7 Seagrass meadows and epibenthic macroalgae

7.1 Background

7.1.1 Seagrasses

7.1.1.1 Importance to marine ecosystems

Seagrasses are marine plants that provide a range of critically important and economically valuable ecosystem services along the coastline of Queensland, including coastal protection by restricting water movement, support of fisheries production, nutrient cycling and particle trapping (Costanza et al. 2014; Hemminga and Duarte 2002). As such, seagrass is acknowledged as contributing to the local expression of OUV of the GBRWHA in the Port of Gladstone (Commonwealth of Australia 2013).

As benthic primary producer habitat, seagrasses have important economic values as they provide nursery and feeding habitats for commercial and recreational fisheries species (Watson et al. 1993; Unsworth and Cullen 2010; Bryant et al. 2016a; Davies et al. 2016). Seagrasses also support an array of epiphytic seaweeds and filter-feeding animals such as bryozoans, sponges and hydroids. These species assemblages are important food resources for a number of species, including fish, mammals and migratory shorebirds (Danaher et al. 2005; Rasheed et al. 2003).

The seagrass communities of Port Curtis and Rodds Bay are of regional significance functioning as important feeding locations, breeding areas and nursery grounds for a diverse range of marine organisms, some of which are of high ecological and economic importance to the Gladstone region (e.g. fish, prawns, marine megafauna). Turtles such as the Green turtle (*Chelonia mydas*) feed directly on seagrasses along with Dugongs (*Dugong dugon*), which feed on the range of seagrass species found in Gladstone, including the sparse colonising species meadows dominated by *Halophila* (deep water species) and *Halodule* (coastal species) (Lanyon 1991; Preen et al. 1995; Rasheed et al. 2017a).

Dugongs were found to feed in all seagrass meadows in Port Curtis to varying extents throughout the year, indicating that all intertidal meadows were of value for dugong feeding (Rasheed et al. 2017a). There is also no clear preference for one seagrass species as a primary food source (Marsh et al. 2011), although dugong feeding was found to significantly increase with both biomass and percent cover of seagrass (Rasheed et al. 2017a). It is also noted that while dugongs preferred to feed in coastal seagrass meadows where the seagrass biomass is greater, they appear to adapt and forage in deep water seagrass when required to avoid predators (Wirsing et al. 2007).

The area of Port Curtis from Rodds Bay to The Narrows was declared a DPA in 1997 to recognise the importance of this seagrass habitat to dugong populations and place extra control measures on gill net fisheries operating in these areas (refer Figure 7.1).

7.1.1.2 Seasonal cycles and environmental drivers

Seagrass seasonal cycles are defined according to the climate-induced annual pattern of growth and senescence, on the east coast of Queensland (McKenzie 1994; Chartrand et al. 2011). Two generalised seasons are distinguished for seagrass in the Gladstone region (Chartrand et al. 2012):

- Growing season, defined as July to January, which typifies seagrass' natural increase in biomass and distribution as ideal growth conditions provide a period of opportunistic expansion

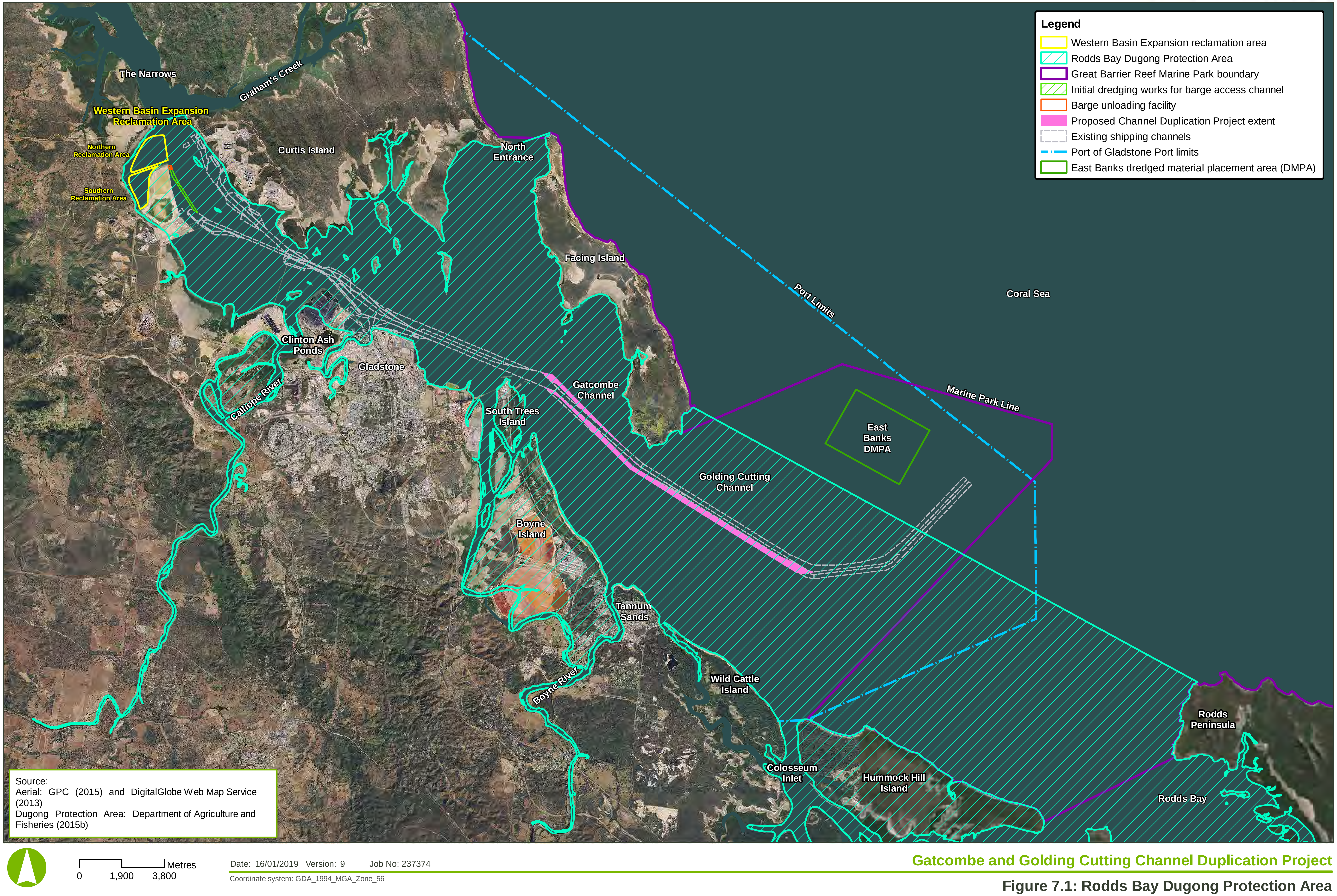

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Figure 7.1: Rodds Bay Dugong Protection Area

- Senescent season, from February to June, is typically when seagrasses retract and rely on stores and/or seeds to get through wet season conditions, including flooding and poor water quality.

Seasonal changes in seagrass abundance and species composition are well documented in Port Curtis and Rodds Bay.

The capacity of seagrass to maintain their population during senescent season and to recover from impacts relies on the density and viability of the seed banks (seeds stored in sediments) (Reason et al. 2017). This recovery is dependent on the species present, the availability of propagules and whether growing conditions favour germination (Bryant et al. 2016b). The maintenance of a viable seed bank is essential for the resilience of seagrass meadows, particularly in the event of large-scale decline.

The availability and quality of light is one of the primary environmental drivers of seagrass distribution, abundance and productivity (Duarte et al. 1997; Vermaat et al. 1997). Seagrass habitat can be highly variable from shallow coastal waters and areas of high turbidity, to deep water areas where the quantity and quality of light reaching the seagrass bed is highly differential. The effect this has on seagrass differs among species and seasons (Lee et al. 2007; Ralph et al. 2007; Erftemeijer and Lewis 2006; Hemminga and Duarte 2000; Bjork et al. 1999). The response of seagrass to low light conditions, and magnitude of impact to the meadow, will depend on a number of factors, including site specific environmental conditions and species composition (Ralph et al. 2007) as well as the intensity and duration of the reduced light (Collier et al. 2012). Recent work in Port Curtis by Chartrand et al. (2012) indicates that temperature may also be a key factor affecting tropical seagrass seasonality and survival.

Seagrasses have also been demonstrated to be one of the world's most powerful carbon sinks capable of storing and sequestering carbon in sediments at rates well in excess of many terrestrial forests (Macreadie et al. 2014). Assessments of carbon stocks in Gladstone found that carbon stored in the sediments was significantly higher in seagrass areas compared with bare sediments (Ricart et al. 2015) and it is likely that locally these meadows represent an important carbon sink.

7.1.1.3 Indicator for ecosystem health

Seagrass meadows have been ranked as one of the most ecologically and economically valuable biological systems on earth, for reasons outlined above (Duarte 2002; Connolly 2009). However, seagrass abundance and distribution have been declining globally, which is attributable to both natural and anthropogenic pressures (Waycott et al. 2009). While Queensland seagrass meadows have tended to fare far better than many other locations (Coles et al. 2015), recent climate related impacts have shown that they are also vulnerable to large scale losses (McKenna et al. 2015; Rasheed et al. 2014). In response to these pressures, a strategic long term assessment and seagrass monitoring program for seagrasses in high cumulative risk areas of Queensland was established by JCU TropWATER in partnership with Port authorities and the Queensland Government. This program has established long term monitoring program locations in most of Queensland's commercial ports, including Gladstone, Hay Point, Abbot Point, Townsville, and Cairns among others (refer Figure 7.2).

Figure 7.2 **Location of Queensland port seagrass assessment sites**

Source: Rasheed et al. (2017b)

Seagrass meadows display measurable responses to changes in water quality, which make them ideal indicators for measuring the health of ecosystems and the impacts of developments and industries along coastlines (Rasheed et al. 2008; Denison et al. 1993). Understanding the relationships that exist between seagrass and environmental variables on a local scale is critical to effectively managing and mitigating the environmental risk from Port operational and development activities.

7.1.2 Epibenthic macroalgae

Macroalgae is the collective term used for seaweeds and other benthic marine algae that are generally visible to the naked eye (Diaz-Pulido and McCook 2008). Although they are photosynthetic, macroalgae differ from other marine plants such as seagrasses and mangroves in that macroalgae lack roots, leafy shoots, flowers, and vascular tissues, although they serve a similar ecological role to other plants (Diaz-Pulido and McCook 2008).

Macroalgae are found in a range of forms from simple crusts, foliose (leafy), and filamentous (threadlike) forms with simple branching structures, to more complex structures designed for light capture, reproduction, support, flotation, and attachment to the seafloor (Diaz-Pulido and McCook 2008). Macroalgae of the Great Barrier Reef are known to occupy a variety of habitats comprising shallow and deep coral reefs, inter-reefal areas, sandy bottoms, seagrass meadows, mangrove roots, and rocky intertidal zones (Diaz-Pulido and McCook 2008). Many macroalgae species make important contributions to the construction of the reef framework and are significant framework builders and framework ‘cementers’ on coral reefs (Diaz-Pulido et al. 2007).

Section 7.7 outlines the ecological values of epibenthic macroalgal species associated with soft sediments, identified in Port Curtis seagrass and benthic community baseline surveys. For a summary of macroalgal species associated with coastal fringing reefs in Port Curtis, refer to Section 8 of this report.

7.2 Methodology

7.2.1 Port Curtis seagrass monitoring overview

A large body of seagrass based research exists for Port Curtis with several current studies and long term monitoring programs likely to continue into the future. Large areas of seagrass were first identified and reported in the Port Curtis region as part of state-wide seagrass surveys conducted in 1988 (Coles et al. 1992) and have been the subject of extensive monitoring since 2002 by the JCU TropWATER seagrass group (formally the Marine Ecology Group, Fisheries Queensland), in partnership with GPC.

An annual seagrass monitoring program was developed in 2004 in response to a whole of Port review (SKM 2004), following recommendations from the PCIMP. In 2009, proposed developments in the Western Basin zone of the Port, including the expansion of the Fisherman's Landing reclamation area and a capital dredging campaign associated with the LNG developments on Curtis Island, led to the requirement for more detailed information on inter and intra-annual seagrass dynamics in Port Curtis (Thomas et al. 2010).

In 2014, as part of the Project EIS baseline surveys, additional seagrass surveys associated with the Project impact areas, were added to the TropWATER seagrass monitoring program to fill existing data gaps. Section 7.2.2 outlines the long term seagrass monitoring efforts undertaken in Port Curtis and Rodds Bay since 2002, and other seagrass research recently undertaken in Port Curtis.

Information from these monitoring programs has been used to describe the existing seagrass meadow values in Port Curtis. It should be noted that other benthic primary producer habitat in Port Curtis has been reported in other sections of this report, including mangroves (Section 4), wetlands (Section 5) and coral (Section 8).

7.2.2 Seagrass monitoring survey methodology

7.2.2.1 Overview

There has been a strategic long term seagrass assessment and monitoring program in place for Port Curtis since baseline mapping of the entire Port limits and Rodds Bay was carried out in 2002 by JCU TropWATER. The monitoring program forms part of a broader long term monitoring program for seagrasses in Queensland Ports and high risk areas of the state that was initially established in 1994 and uses a common method and approach between locations. The approach incorporates periodic reassessments and mapping of all seagrasses within the Port Curtis to Rodds Bay area with annual monitoring (since 2004) between these larger surveys, of a sub-set of seagrass meadows that represent the different seagrass habitat types as well as those meadows most likely to be impacted by activities. In Port Curtis, this program has been scaled up and expanded at various times to include more frequent monitoring and/or expanded spatial scope of assessments in response to development activities such as the WBDDP and EIS preparations for the Gatcombe and Golding Cutting Channel Duplication Project. A summary of the long term monitoring program activities and monitoring scales and approaches from 2002 to 2018 is presented in Table 7.1.

In addition to these long term monitoring assessments of seagrass meadows, smaller sentinel sensitive receptor sites were established during the WBDDP to assess seagrass change at key compliance and reference sites quarterly using fixed transects between November 2009 and 2016. These sites were coupled with light photosynthetically active radiation (PAR) monitoring and for part of the dredging period (October 2011 to December 2013) were ramped up to monthly assessments (refer Table 7.1)

Survey and monitoring methods followed the long term seagrass monitoring program and used the established techniques for the TropWATER Queensland wide Ports seagrass monitoring program (see Unsworth et al. 2012; Rasheed and Unsworth 2011; Taylor and Rasheed 2011). Detailed descriptions of the methods for intertidal, shallow subtidal, and deep water seagrass survey and monitoring methods are provided below. Full methods and results of the program are also available in the detailed reports (refer Table 7.1). This is followed by detail on the various seagrass studies that have been undertaken to date, including a summary of methods for each study and a list of the relevant study reports produced.

Table 7.1 Summary of the seagrass monitoring program for Port Curtis

Years	Long term seagrass monitoring and assessment program				Small scale of sentinel sites during WBDPP	
	Entire Port limits and Rodds Bay	Annual long term seagrass monitoring (November)	Expanded scope annual Western Basin region surveys	Additional low season surveys of Western Basin region (July)	Quarterly transect assessments	Monthly transect assessments
2002	Yes	Yes (subset of port limits survey)				
2004 to 2008		Yes				
2009	Yes	Yes	Yes (subset of port limits survey)	Yes (subset of port limits survey)	November 2009 to November 2016	
2010 to 2012		Yes	Yes	Yes		October 2011 to December 2013
2013	Yes*	Yes	Yes	Yes		
2014	Yes*	Yes	Yes	Yes		
2015 to 2016		Yes	Yes			
2017 to 2018		Yes	Yes			

Table note:

* Whole of Port surveys undertaken as part of the Gatcombe and Golding Cutting Channel Duplication Project EIS

7.2.2.2 Baseline assessments of Port limits and Rodds Bay

General

The baseline assessments of Port limits area and Rodds Bay were carried out in 2002, 2009, 2013 and 2014 and includes intertidal and shallow subtidal methods (refer Table 7.2). These assessments are planned for every three years from 2019.

Table 7.2 Fine-scale seagrass mapping for Port Curtis and Rodds Bay

Survey	Reports
2002 and 2009	**Spatial extent:** Port of Gladstone limits and Rodds Bay ▪ *Port Curtis and Rodds Bay seagrass and benthic macro-invertebrate community baseline survey November/December 2002* (Rasheed et al. 2003) ▪ *Seagrasses of Port Curtis and Rodds Bay and long term seagrass monitoring, November 2009* (Thomas et al. 2010)

Survey	Reports
2013 and 2014	**Spatial extent:** Port of Gladstone limits and Rodds Bay, including extended area - *Seagrasses in Port Curtis and Rodds Bay 2013: Annual long term monitoring, biannual Western Basin surveys and updated baseline survey* (Bryant et al. 2014) - *Seagrasses in Port Curtis and Rodds Bay 2014: Annual long-term monitoring, biannual Western Basin, and updated baseline survey* (Carter et al. 2015)

The objectives of the baseline assessment were to:

- Survey and describe seagrass communities within Port Curtis and the Rodds Bay DPA
- Establish a baseline from which monitoring programs could be developed
- Provide a geographic information system (GIS) database and maps within and adjacent to areas requiring dredging in the Port and potential dredged material placement areas
- Discuss the implications of the survey results for protection of dugongs in the Rodds Bay DPA and during Port development and operational programs.

The 2002 and 2009 fine-scale seagrass survey area originally included all areas within the Port limits and Rodds Bay DPA. In 2013, the survey area was expanded to include areas within the GBRMP (refer Figure 7.3), to account for the Project potential indirect impact areas.

The sampling approach for the survey was based on the need to establish EIS baseline data on seagrass habitat within the enclosed coastal/lower estuary waters and open coastal waters of Port Curtis, including:

- Seagrass characteristics such as above-ground biomass
- Seagrass species composition and sediment characteristics for the major seagrass meadows.

The 2002 baseline seagrass survey identified 135 discrete coastal and deep water seagrass meadows (GPC 2012). These results enabled 13 seagrass meadows to be identified and selected for annual long term monitoring (refer Section 7.2.2.3). The meadows selected represent the range of seagrass communities within Port Curtis and include meadows considered (in 2014) to have the potential to be impacted by Port facilities and developments, as well as reference meadows at Rodds Bay (unlikely to be impacted by Port development).

The objectives of subsequent seagrass surveys in 2009, 2013 and 2014 were to document the spatial extent and biomass of intertidal, shallow subtidal, and deep water (in 2013 and 2014 surveys only) seagrass meadows within Port Curtis and Rodds Bay, and to compare distribution relative to previous baseline surveys. At each survey site, seagrass characteristics, including seagrass percent cover, species composition, above-ground biomass, percent algal cover, depth below mean sea level (dbMSL) (for subtidal meadows), sediment type, time and position (latitude and longitude) were recorded. Spatial data from the fine-scale survey were entered into the Port Curtis GPS.

Methodology

Intertidal and shallow subtidal seagrass

Intertidal meadows were sampled at low tide using a helicopter, and a GPS was used to record the position of meadow boundaries. Seagrass characteristics were recorded at sites scattered within the seagrass meadow as the helicopter hovered 2m above the seagrass. Power analysis techniques were used to determine the appropriate number of sampling sites for each meadow in order to detect seagrass meadow change (Rasheed et al. 2003).

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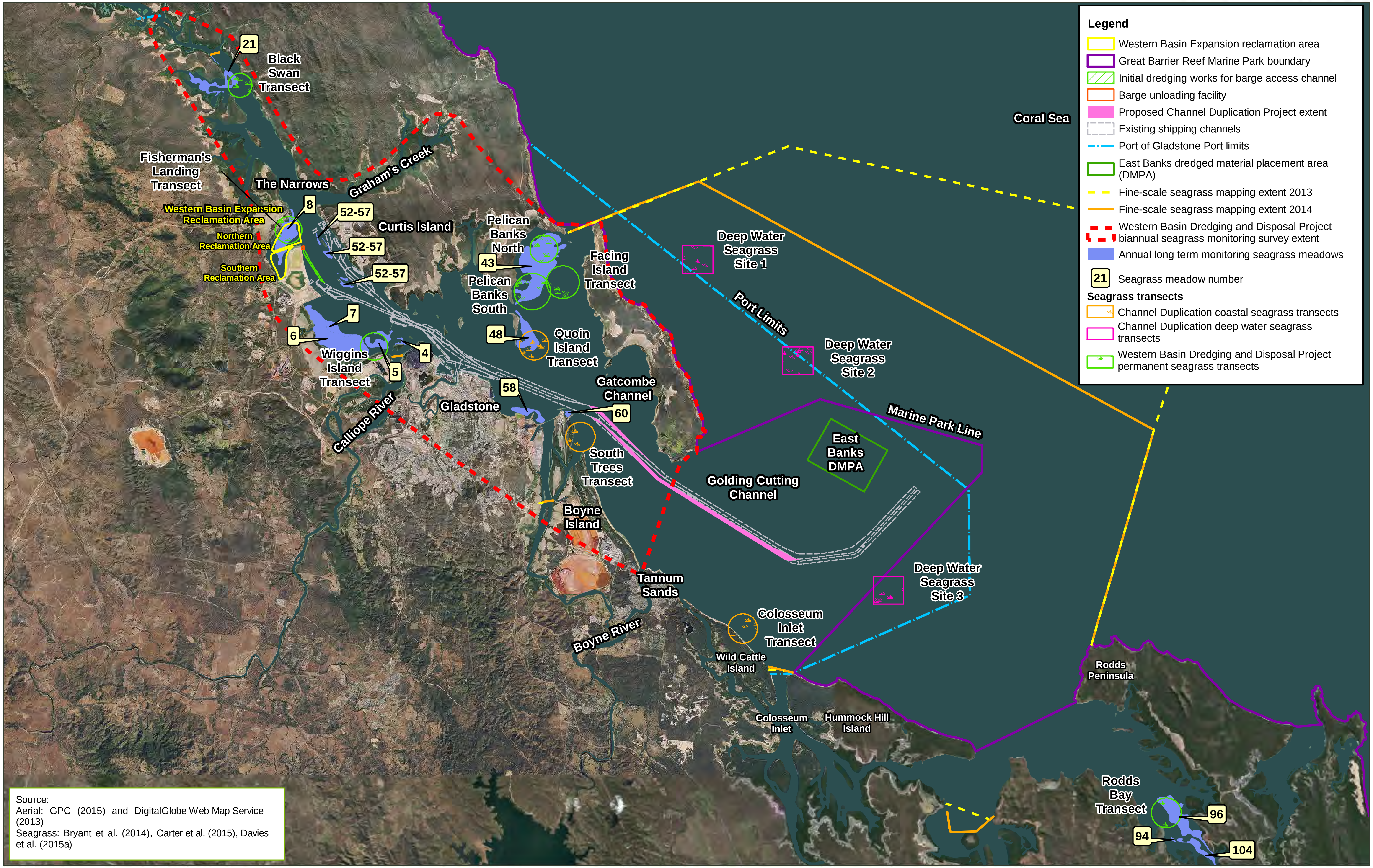

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Gatcombe and Golding Cutting Channel Duplication Project

Figure 7.3: Baseline seagrass monitoring effort

Shallow subtidal meadows were sampled from a small boat using free divers. Seagrass characteristics were recorded at sites located along transects perpendicular to the shoreline at ~100m to 500m intervals, or where major changes in bottom topography occurred. Transects extended to the offshore edge of seagrass meadows, with random sites used to measure continuity of habitat between transects.

Seagrass above-ground biomass was determined using a 'visual estimates of biomass' technique (Mellors 1991; Kirkman 1978). A 0.25m^2 quadrat was placed randomly three times at each site. For each quadrat, an observer assigned a biomass rank made in reference to a series of quadrat photographs of similar seagrass habitats for which the above-ground biomass had previously been measured. Two separate ranges were used, including low biomass and high biomass. The relative proportion of the above-ground biomass (i.e. percentage) of each seagrass species within each quadrat was recorded.

At the completion of ranking, the observer also ranked a series of photographs of calibration quadrats that represented the range of seagrass observed during the survey. These calibration quadrats had previously been harvested and the actual biomass determined in the laboratory. This ensured that estimates made during surveys could be correlated to actual known biomass. A separate regression of ranks and biomass from the calibration quadrats was generated for each observer and applied to the biomass ranks given in the field. Field biomass ranks were converted into above-ground biomass estimates in grams dry weight per square metre (g DWm^{-2}).

Deep water methods

At each offshore sampling site, an underwater camera system was towed for approximately 100m, while footage was observed on a closed circuit television (CCTV) monitor and recorded. Benthos on the seafloor were captured in the net and used to confirm seagrass species observed on the monitor. This technique was used to ensure that a large area of seafloor was sampled at each site so that patchily distributed seagrass typically found in deep water habitats was detected.

Seagrass species composition was measured from the sled net sample and from the video screen when several species were encountered according to Kuo and McComb (1989). Seagrass biomass estimates were made from video images using a calibrated visual estimates technique as described by Kirkman (1978) and Mellors (1991). Algae percent cover was estimated from a video grab, and algae type were identified according to Cribb (1996).

