Port Expansion Project EIS

Appendix K2

Marine Ecology Baseline Report

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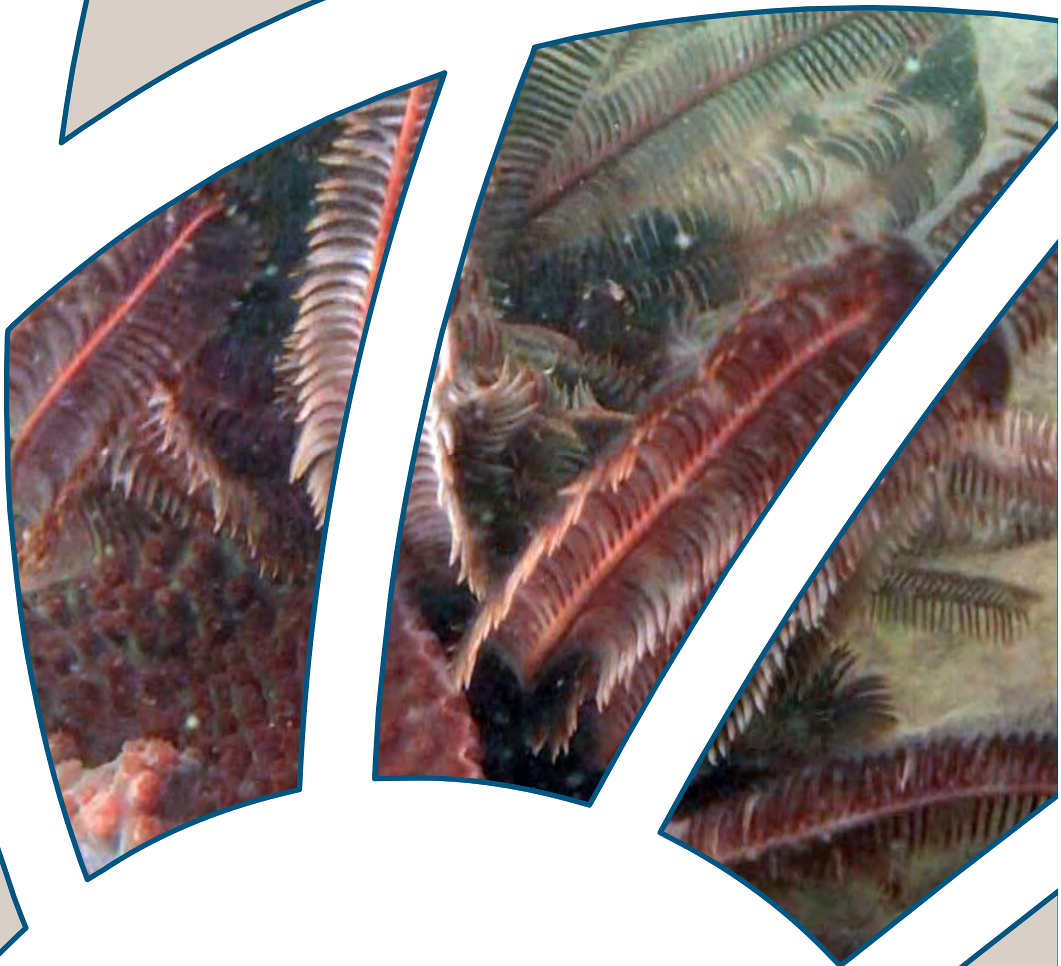
Port of Townsville Port Expansion Project EIS – Marine Ecology Baseline Report



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November 2012

Townsville Port Expansion Project EIS – Marine Ecology Baseline Report

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Title :	Townsville Port Expansion Project EIS – Marine Ecology Baseline Report
Author :	Dr Darren Richardson, Dr Conor Jones, Dr Beth Toki, David Barnes
Synopsis :	This report forms a technical appendix to the Port of Townsville Port Expansion Project EIS. The report provides a description of marine ecological values within Cleveland Bay that could potentially be affected by the proposed port development, and will form the basis of the Existing Environment description for the Port Expansion Project EIS.

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EXECUTIVE SUMMARY

Background

This technical appendix to the Port Expansion Project (PEP) Environmental Impact Statement (EIS) describes the existing marine flora, fauna and biodiversity values of environments potentially affected by the Project and the wider Cleveland Bay region. The report specifically considers the three main areas (collectively referred to as the *study area*) potentially affected by the Project, namely the:

- outer harbour Project area;
- navigation channels subject to capital dredging for the Project; and
- existing offshore dredged material placement area (DMPA).

This report summarises existing information regarding the environmental values of the study area and surrounds (i.e. Cleveland Bay), primarily focusing on marine habitats and communities, threatened species and fisheries resource values. The report also describes the methodology and findings of field investigations undertaken by BMT WBM to support the EIS chapter, which included the following:

- Seabed habitat mapping using acoustic (sonar) based techniques;
- Sediment and epifauna community assessments within representative seabed habitat classes, using a remotely operated underwater video system and grab sampling;
- Sampling of macrobenthic communities based on grab-sampling techniques; and
- Surveys of breakwater habitats and natural reef systems using a diver-operated underwater video system.

The objective of these studies was to characterise sensitive ecological receptors, benthic habitats and communities within the study area and surrounds. Surveys were carried out within and adjacent to the Project areas and representative 'control' areas elsewhere within Cleveland Bay.

Marine Vegetation

Seagrass, mangroves, saltmarsh, benthic algae, together with corals, represent benthic primary producer habitat (BPPH). BPPH play an important role in maintaining coastal ecosystems and associated ecological services, including the provision of food and habitat resources for species of fisheries and conservation significance. BPPH is also sensitive to disturbance and water quality degradation, particularly light limitation.

There are no mangrove and saltmarsh areas within the Project areas. Both of these wetland habitats occur adjacent to the outer harbour Project area at the mouth of Ross River, outside the likely zone of potential impact of the Project.

The nearshore and deep-water seagrass meadows of Cleveland Bay are considered to be among the largest in the central Queensland coast. Seagrass surveys carried out in the 2000s show that the extent and biomass of seagrass within Cleveland Bay varies greatly over time. Temporal changes in seagrass meadows reflect seasonal and inter-annual variability in physical disturbance and turbidity.

Nonetheless, the seagrass meadows of Cleveland Bay are considered by the Department of Agriculture, Fisheries and Forestry to be largely unaffected by port operations.

No seagrass has been recorded to date within or directly adjacent to the outer harbour Project area. Surveys carried out in 2008 recorded a low-density deep-water seagrass meadow throughout much of the Cleveland Bay, including parts of the DMPA, and directly adjacent to Platypus and Sea Channels. This meadow represents a transient feature, and was not recorded in 2009-2011 surveys. Nonetheless, the area occupied by this seagrass meadow is considered to represent potential seagrass habitat.

Seagrass species differ in their sensitivity to disturbance (i.e. resistance) and capacity to recover following disturbance (i.e. resilience). In general, small species such as *Halodule* and *Halophila* tend to have low carbohydrate reserves compared to larger species, and are therefore the most sensitive species to low light conditions (i.e. low resistance). However, *Halodule* and *Halophila* species also have adaptations that allow rapid recovery (i.e. high resilience). Larger species such as *Zostera muelleri* and *Cymodocea serrulata* have high resilience to low light conditions, but are slower to recover should they be lost.

The capacity to recover following disturbance also depends on seagrass condition, which is a function of the previous disturbance history (magnitude, and spatial and temporal scale of disturbance). Successive periods of disturbance (i.e. multiple wet years) have depleted seagrass energy sores, seed banks and standing crop (i.e. seagrass condition), which greatly decrease the capacity for seagrasses to recover following disturbance.

The Reef Rescue Marine Monitoring Program assessed the condition of seagrass meadows based on a range of indicators. Seagrass meadows of the Burdekin-Townsville region were classified as being in a ‘poor state’ throughout the 2009/10 monitoring period (Johnson *et al*. 2011). Successive wet periods since 2007 have reduced the condition of seagrass meadows and their capacity to recover from disturbance. This is particularly the case of seagrass meadows around Magnetic Island, with mainland meadows displaying a higher capacity to recover.

Reefs Habitats and Communities

Cleveland Bay supports numerous reefs, including the fringing reefs of Magnetic Island, Middle Reef Virago Shoal. Middle Reef has particularly high hard coral cover, varying between 19 and 84% cover at/ondifferent parts of the reef. Coral cover and community structure varies greatly among reefs and between depth strata within reefs at Magnetic Island. Highest hard coral cover typically occurs on reef slopes, whereas the reef flats are typically dominated by macroalgae and seagrass (particularly at Cockle Bay Reef). Long term monitoring suggests that coral cover fluctuates over time, with major reductions observed after cyclone events such as Althea, Bronwyn and Yasi. Macroalgae typically dominates reefs shortly after such disturbances.

Cleveland Bay coral communities are subject to a range of environmental pressures. Low salinity flood waters in 2009-2011, as well as physical disturbance by Cyclone Yasi, are likely to be the main drivers of recent declines in coral cover in Cleveland Bay. Numerous coral bleaching events have been observed at Magnetic Island reefs, mostly in response to high seawater temperatures. Low salinity conditions also promote disease incidence in Magnetic Island coral communities.

Like seagrass, coral species differ in their sensitivity to disturbance (i.e. resistance) and capacity to recover following disturbance (i.e. resilience). In terms of resistance, Cleveland Bay has naturally high turbidity levels and therefore corals must have adaptations to cope with periods of low light and high sedimentation rates. The degree of resilience of corals varies among taxa. Acroporidae corals, for example, can show great changes in cover over time but are generally considered to be resilient. While most Acroporidae species are photophilic (sensitive to light deprivation) and break easily, they are also capable of high growth rates and high reproductive output (Thompson *et al*. 2010). Coral reefs of the Cleveland Bay are thought to be resilient to change, showing rapid recovery following disturbance. Notwithstanding this, recovery rates and growth of corals are highly dependent on ambient environmental conditions.

In recent years, Thompson *et al*. (2011) recorded low levels of coral recruitment (predominantly by slow-growing coral species) on settlement plates located at Middle Reef. On the basis of these results, Thompson *et al*. (2011) suggested that conditions in the last few years would not facilitate rapid recovery following any catastrophic disturbance. However, the degree of resilience is expected to improve as communities recover from the successive climatic disturbances in recent years.

Rock Wall Habitats

The existing rock walls around the port support abundant marine plant (algal) and invertebrate (primarily sponge and hydrozoan-dominated) communities. The best-developed hard coral communities occur on the more quiescent western breakwater, although cover and taxa richness was far lower than recorded on reef systems in Cleveland Bay. Rock wall habitats represent aggregation areas and habitat for a range of fish and shellfish species, and as such, can represent locally important fisheries habitats. Anecdotal observations of large numbers of boat-based recreational anglers adjacent to the western breakwater suggest that these areas support locally important fisheries habitats.

Soft Sediment Habitats and Macrobenthos Communities

Sonar-based mapping of benthic habitats showed that the areas surrounding the outer harbour Project area and the DMPA were comprised of five sediment classes: Class 2 = muddy sand with gravel; Class 3 = silty sand; Class 4 = silt with sand; Class 6= silt; and Class 7 = rocky substrates with sand and silt. Class 3 sediments occurred over much of the outer harbour Project area, particularly in higher energy environments adjacent to the eastern breakwater and the northern parts of the Strand. Class 2 sediments had a high proportion of (poorly sorted) muds, and occurred in slightly sheltered and/or deeper areas. Class 4 and 6 sediments were largely comprised of silt, and were found in the quiescent waters on the lee side of the western breakwater and in the deeper (dredged) areas of the harbour and turning basin. Class 7 habitats were rocky and/or gravelly substrates, and were typically found along the sides of dredged channels and basins. Sediments over the DMPA were primarily composed of muddy sand with gravel/rock fragments, with silty sediment classes (4 and 6) prevalent in deeper waters to the north-east of the DMPA. No substantial reef areas were found within the acoustic survey area.

Video-based surveys suggested that epibenthic communities had a sparse cover across the study area and surrounds. Epibenthic fauna community structure varied between offshore and nearshore environments. The DMPA and offshore control locations were dominated by small burrowing gobies and sea pens, whereas hydrozoans (stinging hydroids) were the most abundant taxon in the nearshore areas. Slight differences in communities were observed between the offshore control sites and DMPA, most notably lower alcyoniid soft coral abundance within the DMPA, but higher abundances of fouling species such as sea pens, ascidians and bryozoans, which were associated with isolated patches of gravel and rock fragments. These gravel and rock fragments, which are thought to be associated with dredge spoil, represent micro-habitats of higher biodiversity value.

Macrobenthos communities were sampled in the DMPA, outer harbour project area, existing channels and channel extension project area. These communities were found to be numerically dominated by polychaete worms, amphipods, decapod crustaceans and numerous other invertebrate taxa. Most taxa were recorded as singletons or had low overall abundance, and taxa richness and abundance were consistently low across the study area and surrounds. Like patterns in epifauna community structure, macrobenthos communities differed between nearshore and offshore areas. The dredged channel had an impoverished fauna, as were several sites within the outer harbour Project area. The macrobenthic communities within the DMPA and the channel extension project areas had similar characteristics to those located within adjacent control areas. Previous monitoring studies examining the impacts of disposal of maintaince dredged material suggest that macrobenthic communities within the DMPA are resilient to disturbance, and can rapidly recolonise shortly after dredging.

Threatened and Migratory Marine Species

Cleveland Bay provides important habitat for sea turtles, dugongs and nearshore dolphin species. Of the six turtle species recorded in Cleveland Bay, the green turtle is most abundant, accounting for approximately 90% of turtles within the Bay. Green turtle is a herbivore and has highest densities around seagrass meadows and reef areas containing macroalgae. Green turtle has also been recorded grazing on macroalgae along the rock walls within the Port. Key foraging habitats for other marine turtles in Cleveland Bay are not well known, most likely due to the low numbers of these species. It is expected that the marine turtles that occur within the outer harbour, channel and DMPA Project areas are transients rather than residents, primarily due to the lack of optimal or perennial feeding resources in this area. However, it is likely that the sparse seagrass and epifauna assemblages in the study area are used occasionally by most of the marine turtle species in the area.

Cleveland Bay does not represent a critical turtle nesting area and most turtles in the Bay are believed to have originated from rookeries elsewhere on the central and north Queensland coast and islands, or in other countries. The exceptions to this are flatback and green turtles, which nest in low densities on a number of sandy beaches adjacent to the study area, including Magnetic, Herald and Rattlesnake Islands, the Strand and AIMS beach. The Strand represents the closest turtle nesting site to the study area, but represents a poor quality habitat due to regular human disturbance (i.e. beach skimming, pedestrians, dogs, etc.).

Australian snubfin dolphins and Indo-Pacific humpback dolphins are nearshore, shallow-water habitat specialists. Both species are generalist, opportunistic species that feed primarily on fish, withAustralian snubfin dolphins also feeding on cephalopods. The area within and adjacent to Ross River and Ross Creek is a core area for both species. Both species have home ranges that extend well-beyond Cleveland Bay, and their abundance varies greatly over time.

Dugongs are principally herbivores and feed selectively on *Halodule uninervis* and *Halophila* spp., which are the dominant seagrass species in Cleveland Bay. Cleveland Bay is a regionally important habitat for this species. The key dugong feeding areas in Cleveland Bay are the dense nearshore meadows in eastern Cleveland Bay. The deep-water meadows adjacent to the outer harbour, channel and DMPA Project areas are not known to represent important feeding areas for dugong, possibly due to sparse nature of seagrass in these areas. However, it is likely that the abundant dugong population of Cleveland Bay will transit through these areas and occasionally forage on these sparse seagrass assemblages.

Fisheries

Fisheries are an important commercial, recreational, traditional and biologically diverse resource within the Townsville region. The Townsville region typically contributes approximately 11% to Queensland gross value of production. Some restrictions to commercial fishing activities within Cleveland Bay include a Dugong Protection Area (netting restrictions) and Cleveland Bay Fish Habitat Area (trawling restrictions).

The main commercial fisheries operating directly in Cleveland Bay are the Queensland Mud Crab, East Coast Otter Trawl, Queensland Blue Swimmer Crab, Queensland East Coast Spanish Mackerel and Queensland East Coast Inshore Fin Fish fisheries. The Queensland Spanner Crab Fishery includes waters adjacent to Cleveland Bay.

Based on analysis of catch data, Cleveland Bay is not considered to represent a key production area for mud, spanner, and blue swimmer crabs, but produces regionally important catches for the East Coast Otter Trawl and East Coast Spanish Mackerel fisheries, and has a locally important net fishery (focusing on barramundi, but also threadfin salmon and grey mackerel). Cleveland Bay and surrounds are not known to represent regionally important areas for the aquarium fish or sea cucumber fisheries.

Cleveland Bay supports significant recreational fisheries, and a number of inshore, reef and pelagic species are targeted. Most line-based recreational fishing tends to occur around artificial structures such as navigation structures and breakwaters, as well as reef environments around Middle Reef and Magnetic Island. Some crabbing occurs within coastal creeks throughout the bay. The value of recreational fishing is likely to be considerably more than the commercial fishing industry. There is little information about the amount of indigenous fishing conducted, however, it is likely to be limited compared to the general recreational and commercial sectors.

Introduced Species

A port wide baseline survey of non-indigenous was undertaken James Cook University and the CRC Reef in November 2000 (Neil et al. 2001). This aim of this baseline survey was to describe existing marine communities in the Port, and identify any non-indigenous species, including target pest species listed by the Australian Ballast Water Management Committee, Hewitt and Martin (1996) and Furlani (1996). The baseline survey recorded over 1300 organisms, however no targeted marine pest species were recorded (Neil et al. 2001). A range of species that resemble non-indigenous species were recorded in the baseline survey, however none of these potential non-indigenous species are considered to represent a serious pest in Australian waters (Townsville Port Authority and CRC Reef 2002).

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1 INTRODUCTION

1.1 Background

This report describes the existing marine flora, fauna and biodiversity values of waters within and immediately adjacent to the areas potentially affected by dredging, dredged material disposal and reclamation activities. The key ecological functional groups considered in this report are:

- mangroves and saltmarsh
- seagrass and algal communities
- soft-sediment benthic habitats and fauna communities
- reef and breakwater communities
- introduced marine fauna
- sea turtles
- whales and cetaceans
- dugong
- fisheries species and productivity.

This Draft Final report summarises existing information regarding the environmental values of the study area and surrounds, primarily focusing on marine habitats and communities, threatened species and fisheries resource values. The report also describes the methodology and findings of field investigations undertaken by BMT WBM to support the EIS report.

1.2 Nomenclature and Terminology

For the purpose of this report the following terminology has been adopted:

- The term *study area* refers to all waters within Cleveland Bay. The study area includes the following Project areas (Figure 1-1):
  - *outer harbour Project area* – refers to the proposed construction footprint and immediate surrounds and includes two components: the outer harbour basin and the reclamation area;
  - *offshore dredged material placement area* (DMPA), refers to the existing offshore disposal site or spoil ground;
  - *dredged channel* refers to the existing Platypus and Sea Channels that will be subject to capital dredging as part of this Project;
  - *channel extension project area* refers to seaward extension to the Sea Channel that will be created through capital dredging as part of this Project.
- The surrounding area refers to the intertidal lands and waters of Cleveland Bay, including the foreshore of the mainland and Magnetic Island, as shown in Figure 1-1.

Title:

Location of the Study Area and Surrounding Area

Figure: **1-1**

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Within this report, the conservation status of a species may be described as Critically Endangered, Endangered, Vulnerable, Near Threatened, Least Concern or Conservation Dependent. These terms are used in accordance with the provisions of the Queensland *Nature Conservation Act 1992* (NC Act) and its regulations and amendments, and/or the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). For the purposes of this report, relevant NC Act regulations and amendments refer to the *Nature Conservation (Wildlife) Regulation 2006* reprinted as in force on 21 May 2010. Threatened is a common term used to collectively describe endangered and vulnerable species. Species may also be described as listed Marine or Migratory, as defined under the EPBC Act.

The term epibenthic fauna is used here to refer to animals observed on the surface of the sea floor with video methods, while infauna is used to describe animals living within sediments and were collected in the present study using benthic grabs. The nomenclature used in this report follows Queensland Herbarium census of Queensland plants for plants, Van Dyck and Strahan (2008) for mammals, Cogger (2000) for reptiles and the CAAB database (http://www.marine.csiro.au/caab/) for fish.

2 STUDY METHODOLOGY

2.1 General

Flora and fauna species, communities and habitats within the study area and surrounds were defined through searches of relevant databases, a review of previous studies, and where there was inadequate existing information, through supplementary field investigations. Searches were undertaken of the EPBC Protected Matters Search Tool (31 March 2011 – see Appendix D) and Department of Environment and Heritage Protection Wildlife Online database (7 June 2012 – see Appendix E). References cited in this report are presented in Section 4.

Information gaps were identified in the initial stages of the impact assessment process, and supplementary surveys were undertaken by BMT WBM to fill these gaps. The following describes the sampling and analysis methods used in the present study to describe

- Breakwater habitats;
- Reef habitats and communities;
- Soft sediment habitat types and epifauna communities; and
- Benthic macroinvertebrate communities (infauna).

The timing of surveys is summarised in

Table 2-1. One-off surveys were undertaken, noting that there is already a considerable body of existing information that these studies were intended to build on. Note also that GHD (2011b) also undertook sampling of benthic communities throughout the study and surrounds over the course of this assessment (November 2010 and March 2011), which provide an assessment of short-term temporal changes in these communities.

Table 2-1 Survey episode timing

Component	Locations	Survey dates
Breakwater habitats	• Outer harbour project area	Nov 2010
Reef habitats and community assessments	• Magentic Island and Middle Reef	Mar 2012
Soft sediment habitat types (acoustic and sediment sampling)	• Outer harbour project area	Nov 2010
	• Offshore dredged material placement area (DMPA)	Nov 2010
	• Dredged channel	Nov 2011
	• Channel extension project area	Nov 2011
Epifauna (video and beam trawl) and infauna (grab sampling) assessments	• Outer harbour project area	Nov 2010
	• Offshore dredged material placement area (DMPA)	Nov 2010
	• Dredged channel	Nov 2010
	• Channel extension project area and surrounds	Nov 2011

2.2 Breakwater Habitat Assessment

Three locations were sampled on the eastern breakwater and two locations on the western breakwater (Figure 2-1). At each location, transects ran parallel to the wall for 30 m within two depth strata: (i) the upper subtidal zone; and (ii) at the toe of the wall. Visibility was poor during the surveys 0.1 to 0.3 m. Surveys were undertaken in November 2010.

Two transects on the southern and mid- sections of eastern breakwater were done in low (<10cm) visibility conditions, which prevented the use of a camera. Surfaces of the rocks were visually inspected by a diver for these transects. All other transects were recorded with a high definition video camera by a diver on snorkel. This footage was reviewed and corals were identified to genus level according to nomenclature of Veron (1986). Relative abundance of key taxa was enumerated on each video transect based on methods in Harriott *et al*. (1994).

2.3 Reef Community Assessment

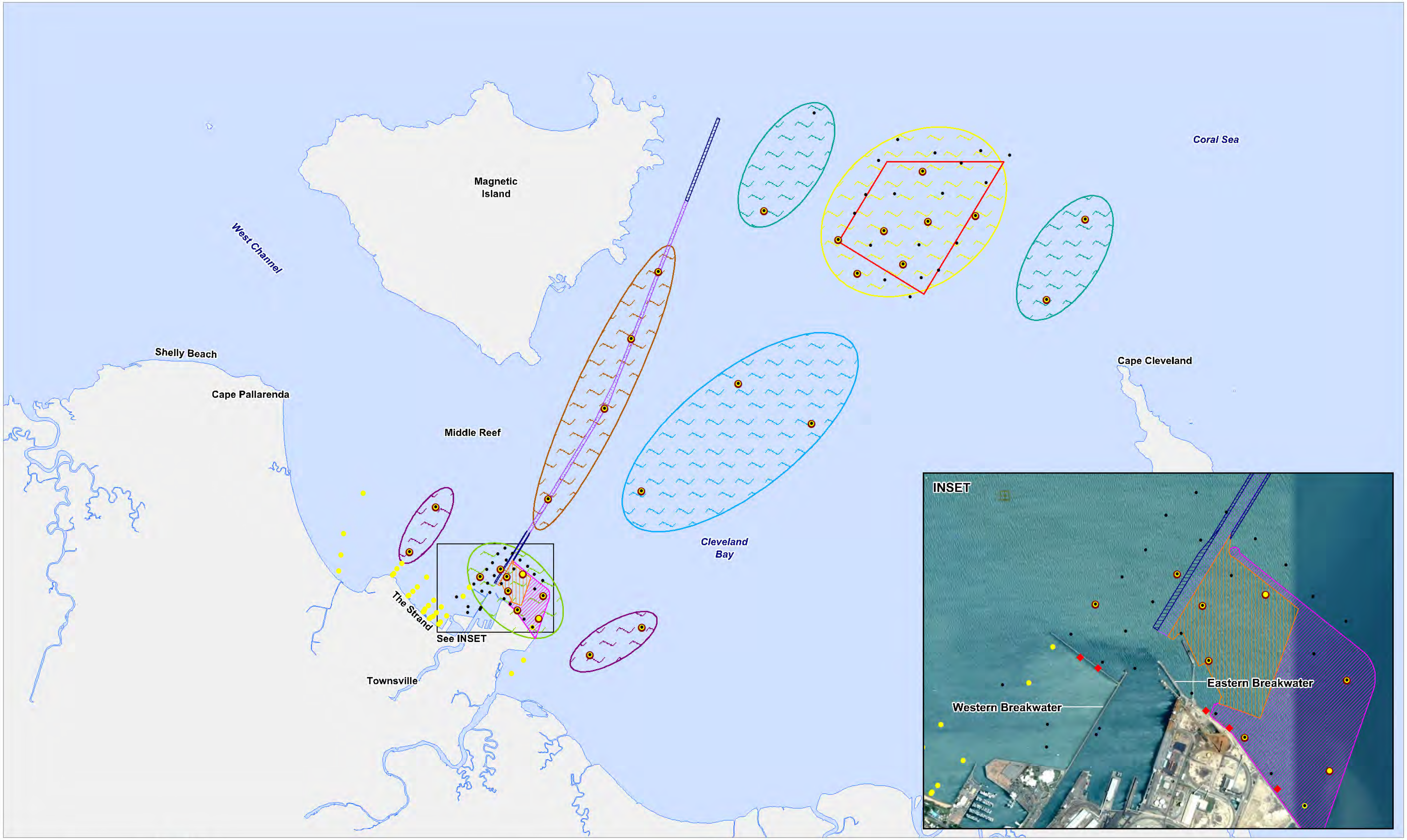
Reef communities at Magnetic Island and Middle Reef were surveyed from 14-18th March 2012 (inclusive) and consisted of snorkel transects across the reef flat as well as photo transects in reef slope and reef crest habitats (Figure 2-3).

Snorkel transects across the reef flat were conducted using a hand-held GPS in order to map major clines in reef flat communities. Three replicate photo transects (30 m in length) were performed by scuba divers at both reef slope and reef crest areas in each location because these zones often have the highest living coral cover. At some sites around Magnetic Island, such as Five Bay Beach and Middle Reef, geomorphic zones were less pronounced and more typical of low wave energy inshore environments. In these areas transects were conducted in equivalent depths; 1-2 m and 3-5 m LAT for “crest” and “slope” areas respectively (Figure 2-3).

Photo transects were conducted using wide-angle, high-definition cameras taking stills every two seconds. Coral Point Count (CPCe 4.1) was used to process imagery from a selection of 30 photos from each transect. Photos were selected from a list, spaced evenly from the transect’s start to finish, to ensure selection was impartial, that representation within the transect was even, and not overlapping (avoiding pseudoreplication). Each photo covered approximately 1 m^2 so that each transect provided a 30m^2 belt transect.

Using CPCe 4.1, a 300 pixel setback was used to ensure point identifications were made in the brightest, clearest part of the photo, and also to reduce the chances of non-independence between partially overlapping photos. Twenty points were identified from each photo, giving 600 point IDs per transect. Hence; estimates of cover for each site and within each depth stratum consisted of 90 photos, and 1800 point IDs.

All of the sites were characterised by having large amounts of macroalgae and occasionally cyanobacteria which occasionally hindered identification of under-storey taxa. Macroalgae, detritus and silt often formed a mixed community, in which case the numerically dominant form of algae was identified.



LEGEND

- DMPA
- New channel areas to be dredged
- Existing channel to be deepened
- Harbour basin
- Reclamation area
- Video Sites
- PSD Sites
- Infauna Sites
- Diver Transects

Locations

- Construction Footprint
- Nearshore Control
- Channel
- Midshore Control
- Offshore Control
- Spoil Ground (DMPA)

Title:

Locations of video transects, diver surveys, infauna and PSD sampling within and adjacent to the outer harbour, dredged channel and DMPA (2010)

Figure: **2-1**

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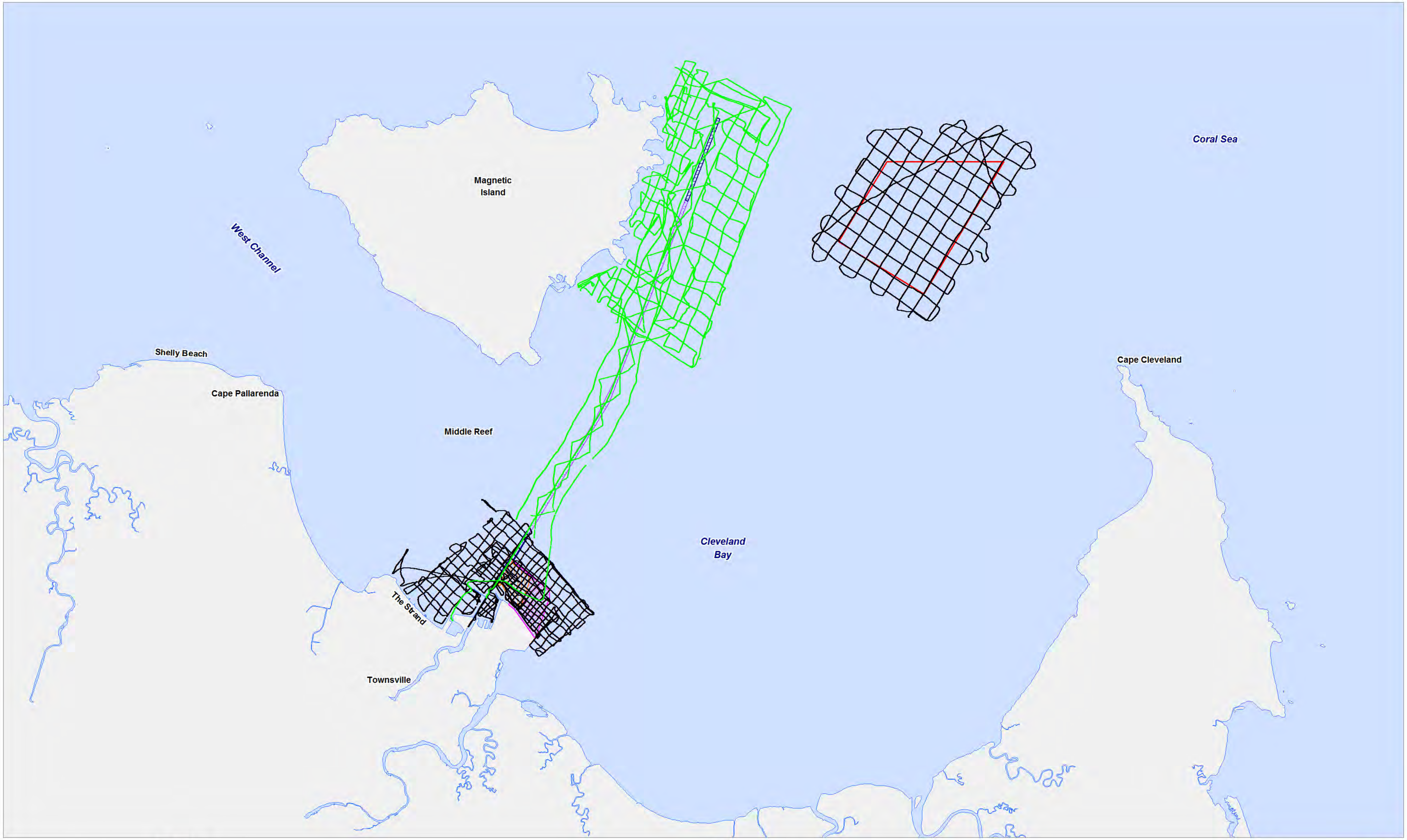

LEGEND

- DMPA
- New channel areas to be dredged
- Existing channel to be deepened
- Harbour basin
- Reclamation area
- 2010 Acoustic Survey Sites
- 2011 Acoustic Survey Sites

Title:
Acoustic Survey Lines

Figure: 2-2

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Title:

Locations of snorkel and photo transects surrounding eastern Magnetic Island and Middle Reef

Figure: 2-3

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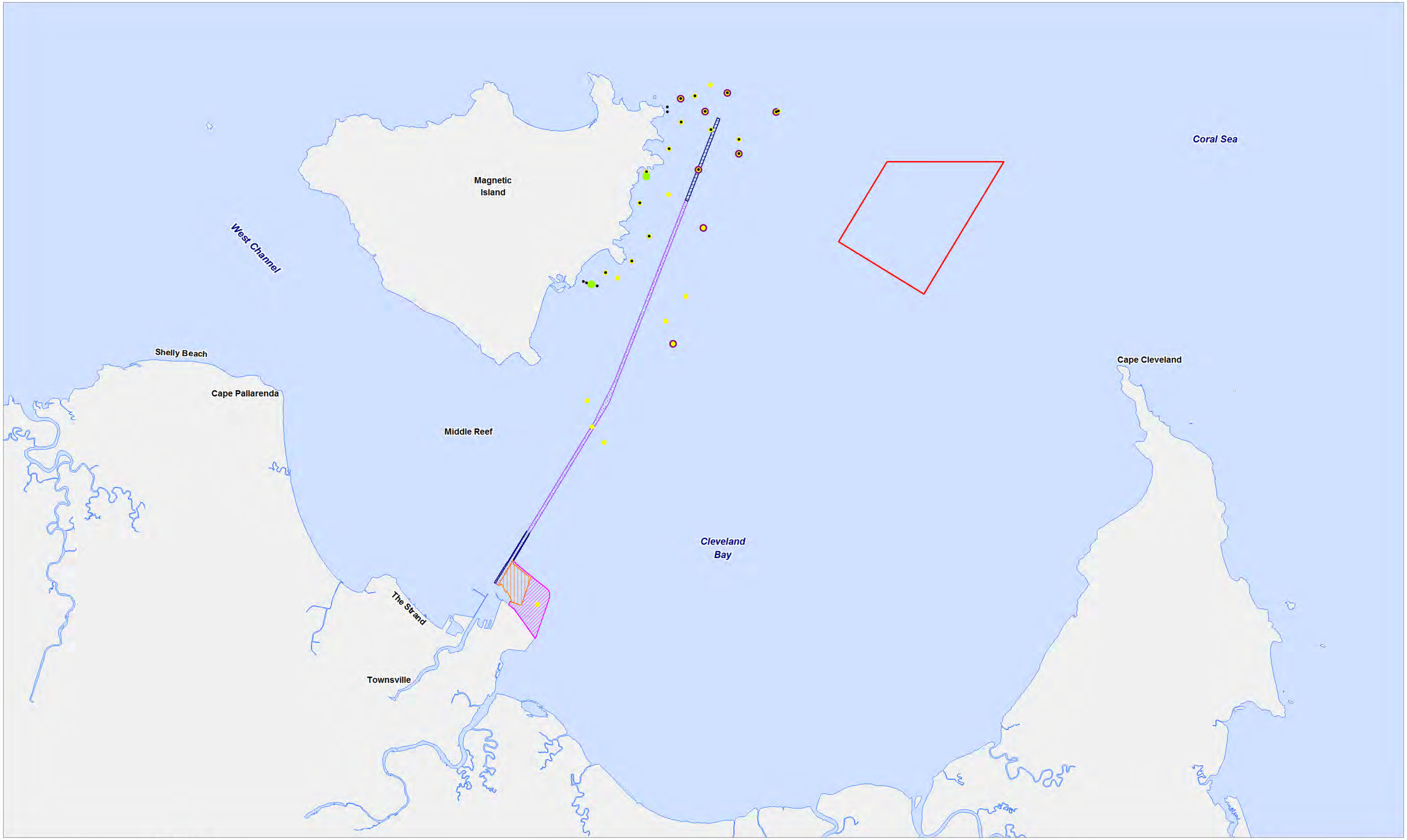

LEGEND

- DMPA
- New channel areas to be dredged
- Existing channel to be deepened
- Harbour basin
- Reclamation area
- Video Sites
- PSD Sites
- Infauna Sites - Inshore Magnetic Island
- Infauna Sites - Channel Extension Project Area and Surrounds

Title:

Locations of video transects, infauna and PSD sampling (2012)

Figure: **2-4**

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There were also difficulties in distinguishing between *Favia* and *Montastrea* without detailed imagery of corallites for every colony present. Coral cover estimates for these two taxa should therefore be interpreted with caution.

The identity (genus) and number of bleached colonies was also counted, as were colonies of less-common genera that occurred within a given photo, but over which, points did not occur.

2.4 Benthic Habitat Mapping

2.4.1 Acoustic Survey Methods

The following areas were surveyed using acoustic methods:

1. Outer harbour project area and surrounds (November 2010);
2. DMPA and surrounds (November 2010);
3. Existing dredged channel and surrounds (November 2011); and
4. Channel extension project area and surrounds (November 2011).

Grid work for the November sampling episode was completed over a period of four days between the 3rd and 6th of November 2010, inclusive. During the survey wind speeds rarely exceeding 10 knots, and seas were less than 1 m. Vessel speed while conducting acoustic surveys was maintained at approximately 5.5 knots (11 km/h).

The November 2011 acoustic sampling episode was completed over a period of 5 days between the 16th and 20th, inclusive. During the survey wind speeds rarely exceeded 15 knots, and seas were less than 1 m. Vessel speed varied between 4 and 5.5 knots (7.4-11 km/h).

Survey lines were spaced at the following intervals (Figure 2-2):

- 500 m over the DMPA and immediate surrounds;
- 300 m over the outer harbour Project area;
- 150 m over the construction footprint within the outer harbour Project area.
- 250 m in the vicinity of Magnetic Island, and;
- at 500 m intervals over the channel extension project area and existing channel.

The acoustic mapping survey was conducted from the single hull survey vessel Echo. For the study, the vessel was equipped with a Trimble Pro XRS differentially corrected GPS. The differential correction of the positioning data was conducted in real-time using the Australian Maritime Safety Authority (AMSA) radio beacon at Ingham to provide sub-metre accuracy. The dGPS antenna was affixed to the top of the acoustic sounding pole to maintain the integrity of all collected survey data.

To minimise the potential for aeration of the transducer resulting from propeller induced turbulence, the sounding pole was positioned 1 m wide of the port outboard engine along the duckboard of the vessel, with the transducer in front of the propeller at a depth of 1.0 m below the waterline. The pole was attached to a permanent transducer bracket specifically designed for survey work on *Echo.* This arrangement facilitated removal of the transducer from the water when the vessel was transiting to and from the survey areas, and a firm attachment point, free of turbulence for the transducer head.

Acoustic sounding and seabed classification was achieved using a single beam dual frequency (50 and 200 kHz) Hondex Model 7300 echo sounder (Figure 2-4A) with sonar beam widths of 28° and 10°, respectively. The echo sounder was interfaced to the Quester Tangent Corporation (QTC) View Series 5 (Version R2.10) system which consists of hydrographic survey hardware and software components (Figure 2-4) tailored to acoustic seabed discrimination based upon the shape of acoustic sonar returns from the seabed. The system records the characteristics of the reflected acoustic waveforms to generate habitat classifications, based upon the diversity of scattering and penetration of the acoustic signal from varying types of seabed. The process involves collection of acoustic data which are time stamped and geo-referenced using dGPS. The raw acoustic data were stored in real-time on a Toshiba Satellite Model U200 laptop computer running the QTC View Series 5 software.

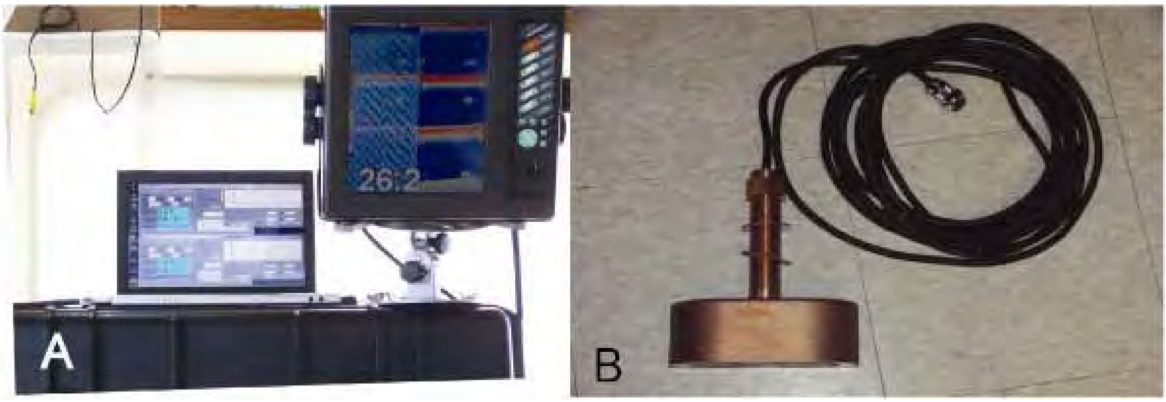

Figure 2-4 Laptop and echo sounder (A); and the transducer head (B).

2.4.2 Acoustic Data Analysis and Mapping

Acoustic data for the 200 kHz and 50 kHz frequencies were analysed and processed. An examination of preliminary results indicated that there was strong agreement in seabed classification patterns produced by the two frequencies, despite the variation in penetration and swath range between the two frequencies. For example, whilst the 200 kHz frequency effectively has no (or very low) penetrative capability, the 50 kHz frequency penetrates up to 10 cm in sandy seabeds and therefore also incorporates factors such as sediment compaction. The penetration of the 50 kHz frequency can also fail to detect epibenthic biota such as fine macroalgae.

Previous studies comparing the results of the two frequencies with the results of video ground-truthing surveys found that the 200 kHz acoustic frequency provided the most reliable and consistent output (BMT WBM 2008). This approach has been utilised previously by Reigl and Purkis (2005), who also found a 200 kHz frequency to provide greater resolution and detail for mapping habitats when compared to the results from a 50 kHz frequency, when using the same QTC View dual frequency methodology.

The QTC suite of programs was used to process acoustic data (Locker and Wright 2003; Riegl and Purkis 2005; Preston *et al*. 2006). Raw data files were post-processed using the QTC IMPACT software package and all data were checked for correct time stamps, correct depths and correct signal strengths. Acoustic records from the outer harbour Project area and the DMPA were combined for the backscatter analysis using the QTC Impact seabed classification software. This allowed comparison of sediments (and eventually habitat classes) between the two areas. In the QTC IMPACT software (version R3.40) the acoustic echoes were digitised and normalised to a range between 0 and 1, before being subjected to further analysis. These data were then reduced by generating Full Feature Vectors, referred to hereafter as acoustic records. Acoustic records were displayed on a bathymetry plot where the recorded depth was checked against the blanking (minimum recordable) depth and the maximum depths expected for the survey areas, based upon existing bathymetric information.

QTC IMPACT was used to classify acoustic signals (echograms) that returned from the seabed into statistically different acoustic classes. All acoustic records were subjected to Principal Components Analysis (PCA) to eliminate redundancies and noise. The first three principal components of each echo (called Q values) were retained, according to the theory that these typically describe 95% of the information within each echo. Data points were then projected into pseudo three dimensional space along these three components, where they were then subjected to cluster analysis to determine echoes of similar signature. In clustering, the user determines the desirable number of clusters (seabed classes) and also chooses which clusters to split and how often. Clustering decisions are guided by three statistics offered by the software package.

For each individual signal, the following data were exported from QTC IMPACT: latitude and longitude; depth (uncorrected for tidal or wave states); three PCA axes (called Q axes); a class category; a class assignment confidence value and a class probability value, which both range from 0 to 100%. These indices may be useful for further determining the overall 'quality' of individual data points and classes. Records with confidence less than 95% were removed from the analysis. For the purposes of data presentation and interpolation, each dataset has been reduced to a three column matrix consisting of a single x, y and geo-referenced seabed class category z.

A natural neighbour interpolation with median values was used to create benthic habitat maps of the Project area using Vertical Mapper v3.1 through the MapInfo 10.0 platform. Median values were used instead of means because habitat classes were categorical and not necessarily ordinal. That is, class 2 and 4 habitats were often adjacent to one another without class 3 habitats existing between them. The parameters used in this procedure included selecting the advanced setting and the maximum aggregation value.

2.4.3 Assessment of Sediments and Epifauna, and Validation of Acoustic Data

The acoustic-derived habitat categories do not, in isolation, provide information on the nature of the actual seabed conditions. The final classification of benthic habitat types was undertaken by ground-truthing and validating acoustic habitat classes using video analysis and particle size distribution (PSD) analysis.

Indirect methods were used to classify benthic habitats developed by acoustic categories. This involved the following process:

- generation of acoustic habitat classifications on each transect line using Vertical Mapper;
- undertaking video analysis at representative sites located on acoustic transect lines; and
- using geographic information systems (GIS) to overlay acoustic classes and video transects to check for correspondence or otherwise.

Video Analysis

Selected seabed habitat communities were assessed using an underwater video camera during the 1st and 4th of November 2010 and on March 3rd 2011. Video ground-truthing surveys were used to characterise each acoustic habitat class and validate the results of the acoustic classification and mapping, as well as describe epibenthic fauna communities. The sites selected for video transects encompassed the range of habitats previously identified by the acoustic methods to be separate classes. The locations of these sites are shown in Figure 2-1 (2010) and Figure 2-4 (2011).

At each transect, an underwater camera system was deployed by the passively drifting vessel for 4 minutes. Video footage was observed on a computer monitor in real-time and recorded to hard drive. A van Veen grab was used to sample the seabed at selected sites to confirm sediment type and collect and identify any seagrass.

Once collected, the video file for each transect was reviewed, noting the following features:

- Substrate type (e.g. soft sediment, consolidated reef).
- Approximate sediment grain size (e.g. silt, sand, rubble).
- The presence, general composition and abundance (i.e. dominant groups) of visually obvious biota, including epibenthic fauna (e.g. corals, sponges, ascidians etc.), epibenthic macroalgae and seagrass.
- Other relevant features influencing seabed habitats (e.g. topography, evidence of trawling activity).

Video transects were recorded at 25 sites at the DMPA, at four offshore control sites, three midshore control sites, four nearshore controls sites, four channel sites, and at 33 sites within the construction footprint of the outer harbour in 2010. The locations of these sites are shown in Figure 2-1. A further 21 sites were sampled within and adjacent to the channel extension project area in 2011 (Figure 2-4). The direction and distance of travel from these intersection points varied according to the wind and current conditions at the time, in order to provide approximately four minutes or at least 100m of useable transect footage.

Particle Size Distribution (PSD) Analysis

PSD samples were taken at sites shown in Figure 2-1 and Figure 2-4. At each site a 0.028 m^2 van Veen Grab was used to collect a sample of surface sediment. These samples were sent to Trilab Pty Ltd for PSD analysis to 0.075 mm using standard Australian Sieve sizes. Particle size distributions were quantified and graphed in order to describe sediment classes based on acoustic data, and to describe differences in sediment type in different parts of the study area and surrounds (e.g. channel, nearshore controls etc.).

2.5 Soft Sediment Benthic Macroinvertebrate Community Assessment

A total of 38 sites were sampled for benthic macroinvertebrate (infauna) communities (Figure 2-1; Table 2-2). At each site, a 0.028 m^2 van Veen Grab was used to collect four replicate sediment samples, which was sieved through a 1 mm screen. Material retained in the sieve was placed in bags, and stored in 35 litre storage drums containg a 10% formalin solution. Samples were provided to James Cook University for processing.

In the laboratory, samples were washed through a 250 µm sieve (to prevent loss of fauna) to remove formalin. Samples were then placed on sorting trays and examined under a stereo-microscope. All animals were removed and placed into labelled vials filled with 70%. Animals were identified and enumerated for each sample. Identifications followed Wilson and Gillett (1979), Lamprell and Whitehead (1992), Jones and Morgan (1994), Jansen (1996), Beesley *et al*. (2000), and Crustaean.net (2009).

Table 2-2 Benthic macroinvertebrate community assessments - sampling sites and timing

Location	Number of sites	Timing
Nearshore Control	4	Nov 2010
Harbour project area (Nearshore Construction)	7	Nov 2010
Midshore Control	3	Nov 2010
Dredged Channel (existing Sea and Platypus Channels)	3	Nov 2010
Offshore Control	3	Nov 2010
DMPA Project area (Spoil Ground)	7	Nov 2010
Inshore Magentic Island	2	Nov 2011
Channel extension project area	9	Nov 2011

2.6 Statistical Analyses

Community differences in epibenthic fauna and infauna among sites were examined with multivariate techniques using PRIMER 6.1.6. Multivariate analyses were used to investigate community differences using abundance data for epibenthic fauna and infauna communities. These methods describe patterns of similarity and variability in the benthic communities (full community data) among sites or transects.

Raw data were initially transformed (Log_x+1) to minimise the effects of highly abundant taxa on results. Singleton taxa (those recorded only once) were also removed from these analyses to minimise the effects of uncommon taxa on results. These procedures were in accordance with Clarke and Warwick (2001).

A resemblance matrix was generated from the transformed data using the Bray-Curtis measure of similarity. The resulting resemblance matrix was used to generate non-metric multi-dimensional scaling (nMDS) ordinations (graphs) of community structure, which provide visual representations of the similarity among samples (i.e. the closer together two samples are in the ordination, the more similar their communities are). Differences among sites and site groupings were analysed using SIMPER routines (Similarity Percentages) to determine the taxa contributing most to differences among sites. For more detail regarding these analyses, see Clarke and Warwick (2001).

3 EXISTING ENVIRONMENT

3.1 Mangroves and Saltmarsh Communities

Mangroves and saltmarshes represent benthic primary producer habitats[1]. Mangrove and saltmarsh communities have a potentially high conservation value as they provide food and shelter resources for a range of invertebrates, birds and fish (e.g. Robertson and Duke 1997). Many of the fish species inhabiting mangals (mangrove forests) and saltmarshes are of direct recreational and commercial fisheries value. Mangroves and saltmarshes are also highly productive (e.g. Hutchings and Saenger 1987), and are important in the stabilisation of the beds and banks of estuaries (Carlton 1974). In accordance with these potential values, mangroves and saltmarshes are protected plants under the *Fisheries Act 1994* and a permit is required for their disturbance/ removal.

The distribution and community structure of mangroves and saltmarsh plants is controlled by four primary environmental factors: salinity, tidal range, degree of wave and current action, and the physical nature of the substrate (King 1981; Odum *et al*. 1985). Saltmarsh and mangroves grow in the intertidal zone, typically within quiescent (calm) environments. The construction footprint does not contain intertidal banks so saltmarsh species do not occur here.

Mangrove forest is mapped as RE 11.1.4 mangrove forest/woodland on marine clay plains and saltmarsh communities are a mosaic of RE 11.1.1 *Sporobolus virginicus* grassland on marine clay plains and RE 11.1.2 samphire forbland on marine clay plains (Figure 3-1). These REs are listed as least concern remnant vegetation under the *Vegetation Management Act 1999* (VM Act). DERM (2011) Regional Ecosystem (RE) mapping shows that large areas of mangrove and saltmarsh communities occur to the south of the Outer Harbour Project area along Ross Creek, Ross River, and the eastern shoreline of Cleveland Bay. A small patch occurs adjacent to the Esplanade. These vegetation communities are located outside the direct area of influence of the Project.

[1] Seagrass, mangroves, saltmarsh, benthic algae, together with corals, represent benthic primary producer habitat (BPPH). BPPH play an important role in maintaining coastal ecosystems and associated ecological services, including the provision of food and habitat resources for species of fisheries and conservation significance.

LEGEND

- DMPA
- New channel areas to be dredged
- Existing channel to be deepened
- Harbour basin
- Reclamation area
- Mangroves
- Saltmarsh

Title:

Mangrove and Saltmarsh Vegetation in Cleveland Bay (Source: DERM 2011)

Figure: **3-1**

Rev: **A**

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0km 3 6

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : I:\B17733_I_CMJ_POTL GWF\DRG\ECO_007_110321 Mangroves Saltmarsh.wor

3.2 Seagrass Communities

General

Seagrasses are benthic primary producer habitats that provide a range of functions in the maintenance of coastal/estuarine ecosystem, including provision of food resources for dugong, green turtles and certain invertebrate species; provision of habitat for adult and juvenile stages of many fish and invertebrate species of fisheries significance; and assisting in the stabilization of sediments and sediment nutrient cycling (Larkum *et al*. 1989). Because of these ecological values, seagrass and other marine plants are protected under the *Fisheries Act 1994* and a permit is required for their disturbance and/or removal.

