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Northern Fisheries Centre
Department of Primary Industries

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PORT OF MACKAY SEAGRASS, ALGAE AND MACRO-INVERTEBRATE COMMUNITIES. FEBRUARY 2001

Michael A. Rasheed, Chantal A. Roder and Ross Thomas

Queensland Fisheries Service
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Foreword

Finding better ways to integrate environmental, economic and social concerns in decision-making is a key theme of Australian Ecologically Sustainable Development (ESD) policy (Environment Australia 2002). ESD is development that aims to meet the needs of Australians today, while conserving our ecosystems for the benefit of future generations.

The maritime industry is committed to development of ports that is consistent with the concepts of ESD. The benefits of expanded sea trade to national prosperity need not result in associated negative environmental impacts.

During 2000/2001, a total of over 185 million tonnes of cargo passed through Queensland's 16 shipping ports (Association of Australian Ports and Marine Authorities 2002). Of this total, more than 1.8 million tonnes of cargo passed through the Port of Mackay making it the seventh largest cargo handler for the year in Queensland.

The Mackay Port Authority (MPA) has identified a requirement for the expansion of existing port facilities to assist its user industries to remain globally competitive. MPA commissioned the CRC Reef Ports & Shipping team to conduct benthic habitat surveys within the port to guide decisions for the conduct of this expansion whilst minimising impacts on the marine environment.

The CRC Reef Ports & Shipping team are part of the Marine Plant Ecology Group (MPEG) based at the Department of Primary Industries, Northern Fisheries Centre in Cairns. MPEG is an internationally recognised team that conducts pure and applied research and provides marine habitat management advice. The group has maintained a reputation as the leading adviser on seagrass management in North Queensland and has developed an Australian Standard for monitoring change in seagrasses and an innovative and internationally accepted method of visual assessment of seagrass habitats and deep-water benthic mapping. The results of the work in Mackay have provided a valuable tool for planning growth and development in the port as well as enhancing our knowledge on the coastal marine resources of the Mackay region.

Ed Casey
Chairman
Mackay Port Authority

Executive Summary

1. A range of benthic community types was described within the Mackay port limits in February 2001. Three seagrass meadows, five algae community types and eight benthic macro-invertebrate region types were identified.

2. The majority of the port limit area was dominated by bare substrate with a low density of benthic life. Higher-density benthic macro-invertebrate and algae communities occurred in proximity to the harbour and approach channels. The density of benthic life within the Mackay port limits appears to be typical of areas to the north and south of the port limits that have been surveyed.

3. Smaller areas of higher benthic habitat complexity were commonly found around reefs and islands and in several patches in deeper offshore waters.

4. The majority of the works proposed for the harbour and approaches in the port development plan appear to be located in areas that would cause minimal impact on Mackay's marine environment. The proposed southern approach channel, northern harbour reclamation and future Cape class berths were all in areas of low-density benthic macro-invertebrate and algae communities.

5. Areas of the harbour that would require capital dredging as part of proposed port expansion did not contain any significant benthic communities.

6. Both offshore berth options passed through areas of high-density benthic habitat and further options for their location or management of impacts associated with their construction may need to be considered.

7. Seagrass was unlikely to be affected by proposed port developments, as there were no meadows in proximity to the harbour or approach channels.

8. Seagrass, algae and benthic communities described in this survey are likely to be dynamic both seasonally and inter-annually.

9. Timing of any dredging works should be performed so as to cause minimal disturbance to fish spawning and migration. Advice on localised fish movements and issues should be sought from local fisheries representatives, Sunfish and Queensland Seafood Industry Association when determining the most appropriate time for capital dredging to be conducted.

10. The higher density algae and benthic macro-invertebrate communities at the mouth of the harbour still contained significant areas of open substrate. It is possible that an approach channel could be placed through this area without a major disturbance to these communities. An intensive survey of the proposed approach channel for approximately 1km from the harbour entrance would help to determine the level of any impact and may aid in the appropriate placement of the channel through this area.

Introduction

Consultancy brief

The Mackay Port Authority (MPA) is responsible for administering port activities and managing the port environment in Mackay. Recently MPA commissioned a port development plan (PDP) to facilitate effective planning for future expansion of the port and its activities (Connell Wagner 2000). In this document MPA identified a strategic goal of developing the port to be fully capable of accommodating Panamax class vessels. Substantial capital dredging of the harbour and approach channels would be required as part of these developments as the existing depth does not allow all-tide access for Panamax class vessels. Proposed works also include the relocation of the approach channel, extension of the harbour and the development of an offshore berth (Connell Wagner 2000).

MPA recognises that benthic communities including seagrass, algae and benthic fauna are ecologically important and environmentally sensitive habitats. MPA aims to minimise impacts of future port activities and infrastructure development on these communities to maintain the health of the Mackay port environment. Prior to the present survey, little information had been collected on the benthic communities within the Mackay port limits. MPA commissioned the Marine Plant Ecology Group (Queensland Fisheries Service (QFS) Department of Primary Industries (DPI)) to conduct a benthic survey within the port limits. The information gathered will be used by MPA to design works programs which minimise the impacts of port developments on Mackay's marine environment, including assisting in the:

- location of shipping channels;
- location of dredge spoil disposal sites and;
- timing of works.

The objectives of this survey were to:

1. Survey and describe seagrass, macro-algae and other benthic communities within the general port limits excluding inland waters (Basset Basin and Pioneer River);

2. Provide a GIS database and maps of the benthic communities within and adjacent to proposed dredging areas in the harbour and approach channels as well as the dredge spoil ground;

3. Identify critical benthic habitat in the port limits of fisheries or conservation significance.

Recommendations on the suitability of proposed developments in terms of minimising impacts on Mackay's marine environment will be made from the results of the survey.

Study site

The Port of Mackay is located on the central Queensland coast at approximately 21° 7' S and 149° 14' E, (Figure 1). It is approximately 4 km north of the Pioneer River and lies within the Pioneer Drainage Basin. Mean annual rainfall for Mackay is 1665 mm, the majority of which falls from January to March. Mean daily temperature minima range from 11.7 °C in July to 23.3 °C in January and maxima range from 21.9 °C in July to 30.3 °C in January (Australian Bureau of Meteorology 2001).

Mackay is a major regional urban centre, and is the main transport and administrative hub catering for the surrounding sugar and coal mining industries. The region has an estimated population of 125000 growing at 1.9% per annum, and an economy worth more than $2.6 billion per annum, representing more than five percent of Queensland's Gross State Product (Central Queensland University 2001). The region is one of the most important sugar producing areas in Australia. Commercial fishing activities in the Mackay region include finfish, scallops, prawns and crabs. The Port of Mackay is used as a base for commercial reef fishing activities including live coral trout export.

Mackay Harbour is formed by two artificial breakwaters that enclose a sheltered harbour. Four commercial shipping berths cater for vessels of lengths up to 230 m, maximum beam of 32.5 m and laden drafts up to 12.2 m (WBM Oceanics Australia 2001). The principal export trade for the Port of Mackay is bulk raw and refined sugar. Current trade through the port of Mackay also includes export of grain, molasses, ethanol, scrap metal and tallow. Import trades through the Port include bulk petroleum, fertiliser, magnetite, and sulphuric acid. Port facilities are also utilised on occasion by naval, cruise, service and repair vessels. Future trade proposals for the port include prilled sulphur, methanol, shale oil, meat and fish products and general cargo (Connell Wagner 2000).

Sections of the Mackay port limits are within the Great Barrier Reef Marine Park (GBRMP) and Great Barrier Reef World Heritage Area (GBRWHA) (Figure 1). Bassett Basin just south of the harbour is listed as a Fish Habitat Area under the Fisheries Act 1994.