Seagrass meadow mapping and geographic information system

The monitoring program created three seagrass GIS layers using ArcGIS to construct seagrass meadow polygon layers containing site information, seagrass meadow characteristics and seagrass landscape category (Rasheed et al. 2017b). The three categories of GIS layers are discussed further below.

Site information

Seagrass site information includes seagrass percent cover, seagrass above-ground biomass for each species, dbMSL, sediment type, algal cover, time, date, latitude, longitude, sampling method, and any observations (Rasheed et al. 2017b).

Seagrass meadow characteristics

Seagrass meadows were assigned a meadow identification number, which was used to compare individual meadows between annual monitoring surveys. Monitoring meadows were referred to by these identification numbers. Seagrass community types were determined according to overall species composition (the mean species composition of all sites within the meadow boundary) from nomenclature developed for seagrass meadows of Queensland (refer Table 7.3) (Rasheed et al. 2017b). Density categories (i.e. light, moderate or dense) were assigned to community types according to above-ground biomass of the dominant species (refer Table 7.4).

Table 7.3 Nomenclature for community types in Port Curtis

Community type	Species composition
Species A	Species A 90% to 100% of composition
Species A with mixed species	Species A is 50% to 90% of composition
Species A/Species B	Species A is 40% to 60% of composition

Source: Rasheed et al. (2003); Rasheed et al. (2017b)

Table 7.4 Density categories and mean above-ground biomass ranges for each species used in determining seagrass community density in Port Curtis

Density	Mean above-ground biomass (g DWm^{-2})				
	***Halodule uninervis* (thin)**	***Halophila ovalis* and *Halophila decipiens***	***Halophila uninervis* (wide)**	***Halophila spinulosa***	***Zostera muelleri* subsp. *capricorni***
Light	< 1	< 1	< 5	< 15	< 20
Moderate	1 to 4	1 to 5	5 to 25	15 to 35	20 to 60
Dense	> 4	> 5	> 25	> 35	> 60

Source: Rasheed et al. (2003); Rasheed et al. (2017b)

Seagrass meadow landscape category

Table 7.5 describes the seagrass landscape category for seagrass meadows in Queensland.

Table 7.5 Seagrass meadow landscape category

Seagrass landscape category	Description
Isolated seagrass patches	The majority of area within the meadow consisted of unvegetated sediment interspersed with isolated patches of seagrass (refer Photograph 7.1)
Aggregated seagrass patches	Meadows are comprised of numerous seagrass patches but still feature substantial gaps of unvegetated sediment within the meadow boundaries (refer Photograph 7.2)
Continuous seagrass cover	The majority of area within the meadows comprised of continuous seagrass cover interspersed with a few gaps of unvegetated sediment (refer Photograph 7.2)

Source: Rasheed et al. (2017b)

Photograph 7.1 Isolated seagrass patches

Source: Rasheed et al. (2003)

Photograph 7.2 Aggregated seagrass patches

Source: Rasheed et al. (2003)

Photograph 7.3 Continuous seagrass cover

Source: Rasheed et al. (2003)

Meadows were also assigned a mapping precision estimate (in metres) based on mapping methods used for that meadow (refer Table 7.6). The mapping precision for coastal seagrass meadows ranged from ±5m for isolated seagrass patches to ±750m for offshore deep water meadows. The mapping precision estimate was used to calculate a range around each meadow area estimate and was expressed as a meadow reliability estimate in hectares.

Table 7.6 Methods used to determine mapping precision estimates for each seagrass meadow

Mapping precision	Mapping method
≤ 5m	Meadow boundaries mapped in detail by GPS from helicopter, intertidal meadows completely exposed or visible at low tide, relatively high density of mapping and survey sites, recent aerial photography aided in mapping
10m to 20m	Meadow boundaries determined from helicopter and diver/grab surveys, intertidal boundaries interpreted from helicopter sites, subtidal boundaries interpreted from survey sites and aerial photography, moderately high density of mapping and survey sites
20m to 50m	Meadow boundaries determined from helicopter and diver/grab surveys, intertidal boundaries interpreted from helicopter sites, subtidal boundaries interpreted from diver/grab survey sites, lower density of survey sites for some sections of boundary
> 50m	Subtidal meadow boundaries interpreted from survey sites

Source: Rasheed et al. (2003)

7.2.2.3 Annual long term monitoring

General

In light of existing and future potential development of Gladstone and the Port, the program was established to routinely monitor the condition of selected seagrass meadows and to complement existing seagrass studies. The annual (November) long term seagrass monitoring program was established in 2004 and involved monitoring 13 key seagrass meadows in Port Curtis (and Rodds Bay reference sites), which expanded to 14 or 15 (depending on the survey) from 2009 due to their proximity to potential dredging and Port developments (refer Table 7.7). The meadows surveyed are outlined in Table 7.8 and shown in Figure 7.3 (Bryant et al. 2014).

Table 7.7 Annual long term monitoring for Port Curtis and Rodds Bay

Survey	Reports
2004 to 2009	**Spatial extent:** Thirteen seagrass meadows between The Narrows and Boyne River mouth, and Rodds Bay reference site - *Long-term seagrass monitoring in Port Curtis and Rodds Bay, Gladstone, October 2007* (Rasheed et al. 2008) - *Seagrasses of Port Curtis and Rodds Bay and long term seagrass monitoring, November 2009* (Thomas et al. 2010).
2010 to 2017	**Spatial extent:** Fourteen to fifteen seagrass meadows between The Narrows and Boyne River mouth, and Rodds Bay reference site - *Seagrasses in Port Curtis and Rodds Bay 2013 – Annual long-term monitoring, biannual Western Basin and updated baseline survey* (Bryant et al. 2014) - *Seagrasses in Port Curtis and Rodds Bay 2014 – Annual long-term monitoring, biannual Western Basin and updated baseline survey* (Carter et al. 2015) - *Seagrasses in Port Curtis and Rodds Bay 2015, Annual long-term monitoring* (Davies et al. 2016) - *Seagrasses in Port Curtis and Rodds Bay 2016 – Annual long-term monitoring* (Rasheed et al. 2017b) - *Seagrasses in Port Curtis and Rodds Bay 2017 – Annual long-term monitoring* (Chartrand et al. 2018).

Seagrass meadows were monitored using survey methodology outlined in Section 7.2.2 and the following data was recorded:

- Seagrass community types in Port Curtis and Rodds Bay
- Changes in biomass
- Meadow area
- Species composition
- Seagrass condition index.

Table 7.8 Annual monitoring meadows in Port Curtis and Rodds Bay

Meadow ID	Location	Meadow depth
4	Wiggins Island	Intertidal
5	Wiggins Island	Intertidal
6	South Fisherman's Landing	Intertidal
7	South Fisherman's Landing	Subtidal
8	South Fisherman's Landing	Intertidal
9^	South Fisherman's Landing	Subtidal

Meadow ID	Location	Meadow depth
23*	The Narrows	Intertidal
43	Pelican Banks	Intertidal
48	Quoin Island	Intertidal/subtidal
52* to 57#	Channel Island	Intertidal
58	South Trees Inlet	Intertidal
60	South Trees Inlet	Intertidal
94	Rodds Bay	Intertidal
96	Rodds Bay	Intertidal
104	Rodds Bay	Intertidal

Table notes:

* Meadows 23 and 52 were not included in the original 13 annual monitored meadows, but have been added to the annual monitoring due to their proximity to potential dredging and Port developments

\# Meadows 52 to 57 formed one isolated patch in the 2011 surveys

^ Due to the expansion of the reclamation area at Fisherman's Landing, Meadow 9 is no longer monitored as part of this program

Source: Adapted from Rasheed et al. (2003) and Bryant et al. (2014)

Statistical analysis

Prior to analysis, data exploration protocols were conducted as defined by Zuur et al. (2010), including checks for zero inflation of biomass data. Following data exploration, all biomass data were square-root transformed to increase homoscedasticity. One-way analysis of variance (ANOVA) was then conducted on monitoring meadows with a non-zero inflated data to test for differences in mean biomass between years. Following analysis, all residuals were inspected visually and pairwise comparisons were made using a Tukey's Honest Significant Differences (HSD) test in the multcomp package (Hothorn et al. 2008). Analysis was conducted using R (R Development Core Team 2013).

When visual inspection of residual plots did not reveal any obvious deviations from homoscedasticity or normality, p-values were obtained by maximum likelihood ratio tests of the model with the effect in question against the null model. Analysis was conducted using the Ime4 package (Bates et al. 2013). Following analysis with the binomial-Gemma hurdle model, all residuals were inspected visually and pairwise comparisons were made using a holm adjusted Tukey's HSD test, as described previously.

Seagrass meadow condition index

A condition index has been applied to the seagrass monitoring meadows since 2013. The condition index is based on changes in mean above-ground biomass, total meadow area and species composition of each seagrass meadow (Carter et al. 2015). Initial classifications of 'good', 'moderate' and 'poor' used in 2013 were expanded to five classifications 'very good', 'good', 'fair', 'poor' and 'very poor' in 2014 for similarity to other report card programs in Queensland that apply condition indices (i.e. Reef Rescue Marine Monitoring Program (MMP) and GHHP).

The condition index allows for comparison of current meadow condition against the long term average. Different threshold ranges were developed for biomass and area to recognise that biomass and area of some seagrass meadows are historically stable while others are relatively variable and fluctuate substantially from year to year (Carter et al. 2015). These differences reflect growth characteristics of species that comprise different meadows, as well as the growing environment subtidal or intertidal (Carter et al. 2015). As such, four classes of monitoring meadow were developed for reporting purposes as summarised in Table 7.9.

Table 7.9 Meadow monitoring classes

Class ID	Description
Class 1 meadows	Stable biomass, stable area
Class 2 meadows	Variable biomass, stable area
Class 3 meadows	Variable biomass, variable area (intertidal)
Class 4 meadows	Variable biomass, variable area (subtidal)

Source: Carter et al. (2015)

For biomass and area, the current value for each meadow was compared against the average for the meadow for the first 10 years of the program (2002, 2004 to 2012) and categorised according to one of the five condition categories (refer Table 7.10) (Carter et al. 2015). For meadows monitored since 2009, the long term average of biomass and area was calculated from 2009 to 2013 data.

Table 7.10 Seagrass condition descriptions

Seagrass condition	Description
Very good	When the species composition remained stable
Good	When there had been minor loss of climax species
Fair	When there had been a substantial shift in species toward colonising species that indicates disturbance or stress
Poor	When the meadow had shifted to become dominated by colonising species
Very poor	When there was a complete loss of the climax species

Source: Adapted from Carter et al. (2015)

Species shifts, from climax to colonising species, are relative and were determined on a meadow by meadow basis, considering both the current years' species composition and their historical trends (Carter et al. 2015).

It is important to note that tropical seagrass communities naturally vary in condition due to a number of factors, including climate. Some monitoring of meadows classified as being in 'poor' condition can reflect the natural range of expected conditions and not necessarily indicate anthropogenic impacts (Carter et al. 2015). The index provides a method of comparing the current meadow condition and likely resilience to impacts against the known long term average (Carter et al. 2015).

The seagrass condition index for biomass, area and species composition is detailed in Table 7.11. The final condition of each monitoring meadow was based on the lowest of the three condition indictors (biomass, area and species composition) to determine the overall seagrass condition (Carter et al. 2015).

Table 7.11 Seagrass condition index for Port Curtis and Rodds Bay seagrass monitoring meadows

Seagrass indicators/class		Very good	Good	Fair	Poor	Very poor
Biomass	Stable	More than 20% above the baseline	Within 20% of the baseline (above or below)	Between 20% and 50% below the baseline	Between 50% and 80% below the baseline	More than 80% below the baseline
	Highly variable	More than 40% above the baseline	Within 40% of the baseline (above or below)	Between 40% and 70% below the baseline	Between 70% and 90% below the baseline	More than 90% below the baseline
Area	Stable	More than 10% above the baseline	Within 10% of the baseline (above or below)	Between 10% and 30% below the baseline	Between 30% and 50% below the baseline	More than 50% below the baseline
	Highly variable intertidal	More than 20% above the baseline	Within 20% of the baseline (above or below)	Between 20% and 50% below the baseline	Between 50% and 80% below the baseline	More than 80% below the baseline
	Highly variable subtidal	More than 40% above the baseline	Within 40% of the baseline (above or below)	Between 40% and 70% below the baseline	Between 70% and 90% below the baseline	More than 90% below the baseline
Species composition		Composition remains stable	Some loss of climax species	Shift towards colonising species	Colonising species dominant	Complete loss of climax species

Source: Carter et al. (2015)

Western Basin Dredging and Disposal Project – biannual monitoring

In addition to annual seagrass monitoring, all seagrasses within the WBDDP survey area (The Narrows to Boyne River mouth) have been mapped biannually since 2009 until 2016 (June and November) (refer Table 7.12). The aim of the monitoring is to determine the total distribution of seagrasses at both the senescent (June) and peak (November) seagrass growing season. These biannual surveys document the spatial extent and biomass of intertidal and shallow subtidal seagrass meadows (refer Table 7.12) and assess seasonal dynamics prior to, during and after the WBDDP (Stage 1A) dredging campaign.

Results from the 2014 biannual WBDDP surveys are discussed in relation to light and temperature data recorded at seagrass meadows as part of the sensitive receptor seagrass transect monitoring program established for the WBDPP.

Table 7.12 Biannual seagrass monitoring in the Western Basin Dredging and Disposal Project survey area

Survey	Reports
2009 to 2015	**Spatial extent:** All seagrass habitat in the 'Western Basin Survey Area' (The Narrows to Boyne River mouth) and Rodds Bay reference site ▪ *Port Curtis and Rodds Bay seagrass monitoring program, Biannual Western Basin & Annual Long Term Monitoring November 2012* (Davies et al. 2013) ▪ *Seagrasses in Port Curtis and Rodds Bay 2013 – Annual long-term monitoring, biannual Western Basin and updated baseline survey* (Bryant et al. 2014) ▪ *Seagrasses in Port Curtis and Rodds Bay 2014 – Annual long-term monitoring, biannual Western basin and updated baseline survey* (Carter et al. 2015)

7.2.2.4 Small scale sentinel permanent transect sites

Overview

In November 2009, quarterly seagrass condition monitoring commenced in the Western Basin survey area at permanent transects established at six locations (increased to seven in 2010) in Port Curtis and Rodds Bay. Permanent transect locations were established to act as sentinel or sensitive receptor assessment sites during the WBDDP (refer Table 7.13 and Figure 7.3), to monitor variations in seagrass condition throughout the year.

The locations selected encompassed the range of representative seagrass meadow types within the area likely to be affected, as well as providing a spatial range of sites, relative to future Port developments. Three additional transects were added during dredging for The Narrows LNG pipeline crossing. Six sites were included in the monitoring program during 2014 for the Project EIS (at three coastal and three deep water sites) to monitor seasonal trends on a finer scale, which had previously not been undertaken at these sites (Carter et al. 2015).

A list of the study reports is provided in Table 7.14 .

Table 7.13 Seagrass transect locations in Port Curtis and Rodds Bay (approximate dates)

Site name	Program	Timeframe
Pelican Banks North	WBDDP	November 2009 to 2016 (ongoing)
Pelican Banks South	WBDDP	November 2009 to 2016 (ongoing)
Wiggins Island	WBDDP	November 2009 to 2016 (ongoing)
Facing Island	WBDDP	November 2009 to 2016 (ongoing)
Fisherman's Landing	WBDDP	November 2009 to 2016 (ongoing)
Rodds Bay	WBDDP	November 2009 to 2016 (ongoing)
Redcliffe	WBDDP	August 2010 to 2016 (ongoing)
Black Swan Island	WBDDP (The Narrows LNG pipeline crossing)	August 2012 to December 2013
Graham Creek	WBDDP (The Narrows LNG pipeline crossing)	August 2012 to December 2013
Duffy Creek	WBDDP (The Narrows LNG pipeline crossing)	August 2012 to December 2013
Colosseum Inlet	Channel Duplication Project EIS	May 2014 to May 2015
South Trees Inlet	Channel Duplication Project EIS	May 2014 to May 2015
Quoin Island	Channel Duplication Project EIS	May 2014 to May 2015
Deep water 1	Channel Duplication Project EIS	May 2014 to May 2015
Deep water 2	Channel Duplication Project EIS	May 2014 to May 2015
Deep water 3	Channel Duplication Project EIS	May 2014 to May 2015

Seagrass condition is monitored quarterly at each of the seven original permanent transect locations from October/November 2009 (excluding Redcliffe which was monitored from August 2010) based on the *Seagrass-Watch: Manual for Mapping and Monitoring Seagrass Resources* (McKenzie et al. 2007). These protocols, which utilise permanent intertidal transects at seagrass meadows, allow for repeated measures to be taken at any future point in time in a relatively simple manner (McKenzie et al. 2000). Four measures of the seagrass meadow are used to determine changes in seagrass, including:

- Abundance and community composition (seagrass health)
- Elemental content of plants (seagrass tissue nutrients)
- Meadow reproductive status (seagrass resilience)
- Sexual, above-ground productivity and asexual growth (seagrass productivity).

In September 2011, additional monthly transect surveys outside of the regular quarterly monitoring were undertaken to provide more frequent assessments of seagrass condition during the WBDDP dredging campaign. Monthly assessments continued until WBDDP Stage 1A dredging was completed in September 2013, reverting back to quarterly monitoring at the seven original locations until 2018 then likely back to annual monitoring.

Table 7.14 Permanent transect seagrass monitoring in the Western Basin Dredging and Disposal Project survey area

Survey	Reports
2009 to 2014	**Spatial extent:** Seven locations at key sensitive receptor sites for assessing seagrass condition before, during and after dredging works for the WBDDP Three sites added in The Narrows for The Narrows LNG pipeline crossing monitored from August 2012 to December 2013 ▪ *Gladstone permanent transects seagrass monitoring sites – February and March 2011* (Sankey and Rasheed 2011) ▪ *Long term seagrass monitoring in the Port Curtis Western Basin: Quarterly seagrass assessments and permanent transect monitoring progress report November 2009 to November 2012* (McCormack et al. 2013) ▪ *Gladstone permanent transect seagrass monitoring – October 2013 update report* (Davies et al. 2013) ▪ *Gladstone permanent transect seagrass monitoring – December 2013* (Bryant and Rasheed 2013) ▪ *Seagrasses in Port Curtis and Rodds Bay 2014 – Annual long-term monitoring, biannual Western basin and updated baseline survey* (Carter et al. 2015) ▪ *Long Term Seagrass Monitoring in Port Curtis: Quarterly Seagrass Assessments & Permanent Transect Monitoring Progress Report, 2009-2014* (Davies et al. 2015b) ▪ *Long term Seagrass monitoring in Port Curtis: Quarterly permanent transect monitoring progress report 2009 to 2015* (Bryant et al. 2016b)
2014	**Spatial extent:** Seven original locations at key sensitive receptor sites Six sites added for the Channel Duplication Project EIS at coastal sites (three) and deep water sites (three) ▪ *Port Curtis, Rodds Bay and Channel Duplication Seagrass and light monitoring: January 2013 to May 2015* (Davies et al. 2015a)

Coastal transects

Each of the WBDDP post-dredging monitoring locations was sampled quarterly over the spring low tides in February, May, August and November each year (2013 to 2015), and the new Channel Duplication Project EIS sites sampled quarterly from May 2014 to May 2015. The survey methodology followed SeagrassWatch standard methodology (McKenzie et al. 2007; refer also Section 7.2.2 and SeagrassWatch 2015) with the addition of seagrass biomass assessments (Mellors 1991).

At each coastal location, sampling included three 50m transects nested in each site, with one to two sites nested per location. A site was defined as a 50m x 50m area within a relatively homogenous section of the meadow (McKenzie et al. 2000). At each transect, seagrass percent cover, above-ground biomass, species composition, canopy height, macroalgae cover and epiphyte cover were recorded for a 0.25m² sampling quadrat placed at 0m and then every 5m along the 50m transect (i.e. 11 sampling points per transect).

Sites which were monitored by helicopter due to access issues included Black Swan and Project EIS sites South Trees Inlet, and Quoin Island. Colosseum Inlet was monitored by divers as the site is not completely exposed. At these sites, only seagrass percent cover, above-ground biomass and species composition were recorded.

Biomass assessments were made using photographs taken in the field. Observers assigned a rank describing the above-ground biomass of seagrass for each quadrat. When assigning ranks, the observer referred to a set of photographs of seagrass plots for which the above-ground biomass had previously been measured. The observer additionally ranked a series of 'calibration' quadrats; a set of photographs of seagrass plots where the actual biomass had been determined in the laboratory. A regression of ranks and biomass from these calibration quadrats was generated for the observer and applied to the ranks given during the survey. Biomass ranks were converted into above-ground biomass estimates in grams dry weight per square metre (g DWm^{-2}).

Deep water transects

Deep water sites were sampled quarterly from May 2014 to May 2015 for the Project EIS. Each deep water site consisted of three random 100m transects nested within three blocks, for a total of nine transects monitored at each deep water site (Bryant et al. 2014). At each transect, an underwater camera was towed for approximately 100m while footage was observed on a monitor and recorded. Benthos on the seafloor was captured in the net and used to confirm seagrass species observed on the monitor. This technique was used to ensure that a large area of seafloor was sampled at each site so that patchily distributed seagrass typically found in deep water habitats was detected (Bryant et al. 2014).

Seagrass species composition was measured from the sled net sample and from the video screen according to Kuo and McComb (1989). Seagrass biomass was estimated by an observer ranking seagrass at 10 random time frames allocated within the 100m of footage for each site. The video was paused at each of the 10 timeframes then advanced to the nearest point on the tape where the bottom was visible and the sled was stable on the bottom. From this frame, the observer recorded an estimated rank of seagrass biomass and species composition. A 0.25m² quadrat, scaled to the video camera lens used in the field, was superimposed on the screen to standardise biomass estimates.

To ensure strict quality assurance (QA) and quality control (QC) for seagrass percent cover data, a second observer assigned percent cover estimates using a subset of photographs of the plots taken in the field to ensure there were no major discrepancies between observers (i.e. outside of a margin of 10%).

7.2.3 Seagrass seed bank density and viability

In 2015, GPC commissioned the TropWATER Seagrass group to conduct seagrass seed banks assessments as part of the ERMP. The study aimed to determine the density and viability of *Zostera muelleri* subsp. *capricorni* (*Z. muelleri*) sediment seed banks in Port Curtis (Jarvis et al. 2015). The study gathered existing information on Port Curtis seed banks and integrating assessments of viability into the current program which monitored the recovery and resilience of seagrass meadows post dredging (Jarvis et al. 2015).

There were three major components to the study (Jarvis et al. 2015) which included:

1. Assessment of the back catalogue of stored seed bank core samples collected quarterly between March 2011 and May 2014 for total numbers of *Z. muelleri* seeds
2. Continue quarterly assessments of total seed bank density for *Z. muelleri* in 2014/15
3. Conduct assessments of seed bank viability for *Z. muelleri.*

Bryant et al. (2016a) examined the density of seagrass seeds and their viability in Port Curtis for the second year of the study. The assessment builds on seagrass assessments that were originally conducted as part of the WBDDP.

Seed bank density assessments were conducted in conjunction with regular measurements of seagrass condition at the permanent transect sites in February, May, August and November. Sediment core samples (50mm in diameter and 100mm in depth) were collected at each sediment sampling site adjacent to transects at 0m, 10m, 20m, 30m, 40m and 50m intervals. Cores were divided into three sections based on sediment depth. All sediment samples were wet sieved with fresh water and the 710µm to 1mm fraction of the sediment was inspected for *Z. muelleri* seeds using a dissecting microscope.

Seagrass seed bank density was assessed quarterly during regular seagrass condition monitoring around February, May, August and November each year.

The ERMP enhanced these surveys to include assessments of viability. Reason et al. (2017) conducted a three year study examining seed bank dynamics for the seagrass *Z. muelleri* subsp. *capricorni* in Port Curtis and Rodds Bay.

The objectives of the study were to:

1. Quantify temporary variation in *Z. muelleri* seed bank density, using the back catalogue of stored seed bank samples collected between 2011 and 2014 and new quarterly samples collected between 2015 and 2017
2. Monitor changes in the proportion of viable *Z. muelleri* seeds in the seed bank before and after the growing season, and among sediment depths for biannual assessments of seed bank viability conducted each February and May from 2015 to 2017.

A subset of monitoring sites (Pelican Banks North, Wiggins Island and Rodds Bay) were selected for this study, based on their geographical location to the dredging associated with the WBDDP and have historically been dominated by *Z. muelleri* (Reason et al. 2017).

The seed bank density assessments were conducted as per the methods discussed above in the Jarvis et al. (2015) and Bryant et al. (2016a) studies. The viability assessments were conducted in February after peak seed release when viable seed densities are expected to be greatest, and in May prior to the onset of the growing season, to test densities of viable seeds (Reason et al. 2017). Sediment cores collected in February and May from 2015 to 2017 were also used to assess seed viability. Within one week of collection using tetrazolium chloride, seed samples were texted for viability. Seed embryos were removed from their seed coats and soaked in a 0.5% tetrazolium chloride solution for 48 hours before examination under a dissecting microscope at 10x magnification. Seeds with a red (pink to brown) stained axial hypocotyl were counted as viable (Reason et al. 2017).