A range of studies have investigated the seagrass communities of Cleveland Bay. To date, eight species of seagrass have been recorded in Cleveland Bay (Rasheed and Taylor 2008), namely *Zostera muelleri*, *Halodule uninervis*, S*yringodium isoetifolium*, *Cymodocea serrulata, Halophila spinulosa*, *Halophila ovalis*, *Halophila decipiens* and *Thalassia hemprichii*. This compares with the 15 species known to occur on the Great Barrier Reef World Heritage Area (GBRWHA) (UNESCO undated). Recent estimates suggest that seagrass beds cover approximately 13% of the GBRWHA (Chin 2005). This consists of approximately 6,000 km^2 of shallow (less than 10 m deep) meadows and 40,000 km^2 of deep-water meadows (10 to 60 m depth).

Cleveland Bay contains some of the most extensive and diverse seagrass meadows in north Queensland. Seagrass meadows in Cleveland Bay have high ecological significance in the context of providing habitat for a range of species of fisheries significance, and the provision of food resources for the threatened dugong and green turtle.

Spatial Patterns

Numerous studies have investigated the seagrass communities of Cleveland Bay. The Queensland Department of Agriculture, Fisheries and Forestry (DAFF, formerly DEEDI) has undertaken routine seagrass meadow surveys since 2007, which included sites located within Cleveland Bay (Rasheed and Taylor 2008; Taylor and Rasheed 2009; Unsworth *et al.* 2009; McKenna and Rasheed 2012).

Three broad meadow types occur in Cleveland Bay:

- Mainland coastal meadows;
- Shallow water meadows around Magnetic Island;
- Deep-water offshore meadows.

Meadows tend to be denser and more structurally complex in the intertidal and shallow subtidal areas than those in deeper offshore waters (Rasheed and Taylor 2008). Shallow waters favour the growth of larger growing species such as *Zostera muelleri*, *Cymodocea serrulata* and *Halodule uninervis* (wide leaf form), and is a consistent pattern of most seagrass areas in north Queensland (Lee Long *et al*. 1993). The most well developed shallow water meadows are located between the mainland (the Strand, Rowes Bay and Pallarenda) and south-western embayments of Magnetic Island (Cockle Bay, Picnic Bay), and adjacent to Cape Cleveland in the vicinity of Alligator Creek and Crocodile Creek (Rasheed and Taylor 2008)(Figure 3-4).

Cleveland Bay has also historically contained extensive deep-water seagrass beds (Rasheed and Taylor 2008). These deep-water meadows are typically patchy (non-contiguous, fragmented beds) with a sparse cover, and low species richness. Sparse deep-water seagrass assemblages have occurred offshore of the nearshore Project area, including areas in the vicinity of the offshore dredged material disposal area (DMPA). However, deep-water seagrass was not recorded by BMT WBM in 2011, or in DAFF surveys carried in 2009-2011 (McKenna and Rasheed 2012)(Figure 3-4). No seagrass has been recorded within POT inner or outer harbour areas, although shallow water and intertidal seagrass beds occur nearby (e.g. near the Ross River mouth and Townsville waterfront).

Temporal Patterns and Drivers

Long term temporal trends in the broader GBRWHA (1980s to present) suggests that seagrass meadows show great variability over a range of temporal scales, and varying across regions (Queensland Seagrass Watch News, February 2003 cited in Chin 2005). At local scales, Pringle (1989) reviewed historical aerial photography to determine long-term (decadal scale) changes in nearshore seagrass meadows within Cleveland Bay[2]. Although seagrass extent was not quantified, the overall sequence of change was as follows:

- 1959-61 - Moderate cover. Several cyclones affected the region leading up to this period.
- 1973-1974 – Seagrass largely absent. It is uncertain when this seagrass disappeared. It is notable that 1973-74 had successive years of above average annual rainfall (Figure 3-3). Furthermore, Townsville was affected by several cyclones leading up to this period: Cyclone Althea in 1971, Bronwyn in 1972, and Cyclones Madge and Una in 1973. Pringle (1973) also noted that large scale dredging was carried out by the Port in 1972-75, peaking in 1973-4 at 2,112,879 tonnes/annum.
- 1978, 1981, 1985 – Steady increase in seagrass cover, with signs of recovery evident in 1978 photographs. By 1981 and 1985, shallow water seagrass meadows were similar in extent to the early 1960's. Figure 3-3 shows that this period generally experienced below average rainfall (except 1981), and therefore represented a period of long term stability and recovery.

Additional assessments by Goldsworthy (1994) indicated that seagrass meadow extent continued to increase between 1985 and 1991. Subsequent assessments of intertidal seagrass meadow extent were undertaken by Goldsworthy (1994) to monitor the potential impact of the 1993 capital dredging program on shallow water (mainly intertidal) seagrass meadows. This monitoring program found that nearshore seagrass meadow extent remained relatively static before and after the dredging program, the exception being minor increases in seagrass within the upper intertidal zone following dredging. However, no assessments were carried out to assess impacts on any deep water seagrass meadows present in Cleveland Bay (if present at that time).

In recent times, several programs monitor changes in seagrass community structure, distribution and/or extent within and adjacent to Cleveland Bay, including:

- Monitoring of the percentage cover of seagrass at sites throughout the Townsville region, carried out by Seagrass Watch as part of the Reef Rescue Marine Monitoring Program. Sites have

[2] It is noted that this assessment did not involve ground-truthing, and that low growing species such as *Halodule* and *Halophila* are unlikely to have been detected

been monitored during winter and summer between 2000 and 2011. Refer to Figure 3-2 for percentage cover estimates for representative sites (Johnson *et al*. 2011).

- Seagrass mapping in Cleveland Bay carried out by DAFF (then DEEDI). Sampling has been undertaken annually during the month of October between 2007 and 2011 (Rasheed and Taylor 2008; Unsworth *et al.* 2009; McKenna and Rasheed 2012).

The results of these monitoring studies indicate that the distribution, extent and density of seagrass assemblages within Cleveland Bay can show great variation over a range of temporal scales (particularly seasonally and inter-annually) in response to variations in a range of environmental factors (Rasheed and Taylor 2008; McKenna and Rasheed 2012). In particular, it is thought that high suspended sediment concentrations resulting from wave driven bed sediment remobilisation (together with runoff) are key drivers of temporal change in seagrass meadows.

At seasonal scales, there is typically a seasonal growth cycle in intertidal and shallow subtidal seagrass meadows (Waycott *et al*. 2005), with higher percentage cover of seagrass in late spring-summer than winter (McKenzie *et al*. 2012; Johnson *et al*. 2011). This is the typical seasonal pattern of seagrass meadows in nearshore waters of the Great Barrier Reef region (Waycott *et al*. 2005; Unsworth *et al*. 2009), with higher water temperatures during summer periods promoting seagrass growth rates (e.g. Collier and Waycott 2010).

Superimposed on these general seasonal growth patterns are longer term (inter-annual) cyclic changes in seagrass meadows due to climate-driven disturbance and subsequent periods of recovery. Large inter-annual changes in seagrass meadow extent and community structure resulting from disturbance have been documented in the POTL annual seagrass monitoring program (Rasheed and Taylor 2008; Taylor and Rasheed 2009; McKenna and Rasheed 2012). In particular, a major reduction in seagrass above-ground biomass and extent (at the deepest boundaries of the meadows) was recorded in Cleveland Bay between 2007 and 2011. Accompanying these overall declines was a change in species composition and community structure, with higher relative cover of primary colonist species (*Halodule uninervis* and *Halophila*), and a reduction in the canopy height of *Zostera muelleri*.

The DAFF/DEEDI seagrass studies (Rasheed and Taylor 2008) documented a major reduction in combined mean above-ground biomass of seagrasses and seagrass extent (at the deepest boundaries of the meadows) between 2007 and October 2009 (Unsworth *et al*. 2009). Accompanying these overall declines was a change in species composition and community structure with increases to the percent composition of colonising *Halodule uninervis* and *Halophila* species, and reduction in the canopy height of *Zostera muelleri*. Similar declines in seagrass cover were recorded by Seagrass Watch at Cape Pallarenda and Magnetic Island over the measurement period (Figure 3-2). Johnson *et al*. (2011) found that there was declining trends in seagrass cover at the mainland sites (i.e. Cape Pallarenda) since 2005 whereas those around Magnetic Island only began to decline in 2008.

Overall, the long-term changes in seagrass are also thought to be attributable to natural cycles of decline in and recovery. Climate change could also impact on seagrasses decreasing growth and reproductive rates, increasing competition from algae, increasing susceptibility to disease and causing burning (due to elevated water temperatures)(Chin 2005).

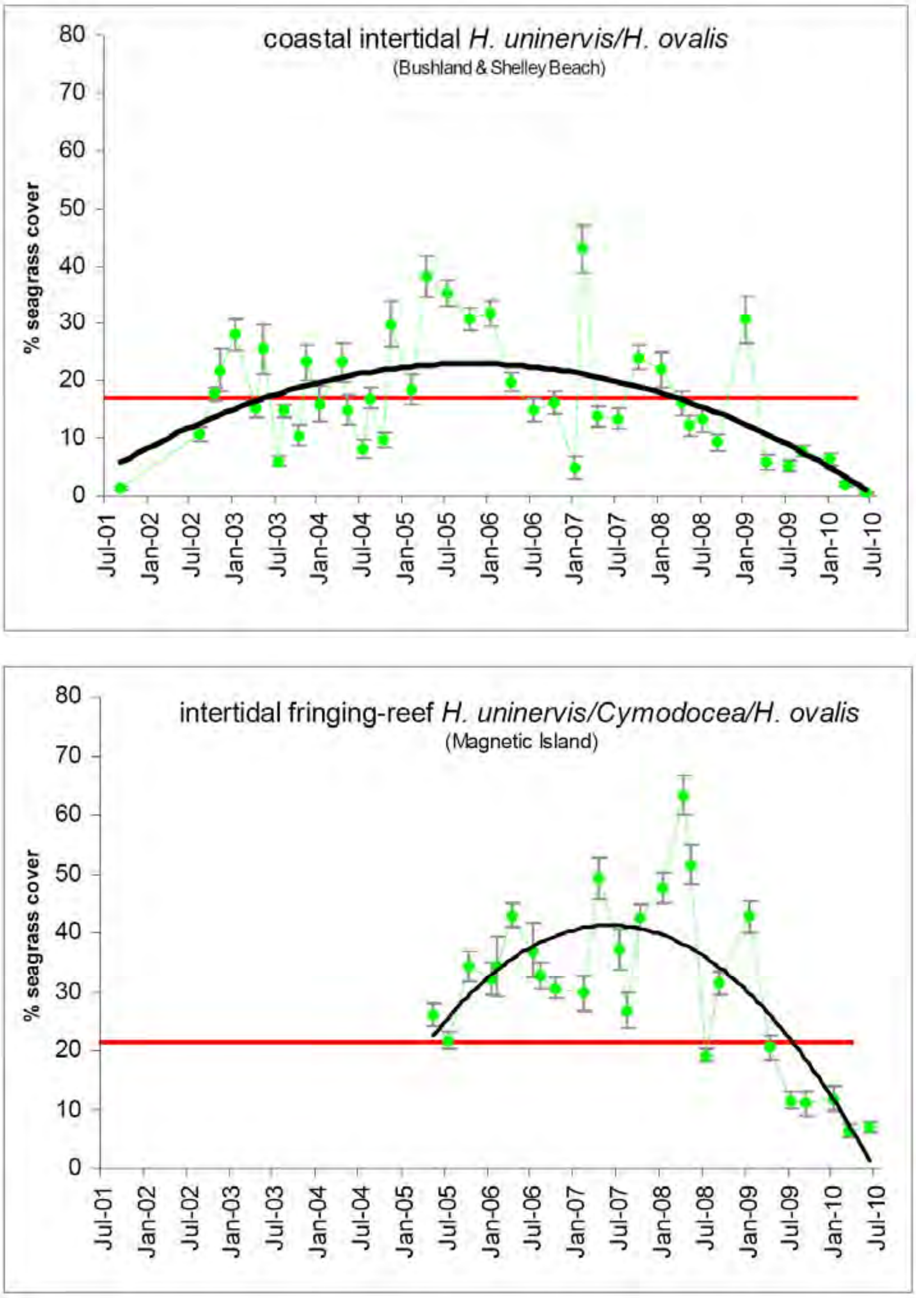


Figure 3-2 Change in seagrass abundance (percentage cover) at intertidal meadows on fringing reef platforms from 2001 to 2010 at Bushland and Shelley Beach (east of Cape Pallarenda) and Magnetic Island sites. Red line = GBR long-term average for reef habitats (average of all sites pooled) (Source: McKenzie *et al*. 2012)

Light limitation is a key driver of spatial and temporal patterns in seagrass distribution and abundance, and is thought to be a key driver of the observed long term temporal patterns in seagrass. As discussed in EIS Chapter B4 (Water Quality), the light climate of Cleveland Bay is mainly a function of high total suspended sediment concentrations rather than high phytoplankton biomass or high concentrations of dissolved organic carbon (e.g. tannins). Periods of high suspended sediment concentrations within Cleveland Bay are controlled mainly by wave driven bed sediment remobilisation, and inputs of terrigenous sediments in flood waters from the Burdekin River and the coastal drainages that enter Cleveland Bay (EIS Chapter B4 - Water Quality). Conversely, when local climate conditions are in a drought-like state, subtidal seagrasses can thrive due to higher light levels reaching the seabed, whereas intertidal seagrasses can decline due to exposure to high temperatures and increased desiccation (Taylor *et al*. 2007; Rasheed *et al*. 2007).

As shown in Figure 3-3, all years in the period 2007-2011 had above average rainfall, with 2010 and 2011 almost double the annual average rainfall. As described in EIS Chapter B4 (Water Quality), water quality monitoring during this period found that photosynthetic active radiation (PAR) levels at the edge of seagrass meadows and coral reefs in Cleveland Bay were very low, particularly when significant rainfall and/or moderate-high winds occurred. Subtidal corals and seagrass were likely to be at or approaching their tolerance limits in terms of light deprivation for most of this measurement period.

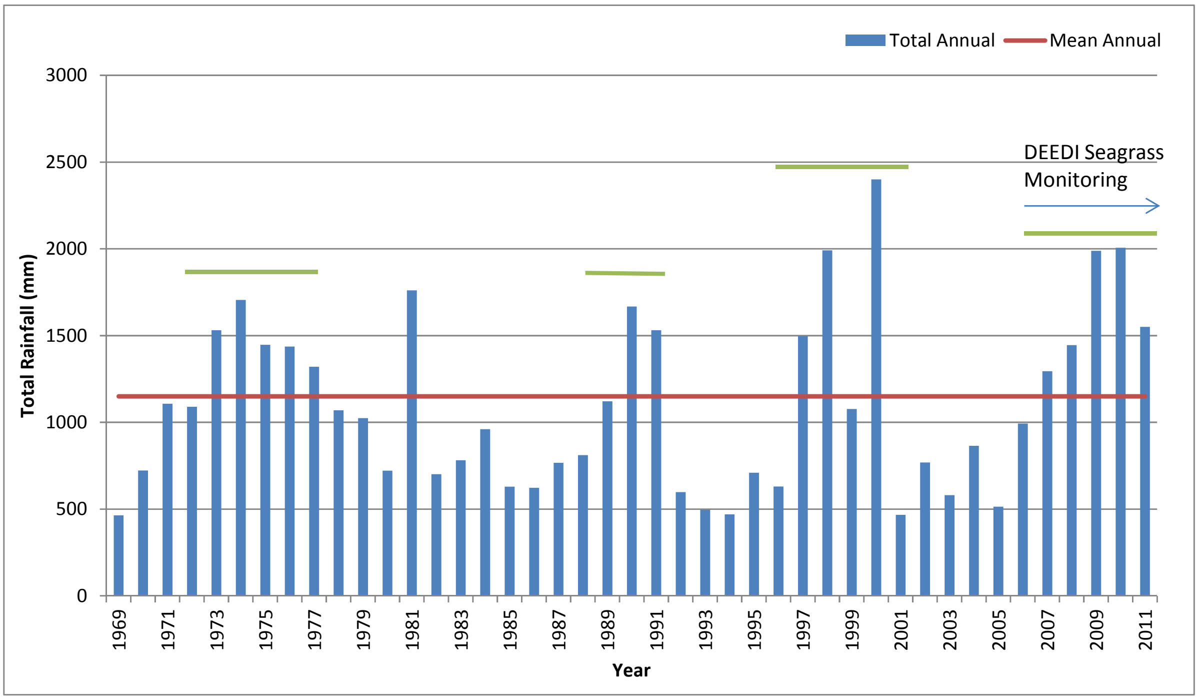


Figure 3-3 Long term average annual rainfall (1940-2011) and total annual rainfall for the period 1969-2011 (Bureau of Meteorology 2012: Station 032040). Green lines show periods when three out of four years were at or above average annual rainfall

The POTL seagrass monitoring program undertaken by DEEDI commenced in November 2007, which was the beginning of this wet period. The previous six year period (2001-2006) were drought years, with three of these six years having less than half the annual average rainfall. The subtidal seagrass extent measured in 2007 is therefore likely to reflect optimal growing conditions. Coincident with these drought years, mean annual solar radiation and mean annual daily temperature was

Seagrass Resistance, Resilience and Condition

Seagrass species differ in their sensitivity to disturbance (i.e. resistance) and capacity to recover following disturbance (i.e. resilience). The degree of resistance and resilience of seagrass depends on a number of often interactive factors including (Kenworthy 2000; Taylor and Rasheed 2009):

- carbohydrate reserves to draw on during low light periods (resistance);
- ability for photosystems to recover (resilience);
- capacity for vegetative propagation (resilience);
- seed bank occurrence (resilience); and
- historical and future disturbance regimes, including frequency, timing, duration and magnitude of disturbance (resistance and resilience).

Table 3-1 outlines the key life history characteristics of the eight seagrass species known from Cleveland Bay. In general, small species such as *Halodule* and *Halophila* tend to have low carbohydrate reserves compared to larger species, and are therefore the most sensitive species to low light conditions (i.e. low resistance). However, *Halodule* and *Halophila* species also have adaptations that allow rapid recovery, including high reproductive output, rapid growth rates and the production of long lived seeds that can live in sediments for many years (i.e. high resilience). Larger species such as *Zostera muelleri* and *Cymodocea serrulata* have higher carbohydrate reserves and can therefore endure unfavourable periods for longer than small-bodied species (i.e. high resilience). These larger bodied species however are slower to recover should they be lost (Rasheed 2004). Most species found in Cleveland Bay (except *H. decipiens* and *H. spinulosa*) are also capable of vegetative growth following disturbance, which increases the capacity to recover following disturbance.

The capacity to recover following disturbance also depends on seagrass condition, which is a function of the previous disturbance history (magnitude, and spatial and temporal scale of disturbance). Successive periods of disturbance (i.e. multiple wet years) can deplete seagrass energy sores, seed banks and standing crop (i.e. seagrass condition), which greatly decrease the capacity for seagrasses to recover following disturbance.

The Reef Rescue Marine Monitoring Program (Johnson *et al*. 2011) assessed the condition of seagrass meadows based on the following indicators:

- Seagrass cover using Seagrass Watch data (see above discussion for temporal trends);
- Seagrass leaf tissue nutrient analysis - metrics of nutrient status and light availability to the plant (leaf tissue nutrient ratios) were determined following laboratory analysis of annually collected seagrass samples.
- Seagrass epiphyte abundance – as an indicator of nutrient enrichment.
- Seagrass reproductive effort and resilience - the ability for seagrass habitats to recover following disturbance is linked to their reproductive ability, so two measures of seagrass reproductive effort (presence of seeds and the number of reproductive structures on the plant) were measured bi-annually as a measure of meadow resilience to changing environmental conditions.

Seagrass meadows of the Burdekin-Townsville region were classified as being in a 'poor state' throughout the 2009/10 monitoring period (Johnson *et al*. 2011). In coastal habitats, seagrass leaf tissue nutrient concentrations indicated potential light limitation with elevated phosphorus and nitrogen. This agrees with the findings of Rasheed and Taylor (2008) and Unsworth *et al.* (2009), who suggested that low light was the primary driver of declines in seagrass extent (see below). In reef habitats around Magentic Island, tissue nutrient concentrations in seagrass indicated that there was more available light. Low epiphyte abundance was recorded on seagrass beds, which Johnson *et al*. (2011) suggested may be a consequence of the seagrass loss experienced across this region.

In terms of reproductive effort (and therefore capacity to recover), Johnson *et al*. (2011) suggested that there was a decline in seed banks across the Burdekin-Townsville region over the monitoring period. The Seagrass Watch data that underpins the Reef Rescue Marine Monitoring Program shows that temporal trends in seed bank densities varied between the mainland and Magnetic Island, and among stations within these two areas (Table 3-2). In this regard, most mainland sites had a peak in seed densities in 2007, but lower densities in the periods before and after 2007. Magnetic Island sites had consistently low seed densities throughout the measurement period, with no apparent temporal trend. The consistently low seagrass seed densities at the two Magnetic Island sites suggest that these meadows may have limited capacity to recover from disturbance (Johnson *et al*. 2011).

Overall, these results indicate that the successive wet periods since 2007 have reduced the condition of seagrass meadows and their capacity to recover from disturbance. This is particularly the case of seagrass meadows around Magnetic Island, with mainland meadows displaying a higher capacity to recover.

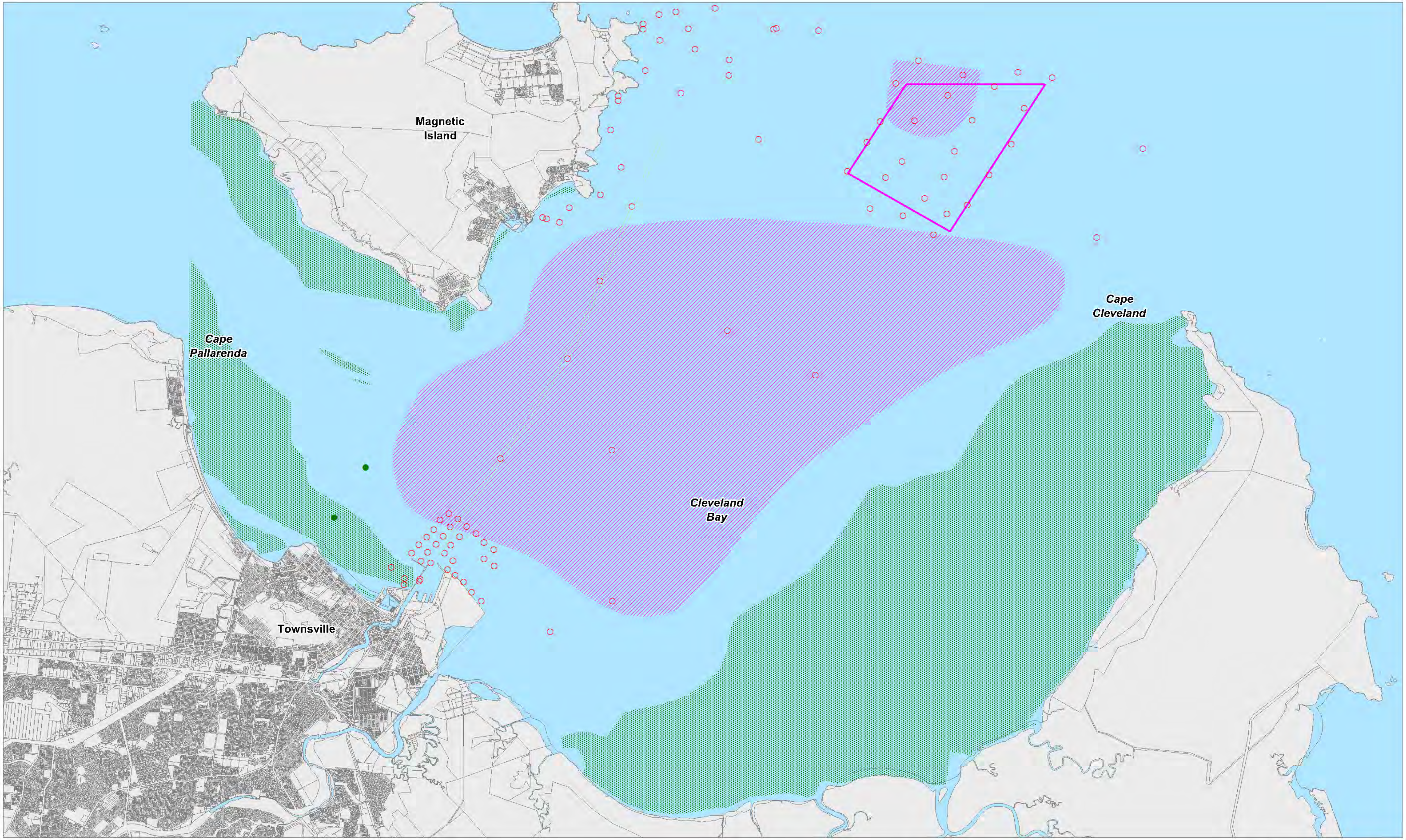
Table 3-1 Cleveland Bay seagrass life-history characteristics

Species	Regional Distribution	Sensitivity to Disturbance	Reproductive Mode
Zostera muelleri	• Among the largest *Zostera* beds in N. Qld [1] • Abundant in intertidal and shallow subtidal waters around Magnetic Is. and mainland coast [2,3]	• Large growing species = large stores of energy reserves • High capacity to endure unfavourable conditions and tend to be stable in their distribution and abundance	• Seed and vegetative • Moderate rhizome persistence, growth & reproductive output c.f. Halophila • Recovery times longer than Halophila
Halodule uninervis	• Dominant in intertidal and shallow subtidal waters around Magnetic Is. and mainland coast	• Small stores of energy reserves • Rapidly decline when conditions become unfavourable for growth	• Seed and vegetative, but asexual dominant process in region5 • Fast growth & high reproductive output
Syringodium isoetifolium	Very uncommon	See *Zostera*	• Seed and vegetative • Low to moderate growth & reproductive output c.f. Halophila, high rhizome persistence • Recovery longer than Halophila
Cymodocea serrulata	• Locally abundant in intertidal of Magnetic Island, uncommon on the mainland coast	See *Zostera*	See *Syringodium*
Thalassia hemprichii	• Locally abundant around Magnetic Island	See *Zostera*	• Seeds and vegetative • High rhizome persistence • Low growth • Seeds are buoyant & can disperse over long distances4
Halophila ovalis	• Dominant in intertidal and shallow subtidal waters around Magnetic Is. and mainland coast	• Small stores of energy reserves • Rapidly decline when conditions become unfavourable for seagrass growth	• Seeds and vegetative • Colonising growth strategy • Fast growth & high reproductive output • Viable seeds can be in sediments for years 2
Halophila decipiens	• Subdominant in places on the mainland coast, and dominant (but sparse) in deep-water environments	See *H. ovalis*	Seeds See *H. ovalis*
Halophila spinulosa	• Sparse, restricted to the mainland coast (Strand)	See *H. ovalis*	Seeds See *H. ovalis*

1 = Coles *et al*. (1992); 2 = Rasheed and Taylor (2008); 3 = Taylor and Rasheed (2009); 4 = Olsen *et al*. 2004); 5 = Unsworth *et al*. (2010)

Table 3-2 Summary of temporal changes in seagrass seed densities measured by Seagrass Watch during 2001-2009 (McKenzie *et al*. 2012)

Station	Location	Trend
Bushland beach (BB1)	Mainland coast	Densities steady between 2003-2006, peak in 2007, decline to pre-2007 levels in 2008-09
Cape Pallarenda (SB1)	Mainland coast	Increasing trend between 2003 and 2007, general decline 2007 to 2009 (but high in Oct 2008)
Shelly Beach (SB2)	Mainland coast	Exceptionally high *Halodule uninervis* seed count that has generally increased slightly between 2001 and 2009
Rowes Bay (RB1)	Mainland coast	No clear temporal trend
Picnic Bay (MI1), Cockle Bay (MI2)	Magnetic Island	Both sites had highly variable seed counts with no clear temporal trend, but densities very low compared to all mainland sites



LEGEND

Dredged Channel

Existing Spoil Ground Site

Cadastre

Video Sites

Seagrass Observed

No Seagrass Observed

Coastal Seagrass Meadows [1]

Deepwater Seagrass Meadows [1]

1. Port of Townsville Marine Precinct EIS 2009, GHD

Title:
Distribution and Extent of Seagrasses within Cleveland Bay

Figure: 3-4

Rev: A

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3.3 Soft-sediment Benthic Habitats

Soft-sediment habitats can include both vegetated (i.e. contains macroalgae, seagrass) and unvegetated habitats. This section describes the physical habitat attributes of 'unvegetated' soft sediment habitats. Note that Section 3.4 describes the benthic fauna communities within these habitats, and Section 3.2 describes seagrass meadows.

3.3.1 Acoustic Mapping

A total of 103,414 acoustic records (data points) were acquired for the 2010 dataset (outer harbour and DMPA areas). For the channel extension project area collected in 2011, a total of 86,947 acoustic records were collected. Based on 20 iterations per class, cluster analyses revealed that the optimum number of seabed classes for the 2010 and 2011 datasets was eight and nine, respectively. PCA ordinations of the 50 and 200 kHz acoustic records were similar; therefore, only 200 kHz results are presented here.

The ordination below (Figure 3-5) shows patterns in similarity among the nine seabed classes, in each of the datasets. PCA using all data showed that the 2010 and 2011 datasets could not be meaningfully combined, which was most likely due to differences in data collection parameters and physical conditions (salinity and temperature) between 2010 and 2011. Instead, the two datasets were matched qualitatively, using geographically overlapping points and the ordination shapes. While this qualitative approach provided a reasonable match between the datasets based on respective particle size distributions (Figure 3-6, Figure 3-7), it should be noted that sediment classes between the two datasets differed slightly in composition.

In broad terms, data-points that are close together within each ordination (Figure 3-5) are similar to each other, whereas data-points that are widely separated are dissimilar. The 2010 data shows that the blue and brown to orange shaded classes (2, 3, 4, 6) were most similar to each other, whereas the pink class (7) and black class (1) were the least similar to other classes. For the 2011 data, there was a similar relationship, except that an extra class (9) was also present.

Following the removal of anomalous data (i.e. records with confidence ratings less than 95%), a total of 68,054 and 55,782 records remained from the 2010 and 2011 datasets, respectively. Three of the habitat classes were comprised entirely of anomalous data: namely classes 1, 5, and 8, (shown in red in Figure 3-5). The refined data (excluding anomalies) were used in all subsequent analyses.

Grain size analysis indicates that there were distinct differences in sediment particle size distribution (PSD) among the seabed classes derived from the 2010 acoustic analysis (Figure 3-6). These classes are summarised in Table 3-3 and screen grabs of these sediment types are shown in Figure 3-8. Sediments in class 3 sediments were composed primarily of silty fine sands, whereas class 2 habitats were composed of a mixture of muddy sands and gravels. Classes 4 and 6 were composed primarily of fine silts, with class 6 having a larger fine sand fraction. Sediment samples could not be collected from areas containing class 7 using the grab sampler, but based on video data, class 7 was found to be composed of rock, rubble and gravel with a small amount of silt. Overall, these results indicate that the acoustic seabed classes can be readily distinguished by their sediment composition.

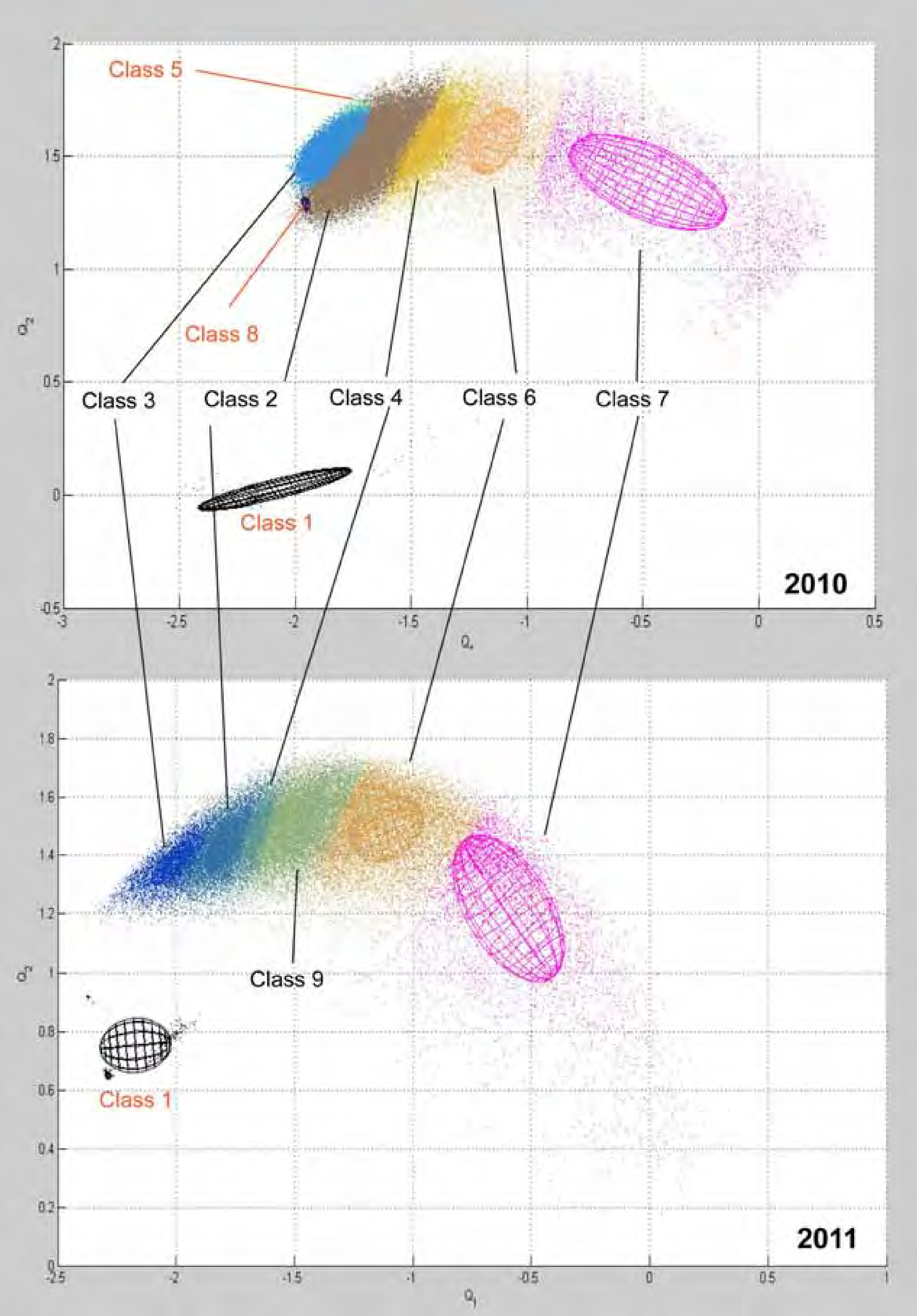


Figure 3-5 Q-space of the entire 200 kHz acoustic dataset, artificial classes or those with confidence <95% are shown in red.

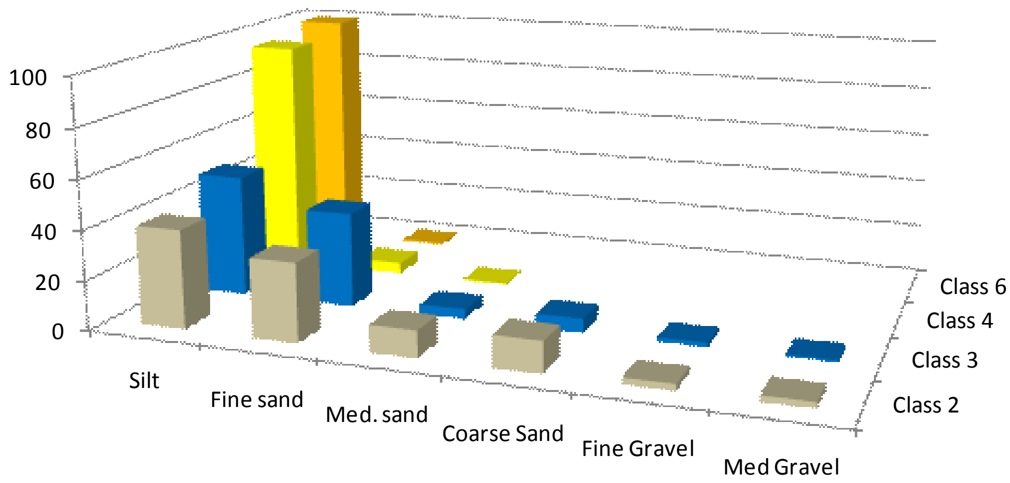


Figure 3-6 Particle size distribution (PSD) data for the 2010 acoustic classes

Table 3-3 2010 acoustic habitat classes and corresponding sediment type class

Class number	Colour Code	Abbreviated Sediment Description
2	grey	muddy sand with gravel
3	navy	Silty fine sand
4	yellow	Silt with sand
6	orange	Silt
7	pink	Rock with silt and sand

Similar particle size distributions for sediment classes were observed in the 2011 data (Figure 3-7), except class 3 and 6 sediments had higher coarse sand compositions. Class 9 sediments were composed entirely of silt.

On the basis of PSD, photo and video data, it appeared that sediments of the inshore Magnetic Island area were distinct from the class 2 and 3 sediments (Figure 3-7). Although this was not resolved by the acoustic data, this sediment class (2a) was composed of coarser weathered granite sand, coral fragments and shell grit (Figure 3-8e). Sediment class 2a was mapped based on bathymetry and ground truthing data and overlain as a purple hatched polygon over the acoustic data interpolation. Abbreviated sediment class descriptions for the 2011 data are provided in Table 3-4.

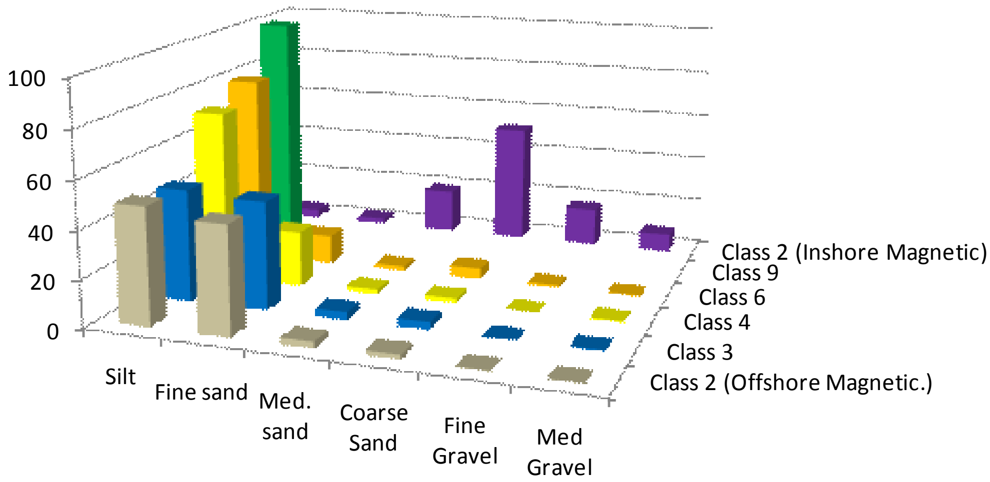


Figure 3-7 Particle size distribution (PSD) data for the 2011 acoustic classes

Table 3-4 2011 habitat classes and corresponding sediment type class

Class number	Colour Code	Abbreviated Sediment Description
2	grey	Mud with sand and occasional gravel
2a	purple	Coarse sands with shell grit
3	navy	Silty fine to medium sands
4	yellow	Silt with fine sand
6	orange	Silt with poorly sorted sands
7	pink	Rock or coral with silt and sand
9	green	Silt

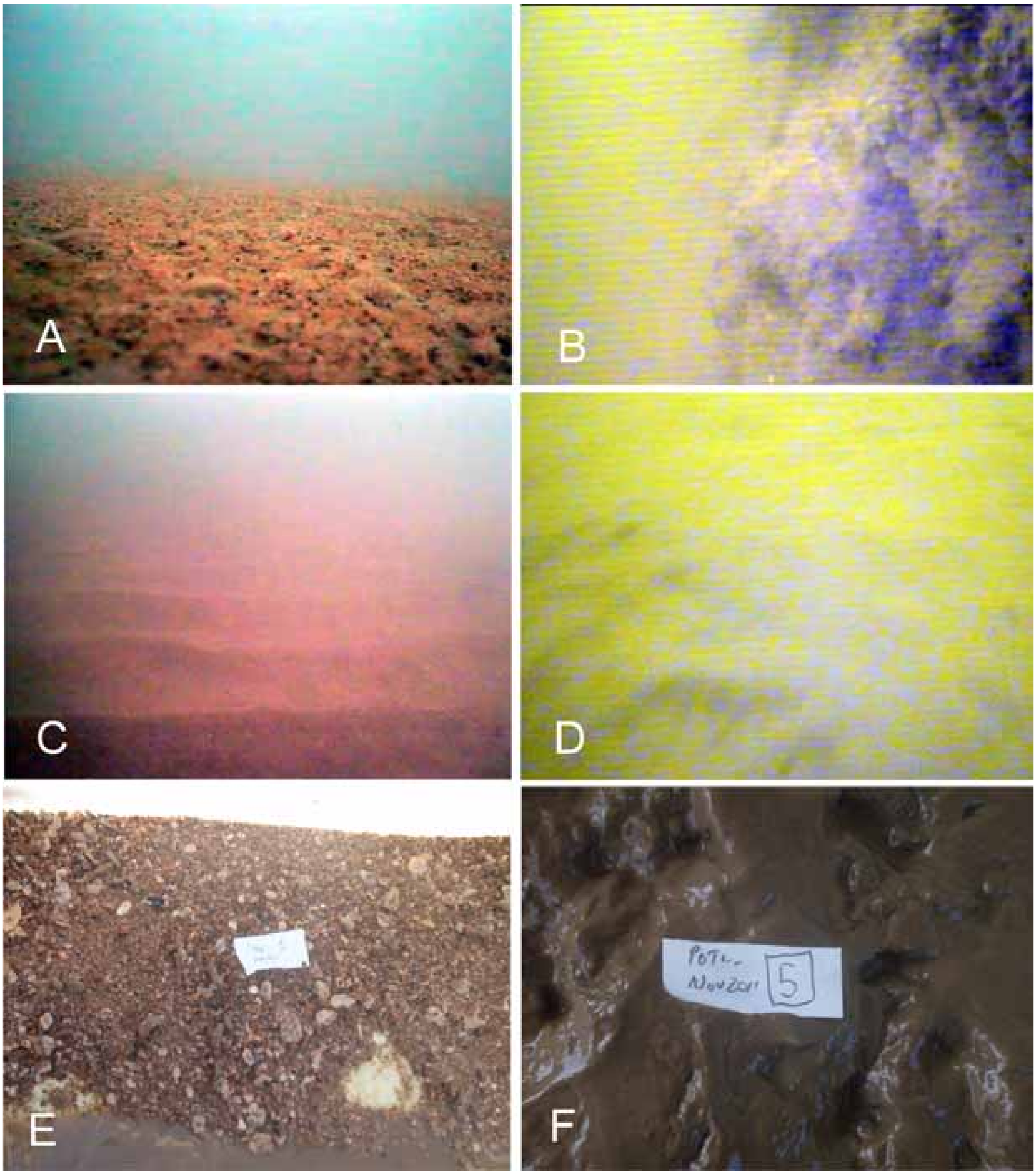


Figure 3-8 Screen grabs and stills of sediment class 2 (A); a silty rock ledge over class 7 (B); small bed forms over class 3 (C); fine silty mud in class 4 (D); coarse sands near Magnetic Island (E); and class 9, pure silt (F).

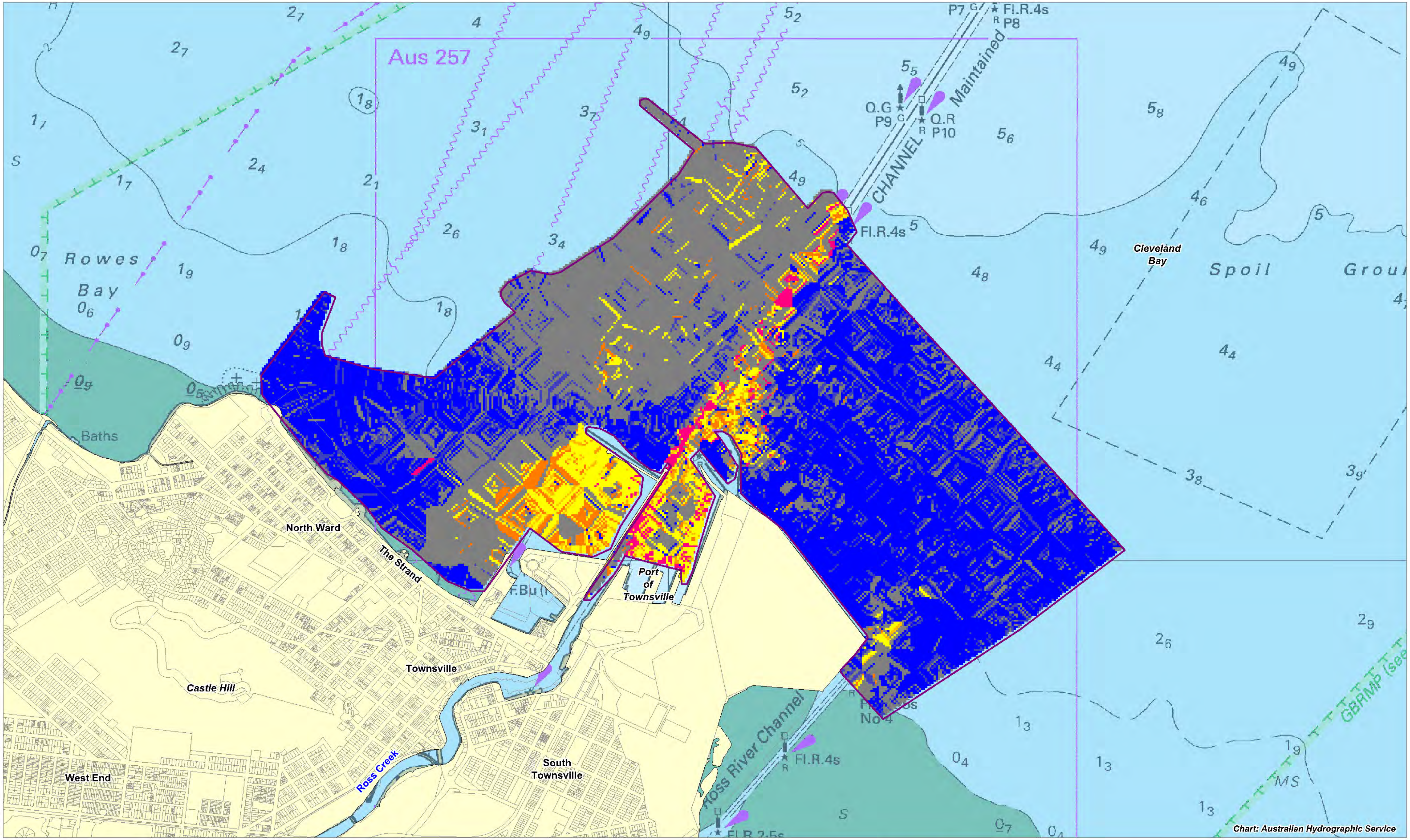
3.3.2 Sediment Distribution

Figure 3-9 and Figure 3-10 show patterns in the distribution of sediment classes in the DMPA and the outer harbour Project area collected in 2010. The outer harbour Project area was dominated by silty sands (class 3), which were present along much of the eastern seawall and offshore from the northern part of the Strand, interspersed with other small patches of seabed classes. Fine sand was particularly prevalent offshore of the eastern seawall where it formed small ridges, especially close to the breakwater in the shallower high-energy environment. With increasing distance from the shore, there was an increased prevalence of muddy sand with gravel (class 2). Within the swing basin for Berth 11 and west of the western seawall, there were depositional areas composed of silt (classes 4 and 6) and muddy sand with gravel (class 2). This depositional area between the western breakwater and the Strand ends abruptly at its southernmost extremity where beach sand intersect with mud. With increasing distance to the north along the Strand, silty sands extend more gradually from the beach out to sea as wave energy increases. Small patches of rock (class 7) occurred adjacent to the breakwaters, and the margins of the dredged channels and the swing basins.

Sediments within the offshore DMPA were more homogeneous than the outer harbour Project area. There was a higher percentage of sands in the shallower south-western part of the dredged material disposal area. With increasing distance in a north-easterly direction (and increased depth), there was a greater proportion of muds and silts. Very few rocky substrates (class 7) were observed in either Project area.

Figure 3-11 shows the distribution of sediment classes surrounding the channel extension project area collected in 2011. Silty sands (class 3) surrounding the outer harbour Project area gradually became less concentrated with distance offshore, being replaced by muds with sand (class 2). Silty sands were more prevalent on the eastern side of the channel, while class 2 sediments dominated the western side of the channel. This difference in distribution may be related to wind driven sediment transport by south-east trades. Mobile silty sands may become trapped in the Platypus Channel as they move in a north-westerly direction.

The inshore area immediately east of Magnetic Island is composed of coarse class 2a sediments which gradually become muddier with depth and distance offshore. This change is more abrupt to the north-east of Magnetic Island, where a deep scour which coincides with a large area of silty class 4 and 6 sediments. Near the northern extent of this of the surveyed area is a patch of silt (sediment class 9). Muddy sands (class 2) cover most of the study area east of the scour with occasional patches of silt and fine sand.