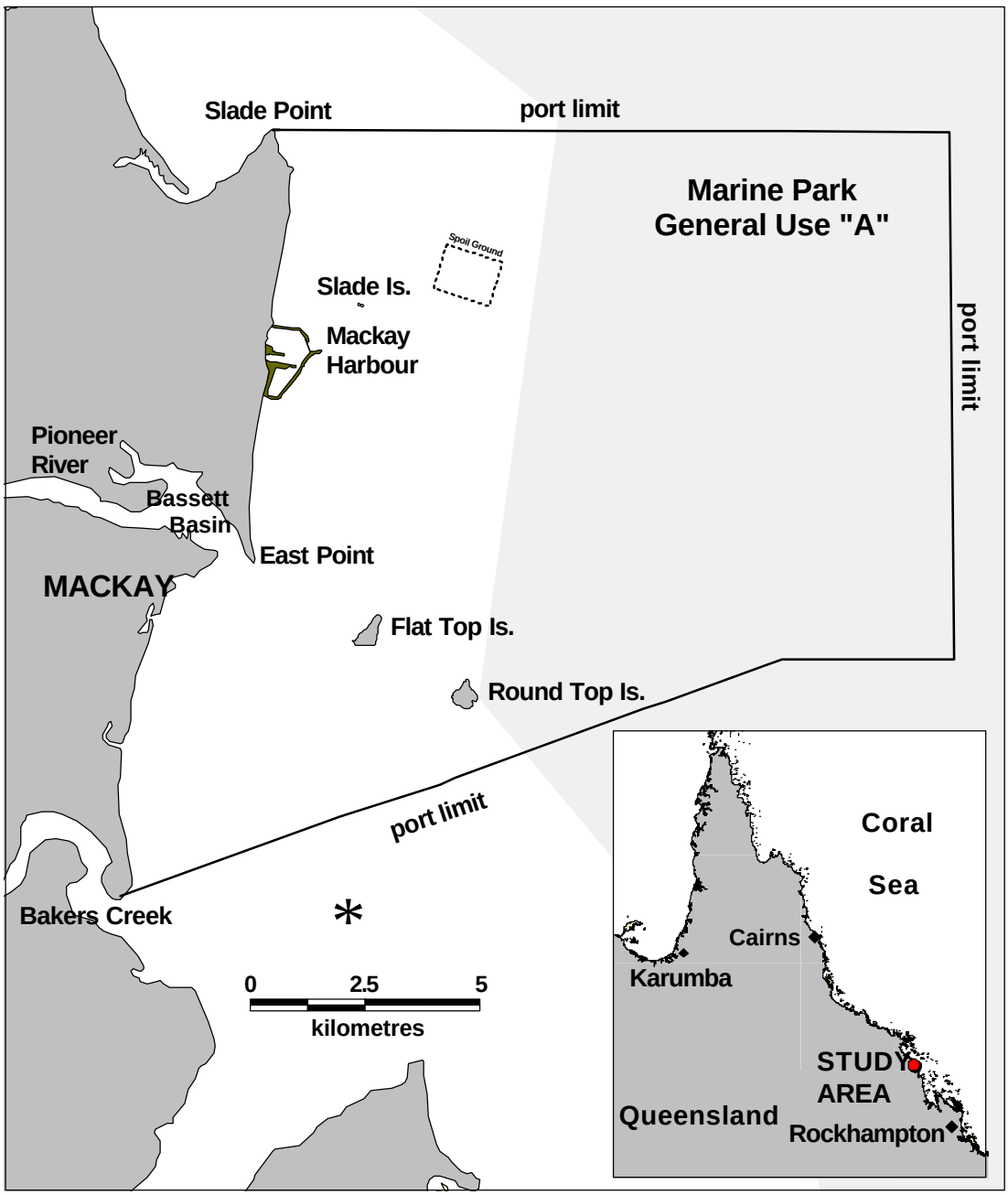


Figure 1. Locality map of Mackay survey area showing port limits.

Port of Mackay Benthic Communities

Seagrass

The importance of seagrass meadows as structural components of coastal ecosystems is well recognised. These marine angiosperms are important for stabilising coastal sediments,

providing food and shelter for a diverse variety of organisms, as a nursery ground for many prawns and fish of commercial importance and for nutrient trapping and recycling (Short 1987; Larkum *et al.* 1989; Edgar and Kirkman 1989). Seagrass/algae beds have been rated the third most valuable ecosystem globally (on a per hectare basis) for ecosystem services, preceded only by estuaries and swamps/flood-plains (Costanza *et al.* 1997).

Seagrass distribution in Mackay was first described during a broad scale survey of coastal and island areas of the Queensland coast by DPI in 1987 (Coles *et al.* 1987). The survey found two small areas of seagrass within the Mackay Port limits, adjacent to the north-western shores of Flat and Round Top Islands. These meadows were comprised of a single species *Halodule uninervis* (wide), with less than 10% cover at Flat Top and 10-50% cover adjacent to Round Top Island (Coles *et al.* 1987). The survey did not measure seagrass abundance and was performed without modern mapping aids such as differential Global Positioning Systems (dGPS) and Geographic Information Systems (GIS). There have been no seagrass surveys in offshore areas within the port limits.

Algae

Algal communities in north Queensland have important ecosystem functions and have been identified as nursery habitats for juvenile commercial prawns (Haywood *et al.* 1995). The distribution of macro-algal communities within the Mackay port limits prior to this survey was largely unknown. Shallow rocky reef communities support macro-algae communities in other locations (Josselyn & West 1985; Haywood *et al.* 1995) and it is likely that Mackay's rocky reef areas at Slade Point, Slade Rock, Dangerous Reef and Slade, Flat Top and Round Top Islands may also have macro-algae communities. Macro-algal communities have been found in deeper inter-reef waters in other areas off the tropical Queensland coast (Coles *et al.* 1996) and it is reasonable to expect that macro-algae would be present in similar areas within the Mackay port limits.

Benthic macro-invertebrates

Sampling for benthic fauna within the Mackay port limits has been conducted in the past. This sampling has been concentrated in the harbour and dredge spoil disposal ground and based on a limited number of grab samples (WBM 2001). Grab sampling in the dredge spoil ground and in two areas north and one south of the spoil site found that benthic macro-invertebrate

diversity and abundance was similar between the disposal and other three sites (WBM 2001). Grab sampling only covers a very small area of the bottom (a total of 1.7 m^2 for all sites combined in the WBM (2001) survey) and is likely to miss significant areas of benthic habitat, particularly where distribution is patchy or inconsistent. Other techniques such as using towed video equipment or trawling apparatus over larger areas of the bottom would be more likely to find patchily distributed organisms. There have been no previous attempts to describe benthic macro-invertebrate communities in the broader port-limit area.

Methods

Survey approach

Seagrass, algae and benthic macro-invertebrate communities were mapped in a survey conducted from 1- 4 February and from 20 - 21 February 2001 (poor weather led to the completion of the survey being postponed from 5 - 20 February). The survey area included coastal and offshore waters within the port limits excluding the inland waters of the Pioneer River and Bassett Basin (Figure 1). A stratified sampling approach was taken due to the large area to be surveyed. Intensive sampling was conducted within the areas most likely to be affected by future port developments outlined in the port development plan. These areas were the harbour, dredge spoil ground and the planned approach channel to the south of the harbour. Sampling intensity was also higher where existing information indicated high habitat complexity such as sheltered areas in the lee of islands.

Survey methods

A range of sampling methodology was used to survey seagrass, algae and benthic macro-invertebrate communities. Methods applied were based on physical characteristics of the area such as depth, visibility, size of area to be surveyed, logistical and safety constraints. Three sampling techniques were used:

1. Dive-based coastal and island survey;

2. Harbour video survey;

3. Offshore video survey.

Dive-based coastal and island survey

Shallow sub-tidal (2-7 m below MSL) coastal areas adjacent to the mainland and islands were surveyed by free-diving observers using a small boat. Sampling was conducted on 1 February (28 sites sampled north of Mackay Harbour to Slade Point) and 21 February 2001 (35 sites sampled south of Mackay Harbour to East Point out to Round Top, Flat Top and Slade Islands). Dive sites were scattered along the coast and around the islands according to changes in depth, benthic habitat type and where seagrass had been previously found. Dive based survey sites extended to approximately 7 m below mean sea level (MSL) (up to 5.5 km offshore). At each site (5 m in diameter) the following information was collected:

- *Seagrass habitat characteristics* including above-ground seagrass biomass and species composition. Seagrass biomass (above-ground) was determined using a modified "visual estimates of biomass" technique described by Mellors (1991). This technique involves an observer ranking seagrass biomass in the field in 3 random placements of a 0.25 m^2 quadrat at each site by referring to a series of quadrat photographs of similar seagrass habitats for which the above-ground biomass has been measured. The relative proportion of each seagrass species (identified according to Kuo and McComb 1989) within each quadrat was also recorded. These ranks were then converted into above-ground biomass estimates in grams dry weight per square metre (g dw m^{-2}) using a linear regression for the observer ranks and the measured biomass value of the reference quadrat photographs.

- *Macro-algae characterisation*. At each site divers estimated the percent cover of macro-algae and the types of macro-algae present (identified according to Cribb 1996).

- *Benthic macro-invertebrates*. A list of the benthic macro-invertebrate taxa observed by divers at each site was recorded. No below-ground macro-invertebrates were sampled at dive sites.

- *Physical characteristics of the site.* Depths were recorded with an echo sounder and converted to depths (m) below MSL, corrected to the tidal plane datum. Field descriptions of sediment categories were a visual estimate recorded by divers at each site. Sediment categories were: shell grit, rock, gravel (>2000 μm), coarse sand (>500 μm), sand (>250 μm), fine sand (>63 μm) and mud (<63 μm)). Sediment categories were determined by the

dominant sediment type (e.g. sand/mud = more sand than mud). A portable dGPS was used to determine geographic position (± 5 m) of all sampling sites.