7.2.4 Benthic photosynthetically active radiation monitoring

7.2.4.1 Overview

The WBDDP adopted a light-based management approach to protect seagrasses from dredging and dredged material placement plume impacts. The WBDDP management plans contained trigger levels for benthic photosynthetically active radiation (BPAR) which were based on findings from two years of seagrass and light research in Port Curtis directed at establishing the required light thresholds for local seagrass species survival (Davies et al. 2015d). The Project has the potential to utilise a similar management approach during dredging activities, therefore BPAR data has been collected during the Project baseline data collection period to describe the benthic light environment of Port Curtis.

BPAR monitoring as part of WBDDP post Stage 1A dredging commitments is undertaken at seven sites which align with quarterly seagrass transect sites within Port Curtis. This BPAR data has been used for the Project EIS baseline data collection, along with eight other BPAR sites established for the Project EIS (refer Table 7.15). For the WBDDP post dredging BPAR monitoring sites, data was collected continuously and downloaded on a quarterly basis between January 2013 and August 2015 with monitoring being undertaken by TropWATER. For the Project EIS new BPAR monitoring sites, data was collected continuously for 13 months between June 2014 and June 2015 with monitoring being undertaken by Vision Environment as part of the Project EIS water quality baseline data collection (refer *Port of Gladstone Gatcombe and Golding Cutting Channel Duplication Project Environmental Impact Statement Water Quality Technical Report* (Project Water Quality Technical Report) (Aurecon 2019).

Table 7.15 summarises the Port Curtis and Rodds Bay BPAR monitoring sites used for the Project EIS baseline data. Figure 7.4 shows the location of the BPAR monitoring sites in Port Curtis.

Table 7.15 Summary of Port of Curtis and Rodds Bay benthic light monitoring sites

Monitoring site name	Monitoring equipment	Monitoring period utilised for EIS baseline conditions	Program
Black Swan	Submersible Odyssey™ photosynthetic irradiance autonomous loggers	January 2013 to August 2015	WBDDP
Fisherman's Landing	Submersible Odyssey™ photosynthetic irradiance autonomous loggers	January 2013 to August 2015	WBDDP
Wiggins Island	Submersible Odyssey™ photosynthetic irradiance autonomous loggers	January 2013 to August 2015	WBDDP
Pelican Banks North	Submersible Odyssey™ photosynthetic irradiance autonomous loggers	January 2013 to August 2015	WBDDP
Pelican Banks South	Submersible Odyssey™ photosynthetic irradiance autonomous loggers	January 2013 to August 2015	WBDDP
Facing Island	Submersible Odyssey™ photosynthetic irradiance autonomous loggers	January 2013 to August 2015	WBDDP
Rodds Bay	Submersible Odyssey™ photosynthetic irradiance autonomous loggers	January 2013 to August 2015	WBDDP
Base (control site)	Submersible OdysseyTM photosynthetic irradiance autonomous loggers	January 2013 to August 2015	WBDDP
Quoin Island	Submersible Odyssey™ photosynthetic irradiance autonomous loggers	May 2014 to August 2015	Channel Duplication Project EIS
South Trees	Submersible Odyssey™ photosynthetic irradiance autonomous loggers	May 2014 to August 2015	Channel Duplication Project EIS
Colosseum Inlet	Submersible Odyssey™ photosynthetic irradiance autonomous loggers	May 2014 to August 2015	Channel Duplication Project EIS
CD 2[1]	Dual LI-COR LI192SA underwater quantum sensors	May 2014 to June 2015	Channel Duplication Project EIS

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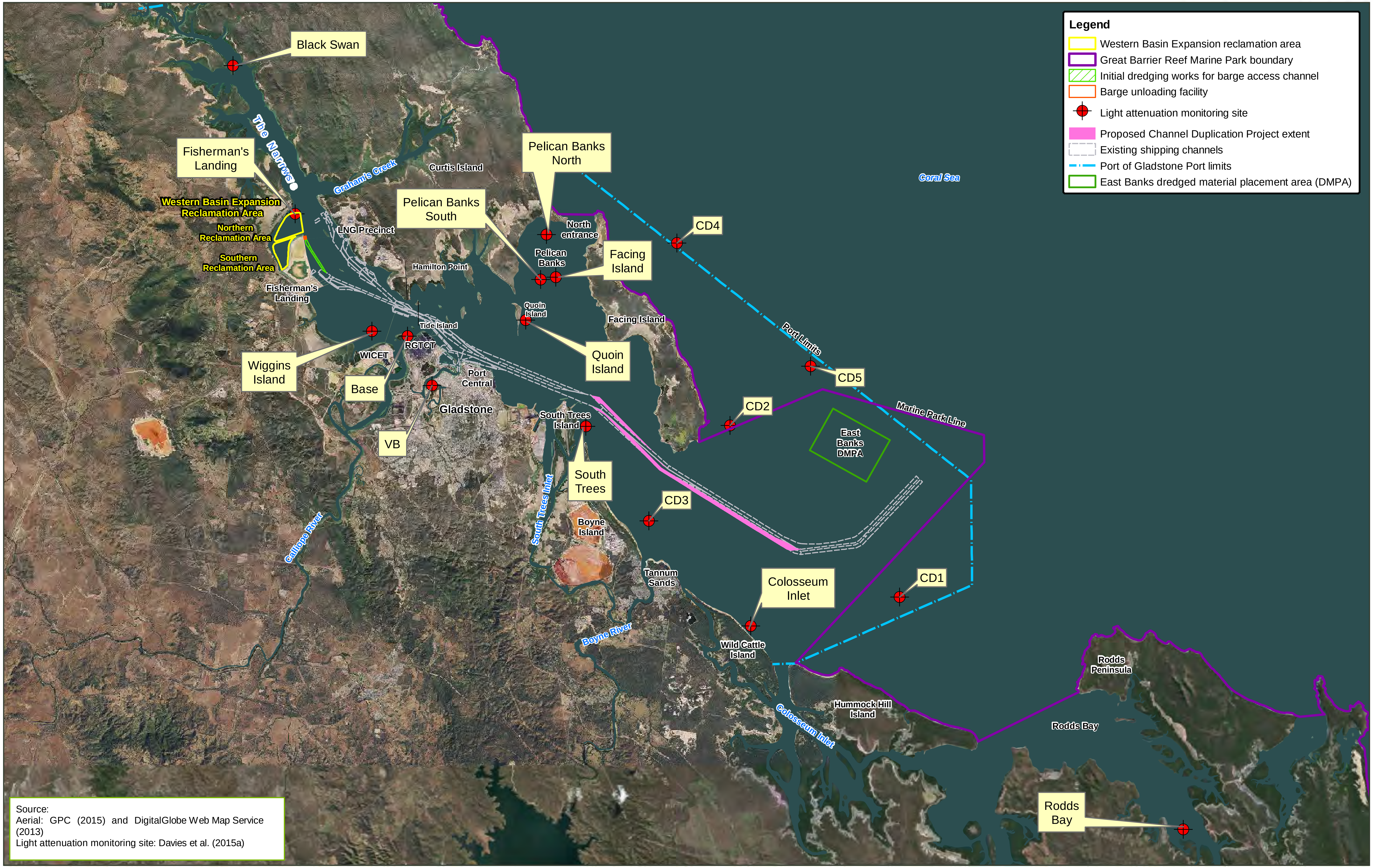

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Gatcombe and Golding Cutting Channel Duplication Project

Figure 7.4: Benthic Photosynthetically Active Radiation monitoring locations

Monitoring site name	Monitoring equipment	Monitoring period utilised for EIS baseline conditions	Program
CD 3[1]	Dual LI-COR LI192SA underwater quantum sensors	May 2014 to June 2015	Channel Duplication Project EIS
Deep water site 1 (CD4)[2]	Dual LI-COR LI192SA underwater quantum sensors	May 2014 to June 2015	Channel Duplication Project EIS
Deep water site 2 (CD5)[2]	Dual LI-COR LI192SA underwater quantum sensors	May 2014 to June 2015	Channel Duplication Project EIS
Deep water site 3 (CD1)[2]	Dual LI-COR LI192SA underwater quantum sensors	May 2014 to June 2015	Channel Duplication Project EIS
VE base (VB) (control site)	Dual LI-COR LI192SA underwater quantum sensors	May 2014 to June 2015	Channel Duplication Project EIS

Table notes:

1. Light monitoring sites were not located directly above seagrass meadows as these sites are proposed to be water quality compliance sites during dredging activities
2. CD1, CD4 and CD5 site numbers refer to the naming convention used in the Project Water Quality Technical Report (Aurecon 2019a)

Source: Adapted from Davies et al. (2015a) and Vision Environment (2015c)

7.2.4.2 Post Western Basin Dredging and Disposal Project monitoring

WBDDP BPAR monitoring sites continuously recorded benthic light and temperature data and were downloaded quarterly in conjunction with seagrass assessments. Submersible Odyssey™ photosynthetic irradiance autonomous loggers were used by TropWATER to record BPAR data.

Automatic wiper brushes cleaned the optical surface of the sensor every 15 minutes to prevent marine organisms fouling the sensors. At each location, two independent light loggers and wiper units were deployed on two separate deployment cradles connected to a surface float so that loggers could be exchanged at high tide. Light loggers were replaced and downloaded every three months at the time of quarterly seagrass surveys. The presence of dual loggers reduced the risk of lost data through unit malfunction, fouling or disturbance during the three months between equipment exchange and download.

Odyssey light loggers logged a cumulative reading at 15 minute intervals, which was calibrated and summed to gain total daily irradiance (i.e. BPAR), expressed in moles per square metre per day (mol m^{-2} day^{-1}) at each site. The raw data captured by the loggers was calibrated to a known light value. A calibration factor was calculated for each logger using a solar simulator and a LI-COR Underwater Radiation Sensor (LI-192) and LI-250A Light Meter. An adjustment for periods when loggers are exposed to air was also made. Air exposure times were calculated using tidal data supplied by MSQ. Periods of exposure were calculated for each site based on the estimated datum depth of the site, with irradiance values during these exposure times divided by 1.3, as outlined in Collier et al. (2009). A reference light logger (Base) already deployed outdoors at the Queensland Boating and Fisheries Patrol office was used to determine trends in ambient PAR and assist QA/QC procedures.

Temperature at the seagrass meadow sites was monitored concurrently with benthic irradiance using a temperature logger (i.e. Tinytag Aquatic 2, Gemini Data Loggers (UK) Ltd) attached to the wiper unit associated with each light logger.

After data deconfounding, a rolling mean total daily irradiance at each location was calculated over a two week period to incorporate both spring and neap tide conditions as well as the variation in tide height and the degree of exposure that affects the light conditions reaching the seagrass (Chartrand et al. 2012; Vision Environment 2013). The total daily irradiance for a given day and the previous 13 days were averaged and the calculation rolled forward each day respectively. The rolling mean irradiance values were plotted against seagrass percent cover recorded at each of the monitoring locations.

7.2.4.3 Channel Duplication Project monitoring

Telemetered BPAR units were located at five sites (i.e. deep water sites 1, 2, and 3, and CD2 and CD3). BPAR was recorded from June 2014 to January 2015 using dual LI-COR LI192SA Underwater Quantum Sensors which were attached to the benthic frame running concurrently with dual benthic data loggers. BPAR was logged every 15 minutes (averaged from 1 minute readings) with data transferred to a cloud database every 30 minutes. Wiper units were attached to the frames and set to clean the light sensors every 15 minutes. Data were transferred to the surface telemetry unit via an umbilical.

Autonomous light loggers (Odyssey™ submersible photosynthetically irradiance recording system with self-cleaning wipers) were utilised during February 2015 until the end of monitoring in July 2015, to replace the LI-COR units which had suffered umbilical transmission failures due to inclement weather. The Odyssey™ loggers were placed in the benthic frame alongside the water quality loggers and programed to record at 15 minute intervals with data recorded within the logger. Loggers were exchanged each fortnight and the recorded data downloaded.

In order to record daily changes in total ambient PAR, a telemetered light logger also operated on shore in Gladstone. The inclusion of the on shore site allowed for variation in daily ambient PAR (e.g. decreased levels of sunlight during overcast days) to be accounted for, thus aiding in the interpretation of BPAR levels within Port Curtis and acting as a ‘control’ PAR site. While small scale daily weather patterns such as scattered cloud were not consistent throughout Port Curtis, substantial overall daily changes were recorded and significant reductions in ambient PAR could be accounted for.

Data management procedures implemented for the offshore BPAR data are provided in the Project Water Quality Technical Report (Aurecon 2019).

7.2.4.4 Environmental data

Light and water temperature data was collected by Vision Environment throughout Port Curtis as part of the WBDDP water quality monitoring program until December 2013. Light and water temperature data for 2014 and 2015 was collected as part of quarterly seagrass transect monitoring.

Tidal exposure to air for Port Curtis intertidal meadows was calculated by summing the total daylight hours that tidal height was < 1m (the tidal height at which seagrass meadows are exposed at this location) for the 12 months preceding each November survey. Tidal data was obtained from the MSQ station #052027A. Total daily rainfall was obtained from the nearest weather station (Gladstone airport station #039123) from the Australian Bureau of Meteorology (BoM) website (BoM 2013) for the 12 months preceding each November survey. Calliope River water flow data (total monthly megalitres (ML)) was obtained from the DNRME (station # 132001A) (DNRME n.d).

7.2.4.5 Establishing benthic light thresholds

Light requirement threshold ranges for seagrasses, determined as part of the Project EIS baseline assessments, are defined as the point at which a change in external conditions will likely cause a significant negative change in seagrass condition, measured as above-ground biomass.

In order to develop these light threshold ranges, a literature review was conducted as well as an investigation into current research conducted on light requirements for tropical seagrasses. Once a range of biologically relevant light values were established from the literature review and ongoing studies, these values were used as a starting point to examine light and seagrass biomass trends at key sensitive receptor sites monitored as part of the Project.

The seagrass and BPAR monitoring sites were chosen based on the dominant species and the abundance of seagrass that would most likely allow for analysis of the emerging trends in light and seagrass data. The sites chosen for *Z. muelleri* subsp. *capricorni* were Pelican Banks North and South Trees (refer Figure 7.3). The sites chosen for *H. uninervis* were Facing Island and Quoin Island. The sites chosen for *H. ovalis* were the offshore deep water monitoring sites 1 and 2, as these sites consistently had the greatest biomass of this species.

7.2.5 Port Curtis epibenthic macroalgae data collection

Information on benthic macroalgal species in Port Curtis has been gathered over the years through various studies into benthic communities. Together with publicly accessible databases, these studies have been utilised to describe the existing epibenthic macroalgae values of Port Curtis. The relevant databases and studies are listed in Table 7.16.

The search area utilised for the database review is shown in Figure 7.5.

Table 7.16 Existing information sources for epibenthic macroalgae within Port Curtis

Title	Reference
Reports	
Port Curtis and Rodds Bay seagrass and benthic macro-invertebrate community baseline survey, November/December 2002	Rasheed et al. (2003)
Surveys and reports for other project EISs in the Gladstone area (e.g. WBDDP EIS, LNG proponent EISs)	GHD (2009c)
Databases	
Atlas of Living Australia (incorporates Queensland Museum Wildnet data and Queensland Herbarium HERBRECS data)	ALA (2019)
EPBC Act PMST (refer Figure 7.5 for search area)	DoEE (2019)
Wildnet (refer Figure 7.5 for search area)	DES (2019)

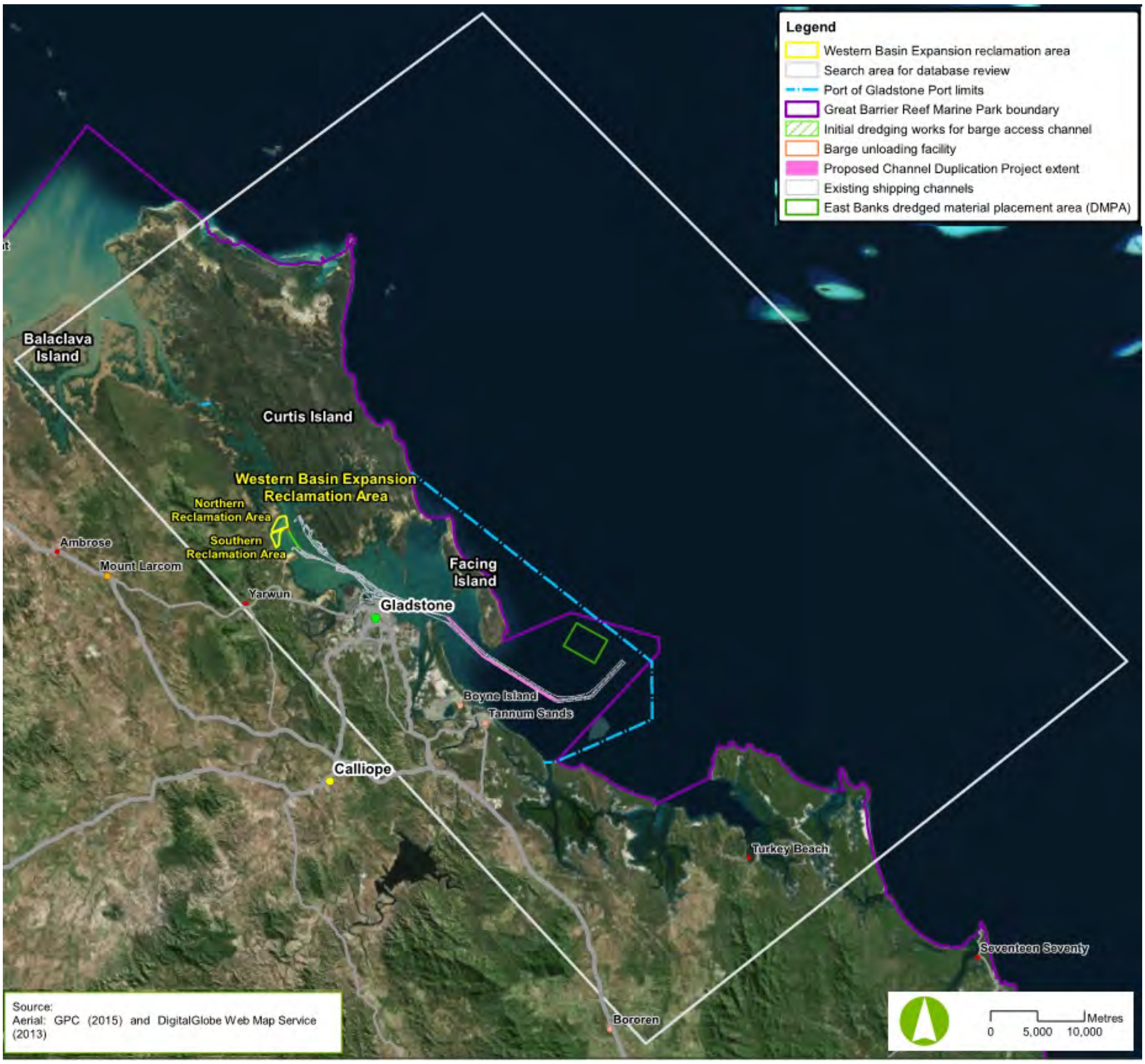


Figure 7.5 **Search area for database review**

An assessment of soft sediment benthic communities, including macroalgae and macroinvertebrates, was undertaken as part of baseline surveys for the Project EIS. The survey was conducted using a video camera and sled sampler (incorporated a sled net 600mm width and 250mm deep with a net of 10mm mesh aperture) at sites where the water depth was greater than 5m below mean sea level. A Van Veen grab (grab area 0.0625 square metres (m^2)) was also used to confirm sediment type and collect infaunal taxa (Rasheed et al. 2003). The methodology used in this survey is further outlined in reports by Rasheed et al. (2003) and McKenna et al. (2014) contained in Appendix D.

7.3 Seagrass values in Port Curtis and Rodds Bay

7.3.1 Overview

Seagrass surveys in Port Curtis have found that the area contains a diverse array of seagrass meadows. The seagrass communities of Port Curtis and Rodds Bay are the largest major areas of seagrass located between Shoalwater Bay and Hervey Bay. Fifteen species of seagrass occur within the GBRWHA and seven of these have been identified within Port Curtis (refer Table 7.17 and Figure 7.6) (GPC 2012). The presence of individual species has varied between monitoring surveys and years.

Table 7.17 Seagrass species recorded in Port Curtis

Family	Species
Cymodocea	*Cymodocea rotundata*
Cymodocea	*Halodule uninervis*
Hydrocharitaceae	*Halophila decipiens*
Hydrocharitaceae	*Halophila ovalis*
Hydrocharitaceae	*Halophila spinulosa*
Hydrocharitaceae	*Halophila minor*
Zosteraceae	*Zostera muelleri* subsp. *capricorni*

Zostera muelleri* subsp. *capricorni

Halodule univervis

Halophila spinulosa

Halophila ovalis

Cymodocea rotundata

Halophila decipiens

Figure 7.6 Seagrass species found in Port Curtis

Source: Rasheed et al. (2002)

7.3.2 Fine-scale seagrass habitat

7.3.2.1 General

In 2002, the first fine-scale survey of seagrass habitats to extend to the Port limits and Rodds Bay identified 135 discrete coastal and deep water seagrass meadows which varied in area, biomass, community structure and species dominance (Rasheed et. al 2003). These meadows comprised 129 coastal meadows (12 completely subtidal), and 6 large deep water meadows. Most seagrasses within the Curtis Coast region are found in mixed associations of up to four species with a percentage foliage cover ranging from less than 10% to greater than 90%. The area covered by seagrass depends on the location, with intertidal and subtidal beds ranging from less than 1ha to over 600ha (Rasheed et al. 2003).

Thirteen meadows from a range of seagrass communities in Port Curtis (and Rodds Bay reference meadows), as well as meadows deemed to be 'at risk' at the time of reporting, were used in the survey. Annual monitoring to assess for changes in biomass, area and species composition, was used to form an overall seagrass condition index which was used to assess these core monitoring meadows along with other meadows that have been added to the program over the years (refer Section 7.2.2.3).

The baseline survey conducted in 2002 found that coastal seagrass communities covered a total area of approximately 7,000ha, and deep water meadows covered a total area of 6,332ha. The extent of this survey was the Port limits. Much of the area is relatively well protected from southeasterly winds by Rodds Peninsula, and from northerly winds by Curtis and Facing Islands. The extensive seagrass distribution is likely due to this protection from wind and wave action (Rasheed et al. 2003). The extent of seagrass meadows observed in 2002 is shown in Figure 7.7a and Figure 7.7b.

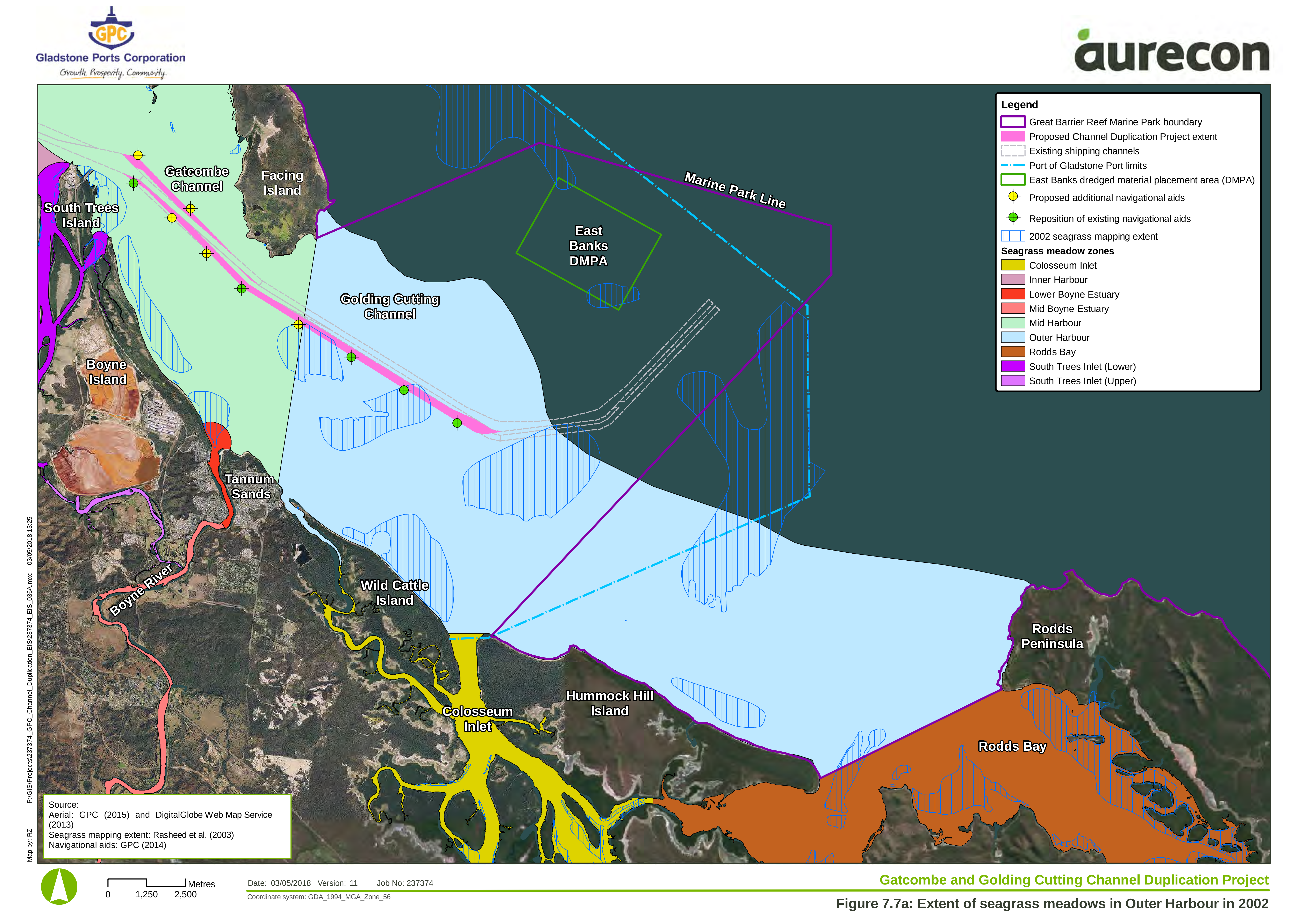
All seagrass meadows within the greater region from The Narrows to Rodds Bay were re-mapped in 2009 with 7,150ha of coastal seagrass meadows and 4,890ha of deep water seagrass meadows observed (Thomas et al. 2010). The extent of seagrass meadows observed in 2009 is shown in Figure 7.8a and Figure 7.8b.