LEGEND

Survey Boundary

Cadastre

Acoustic Class

Grey	2
Blue	3
Yellow	4
Orange	6
Magenta	7

Title:

Acoustic Classes Surrounding the Outer Harbour Project Area

Figure: 3-9

Rev: A

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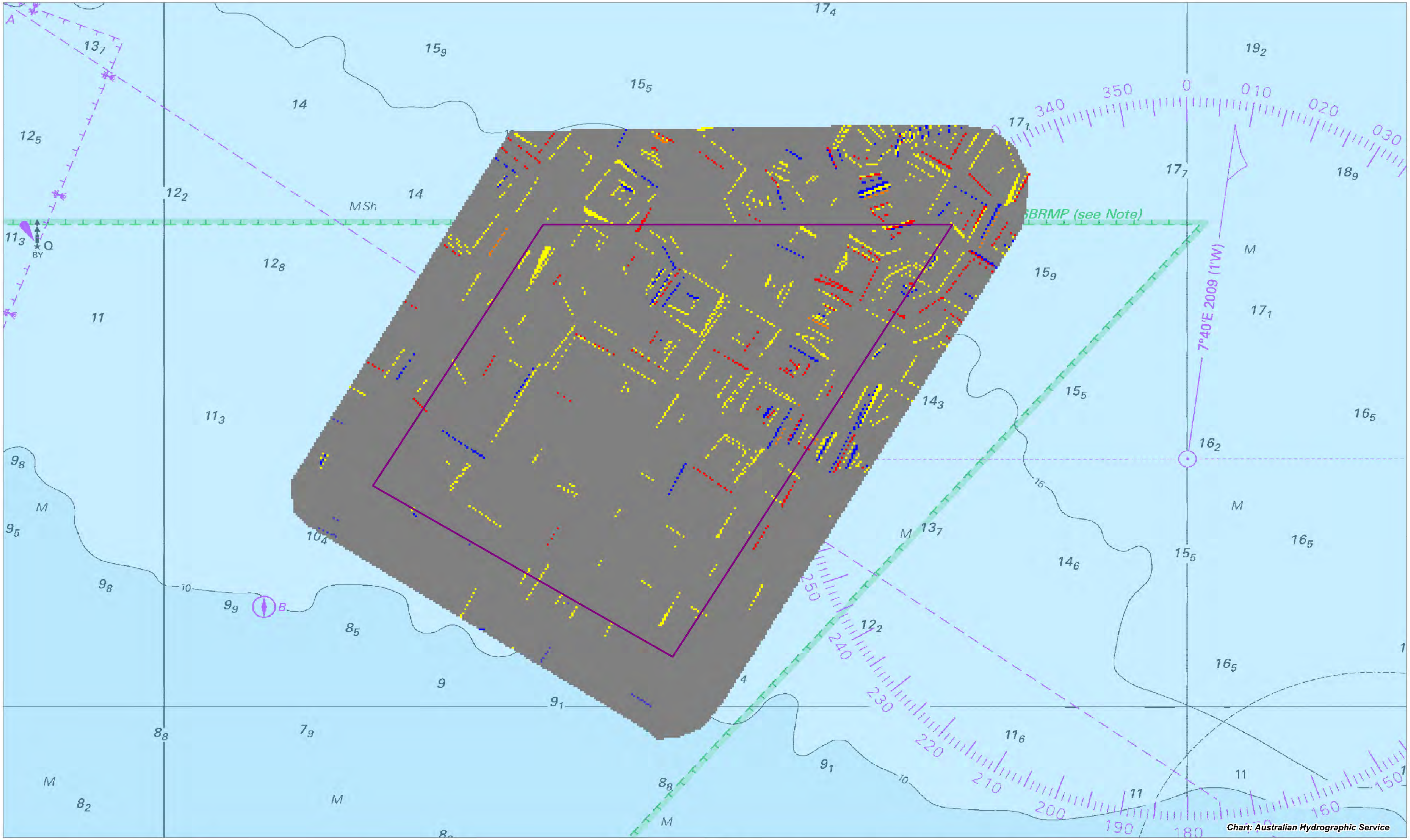

LEGEND

Spoil Ground Disposal Site

Acoustic Class

Grey	2
Blue	3
Yellow	4
Orange	6
Magenta	7

Title:

Acoustic Classes Surrounding the DMPA

Figure: **3-10**

Rev: **A**

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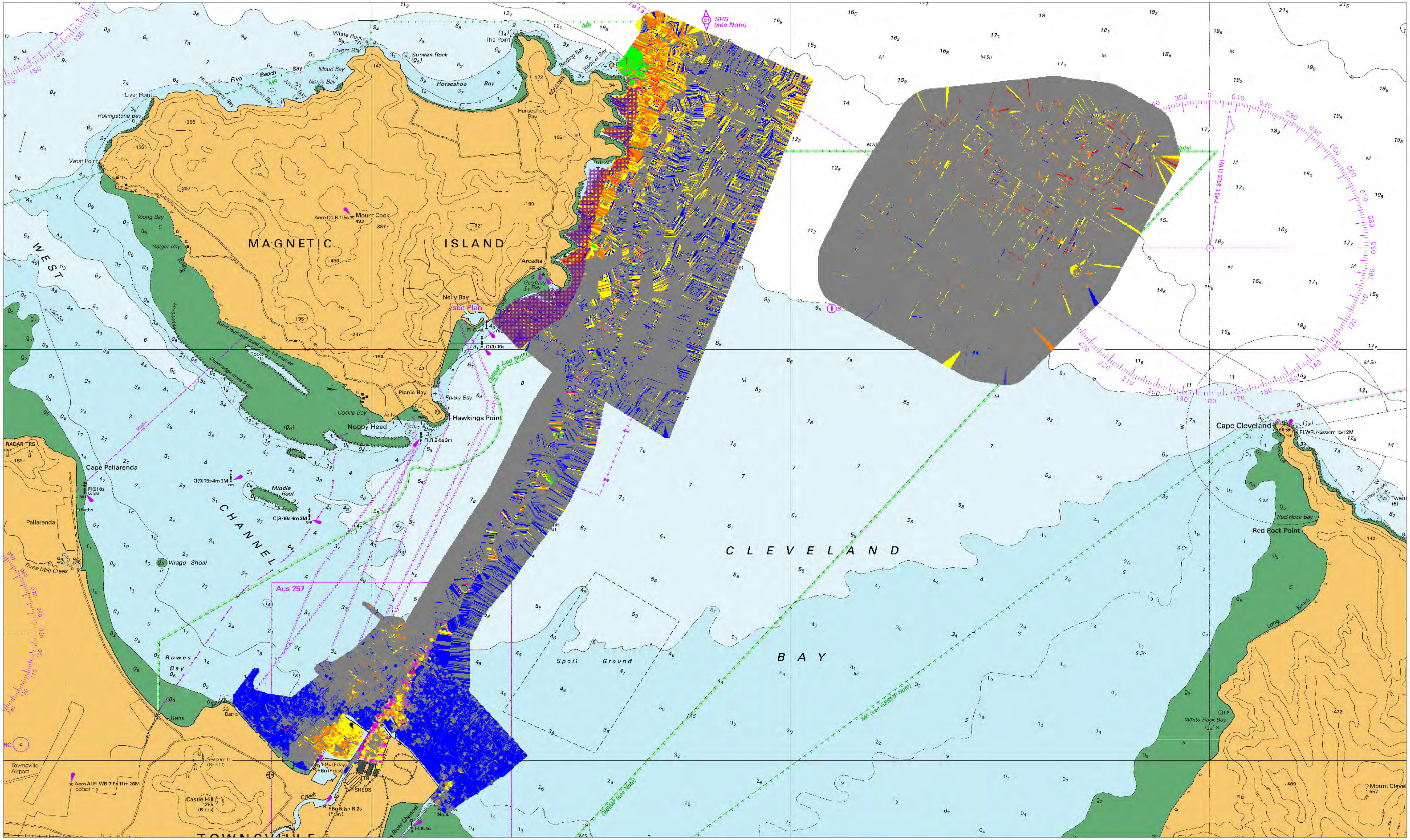

LEGEND

Sediment Class

Acoustic Class

- 2
- 3
- 4
- 6
- 7
- 9

Title:

Acoustic classes surrounding the existing channels and the channel extension project area

Figure: **3-11**

Rev: **A**

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3.3.3 Habitat Condition

As discussed above, most of subtidal habitats within the study area and surrounds are comprised of unvegetated soft sediment habitats (i.e. sandy/muddy substrates). In the surrounding area, large intertidal flats occur throughout Cleveland Bay, and are likely to provide a number of ecological functions that are important to the maintenance of local ecosystem processes, including nutrient cycling processes, provision of food resources, and a linkage between littoral wetland areas (mangroves, saltmarsh), seagrass beds and deeper nearshore soft sediment habitats. Intertidal flat habitats are not represented in the construction footprint, but are present to the south and north of the outer harbour Project area.

Environmental integrity of unvegetated soft-sediment habitats within the port area, navigation channels, DMPA and adjacent areas, including the mouth of Ross Creek and Ross River, have been substantially modified by a number of past anthropogenic activities. Most notably, these include port development works, water quality modifications associated with a wide range of activities in the wider catchment, and flow modifications associated with water infrastructure. Benthic habitats and communities are relatively simplified (SKM 1998), and may not retain particularly high values compared with more diverse habitats elsewhere in the surrounding area.

3.4 Soft Sediment Benthic Communities

3.4.1 Outer Harbour, DMPA Project area and Existing Channels

3.4.1.1 Epibenthos

Sparse and patchy epibenthic communities occurred throughout the study area and surrounds, and were comprised of occasional hydrozoan and soft coral colonies to completely bare substrates. Of the 73 transects, seagrass was recorded on two transects (see section 3.2), and epifauna was observed on 48 transects. In total, 30 fauna taxa, three seagrass species and three genera of macroalgae were recorded.

Epibenthos assemblages in the DMPA were dominated by a type of burrowing goby (Figure 3-13G). Of the 149 fish observed in video transects, 142 (95%) were burrowing gobies, and 124 of these were observed in the spoil ground. These were usually observed in pairs with up to seven pairs of fish observed on some transects in the DMPA. Sea pens (Pennatulacea, Figure 3-13B) were particularly common at the DMPA, but were only occasionally observed in the midshore controls and construction footprint, and absent elsewhere. Bryozoans (Figure 3-12F), sponges (Porifera Figure 3-12C), polychaetes, ascidians (sea squirts), echiurans (spoon worms), hydrozoans and alcyoniid soft corals (Figure 3-12D) were occasionally observed. The small patches of rock within the DMPA provide habitat for reef-associated taxa such as sea pens, ascidians and some crinoids, and represent areas of higher biodiversity within the study area and surrounds.

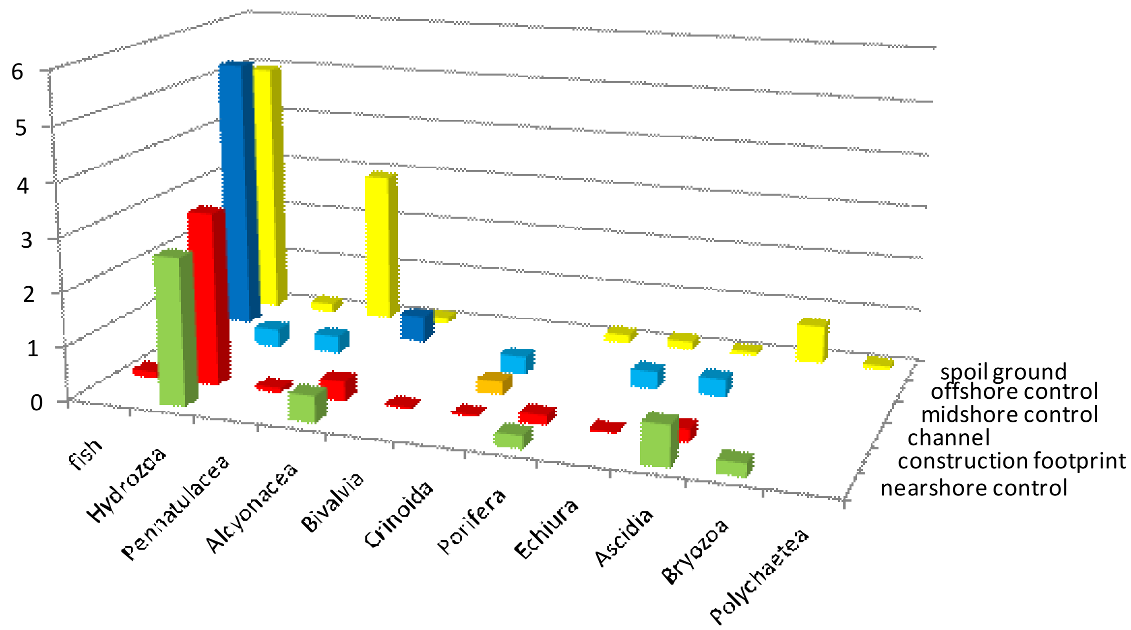

Figure 3-12 Mean abundances (per transect) of epibenthic fauna in each location

Epibenthos assemblages at the offshore control area were generally similar to those at the DMPA, although sea pens and many of the uncommon taxa recorded at the DMPA were not observed at the offshore control (Figure 3-12). Mid-shore control assemblages were comprised of occasional hydrozoans, sea pens, crinoids and ascidians. Channel assemblages were the most depauperate, with only one feather star (crinoid) recorded (Figure 3-13H). Epibenthos assemblages at the nearshore control and construction footprint locations were structurally similar. Hydrozoans were the most abundant taxon in the nearshore areas, and were much less common in the DMPA, mid- and offshore control areas. Assemblages were dominated by plumulariid (Figure 3-13E) and sertularellid stinging hydroids (Figure 3-13F), with occasional alcyonid soft corals, ascidians, and bryozoans.

Spatial patterns in epibenthos community structure were explored through multivariate statistical techniques. Non-metric MDS ordinations showing patterns in community similarity were generated, and transects were coded to show: (i) patterns among locations (i.e. DMPA, near- mid- and offshore controls, channel and construction footprint; see Figure 3-14)[3]; and (ii) patterns among sediment classes defined in section 3.3.1 (Figure 3-15).

Figure 3-14 shows that there was a gradual change in community structure moving from nearshore (which grouped towards the centre of the ordination) to offshore (located to the right side of the location). The ordination shows that assemblages in the spoil ground/offshore control location differed from those in the construction footprint/near-shore control. SIMPER analysis indicates that differences between assemblages among locations were primarily due to high abundance of the burrow dwelling gobies (*Valenciennea* sp.) and sea pens (Pennatulacea) at the DMPAcompared to other locations.

[3] Note: Some sites are not shown as either no animals were present, or because sites were not classified in the acoustic analysis

Figure 3-13 Screen grabs from video transects; seagrass at nearshore controls (A); sea pen at the DMPA (B); orange sponge in the construction footprint (C); *Nephthya* soft coral in the construction footprint (D); stinging hydroid (Plumulariidae) (E); stinging hydroid (*cf Sertularella*) (F); goby (*cf Valenciennea*) (G); feather star (crinoid) (H); orange bryozoans with sponges (Porifera) (I).

Figure 3-15 shows that sediment class was generally a poor predictor of epibenthos community structure. Assemblages in Class 2 sediments (muddy sand and gravel) tended to group towards the left side of the ordination, and class 3 sediments (silty sand) tended to group towards the centre and right side of the ordination, however there was in many cases a high degree of similarity in assemblages between these two classes. The single transect in the rock, silt and sand category (Class 7) differed from other locations. The differences in assemblages among seabed classes appeared to reflect broad spatial differences among locations, with Class 2 dominating at the DMPA and Class 3 generally dominating in near shore locations.

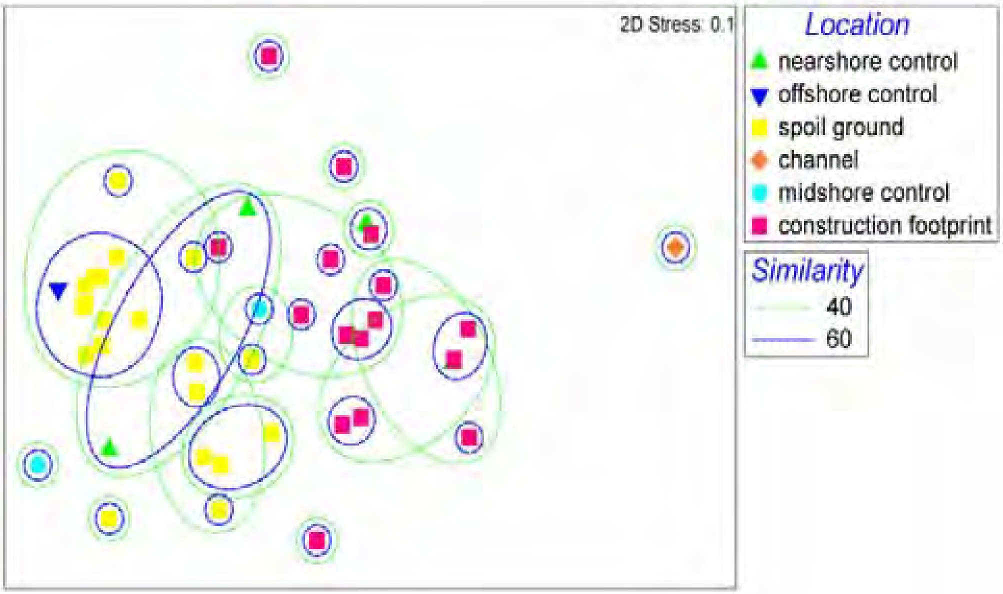

Figure 3-14 nMDS ordination showing patterns in epibenthos among survey transects, grouped by location. 40% and 60% similarity are shown in green and blue, respectively.

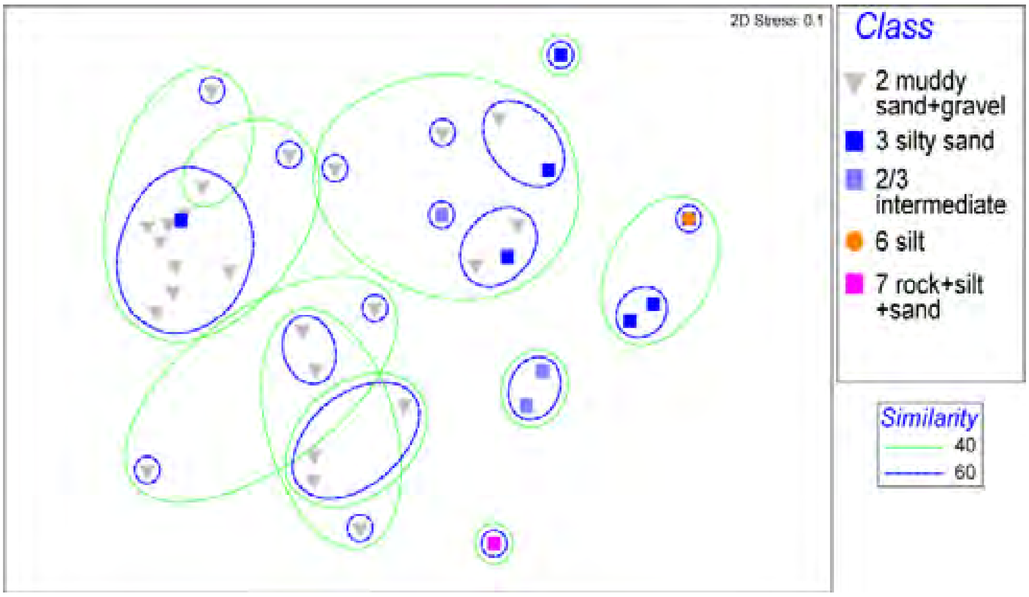

Figure 3-15 nMDS ordination[4] of epibenthic communities in relation to sediment class, groupings at the 40% and 60% similarity are superimposed in green and blue, respectively.

[4] Data points that fell outside of the acoustic sediment mapping were excluded from the analysis, hence, nMDS ordinations in Figure 3-10 and Figure 3-11 differ slightly

3.4.1.2 Soft-sediment Benthic (Infauna) Communities

Community Overview

A total of 106 benthic fauna taxa (i.e. macroinvertebrate species/morpho-species >1 mm) were collected in the present survey. Representative examples of benthic fauna taxa collected in the present study are shown in Figure 3-16.

Most taxa had low abundance, with 90 taxa (approximately 84% of taxa) being represented by five or less individuals. These 16 most common species are listed in Table 3-5, and a complete list of all taxa recorded is provided in Appendix A. The most common taxa include three families of carnivorous polychaete worms, amphipods, crabs, caridean shrimp, bivalve molluscs, brittle stars, nemerteans and chordates. Three taxa accounted for 22% of the total number of individuals collected: a brittle star (*c.f. Amphioplus* sp.) comprising 10% of the total number of individuals collected; an amphipod crustacean (Gammarid 1, 8% of individuals); and a polychaete worm (Glyceridae 1, 4% of individuals). The patterns in dominance were typical to that observed in other grab-based studies within the study area (C&R Consulting 2007) which found that polychaetes were the most abundant taxon, followed by amphipods, bivalves, other marine worms, crabs, isopods, ascidians and brittle stars.

Figure 3-17 shows the total number of animals recorded at each site (grouped by higher taxa). At the DMPA, abundance at all sites was consistently dominated by polychaete worms and, to a lesser degree, crustaceans. At other locations, the dominant taxa tended to vary between sites. For example, at the construction footprint, some sites were dominated by crustaceans, while others were dominated by molluscs. Similarly, at the nearshore control location, the relative proportion of each major taxa group varied inconsistently among sites.

Table 3-5 List of most common infauna species (i.e. >5 individuals collected) during baseline survey

Phyla	Class	Order	Taxa	Common name
Annelida	Polychaeta	Eunicida	Onuphidae 1	segmented worms
			Amphinomidae 1	
			Marphysa sp.1	
			Eunice sp.1	
		Phyllodocida	Glyceridae 1	
		Scolecida	Maldanidae 1	
Crustacea	Malacostraca	Decapoda	Caridean 2	shrimp
			Larval crab 2	crab
		Amphipoda	Gammarid 1	sea lice
			Gammarid 2	
			Gammarid 6	
Mollusca	Bivalvia	Veneroida	*Tellina* sp.1	venus shell/clam
			Mactra sp.1	
Echinodermata	Ophiuroidea	Ophiurida	*c.f. Amphioplus* sp.1	Brittle star
Nemertea	-	-	Nemertean 1	ribbon worm
Chordata	Leptocardii	Amphioxiformes	*Branchiostoma* sp.1	lancelet

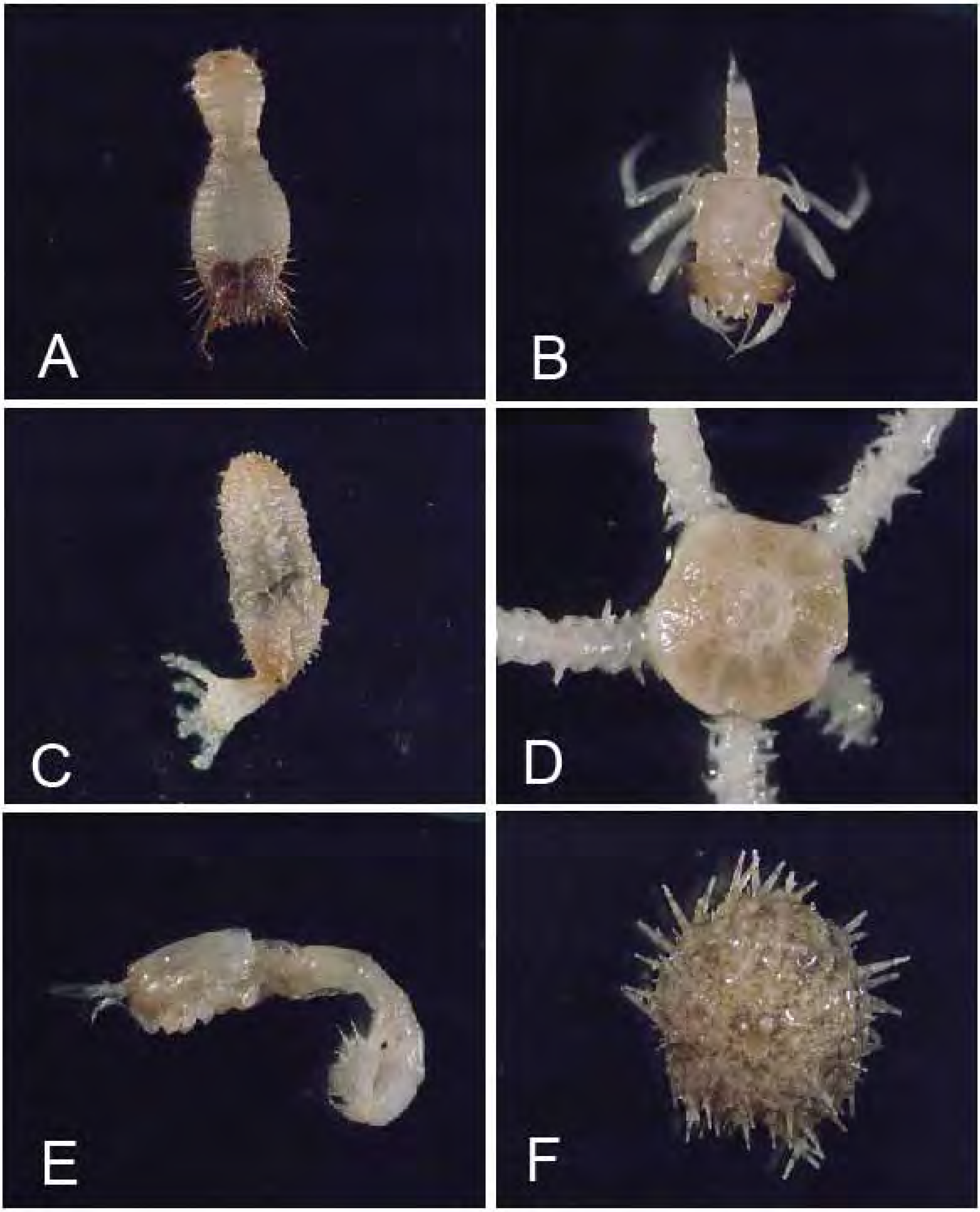

Figure 3-16 Examples of infauna specimens collected during baseline surveys: sternapsid polychaete (A); brachyuran (larval crab) (B); holothurians (sea cucumber)(C); ophiuroid (brittle star) (D); tanaid crustacean (E); echinoid (sea urchin) (F).

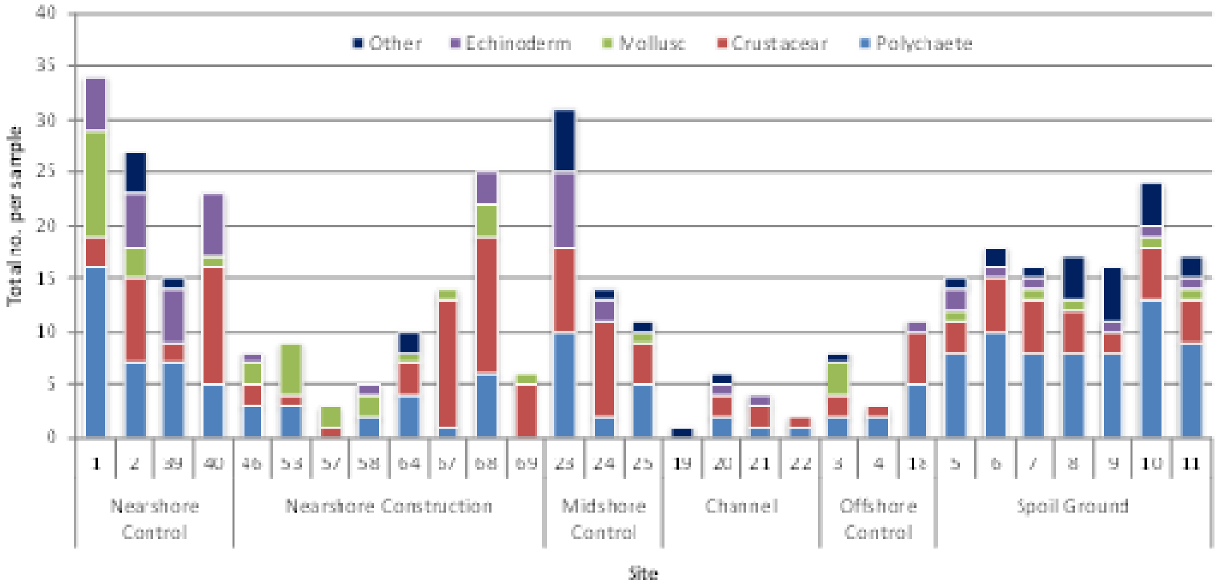

Figure 3-17 Proportion of each major higher taxon contributing to total abundance at each site

Abundance and Diversity

Benthic communities at the time of the field survey were depauperate. More than one third of the 116 samples collected contained only one or fewer macroinvertebrate individuals (i.e. 16% of samples contained zero fauna and 22% contained only one individual macroinvertebrate). The majority (58%) of samples containing ≤1 individuals were collected from the channel and construction footprint, which is likely to reflect ongoing disturbance by dredging and other port related activities.

The mean total abundance of individuals varied among sites and locations (Figure 3-18). Mean abundance was consistently low (<2 individuals per sample) at all four channel sites. Several sites in the construction footprint and offshore control locations had similarly low mean fauna abundance. By comparison, mean abundance at sites within the DMPAwas typically approximately 4 individuals per sample, and some sites at the nearshore and midshore control locations averaged 6-8 individuals per sample.

As many taxa were recorded as singletons (i.e. only one representative collected), patterns in species richness (Figure 3-19) closely reflect those described above for abundance. Mean species richness was consistently very low (<2 species) in the channel. Sites with similarly low species richness were located in the nearshore construction and offshore control locations. Similar to abundance, the highest species richness was recorded at the spoil ground, nearshore control and midshore control locations.

Previous grab-based sampling studies in Cleveland Bay also recorded low fauna abundance and richness. For example, GHD (2009) found that only 8 of 17 sites in the nearshore area south of the Port contained any animals. C&R Consulting (2007) reported mean abundances for sites between the Port and Magnetic Island of 5.17 polychaetes, 1.5 amphipods and between 0.2 and 0.9 individuals of all other taxa per litre of sediment. These values are comparable to the results of the present study.

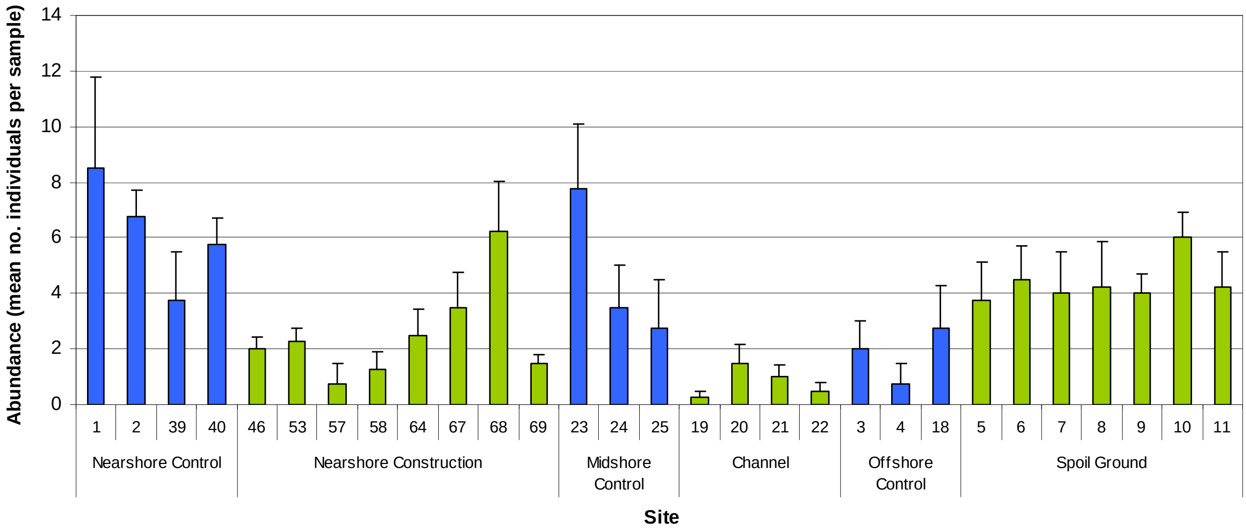

Figure 3-18 Mean (± SE) abundance of macroinvertebrate individuals at each control (blue) and putative impact (green) site

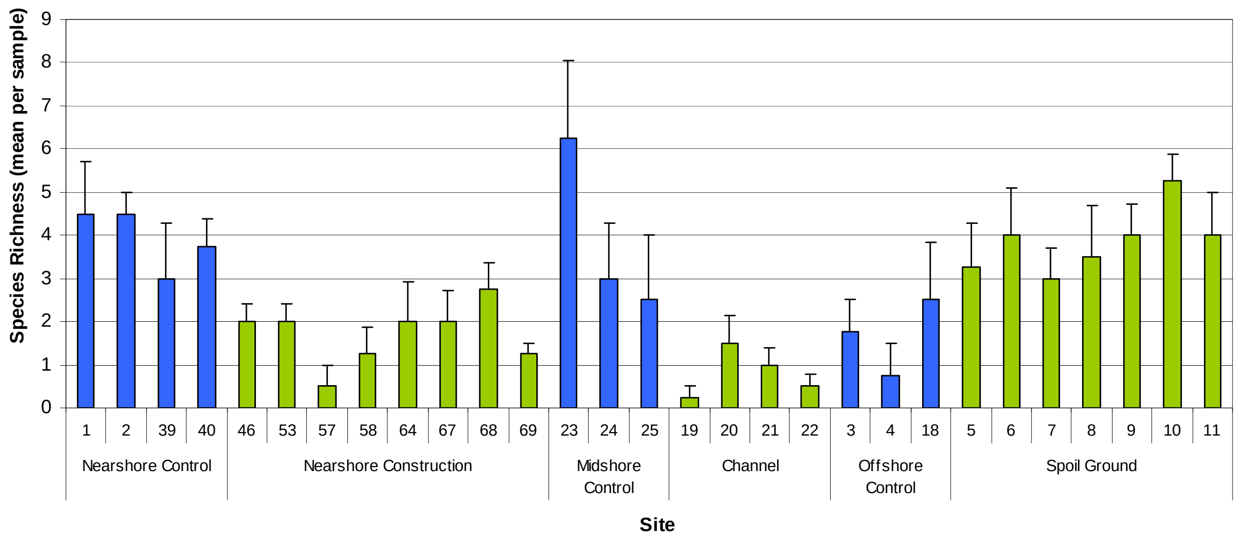

Figure 3-19 Mean (± SE) macroinvertebrate species richness at each control (blue) and putative impact (green) site

Community Trends

When comparing patterns in community structure, there was a high degree of overlap between locations (Figure 3-20), with no notable trends associated with location attributes (i.e. near/mid/offshore or control/putative impact). Note that care should be used when interpreting these results as approximately one third of samples had to be excluded from multivariate analyses due to too few fauna. Despite the high degree of similarity, analyses revealed that there were significant differences between some locations (ANOSIM Global R = 0.288, p = 0.002), with discrete communities being detected at the nearshore control location (i.e. nearshore control location differed significantly to all other locations); and the DMPAdiffered from both the channel and nearshore construction locations. Compared with other locations, the nearshore control location was characterised by higher abundances of the brittle star *c.f. Amphiolpus* 1 and the amphipod gammarid 6, whereas the DMPArecorded higher average abundances of the polychaete Glyceridae 1.

As is typically the case with benthic infauna, community trends appeared to be most closely associated with substrate sediment characteristics. When multivariate analyses examined only the samples for which acoustic data were available (i.e. only included benthic data if sites were located within the limit of the acoustic habitat mapping survey), a strong trend emerged (Figure 3-20). There was a distinct separation between the benthic communities of the two major acoustic classes: class 2 (muddy sand with gravel) and class 3 (silty sand) (ANOSIM Global R = 0.607, p = 0.001). Due to the small size of the remaining classes (i.e. only one representative benthic sample included in analyses for each), there were too few data to statistically test for differences in the benthic fauna communities of other combinations of classes. However, the data available in Figure 3-21, that the remaining classes (primarily finer silty sediments) were again distinct from classes 2 and 3. This could suggest that benthic communities in the study area and surrounds may largely be driven by a gradient in sediment grain size from the coarser acoustic class 2 (muddy sand with gravel) to class 3 (silty sand) to the finer classes 4 and 6 (silt with sand, and silt, respectively). The key benthic fauna species identified as characterising each acoustic class are listed in Table 3-6.

Studies by Cruz-Motta (2000) and Cruz-Motta and Collins (2004) have investigated the benthic communities at the DMPA and at sites on transects radiating away from the DMPAat a range of temporal spatial after maintainence dredge material disposal. They found little evidence of long-term changes in communities, but changes in communities were apparent immediately after disposal. This change was seen as an overall reduction in diversity and abundance inside the DMPA.

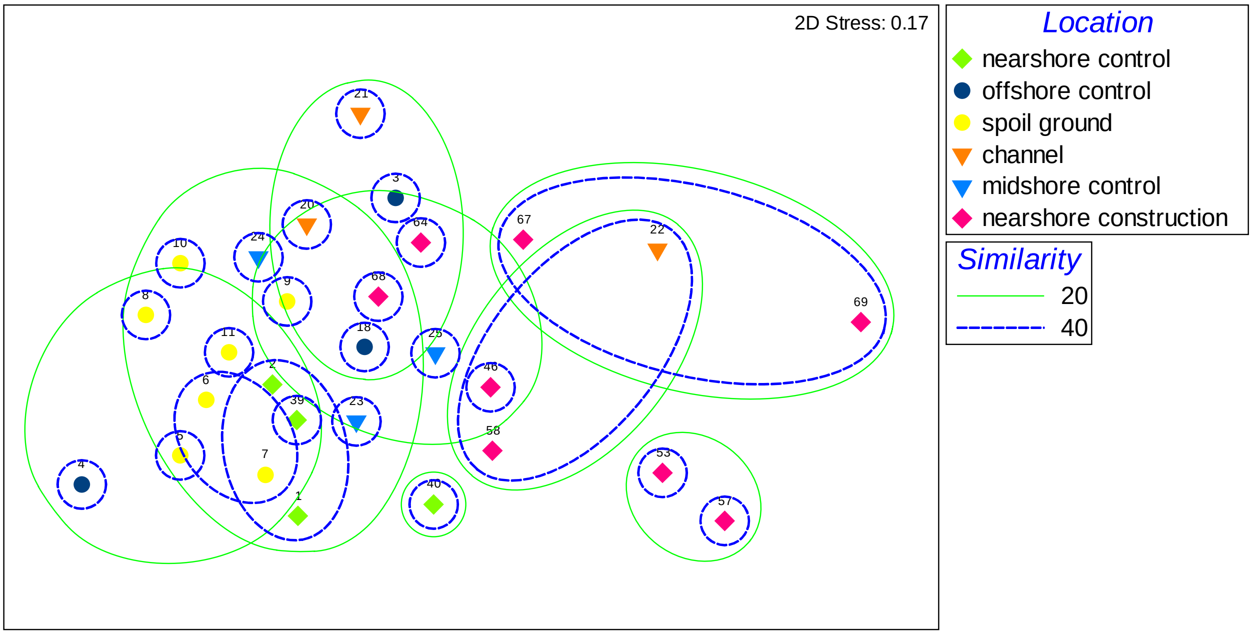

Figure 3-20 nMDS ordination of multivariate benthic infauna similarity where symbols denote collection location (samples averaged by site)

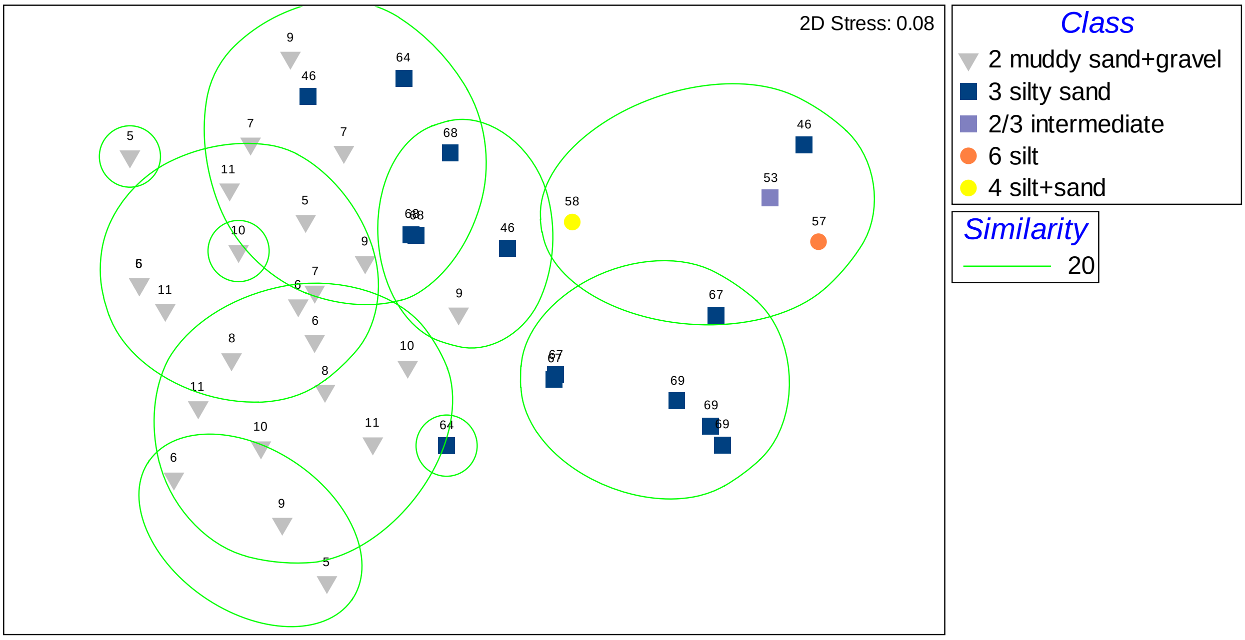

Figure 3-21 nMDS ordination[5] of multivariate benthic infauna similarity where symbols denote the acoustic substrate class for the collection site (excludes samples collected at sites positioned beyond the limit of acoustic mapping data)

[5] Data points that fell outside of the acoustic sediment mapping were excluded from the analysis, hence, nMDS ordinations in Figure 3-16 and Figure 3-17 differ slightly

Table 3-6 Key benthic infauna species characterising samples collected at acoustic habitat classes in 2010

Class number	Colour Code	Sediment Description*	Key benthic infauna species
2	grey	muddy sand with gravel	Glyceridae 1 *Branchiostoma* sp. *Amphinomidae* 11
3	navy	Silty fine sand	Larval crab 2 Gammarid 1
2/3	blue/grey	Intermediate class between classes 2 and 3	Capitellidae 2 Prawn 2 Terebellidae 1
4	yellow	Silt with sand	Polynoidae 2 *c.f. Amphioplus* sp. 1
6	orange	Silt	Tellina 1 Prawn 3
7	pink	Rock with silt and sand	n/a (hard substrate therefore no infauna samples

The results of the present study are broadly consistent with benthic epifauna community assessmenst carried out by GHD (2011b) in Cleveland Bay. GHD (2011b) sampled seven sites in Cleveland Bay on two occasions (November 2010 and April 2011) using a benthic sled towed over 100 m transects. Molluscs were the most abundant phylum, comprsing 48% and 43% of the community composition in Novemeber and April respectively. Cnidarians, echinoderms, crustaceans and ascidains were also relatively abundant, varying among sites and between sampling episodes.

GHD (2011b) found that assemblages differed between nearshore areas and offshore areas, with lower macroinvertebrate abundance and richness in offshore areas (DMPA and dredged channels) than nearshore areas. Variations in assemblage structure were observed over time, with the magnitude of change varying among sites. This high degree of temporal variability in benthic macroinvertebrate community structure is a typical feature of tropical nearshore environments (Alongi 1990), including Cleveland Bay (Cruz-Motta 2000; Cruz-Motta and Collins 2004). This variability is thought to mainly be a consequence of seasonal and inter-annual changes in water quality and physical disturbance, and biological interactions and processes (competition, predation, recruitment).

3.4.2 Channel Extension Project area

3.4.2.1 Epibenthos

Epibenthic communities were very sparse over most of the channel extension project area, consisting of the occasional stinging hydroid, mollusc, crustacean, ascidian and macroalgae over bare muddy, sandy or silty substrates (Figure 3-22). For most transects, only one taxon was recorded at a frequency of 1-2 animals per transect. However, there were two reefal areas with abundant benthic communities found at the northern and southern inshore extremities of the field survey investigation area. Both areas occurred adjacent to the fringing reefs of Magentic Island (see Section 3.5.1), and were outside the channel extension footprint (Figure 3-29).

The northern-most reefal area consisted mostly of large granite boulders with encrusting corals, bryozoans and sponges on the upper surfaces (Figure 3-23a-b). In between the boulders were silty depositions and occasional whip corals (*cf Junceella)*. Hard corals were relatively sparse and consisted of small colonies of *Turbinaria* and encrusting *Montipora.* Commercially and recreationally significant fish species including coral trout (*Plectropomus* sp.) were observed here.

The southern-most reefal area was comprised of small to medium sized coral heads separated by fine to coarse sands (class 2a sediments). Although coral cover was not continuous, hard and soft coral colonies formed substantial, scattered habitat throughout this area (Figure 3-23c-h). Eight hard coral genera and ten soft coral genera were recorded over the three video transects conducted in this area. The most common hard corals were *Porites, Montipora,* and *Turbinaria,* while colonies of *Goniopora, Pocillopora, Patchyseris, Favia,* and *Favites* were less abundant. The most abundant soft coral genera were *Junceella, Sarcophyton, Sinularia,* and *Lobophyton;* colonies of *Subergorgia, Xenia and c.f Annella* were occasionally observed.

The southern-most reef appeared to be in reasonably good condition, although there were some soft coral colonies displaying partial mortality, mostly *Junceella* and *Subergorgia.* Several colonies of *Porites* were displaying partial bleaching around the colony base as seen in Figure 3-23g.

These two reefs were the only areas with significant vertical relief observed during sonar acquisition. Other small patches of class 7 substrate (rock/ coral) were observed, but these were found as isolated data points in the inshore Magnetic Island region (corresponding to isolated rocks/ boulders) or lining the edges of the Platypus Channel.

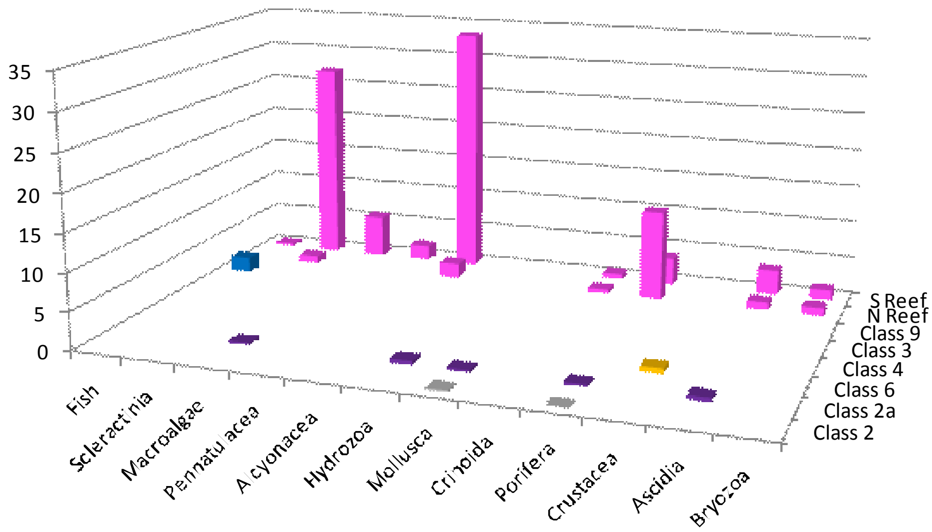

Figure 3-22 Mean abundances (per transect) of epibenthic fauna from sediment classes in the channel extension project area and surrounds

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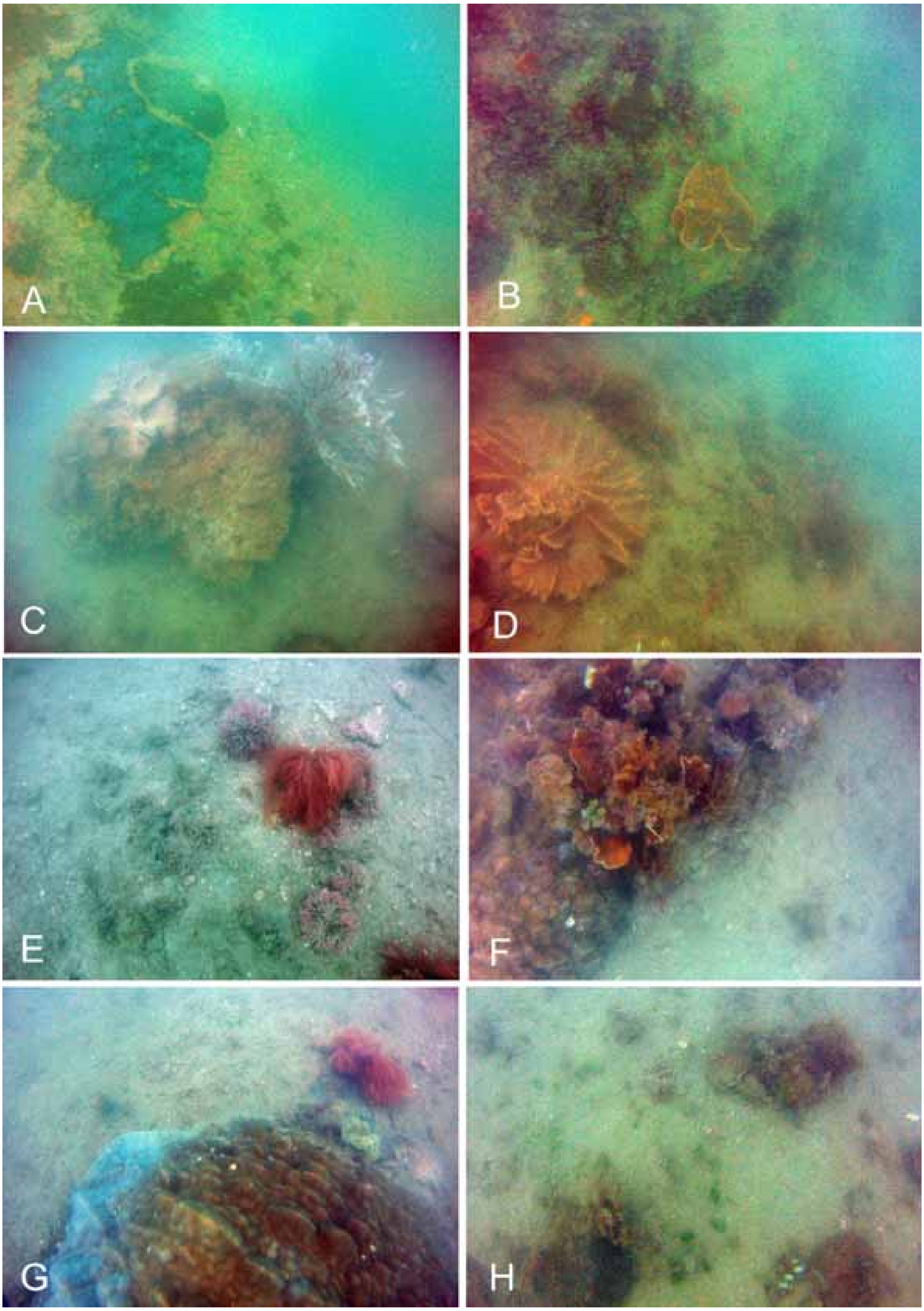

Figure 3-23 Photos from northern (A-B) and southern (C-H) reefal areas adjacent to the proposed channel extension: encrusting sponges corals and bryozoans (A,B);*Montipora, Subergorgia,* and *Sarcophyton* (C); *Lobophyton* (D); macroalgae including *Gracilaria* and *Amphiroa* (E); montiporid and poritid coral heads (F); partially bleached *Porites* (G); sponge and macroalgae with *Caulerpa* (H).

3.4.2.2 Soft-sediment Benthic (Infauna) Communities

Community Overview

A total of 54 benthic fauna taxa (i.e. macroinvertebrate species/morpho-species >1 mm) were collected in from the channel extension project area and surrounds. Most macro-fauna taxa were not very abundant, with 51 taxa (approximately 89% of taxa) represented by less than 5 individuals. The 10 most common abundant species are listed in Table 3-5, and a complete list of all taxa recorded is provided in Appendix A. The most common taxa included four families of carnivorous polychaete worms, tanaidacean shrimp, bivalve molluscs, brittle stars, and peanut worms. The patterns in dominance were similar to those of the outer harbour, DMPA and existing channel project areas.

Figure 3-25 shows the total number of animals recorded at each site (grouped by higher taxa). In the channel extension project area, fauna abundance at all sites was consistently dominated by polychaete worms and, to a lesser degree, crustaceans. At other inshore Magnetic Island sites (within sediment class 2a), there were similar numbers of polychaetes, but substantially more crustaceans and molluscs than at other sites surrounding the proposed channel extension arae.

Table 3-7 List of most common infauna species (i.e. >3 individuals collected) from the channel extension project area

Phylum	Class	Order	Taxon	Common name
Annelida	Polychaeta	Eunicida	*Eunice* sp.4	segmented worms
			Glyceridae sp 1	
			Goniadidae sp 1	
		Nereida	Nereidae sp 3	
		Sabellida	Sabellidae sp 1	
Crustacea	Malacostraca	Tanaidacea	Tanaidacea 6	
Mollusca	Bivalvia	Veneroida	Tellnidae 1	venus shell/clam
Echinodermata	Ophiuroidea	Ophiurida	Ophiuroidea 1	Brittle star
			Amphioplus 1	
Sipuncula	Sipunculidea	Golfingiiformes	Phascolionidae	peanut worm

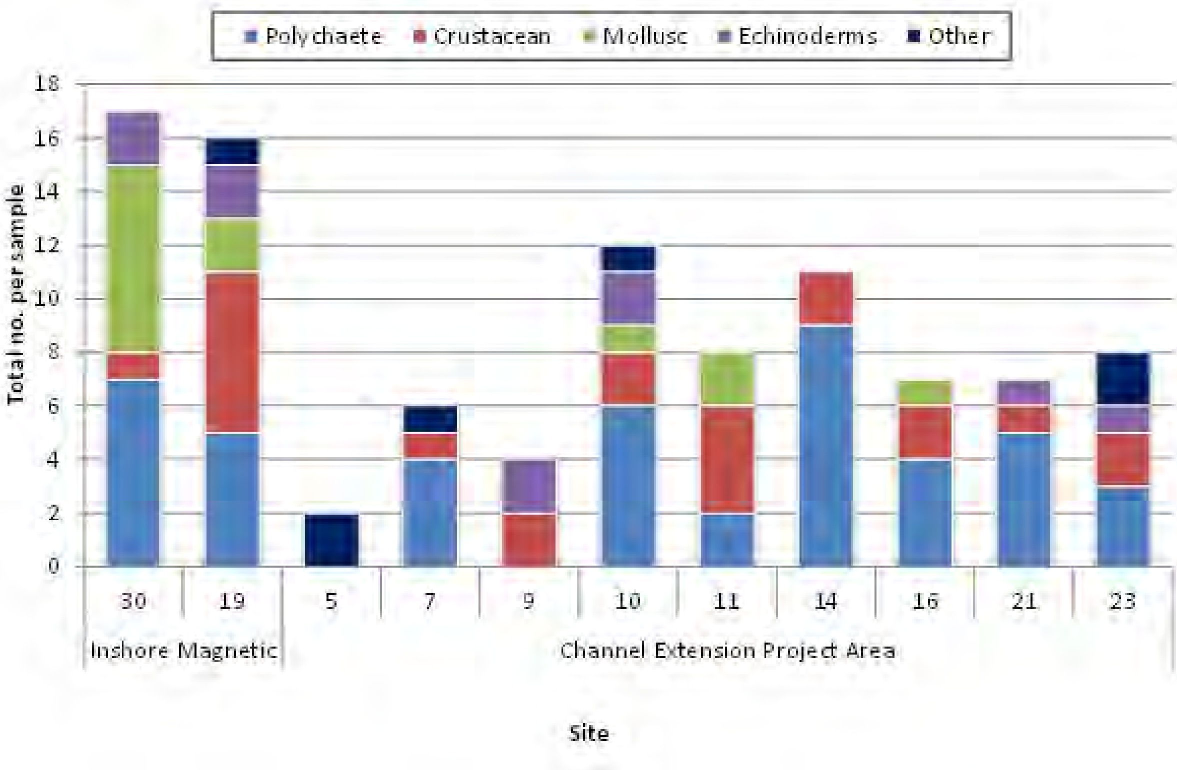

Figure 3-24 Proportion of each major higher taxon contributing to total abundance at each site

Abundance and Diversity

Macrobenthos communities of the channel extension project area and surrounds were depauperate. Almost 23% of samples contained no animals and ~16% of samples contained only 1 macroinvertebrate. Samples from the deeper depositional areas (samples 5, 7 and 9) were the least abundant, samples collected from class 2 and 3 habitats around the proposed channel extension were moderately abundant (sites 10, 11, 14, 16, 21, 23), and samples from the inshore Magnetic area (class 2a sediments) were the most abundant (Figure 3-24, Figure 3-25). These patterns in abundance were mimicked for richness (Figure 3-26). These low levels of richness and abundance are consistent with previous studies in Cleveland Bay (C&R Consulting 2007; GHD 2009).