Harbour video survey

The Mackay Harbour area was sampled using a camera system with a real time video feed to a monitor on a small vessel. At each sampling site the camera was deployed vertically in a fixed frame that displayed a 0.25 m^2 area of the bottom (Plate 1). Three replicate drops of the camera and a Van Veen sediment grab (approximately 1 L volume) were used at each site (approximately 10 m x 10 m area). A total of 21 sites were sampled in the harbour from 20 - 21 February 2001. Sites were scattered throughout the harbour between 50 - 200 m apart. Seagrass, algae and benthic macro-invertebrates were identified as for the dive-based survey (previous section) by an observer viewing the monitor. The Van Veen grab was used to confirm the presence of any benthic macro-invertebrates, algae or seagrass identified on the camera monitor, and to assess sediment type. Presence of macro-infauna in the grab samples was also recorded.

Plate 1. Benthic sampling in coastal areas using vertically deployed video (photo taken in Mourilyan Harbour).

Offshore video survey

Offshore areas within the port limits that were too deep for free divers were sampled using the real time camera system towed behind the research vessel “Gwendoline May”. Eighty offshore sites were sampled between 1 - 4 February 2001. Offshore sites were randomly located on five east-west transects and at sites between transects to check for continuity of

habitat types. At each sampling site the real-time underwater camera system (Cunard CT250, 250-300 W lights) was towed for five minutes (time required to cover approximately 100 metres of benthos) at drift speed (less than one knot). Footage was observed on a TV monitor and recorded to digital tape. The camera was mounted on a sled that incorporated a sled net 600 mm width and 250 mm deep with a net of 10 mm-mesh aperture (Plate 2). Surface benthos was captured in the net (semi-quantitative bottom sample) and used to confirm benthic macro-invertebrates, algal and seagrass habitat characteristics observed on the monitor. Benthic macro-invertebrates collected in the sled net were identified into taxa groups and counts made of individuals (Plate 2). A Van Veen grab (grab area 0.0625 m^2) was used to confirm sediment type.

Seagrass biomass was assessed for sites where seagrass presence was noted in the field. Seagrass biomass estimates were based on ten random time frames allocated within the five minutes of video footage for each site. Above-ground seagrass biomass was determined by a visual estimates of biomass technique modified from Mellors (1991) for use with video recording. Seagrass species composition was also recorded. The video was paused at each of the ten random time frames selected then advanced to the nearest point on the tape where the bottom was visible and sled was stable on the bottom. From this frame an observer recorded an estimated rank of seagrass biomass and species composition. To standardise biomass estimates a 0.25 m^2 quadrat, scaled to the video camera lens used in the field, was superimposed on the screen. On completion of the videotape analysis, the video observer ranked five additional quadrats that had been previously videoed for calibration. These quadrats were videoed in front of a stationary camera, and then harvested, dried and weighed. A linear regression was calculated for the relationship between the observer ranks and the actual harvested value. This curve was used to calculate above-ground biomass for all estimated ranks made from the survey sites.

Plate 2. Offshore video sampling sled and sorting of benthic organisms from sled net.

Table 1. Number of sites sampled in each of the survey areas using various sampling methods in the Mackay port limits area.

Sampling method	Area	No. of sites
Dive survey	**Mainland coast (total)**	**39**
	North of harbour mainland coast	28
	South of harbour mainland coast	11
	Inshore Islands (total)	**24**
	Round Top Island	13
	Flat Top Island	8
	Slade Island	3
Harbour video survey	**Harbour (total)**	**21**
	Swing basin	7
	Other	14
Offshore video survey	**Port limit area (total)**	**80**
	Adjacent to southern approach channel	14
	Spoil disposal site	5
	Other	61
TOTAL	**ALL AREAS**	**164**

Geographic Information System

All survey data were entered into Microsoft Access® then exported to MapInfo® to construct a Geographic Information System (GIS) for mapping and presentation of macro-benthic communities. The MapInfo® layers were converted into ArcView® format for incorporation into MPA's GIS. Four GIS layers were created to describe Mackay's benthic communities:

1. Site information - Point data containing all the information collected at coastal and offshore sampling sites.

2. Seagrass meadows and characteristics - Polygon (area) layer displaying the distribution of seagrass meadows with summary information on the meadow characteristics. Seagrass meadows were differentiated on the basis of the species composition and the above-ground biomass of the meadows. Depth of meadows and overall patchiness of meadows was also taken into account.

3. Macro-algal community types - Polygon layer displaying the distribution of algae community types and descriptions of community characteristics. Algae community types were differentiated based on the species composition and the percentage of the seabed they covered (% cover). Three percentage cover categories were used; *low cover* (< 5%), *medium cover* (5 - 20%) and *high cover* (> 20%).

4. Benthic macro-invertebrate communities - Polygon layer displaying the benthic macro-invertebrate communities and their characteristics. Macro-invertebrate community types were differentiated based on the species composition and the total density of macro-invertebrates. Density of benthic macro-invertebrate communities was determined by reviewing the offshore videotapes and measuring time between the presence of any benthic macro-invertebrates on screen. Four density categories were used:

open substrate - dominant feature was bare substrate with occasional isolated benthic macro-invertebrate individuals;

low density - benthic macro-invertebrates present on the screen for < 10% of the site video record;

medium density - benthic macro-invertebrates present in 10 - 80% of the site video record;

high density - benthic macro-invertebrates present on the screen for > 80% of the site video record.

Rocky reef areas were put in a separate category, and were assumed to have a high density and diversity of benthic macro-invertebrates based on visual reconnaissance of reef areas during the dive surveys.

Site information collected in the survey was the primary data source for mapping GIS polygon layers. A range of other tools were used to assist in determining and refining benthic community boundaries:

- Rectified colour aerial photographs (taken in June 1998, 1:25000, Beach Protection Authority);
- Admiralty Chart Aus 249 (Mackay Port);
- Depth below MSL;
- Substrate type;
- Shape of geographical features such as banks and embayments.

Each benthic habitat area was assigned a mapping quality value, determined by the data sources, range of mapping information available and accuracy of mapping (Table 2). This mapping value was expressed as an *estimate of reliability* (R) or error term in metres taking into account the sources of mapping information for each benthic area (Table 2). The area for the mapping errors was calculated using the polygon buffer function in Mapinfo®. Other sources of mapping error associated with digitising and rectifying aerial photographs and admiralty charts onto base maps and with dGPS fixes for survey sites were much smaller and were embedded within mapping method errors. The larger estimate of reliability (R) values are for areas that were mapped based on the lowest level of information collected, with video survey sites spaced well apart. In the absence of any other mapping information, the distance between these sites determined mapping boundaries. Where the sites were a long way apart the value of R is high.

Table 2. Mapping quality for seagrass, algae and benthic macro-invertebrate areas surveyed in Mackay, February 2001.

(R is an estimate of mapping reliability).

Mapping quality	Data sets	Comments
1	Aerial photos only	Colour aerial photos used with very high definition of submerged reefs. **R = ± 5 m**
2	Aerial photos and dive survey	Colour aerial photos used with high definition of inshore benthic habitat. High density of survey sites. **R = ± 5 m**
3	Aerial photos, dive survey and Admiralty chart depth contours	Colour aerial photos used with high definition of inshore benthic habitat. Admiralty Chart Aus 249 (Mackay Port) depth information used. High density of survey sites used in determining some boundaries. **R = ± 10 m**
4	Aerial photos and offshore video survey	Colour aerial photos used with medium definition of subtidal areas near islands. Some boundaries reliant on site information only. Density of survey sites generally low. **R = ± 100 m**
5	Admiralty chart and offshore video survey	Admiralty Chart Aus 249 (Mackay Port) used for depth information for some boundaries. Low density of offshore video survey sites. **R = ± 100 m**
6	Dive survey, Admiralty chart depth contours and offshore survey	Admiralty Chart Aus 249 (Mackay Port) used for some boundaries. Most boundaries determined by a low density of dive survey and offshore video survey sites. **R = ± 100 - 500 m**
7	Offshore video survey only	Subtidal benthic communities not visible in aerial photos and no assistance available from charts. Boundary mapping reliant solely on low density of survey sites. **R = ± 300 - 500 m**

Results

Seagrass

Three seagrass species (from two families) were found in the survey area:

Family CYMODOCEACEAE Taylor:

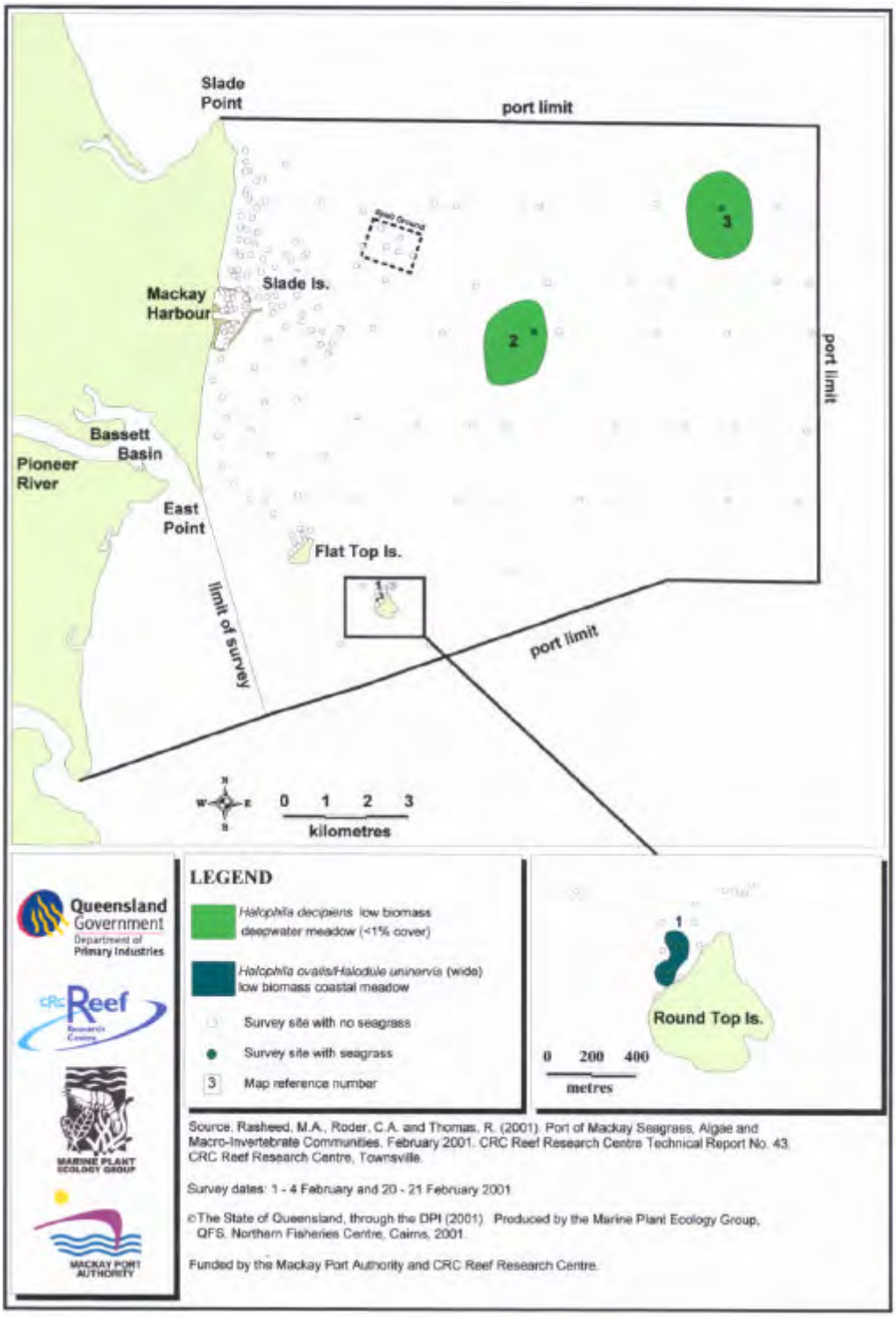
Halodule uninervis (wide leaf morphology) (Forsk.) Aschers.

Family HYDROCHARITACEAE Jussieu:

Halophila decipiens Ostenfeld

Halophila ovalis (R. Br.) Hook.*f.*

Seagrass distribution was confined to three meadows; two offshore *Halophila decipiens* meadows approximately 7 km and 12 km east of the harbour, and a small coastal *Halodule uninervis* (wide)/*Halophila ovalis* meadow adjacent to the north-western shore of Round Top Island (Map 1). The coastal meadow had a mean above-ground biomass of 1.2 g dw m^{-2} and an area of 2.2 ha (Table 3). This meadow was subtidal with a mean depth of 6.3 m below MSL. Biomass could not be determined for the offshore meadows as distribution of seagrass at the sites was very low and undetectable on the video. Presence of seagrass in these meadows was based on collections of a few individual plants within the trawl collection net. Both of these offshore meadows were in relatively deep water (17.7 m and 21.7 m below MSL) and had areas of 272.6 ha and 293.8 ha for meadows 2 and 3 respectively (Table 3).



Map 1. Port of Mackay seagrass distribution and meadow type, February 2001.

Table 3. Area, mean above-ground biomass and depth below MSL for Port of Mackay seagrass meadows, February 2001.

(Values in brackets for area are the estimate of reliability (R)).

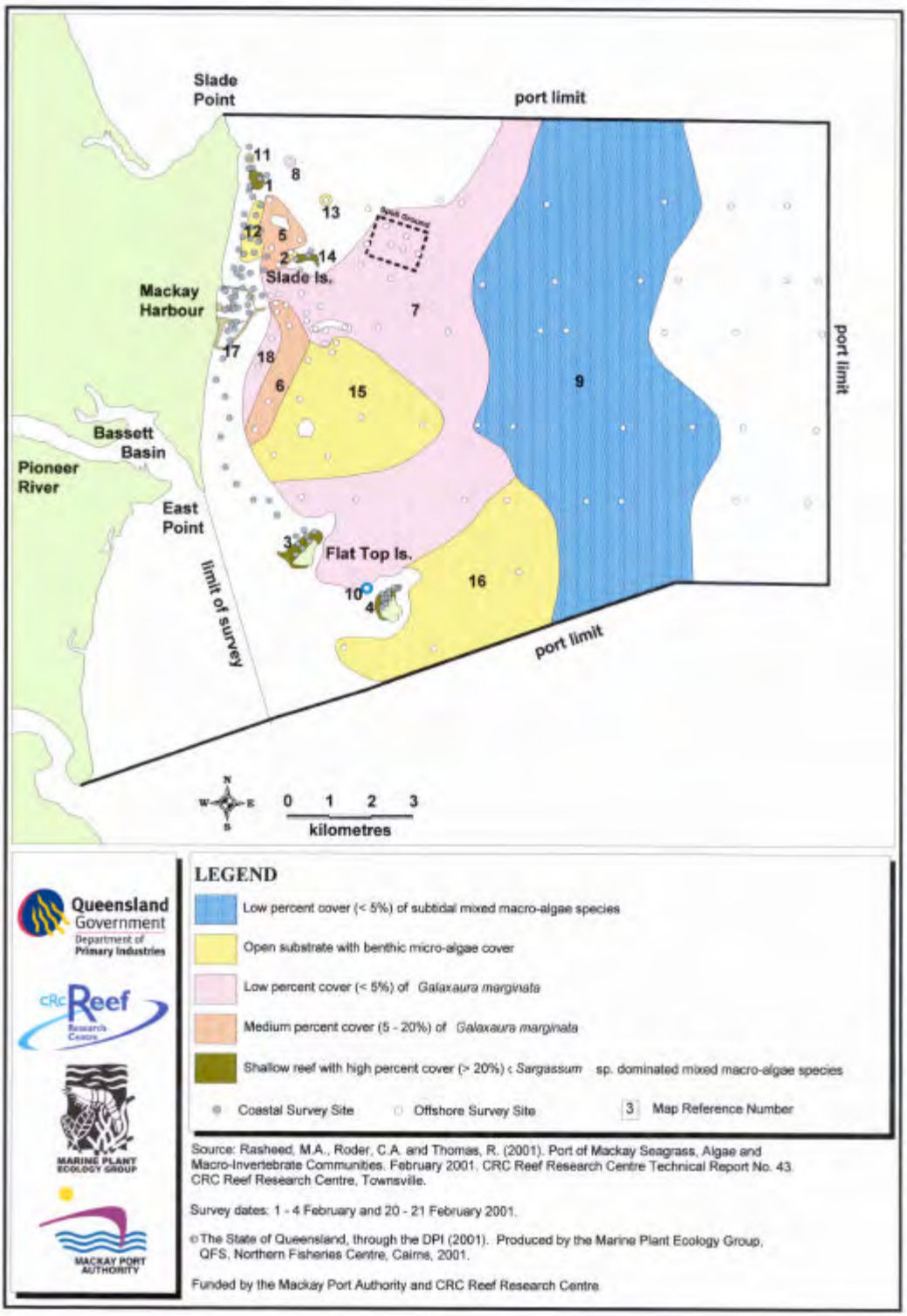
Meadow No. (refer Map 1)	No. of sites	Species present	Area (range) (ha)	Biomass (g dw m^{-2})	Depth below MSL (m)
1	2	*Halodule uninervis* (wide), *Halophila ovalis*	2.2 (0.3 - 4.1)	1.2	6.3
2	1	*Halophila decipiens*	273 (61 - 484)	-	17.7
3	1	*Halophila decipiens*	294 (79 - 508)	-	21.7

Algae

Algal communities were present in 61% of the survey area (Map 2). Four different macro-algal community types and one benthic micro-algal community type were identified (Map 2; Table 4). Although algae communities were found in a large proportion of the port limit area, generally percentage cover of algae within these areas was low (< 1 - 5%) and the dominant feature of habitats was unvegetated substrate (Map 2; Table 4).