7.3.2.2 Coastal seagrass habitat

Extensive areas of coastal seagrass communities were found throughout the coastal component of the 2002 baseline survey from The Narrows in the north, to Rodds Bay in the south. The coastal component of the survey was conducted in intertidal to shallow subtidal areas (< 5m dbMSL) with seagrass communities found on the majority of the shallow coastal intertidal mud and sand banks, but rarely penetrated far into subtidal areas off the edge of the banks (Rasheed et al. 2003). The coastal seagrass habitat in Port Curtis and Rodds Bay was divided into 32 community types, depending on species presence and dominance (e.g. light *Z. muelleri* with *H. ovalis*, moderate *H. decipiens* with *H. spinulosa*).

Communities that were dominated by *Z. muelleri* were the most widely distributed (68% of the coastal seagrass habitat) and most commonly occurred as aggregated patches on the extensive intertidal mud and sand banks (Rasheed et al. 2003). *Z. muelleri* often occurred in conjunction with *H. ovalis* to form both light and moderate biomass mixed species communities.

Communities dominated by *H. uninervis* (wide and thin leaf morphology) were the second most widely distributed and occurred in two main areas, in the intertidal sand and mud banks between Quoin and Facing Islands in the Mid Harbour, and in the shallow subtidal regions of the Mid and Outer Harbour along the exposed coasts of Boyne, Wild Cattle and Hummock Hill Islands (Rasheed et al. 2003).

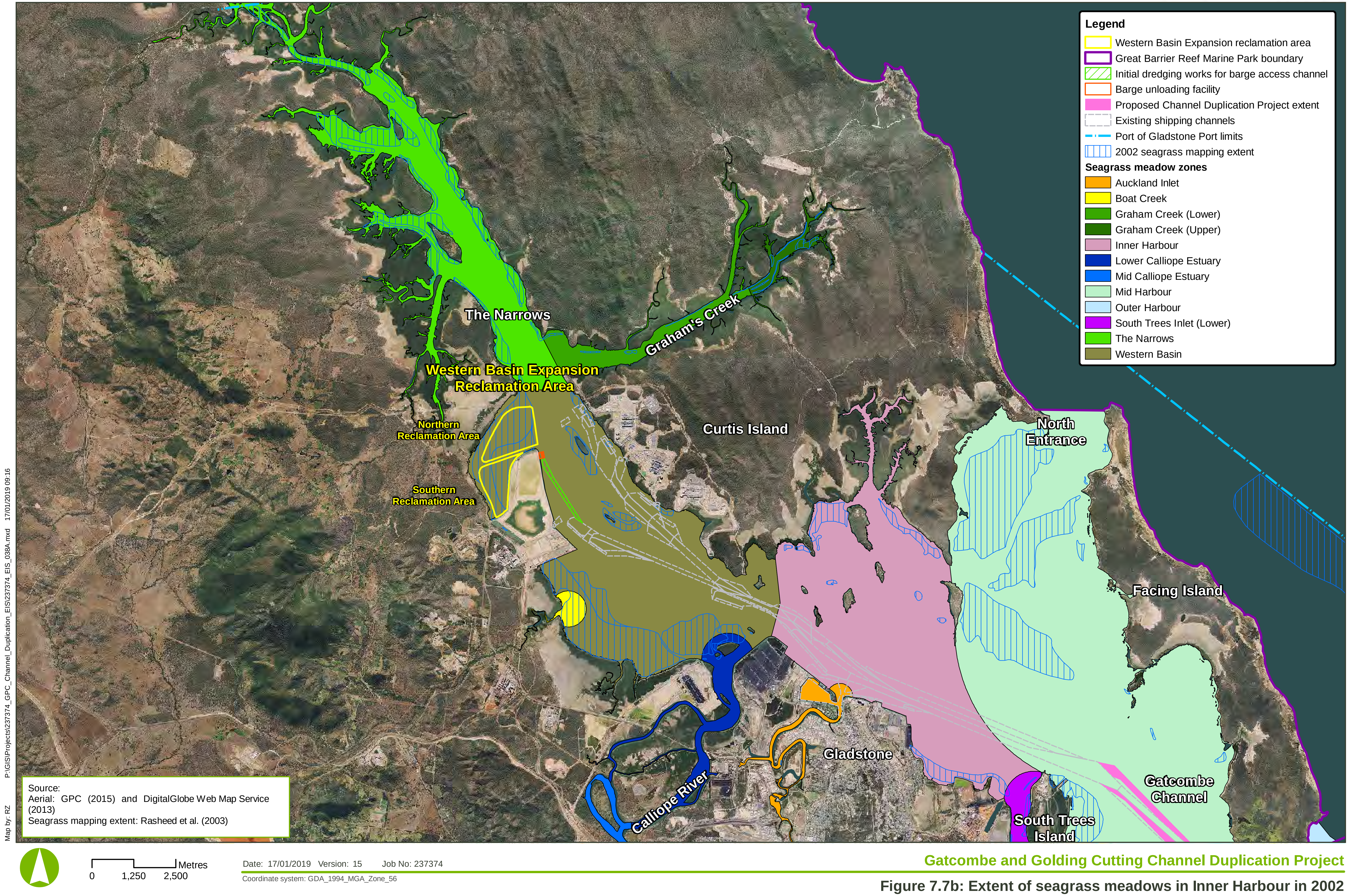


Gatcombe and Golding Cutting Channel Duplication Project

Figure 7.7a: Extent of seagrass meadows in Outer Harbour in 2002

Gladstone Ports Corporation
Growth, Prosperity, Community.

aurecon



Date: 17/01/2019 Version: 15 Job No: 237374

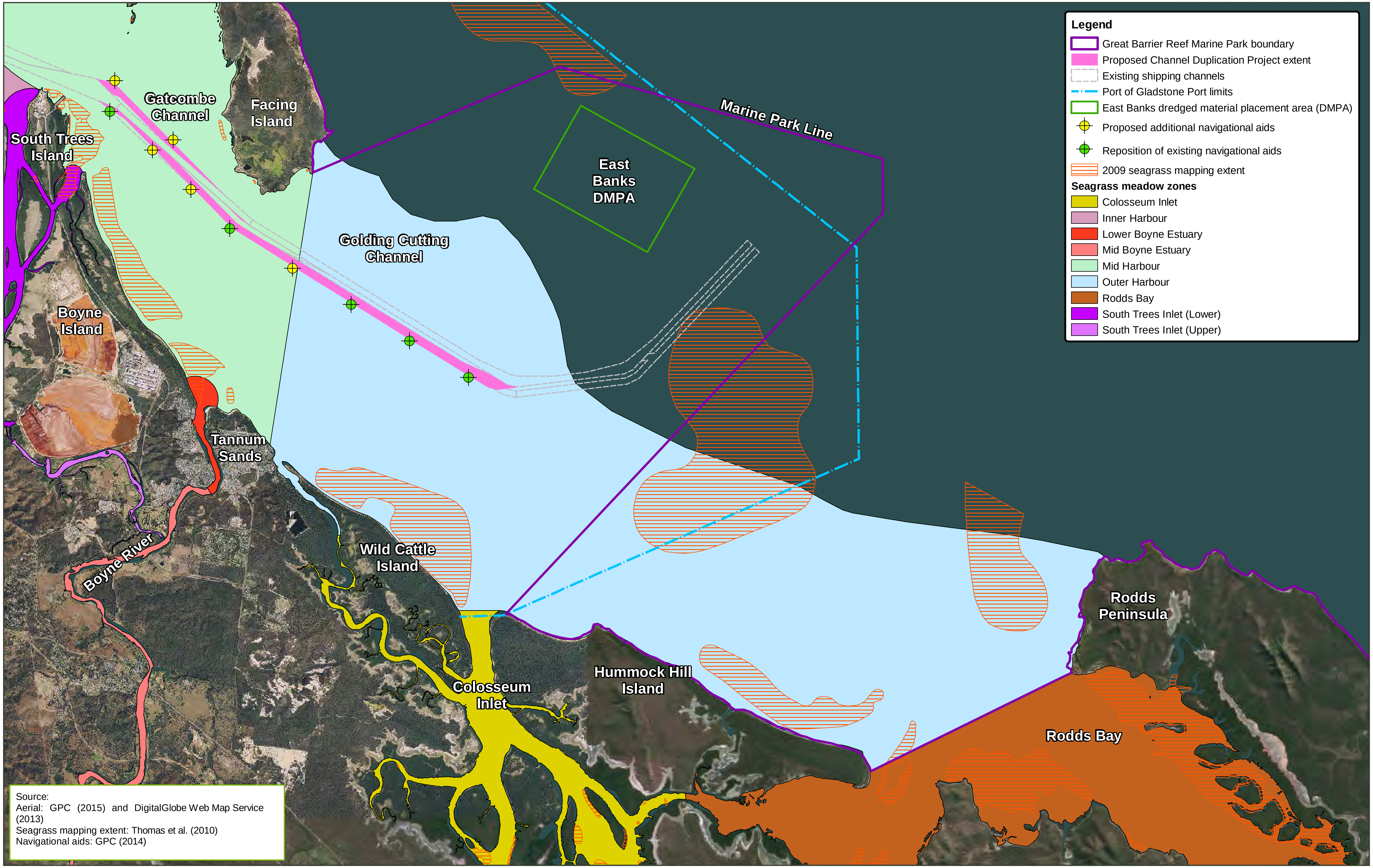
Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 7.7b: Extent of seagrass meadows in Inner Harbour in 2002

Gladstone Ports Corporation
Growth, Prosperity, Community.

aurecon



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Date: 03/05/2018 Version: 12 Job No: 237374

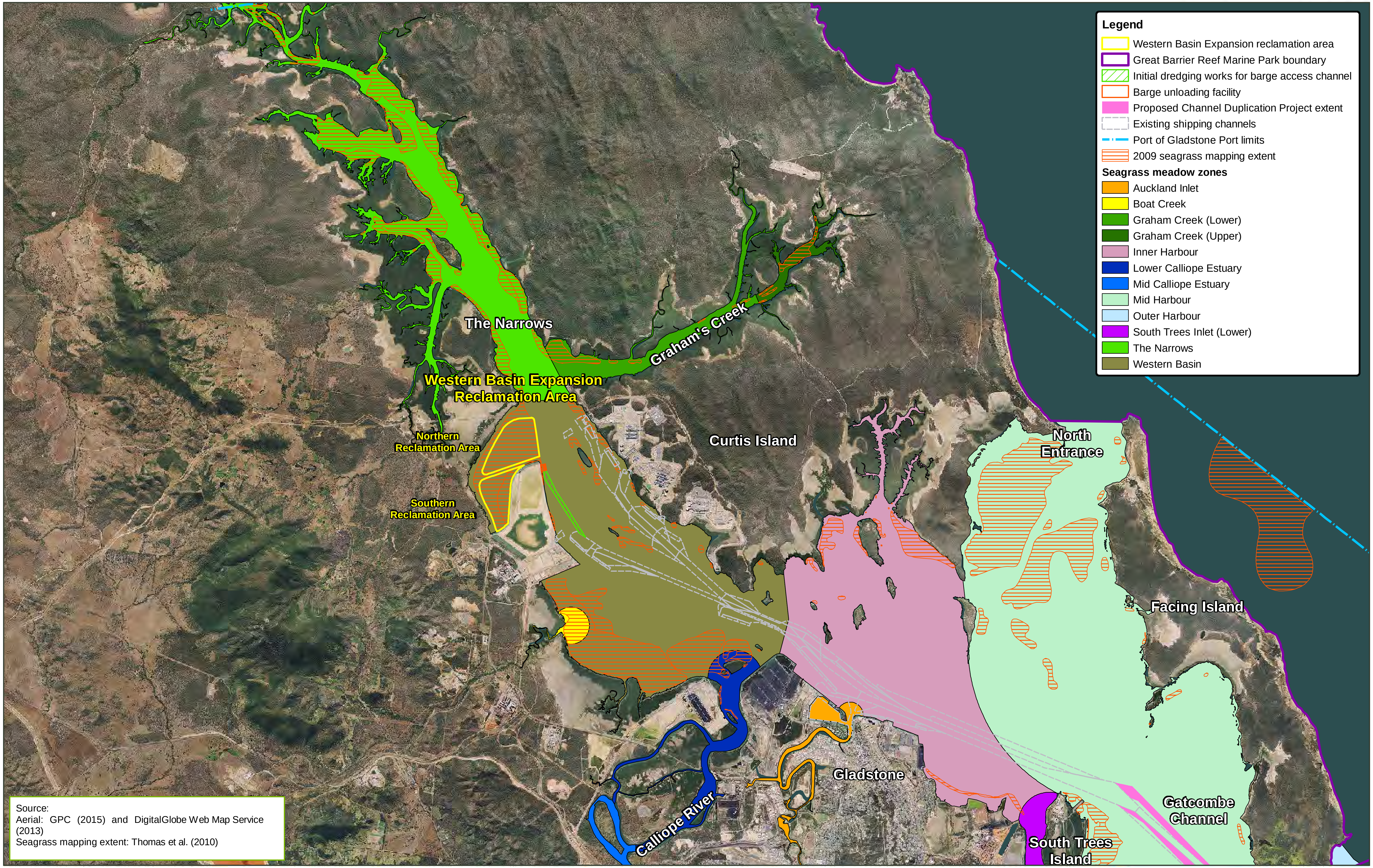
Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 7.8a: Extent of seagrass meadows in Outer Harbour in 2009

Gladstone Ports Corporation
Growth, Prosperity, Community.

aurecon



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Map by: RZ

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Date: 17/01/2019 Version: 15 Job No: 237374

Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 7.8b: Extent of seagrass meadows in Inner Harbour in 2009

Gladstone Ports Corporation
Growth, Prosperity, Community

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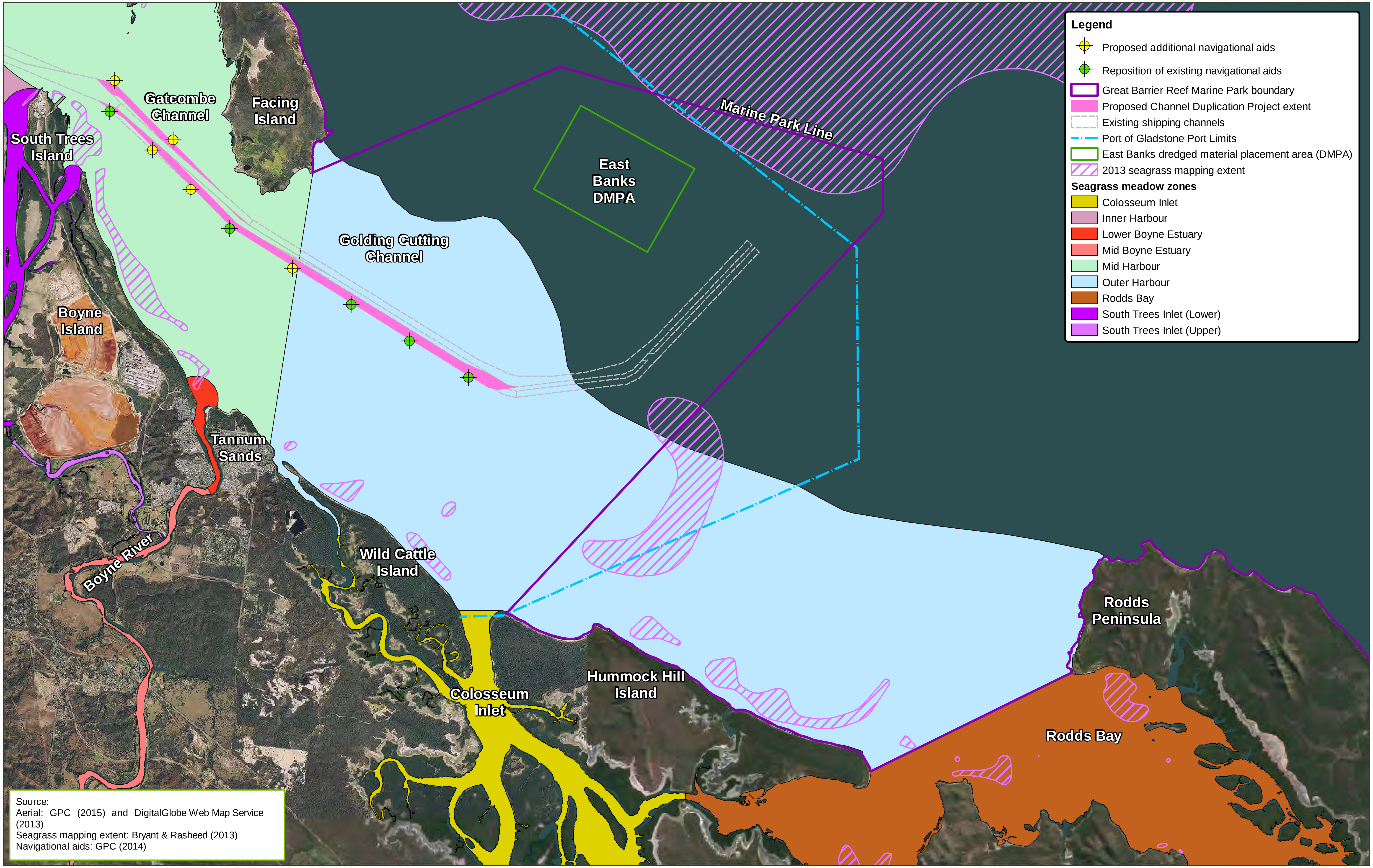

Source:
Aerial: GPC (2015) and DigitalGlobe Web Map Service (2013)
Seagrass mapping extent: Bryant & Rasheed (2013)
Navigational aids: GPC (2014)

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Date: 20/04/2018 Version: 11 Job No: 237374
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Map by: RZ

Gatcombe and Golding Cutting Channel Duplication Project

Figure 7.9a: Extent of seagrass meadows in Outer Harbour in 2013

Gladstone Ports Corporation
Growth, Prosperity, Community.

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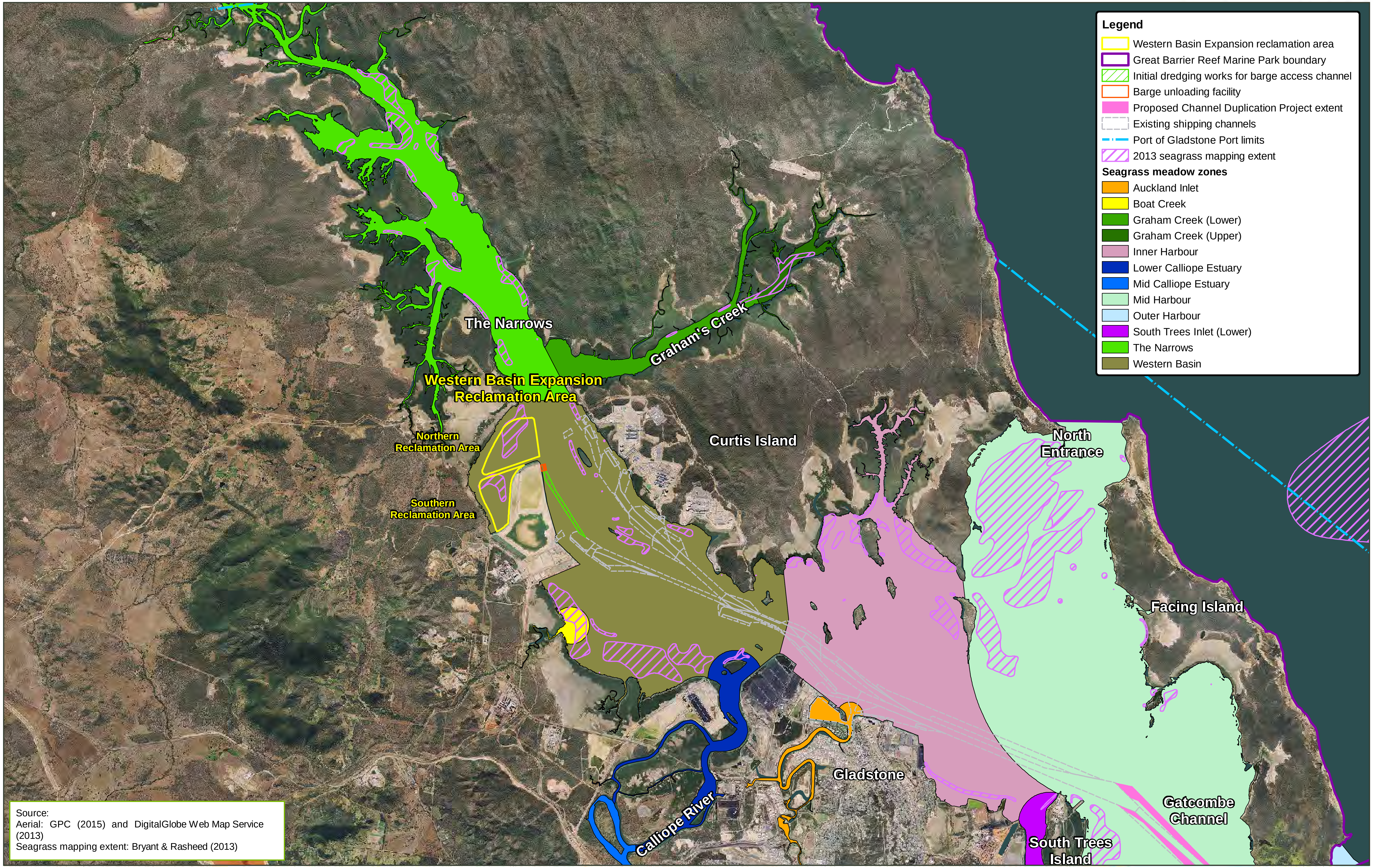

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Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 7.9b: Extent of seagrass meadows in Inner Harbour in 2013

Gladstone Ports Corporation
Growth, Prosperity, Community.

