998 Oct 1998 Mar 1999 Oct 1999 Mar 2000 Oct 2000 Oct 2001	Rasheed et al. 1996 Rasheed et al. 1996 Rasheed et al. 2001 Rasheed et al. 2001 Rasheed et al. 2001 Rasheed et al. 2001 Rasheed et al. 2001 Rasheed et al. 2001 Rasheed et al. 2001 Rasheed et al. 2001 Rasheed et al. 2001 Rasheed et al. 2001 Rasheed & Thomas 2000 Rasheed & Thomas 2002	Completed Completed Completed Completed Completed Completed Completed Completed Completed Completed Completed Completed Completed Completed Completed	QDPI/CRC/PCQ
	Weipa	Fine Fine Fine Fine Fine Fine Fine	April 2000 Sept 2000 April 2001 Sept 2001 April 2002 Sept 2002 Sept 2003	Roelofs et al. 2001a Roelofs et al. 2001a Roelofs et al. 2001b Roelofs et al. 2001b Roelofs et al. 2003 Roelofs et al. 2003 Roelofs et al. (in prep)	Completed Completed Completed Completed Completed Completed In prep	QDPI/CRC/PCQ
	Kirke River	Fine Fine	Aug 1999 Sept 2001	Sheppard et al. 2001	Completed In prep	QDPI QDPI/PCQ
	Love River	Fine	Aug 1999	Sheppard et al. 2001	Completed	QDPI

Scale:

Broad = ground truth sites from 100s of metres to kilometres apart

Medium = ground truth sites predominantly between 100 m and 1 km apart, aerial photos 1: 25000, aerial reconnaissance, satellite TM

Fine = ground truth sites predominantly <100 m apart, aerial photos 1:12000, aerial reconnaissance

Limited = medium to fine scale focused on specific areas within a location

Proprietor

QDPI = Queensland Department of Primary Industries

CRC = CRC for Great Barrier Reef World Heritage Area

PCQ = Ports Corporation of Queensland

AFMA = Australian Fisheries Management Authority

CSIRO = Commonwealth Scientific and Industrial Research Organisation

Region	Location Surveyed	Scale	Date	Citation	GIS / other Status	Proprietor
Torres Strait	Central reefs?	Broad	Feb 1988	Unpublished	Nil	QDPI
	Thursday Island – Engineers Wharf	Medium	Dec 1998	Coles 1998	Completed	QDPI
	Thursday Island Port	Fine	Mar 2002	Rasheed et al. 2003	Completed	QDPI/PCQ
	Torres Strait coverage	Broad		Long & Poiner 1997	Available	CSIRO/AFMA/QDPI
	Central Torres Strait	Broad		Long et al 1997	Available	CSIRO/AFMA/QDPI
	Warrior Reefs	Broad		Mellors/Coles/ unpublished	Nil	QDPI
	Macarthur River	Fine	1994–1996 (annually)	Kenyon et al. 1999	Nil/paper copy	CSIRO
	Sir Edward Pellew Islands to Rose River or South-west Gulf coastal distribution/ abundance surveys	Broad	1984–1995 (annually and bi-annually)	Poiner et al. 1987, 1993 & unreported	Nil/paper copy	CSIRO
	Coastal Aerial	Broad		Smit & Chatto, unpublished	Video	Biodiversity Unit/DIPE
	Port Bradshaw	Fine / point data		Smit (in prep.)	In prep	Biodiversity Unit/DIPE
	Pellews Bioregion	Broad, sat and aerial image analysis, no ground truthing		Hemple & Smit 2000	Paper with preliminary results	Biodiversity Unit/DIPE
	Groote Elyandt North West Bay	Fine	1985–1987 (bi-monthly)	Kenyon et al. 1997 & unreported	Nil/paper copy	CSIRO
	Groote/Blue Mud Bay	Fine		Loneragan et al. 1998	Nil/paper copy	CSIRO
Other Northern Territory	Coastal	Broad	Published 2003	Green & Short 2003	Available/ unverified	UNEP I map
	Bynoe Harbour / Fog Bay (west of Darwin)	Point, fine scale		Smit	In prep	Biodiversity Unit/DIPE
	Darwin	Point	Published	Kirkman 1997	Paper	CSIRO