There was a distinct zonation of macro-algae community types with distance from the mainland shore. A medium percentage cover (5 - 20%) *Galaxaura marginata* dominated community occurred inshore to the north and south of the harbour, in a band between the harbour entrance and Slade Island (Plate 3; Map 2). To the east of this area (further offshore) the substrate was softer and a low percentage cover *Galaxaura marginata* community occurred (Map 2). A large band of low percent cover mixed species algae occurred further offshore (Map 2). No macro-algae occurred in the deeper offshore sections of the survey area from approximately 11 km off the mainland coast to the eastern port limit boundary (Map 2).

Small areas of high percentage cover (> 20%) *Sargassum* dominated mixed algae community occurred on the rocky reef areas adjacent to Flat Top Island, Round Top Island, Slade Island and Slade Point (Map 2). In addition to the macro-algae communities, several areas containing benthic-micro algae were identified (Map 2; Table 4). Benthic micro-algae appeared as a film over patches of otherwise bare substrate. The red algae *Galaxaura marginata* was the most commonly encountered type of macro algae in the Mackay port limit area (Map 2; Table 4).



Map 2. Port of Mackay algae distribution and habitat type, February 2001.

Table 4. Algae community habitat types - presence of algae types and size of each area in the Port of Mackay, February 2001.

(*R is an estimate of mapping reliability).

Algae habitat type	Map reference No.	Area (± R) (ha)	Algae type										
			Galaxaura marginata	*Udotea* sp.	*Codium* sp.	*Halimeda* sp.	*Lobophora* sp.	*Sargassum* sp.	Coralline	Encrusting	Unidentified brown	Unidentified red	Benthic micro-algae
Open bottom with benthic micro-algae cover	11	11 (± 4)	-	-	-	-	-	-	-	-	-	-	✓
	12	59 (± 40)	-	-	-	-	-	-	-	-	-	-	✓
	13	15 (± 5)	-	-	-	-	-	-	-	-	-	-	✓
	14	5 (± 5)	-	-	-	-	-	✓	-	-	-	-	✓
	15	1079 (± 751)	-	-	-	-	-	-	-	-	-	-	✓
	16	1321 (± 940)	-	-	-	-	-	-	-	-	-	-	✓
	17	1 (± 1)	-	-	-	-	-	-	-	-	-	-	✓
Shallow reef with high percentage cover *Sargassum* and other mixed macro-algae	1	16 (± 2)	-	✓	-	-	✓	✓	-	-	-	✓	-
	2	10 (± 1)	-	-	-	-	-	✓	-	-	-	-	✓
	3	34 (± 2)	-	-	-	-	-	✓	-	✓	✓	-	✓
	4	18 (± 1)	-	-	-	-	✓	✓	-	-	-	-	-
Soft substrate with low percentage cover *Galaxaura marginata* dominated community	7	3167 (± 2073)	✓	✓	-	-	-	✓	✓	-	-	-	-
	8	15 (± 5)	✓	-	-	-	-	-	-	-	-	-	-
	18	99 (± 99)	✓	-	-	-	-	✓	-	-	-	-	-
Hard substrate with medium percentage cover *Galaxaura marginata* dominated community	5	128 (± 116)	✓	-	-	-	-	-	-	-	✓	✓	✓
	6	216 (± 181)	✓	-	-	-	-	-	-	-	-	-	-
Soft substrate with low percentage cover subtidal mixed species macro-algae	9	5105 (± 1757)	✓		✓	✓	-	-	✓	-	-	-	-
	10	15 (± 12)	✓	✓	-	-	-	-	✓	-	-	-	-

Benthic macro-invertebrates

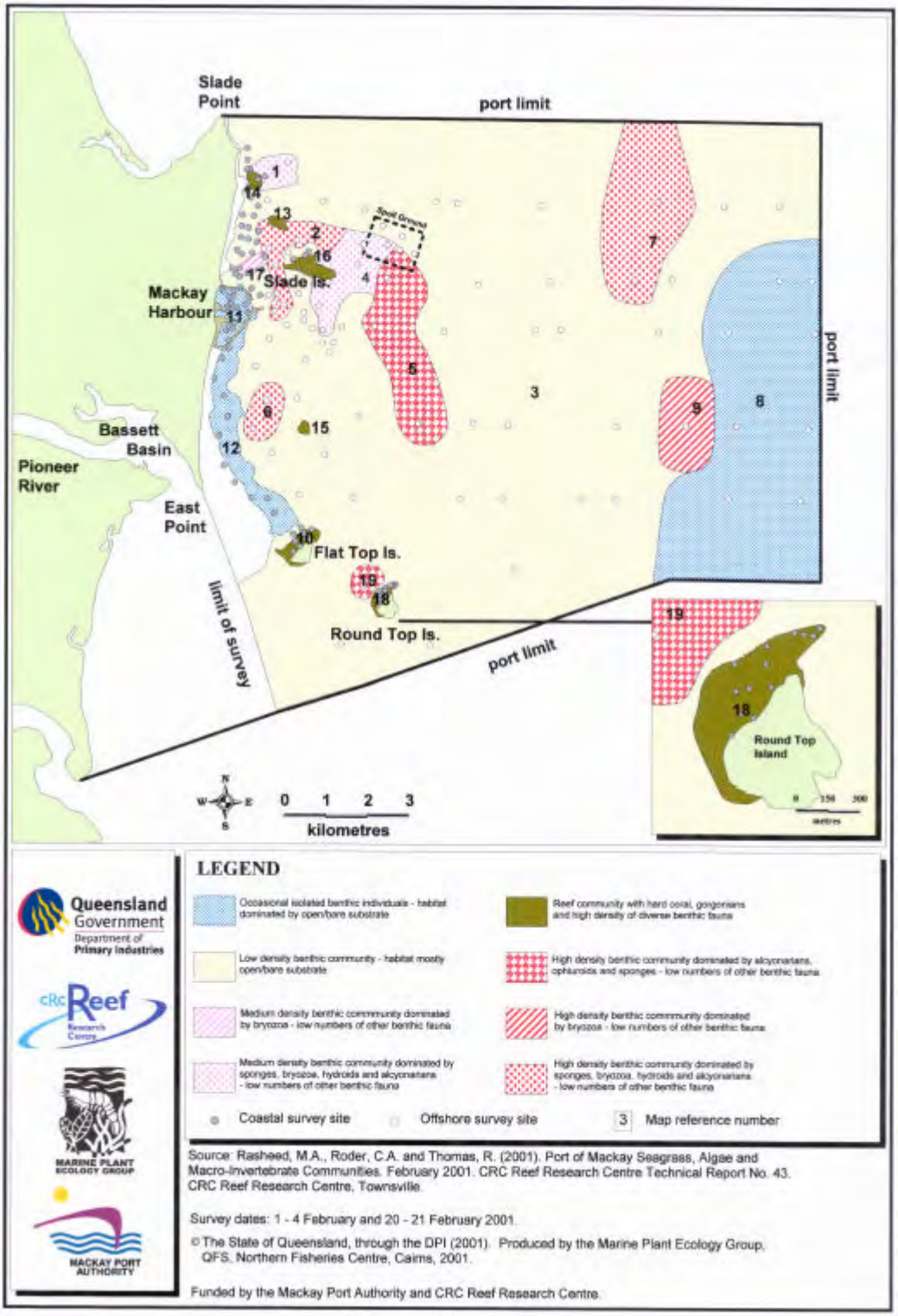
Benthic macro-invertebrates occurred throughout the survey area (Map 3). The dominant community types were those that had a low density of macro-invertebrates with open substrate comprising the majority of the area (Map 3; Table 5). There were areas of higher density macro-invertebrate communities to the north east of the harbour, north east of East Point, adjacent to Round Top Island, south of Slade Point and in two offshore regions near the eastern port limit (Map 3). Benthic macro-invertebrate communities were divided into regions based on density of individuals and community composition. There were five density categories and six community types combining to give eight different benthic macro-invertebrate region types (Table 5).

Open substrate with occasional individual

This was the lowest density category used to describe macro-invertebrate regions and formed 16% of the survey area. There was one community type in this category - *community dominated by open substrate with solitary benthic individuals.* These regions were nearly all bare substrate with small holes created by burrowing worms or crustacea and only an occasional isolated macro-invertebrate (Plate 4). Macro-invertebrate isolates within these regions were from a range of taxa groups (Table 6). There were three regions of this category; region eight, adjacent to the southeastern port limit boundary (2564 ha); region 12, adjacent to the coast between the harbour and East Point (285 ha); and region 11, the area inside the harbour (85 ha) (Map 3; Table 5).

Low density benthic community

Community types in this category covered the largest area within the port limits (12905 ha; 70% of survey area) (Table 5). There was one community type in this density category - *community dominated by open substrate with a low density of varied benthic fauna*. This community formed one large region (region 3) that surrounded the other region types (Map 3). The dominant feature of this region type was large areas of open substrate, which were interspersed with occasional groups of benthic macro-invertebrates (Plate 5). Although density of individuals was low, there was a wide representation of taxa found within the area (Table 6).