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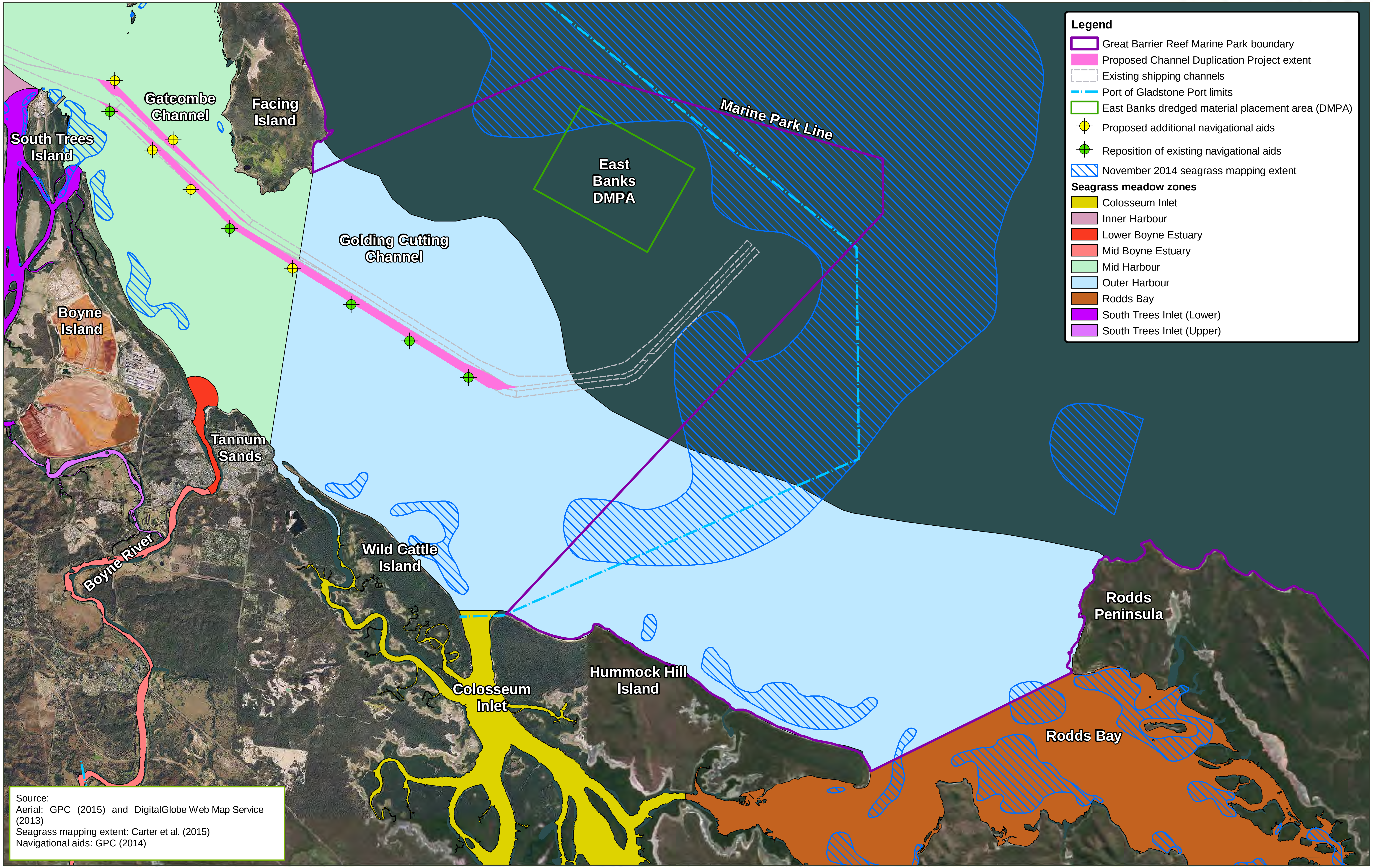

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Date: 03/05/2018 Version: 10 Job No: 237374

Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 7.10a: Extent of seagrass meadows in Outer Harbour in 2014

Gladstone Ports Corporation
Growth, Prosperity, Community.

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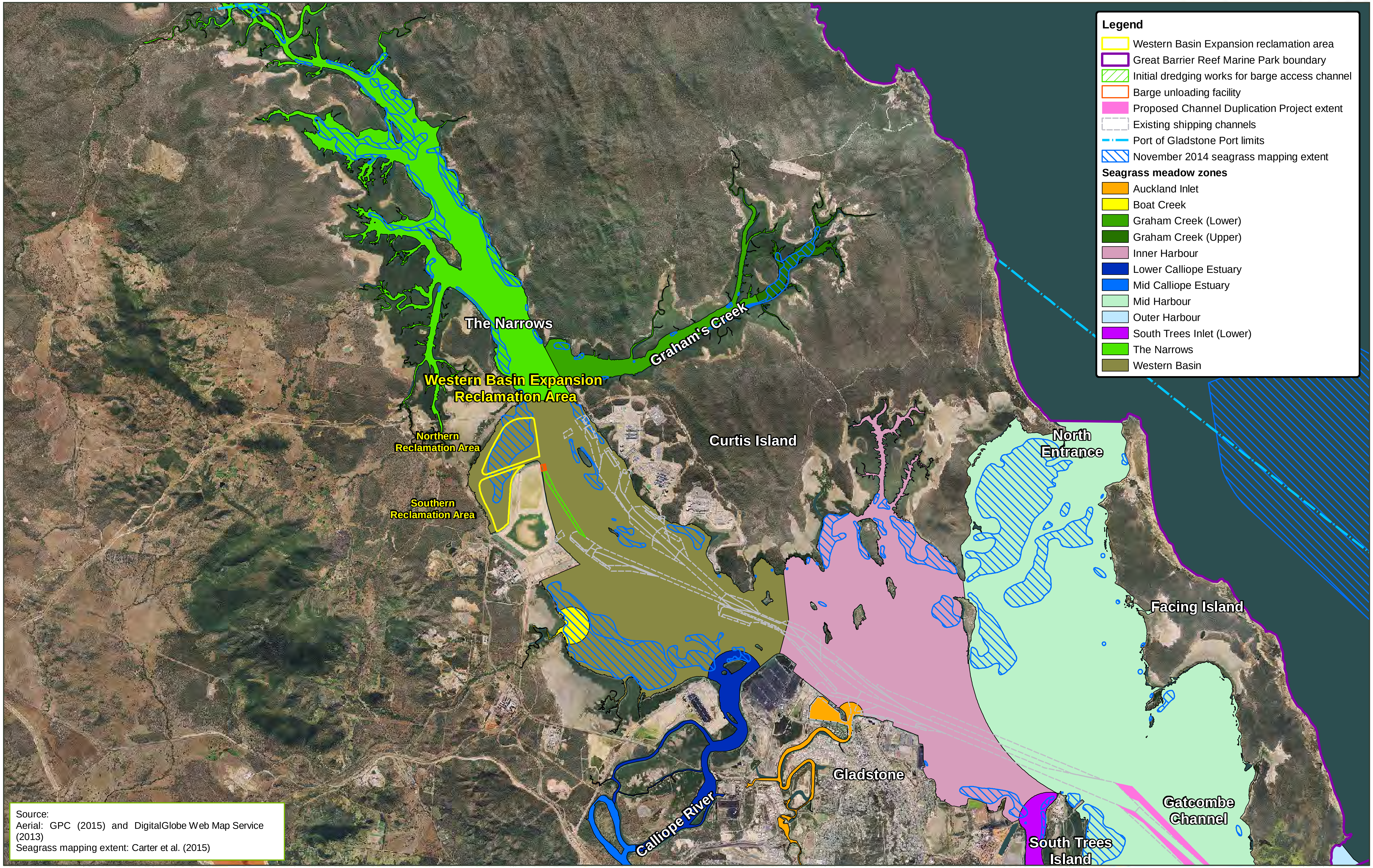

Source:
Aerial: GPC (2015) and DigitalGlobe Web Map Service (2013)
Seagrass mapping extent: Carter et al. (2015)

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Date: 17/01/2019 Version: 14 Job No: 237374

Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 7.10b: Extent of seagrass meadows in Inner Harbour in 2014

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Growth, Prosperity, Community

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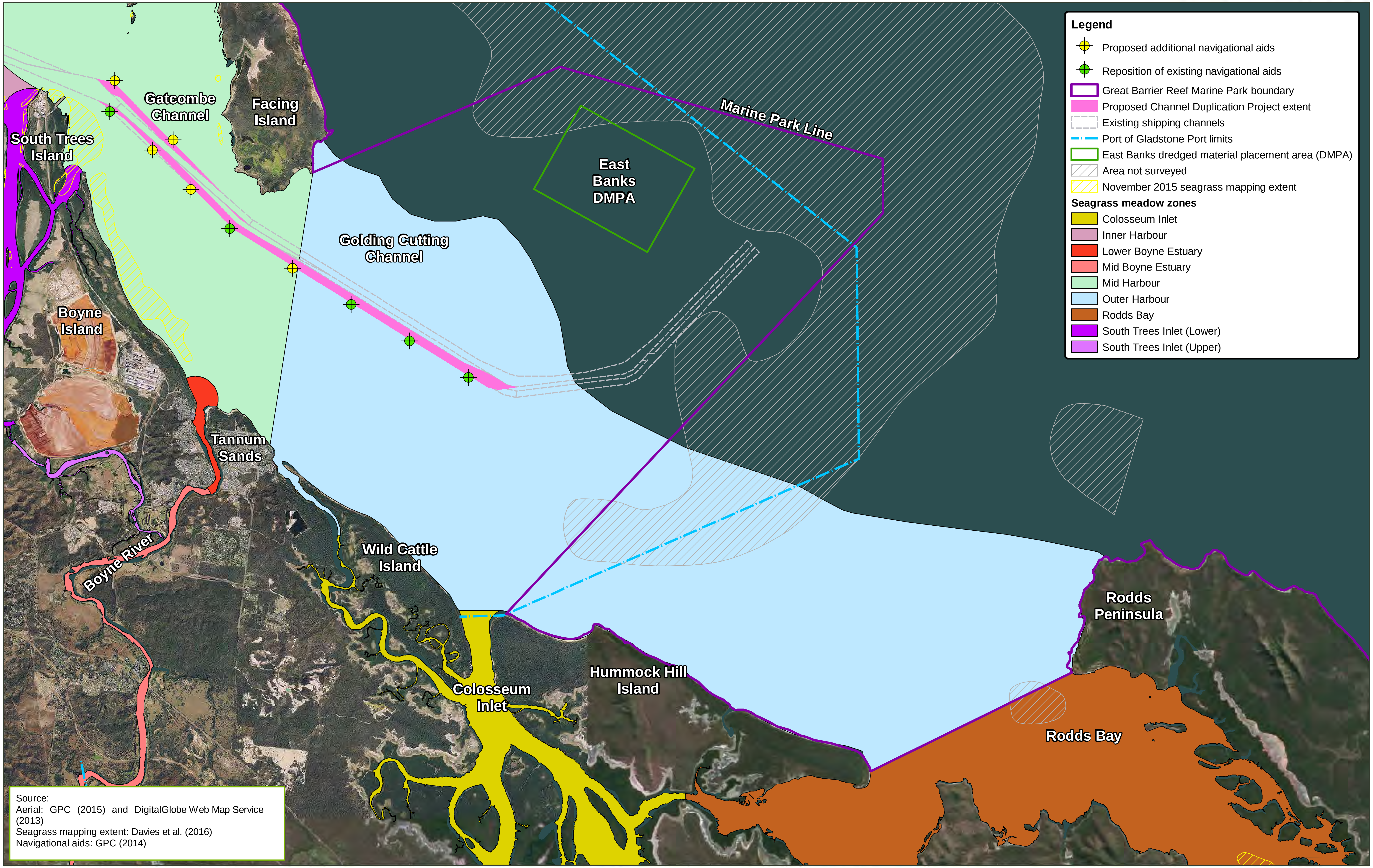

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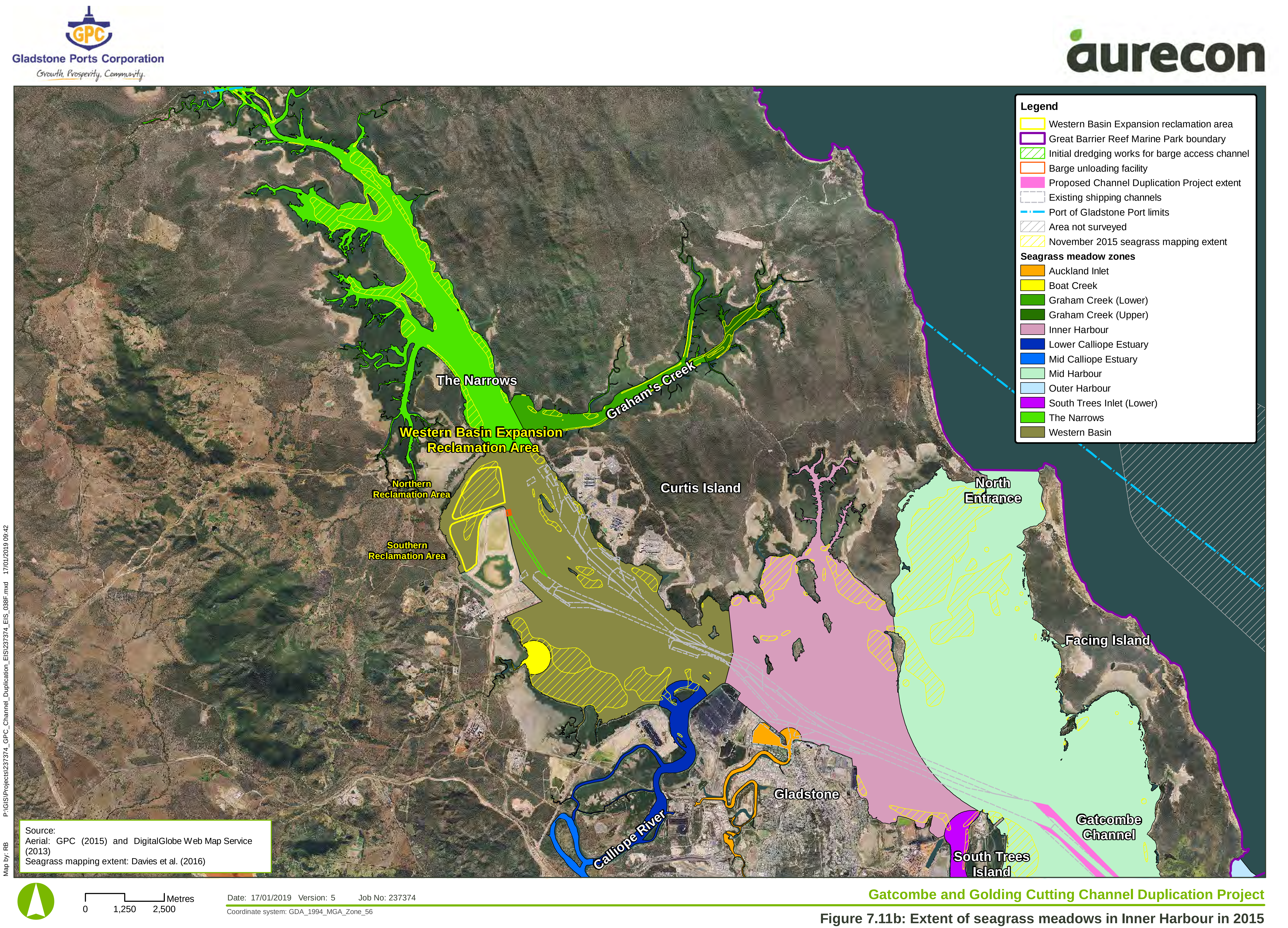
Map by: RB

Date: 03/05/2018 Version: 3 Job No: 237374

Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 7.11a: Extent of seagrass meadows in Outer Harbour in 2015



Gatcombe and Golding Cutting Channel Duplication Project

Figure 7.11b: Extent of seagrass meadows in Inner Harbour in 2015

Gladstone Ports Corporation
Growth, Prosperity, Community

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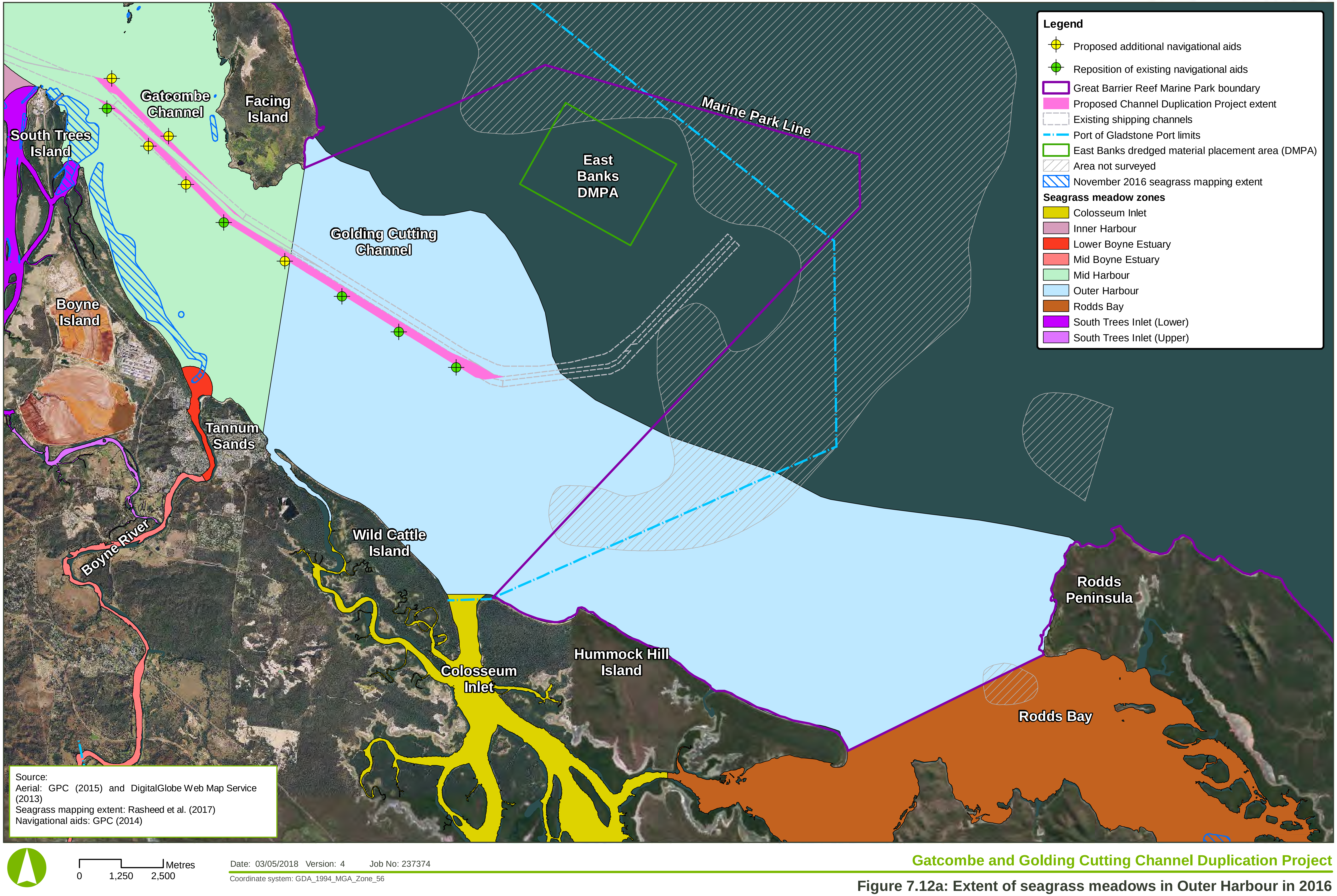

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Date: 03/05/2018 Version: 4 Job No: 237374

Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 7.12a: Extent of seagrass meadows in Outer Harbour in 2016

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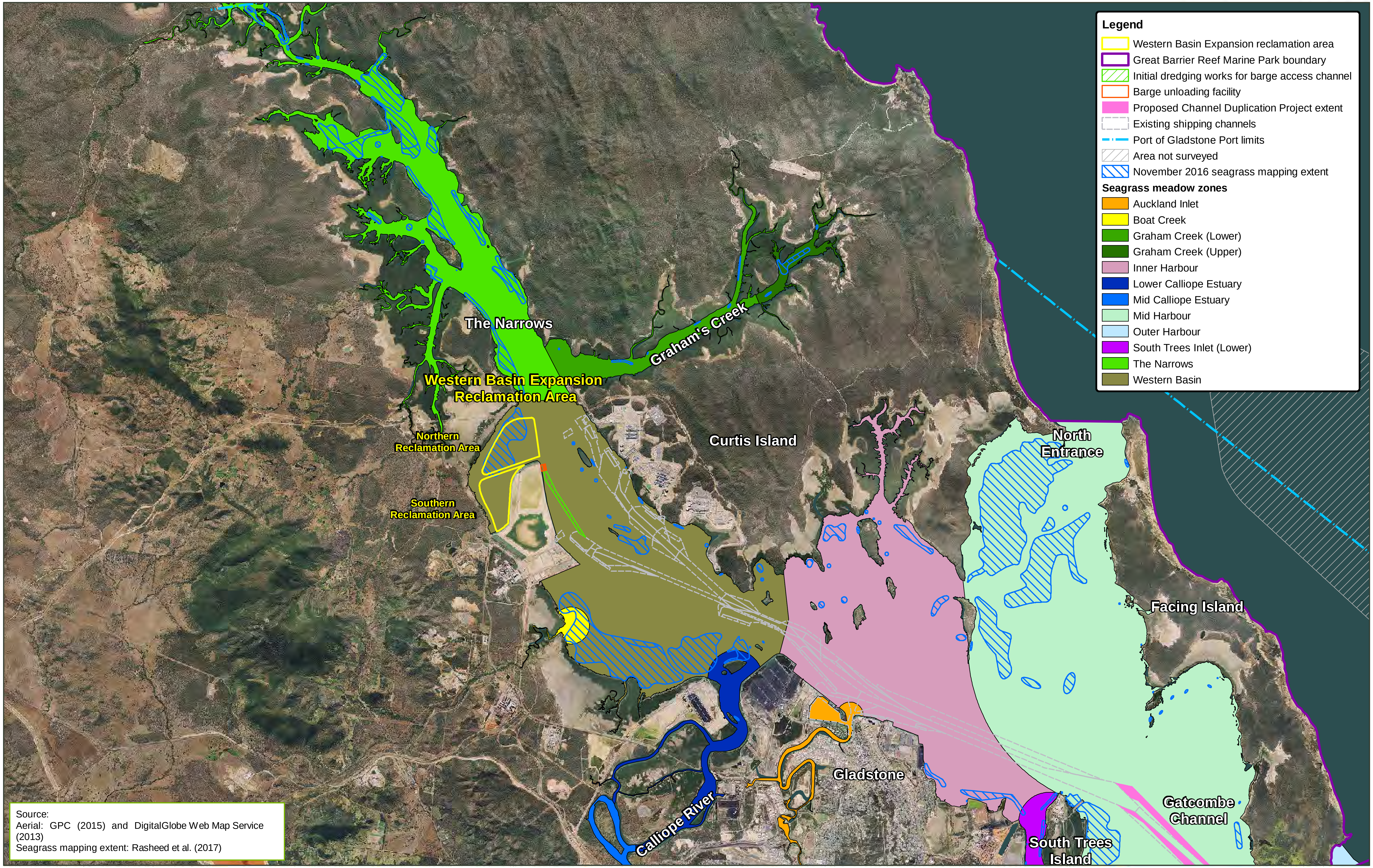
Growth, Prosperity, Community.

aurecon



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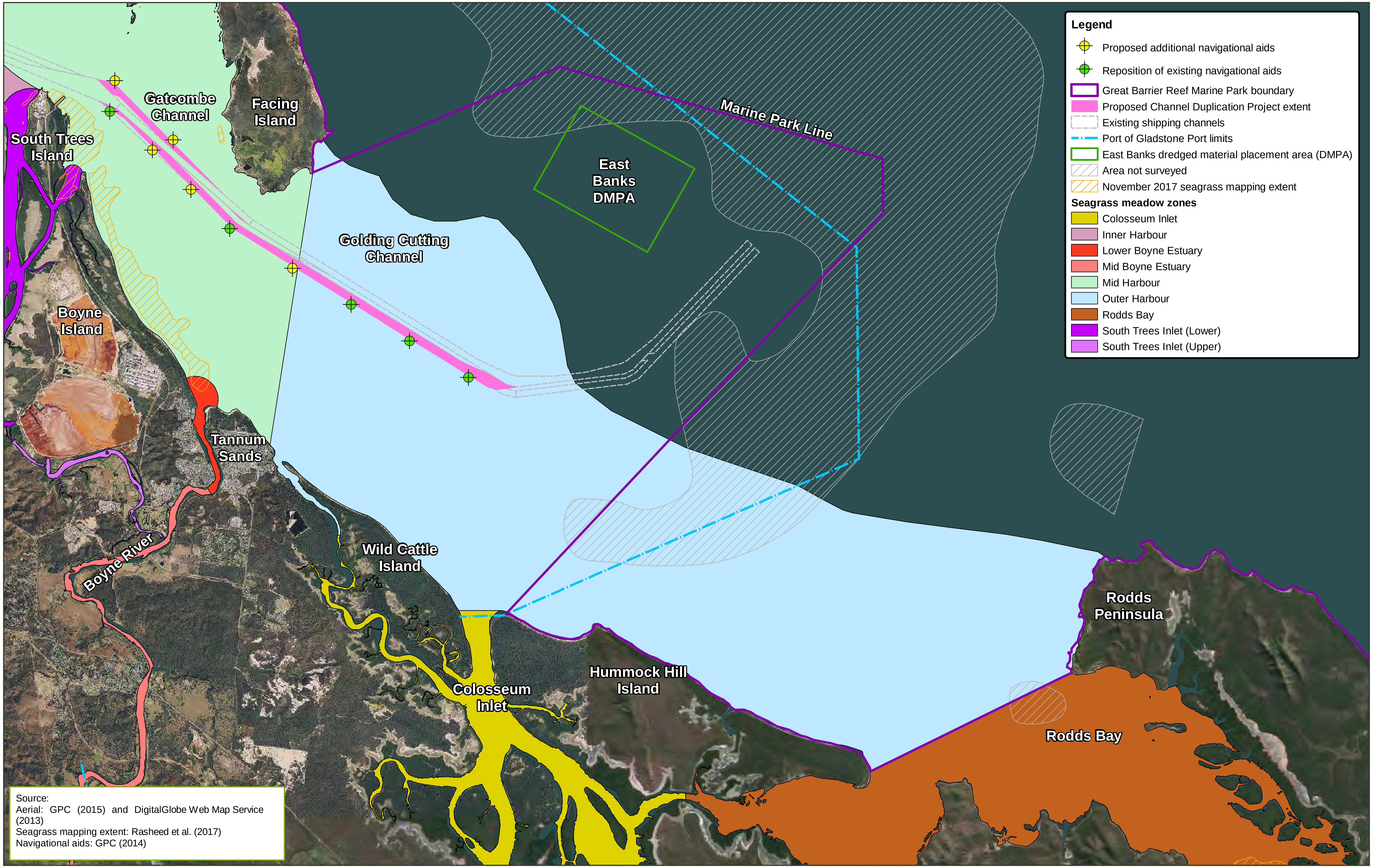
Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 7.12b: Extent of seagrass meadows in Inner Harbour in 2016