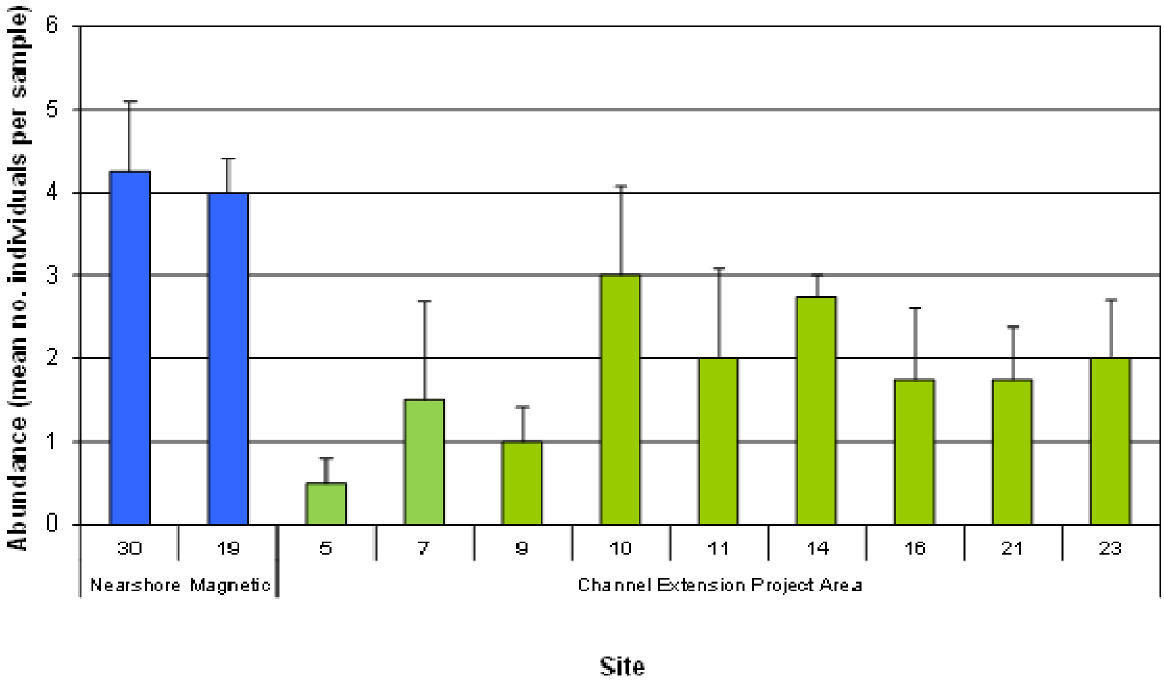

Figure 3-25 Mean (± SE) macroinvertebrate abundance at each site; inshore Magnetic Island sites are shown in blue and sites surrounding the channel extension are shown in green

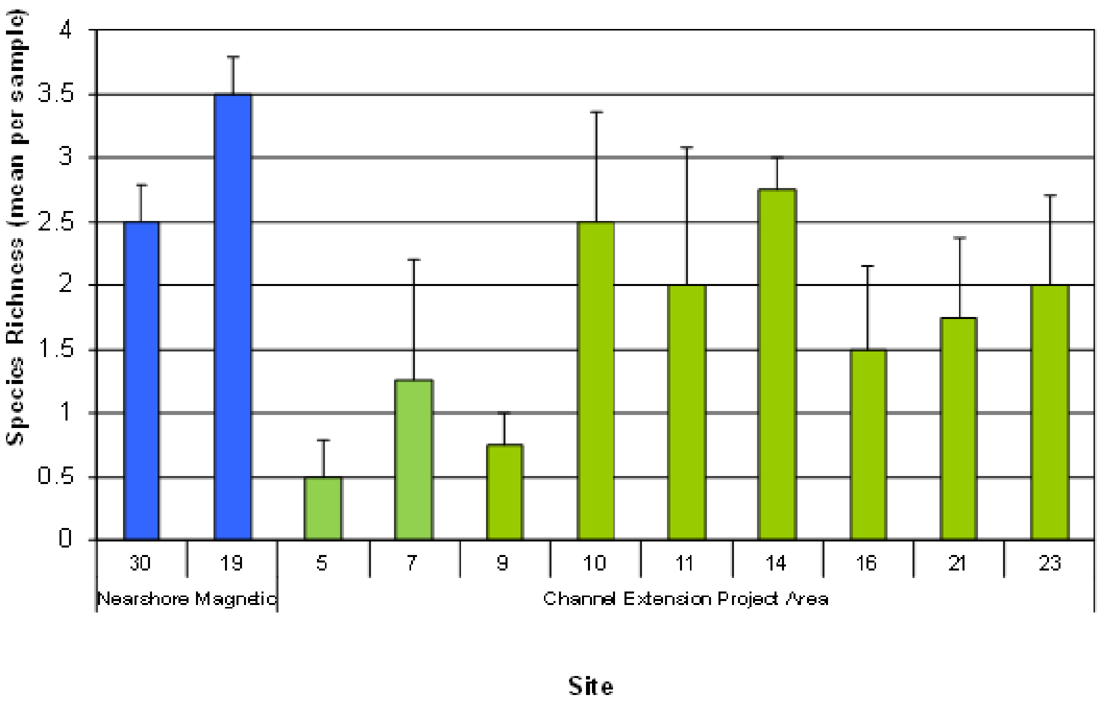

Figure 3-26 Mean (± SE) macroinvertebrate richness at each site; inshore Magnetic Island sites are shown in blue and sites surrounding the channel extension are shown in green

Community Trends

There was very little evidence of discrete communities occurring between various sediment types in the channel extension project area. There was a high degree of community overlap between locations (Figure 3-27) and differences among sediment types were not significant (ANOSIM Global R = 0.017, p = 0.19). Note that care should be used when interpreting these results because of the small number of animals collected; with greater replication differences in communities may have been apparent. However, it appears that the communities surrounding the channel extension project area in November 2011 were extremely depauperate, with the highest richness and abundance observed closer to Magnetic Island in coarser class 2a sediments.

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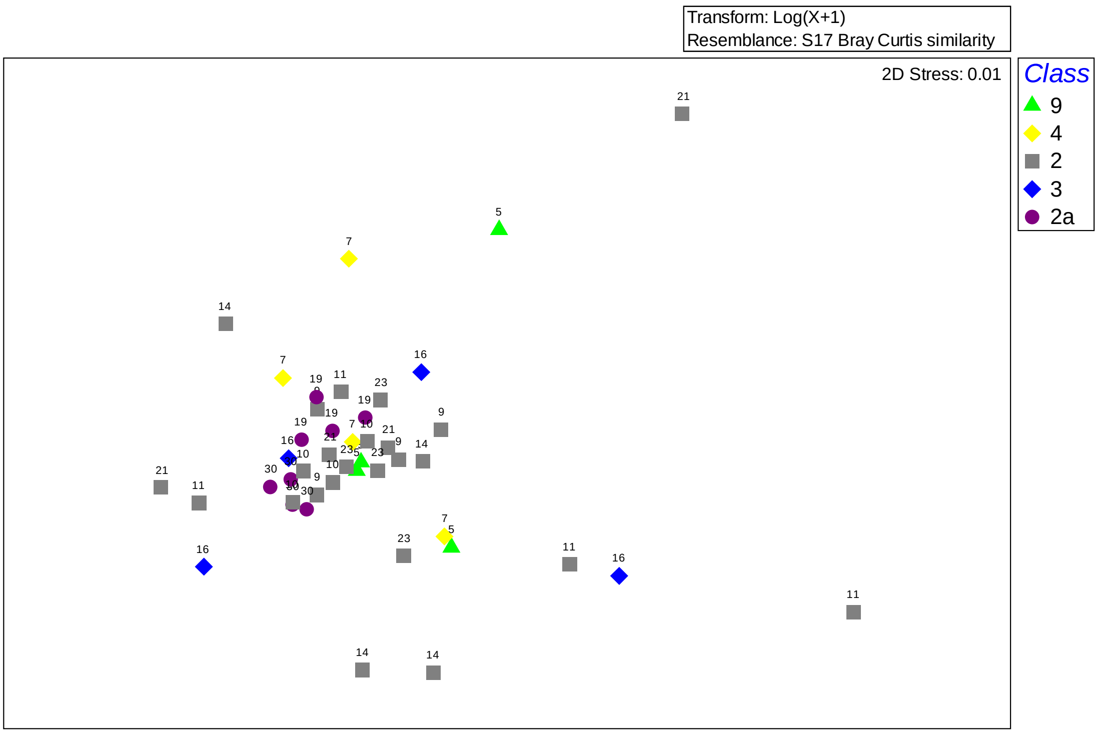


Figure 3-27 nMDS ordination of multivariate benthic infauna similarity among sediment classes

Table 3-8 Key benthic infauna species characterising samples collected at acoustic habitat classes in 2011

Class number	Colour Code	Sediment Description*	Key benthic infauna
2	grey	Mud with sand and occasional gravel	Ophiuroids Glyceridae 1 Tanaidacea sp1
2a	purple	Coarse sands with shell grit	Tellnidae sp1 Sabellidae sp1 Gammarid sp5
3	navy	Silty fine to medium sands	Nereidae sp 3 crab 1 Alpheid 1
4	yellow	Silt with fine sand	*Phascolion* sp1 *Glycera* sp1 *Eunice* sp1
6	orange	Silt with poorly sorted sands	Tellina 1
7	pink	Rock or coral with silt and sand	n/a
9	Green	Silt	*Phascolion* sp1

Temporal Trends

It is known that the benthic communites of Cleveland Bay are dynamic and can show greatly variability over time. Studies by Cruz-Motta (2000) and Cruz-Motta and Collins (2004) at the DMPA and surrounds found that although there was little evidence of long-term changes in communities, but changes occurred over time, including in response to dredged material disposal (reduction in diversity and abundance inside the DMPA). Cruz-Motta and Collins (2004) found that communities rapidly recolonised the DMPA within months of dredged material disposal, which would be a necessary adaptation for dynamic environments such as those in Cleveland Bay.

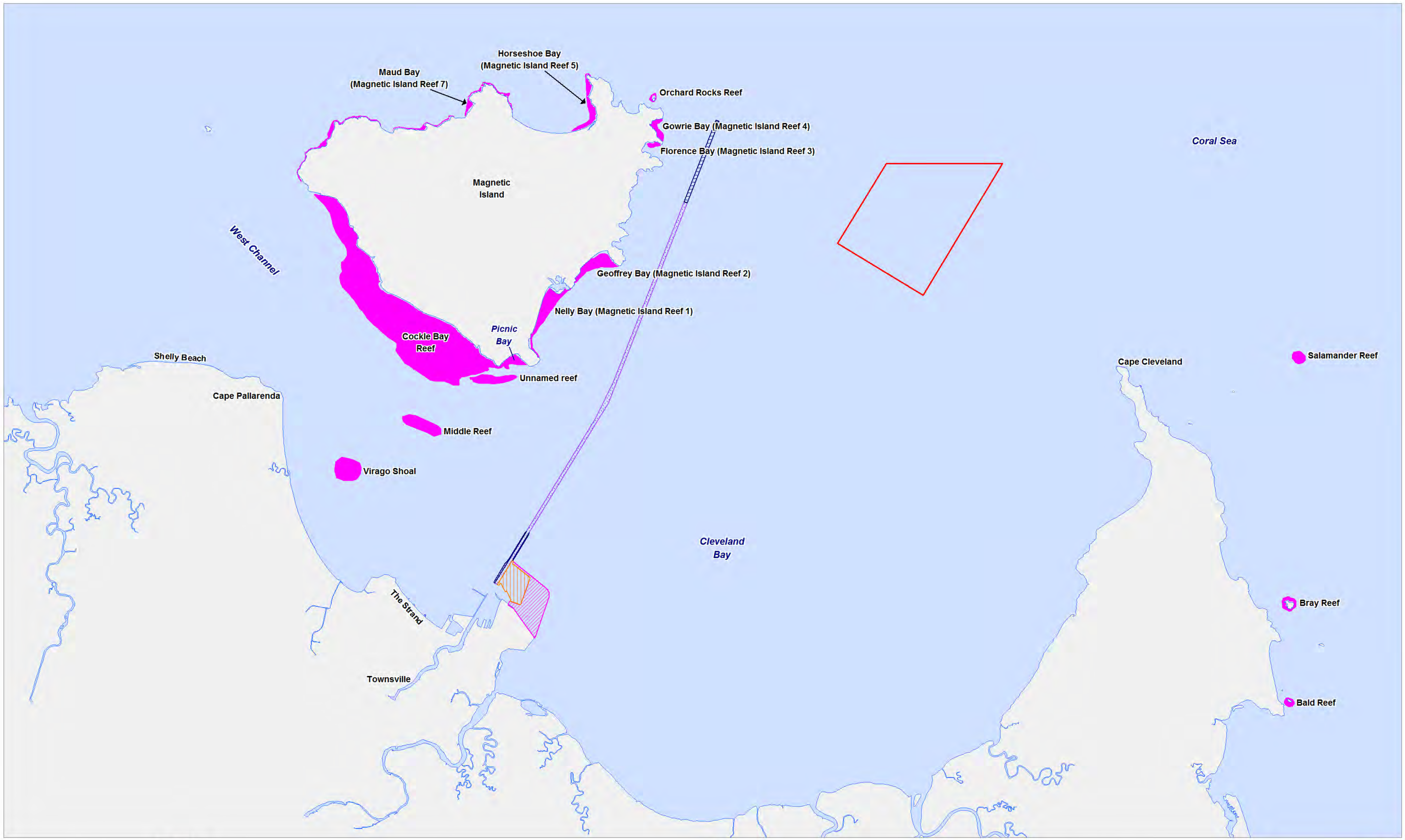
3.5 Reef Habitats and Communities

3.5.1 Natural Reef Habitats

Coral reefs form a benthic primary producer habitat. Based on mapping from the GBRMPA Gazetteer, the total area of reef habitat within Cleveland Bay is approximately 987 hectares (Figure 3-28;Table 3-9). Reef habitats in Cleveland Bay include shallow fringing reefs and rocky shores around Magnetic Island; the well-developed reef platform of Middle Reef; and smaller, less developed reef areas between the mainland and Magnetic Island (e.g. Virago Shoal) (Table 3-9).

Habitat characteristics of reefs vary greatly among locations, reflecting differences in reef morphology. In this regard (Table 3-9):

- The north coast of Magnetic Island is mostly rocky (granite), with volcanic outcrops near West Point. Small fringing reefs have developed in sheltered (western) sections of Maud and Wilsons Bays (north east coast), and adjacent to rock headland on the eastern side of Horseshoe Bay (Pringle 1989). A narrow reef has also been mapped by GBRMPA along the entire rocky coast between western Horseshoe Bay and West Point.
- The south-east coast of Magnetic Island is comprised of a series of granite promontories separated by embayments. These embayments are smaller on the northern sector of the coast (Alma, Arthur, Florence, Gowrie) than those in the southern part (i.e. Picnic, Nelly and Geoffrey Bays). Fringing reefs have developed around these rock headlands, with the largest reefs found in the largest embayments (i.e. Picnic, Nelly and Geoffrey Bays). Bayhead sandy beaches have developed above the low water mark at most bays, and extend onto the upper intertidal zone on most of these reef flats.
- The south coast of Magnetic Island (Cockle Bay) contains an extensive intertidal/shallow subtidal coral reef flat, which is covered by fine sand, mud, seagrass and patches of bare (coral) reef substrate.
- Middle Reef is an elongated structure comprised of four inter-connected reef patches that are aligned with the dominant north-westerly currents. It extends from minus four metres below LAT to sea level, and contains both reef slope and reef flat habitats (Browne 2010). Virago Shoal is located to the south west of Middle Reef, offshore of Rowes Bay. This shoal contains a mosaic of reef patches and sediments.



LEGEND

- DMPA
- New channel areas to be dredged
- Existing channel to be deepened
- Harbour basin
- Reclamation area
- Coral Reefs

Title:
Distribution and extent of reefs within Cleveland Bay as mapped in the GBRMPA Gazetteer

Figure: **3-28**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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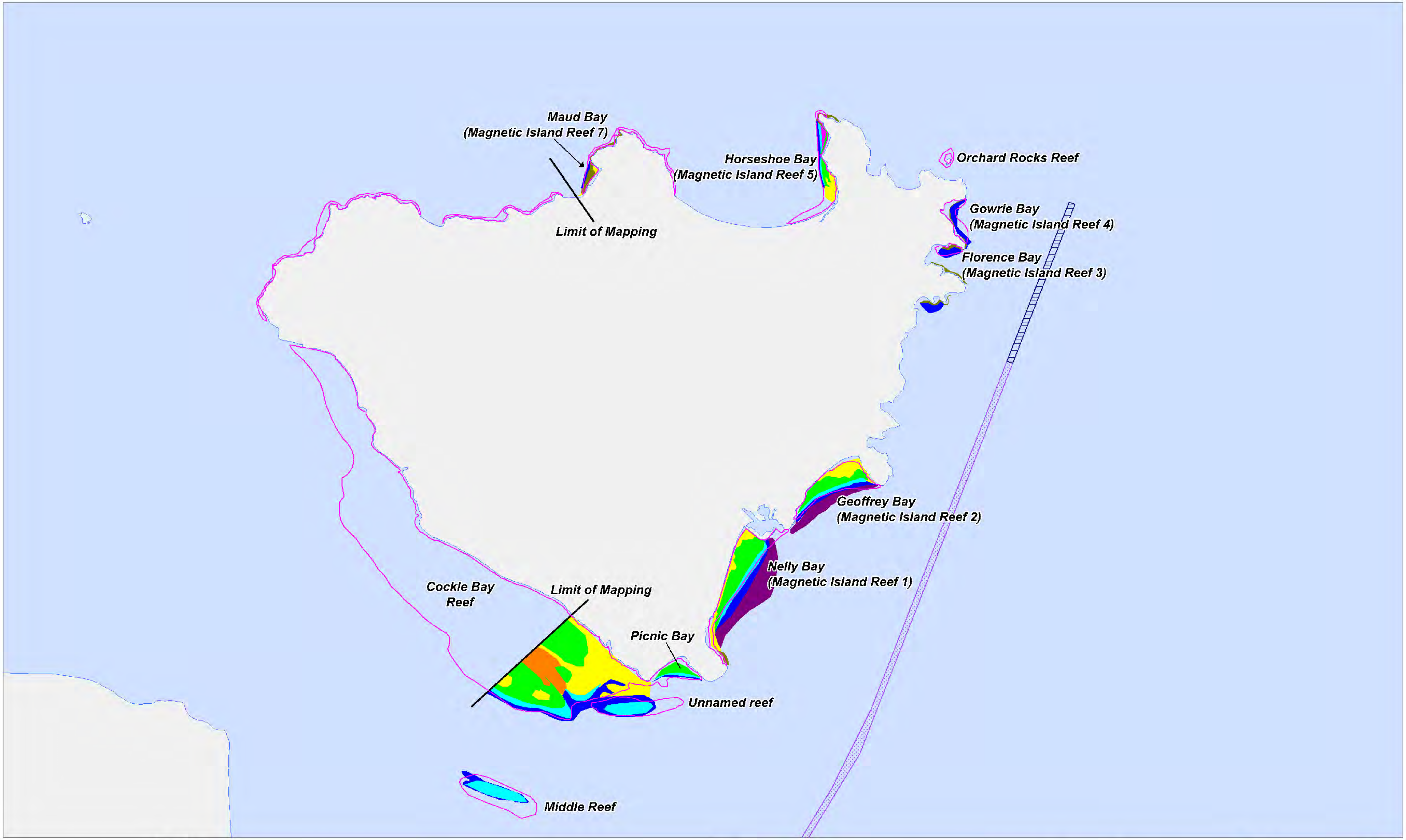

LEGEND

- New channel area to be dredged
- Existing channel to be deepened
- Coral Reefs (GBRMPA Gazetteer)
- Reef Flat with Soft Coral and Algae
- Granite Boulders With Occasional Coral and Algae
- Unconsolidated Reef Flat
- Reef Flat with Macroalgae
- Scattered Micro-atolls
- "Reef Crest"
- Reef Slope
- Occasional Bomboras and Scattered Rubble

Title:
Reef community types around eastern Magnetic Island and Middle Reef

Figure: 3-29

Rev: A

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Cleveland Bay therefore supports a network of near-shore reefs, and which have different levels of inter-connectivity, habitat structure and are regulated by different water quality processes (see below). At broader spatial scales, Cleveland Bay reefs form part of an extensive system of nearshore reefs within the *Coastal Central Reefs Bioregion* (GBRMPA 2012a). Nearby nearshore reef systems include Herald Island, Bramble Rock Reef, Cordelia Rocks Reef, Acheron Reef and the Palm Island group to the northwest of Cleveland Bay, and Salamander, Bray and Bald Reefs around Point Cleveland.

Table 3-9 Cleveland Bay reefs mapped in the GBR Gazetteer

Locality	GBRMPA Gazetteer Name and Number	Description	Area (ha)
Magnetic Island – north coast	Magnetic Is. Reefs No. 6-8 (19-009H, G and J)	Narrow reef system extending from West Point to Horseshoe Bay	41
	Magnetic Is. Reef No. 5 (19.009F)	Broad fringing reef located in eastern Horseshoe Bay	25.7
	Orchard Rocks Reef (19-006)	Fringing reef surrounding a granite outcrop	3.11
Magnetic Island – south-east coast	Magnetic Is. Reef No. 3 (19-009D) and 4 (19-009E)	Rocky shore and fringing reef at Florence Bay	17.6
	Magnetic Is. Reef No. 2 (19-009C)	Rocky shore and fringing flat at Geoffrey Bay	37.4
	Magnetic Is. Reef No. 1 (19-009B)	Rocky shore and fringing flat at Nelly Bay	48.5
Magnetic Island – south coast	Cockle Bay Reef (19-009A) U/N Reef (19-010)	Extensive intertidal and shallow subtidal reef flat extending from Picnic Bay to West Point	810.3
Southern Cleveland Bay	Middle Reef (19-011)	Reef system south of Cockle Bay Reef	40.6
	Virago Shoal (19-012)	Shoal system offshore of Rowes Bay	47.1

The hard corals, algae, seagrasses and invertebrates of the reef habitats provide important shelter, protection and food for numerous fish species of commercial and recreational value. These include species such as coral trout, snapper (lutjanids), sweetlip (lethrinids), trevally (*Caranx* spp.) and red emperor (*Lutjanus seabae*) (Ludescher 1997).

3.5.2 Reef Communities

3.5.2.1 Spatial Patterns – Previous Studies

Background data describing coral and reef communities have been collected by researchers and consultants to monitor changes in reef condition over time, and to inform environmental impact assessments (Bull 1982; Mapstone *et al*. 1989; Pringle 1989; SKM 1991; Kaly *et al*. 1993; 1991; Stafford-Smith *et al*. 1993; C&R Consulting 2008; AIMS 2010).

At least 258 species of hard corals were recorded on reefs in Cleveland Bay and surrounds by Stafford-Smith and Veron (1992). This represents over half of the total number of hard coral species recorded in the Great Barrier Reef (405 hard coral species; see Fabricius 2009). Rapid coral surveys carried out by Stafford-Smith and Veron (1992) indicated that Cleveland Bay reefs (i.e. Florence, Arthur, Geoffrey, Nelly Bay, Middle Reef) generally had lower total numbers of hard coral species than most other nearshore reefs (Bay Rock, Rattlesnake Island, Herald Island). Within Cleveland Bay, Middle Reef had the lowest number of species recorded (79 species) and Florence Bay had the highest (117 species). Sampling effort was not standardised, with a distance of >400m covered at most sites except Rattlesnake Island (additional 500 m searched) and Herald Island (total of two kilometres searched), hence spatial patterns in biodiversity cannot be inferred from these data.

The Museum of Tropical Queensland contains records for 87 hard coral species, from 24 genera and 10 families within Cleveland Bay (C&R Consulting 2008). This is an under-estimate of total species richness in Cleveland Bay, noting that Browne *et al*. (2010) recorded 81 species from 28 genera at Middle Reef alone (including 26 species yet to be identified), and noting that Stafford-Smith and Veron (1992) recorded 158 species during rapid surveys in Cleveland Bay (Table 3-10). The number of hard coral species reported by Browne *et al*. (2010) was similar to Stafford-Smith and Veron (1992) at Middle Reef (94 species), however given differences in sampling effort, it is not possible to quantify whether species richness has remained relatively stable over the last 15 years.

On a GBR wide scale, the species richness recorded on Cleveland Bay reefs was considered to be moderate (e.g. c.f. De Vantier *et al*. 2006). This level of biodiversity is remarkable given the frequent disturbance from floods and bleaching events, and the close proximity of reefs to the major urban centre of Townsville.

Table 3-10 Number of hard coral species recorded in rapid surveys December 1992 (Source: Stafford-Smith and Veron 1992)

Location	Reef	No. hard coral species	No. hard coral genera
Cleveland Bay	Florence Bay	138	43
	Arthur Bay	119	40
	Geoffrey Bay	124	42
	Nelly Bay	116	39
	Middle Reef	94	40
	TOTAL	158	49
Adjacent areas	Bay Rock	128	40
	Rattlesnake Is.	245	60
	Herald Is.	222	55

C&R Consulting (2008) classified reefs into the following based on the relative cover of hard corals and macroalgae:

- Middle Reef, Nelly Bay West and Arthur Bay with very high live coral cover and low algal cover;
- Nelly Bay East and Florence Bay with lower live coral cover and relatively low algal cover; and
- Picnic Bay, Geoffrey West and Geoffrey East, where live coral cover was relatively low and similar to algal cover at the surveyed sites.

The cover of hard corals in Cleveland Bay has generally been highest at Middle Reef, where cover averages around 50% and varies between 19.3 and 83.8% over different parts of the reef (Sinclair Knight 1991; Kaly *et al.*1993; AIMS 2010; Browne *et al*. 2010).

The fringing reefs of Magnetic Island typically have highest hard coral cover along the reef slopes, while the reef flats are dominated by macroalgae and seagrass (seagrass is extensive at Cockle Bay Reef, see Section 3.2). The growing margin of these reefs extends seawards while the landward margins are backfilled with sediment and debris (Sinclair Knight 1991).

Coral cover in Florence and Arthur Bays was similar to Middle Reef, averaging between 55 and 62%, while cover at Nelly and Geoffrey Bays was much lower at approximately 35% (Kaly *et al.*1993). While the community composition is similar among many of these locations, faviid and fungiid corals have been relatively abundant at Florence and Arthur bays, sponges were relatively abundant at all Magnetic Island locations, and acroporids, pocilloporids, montiporids were relatively abundant at Middle Reef (Kaly *et al.*1993).

The three most abundant hard coral genera recorded on Cleveland Bay Reefs were *Acropora*, *Montipora, Turbinaria* (Kaly *et al.*1993; C&R Consulting 2007; Browne *et al*. 2010), with pattrns in relative abundance varying among reefs. C&R Consulting (2007) found that reefs with high coral cover were typically numerically dominated by Acroporidae corals, except at Arthur Bay which had a high cover of fungiid and other hard coral species.

Benthic community structure also varies within reefs, in response to changes in water depth, reef morphology, orientation and degree of wave/current exposure. Surveys by Browne *et al*. (2010) at Middle Reef found that despite both genera being ubiquitous across habitats, *Acropora* was most abundant on the outer and inner reef slopes, whereas *Montipora* was numerically dominant at the edge of the inner reef flat and windward reef edge. Browne *et al*. (2010) identified the following community types at Middle Reef, which broadly divided on differences geomorphic and hydrodynamic settings:

- Type 1 – characterised by high coral cover (71%) and low macro-algal cover (3.8%), which was located on windward reef slope and exposed sections of the eastern linear basin (i.e. exposed windward slope);
- Types 2 and 3 – characterised by medium coral diversity and medium to high coral cover (21%), was confined to the protected environ containing high micro-habitat complexity (i.e. semi-protected leeward slope);
- Types 4 to 6 – characterised by low coral cover (<20%) and high macro-algal cover, which were confined to sheltered reef habitats where sediment cover was high (i.e. inner basin slopes and reef flat).

Similar broad changes in community structure among different morphological settings were reported on Magnetic Island reefs. In this regard, reef flat habitat, which is especially well represented on

Cockle Bay reef, typically has high percentage cover of sediment and macroalgae, but low hard coral cover. The reef slope on most Cleveland Bay reef had the highest hard coral cover, varying in composition among depths and reefs.

3.5.2.2 2011-12 Spatial Patterns

Taxa Richness

Reef community surveys carried out in 2012 recorded a total of 37 hard coral genera on video transects. The highest number of coral genera recorded on transects was at Horseshoe Bay (25 genera) and Cockle Bay (23 genera), and the lowest number of genera was recorded at Nelly Bay (10 genera) and Florence Bay (13 genera)[6]. The mean number of log transformed number of coral genera per transect differed significantly among locations (ANOVA $F_{6,33}$ = 2.74; p = 0.028), with highest richness recorded at Cockle Bay and Horseshoe Bay, but no consistent differences among other locations (Table 3-11). Patterns in hard coral genera richness varied inconsistently between slope and crest strata among locations (Figure 3-30).

Table 3-11 Hard coral genera richness at each site and strata

Location	Average ± S.E. no. genera per 30 transect			No. genera recorded
	Total	Crest	Slope	
Five Beach Bay	6.0 ± 1.82	8.0 ± 4.00	10.5 ± 1.86	18
Horseshoe Bay	9.7 ± 1.20	10.0 ± 1.73	6.8 ± 2.03	25
Florence Bay	6.5 ± 1.31	6.0 ± 1.15	6.0 ± 2.65	13
Geoffrey Bay	6.8 ± 1.02	5.0 ± 1.00	6.5± 1.15	16
Nelly Bay	4.8 ± 0.31	5.0 ± 0.00	6.3 ± 0.67	10
Cockle Bay	10.5 ± 0.67	10.3 ± 1.20	7.3 ± 0.88	23
Middle Reef	6.3 ± 0.84	4.7± 0.88	9.7± 0.00	15

Figure 3-30 shows that taxa richness of all benthic biota generally reflected patterns in hard coral richness. In this regard, Cockle Bay and Horseshoe Bay had higher average numbers of benthic cover groups than most sites, the exception being the crest and slope strata of Five Beach and Geoffrey Bays, respectively. The consistency in spatial patterns between hard corals and total benthos was not unexpected given that hard corals were a dominant component of the reef benthos, and that a greater level of taxonomic precision (genera) was adopted for hard corals compared to other groups.

Coral Cover

Figure 3-38 shows the total percentage cover of hard coral families and soft coral at each location (strata pooled). Figure 3-33, Figure 3-34 and Figure 3-35 shows the mean percentage cover of different coral taxa. Patterns in numerical dominance of hard coral families varied among locations, as follows:

[6] The methodology used in the present assessment aimed to quantify patterns in reef community structure, condition and potential sensitivity to disturbance, rather than compiling a taxonomic list of hard coral species at each reef. For this reason, it is not meaningful to directly compare these results to previous taxonomic surveys.

- Acroporidae numerically dominated at Middle Reef, and Florence, Geoffrey and Horseshoe Bays. *Acropora* was the numerically dominant hard coral genus at Horseshoe Bay (Figure 3-33). Confamiliar *Montipora* was the numerically dominant coral genus at Middle Reef, Florence and Geoffrey Bays, and was sub-dominant to *Acropora* at Horseshoe Bay (Figure 3-34).
- Faviidae was co-dominant with Dendrophyllidae (mostly *Turbinaria*) at Cockle Bay, and Poritidae and Acroporidae at Florence Bay, and was also abundant at Middle Reef.
- Dendrophyllidae (almost exclusively *Turbinaria*) was the dominant hard coral at Nelly Bay, and was abundant at Cockle Bay and Middle Reef.
- Soft corals were a minor part of the benthos at most locations, the exception being Horeshoe Bay and to a lesser extent Five Beach Bay.

The numerical dominance of the *Acropora, Monitpora* and (to a lesser extent) *Turbinaria* in Cleveland Bay coral assemblages has been reported by others (e.g. Kaly *et al.*1993; C&R Consulting 2007; AIMS 2010; Browne *et al*. 2010). It is difficult to directly compare these results with previous studies, given differences in sampling methods and site placement by different workers. However the following broad comparisons can be drawn from three representative reef locations:

Geoffrey Bay

Kaly *et al*. (1993) found that mean hard coral cover was approximately 30% ± 5 (S.E). Thompson *et al*. (2011) found that hard coral cover ranged from 15 to 21% at the 2 m strata, and 25-28% at the 5 m strata (Figure 3-39). C&R Consulting (2007) also noted that hard coral in Geoffrey Bay was lower than other reefs in Cleveland Bay, with mean percentage cover ranging from approximately 25% ± 8 (S.E.) at Geoffrey Bay East and approximately 29% ± 8 (S.E.) at Geoffrey Bay West. In the present study, total hard coral cover was 16% overall, with a mean cover of 11.2% ± 0.15 (S.E) recorded in the reef crest (approximately similar to 2 m strata of Thompson *et al*. 2011), and 20.8% ± 7.67 (S.E) at the reef slope (approximately equivalent to the 5 m strata of Thompson op cit.). It is noted that coral cover at Geoffrey Bay is patchy at the scale of metres to 10's of metres, ranging in the present study between seven and 33%, which further confounds direct comparisons among studies. However in broad terms, the percentage cover of hard corals recorded at Geoffrey Bay in 2012 was within the range recorded previously.

Patterns in the relative abundance of corals at Geoffrey Bay were relatively similar between the present study and previous studies by Kaly *et al*. (1993), Thompson *et al*. (2011) and C&R Consulting (2007). All studies recorded a dominance of Acroporidae, with Faviidae, Poritidae and other corals less common.

Nelly Bay

Kaly *et al*. (1993) found that mean hard coral cover at Nelly Bay was approximately 42% ± 5 (S.E). The mean percentage cover of coral recorded by C&R Consulting (2007) ranged from approximately 65% ± 8 (S.E.) at Nelly Bay West and approximately 50% ± 8 (S.E.) at Nelly Bay East. These results indicate that there is great variability in hard coral cover at scales measured in 100's of metres.

In the present study, mean hard coral cover was 13% ± 6 (S.E) at the reef crest, and 10% ± 0.7 (S.E) at the reef slope. These values were therefore far lower than recorded previously at this location. In terms of relative abundance of corals:

- C&R Consulting (2007) recorded high cover of Acroporidae (approx. 29-38%), followed by Poritidae (approx. 2-5%) and Faviidae (approx. 3-4%). "Deep water corals" and Fungiids were rare, and *Turbinaria* cover was not notably high.
- Kaly *et al*. (1993) recorded far lower "Acroporid[7]" and *Montipora* cover than C&R Consulting (combined cover approx. 10%), but far greater cover of *Turbinaria* (approx. 22%). Both studies recorded low cover (<3%) of Faviids, Poritids, Fungiids and soft corals.
- Patterns in relative abundance of corals observed in the present study (Figure 3-33) were the same as that recorded by Kaly *et al*. (1993): *Turbinaria* > Acroporidae > Faviidae = Portunids = Fugiids = other hard corals (e.g. Agariciidae) and soft corals. However, the present study found recorded far lower cover of *Turbinaria* (mean = 7.7% c.f. 22%) and Acroporidae (2.2% c.f. 10%) than Kaly *et al*. (1993).

These results demonstrate that the cover of most massive corals was consistently low, whereas there are great differences among studies in *Turbinaria* and Acroporid coral cover. Acroporid coral cover can show great variation over time, being sensitive to physical disturbance, but also capable of high growth rates and therefore capacity to recover following disturbance (see temporal patterns discussion below). *Turbinaria* is a moderately fast growing coral (0.7-1.5 cm/year recorded by Browne 2012), but can be susceptible to physical disturbance during major storms and cyclones. While it is possible that there was a large increase in *Turbiniaria* and decrease in Acroporidae cover between the C&R Consulting (2007) and the present study, it is probably more likely that differences in the position of transects accounted for differences between studies.

Middle Reef

Middle Reef is known to support highly abundant hard coral communities. Kaly *et al*. (1993) recorded a mean hard coral cover of approximately 62%, similarly C&R Consulting (2007) recorded a mean hard coral cover of approximately 78% ± 11% (S.E.). In the period 2005-2011, Thompson *et al*. (2011) found that hard coral cover was between approximately 45% and 52% at the permanent transect located at the 2 m depth stratum. As discussed above, there are distinctly different reef community types at Middle Reef (Browne *et al*. 2010), and it would appear that Kaly *et al*. (1993) and C&R Consulting (2007) sampled the particularly abundant coral community type (possibly Browne *et al*.'s Type 1 community, found on exposed windward slope of Middle Reef). The present study sampled sections of Middle Reef containing Browne *et al*.'s Type 2 and 3 (semi-protected slope) and 4 to 6 (reef flat and inner basin slopes) communities. The mean hard coral cover values recorded in the present study (19-21%) was consistent with Browne *et al*. (2010) for these community types.

Patterns in the relative abundance of corals at Middle Reef were relatively similar between the present study and previous studies by Kaly *et al*. (1993), Thompson *et al*. (2011) and C&R Consulting (2007). All studies recorded a dominance of Acroporidae, with Faviidae, Poritidae and other corals less common.

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[7] Kaly *et al*.'s "Acroporid" group included *Acropora, Astreopora* and Pocilliloporidae, but did not include the Acroporid *Montipora*

Other Benthic Groups

In the present study, the dominant benthic cover groups at all sampling locations were macroalgae, turfing algae and bare substrate categories (sand and rubble) (Figure 3-32). Sand cover was highest at Nelly, Horseshoe and Cockle Bay (17-18% cover), and Five Beach Bay (11%). Rubble was the dominant benthic category at Five Beach Bay (28%), and also high at Florence (26%), Nelly (19%) and Horseshoe Bay (15%). Such high cover of sand and rubble on reef slope and crest habitats have not been reported by other workers. Recently dead corals comprised a small proportion of the reef benthos at all locations (Figure 3-35).

Macroalgae and turfing algae were also abundant at all surveyed locations (Figure 3-36; Figure 3-31). *Sargassum* was particularly abundant at east coast reefs (Florence 45%; Geoffrey 47%; Nelly 26%), but less so at the northern reefs (8-10%) and the southern reefs (Cockle 10%; Middle <1%). Turf algae were less abundant at east coast reefs (5-15%) than northern reefs (19-21%), and the southern reefs (Cockle 22%; Middle Reef 39%). *Laurencia* and *Lobophora* were found in moderate abundance, varying among locations.

Algae cover in the present study was higher than recorded previously:

- At Middle Reef, Kaly *et al*. (1993) and C&R Consulting (2007) recorded a mean 'algae' cover of approximately 6-7%. Browne *et al*. (2010) found that macroalgae cover was 18% on the reef flat, 6% at 2 m LAT, and 10% between 2 and 3.7 m LAT. Long term annual monitoring by AIMS (2010) recorded a mean macroalgae cover ranging from approximately 5-12%, and mean turf algae cover of 19 to 45%. In the present study, mean macroalgae cover was 18 and 19% in crest and slope stratum, respectively, which was slightly greater than recorded in previous studies.
- In terms of the eastern reefs, Kaly *et al*. (1993) recorded a mean 'algae' cover of approximately 10% at Nelly Bay, 12% at Geoffrey Bay, 15% at Florence Bay. C&R Consulting (2007) recorded a mean 'algae' cover of approximately 10-22% at Nelly Bay, 19-20% at Geoffrey Bay and 10% at Florence Bay. Mean macroalgae cover in the present study was typically double that recorded previously at Florence and Geoffrey Bays, but only slightly higher than recorded previously at Nelly Bay.

These results suggest that macroalgae cover, as well as the proportion of sand and rubble substrate, are higher than recorded previously. There are two possible, not necessarily mutually exclusive, explanations for this:

1. Macroalgae and bare substrate cover had increased in recent times. Macroalgae can rapidly colonise bare substrate, and can form a dense cover following disturbance to coral reefs (Done 1999). As previously discussed, the two to three year period leading up to sampling had above average rainfall, and the reefs of Cleveland Bay experienced physical disturbance from Cyclone Yasi in February 2011. Thomson *et al*. (2011) reported that most macroalgae at Geoffrey Bay had been removed by Cyclone Yasi in 2011, however since this time it is apparent that macroalgae has proliferated. High macroalgae cover on coral reefs is typically a transient feature (Done 1999), however prolonged periods of high nutrients can result in persistent macroalgae cover, resulting in reduced coral reef resilience (Hughes *et al*. 2007). Temporal patterns in communities are discussed further below.

2. Differences are due to sampling error. It is also possible that differences in sampling effort and transect placement may partly explain differences between studies. The present study used a completely randomised sampling design that did not preferentially sample areas with high or low cover. It is also noted that the number of sample points per transect (and therefore accuracy) was far greater in the present study than many previous studies.

Community Similarity

The ordination presented in Figure 3-37 shows that sites tended to group into the following broad locations

- Western Magnetic Island reef sites (left side of ordination). These sites grouped together at the 60% Bray-Curtis similarity level;
- Northern Magnetic Island sites (centre of the ordination). These sites grouped together with western Magnetic Island sites at the 55% similarity level.
- Southern Magnetic Island sites (right side of ordination). These sites tended to group towards the centre and right side of the ordination, with most sites grouping at the 53% similarity level.

These multivariate results indicate that reef communities vary at broad among reef scales, but that there is also variability at the within-reef scale (i.e. among transects and among depth strata). This variability at multiple spatial scales has important implications from the perspective of monitoring future changes in reef communities (i.e. selection of sampling sites, numbers of sites, site stratification). These variations in community structure are consistent with patterns in cover described above, and the findings of previous surveys.

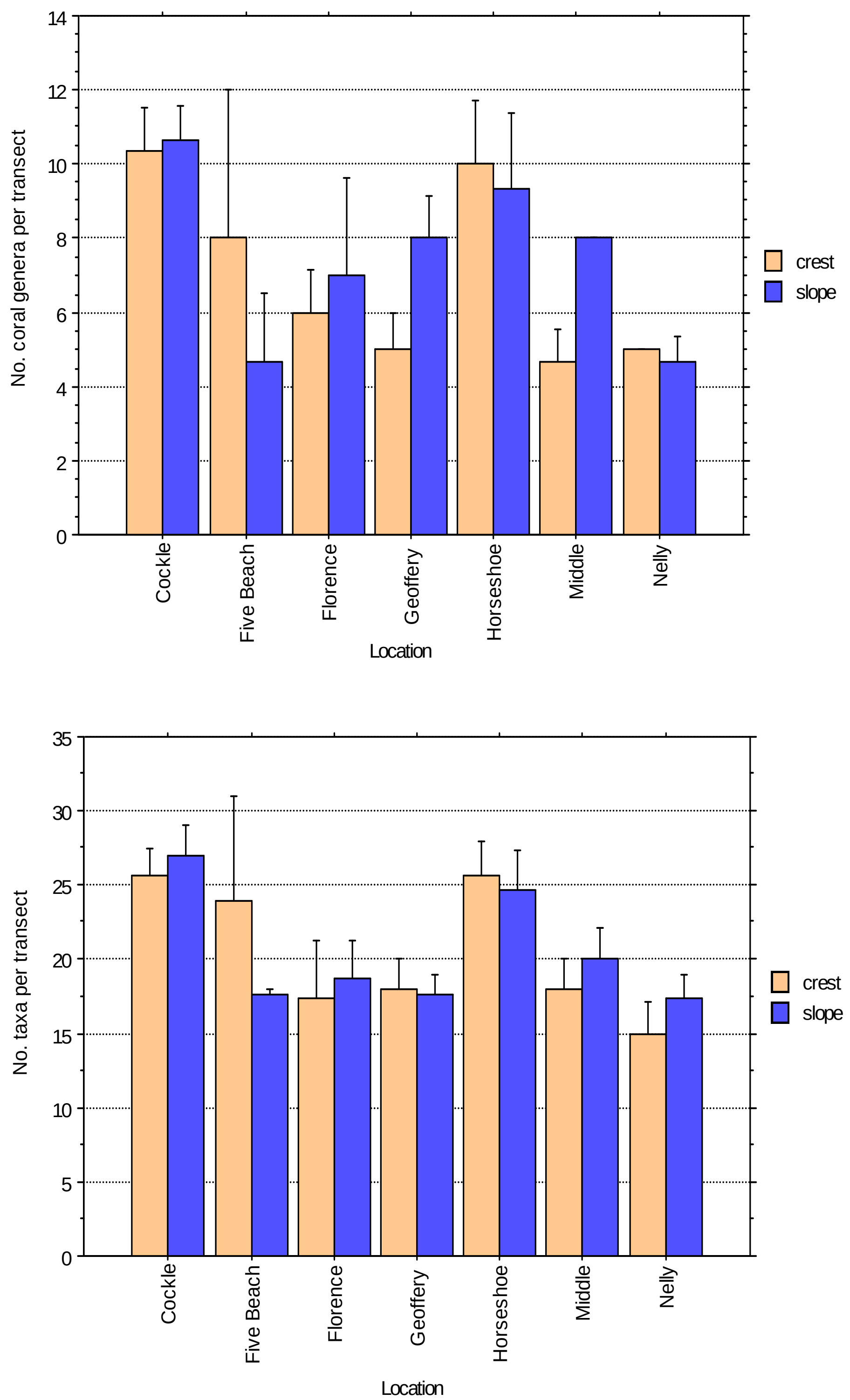


Figure 3-30 Mean (error bars ± S.E.) number of hard coral genera (upper plot) and all reef taxa (lower plot) recorded on 30 m transects at each strata and location – 2012

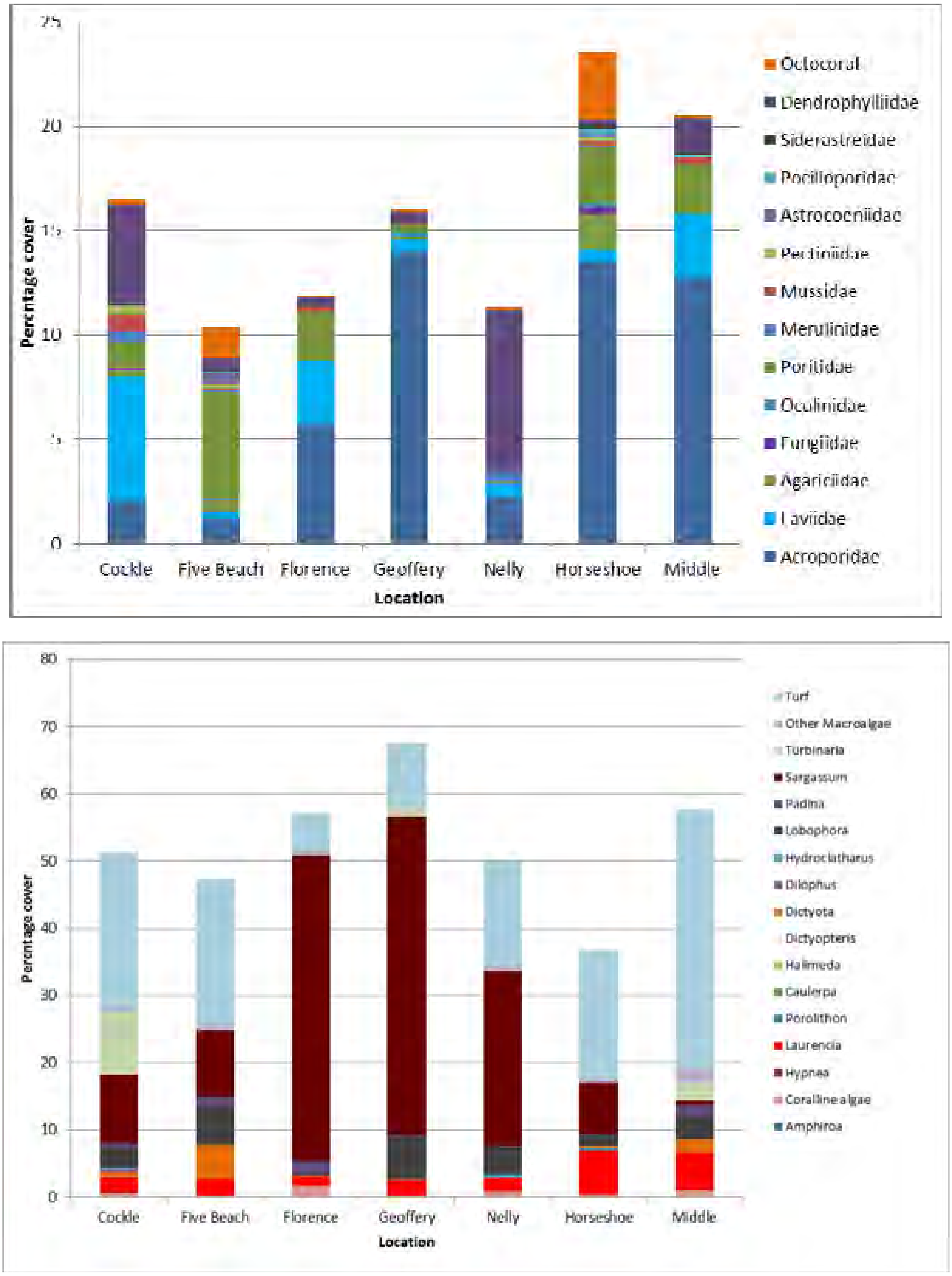


Figure 3-31 Total percentage cover of hard coral families (upper plot) and algae taxa (lower plot) recorded at each location – 2012