Map 3. Port of Mackay benthic macro-invertebrate regions, February 2001.

Medium density benthic community

There were two different benthic macro-invertebrate community types for this density category covering 2% of the survey area:

1. *Community dominated by sponges, bryozoa, hydroids and alcyonarians with lower numbers of other benthic taxa* (Plate 6; Table 5). There were two of these regions in the study area; region 1 (77 ha) adjacent to the shoreline south of Slade Point; and region 4 (274 ha) to the east of Slade Island (Map 3; Table 5).

2. *Community dominated by bryozoa with low numbers of other benthic taxa* (Plate 7;). One small area of this region type (region 17; 26 ha) occurred adjacent to the mainland coast west of Slade Island (Map 3; Table 5).

High density benthic community

There were three different benthic macro-invertebrate community types for this density category forming 11% of the survey area:

1. *Community dominated by sponges, bryozoa, hydroids and alcyonarians with lower numbers of other benthic taxa* (Plate 8; Table 5). There were 3 of these regions in the study area; region 2 (201 ha) to the north and west of Slade Island; region 6 (109 ha) approximately 1 km offshore between the harbour and East Point; and region 7 (774 ha) a large offshore area near the north eastern boundary of the survey area (Map 3; Table 5).

2. *Community dominated by alcyonarians, ophiuroids and sponges with low numbers of other benthic taxa* (Plate 9; Table 6). There were two of these regions in the study area; region 5, a large area (558 ha) 3 km offshore between Slade and Round Top Islands; and region 19 (51 ha) a small area adjacent to Round Top Island (Map 3; Table 5).

3. *Community dominated by bryozoa with low numbers of other benthic taxa* (Table 5). There was one area of this region type near the eastern boundary of the survey area (Map 3).

Rocky reef community

Rocky reef communities with high densities and diversities of benthic macro-invertebrates were found in sheltered coastal waters in the western (inshore) section of the survey area

(Map 3). Reef communities did not occur in deeper offshore areas. They were confined within 2 km of the mainland or island shores, and comprised 1% of the total survey area (Map 3). These regions were small compared with the other region categories found within the port limits (Map 3; Table 5). Six small rocky reef regions were identified, from 8 ha to 40 ha (Map 3; Table 5).

Plate 3. Medium percentage cover *Galaxaura marginata* algae community (frame taken from site video footage).

Plate 4. Open substrate with occasional isolated benthic individual (frame taken from site video footage).

Plate 5. Low density benthic macro-invertebrate community (frame taken from site video footage).

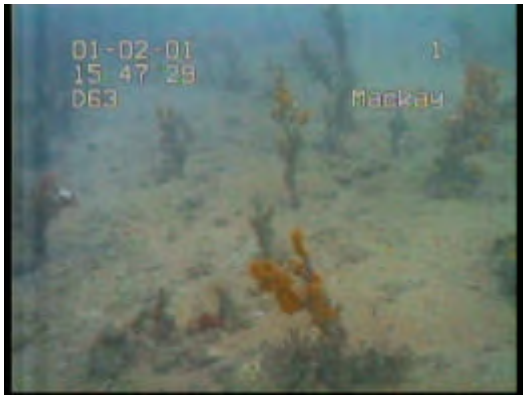


Plate 6. Medium density benthic community dominated by sponges, bryozoa, hydroids and alcyonarians (frame taken from site video footage).

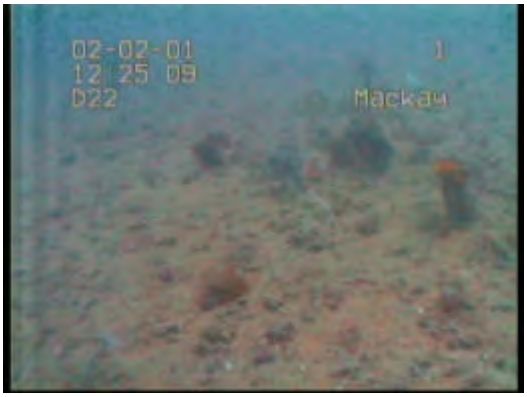


Plate 7. Medium density benthic community dominated by bryozoa, with low numbers of other benthic taxa (frame taken from site video footage).

Plate 8. High density benthic community dominated by sponges, bryozoa, hydroids and alcyonarians (frame taken from site video footage).

Plate 9. High density benthic community dominated by alcyonarians, ophiuroids and sponges (frame taken from site video footage).

Table 5. Benthic macro-invertebrate regions in the Port of Mackay - density, number of sites, area and description for regions mapped in February 2001.

(R is an estimate of mapping reliability).

Density of benthic macro-invertebrates	Benthic macro-invertebrate community description	Region No.	No. of sites	Area ± R (ha)
Open substrate, occasional individual	Soft bottom benthic community with solitary benthic individuals	8	8	2564 ±1276
		11	17	85 ±3
		12	9	285 ±145
Low density benthic community	Soft bottom benthic community dominated by open substrate with low density of varied benthic fauna	3	75	12905 ±4855
Medium density benthic community	Soft bottom benthic community dominated by sponges, bryozoa, hydroids, alcyonarians - low number of other benthic taxa	1	2	77 ±41
		4	6	274 ±187
	Soft bottom benthic community dominated by bryozoa - low numbers of other benthic taxa	17	3	26 ±4
High density benthic community	Soft bottom benthic community dominated by bryozoa - low numbers of other benthic taxa	9	1	295 ±225
	Soft bottom benthic community dominated by alcyonarians, ophiuroids and sponges - low numbers of other benthic taxa	5	4	558 ±379
		19	1	51 ±30
	Soft bottom benthic community dominated by sponges, bryozoa, hydroids, alcyonarians - low number of other benthic taxa	2	8	201 ±101
		6	2	109 ±92
		7	2	774 ±657
Rocky reef community	Reef community with hard coral, gorgonians and diverse benthic fauna	10	6	34 ±2
		13	-	12 ±1
		14	3	16 ±2
		15	-	8 ±1
		16	1	40 ±3
		18	13	18 ±1
TOTAL ALL AREAS		**19**	**161**	**18332 ±8004**

Table 6. Benthic macro-invertebrate communities within Mackay port limits - density and types of taxa present for each benthic community region containing offshore survey sites (taxa sampled with sled net and video footage).

L = low, average of < 6 individuals per site; M = medium, 6 - 20 individuals per site; H = high, average of > 20 individuals per site.

	Benthic community region (refer Map 3)																												
TAXA	**1**			**2**			**3**			**4**			**5**			**6**			**7**			**8**			**9**			**19**		
	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
INVERTEBRATES																														
ANNELIDA																														
Polychaetes					✓		✓			✓			✓			✓						✓			✓					
ARTHROPODA CRUSTACEA																														
Brachyura		✓		✓			✓			✓			✓			✓			✓			✓								
Prawns				✓			✓																							
CNIDARIAN																														
Anthozoa																														
Alcyonarians	✓			✓			✓			✓				✓			✓		✓						✓					✓
Ascidians	✓			✓			✓			✓			✓			✓			✓			✓			✓					
Colonial hard corals				✓			✓						✓																	
Gorgonian	✓			✓			✓			✓			✓			✓			✓						✓					
Other soft corals	✓			✓			✓						✓																	
Sea pens							✓															✓								
Solitary hard corals				✓			✓			✓			✓			✓			✓						✓			✓		
Hydrozoa																														
Hydroids	✓			✓			✓			✓			✓			✓				✓		✓			✓			✓		
Zoantharia																														
Sea anemones							✓																							
Zoanthids	✓						✓			✓			✓						✓			✓			✓			✓		

Table 6 continued…	**1**			**2**			**3**			**4**			**5**			**6**			**7**			**8**			**9**			**19**		
	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
Asteroidea																														
Sea star				✓			✓												✓			✓			✓					
Crinoidea																														
Feather star	✓			✓			✓			✓			✓			✓			✓											
Echinoidea																														
Echinoids	✓			✓			✓			✓			✓			✓			✓						✓			✓		
Holothurioidea																														
Sea cucumber	✓			✓			✓			✓			✓			✓			✓			✓								
Ophiuroidea																														
Brittle star				✓			✓						✓												✓					✓
ECTOPROCTA																														
Bryozoa			✓		✓		✓			✓			✓			✓			✓			✓					✓	✓		
MOLLUSCA																														
Bivalves				✓			✓			✓			✓			✓									✓					
Gastropods				✓			✓			✓			✓						✓			✓			✓					
Other mollusca				✓			✓			✓			✓						✓						✓					
PORIFERA																														
Sponges			✓			✓	✓				✓			✓			✓		✓			✓			✓			✓		
VERTEBRATES																														
Fish	✓			✓			✓			✓			✓			✓			✓			✓						✓		
Sea Horse				✓			✓			✓						✓			✓											

Discussion

A range of benthic community types was found within the Mackay port limits. The majority of the port limit area contained low-density benthic communities dominated by open substrate. Small areas of high benthic habitat diversity were commonly found in shallow water around reefs and islands and in several patches in deeper offshore waters.