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Map by: RB

Date: 31/01/2019 Version: 1 Job No: 237374

Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 7.13a: Extent of seagrass meadows in Outer Harbour in 2015

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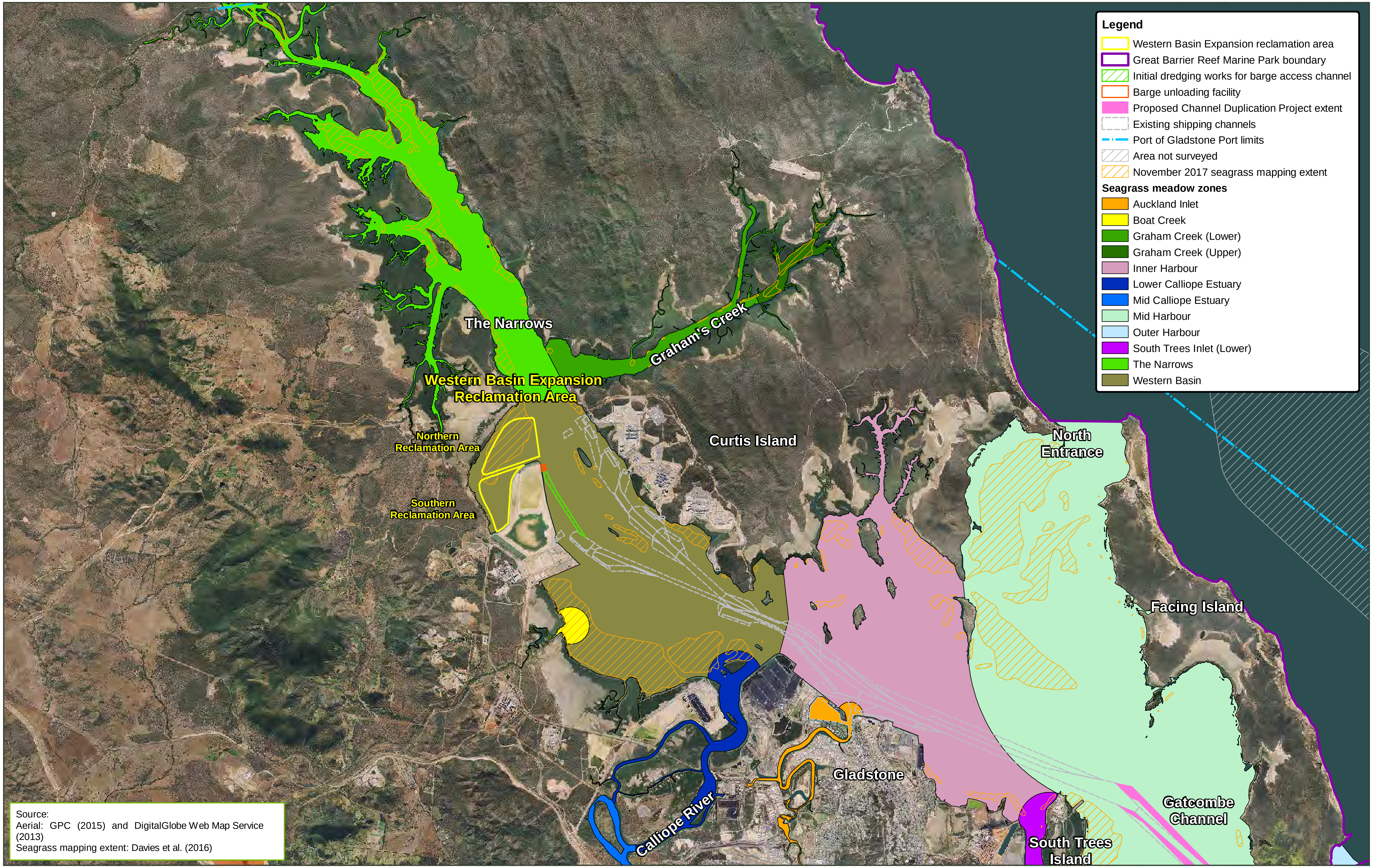

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Map by: RB

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Date: 31/01/2019 Version: 1 Job No: 237374
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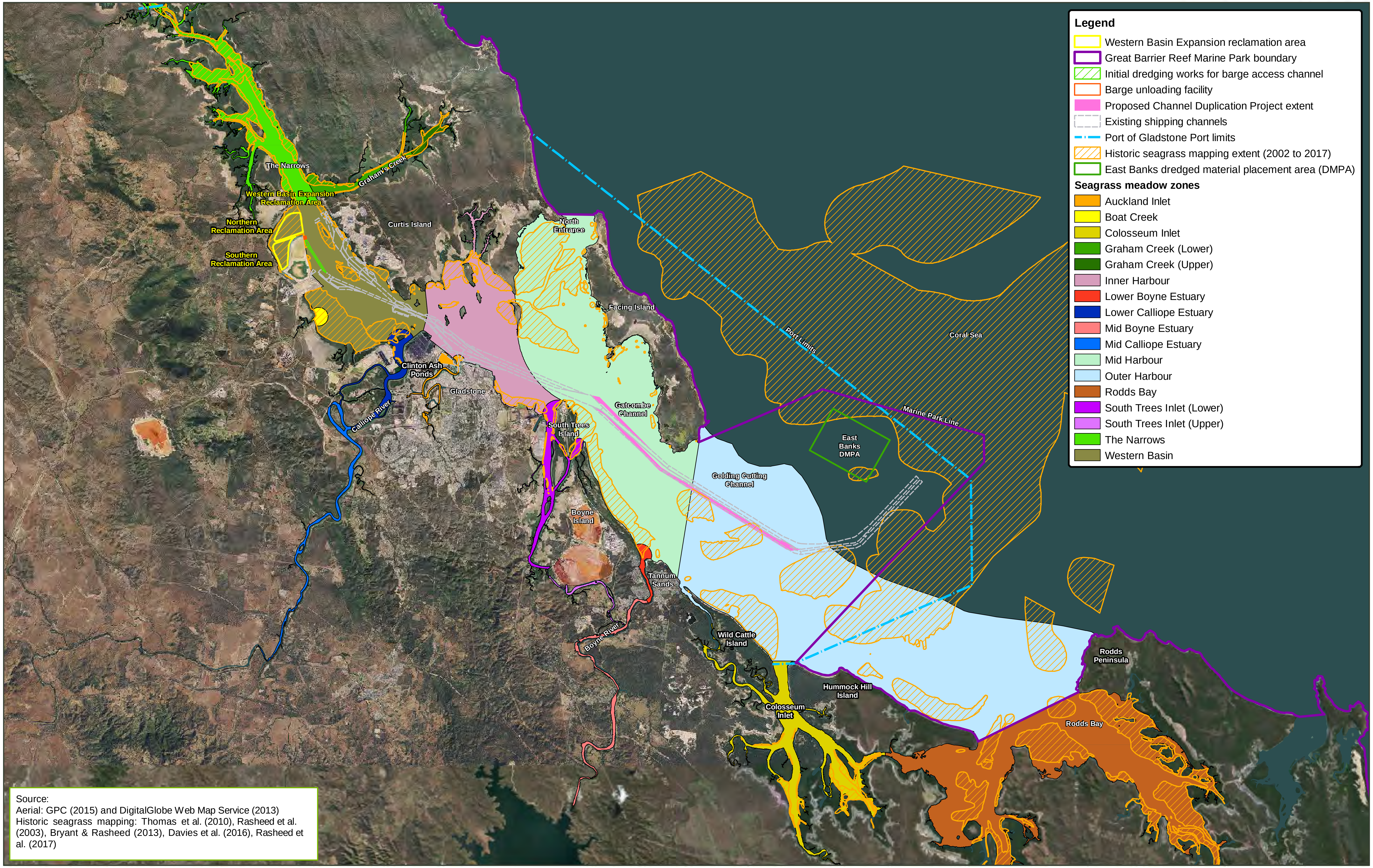
Gatcombe and Golding Cutting Channel Duplication Project

Figure 7.13b: Extent of seagrass meadows in Inner Harbour in 2017



Gladstone Ports Corporation
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Map by: RZ

Date: 30/01/2019 Version: 18 Job No: 237374

Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 7.14: Historical extent of seagrass meadows in Port Curtis and Rodds Bay (2002 to 2017)

Minor coastal seagrass habitats included subtidal *H. ovalis* and *H. decipiens* communities located adjacent to Fisherman's Landing Wharves in the Western Basin zone and intertidal *H. ovalis* dominated communities further south in Rodds Bay (Rasheed et al. 2003). *H. spinulosa* dominated two communities at the mouth of Seven Mile Creek in Rodds Bay and also formed a minor component of other subtidal meadows. *H. minor* was found at only a few sites on intertidal banks in Rodds Bay (Rasheed et al. 2003).

The maximum depth that coastal seagrasses were recorded in the survey was 4.1m dbMSL (Rasheed et al. 2003). The 12 coastal seagrass meadows that were completely subtidal were generally small *Halophila* dominated meadows immediately adjacent to the mud and sand banks (Rasheed et al. 2003).

7.3.2.3 Deep water seagrass habitat

Large areas of deep water seagrass (> 5m dbMSL) were found within the Port limits as part of the 2002 baseline survey. Deep water meadows occurred offshore from Facing Island and around Seal Rocks, West Banks and East Banks (around the Outer Harbour and coastal waters zone). No deep water meadows occurred in or beyond the Mid Harbour areas on the inside of Facing Island. Deep water seagrass meadows were dominated by low biomass *Halophila* species with *H. uninervis* (narrow) occurring in only one meadow. Cover of seagrass in the deep water meadows was low ranging from 0.01% to 1.9% of the total bottom area. The maximum depth recorded for offshore seagrass was 19.1m dbMSL for *H. spinulosa*. The deep water meadows were divided into six individual meadows depending on community type (e.g. light *H. decipiens* with *H. spinulosa*).

7.3.2.4 Temporal patterns

Seagrass meadows in Port Curtis and Rodds Bay undergo distinct seasonal changes as well as significant inter-annual changes in distribution, abundance and species composition. Surveys of seagrass distribution have shown that seagrasses in Port Curtis and Rodds Bay are generally at their peak in distribution and abundance during the late spring/early summer, and decline during winter months (Bryant et al. 2014; Davies et al. 2013; Chartrand et al. 2012; Rasheed et al. 2012; Chartrand et al. 2011). This pattern is consistent with seagrasses in other tropical and subtropical areas of Queensland (Rasheed 2004; McKenzie 1994; Mellors et al. 1993). In addition to annual monitoring, all seagrasses within the seagrass annual monitoring area (refer Figure 7.3), have been mapped biannually since 2009 (June and November) to determine the total distribution of seagrasses during both the senescent (June) and peak (November) seagrass growing season.

7.3.3 Annual long term monitoring seagrass surveys

7.3.3.1 Overview

All seagrasses within the greater region from The Narrows to Rodds Bay were re-mapped in 2013, 2014, 2015, 2016 and 2017 as part of the Project EIS baseline surveys. For the first time these baseline surveys extended beyond Port limits and included adjacent offshore areas in the GBRMP (refer Figure 7.3).

The extent of seagrass meadows surveyed in the Port between 2013 and 2017 is shown in Figures 7.9a to Figure 7.13b. The historical (cumulative) extent of seagrass meadows in Port Curtis and Rodds Bay from 2002 to 2017 is shown in Figure 7.14.

Results from seagrass surveys from January 2013 to November 2017 have been used to document the current state of seagrass meadows in Port Curtis and Rodds Bay. Results have been taken from the reports outlined in Table 7.18. For more information on seagrass survey methodology, refer to the overview in Section 7.2.1.

Table 7.18 Seagrass reports 2013 to 2017

Seagrass report name	Monitoring program	Appendix
Seagrasses in Port Curtis and Rodds Bay 2013 – Annual long-term monitoring, biannual Western basin, and updated baseline survey (Bryant et al. 2014)	Fine-scale baseline, annual long term monitoring meadows, biannual WBDDP monitoring	Appendix E
Seagrass in Port Curtis and Rodds Bay 2014 – Annual long-term monitoring, biannual Western basin, and updated baseline survey (Carter et al. 2015)	Fine-scale baseline, annual long term monitoring meadows, biannual WBDDP monitoring	Appendix F
Port Curtis, Rodds Bay and Channel Duplication Seagrass and Light Monitoring: January 2013 to May 2015 (Davies et al. 2015a)	Quarterly seagrass transects	Appendix G
Seagrasses in Port Curtis and Rodds Bay 2016: Annual long term monitoring (Rasheed et al. 2017b)	Annual long term monitoring meadows	-
Seagrasses in Port Curtis and Rodds Bay 2017: Annual long-term monitoring (Chartrand et al. 2018)	Annual long term monitoring meadows	-

7.3.3.2 Seagrass survey results 2013 (Bryant et al. 2014)

Prior to the fine-scale seagrass survey in 2013 by Bryant et al. (2014), seagrasses within the entire region between The Narrows and Rodds Bay were previously mapped in November 2009, prior to the 2010/2011 Queensland floods that caused major declines in seagrass. Five seagrass species, from two families of seagrass were observed in the Port Curtis, Rodds Bay DPA and adjacent offshore areas during the 2013 baseline survey being: *H. decipiens, H. ovalis, H. spinulosa, H. uninervis, and Z. muelleri* (Bryant et al. 2014).

The 2013 annual assessments of seagrass monitoring meadows and fine-scale remapping showed large declines in seagrass had occurred by November 2013. Annual monitoring and WBDDP survey area mapping found many seagrass areas had shown significant recovery during 2012, following the large declines associated with heavy rainfall and flooding in 2010 (refer Figure 7.9a, Figure 7.9b, Figure 7.10a and Figure 7.10b). However, these gains had largely been lost in 2013 as a likely consequence of high rainfall and another major flooding event from the Calliope River in January 2013 (Bryant et al. 2014). In November 2013, the total distribution of seagrasses within both Port Curtis and the DPA was 4,313 ± 2,196ha, compared with 11,741 ± 2,556ha mapped in 2009. This represented a loss of around 75% of deep water seagrasses and more than 50% of coastal seagrasses since 2009.

Several consecutive years of decline have potentially left seagrasses with a reduced resilience to further impacts and it may take some time for meadows to reach pre-flood (2009) levels. The generally poor condition of seagrasses in Port Cutis in 2013 was reflected in other monitoring locations on the east coast of Queensland. This is in contrast to many of the seagrass areas on Northern Cape York and the Gulf of Carpentaria which were in good condition and not impacted by the severe flooding that occurred on the east coast in recent years.

Further details on the findings of the Port Curtis and Rodds Bay seagrass surveys undertaken in 2013 are included in Appendix E.

Coastal seagrass meadows 2013

The distribution of coastal seagrasses in 2013 was significantly reduced compared with 2009. Approximately 3,027 ± 547ha of coastal seagrasses were mapped in 2013 compared with 6,855 ± 476ha in 2009; a loss of over 50%. The majority of the loss in coastal seagrass distribution occurred in the Western Basin and The Narrows zones, and also outside of the Port in Rodds Bay (Bryant et al. 2014). Biannual mapping of seagrasses in the WBDDP survey area has shown that the majority of these more regional declines occurred following significant river flow events and flooding in 2010 with some recovery occurring in 2012 before declining again in 2013 due to flooding in January 2013.

As a consequence of the 2013 declines, the majority of annual monitoring meadows were classified as being in a 'poor' condition, including the majority of meadows in the Western Basin and The Narrows zones, in the Mid Harbour and at South Trees, and at the out of Port reference meadows in Rodds Bay. Patchier meadows in the Western Basin appeared to be most affected with significant declines in area and a shift in species composition from *Z. muelleri* to the colonising *Halophila* spp. Despite declines in total area, seagrass abundance (biomass) for many meadows remained stable or had increased since 2012. Two meadows in the Western Basin remained in better condition but were classified as 'moderate' due to a shift in species composition towards colonisers (Bryant et al. 2014).

The large Mid Harbour monitoring meadows at Pelican Banks and Quoin Island were in a 'moderate' condition with biomass still remaining below the long term average. Monitoring meadows near South Trees Point were in a 'poor' condition with biomass more than 80% below the long term average and shifts in community type to colonising species. Dugong feeding trails were observed at Pelican Banks and Quoin Island monitoring sites as well as Rodds Bay, and several dugongs were seen feeding during the 2013 survey.

Reference monitoring meadows in Rodds Bay were also in a 'poor' condition in 2013 with only a few patches of seagrass remaining (Bryant et al. 2014). The changes in monitoring meadows were also reflected in the broader regional survey.

Deep water seagrass meadows 2013

Approximately 1,286 ± 545ha of deep water seagrasses were mapped in the Port and the DPA in 2013 compared with 4,886 ± 204ha in 2009; a loss of almost 75%. Outside of the Port limits and the DPA, an additional 20,000ha of deep water seagrass habitat was mapped, compared to previous fine-scale surveys in 2002 and 2009, in adjacent offshore areas of the GBRMP. These vast meadows were relatively low in average biomass and were comprised of several species of the *Halophila* genus. No deep water meadows are included in the annual long term monitoring program (i.e. monitoring meadows) and therefore are not assessed by condition index.

7.3.3.3 Seagrass survey results 2014 (Carter et al. 2015)

Seagrass meadows were re-mapped in November 2014 and marked the largest overall area of seagrass ever recorded in Port Curtis. The survey included both coastal and deep water seagrass with a total of 31,385ha mapped. Comparing just the survey extent common to all previous surveys, over 12,700ha was mapped. This is a substantial increase (> 8,000ha) from 2013, where seagrass area had reduced by 63% compared with the previous 2009 survey of the entire region (Carter et al. 2015). The majority of this expansion occurred in deep water areas offshore outside of Port limits. Coastal seagrass meadows also expanded in area, particularly in Rodds Bay and The Narrows zones where much of the 2013 declines had occurred.

Five seagrass species, from two families, of seagrass were observed in the Port Curtis, Rodds Bay DPA and adjacent offshore areas during the 2014 baseline survey being: *H. decipiens, H. ovalis, H. spinulosa, H. uninervis, and Z. muelleri.*

Seagrasses at other locations along the east coast of Queensland which are monitored by TropWATER were negatively impacted by a number of extreme events between 2010 and 2013, including flooding and cyclones. The trajectory for recovery since then has been varied with the condition of some meadows having substantially improved but many locations remaining in poor condition (Carter et al. 2015). Seagrass meadows in Port Curtis and Rodds Bay generally improved in condition in 2014 compared with 2013, when substantial declines in the condition of many meadows were recorded.

Multiple years of climate related impacts have potentially left a legacy of reduced resilience of seagrasses to impacts and it may take several consecutive years of improved environmental conditions for seagrass meadows in Port Curtis to return to 'very good' condition (Carter et al. 2015).

Further details on the findings of the Port Curtis and Rodds Bay seagrass surveys undertaken in 2014 are included in Appendix F.

Coastal seagrass meadows 2014

In 2014, there were some signs of seagrass recovery in coastal meadows from the reductions seen during 2013. Seagrass meadow area from The Narrows to Rodds Bay increased substantially from 2013, including in the WBDDP survey area (refer Figure 7.15) with 13 of the 14 monitoring meadows having increased in area. Many of the annual seagrass monitoring meadows had also improved in condition from 2013, driven largely by increases in meadow area. Despite these improvements, biomass and area for many meadows were often well below peaks recorded between approximately 2006 and 2009 (Carter et al. 2015). Seagrass meadow area and biomass generally remain below the long term average following significant declines in 2009/2010. This has likely reduced seagrass resilience to further impacts, therefore it may take some time for meadows to reach historical peak levels documented in 2007 to 2008.

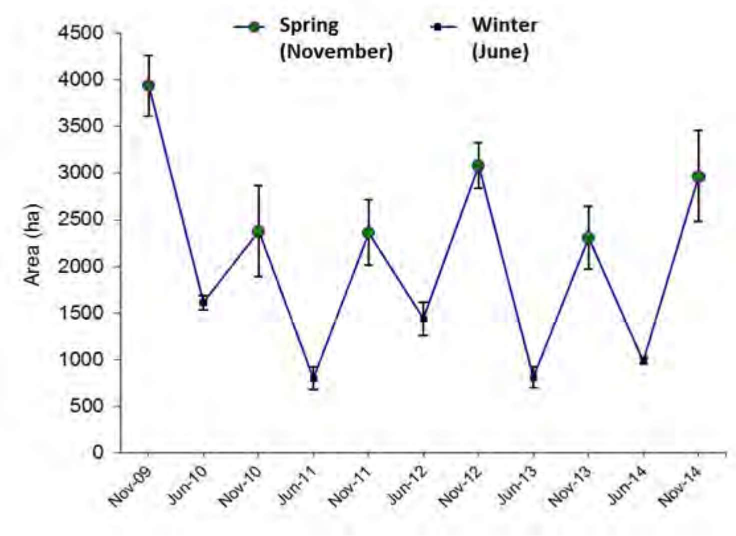

Figure 7.15 **Seasonal changes in total seagrass meadow area in the seagrass annual monitoring survey area, excluding Rodds Bay (2009 to 2014)**

Source: Carter et al. (2015)

Meadow area increased in all of the monitoring meadows in The Narrows and Western Basin zones, with three of the meadows classed as being in 'good' condition. Seagrass biomass generally remained below the long term average following significant declines from peak biomass in 2007 and 2008. Many meadows have experienced long term shifts from dominance by *Z. muelleri* to the colonising *H. ovalis* (Carter et al. 2015).

Monitoring meadows in the Inner Harbour, Mid Harbour and South Trees zones were classified as being in 'poor' to 'fair' condition with biomass remaining below the long term average. This was despite large increases in meadow area for monitoring meadows near South Trees. Dugong feeding trails continued to be observed in the survey area at Pelican Banks and Quoin Island during the 2014 survey.

At the reference monitoring meadows in Rodds Bay, seagrass had increased from only a few remnant patches of seagrass in 2013 to approach peaks in area observed prior to 2009/2010 in the monitoring program, but as with other locations biomass remained below historical levels (Carter et al. 2015).

Seagrass area also expanded in the shallow areas since November 2013 with coastal seagrass area increasing from 3,027 ± 547ha to 5,227 ± 837ha. The majority of the loss in coastal seagrass area in 2013 occurred in the inner harbour zones from The Narrows to Wiggins Island and also outside of the Port in Rodds Bay. These were also the areas where much of the gains in seagrass area occurred in 2014 (Carter et al. 2015).

Deep water seagrass meadows 2014

The deep water areas within the Port limits represented a substantial portion of meadow area increases in 2014 where approximately half of the reduction in seagrass area occurred in 2013. These deep water meadows underwent a net reduction of approximately 3,600ha (~ 75%) from 2009 to 2013 but expanded by over 6,100ha by November 2014 to the largest seagrass extent detected in the deep water baseline surveys. Outside of the Port and the DPA, an additional 18,000ha of deep water seagrass habitat was mapped in adjacent offshore areas within the GBRMP. These vast meadows were relatively low in average biomass and were comprised of several *Halophila* species typical of deep water areas in the Great Barrier Reef lagoon (Carter et al. 2015). No deep water meadows are included in the annual long term monitoring program (i.e. monitoring meadows) and therefore are not assessed by the condition index.

7.3.3.4 Seagrass survey results 2015 (Davies et al. 2015a)

In November 2015, a total of 1,748 sites were surveyed in the Port Curtis and Rodds Bay seagrass annual monitoring survey area. The overall condition of seagrasses in Port Curtis and Rodds Bay was assessed as 'poor' due to low seagrass biomass.

Dugong feeding trails were observed in the Rodd Bay on large *Z. muelleri* meadows, at South Trees, South Fisherman's Landing, the Passage Islands, and throughout the Mid Harbour and The Narrows zones in 2015.

There were five seagrass species (from three families) observed during the survey and included: *Halophila decipiens, H. ovalis, Halophila spinulosa, Z. muelleri* and *H. uninervis.*

Coastal seagrass meadows 2015

In 2015, the seagrass area continued to increase with half of the monitoring meadows recording an increase in area, despite the decline in biomass and shift in species composition. The total distribution of coastal seagrasses from The Narrows to the Boyne River increased by over 1,000ha following the reduction in 2013, and covered the greatest area since November 2009. Seagrass meadows in The Narrows increased in both average biomass and area in 2015, raising the condition index from 'very poor' to 'poor' for biomass, and from 'good' to 'very good' for area.

There was a shift from the once dominant *Z. muelleri* to the colonising *Halophila* species at many of the meadows in the Port.

The Narrows and Western Basin zones recorded the best seagrass condition where substantial increases in area were recorded and average biomass also generally increased or remained above the long term average. Some meadows in The Narrows and Western Basin have also experienced shifts to less persistent species; however, the majority were classed as being in an overall condition of satisfactory or better.