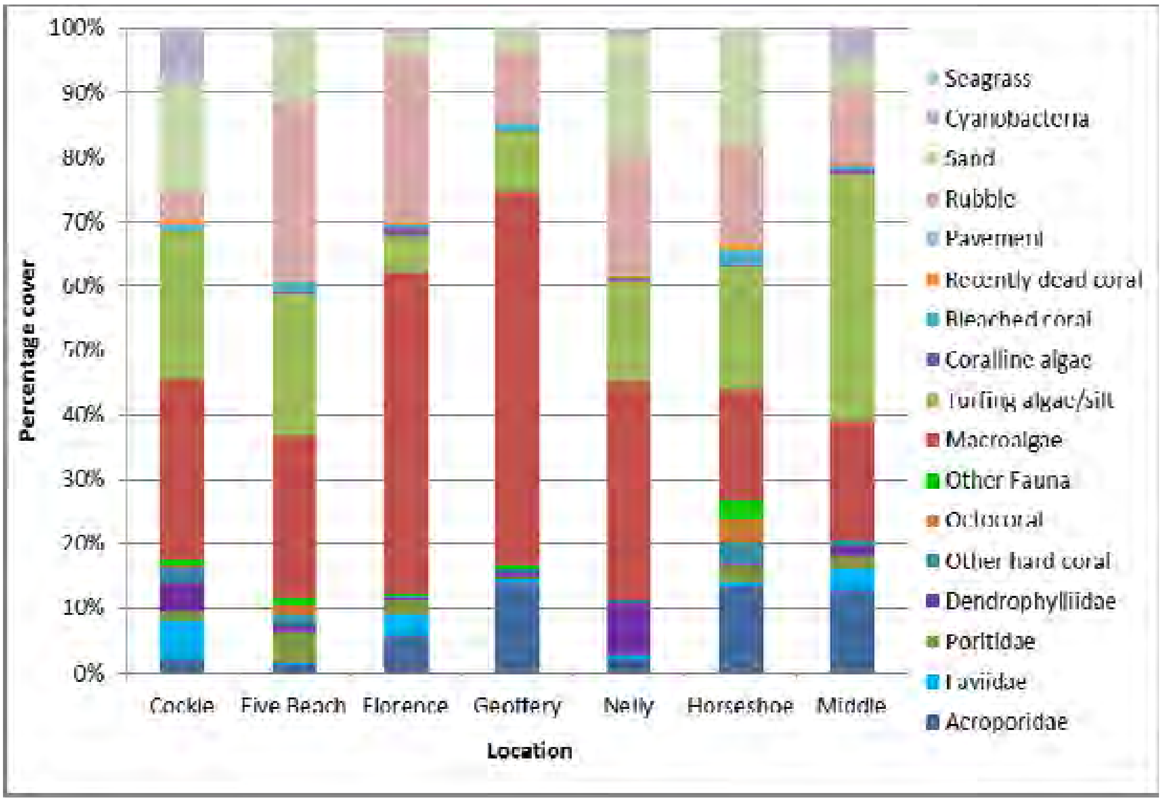


Figure 3-32 Total percentage cover of benthic categories recorded at each location – 2012

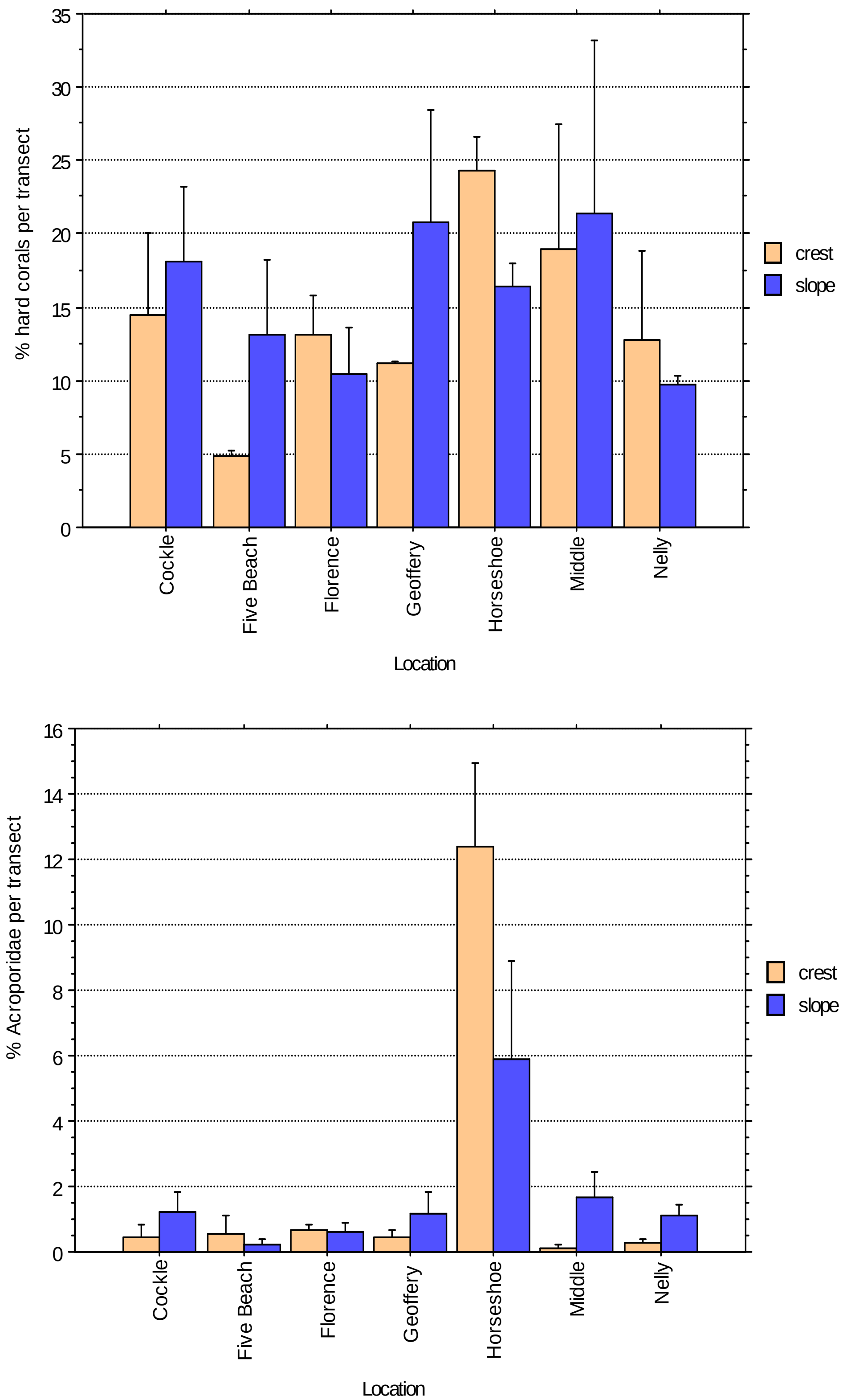
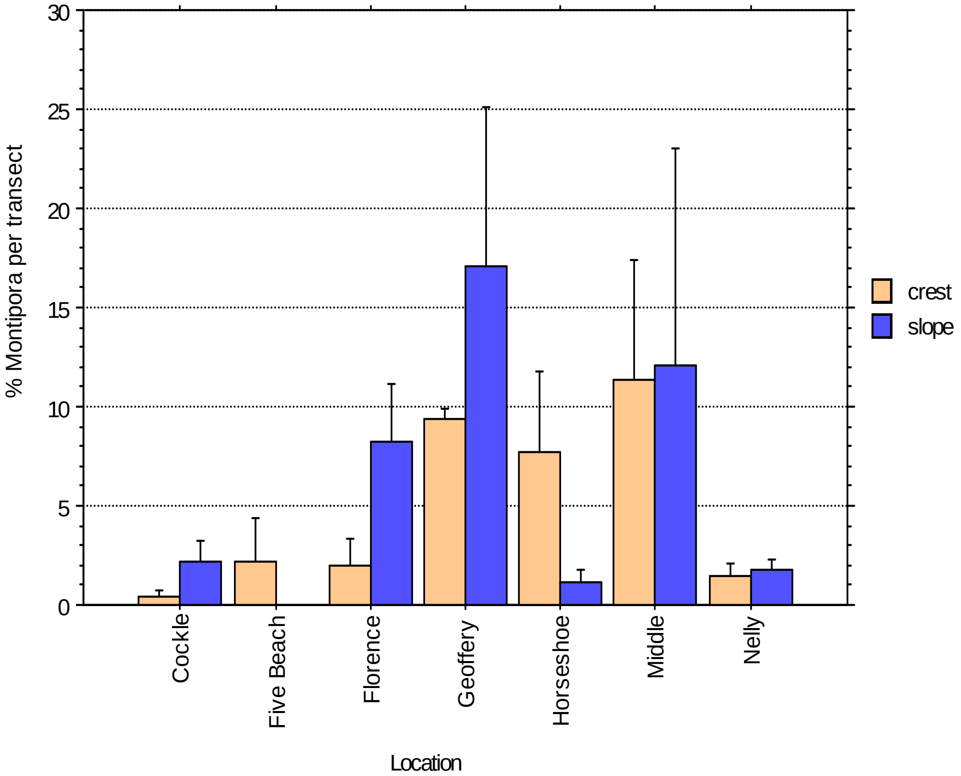


Figure 3-33 Mean (error bars ± S.E.) percentage cover of hard corals (upper plot) and *Acropora* corals (lower plot) recorded on 30 m transects at each strata and location - 2012



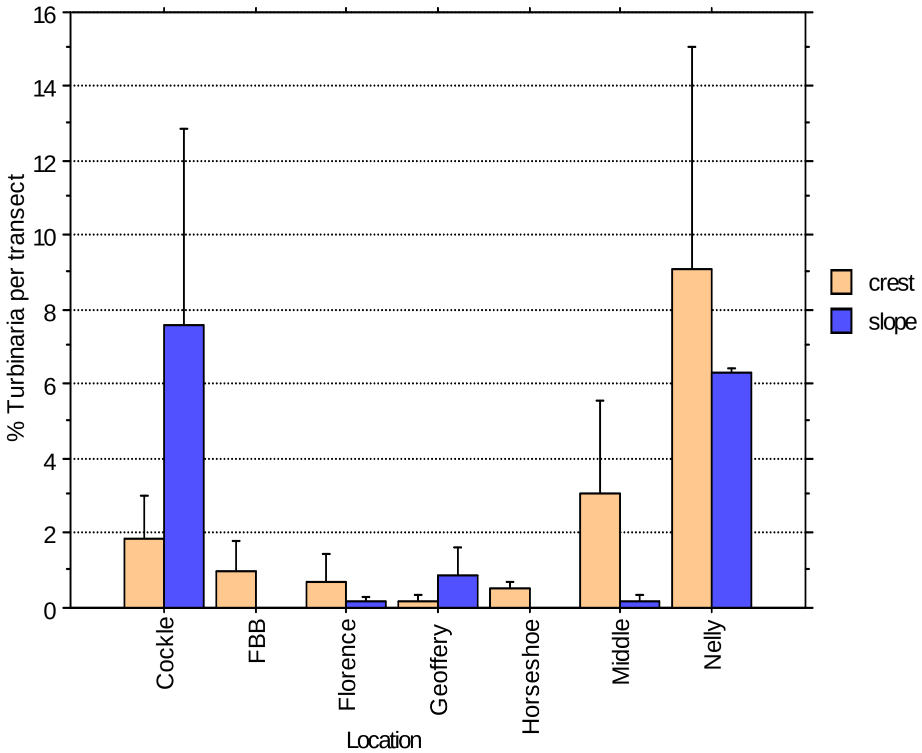
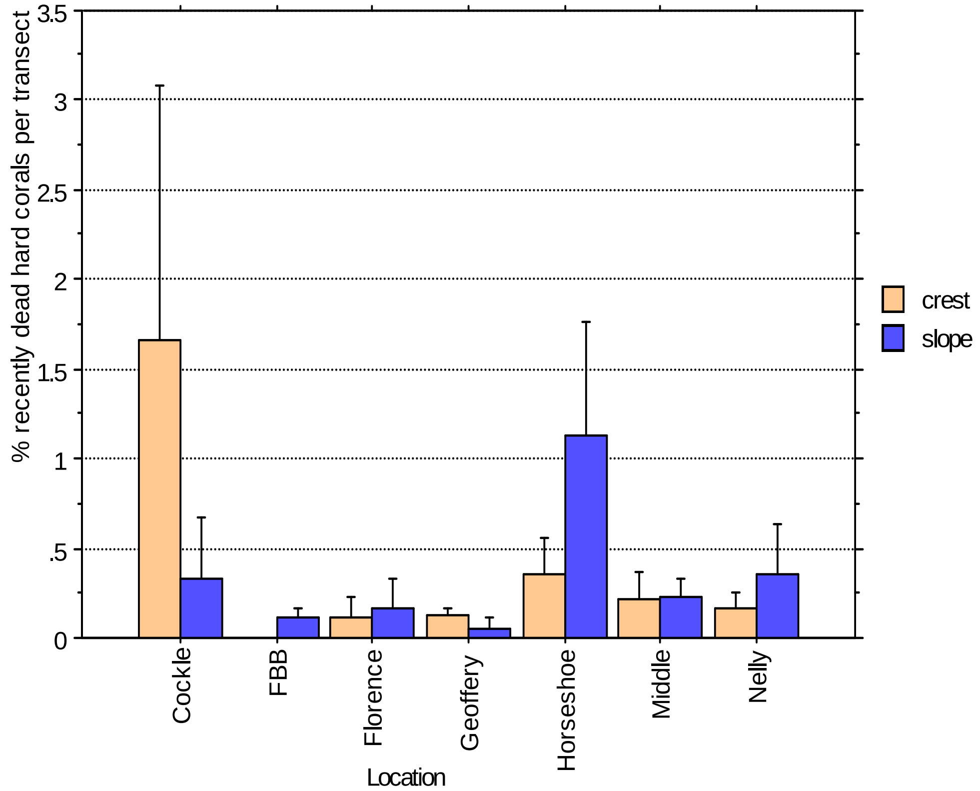


Figure 3-34 Mean (error bars ± S.E.) percentage cover of *Montipora* corals (upper plot) and *Turbinaria* corals (lower plot) recorded on 30 m transects at each strata and location - 2012



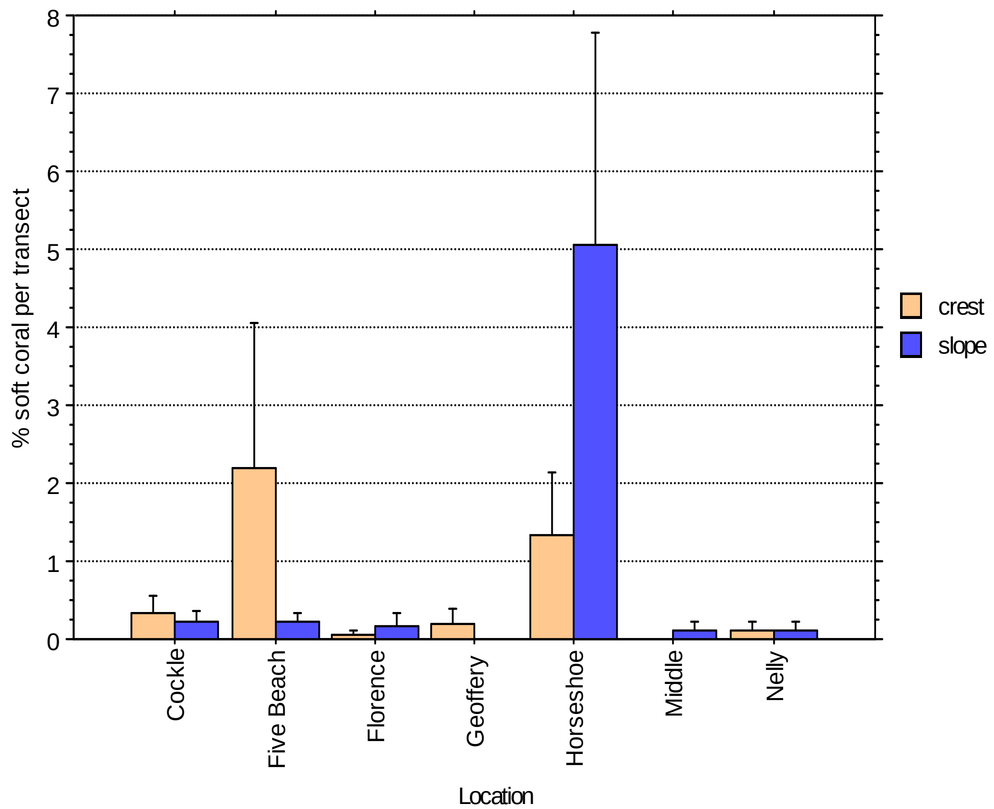


Figure 3-35 Mean (error bars ± S.E.) percentage cover of recently killed hard corals (upper plot) and soft corals (lower plot) recorded on 30 m transects at each strata and location - 2012

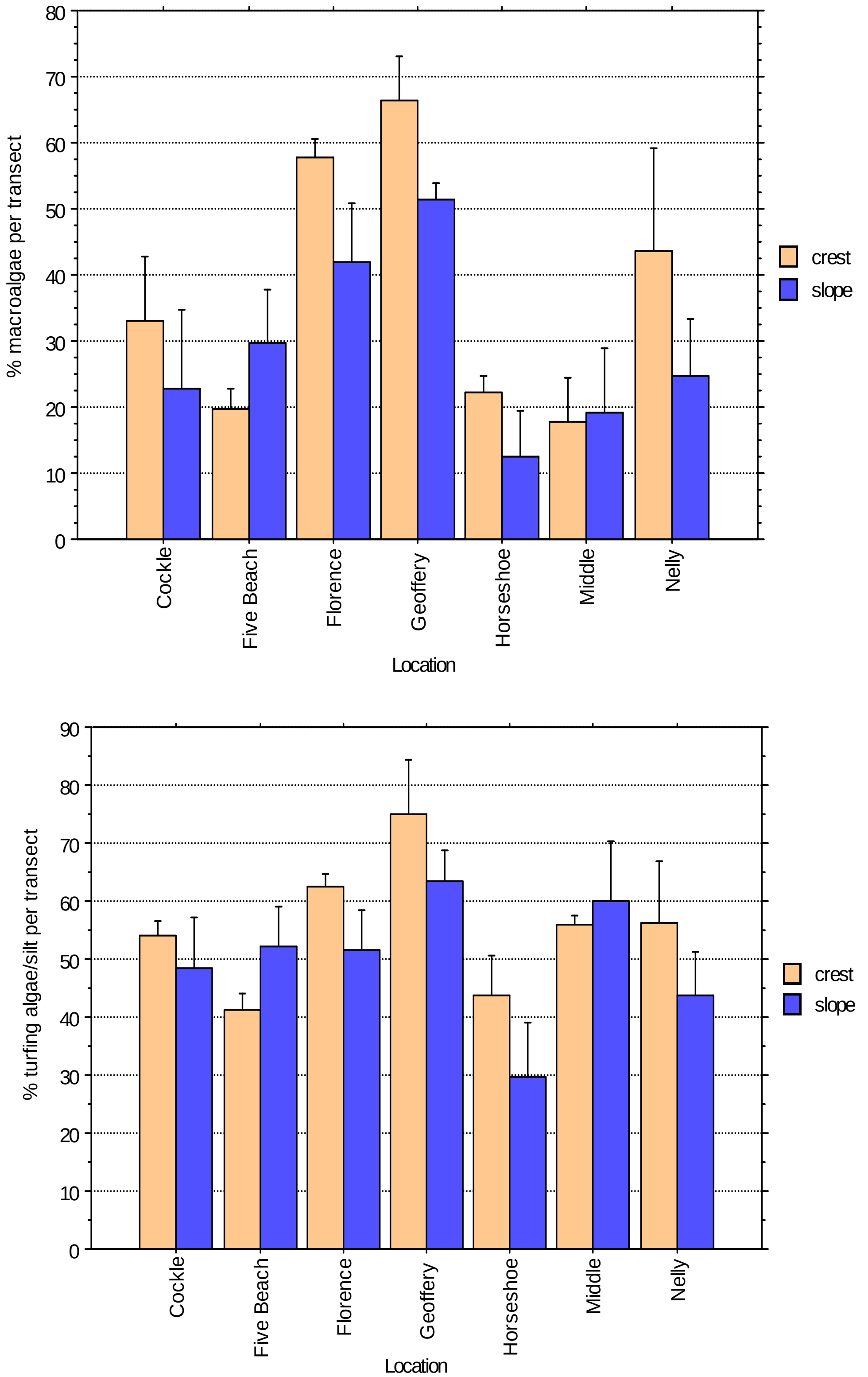


Figure 3-36 Mean (error bars ± S.E.) percentage cover of macroalgae (upper plot) and turfing algae/silt matrix (lower plot) recorded on 30 m transects at each strata and location - 2012

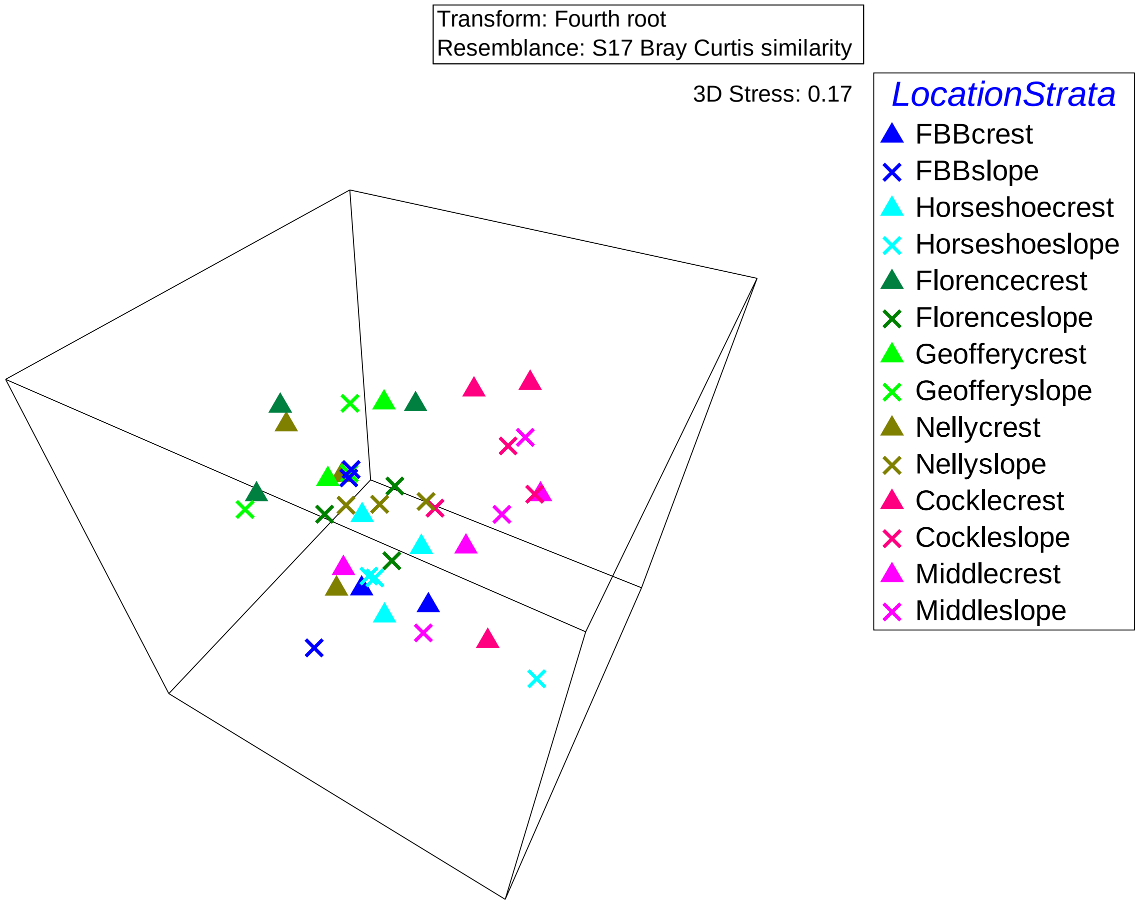


Figure 3-37 Non-metric multi-dimensional scaling ordination based on fourth root transformed reef community data – 2012

3.5.3 Temporal Patterns

Benthic communities on reefs can show marked variation over time in response to seasonal changes in water quality conditions, and in response to disturbance from extreme weather events.

3.5.3.1 Middle Reef

Patterns

The Australian Institute of Marine Science (AIMS) has monitored coral communities at Middle Reef since 1993. Monitoring was undertaken at permanently marked stations using standardised sampling methodologies. Figure 3-38 shows the mean percentage cover recorded at the Middle Reef in the period 1993-2009.

Monitoring results indicate that despite frequent disturbance associated with high temperatures, freshwater and high sediment loads, hard coral cover and diversity has remained relatively stable. Notwithstanding this, declines in hard and soft coral cover were recorded in the period 1998-2002 at

Middle Island and other inshore reefs between Townsville and Cairns, which AIMS (2010) suggested was a response to high water temperatures. This bleaching event has a smaller impact on Middle Reef corals than on nearby Magnetic Island Reefs (AIMS 2010).

Since 2002, soft coral cover has not recovered to pre-1998 levels, remaining between 1-5% cover. Hard coral cover, particularly Poritidae increased between 2002 and 2008, reaching a maximum cover of 45% (compared to maximum of 40% pre-2002). However, hard coral cover (particularly Acroporidae corals) declined again in 2009, most likely in response to a persistent flood plume in February 2009 (AIMS 2010). Coral cover at Middle Reef in the period 2009-2011 again declined (Thompson *et al*. 2011), most likely in response to freshwater and physical disturbance resulting from Cyclone Yasi in 2011. Low levels of coral recruitment have been recorded at Middle Reef in recent years, indicating that corals are under environmental stress from recent climatic disturbances (Thompson *et al*. 2011).

Browne *et al*. (2010) found that coral cover on windward slope transects at Middle Reef had increased since 1993, despite episodic mortality events associated with coral bleaching and floods. Consistent with AIMS (2010), Browne *et al*. (2010) suggested that the coral communities of Middle Reef showed rapid recovery following disturbance, and represented a 'resilient coral reef' (see discussion regarding resilience below).

Algae cover also shows great variation over time (Figure 3-38). Algae cover (particularly turfing algae) typically increased following disturbance, most likely in response to reduced coral cover increase in available bare substratum (see Spatial Patterns discussion). Macroalgae cover was consistently low over time, and did not show any consistent long term trends. Thompson *et al*. (2011) suggested that the high cover of coral and high quantities of silt restrict macroalgae colonisation. In the present study, macroalgae cover was slightly greater than recorded previously, (Figure 3-36), possibly resulting from disturbance by Cyclone Yasi and ongoing good growing conditions (low rainfall) in the period after Yasi. Elsewhere, high cover of fleshy macroalgae can compete with coral, and detrimentally affect coral resilience and its capacity to recover following disturbance (e.g. Birrell *et al*. 2008).

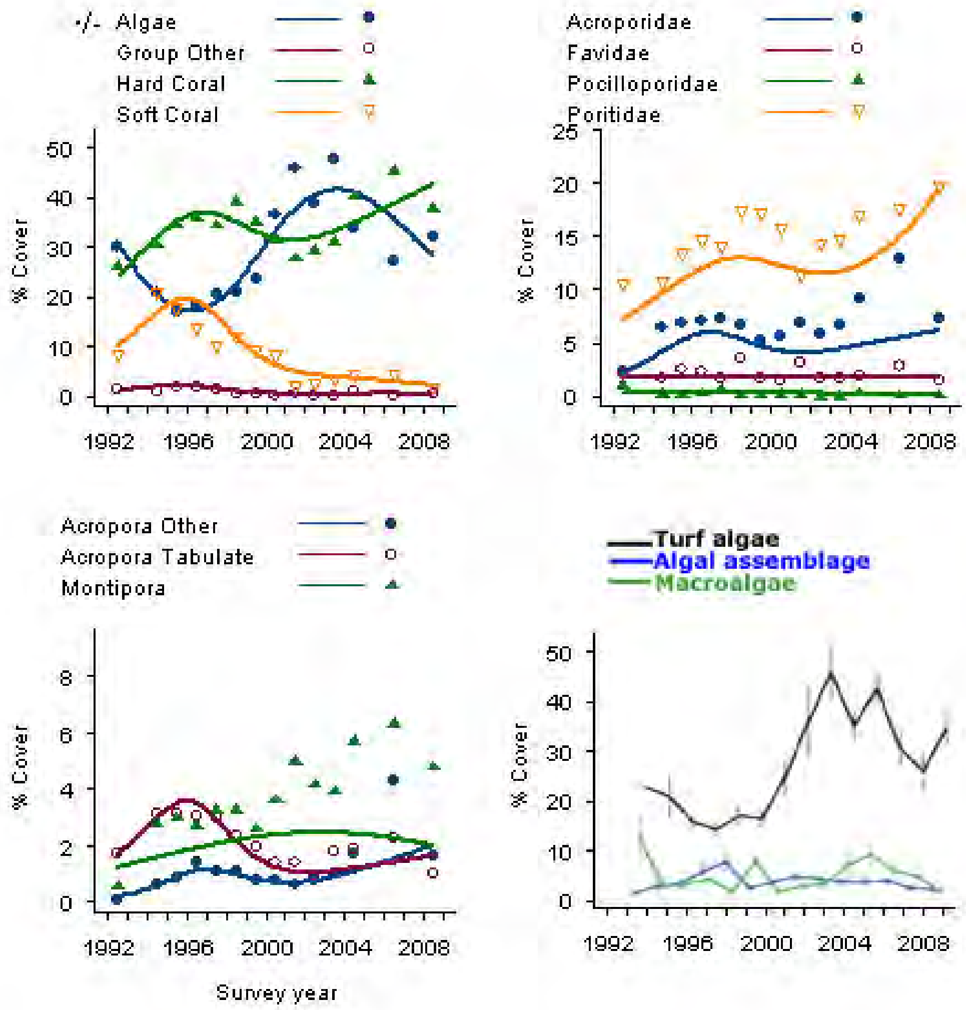


Figure 3-38 Temporal patterns in reef community structure at Middle Reef between 1993-2009 (AIMS 2010)

Drivers

The key drivers of changes to reef communities of Middle Reef include:

- High turbidity - which controls the composition and structure of corals communities at Middle Reef. Only species that are tolerant of high turbidity are able to persistent at this location. Furthermore, reef building corals are largely restricted to shallow waters due to low levels of incident light in water depths <3 m (see Chapter WQ).
- Freshwater inundation and runoff. During flood events from the Burdekin River, freshwater can form a lens above the denser seawater. As approximately 76% of the reef area at Middle Reef is located between zero and three metres LAT (Brown *et al*. 2010), shallow water corals may be exposed to this low salinity lens. The low salinity, together with high levels of nutrients and turbidity, can lead to stress and mortality of corals.
- Bleaching. Bleaching typically occurs in response to high water temperatures, and appears to represent a key agent of change at Middle Reef (see discussion above). However, AIMS (2010) suggested that the high turbidity at Middle Reef may <u>reduce</u> the vulnerability of corals to

bleaching compared to ‘clear water’ reefs around Magnetic Island. AIMS (2010) suggested that turbidity can reduce UV exposure (i.e. temperature stress) and provide a food source for corals.

- Coral disease. AIMS (2010) found that the most common disease detected in reef surveys was ‘atramentous necrosis’. These are legions that form in small depressions on the coral surface, and are thought to be linked to high water temperatures. AIMS (2010) found that disease incidence was low, but also noted that since monitoring at Middle Reef takes place in winter, disease incidence may be under-represented.

3.5.3.2 Magnetic Island Reefs

Patterns

Wachenfeld (1997) revisited reef flat locations (including Geoffrey Bay) where historical (1952) photographs had been taken in order to qualitatively assess potential long term changes (measured in decades) in reef flat benthos. In gross terms, no major changes in reef flat benthos could be discerned between 1952 photographs and site observations in 1995. This contrasts with anecdotal reports of long term declines in coral cover at Magnetic Island (e.g. Endean 1976; Brodie 1997), and documented changes on fringing reefs elsewhere in the GBR (Wachenfeld 1997).

While numerous quantitative reef community surveys have been carried out around Magnetic Island over time, differences in sampling methodologies prevent direct empirical assessments of medium to long-term temporal changes (years to decades). An examination of previous reef survey reports suggests that coral and other reef benthos can show marked short and medium term temporal variability (measured in years), typically in response to flooding of the Burdekin River, disturbance by cyclones and bleaching events.

Monitoring of reef communities by Kaly *et al*. (1993) at Nelly and Geoffrey Bays (12 stations) in the period 1989-92 found that cover of most taxonomic groups (predominantly coral genera) were relatively constant in time (four sampling episodes). The exceptions to this were Acroporids, sponges, *Sargassum* and total algal cover, which all varied significantly in time at some but not stations. Kaly *et al*. (1993) noted that changes in macroalgae were not surprising given that many species are annuals (including the abundant *Sargassum*) are annuals, and display great inter-annual and seasonal variability. The fast growing (and typically fragile) Acroporids can also show marked temporal variability (see Thompson *et al*. 2011), with the direction and magnitude of change varying among stations.

The Reef Rescue Monitoring Program (Thomson *et al*. 2011) has undertaken annual monitoring of benthic communities (coral cover, macroalgae cover and juvenile densities) at Geoffrey Bay since 2005, which provides an assessment of medium-term inter-annual temporal patterns. In summary, (Figure 3-39):

- juvenile densities have remained consistently low across the monitoring period (see discussion below regarding resilience);
- total hard coral cover was relatively static over the monitoring period at the five metre depth stratum;
- total hard coral cover was lower in 2010 and 2011 than the 2005, 2007-2009 sampling episodes at the two metre stratum;

- the reduction in hard coral cover between 2009 and 2011 reflected a reduction in Acroporidae cover. There was an increase in cover of 'other families' and Portidae, but further decline in Acroporidae, between 2010 and 2011.

Coral communities typically rapidly recolonise after such disturbance events, with the rate of recolonisation likely to be dependent on ambient water quality during the recovery period (e.g. Hughes *et al*. 2005).

Drivers of Change

Low salinity flood waters in 2009-2011, as well as physical disturbance by Cyclone Yasi, are likely to be the main drivers of recent changes in coral community structure at Geoffrey Bay. Thompson *et al*. (2011) noted however that Cyclone Yasi caused minor physical damage to Geoffrey Bay coral communities, with some breakage of fragile corals (such as Acroporids) and overturning of loosely attached colonies, but loss of macroalgae.

Bleaching events have been observed at Magnetic Island sites in 1980, 1982, 1987, 1992, 1994, 1998, 2002, 2006 and 2009 (Jones *et al*. 1997; C&R Consulting 2007; GBRMPA 2010). There was a close correlation between bleaching of corals and periods of average daily seawater temperature approaching 32°C in the period (Jones *et al*. 1997). Bleaching also occurs in response to lower salinity due to flooding (GBRMPA 2010).

Low salinity conditions also promote disease incidence in Magnetic Island coral communities (Haapkyla *et al*. 2011). Haapkyla *et al*. (2011) found that summer outbreaks of the disease atrametous necrosis in corals at Geoffrey Bay and Nelly Bay were strongly correlated with reduced salinity and higher concentrations of particulate organic carbon. It was suggested that low salinity (particularly multiple low salinity events) reduces the immune responses of corals, and/or increased the pathogens causing the disease. Other inter-correlated factors, such as total suspended solid concentrations, may also affect incidence of coral disease, but was not identified as a key factor in this study.

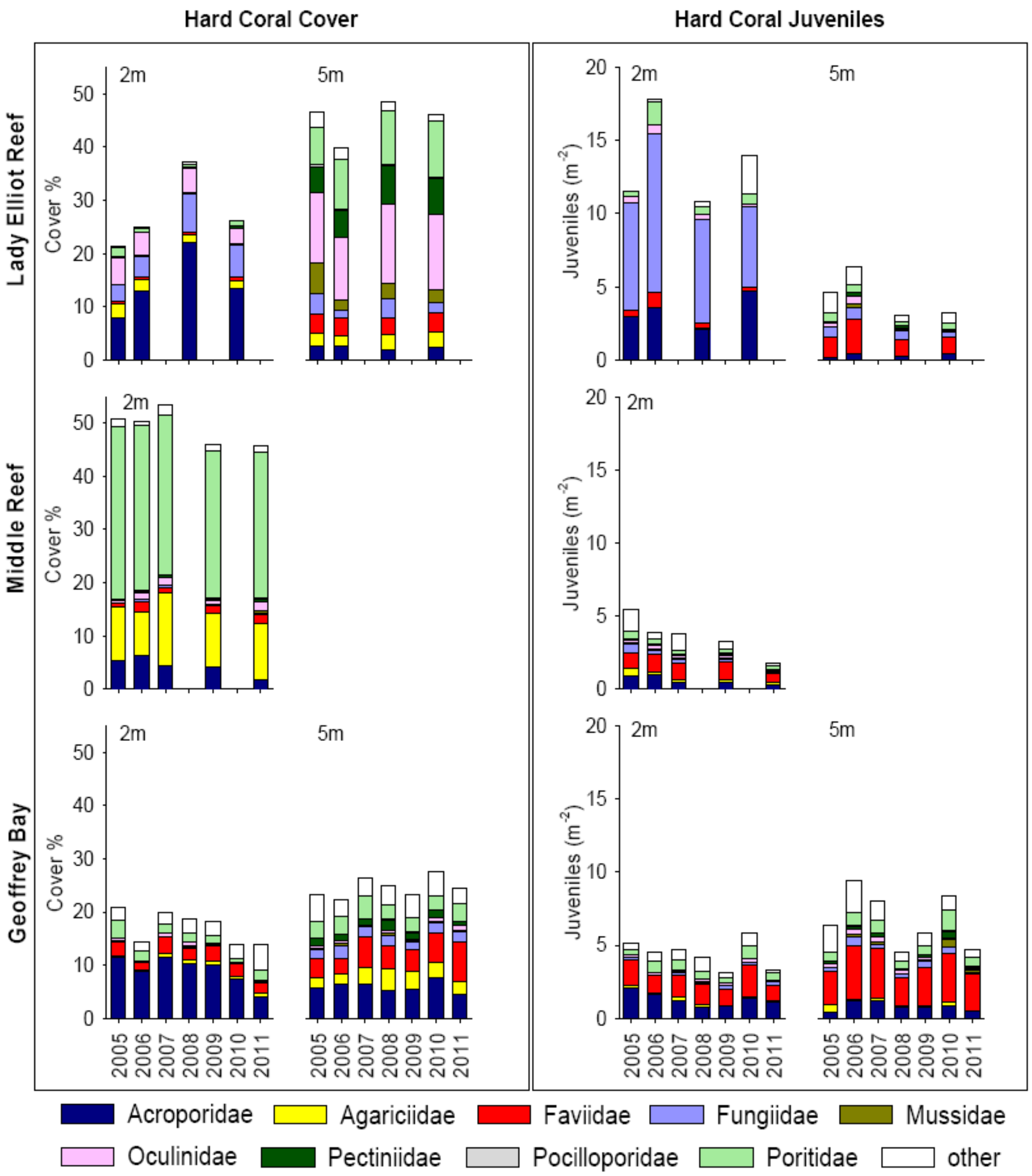


Figure 3-39 Hard coral cover and juvenile densities recorded at Geoffrey Bay, Middle Reef and Lady Elliot Reef (Thompson *et al*. 2011)

3.5.3.3 Coral Reef Resistance and Resilience

Like seagrass, coral species differ in their sensitivity to disturbance (i.e. resistance) and capacity to recover following disturbance (i.e. resilience). The degree of resistance and resilience in corals depends on a number of often interactive factors including:

- adaptations that allow corals to tolerate the stressor (e.g. low light, high sediment etc.) (resistance);
- energy reserves to draw on during low light periods (resistance);

- settlement and subsequent recruitment rates (resilience);
- interactions with other plant (e.g. macroalgae) and animal (e.g. other corals etc.) species;
- historical and future disturbance regimes, including the frequency, timing, duration and intensity of disturbances, and synergistic effects (resistance and resilience).

In terms of resistance, Cleveland Bay has naturally high turbidity levels and therefore corals must have adaptations to cope with periods of low light and high sedimentation rates. This includes for example, (i) the capacity for some corals to switch from phototrophic to heterotrophic feeding strategies by feeding on suspended sediments; (ii) rapid replenishment of energy reserves between turbidity events; (iii) rapid rates of photo-acclimation; and (iv) energy conservation through reduced respiratory and excretory losses (Anthony and Larcombe 2000). Many nearshore turbid water species also produce mucus to slough settled sediment.

The degree of resilience of corals varies among taxa. Acroporidae corals, for example, can show great changes in cover over time but are generally considered to be resilient. While most Acroporidae species are photophilic (sensitive to light deprivation) and break easily, they are also capable of high growth rates and high reproductive output (Thompson *et al*. 2010). These strategies and temporal patterns are somewhat analogous to those displayed by *Halophila* and *Halodule* seagrasses. Many Faviidae, Poritiitidae and Fungiidae corals, by contrast, are relatively resistant to physical disturbance, are relatively tolerant of low light conditions (many species can switch to suspension feeding) and high rates of sedimentation, but have low growth rates and recruitment levels.

As discussed previously, coral reefs of Cleveland Bay are thought to be resilient to change, showing rapid recovery following disturbance (e.g. AIMS 2010; Browne *et al*. 2010). Notwithstanding this, recovery rates and growth of corals are highly dependent on ambient environmental conditions. Browne (2012) for example found that coral growth (calcification) at Middle Reef was lowest in summer months when sea surface temperatures (monthly average 29° C) and rainfall (total >500 mm) were high. She suggested that while corals on Middle Reef were resilient and robust to their marginal environmental conditions (i.e. high turbidity and sedimentation, periodic low salinities), they would be most susceptible to anthropogenic disturbances in summer months.

Both reactive (during operations) and long-term coral monitoring studies have occurred during the previous Platypus Channel dredging in the mid-1990s. Reactive monitoring showed that partial mortality at impact locations did not exceed that of control locations, and control locations also experienced higher levels of total colony mortality (Stafford-Smith *et al*. 1993). Although these findings suggest that the dredging activities were benign, bleaching rates were higher in impact locations (Geoffrey and Florence Bays), and at least one species appeared close to its survival limit.

It was also suggested that environmental conditions experienced during spring tides, high wind and/or swell events co-occurring with dredge events were the times when corals were most susceptible to bleaching and mortality. Longer term monitoring around this event showed that faviid and soft coral abundance was reduced in impact locations, but these constituted a relatively small amount of total cover (6%). To a large extent, the short term responses of reef communities to disturbance will therefore depend on their condition in the period leading up to disturbance, which has important implications from an impact assessment perspective.

In recent years, Thompson *et al*. (2011) recorded low levels of coral recruitment (predominantly by slow-growing coral species) on settlement plates located at Middle Reef. On the basis of these results, Thompson *et al*. (2011) suggested that conditions in the last few years would not facilitate rapid recovery following any catastrophic disturbance. However, the degree of resilience is expected to improve as communities recover from the succussive climatic disturbances in recent years.

3.5.4 Rock Wall Communities

Similar to natural reefs, the hard substrata provided by breakwaters and navigational aids (such as beacons) in and around the Port of Townsville provide artificial habitats (which also provide shelter and food etc.) for benthic fauna and numerous fish species. These structures represent the most popular recreational fishing areas in Cleveland Bay.

Sessile communities of eastern and western (see Figure 2-1) breakwaters within the nearshore Project area were generally similar, the exception being that hard corals were less abundant and diverse on the eastern breakwater than the western breakwater. The subtidal zone of both breakwaters was dominated by a variety of green, brown and red algae as well as stinging hydroids (Figure 3-40 A-C). The percentage of this epibenthic community decreased with proximity to the seafloor. This pattern was likely the result of decreased light conditions sediments that would tend to scour the rock surfaces at the base of the wall.

There were a few small hard coral colonies growing along the eastern breakwater (Figure 3-40A, B). At the northernmost site (see Figure 2-1), three hard coral taxa were observed, including *Turbinaria* (5 colonies), *Favites* (2 colonies), and *Goniopora* (3 colonies). These coral colonies tended to be small and encrusting in form. Trailing colonies of stinging hydroid (*Agalophenia*) and chains of ascidians with secondary growths were much more abundant than corals (Figure 3-40C).

The western breakwater had higher hard coral growth and richness (nine genera) than the eastern breakwater. This included two forms of *Montipora* and *Goniastrea,* and single forms of *Turbinaria, Favites, Moseleya, Goniopora* and *Lobophyllia* (Figure 3-40). *Turbinaria* was the most abundant colony, with 8 ± 0.6 colonies observed per 30 m transect. *Favites* (3.3 ± 1.7 colonies) and *Montipora* (2.3 ± 1.3 colonies) were the next most commonly observed genera. The remaining genera were recorded infrequently. Hard coral colony sized varied between 5 and 75 cm and colonies adopted a wider range of growth forms than those of the eastern breakwater, including encrusting, foliose, plating, and columnar forms. The soft coral *Carijoa* (Figure 3-40H) and numerous small hydrozoans were also observed here. Amongst the turfing algae and hydrozoans were occasional encrusting sponges and ascidians. Visibility at the western breakwater (approximately 2 m recorded during November field surveys) was greater than the eastern breakwater (approximately 0.2 m visibility). Sediments at the base of the western breakwater were finer than those of the eastern breakwater, indicating more quiescent conditions along the western breakwater.

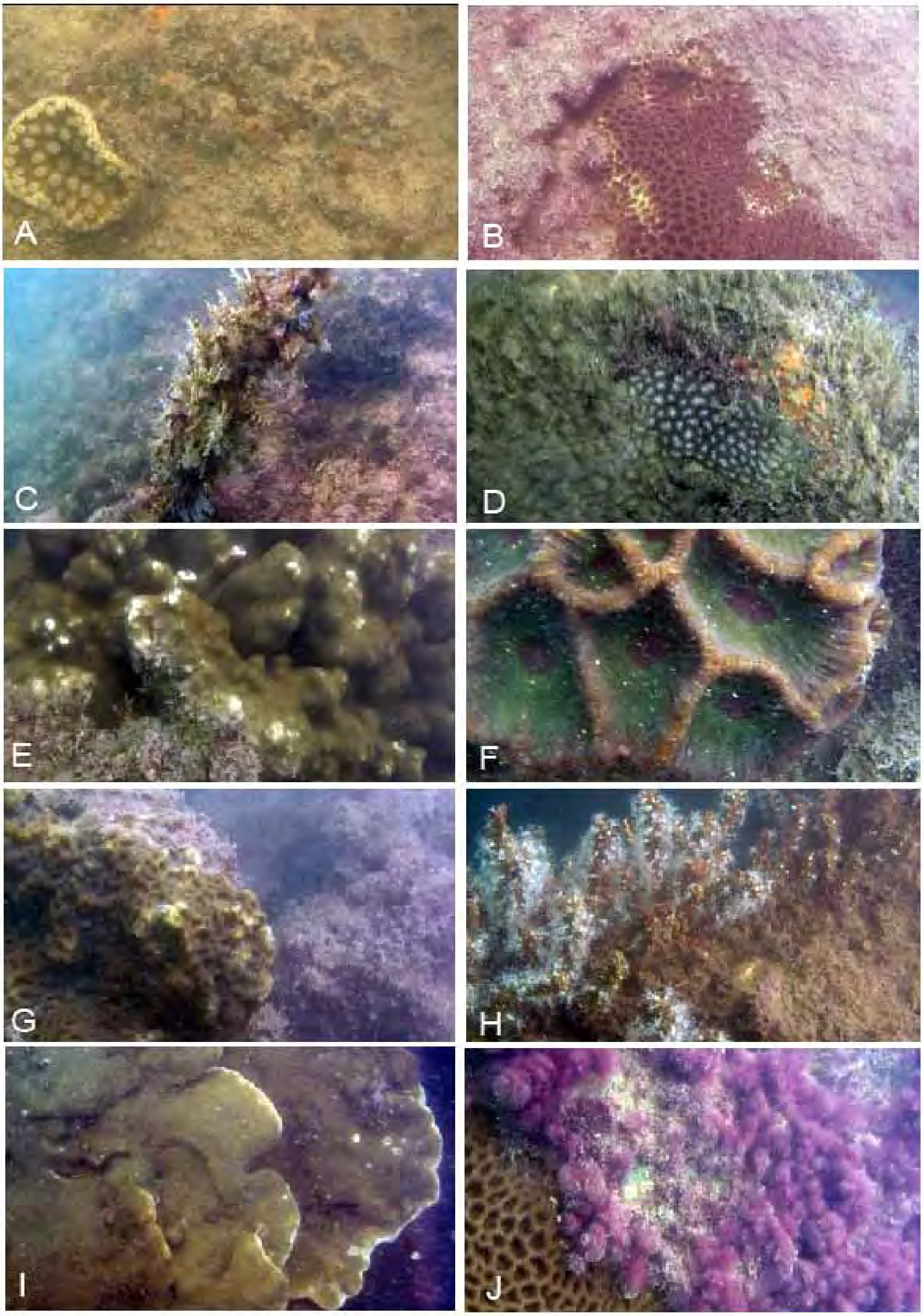


Figure 3-40 Screen grabs from video transects along the breakwaters, *Turbinaria,* encrusting sponge and algae (A); *Goniastrea* and turfing algae (B); turfing and macroalgae with *Agalophenia* and other hyrdoids (C); *Goniastrea* sp1*,* encrusting sponge and turfing algae (D); *Porites* (E); *Moseleya* (F); *Goniastrea* sp2 (G); *Carijoa* soft coral (H); *Montipora* sp1 (I); and *Favites* and red algae (J)

The low abundance of hard coral along the eastern breakwater compared to the western breakwater was likely due to high turbidity, high wave energy and sediment scour along the eastern breakwater. The poor visibility along the eastern breakwater appeared to be the result of a combination of remobilisation of sediments by wave action, as well as discharges of sediment laden waters from Ross Creek.

3.6 Listed Species

3.6.1 Previous Studies

Most listed marine species can be broadly described as marine megafauna. Numerous marine megafauna studies have been carried out in Cleveland Bay, with the most comprehensive assessments of the distribution, abundance and habitat usage being the monitoring program carried out by GHD (2011). This monitoring involved four assessment methods:

- Aerial surveys undertaken at three times (August 2010, November/December 2010 and June 2011) at a whole of Cleveland Bay spatial scale. This was used to assess the relative density and potential patterns in habitat usage of marine megafauna species.
- Boat-based surveys were undertaken at three times (May 2010, October 2010 and May 2011) within nearshore environments of Cleveland Bay. This was used to assess the relative density of marine megafauna and potential patterns in habitat usage.
- Passive acoustic monitoring was carried between November 2010 and May 2011 within nearshore environments of Cleveland Bay and Cockle Bay. This method was used to asses inshore foraging behaviour by green turtles.
- Passive Acoustic Detection of Cetaceans (C-Pods). C-Pods were aa complementary survey tool for acoustic monitoring of inshore dolphins. Sampling was carried out between November 2010 to May 2011.

The findings of these surveys are summarised in the following sections.

3.6.2 Threatened Species

The EPBC Act Protected Matters Search Tool was used to identify threatened marine[8] species and ecological communities that occur or could occur within the study area. In summary, the following were identified:

- Threatened plants: 1 species
- Threatened marine mammals: 2 species
- Threatened marine reptiles: 6 species
- Threatened sharks: 2 species
- Threatened ecological communities: 0.

[8] Note – terrestrial mammals, birds and terrestrial reptiles are considered in the Terrestrial Ecology report section

Section 3.6.5 considers marine mammals and section 3.6.4 considers threatened marine reptiles (turtles). The threatened plant species (frogbit, *Hydrocharis dubia*) is restricted to freshwater lagoons, a habitat type that is not supported in the study area. It is therefore not considered further.

Two threatened shark species were identified in the search: whale shark *Rhincodon typus* and green sawfish *Pristis zijsron*. The whale shark is a pelagic species that tends to prefer offshore tropical waters. This species is known to form seasonal feeding aggregations in the Coral Sea between November and December, although Ningaloo Reef is thought to represent the only critical habitat for this species in Australian waters (DEH 2005). There are occasional records of this species in Cleveland Bay, although it is considered to represent a transient visitor. Neither species were recorded in the GHD (2011) survey, with the most abundant shark species recorded in these surveys being the leopard shark (probably *Stegostoma fasciatum*).

Although once a widespread species (occurring south to southern NSW), green sawfish is now thought to be restricted to waters north of Cairns, located approximately 280 kilometres north of the study area. Based on the analysis of Queensland Beach Control Program catch records for the Townsville region (Stevens *et al*. 2005), a major decline in sawfish catches was observed in the 1970's and 1980's, and no sawfish have been recorded by the netting program in the Townsville region since the early 1990's (Figure 3-41). The disappearance of this species from areas adjacent to dense human habitation suggest that this species is sensitive to human disturbance, including habitat degradation (Stevens *et al*. 2005). Therefore, on the basis of the range retraction and its sensitivity to disturbance, it is considered unlikely that the nearshore waters of study area, including the outer harbour project area, currently represent important habitat for green sawfish.