Seagrass distribution was small compared with other areas that have been surveyed in tropical Queensland waters (e.g. Coles *et al.* 2001; Rasheed *et al.* 2001; Roelofs *et al.* 2001). Only one small coastal meadow and two offshore meadows were described in the survey area. A broad scale survey of coastal seagrasses along the eastern Queensland coast in 1987 identified two small seagrass meadows in the port limits (Coles *et al.* 1987). One of these meadows, adjacent to Round Top Island, was found in the present survey. The second meadow identified in 1987, northwest of Flat Top Island, was not present in February 2001. The absence of this meadow may be due to the high seasonal and inter-annual variability, which is common for similar tropical seagrass meadows in north Queensland (e.g. Rasheed *et al.* 2001; McKenzie *et al.* 1998). In 1987 seagrass cover was low for the Flat Top Island meadow (< 10%) (Coles *et al.* 1987) and the seagrass species found there, *Halodule uninervis,* is known to be ephemeral and capable of lying dormant as a seed bank stored in the sediments for extended periods of time (Inglis 2000).

Two new areas of seagrass were identified in the deeper offshore areas within the port limits. These areas had very low abundances of *Halophila decipiens* a seagrass species commonly found in deeper waters inside the Great Barrier Reef (Coles *et al.* 1996). *Halophila decipiens* is also a seasonal species with abundance and distribution peaking between September and November. At other times of the year such as late in the dry-season, distribution and abundance of *Halophila decipiens* in Mackay may be greater than was found in the February survey.

Apart from small *Sargassum* communities on rocky reef areas, macro-algae did not form dense beds within the Mackay port limits. The ecological and fisheries values of the sparse algae communities that typified Mackay is not known. Denser algae beds in the Gulf of Carpentaria provide nursery habitat for juvenile commercial prawns (Haywood *et al.* 1995) and on a global scale algae beds are considered as important as seagrasses for their ecosystem services role (Costanza 1997). In Mackay, diversity of benthic fauna tended to be greater at

sites that had macro-algae, but further study would be required to confirm a relationship between the two.

This survey was the first to describe benthic macro-invertebrate communities within the wider port limits of Mackay. Although only identified into broad taxonomic groups a high diversity of benthic macro-invertebrates were found within the survey area. Using the camera and sled net to sample benthic macro-invertebrates allowed larger areas of the bottom to be sampled than by traditional grab techniques. Video images also allowed broader community characteristics to be described by providing a visual record of the community structure and density.

While a low-density community covered most of the survey area, significant areas of benthic macro-invertebrate communities with higher density were found in proximity to the harbour and approach channels (Map 4). The proposed position of the southern approach channel appears to be well situated to cause minimal impact on Mackay's marine environment (Map 4). The proposed channel passes through low-density benthic communities for most of its length, apart from a small higher density section near the mouth of the harbour (Map 4). Algae communities in the path of the channel were also mostly low density apart from a small section at the mouth of the harbour (Map 5). The higher density algae and benthic macro-invertebrate communities at the mouth of the harbour still contained significant areas of open substrate. It is possible that an approach channel could be placed through this area without a major disturbance to these communities. An intensive survey of the proposed approach channel for approximately 1 km from the harbour entrance may aid in the appropriate placement of the channel through this area.

Areas of the harbour that would require capital dredging as part of proposed port expansion did not contain any significant benthic communities (Maps 4, 5 and 6). Similarly, proposed reclamation and Cape class berths to the north of the harbour were positioned in regions with low benthic macro-invertebrate density and no macro-algae communities (Maps 4 and 5).

Both of the proposed offshore berth options pass over high-density benthic macro-invertebrate and algae regions mapped in this survey and further options for their location or management of impacts associated with their construction may need to be considered (Maps 4 and 5).

Low density *Galaxaura marginata* algae communities and high-density benthic macro-invertebrate communities were found in sections of the designated spoil disposal ground (Maps 4 and 5). The dredge spoil ground contained three benthic macro-invertebrate community types and one macro algae community type (Maps 4 and 5). All of these areas extended outside the spoil ground area and there were no apparent differences between the communities inside or outside the dredge spoil ground. This indicates that current levels of dumping are unlikely to have had a major impact on the benthic communities in the spoil ground. Further experimental investigations would be required to determine the tolerance limits of these communities to increased sedimentation.

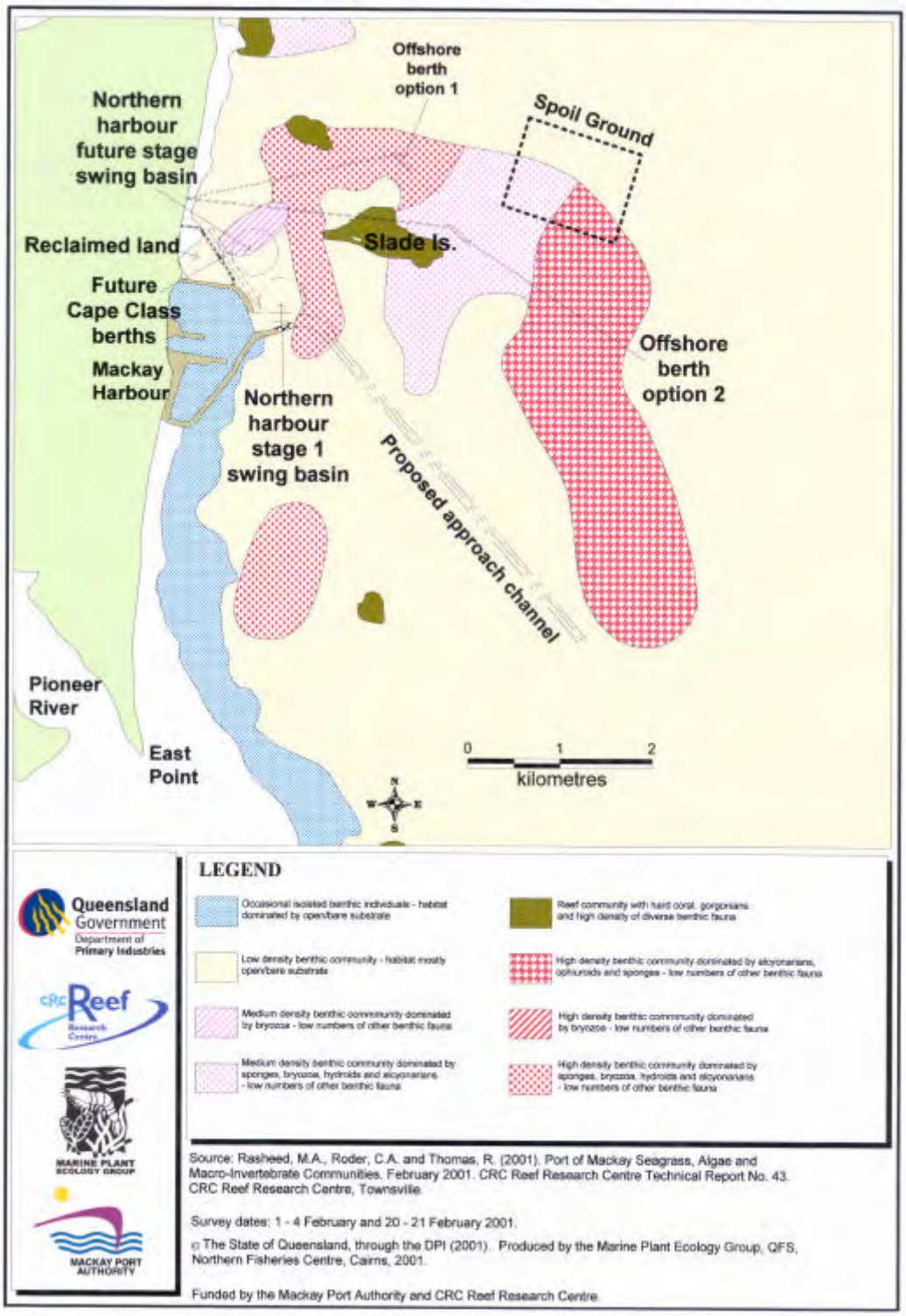
Seagrasses were unlikely to be affected by proposed works because there were no seagrass meadows in proximity to the harbour or approach channel (Map 6). However, caution should be used when interpreting these results because the seagrass, algae and benthic communities are likely to be dynamic both seasonally and inter-annually.

No rare, threatened or introduced marine species were identified in this survey. The survey was not intended as an exhaustive search for introduced organisms, nor conducted using the Centre for Research on Introduced Marine Pests (CRIMP) protocols so it does not exclude the possibility that introduced organisms are present in Mackay Port.