In other zones, from the Inner Harbour to Rodds Bay, there was no improvement in meadow condition.

From 2014 to 2015, the total area of seagrass survey continued to increase, with expansions in area mostly concentrated to these zones where major seagrass declines had occurred in proximity to the source of recent episodic flooding (2010 to 2013) and the Western Basin dredging operation.

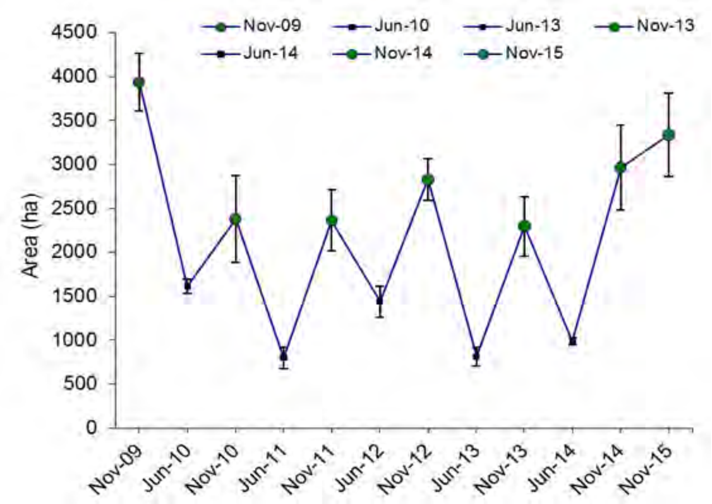

Figure 7.16 **Seasonal changes in total seagrass meadow area in the seagrass meadow area in Port Curtis, excluding Rodds Bay (2009 to 2015)**

Source: Davies et al. (2016a)

7.3.3.5 Seagrass survey results 2016 (Rasheed et al. 2017b)

A total of 1,860 sites were surveyed in the Port Curtis and Rodds Bay seagrass annual monitoring survey area in November 2016 (Rasheed et al. 2017b). In the mapped annual monitoring survey area, the total area of seagrass mapped was 2,702 ± 389ha in 2016, similar to the long term average of 2,873ha.

Dugong feeding trails were observed in Rodds Bay, South Trees and in the meadows extending further south to the survey boundary, south Fisherman's Landing, the Passage Islands and throughout the Mid Harbour zone in 2016. High density dugong feeding trails were observed at Wiggins Island and South Fisherman's Landing on a large portion of the exposed bank. There were fewer sites with evidence of feeding trails, particularly throughout The Narrows and across the Facing Island meadow in 2016.

Coastal seagrass meadows 2016

The overall condition of seagrass in Port Curtis and Rodds Bay remained poor in 2016. Figure 7.17 shows the total area of seagrass mapped within the monitoring area. The 2016 seagrass was close to the long term average but had decreased from 2015 (Rasheed et al. 2017b).

For 2016, many meadows in the Western Basin, The Narrows and South Trees areas were in a better condition than in 2015. However, the Inner Harbour, Mid Harbour and Rodds Bay zone meadows remained in a 'poor' to 'very poor' condition.

The Western Basin zone saw an increase in meadows classified as having a moderate cover in 2016. *H. ovalis* was the dominate species of seagrass in this area. The intertidal meadow at north of Fisherman's Landing adjacent to the existing Western Basin reclamation area was in a 'very poor' condition. The Passage Island meadows had an overall 'good' condition.

The Pelican Banks meadow saw significant losses in 2016 where the meadow had declined to its lowest biomass and area. There was also a shift in species composition at the Pelican Banks meadow (Rasheed et al. 2017b).

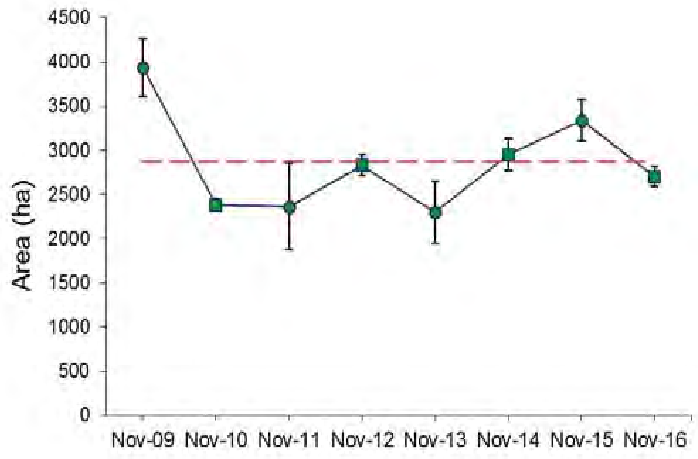

Figure 7.17 Annual changes in total seagrass area in Port Curtis, excluding Rodds Bay (2009 to 2016)

Figure note:

Red dashed line represents the long term average of meadow area mapped (2009 to 2015)

Source: Rasheed et al. (2017b)

7.3.3.6 Seagrass survey results 2017 (Chartrand et al. 2018)

The annual seagrass survey was conducted on the Port Curtis and Rodds Bay seagrass during November 2017 (Chartrand et al. 2018). A total of 1,739 sites were surveyed using methods that followed the established techniques for the TropWATER Queensland-wide ports seagrass monitoring program. This methodology included the sampling of intertidal areas with helicopter surveys and shallow subtidal using boat-based free diving.

Five seagrass species (from three families) were observed during the survey. In Port Curtis, a total of 3,218 ± 391ha of seagrasses was mapped demonstrating a return to above-average distribution as mapped in 2015 and in Rodds Bay a total of 311 ± 14ha of seagrasses was mapped, a similar increase from 2016 seagrass area coverage (Chartrand et. al. 2018).

Dugong feeding trails were found in 12 of the 15 meadows that previously recorded dugong feeding trails in 2016; from the Western Basin, Mid Harbour, South Trees Inlet, and Rodds Bay zones. Overall, dugong feed trail surveys in 2017 showed a similar level of herbivory to previous annual surveys (Rasheed et al. 2017).

Coastal seagrass meadows 2017

The total area of seagrass was above the long term average and slightly up from 2016 but the overall condition of seagrass in Port Curtis and Rodds Bay remained ‘poor’ for a third consecutive year according to the 2017 survey (refer Figure 7.13a and 7.13b) (Chartrand et al. 2018). Figure 7.18 shows the total area of seagrass mapped within the monitoring area. Most of the seagrass meadows had a low biomass and high proportion of colonising species, leading to the overall ‘poor’ condition score. Only four meadows were in ‘very good’ or ‘satisfactory’ condition, while the remaining ten were considered ‘poor’ or in a ‘very poor’ state. Meadow condition appeared to be independent of zone or proximity to anthropogenic or port activity. All seagrass species previously recorded remained present (Chartrand et al. 2018).

The 2017 survey showed an improvement in biomass and species composition at the largest and densest area of seagrass near Pelican Banks, changing its condition from ‘very poor’ to ‘poor’. Meadows at a greater distance from human disturbances at Rodds Bay had further declines and remained in a ‘very poor’ state. The annually averaged environmental conditions were within expected ranges for favourable seagrass growth in 2017. However, large rainfall events, leading to well above average flows of local rivers occurred in March and October which may have prevented substantial seagrass recovery. The proportion of more resistant and stable species were at historically low levels indicating that resilience of seagrasses in Port Curtis to future natural or anthropogenic impacts is likely to be low (Chartrand et al. 2018).

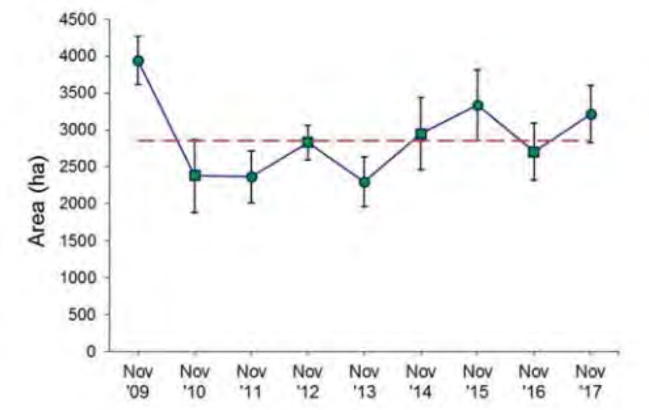

Figure 7.18 Annual changes in total seagrass area in Port Curtis, excluding Rodds Bay 2009-2017

Figure note:

Red dashed line represents the long term average of meadow area mapped (2009 to 2016)

Source: Chartrand et al. (2018)

7.3.3.7 Temporal changes

Quarterly seagrass transects have been assessed since 2009 when they were established as part of the WBDDP. This monitoring is in addition to the long term annual seagrass monitoring (i.e. monitoring meadows) that has been conducted since 2004, which examines the full extent of seagrasses each November at the time of their maximum distribution. Permanent transect locations were established to act as sentinel or sensitive receptor assessment sites during the WBDDP to monitor variations in seagrass conditions throughout the year. As part of the Project EIS, six sites were added to the 2014 TropWATER seagrass monitoring program at three coastal and three deep water sites, to monitor seasonal trends on a finer scale, which had previously not been undertaken at these sites (refer Figure 7.3). Sites were assessed quarterly throughout the year with results up to 19 May 2015 (refer Appendix G for detailed results) updating the most recent annual report for the program which included data up to November 2014.

Transect monitoring results indicated that seagrasses in Port Curtis and Rodds Bay underwent distinct seasonal changes as well as significant inter-annual changes in seagrass distribution, abundance and species composition.

Record levels of stormwater runoff from the Calliope River in January 2013 saw a decline in seagrass detected across most seagrass monitoring sites. Recovery over the 2013 and 2014 growing seasons varied with some sites remaining atypically low in seagrass cover (e.g. Pelican Banks South), while the out of Port reference sites at Rodds Bay had substantial recovery. In the first half of 2015, seagrasses at most sites had declined in line with seasonal trends.

The three coastal sites established in May 2014 as part of the Project EIS at Quoin Island, South Trees and Colosseum Inlet followed seasonal trends in biomass and seagrass percent cover, with peaks during the growing season in November 2014. These sites generally had higher seagrass cover at their peak (5% to 20%) than other coastal sites within the Port.

The three deep water transect blocks established in May 2014 as part of the Project EIS, were dominated by *H. ovalis* with a very small proportion of *H. decipiens* and *H. spinulosa*. All three sites (i.e. Deep water site 1, Deep water site 2, and Deep water site 3) had extremely low biomass (< 1g DWm^{-2}) throughout the monitoring period, with peaks in above-ground biomass in either September or November 2014. By March 2015, seagrass was absent from all three sites, as expected for meadows dominated by highly ephemeral species.

Currently seagrasses have shown a capacity to recover from natural and anthropogenic impacts in Port Curtis, but has been seen in other Queensland locations, repeated disturbances over multiple years may lead to long term loss, with recovery trajectories far less certain (Carter et al. 2015).

In 2016, environmental conditions were generally favourable for seagrass growth with low rainfall and river flow compared with recent years, and tidal exposure had reduced from 2015, although it remained slightly higher than average and may have contributed to the change (Rasheed et al. 2017b). Benthic light available to seagrass also remained well above locally derived thresholds required for seagrass maintenance or growth in meadows where it was measured.

During March 2017 and October 2017 the Calliope River experienced increased flows resulting from high rainfall which likely prevented seagrass recovery for that year (Chartrand et al. 2018).

7.3.3.8 Seagrass seed bank and density studies

The results from both the 2015 (Jarvis et al. 2015) and 2016 (Bryant et al. 2016b) survey are summarised below.

- During all quarterly sampling, seeds were present at all sites, with a total seed density relatively high compared with other locations in Queensland where seed banks have been assessed
- In 2015, seed density varied over time at Rodds Bay and Wiggins Island but was relatively stable at Pelican Banks
- Over the duration of monitoring (2011 to 2016), seed bank density changed significantly at all sites. Temporary trends in seed bank density differed between sites and did not always follow expected seasonal patterns
- The average proportion of viable seeds decreased at all sites over the senescent season (from February to May) in 2015, but in 2016, either remained stable (Pelican Banks North), increased (Rodds Bay) or decreased (Wiggins Island)
- In 2015, greater than 60% of all seeds were found at sediment depths > 20mm with greater than 50% found at depths deeper than 50mm.
- Seasonal trends in total seed bank density were not consistent, with some sites unexpectedly containing significant higher seed densities following the senescent period (May) compared with densities following replenishment (February), indicating secondary dispersal events or possibly delayed recruitment of seeds to some meadows.
- Results from the first two years for this study have highlighted new insights into seed banks in Port Curtis but have also highlighted the complexity of seed bank dynamics.

The above seed bank and density surveys did not include assessments of viability, depth structure and temporal and spatial change in seagrass seed banks (Reason et al. 2017). A study by Reason et al. (2017) conducted a three year assessment to address some of these gaps and with findings summarised as follows:

- At all times examined *Z. muelleri* seed bank was generally present across all sites, however temporary trends in seed bank density differed between sites and did not always follow expected seasonal patterns
- Viability assessments found that the available seed bank was lower than total seed numbers would suggest, there were some sites at time that has no viable seeds present

- Viable seeds tended to be located deeper below the sediment surface potentially making them less available for germination and the proportion of the total seed bank that was viable varied considerably between and within sites and over time.

7.3.4 Gladstone Healthy Harbour Partnership

7.3.4.1 Overview

The GHHP report uses the seagrass meadow monitoring data collected during the annual long term monitoring surveys (refer Section 7.3.3). Three indicators of seagrass health are used to calculate the seagrass grades for the report card at six reporting zones, including:

- Biomass – changes in average above-ground biomass within a monitoring meadow
- Area – changes in the total area of monitoring meadow
- Species composition – changes in the relative proportions of species.

Fourteen monitored seagrass meadow sites are used for the GHHP reporting and are located within six harbour zones, including: The Narrows, Western Basin, Inner Harbour, Mid Harbour, South Trees Inlet and Rodds Bay (Bryant et al. 2014; GHHP 2015a; 2016a; 2017a).

The key GHHP monitoring reports relevant to seagrass are listed in Table 7.19.

Table 7.19 Gladstone Healthy Harbour Partnership reports that contain information relevant to seagrass health

Survey	Reports
2017	▪ *Gladstone Harbour Report Card 2017* (GHHP 2017a) ▪ *Technical Report, Gladstone Harbour Report Card 2017* (GHHP 2017b)
2016	▪ *Gladstone Harbour Report Card 2016* (GHHP 2016a) ▪ *Technical Report, Gladstone Harbour Report Card 2016* (GHHP 2016b)
2015	▪ *Gladstone Harbour Report Card 2015* (GHHP 2015a) ▪ *Technical Report, Gladstone Harbour Report Card 2015* (GHHP 2015b)
2014	▪ *Piloting of Seagrass Indicators for the Gladstone Healthy Harbour Partnership* (Bryant et al. 2014)

7.3.4.2 Results

The results from the four report cards (Bryant et al. 2014; GHHP 2015b; 2016b; 2017b) are summarised below.

- The overall score of seagrass meadows for four consecutive years (2014, 2015, 2016 and 2017) has been ‘poor’ indicating that the seagrass meadows in the Gladstone Harbour remain in a stable state but vulnerable state
- The Narrows overall condition has improved from ‘very poor’ in 2015 to ‘satisfactory’ in 2017. The score for area had declined however scores for biomass and species composition both improved.
- The Western Basin overall score remained ‘satisfactory’ for the third consecutive year however, the score decreased in 2017
- The Inner Harbour only has one monitored meadow and received a ‘very poor’ score based on species composition
- The Mid Harbour received a ‘poor’ score, similar to the scores received from the previous years
- The condition at South Trees Inlet improved from ‘poor’ to ‘good’ in 2017. The scores for all the indicators improved in 2017.

- Rodds Bay overall score in 2017 was 'very poor', which is a decline from 2016 where it scored a 'poor' result. Species composition appeared to have declined the most.
- Seagrasses in the Gladstone region have undergone significant declines during and immediately following years of above average rainfall and flow from the Calliope River since monitoring commenced in 2002.

7.4 Port Curtis benthic light environment and seagrass above-ground biomass

7.4.1 Overview

To address the potential Project impacts to Port Curtis seagrass meadows, BPAR was monitored as part of the Project EIS data baseline collection in order to develop initial light threshold ranges for individual seagrass species (refer Figure 7.19 and Appendix H). The light requirement threshold range is defined as the point at which a change in external conditions will likely cause a significant negative change in seagrass condition (measured as above-ground biomass). These threshold ranges have the potential to be used during the EIS impact assessment process, and for inclusion in future management plans. Thresholds that have been calculated are based on the information available at the time of reporting.

Over the baseline data collection period, BPAR monitoring and annual seagrass monitoring during the growing season (November) indicated that the light environment remained favourable for seagrass growth in 2013 and the lack of recovery of *Z. muelleri* at some meadows may be due to other factors such as a lack of viable propagules.

During the 2014 growing season, monitoring of BPAR in Port Curtis and Rodds Bay indicated that BPAR levels remained above the levels required for Gladstone seagrass at sites in the WBDDP survey area. The favourable light environment combined with below average rainfall and flow of the Calliope River (refer Figure 7.20) may have allowed for increases in meadow area over the 2014 growing season; however the magnitude of declines over the previous senescent season meant that seagrasses were re-establishing from very low levels (Carter et al. 2015). Further details on the mean total daily irradiance and percentage seagrass relationships for the seagrass meadow monitoring sites are provided in Appendix G.

Rodds Bay meadow surveys showed a decline in above-ground biomass during 2015 and 2016 period. This coincides with light steadily increasing, from 6mol photons $m^{-2}day^{-1}$ since March 2013, during the 2016 growing and senescent seasons (Rasheed et al. 2017b).

Over the duration of this study, the local climate in Gladstone has been characterised by above average rainfall, punctuated by severe flood events. River flow peaked in January 2013 well above the long term monthly average. The peak in January 2013 is the highest on record with discharges of over 600,000ML of water causing severe flooding in the Gladstone region.

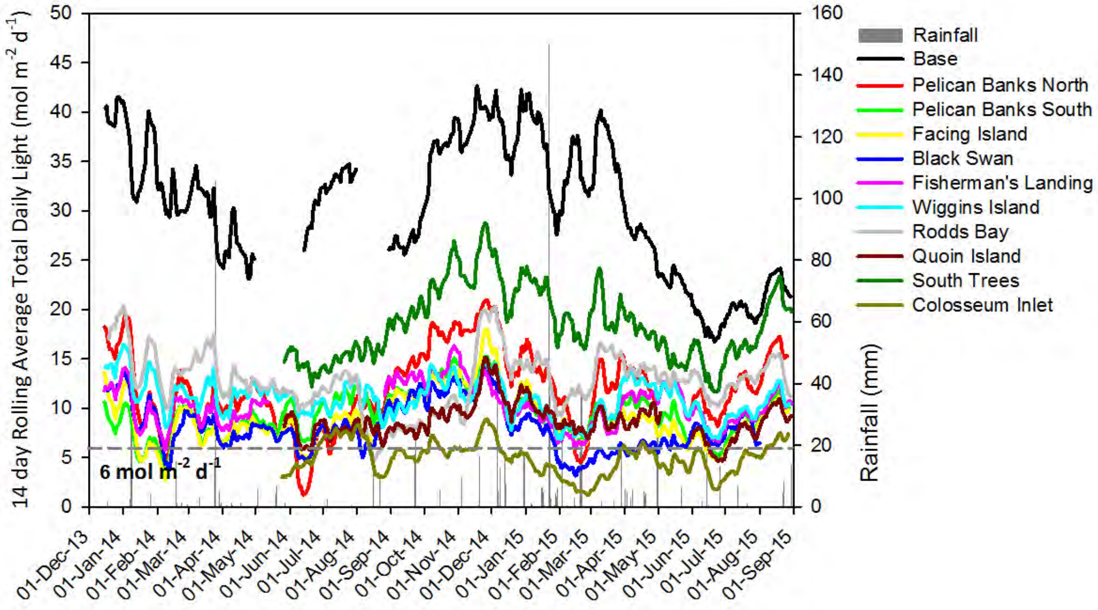

Figure 7.19 **Average total daily benthic light (presented as a 14 day rolling average) at seagrass permanent transect sites in Port Curtis and Rodds Bay**

Source: Davies et al. (2015a)

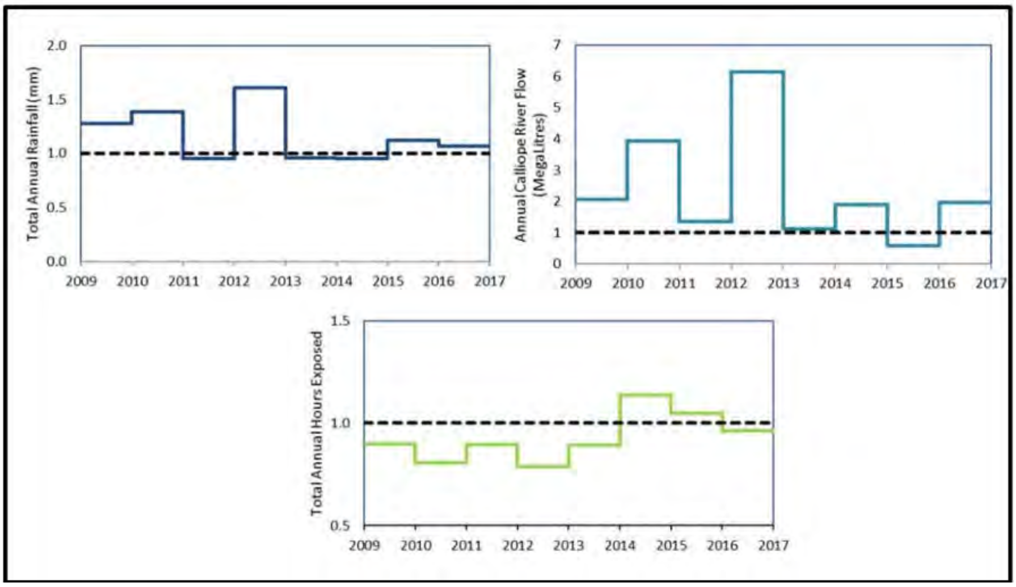

Figure 7.20 **Recent climate trends in Gladstone 2009 to 2017**

Figure note:

Annual average (solid line) compared to the long term average scaled to 1.0 (dashed line)

Source: Chartrand et al. (2018)

7.4.2 Fisherman's Landing and Wiggins Island

The rolling mean total daily irradiance at Fisherman's Landing and Wiggins Island BPAR monitoring sites frequently fell to low light levels over both growing and senescent seasons earlier in the program (late 2009 to early 2011) (McCormack et al. 2013). Since mid-2011 however, the light environment appears to have improved, with light conditions at Fisherman's Landing and Wiggins Island remaining favourable for seagrass growth over the majority of 2013 and 2014.

Seagrass above-ground biomass at Fisherman's Landing has remained very low (< 2g DWm^{-2}) over the duration of the program, with small increases over the growing season and declines early in the year (Davies et al. 2015b).

Seagrass above-ground biomass at Wiggins Island has remained low, generally < 1g DWm^{-2}, but have remained stable since 2013 (Davies et al. 2015b).

7.4.3 Pelican Banks North

The rolling mean total daily irradiance at Pelican Banks North has remained generally favourable during the growing season since the end of 2010, when there was a major flood event and peaks in river flow (Davies et al. 2015b). During the growing season in 2013, mean total daily irradiance at Pelican Banks North reached the highest levels recorded over the duration of the program (> 30 mol photons m^{-2} day^{-1}). During 2014, irradiance declined in February and June/July, and increased during the August and November surveys, corresponding to peaks in seagrass percent cover. Seagrass percent cover continued to decline in March and May 2015, despite light levels remaining adequate, likely as a consequence of other environmental factors such as high temperature, cuing the start of the senescent season.

Seagrass above-ground biomass was also generally low in 2014 (i.e. < 7g DWm^{-2}) with less recovery than recorded in November of previous years and significantly lower than peaks (i.e. approximately 10g DWm^{-2}) observed in November 2013 (Davies et al. 2015b).

The seagrasses at Pelican Banks North generally remain the most abundant in terms of above-ground mass in Port Curtis and Rodds Bay.

7.4.4 Pelican Banks South

At Pelican Banks South, mean total daily irradiance has also remained favourable for seagrass growth for the duration of the monitoring with the exception of a period in February 2013 following extreme rainfall and river flow event, and again in January/February 2014. Total daily irradiance at the southern end of Pelican Banks generally aligns with light conditions at the northern end, however seasonal peaks in light levels were not as pronounced at Pelican Banks South during the 2013 growing season as in the northern section. Irradiance was generally lower in 2014 and 2015 at this site compared with 2013, and although light levels increased during the growing season, seagrass percent cover did not recover. Seagrass abundance has often remained at low levels despite light improving significantly over the latter part of the program. This demonstrates that while light is an important factor in determining seagrass growth, there are a range of other variables that influence seagrass growth.

Seagrass above-ground biomass have remained relatively low during 2013 and 2014 (i.e. general < 2g DWm^{-2}) (Davies et al. 2015a).