Table 3-12 EPBC Protect Matters database search results – Threatened Species

Species	Status (EPBC/ NCA)	Distribution / Habitat[A]	Outer Harbour/ nearshore channel	Offshore disposal site/ offshore channel
Flora				
Hydrocharias dubia Frogbit	EPBC: V	Aquatic plant found in freshwater lagoons.	No – no suitable habitat	No – no suitable habitat
Marine Mammals				
Balaenoptera musculus Blue Whale	EPBC: E	Oceanic waters	Unlikely – shallow water depths and port infrastructure limits values.	Unlikely – not common in Cleveland Bay
Megaptera novaeangliae Humpback Whale	EPBC: V NCA: V	Oceanic waters	Unlikely – shallow water depths and port infrastructure limits values.	**Possible**
Marine Reptiles				
Caretta caretta Loggerhead Turtle	EPBC: E, M, LM NCA: E	Pelagic and benthic species. Cleveland Bay is not known to represent a nesting site. Forages on marine invertebrates (Wilson and Swan 2004).	**Likely – transient visitor to site.**	**Likely - suitable habitat located at reef and seagrass areas of Cleveland Bay**
Chelonia mydas Green Turtle	EPBC: V, M, LM NCA: V	Marine waters and near the seabed. Cleveland Bay is recognised as an important foraging area, where it feeds mainly on seagrass and benthic invertebrates (Wilson and Swan 2004). Low density nesting occurs in Cleveland Bay.	**Likely – transient visitor to site.**	**Likely - suitable habitat located at nearby reef and seagrass areas of Cleveland Bay**
Dermochelys coriacea Leathery Turtle, Leatherback Turtle	EPBC: V, M, LM NCA: E	Oceanic species which feeds on jellyfish and other soft bodied invertebrates (DEWHA 2007, Wilson 2005). Rarely sighted in Cleveland Bay and then only in deep waters. Rarely nests on the Australian coastline (mostly Territory and Cape York Peninsula).	Unlikely – oceanic species	Possible transient visitor
Eretmochelys imbricata Hawksbill Turtle	EPBC: V, M, LM NCA: V	Marine species. No critical nesting areas known in Cleveland	Possible transient visitor	Possible transient visitor

Species	Status (EPBC/ NCA)	Distribution / Habitat[A]	Outer Harbour/ nearshore channel	Offshore disposal site/ offshore channel
		Bay. Not thought to be common in Cleveland Bay.		
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle	EPBC: E, M, LM NCA: E	Deep waters around Magnetic Island. May be a transient visitor to Cleveland Bay, but not common.	Unlikely – oceanic species	Possible transient visitor
Natator depressus Flatback Turtle	EPBC: V, M, LM NCA: V	Marine species found around reef areas. Low density nesting occurs in Cleveland Bay but is not known to be abundant.	Possible transient visitor	Possible transient visitor
Sharks				
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish	EPBC: V	Thought to occur north of Cairns in estuaries and river mouths, embankments and beaches. Benthic feeder, found in depths from 1 m to 70 m.	Unlikely – while suitable habitat is present in the Project area, the Project area appear to be outside known geographic range.	Unlikely
Rhincodon typus Whale Shark	EPBC: V	Wide ranging tropical species. Critical habitat in Australia includes Ningaloo Reef in WA, the Coral Sea and Christmas Island. Cleveland Bay not known to represent an important habitat for this species.	Unlikely – Low abundance regionally and lack of deep waters limit habitat value of the Project area.	Unlikely

A = unless cited otherwise, information was derived from the SPRAT database (SEWPAC 2012d)

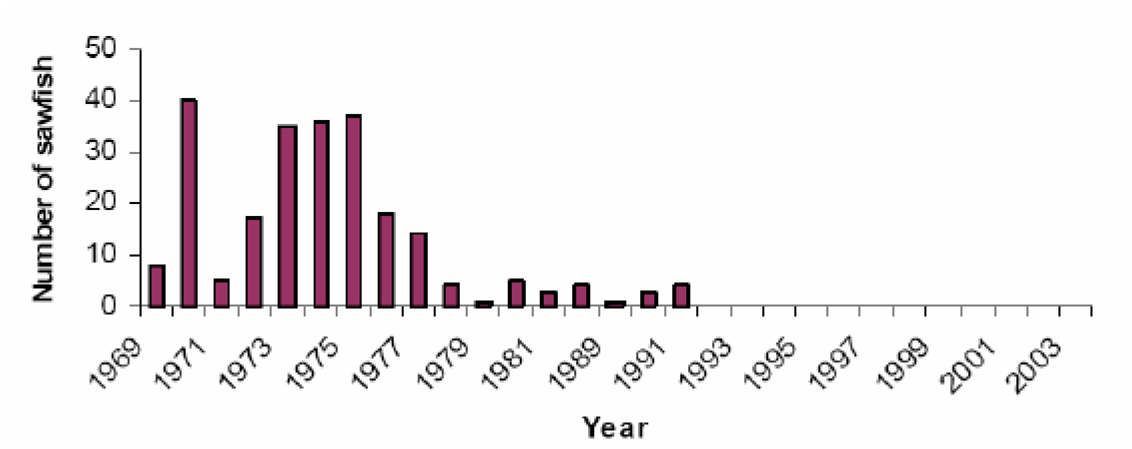


Figure 3-41 Catches of unidentified sawfish from Townsville in the Queensland Beach Control Program (Stevens *et al*. 2005)

3.6.3 Listed Migratory or Marine Species

The EPBC Act Protected Matters Database identified a range of migratory and listed marine species in the study area and surrounds, as summarised below (see Table 3-13):

- migratory mammals: seven species – refer to section 3.6.5,
- migratory reptiles: seven species, including six species of marine turtle (Section 3.6.4) and estuarine crocodile
- migratory sharks – one species (see Section 3.6.2).
- listed ray-finned species – 34 pipefish and seahorse species;
- listed marine reptiles – 15 species of sea snake, six species of marine turtles (see Section 3.6.2) and the saltwater crocodile;
- cetaceans – 11 dolphin and whale species (see section 3.6.5).

Listed migratory and marine species not considered in other report sections are described as follows.

Saltwater crocodile *Crocodylus porosus* is a listed migratory and marine species under EPBC Act, and is considered to be least concern wildlife under the NC Act. Saltwater crocodiles occur in Cleveland Bay region, although there are few confirmed records for the Ross River and nearshore areas of Cleveland Bay. There are no known nesting sites or preferred feeding habitats in the study area and surrounds (i.e. typically mangrove lined creeks), and it is not expected that the proposal would interfere with any movements through the site (should it occur).

The EPBC Protected Matters database search results indicate that 15 species of sea snake and 34 species of pipefish and sea horses occur or could occur in Cleveland Bay. These species are listed marine species and are protected under the EPBC Act, but are not considered to be threatened under EPBC or state legislation. While GHD (2011) recorded a sea snake (unidentified species) at two locations: to the east of Magnetic Island the Port, and near the mouth of Ross River. This indicates that sea snakes occasionally occur in the Project area.

3.6.4 Marine Turtles

Six species of marine turtle are known to use Cleveland Bay as a feeding ground, all of which are considered threatened under the EPBC Act and NC Act. These species have been recorded in offshore, nearshore and intertidal habitats within Cleveland Bay.

Surveys undertaken in 2000 (Preen 2000) suggest that the average total abundance of turtles in Cleveland Bay was 416 individuals ± 105 S.E. This is likely to be an underestimate the true local 'population' size due to bias inherent in the aerial survey methodology.

Table 3-13 Migratory marine species known or potentially occurring in the Cleveland Bay based on results from the EPBC Protect Matters search tool

MIGRATORY MARINE SPECIES	Distribution / Habitat	Channel and nearshore Project areas	Offshore DMPA and channel Project areas
Mammals			
Balaenoptera edeni Bryde's whale	Coastal waters of much of Australia and southern Africa where it searches for baitfish (Van Dyck and Strahan 2008).	Possible transient visitor	Possible transient visitor
Balaenoptera musculus blue whale	See threatened species table		
Dugong dugon Dugong	Marine habitats with shallow nutrient rich water with silt allowing intact sea grass meadows to grow. Distributed from coastal Shark Bay in Western Australia to Moreton Bay in Queensland (Van Dyck and Strahan 2008).	Possible transient visitor	Likely – deepwater seagrass near DMPA
Megaptera novaeangliae humpback whale	See threatened species table		
Orcaella heinsohni Australian snubfin dolphin	Nearshore waters; mouths of rivers and estuaries in shallow coastal waters. The area of occupancy cannot be calculated due to the paucity of sighting records for a large proportion of the range, however, it is likely to be greater than 2000 km^2.	Likely	Likely
Orcinus orca killer whale, Orca	Occurs throughout the world's oceans. Marine mammals provide much of the food required by the killer whale (Van Dyck and Strahan 2008).	Unlikely	Possible transient visitor
Sousa chinensis Indo-Pacific humpback dolphin	Occurs in coastal and estuarine areas in association with rocky reef areas. Food is comprised of fish and the range of this species in Australia is diminishing (Van Dyck and Strahan 2008).	Likely	Likely
Reptiles			
Caretta caretta loggerhead turtle	See threatened species table		
Chelonia mydas green turtle	See threatened species table		
Crocodylus porosus estuarine crocodile, salt-water crocodile	Coastal rivers, swamps, inland rivers, open sea (Wilson and Swan 2004). Rare in Cleveland Bay (GHD 2009)	Unlikely	Unlikely
Dermochelys coriacea leathery turtle, leatherback turtle	See threatened species table		
Eretmochelys imbricata hawksbill turtle	See threatened species table		
Lepidochelys olivacea olive Ridley turtle	See threatened species table		
Natator depressus flatback turtle	See threatened species table		
Sharks			
Rhincodon typus whale shark	See threatened species table		

GHD (2011) undertook the most comprehensive surveys of the distribution and abundance of marine megafauna (including marine turtles) in Cleveland Bay to date. While patterns in relative abundance were mapped, GHD did not attempt to calculate an overall 'population' estimate of turtles. They found that highest numbers of marine turtles occurred near seagrass and reef habitats, most notably (Figure 3-42):

- at and adjacent to Cockle Reef at southern Magnetic Island;
- at and adjacent to coastal seagrass meadows between the Strand and Cape Pallarenda;
- offshore of the Port in central Cleveland Bay;
- at and adjacent to coastal seagrass meadows near the mouth of Alligator Creek to Cape Cleveland.

Overall, the distribution and abundance patterns of turtles within Cleveland Bay are thought to be mainly a function of the availability of suitable food resources, as summarised below.

Green Turtle Distribution and Abundance

Green turtle (*Chelonia mydas*) is listed as vulnerable under both the EPBC Act and the NC Act. Cleveland Bay, together with nearby Halifax and Bowling Green Bay, represent regionally important feeding areas for this species (Ian Bell pers. comm. in GHD 2011).

Green turtles are the most abundant turtle species within Cleveland Bay, which based on surveys undertaken in 2000 (Preen 2000), accounted for over 90% of the total abundance in the Bay. Surveys carried out by GHD (2011) also indicated that green turtles were the most abundant sea turtle species in Cleveland Bay during 2008-2011. Given the almost complete numerical dominance of this species in Cleveland Bay, the spatial patterns in abundance of sea turtles shown in Figure 3-42 are expected to be mainly indicative of those of green turtle.

Green turtles feed directly on seagrasses and algae (Brand-Gardner *et al*. 1999), and therefore highest numbers tend to occur around dense and abundant coastal seagrass meadows. Important foraging areas are therefore present at seagrass meadows and reefs at Cape Cleveland and Cockle Bay, and seagrass meadows adjacent to the Strand, Cockle Bay (Magnetic Island) and seaward of the Port (GHD 2011; see Figure 3-42). Green turtles were also recorded feeding on algae on the northern breakwater wall. Some turtles were recorded away from reefs and seagrass meadows, most likely transiting between feeding sites.

Acoustic tracking of juvenile green turtles by GHD (2011) suggests that individuals can display high degree of site fidelity. GHD (2011) cited turtle tracking work done by Dr Mark Hamann (James Cook University) in Cleveland Bay, which also suggested that green turtles display high site fidelity when foraging. However, green turtles are known to move between seagrass meadows fairly regularly, in response to drying of intertidal flats, and episodic losses (and gains) in seagrass meadows. Adult green turtles can move great distances (hundreds to thousands of kilometres) when migrating to turtle nesting beaches.

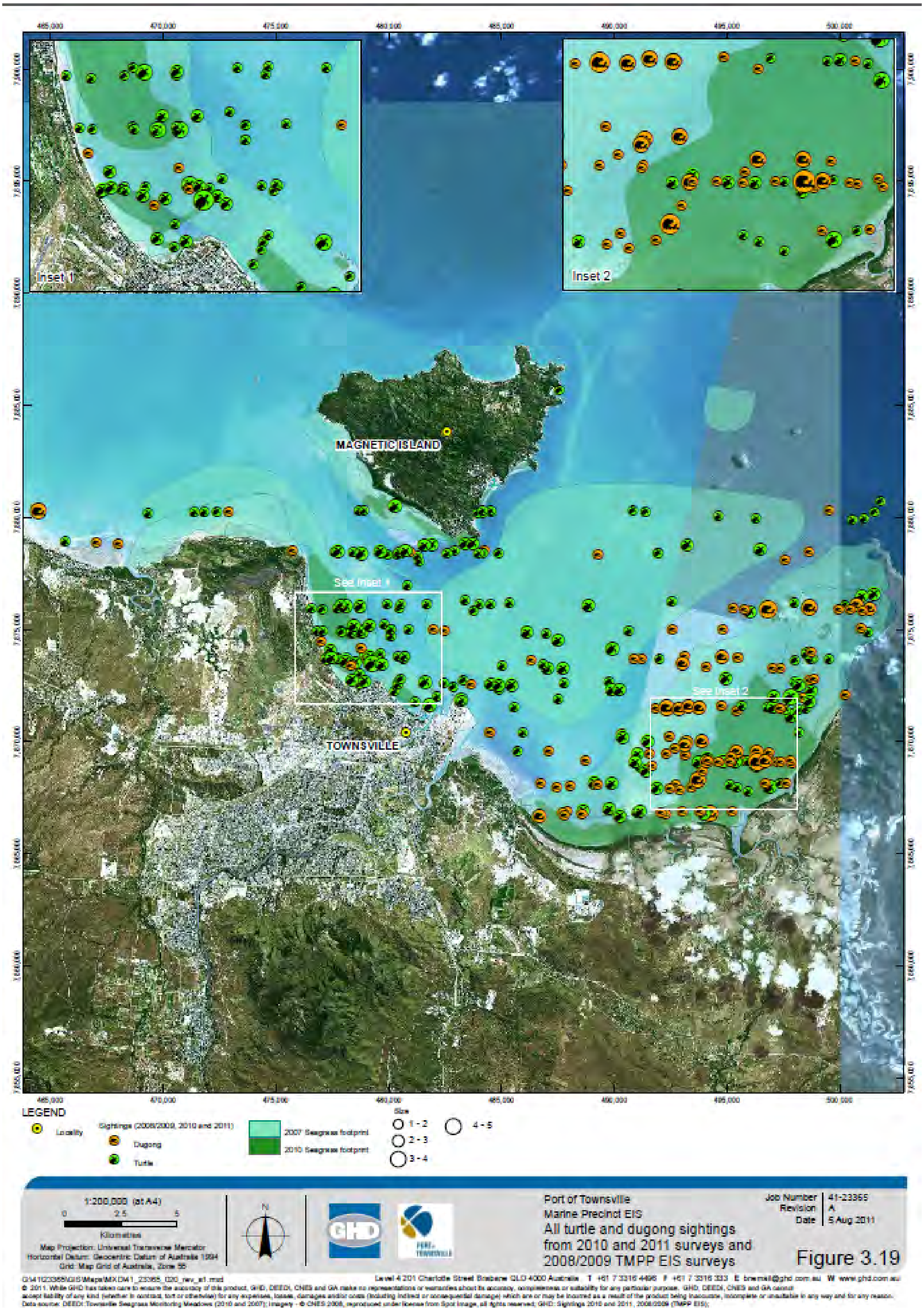


Figure 3-42 Turtle and dugong sightings in 2008-2011 surveys (Source: GHD 2011)

Other Species

Preen (2000) estimates that other sea turtle species represented approximately 10% of the total number of sea turtles in Cleveland Bay. The other sea turtle species known or likely to occur in Cleveland Bay are primarily carnivorous, as described below.

Olive Ridley turtle (*Lepidochelys olivacea*) is listed as endangered under both the EPBC Act and the NC Act. This species is typically found in deeper waters around Magnetic Island, but has been recorded in waters as shallow as five metres in Cleveland Bay (GHD 2011). This species is mostly carnivorous, with a diet mostly comprised of urchins, small crabs, and molluscs (Wilson 2005). This species is not known to favour shallow seagrass meadows or coral reef habitats (Limpus 2008). All soft sediment habitats in deeper waters of Cleveland Bay and surrounds represent potential foraging habitat for this species, however this species is not common in the GBR region (Limpus 2008).

Hawksbill turtle (*Eretmochelys imbricata*) is listed as vulnerable under both the EPBC Act and the NC Act. The diet of this species is primarily sponges seagrasses, algae, soft corals and a range of benthic shellfish (Whiting 2000). GHD (2011) did not record this species in their baseline surveys, however they are known to occur around inshore reefs of Cleveland Bay (Ian Bell pers. comm. in GHD 2011).

Loggerhead turtle (*Caretta caretta*) is listed as endangered under both the EPBC Act and the NC Act. It is a carnivorous species which feeds on jellyfish, crustaceans, echinoderms, and bivalve molluscs from seagrass meadows and reef areas (Limpus *et al*. 1994). Surveys by GHD (2011) did not record loggerhead turtle, although it would be expected to forage on reefs around Magnetic Island and Middle Reef.

Flatback turtles (*Natator depressus*) are listed as vulnerable under both the EPBC Act and the NC Act. They are carnivorous, feeding mainly on soft-bodied invertebrates (sea cucumbers, sponges, soft corals, jellyfish etc.) from the sea floor (Wilson 2005, Wilson and Swan 2003). It would be expected that soft sediment habitats of Cleveland Bay would provide potential foraging habitat for this species, however it is not known to be particularly abundant here (GHD 2011).

Leatherback turtles (*Dermochelys coriacea*) are listed as vulnerable under the EPBC Act and endangered under the NC Act. They are not known to be common in Cleveland Bay, possibly reflecting their preference for deeper waters (GHD 2009). Leatherbacks feed on jellyfish and other soft bodied invertebrates (DEWHA 2007, Wilson 2005). Leatherbacks suffer from high mortality associated with accidental ingestion of plastic bags, due to their resemblance to jellyfish (Wilson and Swan 2003).

It is likely, that marine turtles that exist within the construction footprint, channel and DMPA Project areas as transients rather than resident, primarily due to the lack of optimal or perennial feeding resources in this area. However, it is likely that the sparse seagrass and epibenthic fauna assemblages in the study area and surrounds (particularly the DMPA) are used sporadically or occasionally by some marine turtles. Loggerhead turtles may also feed on jellyfish that occur in the study area.

Turtle Reproduction and Recruitment

Cleveland Bay is not an important turtle breeding area, with most turtles in the Bay believed to have originated from rookeries elsewhere on the central and north Queensland coast and islands, or in other countries. The exceptions to this are flatback and green turtles. Low density nesting for these species has been reported on a number of sandy beaches adjacent to the study area and surrounds, including Magnetic, Herald and Rattlesnake Islands, the Strand and AIMS beach (GHD 2009). The most notable flatback turtle nesting areas occur around the Shoalwater coast, and on beaches north of Bundaberg (Table 3-14).

With the exception of the juvenile green turtle tracking studies (GHD 2011), there are few data describing patterns in habitat use by different life-stages of turtles. Young turtles are primarily pelagic, and are mainly carnivorous during this period. Green turtles undergo rapid ontogenetic shift in habitat and diet at three to five years age, to benthic algae and seagrass (Reich *et al*. 2007). It is unknown whether older juvenile, sub-adult and adult turtles display ontogenetic partitioning of food resources in Cleveland Bay.

Population Resilience

Food resource availability is likely to be a key control on green turtle populations, particularly during years when seagrass abundance is low. As discussed in Section 3.2, seagrasses meadows of Cleveland Bay vary greatly in extent in time, mainly in responses to periodic storm and flood disturbance. The period 2009 to 2011 were exceptionally wet years, which in combination with disturbance from Cyclone Yasi, caused major declines in seagrass meadows throughout Cleveland Bay and the wider Burdekin region. Cyclone Yasi represented a significant weather event, being the first category five cyclone to cross the coast since 1918 (GBRMPA 2012c).

The loss of seagrass meadows has been implicated as the major cause of turtle strandings (and dugong – see Section 3.6.5.2) in the region. Turtle stranding reports for the GBR region (i.e. south of Port Douglas) increased from an annual average of 678 per annum in the period 2008-2010, to 1232 turtles in 2011 (GBRMPA 2012b,c). The Townsville region was identified as a hot-spot for strandings in 2011, with 262 marine turtle stranding's compared to 35 (2008), 44 (2009) and 93 (2010) turtles in the period 2008 to 2010. Furthermore, in the period January to May 2012, there has been 58 recorded strandings in the Townsville region, which is comparable to the number of strandings for the same period (Jan-May) in 2011 (64 turtles) (DEHP 2012; see Figure 3-43).

Research is currently underway to assess resilience of sea turtles to periodic major loses in seagrass food resources (GBRMPA 2012c). The following key factors are thought to enable turtle populations to cope with periodic disturbance:

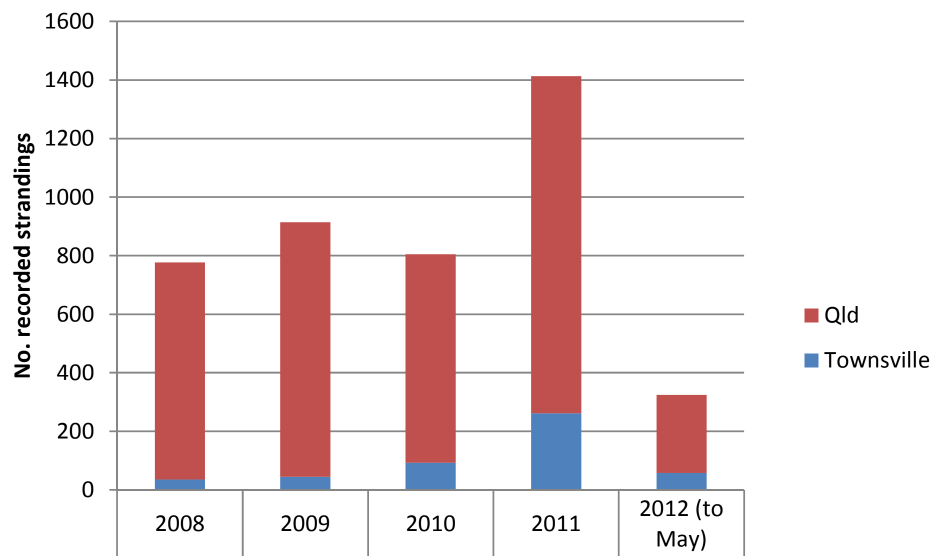
- While there has been a large decline in seagrass meadows in Cleveland Bay, relatively large coastal meadows still persisted in 2011 (1267.7 ± 287.7 ha). Surveys carried out in October-December 2011 show that Cape Cleveland had the largest seagrass meadows, with small fragmented meadows also present at Cockle Bay, Cape Pallarenda and the Strand. All meadows suffered a major decline in biomass, however this trend has been evident since monitoring commenced in 2007 (McKenna and Rasheed 2012). The seagrass meadows persisting in 2011 contain the preferred seagrass species utilised by turtles (and dugongs).

Table 3-14 Breeding activities of key marine megafauna species

Species	Reproductive activities in Cleveland Bay	Breeding/nesting season in central Qld	Main breeding/nesting areas
Sea Turtles			
Caretta caretta loggerhead turtle	None known	• Nesting: • Hatchlings emerge December to April	Southern Great Barrier Reef (Capricorn/Bunker group) and adjacent mainland near Bundaberg
Chelonia mydas green turtle	Nesting – low density nesting recorded at Sandy beaches at Magnetic Island and the Strand.	• Nesting: Late October to February • Hatchlings emerge December to May	Southern GBR Stock: Mackay and offshore islands in the Capricorn/Bunker group
Dermochelys coriacea leathery turtle, leatherback turtle	None known	• Nesting: December to January • Hatchlings emerge February to March	Indonesia and PNG – no major rookeries in Australia, but nesting recorded around Mackay and Bundaberg
Eretmochelys imbricata hawksbill turtle	None known	• Not known for region	Three main breeding areas in Australia, including northern Great Barrier Reef (several thousand nesting females). In the GBR region, nesting areas mainly occur north of Princess Charlotte Bay and in the Torres Strait
Lepidochelys olivacea olive Ridley turtle	None known	• Not known for region	No nesting by the species has been recorded in the Great Barrier Reef World Heritage Area.
Natator depressus flatback turtle	Nesting – low density nesting recorded at Sandy beaches at Magnetic Island and the Strand.	• Nesting: November to February • Hatchlings emerge January to April	Breeding is centred in the southern Great Barrier Reef around Peak, Wild Duck, Curtis and Facing Islands. Low density nesting by flatbacks occurs on many mainland beaches and offshore islands north of Gladstone. The largest amount of nesting occurs in Torres Strait.
Marine Mammals			
Dugong dugon Dugong	Mating and calving – sandbanks and estuaries (SEWPAC 2012c)	• Mating and calving peaks in spring and summer, but year-round	Cooktown, Hinchinbrook Island, Cleveland Bay, Shoalwater Bay, Hervey Bay and Moreton Bay (Marsh *et al*. 2002).
Megaptera novaeangliae humpback whale	Nursery habitat	• Humpback whales come from Antarctic waters to the Great Barrier Reef World Heritage Area from May to September to calve before they return to the Antarctic in summer.	GBR lagoon – see Red = most suitable; green = moderate suitability; blue = least suitable Figure 3-49.
Orcaella heinsohni Australian snubfin dolphin	Calving & likely mating	• Year-round calving (Parra 2006)	No detailed information.
Sousa chinensis Indo-Pacific humpback dolphin	Calving & likely mating	• Year-round calving (Parra 2006)	Insufficient information, but high abundances recorded in Moreton Bay & Great Sandy Strait regions (Bannister *et al*. 1996), as well as Cleveland Bay.

- While seagrass represents the main food resource of green turtles, they can supplement their diet with red algae and mangrove leaves and fruit (Limpus and Limpus 2000; Arthur *et al*. 2009), and are also known to eat jellyfish. Arthur *et al*. (2009) described green turtles as "an opportunistic and versatile forager", which has the ability to switch their diet to red algae and mangroves during periods when seagrass is limited. Arthur *et al*. (2009) further suggested that mangroves also had similar (or greater) nutrient content as seagrass. Turtles therefore have some capacity to seek these alternate (and plentiful) food resources during periods when seagrass biomass is low. As discussed in Section 3.5.2, macroalgae cover appears to have greatly increased on Cleveland Bay reefs following Cyclone Yasi, whereas mangroves forests did not significantly decline.
- Green turtles are capable of moving large distances. Few studies have examined the movement patterns of green turtles associated with shortage of food resources.

Notwithstanding the above, the resilience of local sea turtle 'populations' is expected to be comparatively lower during periods when seagrass is least plentiful.



	2008	2009	2010	2011	2012 (to May)
Qld	742	870	712	1151	267
Townsville	35	44	93	262	58

Figure 3-43 Number of marine turtle strandings recorded in the Queensland standings database (Department of Environment and Heritage Protection 2012)

3.6.5 Migratory Marine Mammals

There are a number of listed migratory marine mammals that could occur within or adjacent to the Project area (Table 3-13). The four species with a known or likely regular occurrence in the Project area or the DMPA are the Australian snubfin dolphin (*Orcaella heinsohni*), Indo-Pacific humpback dolphin (*Sousa chinensis*), dugong (*Dugong dugon*) and humpback whale (*Megaptera novaeangliae*).

GHD (2011) notes that the two dolphin species are common in nearshore environments throughout Cleveland Bay, and are likely to regularly feed in the port area, including the Project area (Figure 3-44). The Indo-Pacific humpback dolphin also has important feeding and nursing areas in Cleveland Bay, particularly in the vicinity of the mouth of the Ross Creek and Ross River. It is also likely that both species occur in the DMPA. The following summarises known patterns in usage by these dolphin species.

3.6.5.1 Nearshore Dolphin Species

Australian Snubfin Dolphin Distribution and Abundance

The Australian snubfin dolphin has a global IUCN listing of “near threatened” (IUCN 2010). It is listed as a migratory marine mammal under the EPBC Act and near threatened under the NC Act.

Australian snubfin dolphin is the only cetacean that is restricted to northern Australian and possibly Papua New Guinean waters (Beesley *et al*. 2005; Figure 3-45). They have been recorded from Roebuck Bay in Western Australia, across northern Australia, and south-east to the Fitzroy River region (Parra *et al*. 2002; 2004). While this species has a relatively broad geographic distribution, it is uncommon in most areas, and is often found in small groups (Parra 2005; 2006a)

Studies to date indicate that this species generally occurs in waters less than 15 m deep, within 10 kilometres of the coast and within 20 kilometres of a river mouth (Parra *et al.* 2004). The species is an opportunistic generalist, feeding on fish and cephalopods (octopus, squid etc.) from coastal, estuarine and nearshore reef habitats (Parra 2006a, Parra *et al.*2006b).

The estimate for the Australian snubfin dolphin “sub-population” in 2002 in Cleveland Bay was 63 individuals (95% confidence interval = 51-88) (Parra *et al.* 2006a,b). Of this number 51 were observed in more than one calendar year between 1999 and 2002 and certain individuals repeatedly came back to specific areas within the broader Cleveland Bay area. Parra (2006a,b) found a core use area for this species around Ross Creek and Ross River mouth. GHD (2011) also found that the Ross River and Creek areas were a centre of dolphin abundance with Cleveland Bay (Figure 3-44). This species was also found to favour shallow waters (1-2 m deep) where seagrass is present. The Ross River and Creek mouths and adjacent seabeds are therefore considered to represent important habitat for Australian snubfin dolphin.

At a state scale, the Australian snubfin dolphin population for Queensland is expected to be in the thousands rather than 10s of thousands (Parra 2006a). SEWPAC (2012b) suggests that the distribution of this species is contiguous throughout its geographic range, with areas of high usage having locally higher abundances.

GHD (2011) concluded that observations of recurrent use of Cleveland Bay by adult and calf snub-fin and Indo-Pacific humpback dolphins for foraging indicates that this area, particularly around the mouth of Ross Creek and River, is an important feeding area at a local scale. There is limited information on the reproductive ecology of this species. In Cleveland Bay, Australian snubfin dolphins socialise year-round, and calves have also been observed year-round (Parra 2006a,b). This suggests that this species does not have a defined mating season (SEWPAC 2012b).

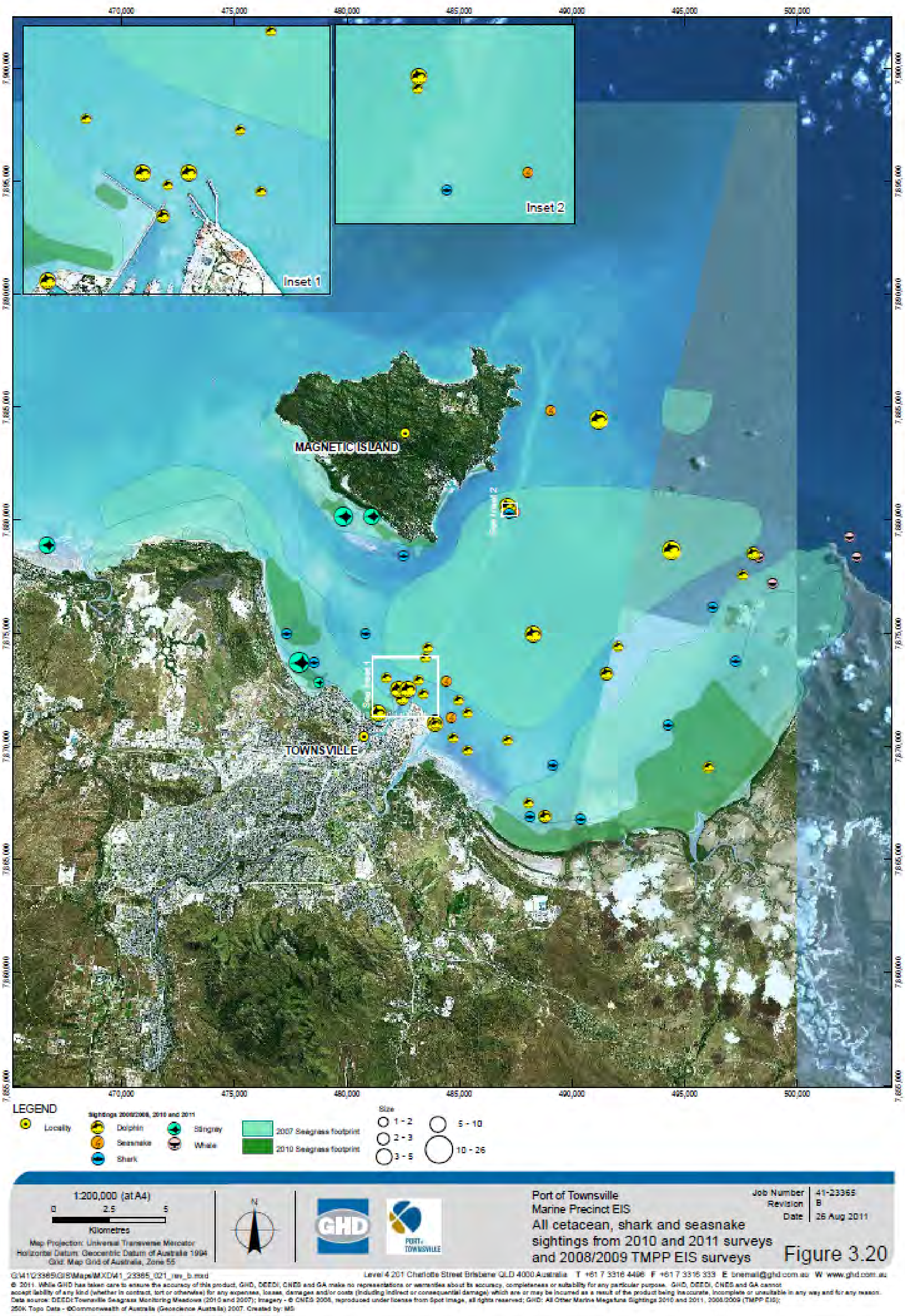
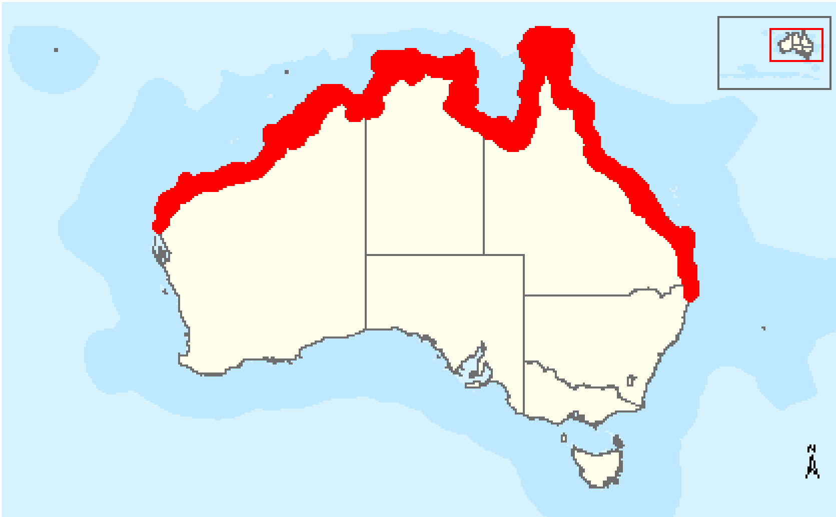


Figure 3-44 Cetacean, shark and sea-snake sightings in 2008-2011 surveys (Source: GHD 2011)



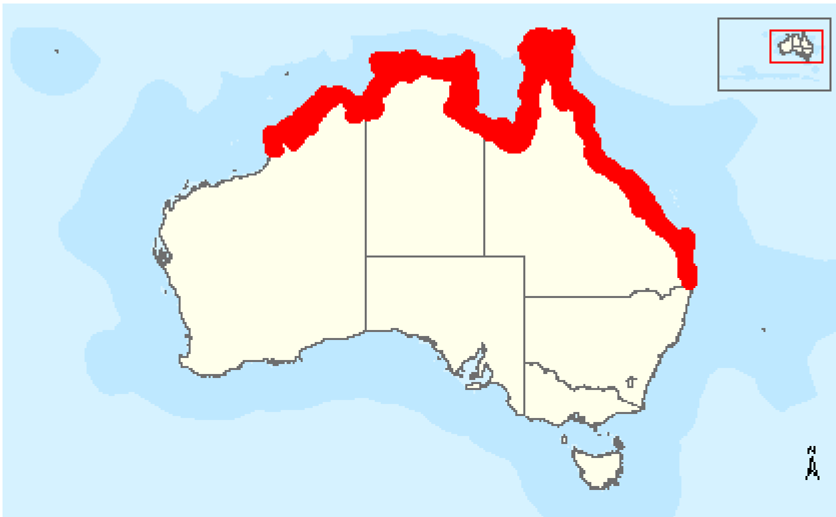


Figure 3-45 Inferred geographic distribution of Indo-Pacific humpback dolphin, *Sousa chinensis* (top map) and Australian snubfin dolphin, *Orcaella heinsohni* (bottom) (Source: SEWPAC 2012a,b)

Indo-Pacific humpback Dolphin Distribution and Abundance

Indo-Pacific humpback dolphin has a global IUCN listing of "near threatened" (IUCN 2010). It is listed as a migratory marine mammal under the EPBC Act and near threatened under the NC Act.

In Australia its distribution stretches from northern New South Wales along the coast of Queensland to Shark Bay in Western Australia. Studies to date indicate that this species, like the Australian snub-nosed dolphin, generally occurs in waters less than 15 m deep, within 10 kilometres of the coast and within 20 kilometres of a river mouth (Parra *et al.*2004). Indo-Pacific humpbacks do not display any preference for turbid or clear-waters, and have been recorded from a broad range of coastal habitats including coastal lagoons, enclosed bays, and open coastal waters (Jefferson and Karczmarski 2001). The species is also an opportunistic generalist, feeding on fish and crustaceans from coastal, estuarine and nearshore reef habitats (Parra 2006, Parra *et al.*2006b).

Parra *et al.* (2006a) estimated that the Indo-Pacific humpback dolphin sub-population in Cleveland Bay during 2002 was 54 (95% confidence limit = 38-77). Of this number 32 were observed in more than one calendar year between 1999 and 2002. A core area for this species was centred on around Ross Creek and Ross River mouth (Parra 2006). This species also favoured water two to five metres deep in dredged channels. The Ross River and Creek mouths and adjacent seabeds are therefore considered to represent important habitat for Indo-Pacific humpback dolphin, as shown in Figure 3-46.

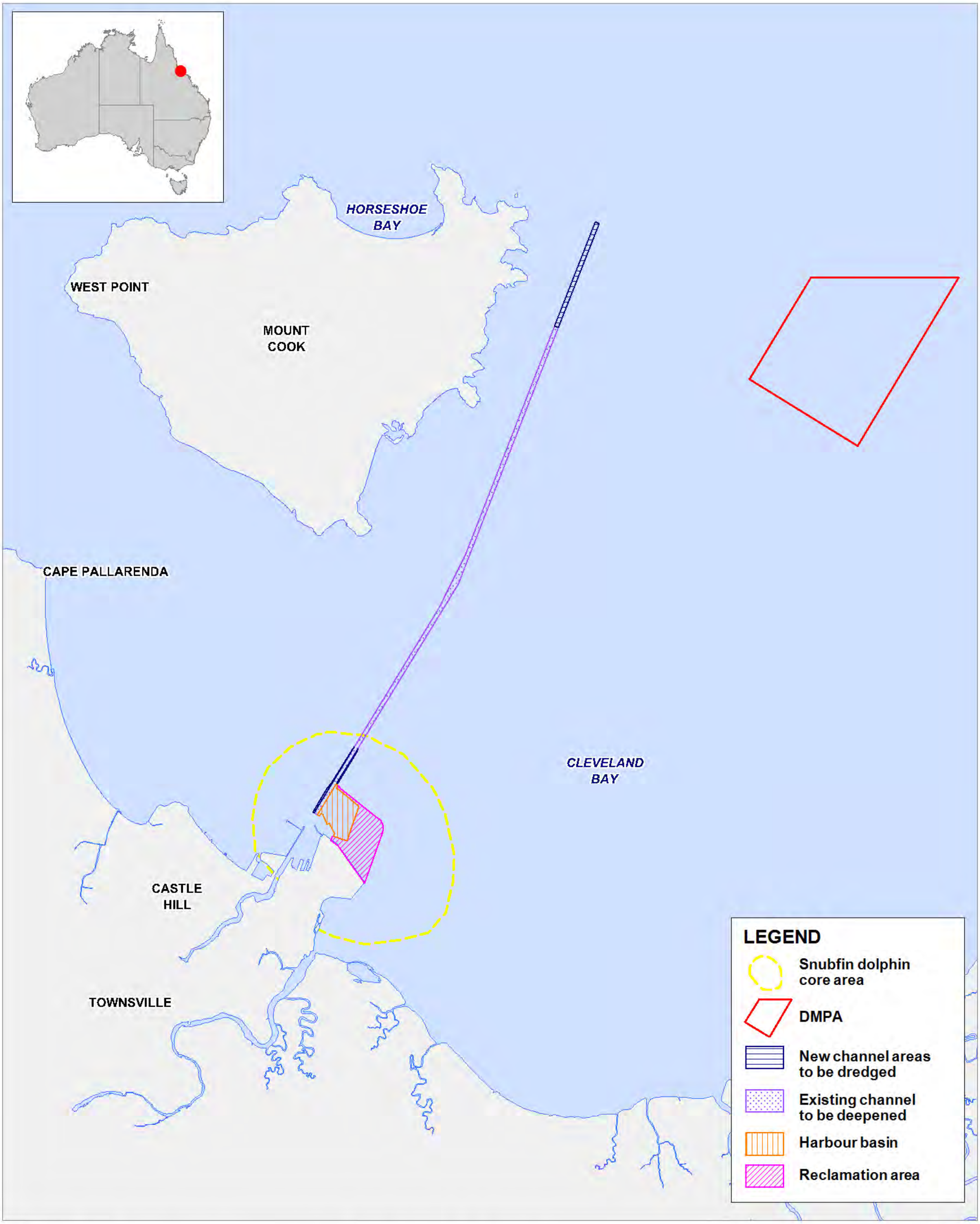
This species, like Australian snubfin dolphin, has a wide home-range and undertakes regular movements within and out of Cleveland Bay. However, in the Great Sandy Straits region, this species forms relatively discrete local sub-populations with little genetic mixing with other sub-populations (Cagnazzi *et al*. 2011).

Resistance and Resilience of Near-Shore Dolphins

As discussed in the Water Quality chapter and other sections of this report, the preferred nearshore habitat of both of these dolphin species represents a highly dynamic environment. These nearshore environments are highly turbid, subject to periodic physical disturbance (storms, cyclones, floods) have characteristically highly temporally variable water quality conditions. As a result, benthic communities in these areas are in a state of flux, and are typically comprised of species that are capable of rapid recovery, or are able to move between areas.

This has important implications in terms of resistance of near-shore dolphin species to changes in environmental conditions. In this regard, near-shore dolphins have the following biological characteristics that allow them to cope with altered environmental conditions:

- Feeding behaviour and turbidity. Nearshore dolphin species are capable of successfully foraging in turbid waters. Dolphins often stir up bed sediments when foraging for benthic prey, resulting in limited to no visibility for prey detection. It is thought that dolphins detect prey using echolocation rather than visual cues (Mustoe 2006, 2008). On this basis, nearshore dolphins therefore have adaptations that allow them to feed in high turbidity waters (Parra and Jedensjö 2009).
- Opportunistic diet. Both nearshore dolphin species are considered to be “opportunistic-generalist feeders” (Parra and Jedensjö 2009). Gut contents analysis performed on dolphins captured along the Queensland coast (Parra and Jedensjö 2009) found that both dolphins primarily fed on a range of demersal and pelagic fish species commonly found in estuarine and shallow nearshore habitats. In addition to fish, snubfin dolphins were found to feed on squid and cuttlefish, which typically occur in the water column. The opportunistic, generalist diet of these species reduces their susceptibility to changes in availability of particular prey types.
- Home range and site fidelity. Indo-Pacific dolphins are migratory species, with studies elsewhere suggesting that they can have a large home range (up to 395 km^2; Hung in SEWPAC 2012a). Snub-fin dolphins are also thought to have large home ranges. Surveys by Parra (2006) in Cleveland Bay found that most identified individuals spent <30 days at a time within the 310 km^2 Cleveland Bay area, and periods of over a month before entering the Bay again. On the basis of these findings, Parra (2006) concluded that snub-fin dolphins in Cleveland Bay were not permanent residents, but regularly visit the area. Both dolphin species can therefore temporarily move from habitats that have sub-optimal environmental conditions.



Title:

Important habitat for Australian snubfin and Indo-Pacific dolphins in Cleveland Bay (Parra 2006)

Figure: **3-46**

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Despite possessing a range of adaptations that allow a degree of resistance to short-term changes in environmental conditions, both nearshore dolphin species are considered to have low capacity to recover from population declines. In this regard:

- Both are long-lived species with low reproductive rate. While the reproductive ecology of these species has not been well studied, most Delphinids bear one calf every two to three years (SEWPAC 2012a,b). Consequently, these species would have slow rates of population recovery.
- Both species have small overall population sizes, and also have small local sub-population sizes. The state wide populations of both species are less than 10,000 individuals. Despite having wide home-ranges, both species can form small localised groups (such as the Cleveland Bay "sub-populations"). There are conflicting views regarding the degree of inter-mixing among these groups. SEWPAC (2012a,b) argues that populations of both nearshore dolphins are contiguous, citing the extensive home range and broad movement patterns of these species (see also Cleveland Bay findings reported by Parra 2006). However, in the Great Sandy Straits region, Indo-Pacific humpback dolphins were observed to form small discrete groups with little interactions among groups (Cagnazzi 2011). Whatever the case, a substantial decline in dolphin numbers is expected to reduce the viability of local sub-populations.
- Both species are under increasing threat from human activities. In this regard, both species have narrow habitat requirements, being restricted to near-shore habitats (often around river mouths and seagrass meadows). These environments are subject to the high levels of anthropogenic pressures. Key threats include habitat loss and degradation, entanglement in gill nets, pollution (both direct and indirect impacts) and vessel strike from fast-moving watercraft (Parra *et al.* 2004; SEWPAC 2012a,b).

3.6.5.2 Dugong

Habitat Use, Distribution and Abundance

The dugong has a global IUCN listing of "vulnerable to extinction" (IUCN 2010). It is 'listed threatened', 'listed migratory' and 'listed marine' species under the EPBC Act 1999 and the Queensland dugong population is considered as "vulnerable" under the NC Act 1992.

The dugong has a relatively broad geographic range that extends from east Africa to Vanuatu, between the latitudes of approximately 27° north and south (Marsh *et al*. 2002). The IUCN listing reflects the significant contraction in their global distribution and abundance. Australia is thought to represent the last strong-hold for this species, where it occurs from Shark Bay in the west to Moreton Bay in the east. The most important dugong areas south of Cooktown are Hinchinbrook Island, Cleveland Bay, Shoalwater Bay, Hervey Bay and Moreton Bay (Marsh *et al*. 2002).

Population estimates for the broader region have been developed from aerial survey data. Marsh *et al*. (2002) estimated that the number of individuals in the area between Hinchinbrook Island (north of Townsville) and the southern boundary of the Great Barrier Reef Marine Park (north of Bundaberg) was approximately 3500 in 1986, and in 1994 at 1700 individuals. Marsh (2000) examined changes in dugong numbers between the 1960s and 2000 for the Queensland coastline south of Cairns, based on by-catch records from the government shark-netting program. It was estimated that dugong catch-per unit effort declined by approximately 3% during this period. Notwithstanding these results, it is not possible to quantify the direction and magnitude of change in dugong populations in the region. It is thought however that numbers in the region are now relatively stable (SEWPAC 2012c).

Dugongs are principally herbivores and have been shown to be highly selective feeders, preferring certain species of seagrass to others. Preen (1995a) reported dugongs showing a preference for grazing on seagrass from the genus *Halophila*, which dominate seagrass meadows in Cleveland Bay (refer to section 3.2). Elsewhere (Moreton Bay), dugongs are also reported to feed deliberately on invertebrates such as ascidians. This omnivory is thought to be a response to nutritional stress caused by seasonality in abundance of seagrasses (Preen 1995b).

Dugongs are abundant in Cleveland Bay, and as mentioned above, the Bay is thought to be an important dugong habitat at a regional scale (Sheppard 2007). Aerial survey data collected in 2008, 2010 and 2011 was modelled by James Cook University to determine relative density of dugong habitat use in Cleveland Bay (GHD 2011). Records of dugong observations are shown in Figure 3-42, and modelled dugong relative density data are shown in Figure 3-47.

The greatest density of dugongs was recorded in eastern Cleveland Bay, which is consistent with previous modelling undertaken by Sheppard (2007). Cape Pallarenda was observed to support medium dugong densities. Patterns in relative abundance varied between tidal stages, with high densities recorded in eastern Cleveland Bay on high tides, and medium densities recorded in the same area during low tides. Sandfly Creek was the only area in Cleveland Bay observed to support high densities during low tide (GHD 2011). The change in abundance between tidal stages reflects the drying of intertidal flats during low tides, and the associated movement of dugongs into deeper waters.

At a local scale, the patterns in relative abundance of dugongs in Cleveland Bay reflect patterns in seagrass meadow distribution and abundance. Figure 3-4 shows that medium and high dugong densities in eastern Cleveland Bay were coincident with the largest and most abundant seagrass meadows in Cleveland Bay. The seagrass meadows at Cape Pallarenda and southern Magnetic Island, despite being relatively abundant, were found to have medium to low dugong abundance. GHD (2011) suggested that changes in relative densities of dugongs in time could reflect changes in seagrass extent/abundance, or sampling error due to high turbidity in 2010.

While dugongs are most abundant around dense seagrass meadows, it is apparent that move throughout Cleveland Bay as they move between feeding sites (seagrass meadows). There is little seagrass within the outer harbour Project area and sparse seagrass cover has been reported previously in the DMPA and surrounds by others, but none was observed in the present study. It is possible that dugongs move through both of these areas from time to time, although aerial surveys suggest that dugongs have low abundance in these areas (GHD 2011; Figure 3-47).

Dugongs also breed in Cleveland Bay. While dugongs breed year round, mating and calving tend to peak in spring and summer, particularly at high latitudes (SEWPAC 2012c). Calving sites reportedly include sandbanks and estuaries, which is possibly a strategy to avoid predation by sharks (SEWPAC 2012c). Dugongs delay their breeding until there are sufficient seagrass food resources (SEWPAC 2012c). Females do not bear their first calf until they are 10 to 17 years old. Juveniles begin to feed on seagrasses shortly after birth, but also suckle during time (SEWPAC 2012c).