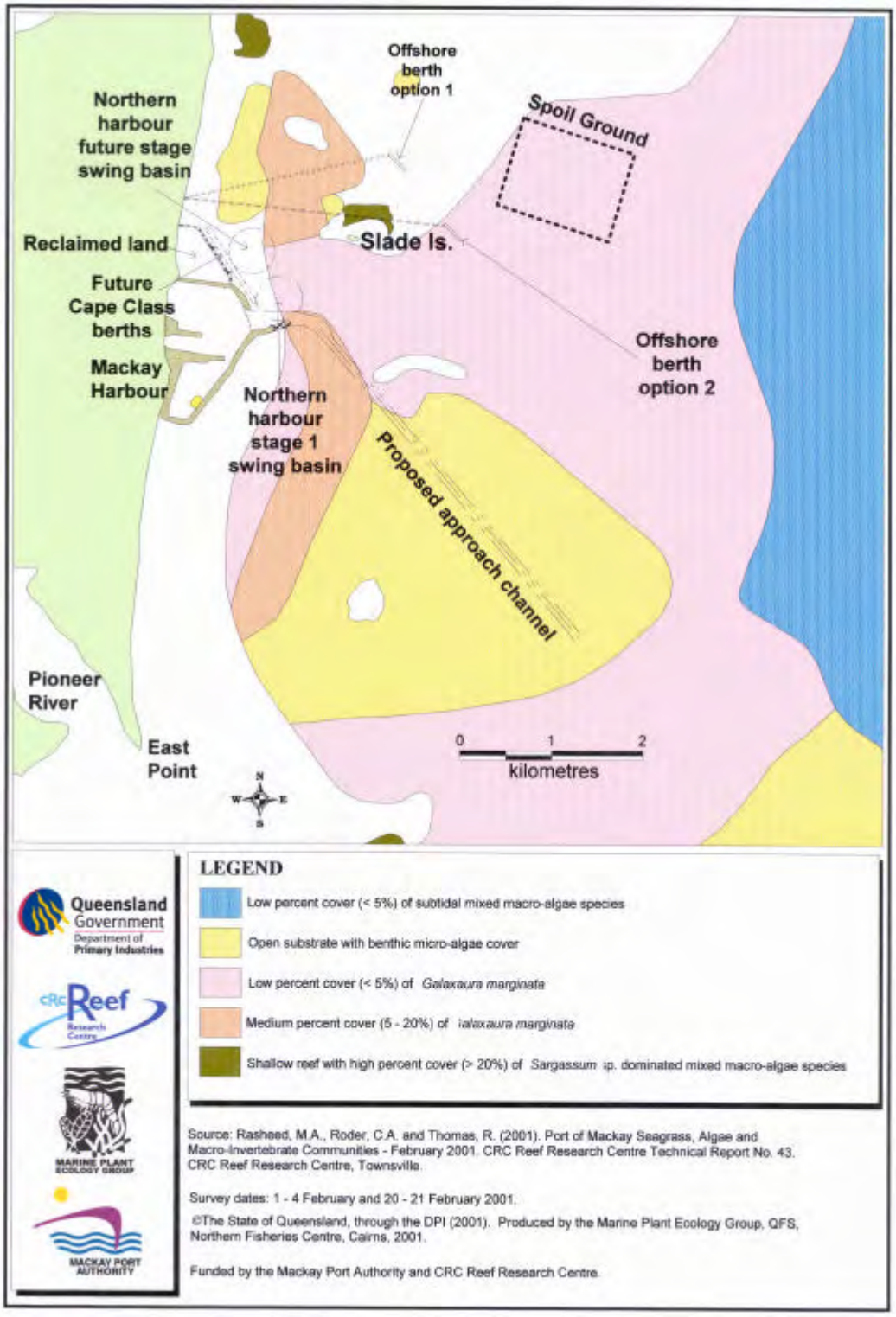
The results of this survey indicate that proposed works were generally located in areas that would minimise the impacts to Mackay's marine environment. Apart from the initial section of the approach channel near the harbour entrance there were no sensitive habitats in the vicinity of the harbour and development area that would require ongoing monitoring. The higher density algae and benthic macro-invertebrate communities near the harbour entrance still contained significant areas of open substrate. It is possible that an approach channel could be placed through this area without major disturbance to these communities. An intensive survey of the proposed approach channel for approximately 1 km from the harbour entrance would help to determine the level of any impact and may aid in the appropriate placement of the channel through this area.

We recommend that consideration be given to the timing of any dredging works so as to minimise the effects on local fisheries. Queensland Fisheries Service has a policy document that explains the department's position on assessment of dredging applications (Hopkins & White 1998). This policy outlines the criteria for assessment of capital dredging operations

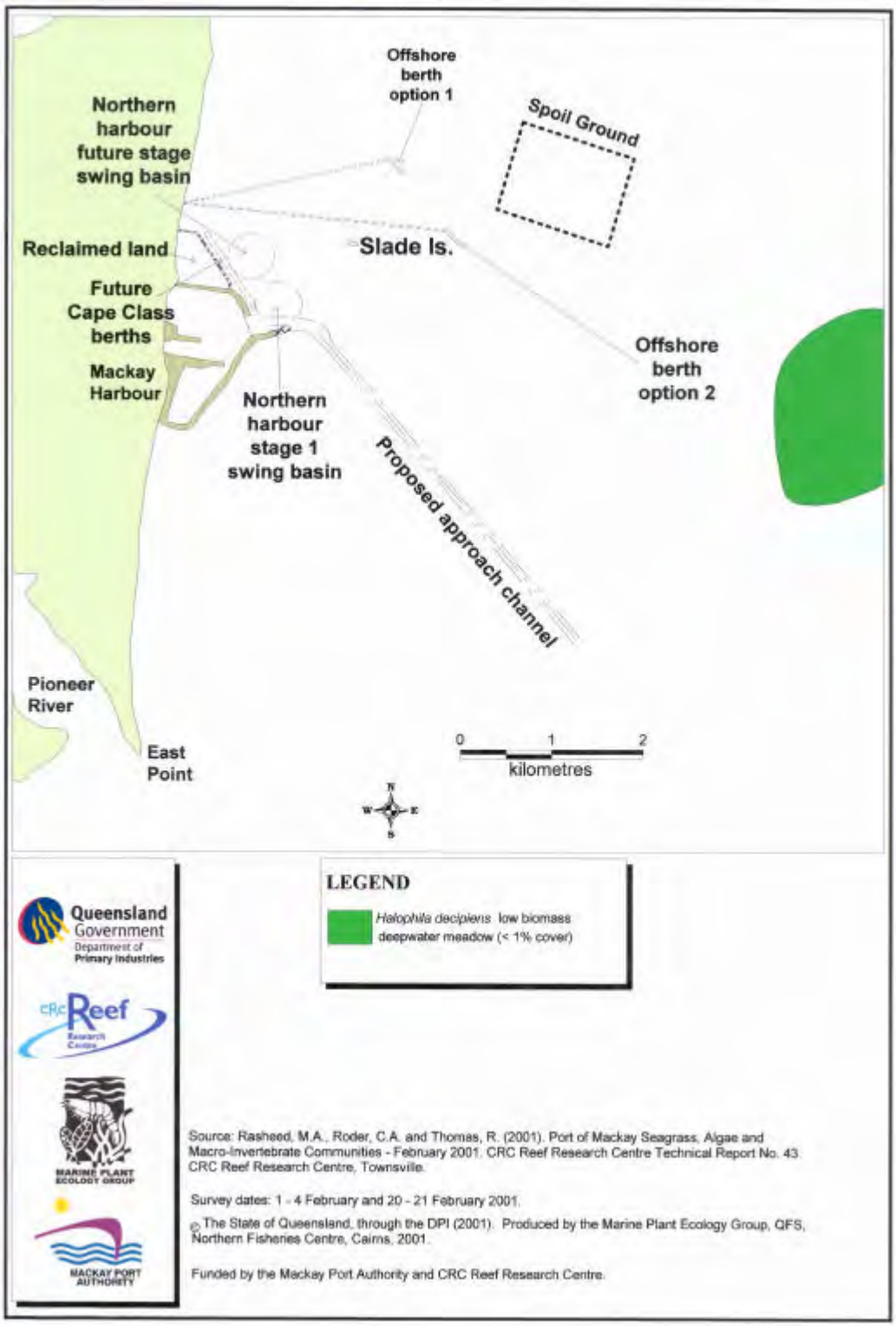
including the provision of appropriate mitigation. Conducting dredging works outside peak times for spawning and migration of economically important marine finfish, such as barramundi and king salmon is recommended. Advice on localised fish movements and issues should be sought from local fisheries representatives, Sunfish and Queensland Seafood Industry Association when determining the most appropriate time for capital dredging to be conducted in Mackay.



Map 4. Proposed works for the Port of Mackay and benthic macro-invertebrate regions mapped in February 2001.



Map 5. Proposed works for the Port of Mackay and algae habitat mapped in February 2001.



Map 6. Proposed works for the Port of Mackay and seagrass habitat mapped in February 2001.

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