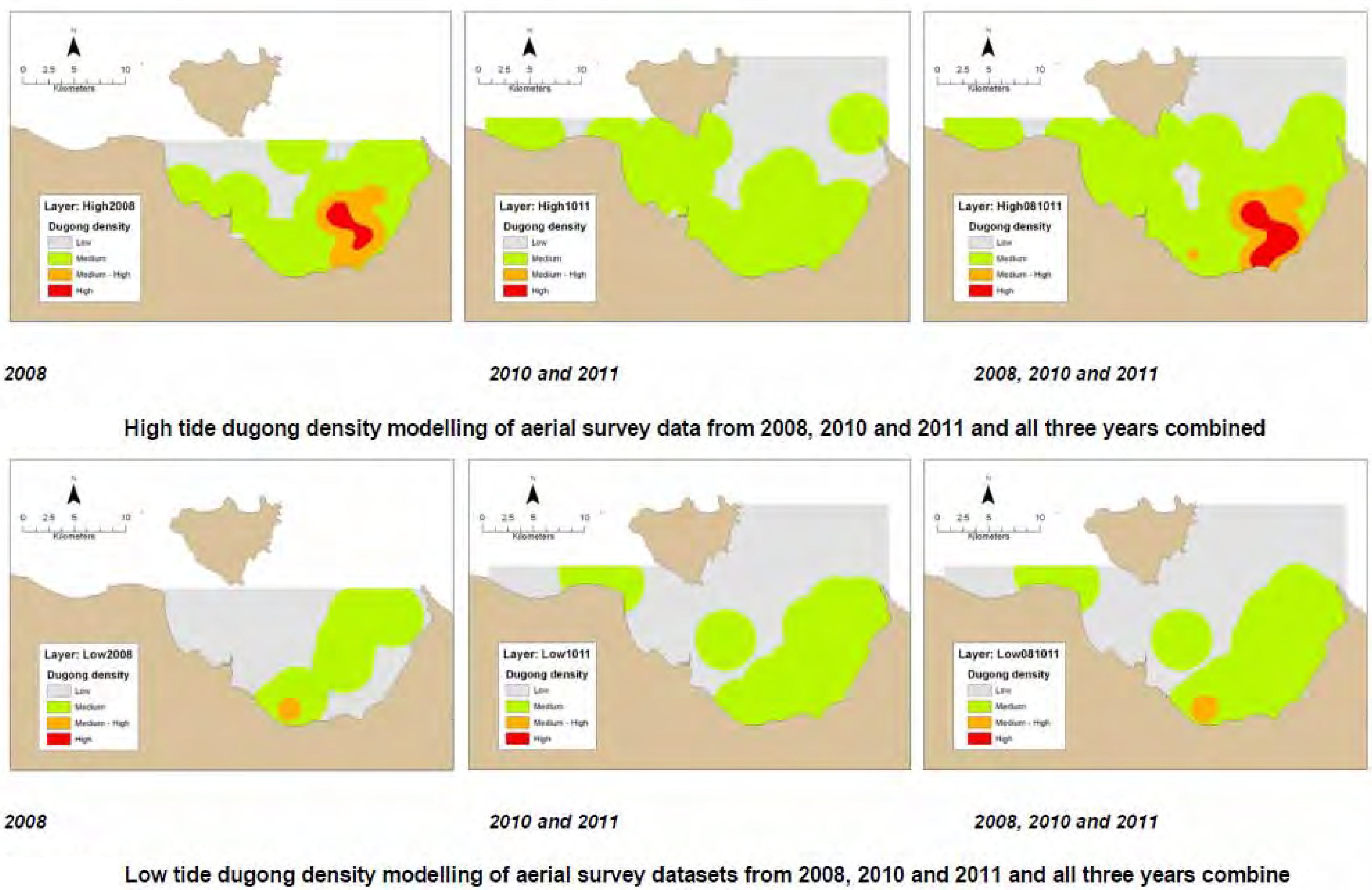


Figure 3-47 Dugong relative densities during high and low tide surveys (Source: GHD 2011)

Resilience

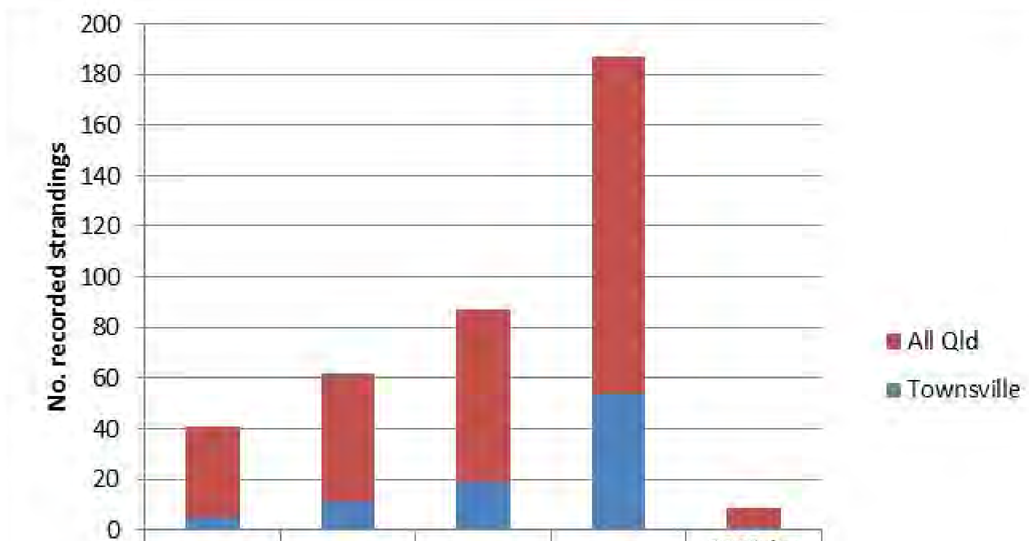
Like green turtles (see Section 3.6.4), food resource availability is thought to be a key control on dugong populations. The loss of seagrass meadows has been implicated as the major cause of dugong strandings in the region. Dugong stranding reports for the GBR increased from an annual average of 63 per annum in the period 2008-2010, to 187 turtles in 2011 (GBRMPA 2012b,c). The Townsville region was identified as a hot-spot for strandings in 2011, with 54 marine turtle strandings compared to 5 (2008), 11 (2009) and 19 (2010) turtles in the period 2008 to 2010. Furthermore, in the period January to May 2012, there was only one recorded stranding in the Townsville region, which was relatively low compared to previous years (DEHP 2012; see Figure 3-48).

Similar to green turtles, a number of factors facilitate dugong population's capacity to cope with periodic disturbance:

- Maintenance of 'permanent' seagrass meadows in eastern Cleveland Bay – see Section 3.6.4;
- Dugongs may supplement their diet with algae (Marsh *et al*. 1982) and benthic macroinvertebrates (Preen 1995b) during periods when seagrass resource availability is low.
- Dugongs are capable of moving large distances (measured in hundreds of kilometres; see SEWPAC 2012c). It is thought that these extensive movements are a response to food resource availability (SEWPAC 2012c).

Notwithstanding the above, it is apparent that dugong population resilience was markedly reduced as a result of the 2011 floods. Reductions in dugong abundance associated with post-flood reductions in seagrass meadows are well documented (e.g. Preen and Marsh 1995). However, the number of strandings recorded in 2011 was considered by Department of Environment and Heritage Protection (2012b) to be 'exceptional', reflecting the significant severity and wide geographic extent of the 2011 floods compared to previous events.

Recovery rates of dugong populations will be slow (due to low birth rates of dugongs), and contingent on the recovery of seagrass meadows. Marsh *et al*. (2002) estimated that under optimum conditions (i.e. low natural mortality), the maximum rate of population increase would be 5% per annum. Key anthropogenic threats that could impact on recovery of dugongs include boat strike, loss of seagrasses and entanglement in gill nets (DERM 2010).



	2008	2009	2010	2011	2012 (to May)
All Qld	36	51	68	133	8
Townsville	5	11	19	54	1

Figure 3-48 Number of dugong strandings recorded in the Queensland standings database (Department of Environment and Heritage Protection 2012)

3.6.5.3 Humpback Whale

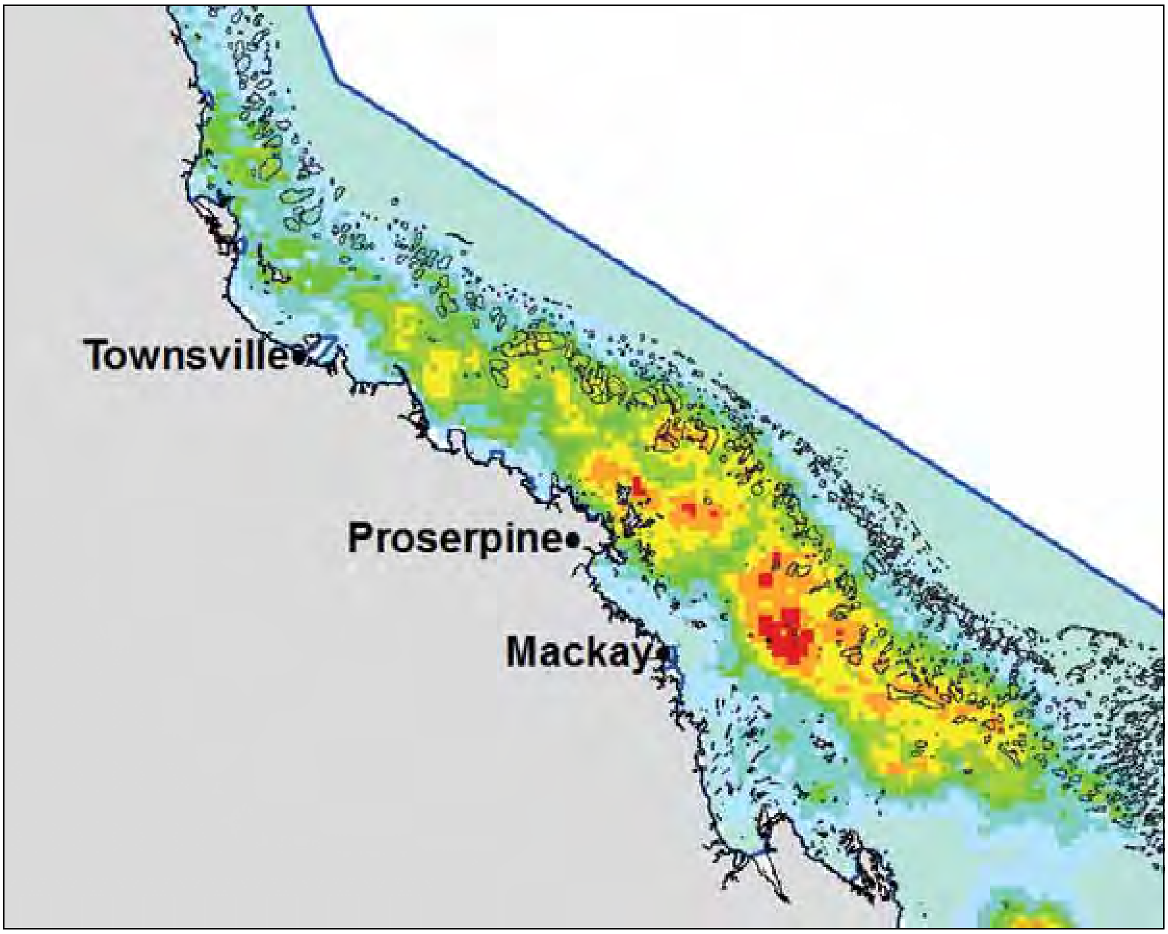
The humpback whale has a global IUCN listing of least concern (IUCN 2010). It is listed as vulnerable under both the EPBC Act and the NC Act.

Humpback whales calve in the protected waters of the GBR between July and August then travel down the Australian coast to Antarctic waters where they spend spring and summer before returning (DERM 2010). They mainly feed on krill (*Euphausia superba*) and small fish while in Antarctic waters, but may undertake opportunistic feeding while migrating along the Australian coast (SEWPAC 2012d).

Prior to whaling, 40,000 animals were estimated to migrate along the east coast of Australia (DERM 2010). When whaling in Australian coastal waters ceased in 1962, numbers had dwindled to an estimated 500. In 2007 the total population estimate was between 9,500 and 12,500. Their numbers appear to be increasing at approximately 10% per annum now that commercial whaling has ceased. Nonethless, populations are vulnerable to further change.

Smith *et al*. (2012) developed a predictive spatial habitat model of humpack whale occurrence within the Great Barrier Reef, based on presence-absence data from aerial surveys. The model identified two core areas of higher probability of occurrence: (1) offshore of Proserpine extending south to Mackay within the inner reef lagoon region, and (2) the Capricorn and Bunker groups of islands and reefs approx. 100 km east of Gladstone. (Figure 3-49). They suggested that the first area was an important wintering area, whereas the second area represented an important migration route. The waters of Cleveland Bay were predicted to have a low level of environmental suitability for humpack whales.

A search of the Wildlife Online database for Cleveland Bay has 15 confirmed humpback whale records since 1980 (Appendix E). GHD (2011) recorded humpback whales, including calves, within Cleveland Bay during August-September 2010 (n = 19 incidental observations). The timing of these records indicates that were whales were making their return journey to southern waters. These whales were recorded in deep waters of Cleveland Bay and adjacent to Cape Cleveland. Predictive modelling suggests that humpack whales are most likely to occur in water depths of 30 to 58 m (Smith *et al*. 2012), however they are known to occur in shallow waters from time to time. This species has been recorded in both turbid and clear waters; however the behavioural response of whales to turbid plumes is unknown.



Red = most suitable; green = moderate suitability; blue = least suitable

Figure 3-49 Model prediction of environmental suitability for humpback whales in the GBRWHA (Source: Smith *et al*. 2012)

3.7 Fisheries Species and Productivity

3.7.1 Commercial Fisheries

Fisheries are an important commercial, recreational, traditional and biologically diverse resource within the Townsville region. C&R Consulting (2007) estimate that of the 253 fish species recorded from Cleveland Bay and the Ross River and Creek 163 species are of low to medium commercial fisheries value; 60 species are of recreational fisheries value; 34 species are of aquaculture industry value and 25 species are of value to the aquarium fishery.

Some commercial fishing activities within Cleveland Bay are restricted by the establishment of a Dugong Protection Area (Zone A). Within this zone, the use of offshore set, foreshore set and drift nets are prohibited. Other netting practices such as ring, seine, tunnel and set pocket netting which are not considered to pose a serious threat to dugong are allowed, whereas the use of river set nets is allowed with modifications. Trawling and line fishing is also allowed within this zone. The Cleveland Bay Fish Habitat Area (FHA 071) has recently been declared which covers most of eastern portion of Cleveland Bay. Legal fishing activities are still allowed within FHAs.

The main commercial fisheries operating in Cleveland Bay are:

- Queensland Mud Crab Fishery. This fishery is based on the use of crab pots, which are deployed in mangrove lined estuarine creeks and offshore areas. Based on analysis of mud crab catch data, Cleveland Bay is not considered to represent a key production area for this fishery (DEEDI 2011; DEEDI 2010a), however nearshore areas to the north of Cleveland Bay are of state-wide significance.
- East Coast Otter Trawl Fishery. Areas to the south and north of Cleveland Bay represent regionally important fishing areas for the otter trawl fishery (e.g. Healy 2007; DEEDI 2005; DEEDI 2010b; see Figure 3-51). However, on a state-wide basis the fishery is not as large as, for example, key trawl areas such as Moreton Bay (DEEDI 2011b). Soft sediment habitats with low topographic relief, and free of hook-ups (i.e. hard objects such as reefs, artificial structures etc.), as found throughout Cleveland Bay, are targeted by commercial trawlers. Key species include prawns, Moreton Bay bugs and scallop.
- Queensland Spanner Crab Fishery. Cleveland Bay does not represent a key production area for this fishery, although areas immediately north and east represent regionally significant fishing areas (DEEDI 2011c). Dilly traps are used for this fishery (DEEDI 2010c), which are set in offshore and coastal open waters.
- Queensland Blue Swimmer Crab Fishery. Cleveland Bay is not known to represent an important area for this fishery (DEEDI 2010d), especially compared with south-east Queensland region (DEEDI 2010d). Crab pots are the main fishing method used in this fishery (DEEDI 2010d).
- Queensland East Coast Spanish Mackerel Fishery. This fishery is based on line-fishing. Spanish mackerel aggregate in large numbers from around Cleveland Bay to Bowen to spawn. Waters offshore of Cleveland Bay represent important commercial fishing areas on a state-wide basis (DEEDI 2011b).

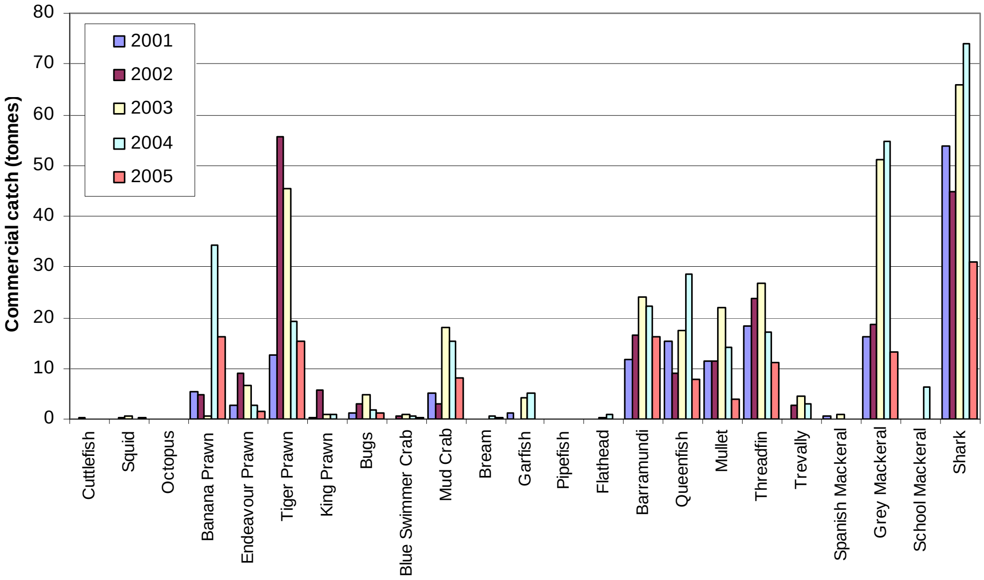
- Queensland East Coast Inshore Fin Fish Fishery. A range of net types are used in this fishery, subject to gear restrictions outlined above and the target species (DEEDI 2009). In 2005, Cleveland Bay represented a locally important net fishing area (DEEDI 2011a).

The key species targeted by commercial trawl, net, line and crab fisheries in Cleveland Bay are prawns (i.e. tiger, banana and Endeavour prawns), mud crabs, blue swimmer crabs, bugs, barramundi, tropical sharks, mackerel (primarily grey mackerel) and threadfin, Spanish mackerel, coral trout and red throat emperor. Many other species of molluscs, crustaceans and finfish are also retained by trawl fishers as commercial by-product, mainly by trawl fishers.

Sea cucumber (*Beche-de-mer*), marine aquarium fish and coral are harvested by small commercial collection fishers. The main aquarium fish families that are harvested include damsel fish (Pomacentridae), butterfly fish (Chaetodontidae), angel fish (Pomacanthidae), and wrasses (Labridae), which would be collected from reef habitats. There is little existing information describing the main collection fishery areas within the wider region, although, the study area and surrounds are not known to represent regionally important areas for this fishery.

The Townsville area's gross value of production typically contributes approximately 11% to total Queensland commercial fisheries production (Fenton and Marshall 2001). Based on the five years between 2001 and 2005[9], the estimated value of the commercial fisheries varied between 1.0 and 2.25 million dollars annually (approx. 138 - 325 tonnes) (DEEDI 2011a). For the trawl fishery, tiger and banana prawns were the most important in terms of both catch and value, followed by endeavour prawns (Figure 3-50). For the net fishery, sharks and grey mackerel were the most important in terms of both catch and value, followed by barramundi and threadfin.

[9] Most data provided on productivity has been compiled from publicly available data on the DEEDI Coastal Resources and Habitat Information System (DEEDI 2011a). Within this information system, data are not provided for areas or fisheries with a low fishing effort or usage (i.e. less than 5 boats) to alleviate privacy concerns. The 30-minute commercial catch reporting grid J21 covers all of Cleveland Bay, as well as coastal areas to the north west of Cape Pallarenda.



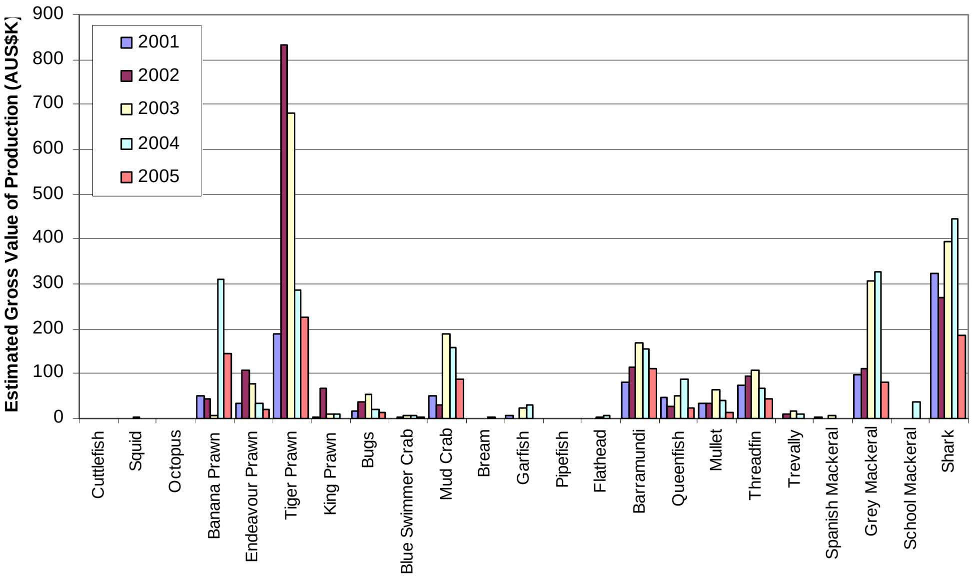
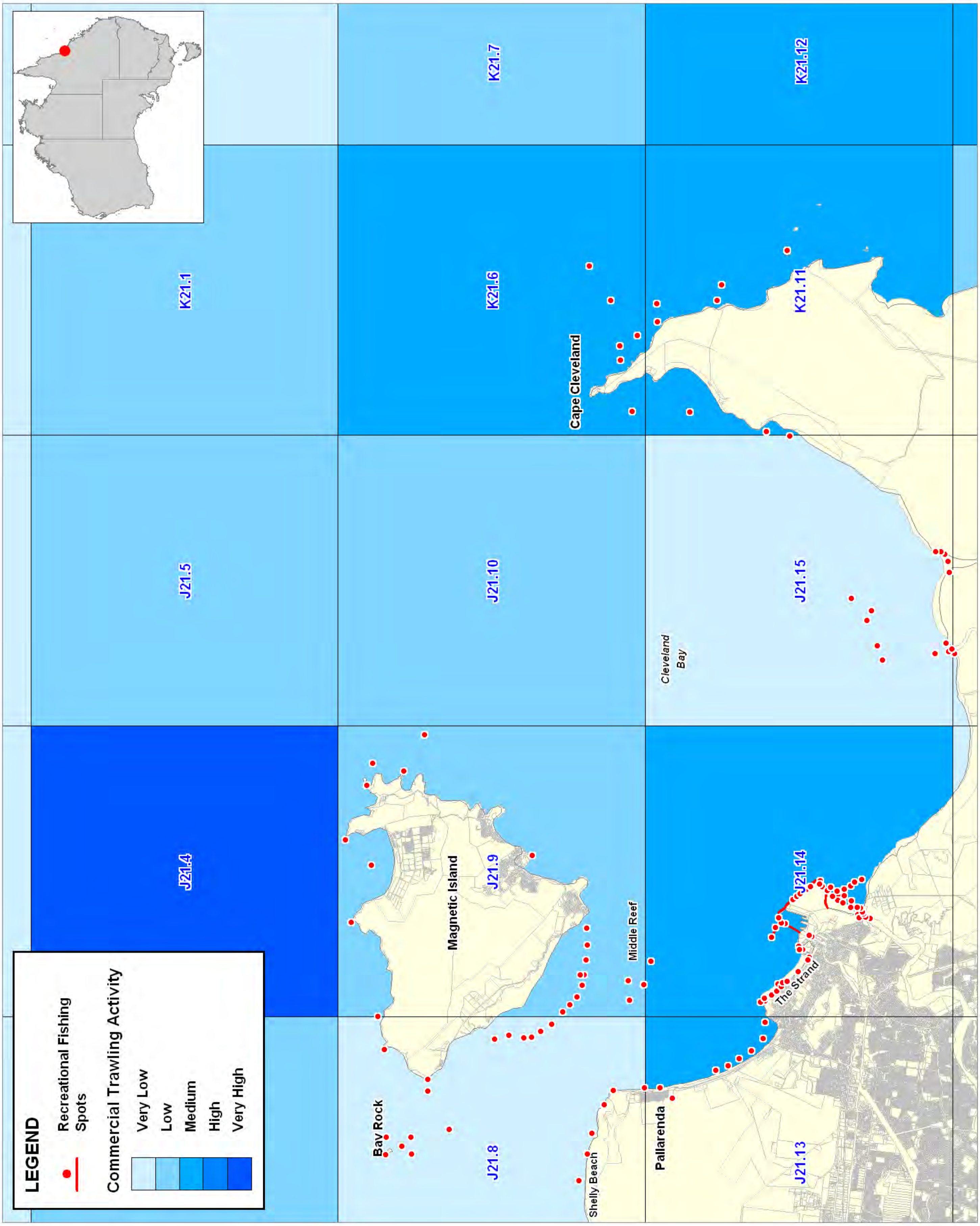


Figure 3-50 Annual commercial catch of key species (a) and estimated commercial fisheries value of key species (b) for Cleveland Bay and surrounds 2001-2005 (DEEDI 2011a)



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Commercial Trawling and Key Recreational Fish Activity at Cleveland Bay and Surrounds (DEEDI 2011a)

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Approx. Scale

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3.7.2 Recreational Fisheries

Recreational fishers generally target similar species to commercial fishers, with a strong focus on barramundi, mullet, whiting, bream and mud crabs in inshore areas; and reef fish such as coral trout (*Plectropomus* spp.), snapper (Lutjanidae), sweetlip (Lethrinidae) and trevally (*Caranx* spp.) when further from shore (Ludescher 1997).

Estuarine areas in the south-east of Cleveland Bay (e.g. Ross River, Alligator and Crocodile Creeks) are commonly used for targeting species such as barramundi, mangrove jack, flathead, whiting and mud crabs. Cast netting for prawns and herring occurs extensively along Ross Creek, the Ross River mouth and along foreshore areas; and yabbie pumping occurs on the eastern side of Ross River (Sinclair Knight 1991). The breakwaters around the Port of Townsville are popular recreational fishing locations, primarily for fishing from small boats (CPL 2007). The only Port of Townsville breakwater that recreational anglers have access to for land-based fishing is the western breakwater. Reef and deep-sea recreational fishing is focused around Cape Cleveland, Middle Reef, the shipping channel, Pallarenda Point and Magnetic Island (Sinclair Knight 1991).

Little is known about the catch and value of recreational fishing. Some limited recreational fishing data are collected by DEEDI (2011a) for the wider region, which forms the basis of information on recreational catch presented in Figure 3-52, and locations of key fish areas shown in Figure 3-51. It is also difficult to quantify the overall market value of the recreational fishing industry because it supports a wide network of businesses and tourism-related operations in Townsville and on Magnetic Island. It is likely to be considerably more than the commercial fishing industry, as previous estimates of the economic value of recreational fishing in the area (Sinclair Knight 1991) are high. At that time, approximately 70,000 kg of bait was sold annually at a retail value of ~$200,000. They also estimated the annual retail value of bait and tackle sales to be $2.5 million, whilst outlay on boats, motors and chandlery was estimated to be a further $2 million.

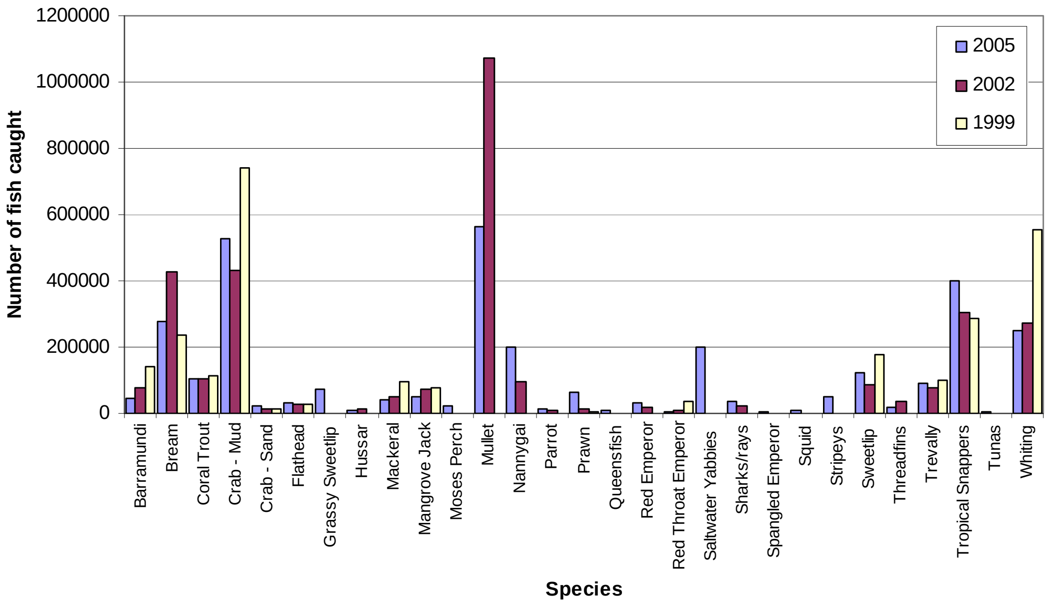


Figure 3-52 Reported fish caught by recreational fishers in the northern QLD statistical division (DEEDI 2011a)

3.7.3 Traditional Fisheries

Much of the fishing activity in the area that is undertaken by indigenous Australians is largely encompassed by recreational fishing, however, there are some additional fisheries values that are important culturally. Fish, shellfish and turtles continue to be an important indigenous food source in the wider area, and may be used for ceremony and/or subsistence (Ludescher 1997).

There is little information about the amount of indigenous fishing conducted, however, it is likely to be small when compared to the general recreational and commercial sectors (CRC Reef 2002).

3.8 Introduced Marine Fauna

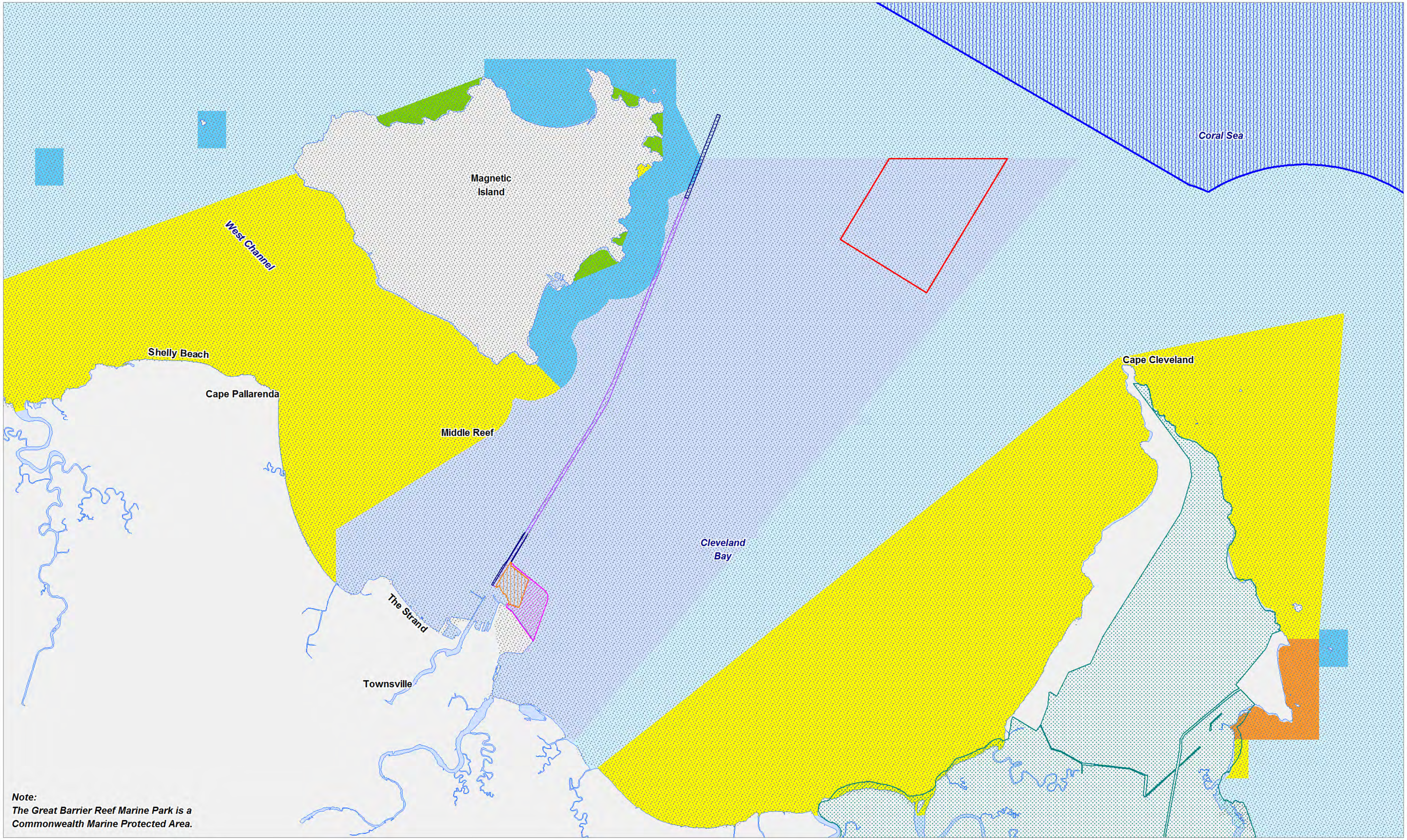
More than 250 non-indigenous marine species have been recorded in Australian waters to date (Hayes *et al*. 2005). There are several potential vectors by which non-indigenous species may enter domestic waters, however it is thought that most species are unintentionally introduced through shipping and vessel movements, either in ballast waters or from biofouling on the hull of vessels (Hewitt and Campbell 2010). Other vectors include intentional transfer of aquaculture and mariculture organisms, transfer of food products for the aquarium trade and use of biological material for packing (Hewitt and Campbell 2010). Asian green mussel (*Perna viridis*), considered to be a potential threat in tropical waters, was found on a vessel's hull in Cairns harbour 2001 and Caribbean tubeworm (*Hydroides sanctaecrucis*) has also been introduced there (Souter 2009).

A port wide baseline survey of non-indigenous fauna was undertaken by James Cook University and the CRC Reef in November 2000 (Neil *et al*. 2001). This aim of this baseline survey was to describe existing marine communities in the Port, and identify any non-indigenous species, including target pest species listed by the Australian Ballast Water Management Committee, Hewitt and Martin (1996) and Furlani (1996). The baseline survey recorded over 1300 organisms, however no targeted marine pest species were recorded (Neil *et al*. 2001). A range of species that resemble non-indigenous species were recorded in the baseline survey, however none of these potential non-indigenous species are considered to represent a serious pest in Australian waters (Townsville Port Authority and CRC Reef 2002).

3.9 Matters of National Environmental Significance

In addition to threatened and migratory species considered in Section 3.6, the following matters of national environmental significance are relevant to the Project (Figure 3-53):

- World Heritage Properties – specifically Great Barrier Reef World Heritage Area (GBRWHA) (see Section 3.9.1).
- National Heritage Places – this includes the GBRWHA (see Section 3.9.1).
- Wetland of international importance – specifically Bowling Green Bay Ramsar site (see Section 3.9.2).
- Great Barrier Reef Marine Park – which includes most of Cleveland Bay (see Section 3.9.3).
- Commonwealth Marine Areas – which includes areas offshore of Cleveland Bay (see Section 3.9.4).



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Location of Areas Listed as Matters of National Environmental Significance

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3.9.1 Great Barrier Reef World Heritage Area

The Great Barrier Reef World Heritage Area (GBRWHA) extends from the low water mark on the Queensland coast to past the edge of the continental shelf, and from the tip of Cape York Peninsula to just north of Fraser Island. It includes mangroves, rocky reefs, sandflats, open ocean and the deep sea floor. GBRWHA, like other Australian World Heritage Properties, is listed as a Matter of National Environmental Significance (MNES) under sections 12 and 15A of the EPBC Act. The Great Barrier Reef is also listed as a Natural Heritage Place, which is listed as a MNES under sections 15B and 15C of the EPBC Act.

Waters within Cleveland Bay, including the outer harbour Project area, channels, wider port area and DMPA, are located within the GBRWHA (Figure 3-53). Cleveland Bay represents a small proportion of the overall area of the GBRWHA (approximately 0.07%; C&R Consulting 2007).

The GBRWHA was listed in 1981 on the basis of meeting a range of criteria, including all four natural criteria at the time of its listing:

- *An outstanding example representing the major stages of the earth's evolutionary history.*
- *An outstanding example representing significant ongoing geological processes, biological evolution, and man's interaction with his natural environment.*
- *Contain unique, rare or superlative natural phenomena, formations, or features or areas of exceptional natural beauty, such as superlative examples of the most important ecosystems to man.*
- *Provide habitats where populations of rare or endangered species of plants and animals still survive.*

Since the original listing, the wording and numbering of these criteria have changed slightly. Their environmental concepts remain similar, but interactions with people are now recognised as 'cultural' criteria rather than natural. The Great Barrier Reef World Heritage Area extends to mean low water and is also listed on the Register of The National Estate.

The GBRWHA listing document identifies specific examples of values/attributes underpinning each criteria. With few exceptions, the examples of values/attributes identified in the GBRWHA listing document are not location specific, and therefore do not specifically define marine ecological values/assets supported in Cleveland Bay. For this reason, it is not meaningful or practicable to identify specific features within the Cleveland Bay that meet each of the criteria.

For this reason, key marine ecological values of Cleveland Bay that are considered to be broadly representative of the four natural World Heritage criteria (and the examples of values/attributes identified in the GBRWHA listing document) were selected. These key marine ecological values include:

- Seagrass meadows and mangrove ecosystems – refer to Section 3.1 and 3.2;
- Inter-reefal and lagoonal benthos – refer to Section 3.3 and 3.4;
- Coral reefs – refer to Section 3.5;
- Habitats for threatened species – refer to Section 3.6;

- Many species of coral, macroalgae, crustaceans, polychaetes, molluscs, phytoplankton, fish, seabirds, mammals and reptiles. Refer to each of the sections describing notable marine flora and fauna species and their diversity.

In addition to individual biological components, the listing criteria also refer to the values provided by the interactions among habitats and species, and the underpinning biological processes. Like other nearshore environments in the bioregion, Cleveland Bay supports a range of marine habitat types, which have varying levels of inter-connectivity. It contains a complex mosaic of coral reefs, mangroves, seagrass, unvegetated shoals and deeper waters, all within relatively close proximity to each other. Elsewhere, this combination and diversity of habitat types represent important nursery habitat values for many fish and prawn species of commercial significance (e.g. Nagelkerken 2009; Unsworth *et al*. 2010).

There are a number of broad scale processes that are seen as important to maintaining the overall diversity of habitat types and functioning of ecosystems within Cleveland Bay. These include:

- Climate – including patterns of temperature, rainfall and evaporation, and periodic disturbance from severe storms and cyclones (see EIS Chapter B8 - Climate).
- Physical Coastal Processes - natural (equilibrium) hydrodynamic controls on habitats through tides, currents, erosion and accretion (see EIS Chapter B3 – Coastal Processes);
- Geomorphology. Key geomorphologic/topographic features of the Bay (see EIS Chapter B3 – Coastal Processes);
- Hydrology. Natural patterns of tidal inundation and freshwater flows to Cleveland Bay (see EIS Chapter B2 – Water Resources);
- Water Quality. Water quality that provides aquatic ecosystem values within wetland habitats (see EIS Chapter B4 – Water Quality);
- Energy and Nutrient Dynamics. Primary productivity (Sections 3.1, 3.2 and 3.5) and the proper functioning of carbon and nutrient cycling processes.

The existing integrity of marine habitats varies throughout Cleveland Bay, however nearshore areas around Townsville, particularly those within the operational port areas, are generally in the most modified condition. Construction of the present day port facilities, most notably reclamation and dredging of intertidal and sub tidal areas, has resulted in extensive changes to habitats at the mouth of Ross Creek. Furthermore, a range of ongoing port-related pressures continue to affect the environmental values of nearshore areas, including maintenance dredging of berths and channels, and general disturbance associated with day to day port operations. The Port facilities are situated between the mouths of Ross Creek and Ross River, which experiences freshwater flows and ongoing inputs of sediments and contaminants derived from human activities in the catchment (i.e. urban development, agriculture, industrial land uses etc.).

3.9.2 Bowling Green Bay Ramsar site

Wetlands of international importance are listed as a Matter of National Environmental Significance (MNES) under sections 16 and 17B of the EPBC Act. Such wetlands are commonly referred to as Ramsar wetlands, and are considered to represent wetlands of international significance.

Bowling Green Bay Ramsar site is the closest Ramsar site to the study area. Ramsar sites are protected under international agreements (e.g. Ramsar Convention) and National legislation (EPBC Act). This Ramsar site is largely situated to the east of Cape Cleveland, and extends partly along the southeast coastline of Cleveland Bay.

At the time of the EIS report preparation there was no Ecological Character Description for this site. However, the most up to date published Ramsar Information Sheet for the site (Blackman 1999) indicates that the key values of the site are based on habitat provisioning for migratory and resident waterbirds, marine megafauna (turtles, dugong) and a range of other natural resource values supported by the diversity and extent of wetland types. Based on Blackman (1999), the following components, processes and services are likely to be critical in the context of maintaining the ecological character of the site:

- Diversity of wetland types – the site supports a diverse complex of wetland types. A total of 14 different wetland types were identified by Blackman (1999), with the largest by area being Tidal mud flats (Ramsar Wetland Type G), Mangrove/tidal forest (Ramsar Wetland Type I) and saltmarsh/saltpan (Ramsar Wetland Type H). The site includes terrestrial areas, as well as freshwater and marine environments. Extensive areas of forest and woodland are present in elevated areas (mountainous and coastal sand dunes), before giving way to brackish and freshwater communities on the low lying coastal plain (including both stream and palustrine marsh habitats). Saltmarsh and saltpans occur landward of mangrove forests, before giving way to intertidal flats associated with the prograding spit of Cape Bowling Green.
- Hydrological conditions - the site is drained by the Haughton River, together with several major creeks (Barramundi, Barratta and Sheep Station creeks) and smaller drainages. Groundwater is stored in two main aquifers that are recharged mostly by stream flows. These hydrological processes ultimately control freshwater ecosystems within the site, as well as representing a key control on marine communities during significant flow events.
- Provision of feeding grounds for threatened marine megafauna species. Blackman (1999) found that the intertidal and subtidal seagrass meadows of the site, together with those at nearby Cleveland Bay outside the site, provide an important food resource for dugongs and green turtles.
- Provision of nursery areas for species of economic importance. The mosaic of habitat types present within close proximity to each other, together with the presence of extensive seagrass meadows, mangrove forest, saltmarsh and freshwater marshes, represent high quality fisheries habitat. Key fisheries groups include prawns, crabs (including the mud crab *Scylla serrata*), baitfish and finfish (including barramundi *Lates calcarifer*) species. Blackman (1999) notes that these habitats are used by a wide variety of life-stages for species of economic importance, particularly as a nursery habitat.
- Provision of breeding and feeding areas for waterbirds. Blackman (1999) notes that the site is particularly important for post breeding groups of brolga, magpie geese and various other species of Anatidae (ducks, geese and swans). The brolga and magpie geese are mainly associated with shallow sedge swamps and marine plains of the site, where they undertake breeding during late summer. The site also supports a wide range of migratory shorebirds, with approximately 50% of the species listed under JAMBA and CAMBA recorded in the site. Little

tern can reach high numbers (1000 individuals), and is known to breed on Bowling Green Bay spit. At least 103 birds (including terrestrial birds) are known to breed within the site.

- The site also supports a range of ecosystem services/benefits including sediment trapping, control of coastal erosion, and maintenance of water quality.

The outer harbour Project area is located >9 kilometres from the Bowling Green Bay Ramsar site. There are however functional linkages between the site and Cleveland Bay, particularly for species that are migratory or have large home ranges. Of particular relevance are dugongs, turtles and nearshore dolphin species, which are likely to move regularly between the Ramsar site, Cleveland Bay and other coastal areas in the wider region.

3.9.3 Great Barrier Reef Marine Park (GBRMP)

Great Barrier Reef Marine Park (GBRMP) is managed under the Great Barrier Reef Marine Park Act 1975, and is a MNES under Sections 24B & 24 of the EPBC Act.

The GBRMP is managed as a multi-use Under the existing zoning plan, Cleveland Bay contains the following zones (Figure 3-53):

- Habitat Protection (the north eastern and eastern coast of Magnetic Island),
- Conservation Park (coastal areas between Cape Pallarenda and Magnetic Island, and the eastern section of Cleveland Bay),
- Marine National Park (several embayments around Magnetic Island) and
- General Use zones.

The Port of Townsville, which includes the outer harbour Project area and DMPA, is located outside the GBRMP. However, a small proportion of the Sea Channel (adjacent to Bremner Point) intersects the GBRMP in an area zoned as Habitat Protection. The Project will see the deepening and of the portion of the Sea Channel within the GBRMP, as well as the lengthening of the channel into the GBRMP (General Use Zone).

3.9.4 Commonwealth Marine Area

The Commonwealth marine area is any part of the sea within Australia's exclusive economic zone and/or over the continental shelf of Australia outside State or Northern Territory waters. The Commonwealth marine area stretches from three to 200 nautical miles from the coast. The Commonwealth marine area is a MNES under Sections 23 & 24A of the EPBC Act.

The outer harbour Project area, offshore DMPA and navigation channels are located wholly within Queensland State waters. The closest portion of the Commonwealth marine area to Cleveland Bay is located approximately six kilometres north-east of the north-eastern tip of Magnetic Island, and approximately three kilometres from the nearest portion of the channel extension project area.

The sections of the Commonwealth marine area (CMA) located directly adjacent to proposed Project disturbance areas (i.e. the Sea Channel extension near Magnetic Island and the offshore DMPA) have the following environmental characteristics.

The CMA is more exposed to swell and local seas originating from the south-east than the Cleveland Bay. However, as the CMA is located in deep waters, there is typically little re-suspension of bed sediments under typical conditions, as indicated by the low bed sheer stress predicted by hydrodynamic modelling (see EIS Chapter B3 – Coastal Processes). During higher winds periods and extreme events (such as cyclones), resuspension would occur throughout Cleveland Bay and the adjacent CMA.

The sediments of the CMA and offshore waters of Cleveland Bay reflect these hydraulic conditions. Grab samples collected by BMT WBM (February 2012) from two sites within the CMA, together with samples collected from within and adjacent to the DMPA and channel extension project area, were found to be composed of fine silty upper layer underlain by sandy muds (i.e. similar parts of sand and mud). This sediment type was found to be relatively uniform at two locations within the CMA, and similar to those of the existing DMPA and channel extension project area.

These sediment conditions control the composition and structure of benthic communities. The benthic flora and fauna assemblages between outer Cleveland Bay and the deeper parts of the inner continental shelf between Magnetic Island and John Brewer Reef can be characterised and differentiated along depth and sediment gradients (e.g. Birtles and Arnold 1983; 1989). Surveys by Birtles and Arnold (1989) found that the inner shelf zone (<22 m depth contour, which included both Cleveland Bay and the adjacent CMA) had distinctly different habitats and epifauna echinoderm and molluscs communities (composition and lower abundance) than those further offshore (26-41 m). They suggested that these differences mostly reflected changes in habitat conditions, including sediment types.

Surveys were carried out in March 2012 to qualitatively assess the habitat and epifauna community characteristics at two representative locations within the CMA. Four minute video recordings and benthic grabs were taken from four stations within two locations (locations A and B). The survey found that the epibenthic communities at both locations were very sparse, similar to that found in the adjacent DMPA. Occasional sea pens and sea cucumbers were observed at location A, but in low abundance (<10 individuals per four minute transect. Burrows (bioturbation) were abundant at both locations, as also occurs in the offshore sections of Cleveland Bay (see Section 3.4).

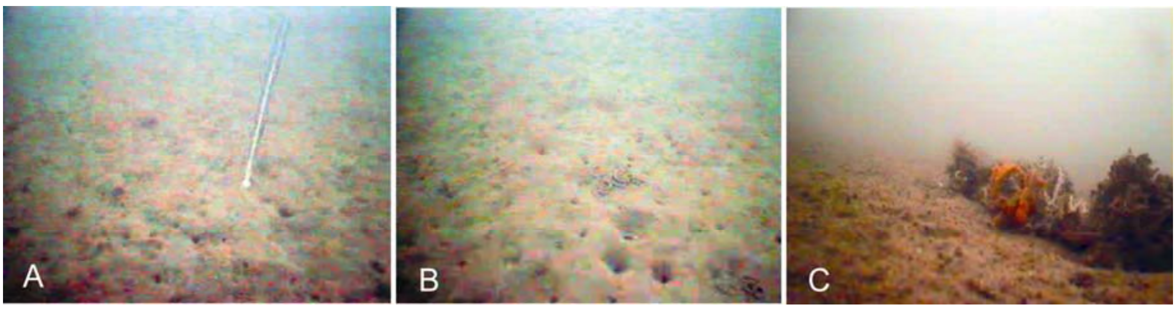

Figure 3-54 Screen grabs from video transects collected at a range of sites within the CMA, showing (a) sea pens; (b) worm casings and bioturbation and (c) sponges, bryozoans and algae

No reefs or similar hard substrates were found at either location in this survey. This is consistent with Great Barrier Reef Gazetteer, which does not identify any reefs within the section of the CMA adjacent to Magnetic Island or the offshore DMPA. Furthermore, there was no evidence of deepwater seagrass or algal/sponge beds within the two locations. It is likely that low light conditions would prevent the development of extensive seagrass meadows in this area, however like the offshore waters of Cleveland Bay, sparse transient seagrass meadows could occur in this area from time to time.

Overall, the seabed habitat characteristics of the CMA appear to be similar to those found within the offshore sections of Cleveland Bay. No seabed features of outstanding biodiversity significance are known or likely to occur within the CMA. As discussed in Section 3.6, the offshore waters of Cleveland Bay and the CMA are occasionally visited by offshore, marine megafauna species, such as humpback whales and a range of marine turtles and dolphin species. Areas to the north of Magnetic Island are known to represent important trawling grounds compared to Cleveland Bay and other sections of the CMA (Figure 3-51).

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APPENDIX A: BENTHIC INFAUNA SPECIES LIST

Table A- 1 List of all benthic macrofauna species collected during baseline surveys

Order / Family	Morpho-species	Common name
Family Alpheidae	Alpheidae 1	Snapping shrimp
Family Ampharetidae	Ampharetidae 1	Polychaete
Family Amphinomidae	*Aphrodite* 1	Polychaete
Family Paraonidae	Aricidea 1	Polychaete
Family Opheliidae	*Armandia* 1	Polychaete
Family Haminoidae	Atys 1	Bubble shell
Subclass Chondrostei	Blind goby	Blind goby
Family Branchiostomidae	*Branchiostoma* 1	Lancelets
Class Ophiuroidea	c.f. *Amphioplus* 1	Brittle star
Family Veneridae	c.f. *Tapes* 1	Bivalve
Family Capitellidae	Capitellidae 2	Polychaete
Infraorder Caridea	Caridean 1	Caridean
Infraorder Caridea	Caridean 2	Amphipod
Family Cirolanidae	*Cirolana* 1	Isopod
Family Cirratulidae	Cirratulidae 1	Polychaete
Family Cirratulidae	Cirratulidae 2	Polychaete
Family Cirratulidae	Cirratulidae 3	Polychaete
Infraorder Brachyura	Crab 1	Crab
Infraorder Brachyura	Crab 2	Crab
Infraorder Brachyura	Crab 3	Crab
Order Cumacea	Cumacean 1	Cumacean
Family Diogenidae	*Diogenes* 1	Hermit crab
Family Dorvillidae	Dorvilleidae 1	Polychaete
Class Echinoidea	Echinoid 1	Urchin
Family Elphidiidae	*Elphidium* 1	Foram
Family Elphidiidae	*Elphidium* 2	Foram
Family Eunicidae	*Eunice* 1	Polychaete
Cardiidae	*Fragnum* 1	Bivalve
Suborder Gammaridea	Gammarid 1	Amphipod
Suborder Gammaridea	Gammarid 10	Amphipod
Suborder Gammaridea	Gammarid 2	Amphipod
Suborder Gammaridea	Gammarid 3	Amphipod
Suborder Gammaridea	Gammarid 4	Amphipod
Suborder Gammaridea	Gammarid 6	Amphipod
Suborder Gammaridea	Gammarid 7	Amphipod
Suborder Gammaridea	Gammarid 8	Amphipod

Order / Family	Morpho-species	Common name
Suborder Gammaridea	Gammarid 9	Amphipod
Family Psammobiidae	*Gari* sp 1	Bivalve
Family Veneridae	*Globivenus embrithes*	Bivalve
Family Glyceridae	Glyceridae 1	Polychaete
Family Goniadidae	Goniadidae 2	Polychaete
Family Goniadidae	Goniadidae 3	Polychaete
Class Bivalvia	Hairy bivalve 1	Bivalve
Class Holothuroidea	Holothurean 1	sea cucumber
Class Holothuroidea	Holothurean 2	sea cucumber
Class Holothuroidea	Holothurean 3	Sea cucumber
Infraorder Brachyura	Larval crab 1	Crab
Infraorder Brachyura	Larval crab 2	Crab
Infraorder Brachyura	Larval Crab 4	Crab
Family Lumbrineridae	Lumbrineridae 1	Polychaete
Family Lumbrineridae	Lumbrineridae 2	Polychaete
Family Mactridae	*Mactra* 1	Bivalve
Family Mactridae	*Mactra* 2	Bivalve
Family Magelonidae	*Magelona* 1	Polychaete
Family Magelonidae	*Magelona* 2	Polychaete
Family Magelonidae	*Magelona* 3	Polychaete
Family Maldanidae	Maldanidae 1	Polychaete
Family Eunicidae	*Marphysa* 1	Polychaete
Family Mytilidae	Modiolus 1	Bivalve
Family Mysidae	Mysid 1	Shrimp
Family Buccinidae	*Nassarius* 1	Whelk
Phylum Nemertea	Nemertean 1	Nemertean
Family Nereidae	*Nereis* 1	Polychaete
Family Nereidae	*Nereis* 2	Polychaete
Family Nereidae	*Nereis* 3	Polychaete
Family Nereidae	*Nereis* 4	Polychaete
Family Ocypodidae	*Ocypode* 1	Ghost crab
Family Onuphidae	Onuphidae 1	Polychaete
Family Orbiniidae	Orbiniidae 1	Polychaete
Family Orbiniidae	Orbiniidae 2	Polychaete
Family Orbiniidae	Orbiniidae 3	Polychaete
Family Oweniidae	*Owenia* 1	Polychaete
Family Phyllodocidae	Phyllodocidae 1	Polychaete
Family Phyllodocidae	Phyllodocidae 2	Polychaete
Family Veneridae	*Placamen* 1	Bivalve
Family Naticidae	*Polinices* 1	Gastropod
Class Polychaeta	Polychaete	Polychaete

Order / Family	Morpho-species	Common name
Family Polynoidae	Polynoidae 1	Polychaete
Family Polynoidae	Polynoidae 2	Polychaete
Class Malacostraca	Prawn 1	Prawn
Class Malacostraca	Prawn 2	Prawn
Class Malacostraca	Prawn 3	Prawn
Sabellidae	Sabellidae 1	Polychaete
Phylum Sipuncula	Sipunculid 1	Peanut worm
Phylum Sipuncula	Sipunculid 2	Peanut worm
Phylum Sipuncula	Sipunculid 3	Peanut worm
Phylum Sipuncula	Sipunculid 4	Peanut worm
Family Psammobiidae	*Soletellina* 1	Bivalve
Family Spionidae	Spionidae 1	Polychaete
Family Spionidae	Spionidae 2	Polychaete
Family Spionidae	Spionidae 3	Polychaete
Phylum Porifera	Sponge 1	Sponge
Family Sternaspidae	Sternaspidae 1	Polychaete
Family Syllidae	Syllidae 1	Polychaete
Family Syllidae	Syllidae 2	Polychaete
Family Syllidae	Syllidae 3	Polychaete
Order Tanaidacea	Tanaid 1	Tanaid
Family Tellinidae	*Tellina* 1	Bivalve
Family Tellinidae	*Tellina* 2	Bivalve
Family Tellinidae	*Tellina* 3	Bivalve
Family Terebellidae	Terebellidae 1	Polychaete
Glycmerididae	*Tucetona* 1	Bivalve
Family Volutidae	Volutidae 1	Gastropod

APPENDIX B: 2012 REEF SURVEY TAXA / CATEGORY LIST

Phylum/Division	Order	Family	Taxa	Common name
Cyanobacteria	N/A	N/A	N/A	Cyanobacteria
Rhodophyta	Ceramiales	Rhodomelaceae	*Laurencia*	Macroalgae
Rhodophyta	Corallinales	Corallinaceae	*Amphiroa*	Macroalgae
Rhodophyta	Corallinales	Corallinaceae	*Porolithon*	Macroalgae
Rhodophyta	Gigartinales	Hypneaceae	*Hypnea*	Macroalgae
Rhodophyta	N/A	Coralline algae (CCA)	*Coralline*	Coralline algae
Chlorophyta	Bryopsidales	Caulerpaceae	*Caulerpa*	Macroalgae
Chlorophyta	Bryopsidales	Halimedaceae	*Halimeda*	Macroalgae
Phaeophyta	Dictyotales	Dictyotaceae	*Dictyopteris*	Macroalgae
Phaeophyta	Dictyotales	Dictyotaceae	*Dictyota*	Macroalgae
Phaeophyta	Dictyotales	Dictyotaceae	*Dilophus*	Macroalgae
Phaeophyta	Dictyotales	Dictyotaceae	*Lobophora*	Macroalgae
Phaeophyta	Dictyotales	Macroalgae	*Padina*	Macroalgae
Phaeophyta	Ectocarpales	Chordariaceae	*Hydroclathrus*	Macroalgae
Phaeophyta	Fucales	Sargassaceae	*Sargassum*	Macroalgae
Phaeophyta	Fucales	Sargassaceae	*Turbinaria*	Macroalgae
N/A	N/A	N/A	Turf algae	Turf algae
N/A	N/A	N/A	Other macroalgae	Macroalgae
Angiosperm	Alismatales	Hydrocharitaceae	*Halophila*	Seagrass
Porifera	N/A	N/A	Sponges	Sponges
Cnidaria	Alcyonacea	Alcyoniidae	*Lobophyton*	Soft coral
Cnidaria	Alcyonacea	Alcyoniidae	*Cladiella*	Soft coral
Cnidaria	Alcyonacea	Alcyoniidae	*Sarcopyton*	Soft coral
Cnidaria	Alcyonacea	Alcyoniidae	*Sinularia*	Soft coral
Cnidaria	Alcyonacea	N/A	Other soft coral	Soft coral
Cnidaria	Alcyonacea	Nephtheidae	*Nephthya*	Soft coral
Cnidaria	Alcyonacea	Tubiporidae	*Tubipora*	Soft coral
Cnidaria	N/A	N/A	Hydrozoan	Hydrozoan
Cnidaria	Scleractinia	Acroporidae	*Acropora*	Coral
Cnidaria	Scleractinia	Acroporidae	*Montipora*	Coral
Cnidaria	Scleractinia	Agariciidae	*Coeloseris*	Coral
Cnidaria	Scleractinia	Agariciidae	*Coscinaraea*	Coral
Cnidaria	Scleractinia	Agariciidae	*Leptoseris*	Coral
Cnidaria	Scleractinia	Agariciidae	*Pavona*	Coral
Cnidaria	Scleractinia	Agariciidae	*Psammocora*	Coral
Cnidaria	Scleractinia	Astrocoeniidae	*Palauastrea*	Coral
Cnidaria	Scleractinia	Dendrophylliidae	*Turbinaria*	Coral
Cnidaria	Scleractinia	Faviidae	*Caulastrea*	Coral
Cnidaria	Scleractinia	Faviidae	*Cyphastrea*	Coral
Cnidaria	Scleractinia	Faviidae	*Echinopora*	Coral

Phylum/Division	Order	Family	Taxa	Common name
Cnidaria	Scleractinia	Faviidae	*Favia*	Coral
Cnidaria	Scleractinia	Faviidae	*Favites*	Coral
Cnidaria	Scleractinia	Faviidae	*Goniastrea*	Coral
Cnidaria	Scleractinia	Faviidae	*Leptastrea*	Coral
Cnidaria	Scleractinia	Faviidae	*Montastrea*	Coral
Cnidaria	Scleractinia	Faviidae	*Moseleya*	Coral
Cnidaria	Scleractinia	Faviidae	*Oulophyllia*	Coral
Cnidaria	Scleractinia	Faviidae	*Platygyra*	Coral
Cnidaria	Scleractinia	Fungiidae	*Fungia*	Coral
Cnidaria	Scleractinia	Fungiidae	*Heliofungia*	Coral
Cnidaria	Scleractinia	Fungiidae	*Podabaci*	Coral
Cnidaria	Scleractinia	Merulinidae	*Hydnophora*	Coral
Cnidaria	Scleractinia	Merulinidae	*Merulina*	Coral
Cnidaria	Scleractinia	Mussidae	*Lobophyllia*	Coral
Cnidaria	Scleractinia	Mussidae	*Scolymia*	Coral
Cnidaria	Scleractinia	Mussidae	*Symphyllia*	Coral
Cnidaria	Scleractinia	Oculinidae	*Galaxea*	Coral
Cnidaria	Scleractinia	Pectiniidae	*Mycedium*	Coral
Cnidaria	Scleractinia	Pectiniidae	*Oxypora*	Coral
Cnidaria	Scleractinia	Pectiniidae	*Pectinia*	Coral
Cnidaria	Scleractinia	Pocilloporidae	*Pocillopora*	Coral
Cnidaria	Scleractinia	Pocilloporidae	*Seriatophora*	Coral
Cnidaria	Scleractinia	Poritidae	*Goniopora*	Coral
Cnidaria	Scleractinia	Poritidae	*Porites*	Coral
Cnidaria	Scleractinia	Siderastreidae	*Pseudosiderastrea*	Coral
Cnidaria	Zoanthidea	Sphenopidae	*Palythoa*	Zoanthids
Cnidaria	Zoanthidea	Zoanthidae	Zoanthid	Zoanthids
Tunicata	Ascidiacea	N/A	Ascidian	Sea squirt
N/A	N/A	N/A	Bleached coral	
N/A	N/A	N/A	Recently dead coral	
N/A	N/A	N/A	Pavement	
N/A	N/A	N/A	Rubble	
N/A	N/A	N/A	Sand	

APPENDIX C: CORAL TAXA RECORDED IN 1992

(Source: Stafford-Smith and Veron 1992)

Species	Florence Bay	Arthur Bay	Geoffrey Bay	Nelly Bay	Middle Reef	Bay Rock	Rattlesnake Is.	Herald Is.
Acanthastrea echinata							X	X
Acropora aculeus	X	X	X	X	X	X	X	X
Acropora acuminata								X
Acropora anthocercis							X	X
Acropora aspera	X					X	X	X
Acropora Bustera							X	X
Acropora brueggemanni							X	X
Acropora cerealis						X	X	X
Acropora cytherea						X	X	X
Acropora danai								X
Acropora dendrum	X	X	X	X	X	X	X	X
Acropora digitifera	X	X	X	X	X	X	X	X
Acropora divaricata	X	X	X	X	X	X	X	X
Acropora donei							X	X
Acropora elseyi	X	X	X	X	X	X	X	X
Acropora florida							X	X
Acropora formosa	X	X	X	X	X	X	X	X
Acropora grandis	X		X	X			X	
Acropora granulosa	X		X	X			X	X
Acropora horrida							X	
Acropora humilis							X	X
Acropora hyacinthus	X	X-	X	X	X	X	X	X
Acropora kirstyae	X						X	

Species	Florence Bay	Arthur Bay	Geoffrey Bay	Nelly Bay	Middle Reef	Bay Rock	Rattlesnake Is.	Herald Is.
Acropora latistella	X	X	X	X	X	X	X	X
Acropora listeri							X	
Acropora longicyathus	X	X	X	X			X	X
Acropora loripes							X	X
Acropora microclados							X	X
Acropora microphthalma	X	X	X			X	X	X
Acropora millepora	X	X	X	X	X	X	X	X
Acropora monticulosa							X	X
Acropora nana	X					X	X	X
Acropora nasuta	X	X	X		X		X	X
Acropora palifera							X	X
Acropora polystoma							X	
Acropora pulchra				X		X	X	X
Acropora samoensis	X		X	X	X		X	X
Acropora sarmentosa	X						X	X
Acropora secale	X	X	X	X		X	X	X
Acropora subulata	X	X	X				X	
Acropora tenuis							X	X
Acropora valenciennesi							X	X
Acropora valida	X	X	X	X	X	X	X	X
Acropora vaughani		X	X				X	X
Acropora verweyi								X
Acropora wallaceae							X	X
Acropora willisae						X	X	X
Acropora yongei							X	X
Alveopora catali							X	
Alveopora spongiosa							X	
Alveopora tizardi							X	
Alveopora verilliana							X	

Species	Florence Bay	Arthur Bay	Geoffrey Bay	Nelly Bay	Middle Reef	Bay Rock	Rattlesnake Is.	Herald Is.
Anacropora forbesi							X	
Astreopora explanata	X	X	X	X	X	X	X	X
Astreopora gracilis							X	X
Astreopora moretonensis							X	
Astreopora myriophthalma	X	X	X	X			X	X
Barabattoia amicorum	X	X	X	X	X		X	X
Blastomussa merleti								X
Caulastrea furcata							X	X
Coeloseris mayeri							X	X
Coscinaraea columna	X	X	X	X	X	X	X	X
Coscinaraea exesa	X			X		X	X	X
Ctenactis echinata	X	X	X	X	X	X	X	X
Cycloseris patelliformis							X	
Cyphastrea agassizi					X			
Cyphastrea chalcidium	X	X	X	X	X	X	X	X
Cyphastrea japonica							X	X
Cyphastrea microphthalma	X	X	X	X	X	X	X	X
Cyphastrea serailia	X	X	X	X	X	X	X	X
Diploastrea heliopora							X	X
Duncanopsammia axifuga	X						X	
Echinophyllia aspera	X	X	X	X	X	X	X	X
Echinophyllia echinata								X
Echinophyllia echinoparoides							X	X
Echinophyllia orpheensis	X	X	X		X	X	X	X
Echinopora gemmacea				X		X	X	X
Echinopora horrida							X	X
Echinopora lamellosa	X	X	X	X	X	X	X	X
Echinopora pacificus	X	X					X	X
Euphyllia ancora	X	X	X	X	X	X	X	X

Species	Florence Bay	Arthur Bay	Geoffrey Bay	Nelly Bay	Middle Reef	Bay Rock	Rattlesnake Is.	Herald Is.
Euphyllia cristata							X	
Euphyllia divisa	X						X	X
Euphyllia glabrescens						X	X	X
Favia danae	X	X	X	X		X	X	X
Favia favus	X	X	X	X	X	X	X	X
Favia helianthoides							X	X
Favia laxa							X	X
Favia lizardensis	X	X	X	X	X	X	X	X
Favia maritima	X	X	X	X	X	X	X	X
Favia matthaii	X	X	X	X		X	X	X
Favia maxima	X					X	X	X
Favia pallida	X	X	X	X	X	X	X	X
Favia rotumana			X	X		X	X	X
Favia rotundata						X	X	X
Favia speciosa	X	X	X	X	X	X	X	X
Favia stelligera							X	X
Favia veroni		X	X			X	X	X
Favites abdita	X	X	X	X	X		X	X
Favites chinensis	X	X	X	X	X	X	X	X
Favites complanata						X	X	X
Favites flexuosa						X	X	X
Favites halicora						X	X	X
Favites pentagona	X	X	X	X	X	X	X	X
Favites russelli						X	X	X
Fungia concinna	X	X	X	X	X	X	X	X
Fungia danai	X	X	X	X	X		X	X
Fungia fungites	X	X	X	X	X	X	X	X
Fungia granulosa							X	X
Fungia horrida	X	X	X				X	X

Species	Florence Bay	Arthur Bay	Geoffrey Bay	Nelly Bay	Middle Reef	Bay Rock	Rattlesnake Is.	Herald Is.
Fungia klunzingeri							X	
Fungia moluccensis			X				X	X
Fungia paumotensis	X	X	X			X	X	X
Fungia repanda	X	X	X	X	X	X	X	X
Fungia scabra	X	X	X				X	X
Fungia scutaria	X						X	X
Fungia valida	X	X	X	X			X	X
Galaxea astreata	X	X	X	X	X	X	X	X
Galaxea fascicularis	X	X	X	X	X	X	X	X
Gardineroseris planulata							X	X
Goniastrea aspera	X	X	X	X	X		X	X
Goniastrea australensis	X	X	X	X	X		X	X
Goniastrea edwardsi			X	X				X
Goniastrea favulus							X	X
Goniastrea palauensis	X	X	X	X		X	X	X
Goniastrea pectinata	X	X	X	X	X	X	X	X
Goniastrea retiformis							X	X
Goniopora columna	X	X	X	X	X	X	X	X
Goniopora djiboutensis	X	X	X	X		X	X	X
Goniopora eclipsensis	X	X				X	X	X
Goniopora lobata	X	X	X	X	X	X	X	X
Goniopora minor		X			X	X	X	X
Goniopora palmensis	X			X		X	X	X
Goniopora pandorensis	X	X	X			X	X	X
Goniopora stokesi							X	
Goniopora stutchburyi	X	X	X	X	X	X	X	X
Goniopora tenuidens	X			X		X	X	X
Halomitra pileus							X	
Heliofungia actiniformis	X	X	X	X	X	X	X	X

Species	Florence Bay	Arthur Bay	Geoffrey Bay	Nelly Bay	Middle Reef	Bay Rock	Rattlesnake Is.	Herald Is.
Herpolitha limax	X	X	X	X	X	X	X	X
Hydnophora exesa	X	X	X	X	X	X	X	X
Hydnophora microconos							X	X
Hydnophora pilosa	X			X	X		X	
Hydnophora rigida							X	X
Leptastrea pruinosa							X	X
Leptastrea purpurea	X	X	X	X	X	X	X	X
Leptastrea transversa						X	X	X
Leptoria phrygia							X	X
Leptoseris explanata							X	X
Leptoseris mycetoseroides							X	X
Lithophyllon mokai							X	X
Lobophyllia corymbosa						X	X	X
Lobophyllia hemprichii	X	X	X	X	X	X	X	X
Lobophyllia pachysepta							X	X
Lobophyllia robusta	X	X	X	X	X		X	X
Merulina ampliata	X	X	X	X	X	X	X	X
Merulina scabricula	X	X	X				X	X
Montastrea annuligera				X			X	X
Montastrea curta							X	X
Montastrea magnistellata	X	X	X	X	X		X	X
Montastrea valenciennesi	X	X	X	X	X	X	X	X
Montipora aequituberculata	X	X	X	X	X	X	X	X
Montipora caliculata					X	X	X	X
Montipora corbettensis						X	X	X
Montipora crassituberculata							X	
Montipora danae	X	X	X			X	X	X
Montipora digitata	X	X	X	X			X	X
Montipora efflorescens	X	X	X	X	X	X	X	X

Species	Florence Bay	Arthur Bay	Geoffrey Bay	Nelly Bay	Middle Reef	Bay Rock	Rattlesnake Is.	Herald Is.
Montipora floweri						X	X	X
Montipora foliosa	X					X	X	X
Montipora foveolata							X	
Montipora grisea					X	X	X	X
Montipora hispida	X	X	X	X	X	X	X	X
Montipora hoffmeisteri	X	X	X	X	X	X	X	X
Montipora incrassata	X	X	X	X		X	X	X
Montipora informis						X	X	X
Montipora millepora	X	X	X	X		X	X	X
Montipora mollis	X	X	X	X	X	X	X	X
Montipora monasteriata	X	X	X	X		X	X	X
Montipora nodosa							X	X
Montipora peltiformis						X	X	X
Montipora sponnodes	X	X	X	X		X	X	X
Montipora stellata	X	X	X	X	X		X	X
Montipora tuberculosa	X	X	X	X	X		X	X
Montipora turgescens	X						X	X
Montipora turtlensis	X		X			X	X	X
Montipora undata								X
Montipora verrucosa							X	X
Moseleya latistellata	X	X	X	X	X	X	X	X
Mycedium elephantotus	X	X	X	X	X	X	X	X
Oulophyllia bennettae							X	X
Oulophyllia crispa	X						X	
Oxypora glabra	X	X	X	X	X		X	
Oxypora lacera						X	X	X
Pachyseris rugosa	X						X	X
Pachyseris speciosa	X	X	X	X	X	X	X	X
Palauastrea ramosa							X	

Species	Florence Bay	Arthur Bay	Geoffrey Bay	Nelly Bay	Middle Reef	Bay Rock	Rattlesnake Is.	Herald Is.
Pavona cactus							X	
Pavona decussata				X		X	X	X
Pavona explanulata						X	X	X
Pavona minuta							X	X
Pavona varians	X	X	X				X	X
Pavona venosa	X							
Pectinia alcicornis	X	X	X	X	X			
Pectinia lactuca	X	X	X	X	X	X	X	X
Pectinia paeonia	X	X	X	X		X	X	X
Physogyra lichtensteini							X	X
Platygyra daedalea	X	X	X	X	X	X	X	X
Platygyra lamellina	X	X	X	X		X	X	X
Platygyra pini	X	X	X	X		X	X	X
Platygyra sinensis	X	X	X	X		X	X	X
Plerogyra sinuosa							X	
Plesiastrea versipora	X	X	X	X	X	X	X	X
Pocillopora damicornis	X	X	X	X	X	X	X	X
Pocillopora verrucosa							X	
Podabacia crustacea	X	X	X	X	X	X	X	X
Podabacia motuporensis	X	X					X	X
Polyphyllia talpina	X	X	X	X	X		X	X
Porites annae				X	X		X	X
Porites australiensis				X	X	X	X	X
Porites cylindrica							X	X
Porites densa							X	X
Porites evermanni								X
Porites lichen							X	X
Porites lobata	X	X	X	X	X	X	X	X
Porites lutea	X	X	X	X	X	X	X	X

Species	Florence Bay	Arthur Bay	Geoffrey Bay	Nelly Bay	Middle Reef	Bay Rock	Rattlesnake Is.	Herald Is.
Porites murrayensis	X	X	X	X			X	X
Porites rus	X		X				X	X
Porites solida						X	X	X
Porites stephensoni							X	X
Psammocora contigua	X	X	X	X	X	X	X	X
Psammocora digitata		X				X	X	
Psammocora explanulata						X	X	X
Psammocora haimeana							X	
Psammocora profundacella	X	X	X	X	X	X	X	X
Psammocora superficialis	X	X	X	X	X	X	X	X
Pseudosiderastrea tayamai						X	X	X
Sandalolitha robusta	X	X	X	X			X	X
Scapophyllia cylindrica							X	X
Scolymia vitiensis			X					
Seriatopora hystrix			X			X	X	X
Stylocoeniella armata							X	
Stylocoeniella guentheri	X	X	X		X		X	X
Stylophora pistillata	X	X	X	X	X	X	X	X
Symphyllia agaricia							X	X
Symphyllia radians							X	X
Symphyllia recta	X				X	X	X	X
Symphyllia valenciennesi							X	X
Trachyphyllia geoffroyi					X		X	
Turbinaria bifrons	X	X	X	X	X	X	X	X
Turbinaria frondens	X	X	X	X	X	X	X	X
Turbinaria heronensis		X		X				
Turbinaria mesenterina	X	X	X	X	X	X	X	X
Turbinaria patula	X	X	X	X	X	X	X	X
Turbinaria peltata	X	X	X	X	X	X	X	X

Species	Florence Bay	Arthur Bay	Geoffrey Bay	Nelly Bay	Middle Reef	Bay Rock	Rattlesnake Is.	Herald Is.
Turbinaria radicalis	X	X	X	X	X	X	X	X
Turbinaria reniformis	X	X	X	X	X	X	X	X
Turbinaria stellulata	X	X	X	X	X	X	X	X
TOTAL no. spp.	**138**	**119**	**124**	**116**	**94**	**128**	**245**	**222**

APPENDIX D: EPBC SEARCH RESULTS

Australian Government
Department of Sustainability, Environment, Water, Population and Communities

Protected Matters Search Tool

EPBC Act Protected Matters Report: Coordinates

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

You may wish to print this report for reference before moving to other pages or websites.

Information about the EPBC Act including significance guidelines, forms and application process details can be found at http://www.environment.gov.au/epbc/assessmentsapprovals/index.html

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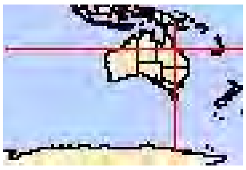

Coordinates

Buffer: 1Km

Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance - see http://www.environment.gov.au/epbc/assessmentsapprovals/guidelines/index.html.

World Heritage Properties:	1
National Heritage Places:	1
Wetlands of International Significance (Ramsar Wetlands):	1
Great Barrier Reef Marine Park:	Relevant
Commonwealth Marine Areas:	Relevant
Threatened Ecological Communitites:	1
Threatened Species:	27
Migratory Species:	55

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place and the heritage values of a place on the Register of the National Estate. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage/index.html

Please note that the current dataset on Commonwealth land is not complete. Further information on Commonwealth land would need to be obtained from relevant sources including Commonwealth agencies, local agencies, and land tenure maps.

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species. Information on EPBC Act permit requirements and application forms can be found at http://www.environment.gov.au/epbc/permits/index.html.

Commonwealth Lands:	6
Commonwealth Heritage Places:	2
Listed Marine Species:	110

Whales and Other Cetaceans:	12
Critical Habitats:	None
Commonwealth Reserves:	None

Report Summary for Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

Place on the RNE:	46
State and Territory Reserves:	15
Regional Forest Agreements:	None
Invasive Species:	10
Nationally Important Wetlands:	3

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	Status
Great Barrier Reef QLD	Declared property

National Heritage Places [Resource Information]

Name	Status
Natural	
Great Barrier Reef QLD	Listed place

Wetlands of International Significance (RAMSAR Sites) [Resource Information]

Name	Proximity
Bowling green bay	Within Ramsar site

Great Barrier Reef Marine Park [Resource Information]

Zone Type	Zone Name	IUCN
Marine National Park	MNP-19-1094	II
Conservation Park	CP-19-4057	IV
Marine National Park	MNP-19-1091	II
Conservation Park	CP-19-4059	IV
Conservation Park	CP-19-4058	IV
Marine National Park	MNP-19-1090	II
Habitat Protection	HP-19-5161	VI
Marine National Park	MNP-19-1089	II
General Use	GU-16-6004	VI
Marine National Park	MNP-19-1093	II
Marine National Park	MNP-19-1092	II

Commonwealth Marine Areas [Resource Information]

Approval may be required for a proposed activity that is likely to have a significant impact on the environment in a Commonwealth Marine Area, when the action is outside the Commonwealth Marine

Area, or the environment anywhere when the action is taken within the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

EEZ and Territorial Sea

Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Name	Status	Type of Presence
Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions	Endangered	Community likely to occur within area

Threatened Species [Resource Information]

Name	Status	Type of Presence
BIRDS		
Erythrotriorchis radiatus		
Red Goshawk [942]	Vulnerable	Species or species habitat likely to occur within area
Geophaps scripta scripta		
Squatter Pigeon (southern) [64440]	Vulnerable	Species or species habitat likely to occur within area
Neochmia ruficauda ruficauda		
Star Finch (eastern), Star Finch (southern) [26027]	Endangered	Species or species habitat likely to occur within area
Poephila cincta cincta		
Black-throated Finch (southern) [64447]	Endangered	Species or species habitat likely to occur within area
Rostratula australis		
Australian Painted Snipe [77037]	Vulnerable	Species or species habitat may occur within area
MAMMALS		
Balaenoptera musculus		
Blue Whale [36]	Endangered	Species or species habitat may occur within area
Dasyurus hallucatus		
Northern Quoll [331]	Endangered	Species or species habitat likely to occur within area
Hipposideros semoni		
Semon's Leaf-nosed Bat, Greater Wart-nosed Horseshoe-bat [180]	Endangered	Species or species habitat may occur within area
Megaptera novaeangliae		
Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Pteropus conspicillatus		
Spectacled Flying-fox [185]	Vulnerable	Species or species habitat may occur within area
Rhinolophus philippinensis (large form)		
Greater Large-eared Horseshoe Bat [66890]	Endangered	Species or species habitat known to occur within area

Xeromys myoides Water Mouse, False Water Rat [66]	Vulnerable	Species or species habitat may occur within area
PLANTS		
Croton magneticus [16681]	Vulnerable	Species or species habitat likely to occur within area
Hydrocharis dubia Frogbit [3650]	Vulnerable	Species or species habitat likely to occur within area
Leucopogon cuspidatus [9739]	Vulnerable	Species or species habitat likely to occur within area
Marsdenia brevifolia [64585]	Vulnerable	Species or species habitat likely to occur within area
Taeniophyllum muelleri Minute Orchid, Ribbon-root Orchid [10771]	Vulnerable	Species or species habitat may occur within area
REPTILES		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Delma labialis Striped-tailed Delma, Single-striped Delma [25930]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Egernia rugosa Yakka Skink [1420]	Vulnerable	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
SHARKS		
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat may occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area

Migratory Species [Resource Information]

Name	Status	Type of Presence
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat may occur within area

Ardea alba		
Great Egret, White Egret [59541]		Breeding likely to occur within area
Ardea ibis		
Cattle Egret [59542]		Breeding likely to occur within area
Sterna albifrons		
Little Tern [813]		Species or species habitat may occur within area
Migratory Marine Species		
Balaenoptera edeni		
Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Species or species habitat may occur within area
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus porosus		
Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Dugong dugon		
Dugong [28]		Species or species habitat likely to occur within area
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Lepidochelys olivacea		
Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat likely to occur within area
Megaptera novaeangliae		
Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcaella brevirostris		
Irrawaddy Dolphin [45]		Species or species habitat may occur within area
Orcinus orca		
Killer Whale, Orca [46]		Species or species habitat may occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sousa chinensis		
Indo-Pacific Humpback Dolphin [50]		Species or species habitat may occur within area
Migratory Terrestrial Species		
Haliaeetus leucogaster		
White-bellied Sea-Eagle [943]		Species or species habitat likely to occur within area
Hirundapus caudacutus		
White-throated Needletail [682]		Species or species habitat may occur within area
Hirundo rustica		

Barn Swallow [662]	Species or species habitat may occur within area
Merops ornatus	
Rainbow Bee-eater [670]	Species or species habitat may occur within area
Monarcha melanopsis	
Black-faced Monarch [609]	Breeding may occur within area
Monarcha trivirgatus	
Spectacled Monarch [610]	Breeding likely to occur within area
Myiagra cyanoleuca	
Satin Flycatcher [612]	Species or species habitat likely to occur within area
Rhipidura rufifrons	
Rufous Fantail [592]	Breeding may occur within area
Migratory Wetlands Species	
Actitis hypoleucos	
Common Sandpiper [59309]	Roosting known to occur within area
Ardea alba	
Great Egret, White Egret [59541]	Breeding likely to occur within area
Ardea ibis	
Cattle Egret [59542]	Breeding likely to occur within area
Arenaria interpres	
Ruddy Turnstone [872]	Foraging, feeding or related behaviour known to occur within area
Calidris acuminata	
Sharp-tailed Sandpiper [874]	Roosting known to occur within area
Calidris alba	
Sanderling [875]	Foraging, feeding or related behaviour known to occur within area
Calidris canutus	
Red Knot, Knot [855]	Roosting known to occur within area
Calidris ferruginea	
Curlew Sandpiper [856]	Foraging, feeding or related behaviour known to occur within area
Calidris ruficollis	
Red-necked Stint [860]	Roosting known to occur within area
Calidris tenuirostris	
Great Knot [862]	Roosting known to occur within area
Charadrius leschenaultii	
Greater Sand Plover, Large Sand Plover [877]	Roosting known to occur within area
Charadrius mongolus	
Lesser Sand Plover, Mongolian Plover [879]	Roosting known to occur within area
Charadrius veredus	
Oriental Plover, Oriental Dotterel [882]	Foraging, feeding or related behaviour known to occur within area
Gallinago hardwickii	
Latham's Snipe, Japanese Snipe [863]	Roosting may occur within area
Heteroscelus brevipes	
Grey-tailed Tattler [59311]	Roosting known to occur within area
Limicola falcinellus	

Broad-billed Sandpiper [842]	Foraging, feeding or related behaviour known to occur within area
Limosa lapponica	
Bar-tailed Godwit [844]	Roosting known to occur within area
Limosa limosa	
Black-tailed Godwit [845]	Roosting known to occur within area
Nettapus coromandelianus albipennis	
Australian Cotton Pygmy-goose [25979]	Species or species habitat may occur within area
Numenius madagascariensis	
Eastern Curlew [847]	Roosting known to occur within area
Numenius minutus	
Little Curlew, Little Whimbrel [848]	Roosting known to occur within area
Numenius phaeopus	
Whimbrel [849]	Roosting known to occur within area
Pluvialis fulva	
Pacific Golden Plover [25545]	Roosting known to occur within area
Pluvialis squatarola	
Grey Plover [865]	Roosting known to occur within area
Rostratula benghalensis s. lat.	
Painted Snipe [889]	Species or species habitat may occur within area
Tringa glareola	
Wood Sandpiper [829]	Foraging, feeding or related behaviour known to occur within area
Tringa stagnatilis	
Marsh Sandpiper, Little Greenshank [833]	Roosting known to occur within area
Xenus cinereus	
Terek Sandpiper [59300]	Roosting known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Defence - JEZZINE BARRACKS - TOWNSVILLE
Defence - NORTH WARD TRAINING DEPOT - TOWNSVILLE
Defence - TOWNSVILLE - RAAF BASE
Defence - TOWNSVILLE - AP37 NAVAID
Defence - Commonwealth Centre
Defence - AMAROO - MAGNETIC ISLAND

Commonwealth Heritage Places [Resource Information]

Name	Status
Natural	
Great Barrier Reef Region (Commonwealth) QLD	Indicative Place
Historic	
RAAF Base Townsville QLD	Indicative Place

Listed Marine Species [Resource Information]

Name	Status	Type of Presence
Birds		
Actitis hypoleucos		
Common Sandpiper [59309]		Roosting known to occur within area
Anseranas semipalmata		
Magpie Goose [978]		Species or species habitat may occur within area
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat may occur within area
Ardea alba		
Great Egret, White Egret [59541]		Breeding likely to occur within area
Ardea ibis		
Cattle Egret [59542]		Breeding likely to occur within area
Arenaria interpres		
Ruddy Turnstone [872]		Foraging, feeding or related behaviour known to occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba		
Sanderling [875]		Foraging, feeding or related behaviour known to occur within area
Calidris canutus		
Red Knot, Knot [855]		Roosting known to occur within area
Calidris ferruginea		
Curlew Sandpiper [856]		Foraging, feeding or related behaviour known to occur within area
Calidris ruficollis		
Red-necked Stint [860]		Roosting known to occur within area
Calidris tenuirostris		
Great Knot [862]		Roosting known to occur within area
Charadrius leschenaultii		
Greater Sand Plover, Large Sand Plover [877]		Roosting known to occur within area
Charadrius mongolus		
Lesser Sand Plover, Mongolian Plover [879]		Roosting known to occur within area
Charadrius ruficapillus		
Red-capped Plover [881]		Roosting known to occur within area
Charadrius veredus		
Oriental Plover, Oriental Dotterel [882]		Foraging, feeding or related behaviour known to occur within area
Gallinago hardwickii		
Latham's Snipe, Japanese Snipe [863]		Roosting may occur within area
Gallinago megala		
Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura		
Pin-tailed Snipe [841]		Roosting likely to occur within area
Haliaeetus leucogaster		
White-bellied Sea-Eagle [943]		Species or species habitat likely to occur within area
Heteroscelus brevipes		

Grey-tailed Tattler [59311]	Roosting known to occur within area
Heteroscelus incanus	
Wandering Tattler [59547]	Foraging, feeding or related behaviour known to occur within area
Himantopus himantopus	
Black-winged Stilt [870]	Roosting known to occur within area
Hirundapus caudacutus	
White-throated Needletail [682]	Species or species habitat may occur within area
Hirundo rustica	
Barn Swallow [662]	Species or species habitat may occur within area
Limicola falcinellus	
Broad-billed Sandpiper [842]	Foraging, feeding or related behaviour known to occur within area
Limosa lapponica	
Bar-tailed Godwit [844]	Roosting known to occur within area
Limosa limosa	
Black-tailed Godwit [845]	Roosting known to occur within area
Merops ornatus	
Rainbow Bee-eater [670]	Species or species habitat may occur within area
Monarcha melanopsis	
Black-faced Monarch [609]	Breeding may occur within area
Monarcha trivirgatus	
Spectacled Monarch [610]	Breeding likely to occur within area
Myiagra cyanoleuca	
Satin Flycatcher [612]	Species or species habitat likely to occur within area
Nettapus coromandelianus albipennis	
Australian Cotton Pygmy-goose [25979]	Species or species habitat may occur within area
Numenius madagascariensis	
Eastern Curlew [847]	Roosting known to occur within area
Numenius minutus	
Little Curlew, Little Whimbrel [848]	Roosting known to occur within area
Numenius phaeopus	
Whimbrel [849]	Roosting known to occur within area
Philomachus pugnax	
Ruff (Reeve) [850]	Foraging, feeding or related behaviour known to occur within area
Pluvialis fulva	
Pacific Golden Plover [25545]	Roosting known to occur within area
Pluvialis squatarola	
Grey Plover [865]	Roosting known to occur within area
Recurvirostra novaehollandiae	
Red-necked Avocet [871]	Foraging, feeding or related behaviour known to occur within area
Rhipidura rufifrons	
Rufous Fantail [592]	Breeding may occur within area
Rostratula benghalensis s. lat.	
Painted Snipe [889]	Species or species habitat may occur within area
Sterna albifrons	
Little Tern [813]	Species or species habitat may occur within area

Tringa glareola	
Wood Sandpiper [829]	Foraging, feeding or related behaviour known to occur within area
Tringa stagnatilis	
Marsh Sandpiper, Little Greenshank [833]	Roosting known to occur within area
Xenus cinereus	
Terek Sandpiper [59300]	Roosting known to occur within area
Fish	
Acentronura tentaculata	
Shortpouch Pygmy Pipehorse [66187]	Species or species habitat may occur within area
Campichthys tryoni	
Tryon's Pipefish [66193]	Species or species habitat may occur within area
Choeroichthys brachysoma	
Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]	Species or species habitat may occur within area
Choeroichthys suillus	
Pig-snouted Pipefish [66198]	Species or species habitat may occur within area
Corythoichthys amplexus	
Fijian Banded Pipefish, Brown-banded Pipefish [66199]	Species or species habitat may occur within area
Corythoichthys flavofasciatus	
Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]	Species or species habitat may occur within area
Corythoichthys intestinalis	
Australian Messmate Pipefish, Banded Pipefish [66202]	Species or species habitat may occur within area
Corythoichthys ocellatus	
Orange-spotted Pipefish, Ocellated Pipefish [66203]	Species or species habitat may occur within area
Corythoichthys paxtoni	
Paxton's Pipefish [66204]	Species or species habitat may occur within area
Corythoichthys schultzi	
Schultz's Pipefish [66205]	Species or species habitat may occur within area
Cosmocampus darrosanus	
D'Arros Pipefish [66207]	Species or species habitat may occur within area
Cosmocampus maxweberi	
Maxweber's Pipefish [66209]	Species or species habitat may occur within area
Doryrhamphus dactyliophorus	
Banded Pipefish, Ringed Pipefish [66210]	Species or species habitat may occur within area
Doryrhamphus excisus	
Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]	Species or species habitat may occur within area
Festucalex cinctus	
Girdled Pipefish [66214]	Species or species habitat may occur within area
Festucalex gibbsi	
Gibbs' Pipefish [66215]	Species or species habitat may occur within area
Halicampus dunckeri	
Red-hair Pipefish, Duncker's	Species or species habitat may occur within area

Pipefish [66220]	
Halicampus grayi	
Mud Pipefish, Gray's Pipefish [66221]	Species or species habitat may occur within area
Halicampus macrorhynchus	
Whiskered Pipefish, Ornate Pipefish [66222]	Species or species habitat may occur within area
Halicampus nitidus	
Glittering Pipefish [66224]	Species or species habitat may occur within area
Halicampus spinirostris	
Spiny-snout Pipefish [66225]	Species or species habitat may occur within area
Hippichthys cyanospilos	
Blue-speckled Pipefish, Blue-spotted Pipefish [66228]	Species or species habitat may occur within area
Hippichthys heptagonus	
Madura Pipefish, Reticulated Freshwater Pipefish [66229]	Species or species habitat may occur within area
Hippichthys penicillus	
Beady Pipefish, Steep-nosed Pipefish [66231]	Species or species habitat may occur within area
Hippichthys spicifer	
Belly-barred Pipefish, Banded Freshwater Pipefish [66232]	Species or species habitat may occur within area
Hippocampus bargibanti	
Pygmy Seahorse [66721]	Species or species habitat may occur within area
Hippocampus histrix	
Spiny Seahorse, Thorny Seahorse [66236]	Species or species habitat may occur within area
Hippocampus kuda	
Spotted Seahorse, Yellow Seahorse [66237]	Species or species habitat may occur within area
Hippocampus planifrons	
Flat-face Seahorse [66238]	Species or species habitat may occur within area
Hippocampus zebra	
Zebra Seahorse [66241]	Species or species habitat may occur within area
Micrognathus andersonii	
Anderson's Pipefish, Shortnose Pipefish [66253]	Species or species habitat may occur within area
Micrognathus brevirostris	
thorntail Pipefish, Thorn-tailed Pipefish [66254]	Species or species habitat may occur within area
Nannocampus pictus	
Painted Pipefish, Reef Pipefish [66263]	Species or species habitat may occur within area
Siokunichthys breviceps	
Softcoral Pipefish, Soft-coral Pipefish [66270]	Species or species habitat may occur within area
Solegnathus hardwickii	
Pallid Pipehorse, Hardwick's Pipehorse [66272]	Species or species habitat may occur within area
Solenostomus cyanopterus	
Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]	Species or species habitat may occur within area

Solenostomus paegnius		
Rough-snout Ghost Pipefish [68425]		Species or species habitat may occur within area
Solenostomus paradoxus		
Ornate Ghostpipefish, Harlequin Ghost Pipefish, Ornate Ghost Pipefish [66184]		Species or species habitat may occur within area
Syngnathoides biaculeatus		
Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus		
Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris		
Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammals		
Dugong dugon		
Dugong [28]		Species or species habitat likely to occur within area
Reptiles		
Acalyptophis peronii		
Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus duboisii		
Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii		
Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis		
Olive Seasnake [1120]		Species or species habitat may occur within area
Astrotia stokesii		
Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus porosus		
Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Disteira kingii		
Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major		
Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Enhydrina schistosa		
Beaked Seasnake [1126]		Species or species habitat may occur within area
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area

Hydrophis elegans		
Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis mcdowelli		
null [25926]		Species or species habitat may occur within area
Hydrophis ornatus		
a seasnake [1111]		Species or species habitat may occur within area
Lapemis hardwickii		
Spine-bellied Seasnake [1113]		Species or species habitat may occur within area
Laticauda colubrina		
a sea krait [1092]		Species or species habitat may occur within area
Laticauda laticaudata		
a sea krait [1093]		Species or species habitat may occur within area
Lepidochelys olivacea		
Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat likely to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Pelamis platurus		
Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and Other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata		
Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera edeni		
Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Species or species habitat may occur within area
Delphinus delphis		
Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Grampus griseus		
Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Megaptera novaeangliae		
Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Orcaella brevirostris		
Irrawaddy Dolphin [45]		Species or species habitat may occur within area
Orcinus orca		
Killer Whale, Orca [46]		Species or species habitat may occur within area
Sousa chinensis		
Indo-Pacific Humpback Dolphin [50]		Species or species habitat may occur within area
Stenella attenuata		
Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Tursiops aduncus		
Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops truncatus s. str.		
Bottlenose Dolphin [68417]		Species or species habitat may occur within area

Extra Information

Places on the RNE	**[Resource Information]**

Note that not all Indigenous sites may be listed.

Name	Status
Natural	
Ross River to Alligator Creek Coastal Area QLD	Indicative Place
Cape Cleveland National Park (1978 boundary) QLD	Registered
Great Barrier Reef Region QLD	Registered
Great Barrier Reef Region (Commonwealth) QLD	Registered
Horseshoe Bay Lagoon Environmental Park QLD	Registered
Magnetic Island (in part) QLD	Registered
Townsville Town Common and Environs QLD	Registered
Upstart Bay - Bowling Green Bay Area QLD	Registered
Indigenous	
Cape Cleveland - Bowling Green Bay NP CC4 QLD	Indicative Place
Cape Cleveland - Bowling Green Bay NP Site CC3 QLD	Indicative Place
Cape Cleveland - Bowling Green Bay NP Sites CC5, CC6 and CC7 QLD	Indicative Place
Florence Bay Area QLD	Registered
Historic	
Kardinia QLD	Indicative Place
Melton Hill Precinct QLD	Indicative Place
RAAF Base Townsville QLD	Indicative Place
Townsville Slipways QLD	Indicative Place
Townsville Drill Hall Complex (former) QLD	Interim List
AMP Building QLD	Registered
ANZ Bank (former) QLD	Registered
Anzac Park Bandstand QLD	Registered
Australian Bank of Commerce (former) QLD	Registered
Australian Institute of Tropical Medicine (former) QLD	Registered
Burns Philp Offices (former) QLD	Registered
Cape Cleveland Lightstation Precinct QLD	Registered
Commonwealth Offices (former) QLD	Registered
Forts QLD	Registered
Kissing Point Fort QLD	Registered
Magistrates Court Building (former) QLD	Registered
Magnetic House QLD	Registered
Matthew Rooney House (former) QLD	Registered
National Bank of Australia (former) QLD	Registered
Queens Hotel (former) QLD	Registered
Queensland Building QLD	Registered
Sacred Heart Cathedral QLD	Registered
Samuel Allen & Sons Ltd Building (former) QLD	Registered
St James Anglican Cathedral QLD	Registered

State Government Offices QLD	Registered
State Government Offices QLD	Registered
Tattersalls Hotel (former) QLD	Registered
Tobruk Memorial Baths QLD	Registered
Townsville Customs House QLD	Registered
Townsville General Hospital Block A QLD	Registered
Townsville Post Office (former) QLD	Registered
Townsville War Memorial QLD	Registered
Victoria Bridge QLD	Registered
Warringa QLD	Registered

State and Territory Reserves [Resource Information]

Great Barrier Reef Coast, QLD
Bolger Bay, QLD
Cleveland Bay, QLD
Horseshoe Bay Lagoon, QLD
Townsville Town Common, QLD
Endeavour, QLD
Cleveland Bay - Magnetic Island, QLD
Magnetic Island, QLD
Bolger Bay, QLD
Bowling Green Bay, QLD
Horseshoe Bay, QLD
Bowling Green Bay, QLD
Bowling Green Bay, QLD
Bowling Green Bay, QLD
Cape Pallarenda, QLD

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Mammals		
Felis catus		
Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Oryctolagus cuniculus		
Rabbit, European Rabbit [128]		Species or species habitat may occur within area
Vulpes vulpes		
Red Fox, Fox [18]		Species or species habitat may occur within area
Plants		
Acacia nilotica subsp. indica		
Prickly Acacia [6196]		Species or species habitat may occur within area
Cryptostegia grandiflora		
Rubber Vine, Rubbervine, India Rubber Vine, India Rubbervine, Palay Rubbervine, Purple Allamanda [18913]		Species or species habitat may occur within area
Hymenachne amplexicaulis		
Hymenachne, Olive		Species or species habitat likely to occur within area

Hymenachne, Water Stargrass, West Indian Grass, West Indian Marsh Grass [31754]	
Lantana camara	
Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]	Species or species habitat may occur within area
Parkinsonia aculeata	
Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301]	Species or species habitat may occur within area
Parthenium hysterophorus	
Parthenium Weed, Bitter Weed, Carrot Grass, False Ragweed [19566]	Species or species habitat likely to occur within area
Salvinia molesta	
Salvinia, Giant Salvinia, Aquarium Watermoss, Kariba Weed [13665]	Species or species habitat may occur within area

Nationally Important Wetlands [Resource Information]

Burdekin - Townsville Coastal Aggregation, QLD
Great Barrier Reef Marine Park, QLD
Bowling Green Bay, QLD

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World Heritage and Register of National Estate properties, Wetlands of International Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under 'type of presence'. For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the following provisions of the EPBC Act have been mapped:
- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:
- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:
- non-threatened seabirds which have only been mapped for recorded breeding sites;
- seals which have only been mapped for breeding sites near the Australian continent.

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

146.76216 -19.17902,146.75859 -19.1814,146.75978 -19.17784,146.78596 -19.11597,146.87162 -19.10169,147.13812 -19.0898,146.98702 -19.28372,146.93348 -19.30514,146.874 -19.30514,146.8395 -19.26944,146.80499 -19.24327,146.78358 -19.2278,146.7574 -19.18259,146.76216 -19.17902

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-Department of Environment, Climate Change and Water, New South Wales
-Department of Sustainability and Environment, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment and Natural Resources, South Australia
-Parks and Wildlife Service NT, NT Dept of Natural Resources, Environment and the Arts
-Environmental and Resource Management, Queensland
-Department of Environment and Conservation, Western Australia
-Department of the Environment, Climate Change, Energy and Water
-Birds Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-SA Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Atherton and Canberra

-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
-State Forests of NSW
-Other groups and individuals

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Please feel free to provide feedback via the Contact Us page.

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APPENDIX E: WILDLIFE ONLINE SEARCH

Box bounded by coordinates: 19.05S, 19.32S, 146.70E, 147.05E.

Search date: 7 June 2012

Fish, marine mammals, marine reptiles records only

Description of the CODES

I -	Y indicates that the taxon is introduced to Queensland and has naturalised.
Q -	Indicates the Queensland conservation status of each taxon under the Nature Conservation Act 1992. The codes are Extinct in the Wild (PE), Endangered (E), Vulnerable (V), Near Threatened (NT), Least Concern (C) or Not Protected ( ).
A -	Indicates the Australian conservation status of each taxon under the Environment Protection and Biodiversity Conservation Act 1999. The values of EPBC are Conservation Dependent (CD), Critically Endangered (CE), Endangered (E), Extinct (EX), Extinct in the Wild (XW) and Vulnerable (V).
Records –	The first number indicates the total number of records of the taxon for the record option selected (i.e. All, Confirmed or Specimens). The second number located after the / indicates the number of specimen records for the taxon.

Disclaimer

As the DERM is still in a process of collating and vetting data, it is possible the information given is not complete. The information provided should only be used
for the Project for which it was requested and it should be appropriately acknowledged as being derived from Wildlife Online when it is used.

The State of Queensland does not invite reliance upon, nor accept responsibility for this information. Persons should satisfy themselves through independent
means as to the accuracy and completeness of this information.

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and costs you may incur as a result of the information being inaccurate or incomplete in any way for any reason.

Feedback about Wildlife Online should be emailed to Wildlife.Online@derm.qld.gov.au

Class	Family	Scientific Name	Common Name	I	Q	A	Sighting Records	Specimen Records
bony fish	Ambassidae	*Ambassis macleayi*	Macleay's glassfish				1	0
bony fish	Anguillidae	*Anguilla reinhardtii*	longfin eel				1	0
bony fish	Apogonidae	*Glossamia aprion*	mouth almighty				1	0
bony fish	Atherinidae	*Craterocephalus stercusmuscarum*	flyspecked hardyhead				1	0
bony fish	Belonidae	*Strongylura krefftii*	freshwater longtom				1	0
bony fish	Cichlidae	*Tilapia mariae*	spotted tilapia	Y			2	0
bony fish	Cichlidae	*Oreochromis mossambicus*	Mozambique mouthbrooder	Y			1	0
bony fish	Eleotridae	*Mogurnda adspersa*	southern purplespotted gudgeon				1	1
bony fish	Eleotridae	*Mogurnda mogurnda*	northern purplespotted gudgeon				1	0
bony fish	Eleotridae	*Giurus margaritacea*	snakehead gudgeon				2	0
bony fish	Eleotridae	*Ophiocara porocephala*	spangled gudgeon				2	0
bony fish	Eleotridae	*Hypseleotris compressa*	empire gudgeon				1	0
bony fish	Gobiidae	*Redigobius bikolanus*	speckled goby				1	0
bony fish	Gobiidae	*Glossogobius species 1*	false celebes goby				2	0
bony fish	Gobiidae	*Chlamydogobius ranunculus*	tadpole goby				1	1
bony fish	Lutjanidae	*Lutjanus argentimaculatus*	mangrove jack				2	0
bony fish	Megalopidae	*Megalops cyprinoides*	oxeye herring				1	0
bony fish	Melanotaeniidae	*Melanotaenia splendida splendida*	eastern rainbowfish				10	9
bony fish	Percichthyidae	*Macquaria novemaculeata*	Australian bass				1	0
bony fish	Plotosidae	*Neosilurus ater*	black catfish				1	0
bony fish	Poeciliidae	*Gambusia holbrooki*	mosquitofish	Y			1	0
bony fish	Poeciliidae	*Poecilia reticulata*	guppy	Y			1	0
bony fish	Pseudomugilidae	*Pseudomugil signifer*	Pacific blue eye				4	1
bony fish	Terapontidae	*Amniataba percoides*	barred grunter				1	0
bony fish	Terapontidae	*Leiopotherapon unicolor*	spangled perch				1	0
bony fish	Toxotidae	*Toxotes chatareus*	sevenspot archerfish				3	0
bony fish	Toxotidae	*Toxotes jaculatrix*	banded archerfish				1	0
cartilaginous fishes	Mobulidae	*Manta birostris*	manta ray				1	0
cartilaginous fishes	Myliobatidae	*Aetobatus ocellatus*	whitespotted eagle ray				1	0
mammals	Balaenopteridae	*Megaptera novaeangliae*	humpback whale		V	V	15	0
mammals	Delphinidae	*Tursiops aduncus*	Indo-Pacific bottlenose dolphin		C		4	3
mammals	Delphinidae	*Sousa chinensis*	Indo-Pacific humpback dolphin		NT		10	10

Class	Family	Scientific Name	Common Name	I	Q	A	Sighting Records	Specimen Records
mammals	Delphinidae	*Orcaella heinsohni*	Australian snubfin dolphin		NT		34	22
mammals	Dugongidae	*Dugong dugon*	dugong		V		11	1
reptiles	Cheloniidae	*Natator depressus*	flatback turtle		V	V	3	0
reptiles	Cheloniidae	*Chelonia mydas*	green turtle		V	V	11	0
reptiles	Cheloniidae	*Eretmochelys imbricata*	hawksbill turtle		V	V	2	0
reptiles	Colubridae	*Tropidonophis mairii*	freshwater snake		C		25	1
reptiles	Crocodylidae	*Crocodylus porosus*	estuarine crocodile		V		10	2
reptiles	Crocodylidae	*Crocodylus johnstoni*	Australian freshwater crocodile		C		1	0

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