7.4.5 Facing Island

At the nearby Facing Island site, the light environment has been more variable. Over the first few years of the study when the site was more heavily dominated by *Z. muelleri* the rolling average irradiance at Facing Island fell to low levels (below 6 mol photons m^{-2} day^{-1} over a 14 day rolling average) almost as much as it remained at higher levels, with light conditions at Facing Island appearing to be far poorer than at the turbid Western Basin sites (McCormack et al. 2013). In 2013, light levels at the site improved and mean total daily irradiance remained favourable for seagrass growth for the majority of the year, with the exception of a few days in February 2013 following the extreme rainfall and river flow event and longer periods in January, February and June 2014. Since early 2014, the species composition has shifted to a *H. uninervis* dominated meadow, which may not require as much light as *Z. muelleri.*

Seagrass above-ground biomass over the 2014 growing season was similar to 2013 and less than 2g DWm^{-2} (Davies et al. 2015a).

7.4.6 Colosseum Inlet

Light recorded at the subtidal site at Colosseum Inlet revealed a much lower light environment than other coastal sites which expose at low tide. Increases in seagrass percent cover corresponded with increased light during the 2014 growing season, and declined to low levels during the 2015 senescent season. A similar trend was seen at Quoin Island, however irradiance was much higher than at Colosseum Inlet with light levels ranging from 5 to 15 mol photons m^{-2} day^{-1} over a two week period. Seagrass cover peaked in November 2014, which corresponds to this peak in light.

Seagrass above-ground biomass followed a seasonal trend, peaking in November 2014 (i.e. > 2g DWm^{-2}) (Davies et al. 2015a).

7.4.7 Quoin Island

Mean total daily irradiance at Quoin Island follows a similar seasonal trend yet is much higher than at Colosseum Inlet, with light levels ranging between 5 to 15 mol photons m^{-2} day^{-1} over a two week period (Davies et al. 2015a). The seagrass cover peaked in November 2014, which corresponded with peaks in light; however the light levels did not decline to the same degree as many of the other sites during the senescent season. Temperature was similar between the sites.

Seagrass above-ground biomass shows a seasonal trend with a peak between November 2014 and March 2015 (i.e. > 3g DWm^{-2}) (Davies et al. 2015a).

7.4.8 South Trees Inlet

Mean total irradiance at South Trees Inlet meadow stayed well above 10 mol photons m^{-2} day^{-1} for the growing season in 2014 and the senescent season in 2015 (Davies et al. 2015a). This was one of a few sites to peak in cover in March 2015 rather than at the height of the growing season suggesting that light is not limiting at this site and the delay in peak abundance relates to a different variable for this site.

Seagrass above-ground biomass had an increasing trend during 2014, peaking in March 2015 (approximately 6g DWm^{-2}) (Davies et al. 2015a).

7.4.9 Rodds Bay reference site

At the out of Port reference site at Rodds Bay, the rolling average total daily irradiance remained above 6 mol photons m^{-2} day^{-1} over the majority of baseline monitoring with the exception of a short duration of time when the logger was shifted to a deeper location (Davies et al. 2015a). In 2013, there was a correlation in declines in irradiance following the extreme rainfall and river flow which aligned to patterns seen in Western Basin and Mid Harbour zones. During 2014 and 2015, irradiance was generally high and conditions for seagrass growth were favourable with a substantial peak in percent cover in November 2014.

Seagrass above-ground biomass was the highest during 2014 growing season (i.e. > 2g DWm^{-2}) since peaks observed in 2007 and had entered the senescent season by March 2015 (Davies et al. 2015a).

7.4.10 Deep water sites

Mean total daily irradiance at Deep water site 1 has been extremely low (< 4 mol photons m^{-2} day^{-1} over a 7 day period) since monitoring began in June 2014, as expected from a site at this depth. The light environment at Deep water site 1 was generally higher during the growing season, and fell below a rolling average of 1 mol photons m^{-2} day^{-1} over a 7 day period in January 2015. Above-ground biomass was also extremely low (< 0.2g DW m^{-2}) but showed a distinct seasonal trend, with biomass peaking during the growing season in August and November 2014 (Davies et al. 2015a).

Mean total daily irradiance at Deep water site 2 was similar to Deep water site 1, generally remaining below 5 mol photons m^{-2} day^{-1} over a 7 day period since monitoring began in June 2014. The light environment at Deep water site 2 was generally higher during the growing season, and fell below a rolling average of 2 mol photons m^{-2} day^{-1} over a 7 day period in January 2015 as the senescent season began (Davies et al. 2015a). Above-ground biomass at Deep water site 2 was the greatest of the three deep water sites, peaking at 0.8g DWm^{-2} in November 2014.

Deep water site 3 had the highest light environment during both the growing season and into the senescent season, reaching a peak of nearly 10 mol photons m^{-2} day^{-1} over a 7 day rolling average period at the end of September 2014 (Davies et al. 2015a). This site also showed a strong seasonal trend in light, however the light level at the start of the senescent season (< 2 mol photons m^{-2} day^{-1} over a 7 day period) was more similar to the range of light experienced during the growing season at Deep water sites 1 and 2. Despite this, Deep water site 3 had the lowest biomass, with seagrass present only in August and November 2014 at extremely low levels (0.02g DWm^{-2}) (Davies et al. 2015a).

Additional detail on the benthic light environment and seagrass above-ground biomass and percent cover at seagrass meadows monitoring sites are provided in Appendix G.

7.5 Light thresholds for seagrass species within Port Curtis

7.5.1 Coastal seagrass – *Zostera muelleri* subsp. *capricorni* dominated meadows

Examination of light history and biomass trends at coastal sites, with the values derived from previous studies conducted in Port Curtis, as well as other literature derived values, supports a light threshold of a rolling average of 6 mol photons m^{-2} day^{-1} over 14 days. During the growing season in 2013 and 2014, seagrass was maintained or increased when light was at least 6 mol photons m^{-2} day^{-1} over a two week rolling average (refer Figure 7.19), which is consistent with findings from Chartrand et al. (2012).

Light attenuation events were simulated for the *Z. muelleri* dominated Pelican Banks North for two growing seasons and two senescent seasons from 2010 to 2013 (Chartrand et al. 2016). Short term, repeated shading and respite was undertaken to mimic turbidity plumes from dredging events. The study concluded that *Z. muelleri* appeared to cope for 12 weeks of the highest shade treatment, provided 14 days of respite after shading was applied (Chartrand et al. 2016).

The light data collected at *Z. muelleri* dominated Pelican Banks North and South Trees Inlet sites indicates that these meadows are not growing in a light-limited environment (Davies et al. 2015a). Mean total daily irradiance during growing seasons in 2013 and 2014 was maintained well above the suggested light threshold of 6 mol photons m^{-2} day^{-1} over a 14 day period, with the exception of a few days in early July 2014 (refer Figure 7.19) (Davies et al. 2015a).

7.5.2 Coastal seagrass – *Halodule uninervis* dominated meadows

Examination of light history and biomass trends at these sites with the literature derived range supported using a light threshold of approximately 5 mol photons m^{-2} day^{-1} over a 14 day period (refer Figure 7.19). Seagrass abundance, though very low, was maintained at the Facing Island site for the entirety of the study and for the majority of time, light levels exceeded the maximum threshold range derived from literature and other studies. Mean total irradiance during the majority of the growing season in 2013 and 2014 was maintained well above the suggested light threshold of 5 mol photons m^{-2} day^{-1}, meaning that this literature derived range was unable to be further refined to a local value from the Project EIS baseline studies. Further refinement in this coastal seagrass light threshold is required to be undertaken prior to Project activities commencing.

7.5.3 Deep water seagrass – *Halophila* spp. dominated meadows

Examination of light history and biomass trends at deep water sites with the literature derived range found the light threshold range of 1 to 2 mol photons m^{-2} day^{-1} describes the environment where *Halophila* spp. seagrass abundance was generally maintained or had increased. Seagrass was completely lost when light fell below 1 mol photons m^{-2} day^{-1} for periods of time greater than 4 weeks. It is likely that seagrass above-ground biomass decline would have been detected earlier than 4 weeks had there been a seagrass sampling event prior to the quarterly sampling in March 2015. *Halophila* spp. are physically very small and are not as structurally replete below-ground compared with other large and longer-lived species, which are able to rely on these below-ground stores to temporarily alleviate stresses incurred by reductions in light and water quality (Ralph et al. 2007). For this reason, the rolling average period for the light trigger has been suggested to be reduced to 7 days rather than the longer 14 days used for the larger growing species.

While light is generally accepted as the primary environmental factor limiting the growth of tropical seagrasses, several studies on *Zostera* spp. have indicated that the interaction between temperature and irradiance may play a key role in the seasonality and survival of seagrasses in the inshore turbid environments (York et al. 2014; Collier et al. 2011; Olesen and Sand-Jensen 1994). Collier et al. (2011) found that high temperatures (> 33°C) combined with either light limiting or saturating conditions will lead to declines in seagrass growth.

7.6 Summary of seagrass surveys and benthic light results

7.6.1 General

There appears to be a good link between seagrass condition in Port Curtis and major climate events, especially high rainfall and flow events of the Calliope River (McCormack et al. 2013; GHHP 2016b; Chartrand et al. 2018). Above average rainfall and flow from the Calliope River was recorded in 2010, 2011, 2013, 2015 and 2016, often coinciding with tropical cyclones in the region. For seagrasses in the Port Curtis, these years were characterised by significant declines in seagrass biomass and meadow area and a shift in species composition from *Z. muelleri* to the colonising *H. ovalis* in many of the monitoring meadows. Increases in seagrass biomass and meadow area during 2012 were reversed in 2013, likely due to high rainfall and the greatest river flow from the Calliope River, and high flows from the Boyne River, in over a decade in early 2013. This led to the majority of monitoring meadows classified as being in 'poor' condition in 2013 and again in 2016. Environmental conditions in 2014 however were more favourable for seagrass growth, with below average rainfall and river flow. Resultant increases in meadow area at the majority of monitoring meadows meant that the overall condition of seagrass in 2014 had improved to 'fair' in both the Port Curtis region and at Rodds Bay. Total monthly rainfall was well above the long-term monthly average in March and October 2017 in Port Curtis. These rainfall events were likely to have impacted seagrasses, particularly those close to the mouth of the Calliope River and previous monitoring in the area has shown that benthic light is generally reduced by these types of river flow events (Chartrand et.al. 2018).

The updated surveys of the Port Curtis region in 2016 and 2017 revealed no correlation between distance from anthropogenic activities and condition of seagrass with many meadows in improved condition closer to port activity and some areas furthest from port activity in decline (Rasheed et al. 2017b; Chartrand et al. 2018). The November 2014 survey found the meadow area increases seen in monitoring meadows were reflected in the broader region from The Narrows to Rodds Bay. From November 2013 to November 2014, deep water seagrass habitat expanded by over 6,100ha, and by over 8,300ha for coastal seagrass. This followed reductions of around 75% in deep water seagrass meadow area between November 2009 and 2013, and reductions of more than 50% for coastal seagrasses. These reductions in seagrass area also correspond with several years (2010, 2011 and 2013) of above average rainfall and peak river flow events, along with capital dredging activities for the WBDDP in the years between baseline surveys (refer Appendix E).

The large changes seen in deep water seagrass meadows reflects the high level of environmentally-driven, inter-annual variability expected in these types of seagrass meadows (Rasheed et al. 2014). Deep water meadows and species are naturally highly variable, and large changes between years are not unexpected. Surveys of deep water seagrasses in the Port Curtis region and in other areas of Queensland (e.g. Townsville, Abbot Point, Mackay) have shown high levels of inter-annual variability in this type of seagrass habitat (Davies et al. 2014; Rasheed et al. 2014; Thomas and Rasheed 2011). While not the only factor to effect seagrass growth, changing light levels are thought to be one of the principal factors driving deep water seagrass changes.

The survey in 2016 revealed a significant decline in biomass for the seagrass meadow, Pelican Banks, which has been the largest and most stable seagrass meadow in the region. Despite there being no definitive reason for the meadow's seagrass decline, potential contributors include high levels of herbivory from dugong and turtle, changes to sediment structure and/or cumulative impacts from multiple stressors over several years (Rasheed et al. 2017b). This trend was reversed in 2017 with biomass and species composition improving and shifting the meadow condition from very poor to poor (Chartrand et al. 2018).

In low light conditions, the *Halophila* spp. that dominate deep water meadows show rapid declines (Durako et al. 2003; Kenworthy et al. 1989), but may respond quickly with fast growth and recovery when conditions improve (Rasheed et al. 2014; Hammerstrom et al. 2006). Large areas of deep water seagrasses were identified further offshore outside of Port limits in November 2013. In November 2014, the deep water seagrass meadows in this region had substantially increased and seagrass was observed in areas where no meadows had been mapped previously (refer Appendix F).

In The Narrows, Graham's Creek, Western Basin and Inner Harbour zones, there was an increase in seagrass meadow area between November 2013 and November 2014, but seagrass did not reach the peaks recorded during the earlier years of the monitoring program (2002 to 2009). Reductions in coastal seagrasses in 2013 were most concentrated in The Narrows and Western Basin zones; these meadows are closest to the source of episodic flooding from the Calliope River, and potential impacts from WBDDP operations. BPAR is considered the key environmental determinant of the distribution, abundance and species composition of seagrass assemblages (Duarte et al. 1997; Vermaat et al. 1997) and flood plumes and dredging have been linked to seagrass declines at other sites due to a reduction in available light (Erftemeijer and Lewis 2006; Campbell and McKenzie 2004).

The species composition of several meadows in The Narrows and Western Basin zones had also changed from *Z. muelleri* dominated communities to those increasingly dominated by colonising *H. ovalis* between 2009 and 2013. In November 2014, the proportion of *Z. muelleri* had increased in several meadows (e.g. meadow 52-57 at the Channel Islands (refer Appendix F), indicating an availability of propagules for successful recruitment. Viable *Z. muelleri* seed banks have been detected in these zones over the course of monitoring; however there have been no local flowering events recorded in these meadows in recent years to replenish seeds (McCormack et al. 2013). As a consequence, the age and viability of remaining seeds will be critical in understanding the ongoing ability of these meadows to regenerate. Seeds and viable fragments may be able to disperse to these sites from more robust meadows in the Mid and Outer Harbours, such as at Pelican Banks.

Severe weather events, including tropical cyclones and high rainfall and river flows from the Port Curtis catchments between 2010 and 2013, and 2015 are likely to have been the main drivers of seagrass declines observed in Port Curtis and Rodds Bay. Declines in seagrass biomass and area generally occurred before the onset of the WBDDP capital dredging activities, with declines also occurring at the out of Port reference sites in Rodds Bay, and more broadly on the east coast of Queensland between Cairns and Hervey Bay during the same period. In comparison, 2012 was a relatively dry year with below average rainfall and river flow with improved water quality conditions allowing an increase in seagrass meadow area, and biomass to a lesser extent. As discussed earlier, those gains were reversed during 2013, with timing of losses seen at sites where quarterly assessments are performed suggesting they were linked with the flooding events of the Calliope River (Davies et al. 2015b). An analysis of the relationship between a broad range of environmental variables and seagrass change in Port Curtis and Rodds Bay was performed at permanent transect monitoring sites between 2009 and 2012 (McCormack et al. 2013) and found significant relationships between river discharges into Port Curtis and seagrass abundance, with the strongest relationships for those meadows closest to the mouth of the Calliope River (Wiggins Island and Pelican Banks South). The patterns in seagrass change and river flow since that analysis remain consistent with major declines during 2013 following record flows of the Calliope River and Boyne River into Port Curtis, followed by increases in seagrass cover in 2014 with a return to below average rainfall and river flow conditions.

Light levels were generally favourable for seagrasses in the 12 months preceding the 2014 survey, remaining above the locally derived light requirement threshold for *Z. muelleri* for the majority of the year at monitoring sites (6 mol photons $m^{-2}day^{-1}$ over a two week period) (Chartrand et al. 2012). The favourable light conditions allowed for some of the seagrass increases recorded during 2014, including a greater presence of higher light requiring species in The Narrows and Western Basin zones. However, the range of seagrass responses at the different monitoring areas emphasises that it is not light alone that determines the fate of seagrass change and recovery. It is likely that light in combination with other environmental parameters such as water temperature and daytime tidal exposure provides a more complete understanding of the seasonal drivers of seagrass productivity and expansion (Carter et al. 2015), although the influence of different environmental factors is likely to be site-specific. In addition, factors such as propagule supply the status of seed banks and success of seagrass seed germination will also likely play a critical role (Rasheed et al. 2014).

7.6.2 Comparisons to Queensland seagrass monitoring outside of Port Curtis

Patterns of seagrass change observed in Port Curtis have been generally consistent with similar changes to seagrasses recorded on the east coast of Queensland between Cairns and Gladstone. Large scale declines in seagrass distribution and meadow biomass occurred in 2009/2010 throughout the northeastern coast of Queensland, including in Cairns (Jarvis et al. 2014), Mourilyan (York et al. 2014), Townsville (Davies et al. 2014), and Abbot Point (McKenna and Rasheed 2014; Rasheed et al. 2014). These declines coincided with above average rainfall and river flow (McKenna et al. 2015) often associated with tropical cyclones (TCs) that have impacted the Cairns to Gladstone region such as TC Hamish (March 2009), TC Ului (March 2010), TC Anthony (January 2011), TC Yasi (March 2011), TC Oswald (January 2013), TC Marcia (February 2015) and TC Debbie (March 2017).

The trajectory of recovery since the declines has varied somewhat between locations, most likely as a response to local differences in climate since, as well as the severity of the initial declines. For some sites, the loss of seagrass meadows was total (e.g. Mourilyan) but in others such as Townsville remnant populations of adult plants remained. Reductions in meadow area and biomass during years of extreme weather events reduce not only the adult plant population but also limit the resources available for that meadow to initiate recovery. With limited or no adult plants remaining, recovery will depend upon seed banks in the sediment or sexual propagules sourced from nearby locations (Jarvis and Moore 2010; Duarte and Sand-Jensen 1990; Phillips and Lewis 1983). Under these circumstances, the rate of recovery is likely to be much slower, particularly where no local or nearby sources of propagules exist.

Tropical seagrasses in Queensland have generally demonstrated an ability to recover from previous impacts locations (Davies et al. 2013; Rasheed and Unsworth 2011; Rasheed 2004). Coastal seagrass meadows in monitoring locations such as Townsville (Davies et al. 2014) have returned to conditions similar to the pre-2009 levels, and at other locations such as Abbot Point foundation species have returned and signs of ongoing recovery are positive. Other monitoring locations such as Cairns (Jarvis et al. 2014) and Mourilyan, (York et al. 2014) did not show similar signs of improvement in 2014, although recent information from the 2016 survey suggests recovery may have begun in Cairns (York and Rasheed 2017). In Mourilyan, there seems little prospect of the foundation seagrass species returning to the site without some form of restoration. In this context, meadows in Port Curtis have shown resilience and capacity for recovery.

On the northern Cape York, Torres Strait and Gulf of Carpentaria seagrasses have fared much better over recent times. Seagrass meadows at monitoring locations in Thursday Island (Carter et al. 2014), Weipa (Taylor et al. 2015) and Karumba (Sozou et al. 2015) have not followed the same patterns of decline and were in a ‘good’ condition in 2014, with meadows remaining relatively stable in biomass and meadow area. These regions generally experienced a lower frequency or severity of the extreme weather events, rainfall and flooding than that of the east coast south of Cooktown.

7.7 Marine epibenthic macroalgae values

7.7.1 Database search results

Public database searches (i.e. EPBC Act PMST and Wildnet) indicate that 244 species of marine algae are known, or are predicted to occur within the database search area (refer Figure 7.5). These comprise 11 blue-green algae (i.e. Cyanophyceae), 87 species of green algae (i.e. Chlorophyceae), 30 species of brown algae (i.e. Phaeophyceae) and 116 species of red algae (i.e. Rhodophyceae). These species are listed in Appendix I.

7.7.2 Macroalgal communities

As part of the WBDDP EIS baseline benthic community assessment (GHD 2009c), data on macroalgae were collected in Port Curtis zones around The Narrows, Western Basin (around Fisherman's Landing, North Passage Island and South Passage Island), and within existing shipping channels in the Western Basin and the Inner Harbour zones. Pelican Banks was also surveyed as a reference site. Sites were sampled using a benthic sled capture technique with sorting and identification done in situ.

Across 47 sample sites, 23 algal taxa were recorded comprising of 7 Chlorophyta (green algae), 7 Phyaeophyta (brown algae) and 8 Rhodophyta (red algae). The most prevalent taxa was a green filamentous algae that occurred at 28 sites (GHD 2009c) (refer results in Table 7.20).

Table 7.20 WBDDP EIS benthic survey algal taxa occurrence per location

	Western Basin	Fisherman's Landing	The Narrows	Channels	Passage Islands	Pelican Banks	Total
Chlorophyta							
Udotea sp.	2	0	0	0	0	0	**2**
Halimeda sp.	0	0	0	0	0	2	**2**
Codium geppi	0	0	0	0	0	1	**1**
Caulerpa sp.	0	0	0	0	0	1	**1**
Acetabularia calyculus	0	0	0	0	0	1	**1**
Green filamentous algae	11	4	0	7	3	3	**28**
Unidentifiable green algae	2	0	0	0	0	0	**2**
Phaeophyta							
Dictyota sp.	0	0	0	1	0	6	**7**
Lobophora variegata	0	0	0	0	0	2	**2**
Padina sp.	0	0	0	0	0	2	**2**
Sargassum sp.	0	0	0	0	0	2	**2**
Hydroclathrus clathratus	0	0	0	0	0	1	**1**
Brown filamentous algae	0	0	0	0	0	1	**1**
Unidentified brown algae	0	0	0	0	0	5	**5**
Rhodophyta							
Champia parvula	0	0	0	0	0	2	**2**
Dasya sp.	1	0	1	0	0	0	**2**
Martensia fragilis	0	0	0	0	0	2	**2**
Chondria succulenta	2	0	0	0	0	5	**7**
Asparagopsis taxiformis	0	0	0	1	0	5	**6**
Red filamentous algae	2	0	1	0	2	1	**6**

	Western Basin	Fisherman's Landing	The Narrows	Channels	Passage Islands	Pelican Banks	Total
Calcareous Algae (unidentified)	0	0	1	0	0	0	**1**
Unidentified red algae	1	1	0	0	0	0	**2**
Total							**42**

Source: GHD (2009c)

A study by McKenzie et al. (2008) revealed epiphyte cover on seagrass at coastal sites in the Fitzroy River region were relatively low but higher with greater variability at estuarine sites, whilst macroalgae at coastal sites had decreased with high variability in estuarine sites throughout the study duration. Epiphytes and macroalgae fluctuate greatly at intertidal estuarine habitats and correlate highly with seagrass abundance and epiphytic cover is commonly associated with elevated nutrient levels (Burkholder et al. 2007).

Broad-scale macroalgae surveys were undertaken as part of deep water (> 6m) Port Curtis benthic community surveys in November 2013 to describe the presence or absence, percent cover and benthic algal types (identified according to Cribb (1996)) within Port Curtis. Algal community density categories were used to describe the algae habitat. Benthic macroalgal communities, as surveyed and mapped in November 2013 in Port Curtis, occurred in aggregated patches throughout the survey area and covered approximately 26,008ha (i.e. 28.7%) (refer Figure 7.21). Erect macrophytic, erect calcareous and filamentous algae were the dominant algal types (McKenna et al. 2014).

Algal habitats in the survey area were allocated to 5 density categories, with 11 different community types identified within these categories, which are provided in McKenna et al. (2014) and summarised in Table 7.21. Based on this, nine regions containing macroalgal communities were identified, based on their density and species diversity. These regions are outlined below and shown in Figure 7.21.

High density macroalgal communities (i.e. > 80% cover) were not identified in the 2013 survey area.

Significant areas (medium density) of habitat-forming algal communities occurred in both offshore and nearshore areas (refer Figure 7.21). Medium density algae communities coincided with regions of medium density benthic macroinvertebrate communities, and tended to be concentrated around habitat-forming 'live' and dead rock/rubble and reef (refer Section 11). This association was the driver behind the patches of higher algae biodiversity and density observed in the survey area.

Algal communities were divided into regions based on the density of taxa present in the video analysis and taxa that were collected in the sled net. Algal habitats in the survey area fell into five density categories, with eleven different community types identified within these categories, which are provided in McKenna et al. (2014) and summarised in Table 7.21.

Table 7.21 Project EIS baseline macroalgae survey sites

Density category	Community type	Description
Open substrate	**Region 0:** Open substrate with no algae present	▪ This region was used to describe areas where no algae were found ▪ This region was the most dominant in the survey area and covered approximately 64,684ha
Very low density macroalgae communities	**Region 2:** Mostly open substrate with very low densities of erect macrophytic and erect calcareous algae	▪ This was the lowest density category used to describe the algae regions within the survey area and covered approximately 2,486ha of the survey area ▪ There was only one community type in this category (i.e. Region 2) ▪ This region was located in the far east corner of the survey area ▪ The dominant algal type in this community was erect macrophytic algae, predominantly *Sargassum*

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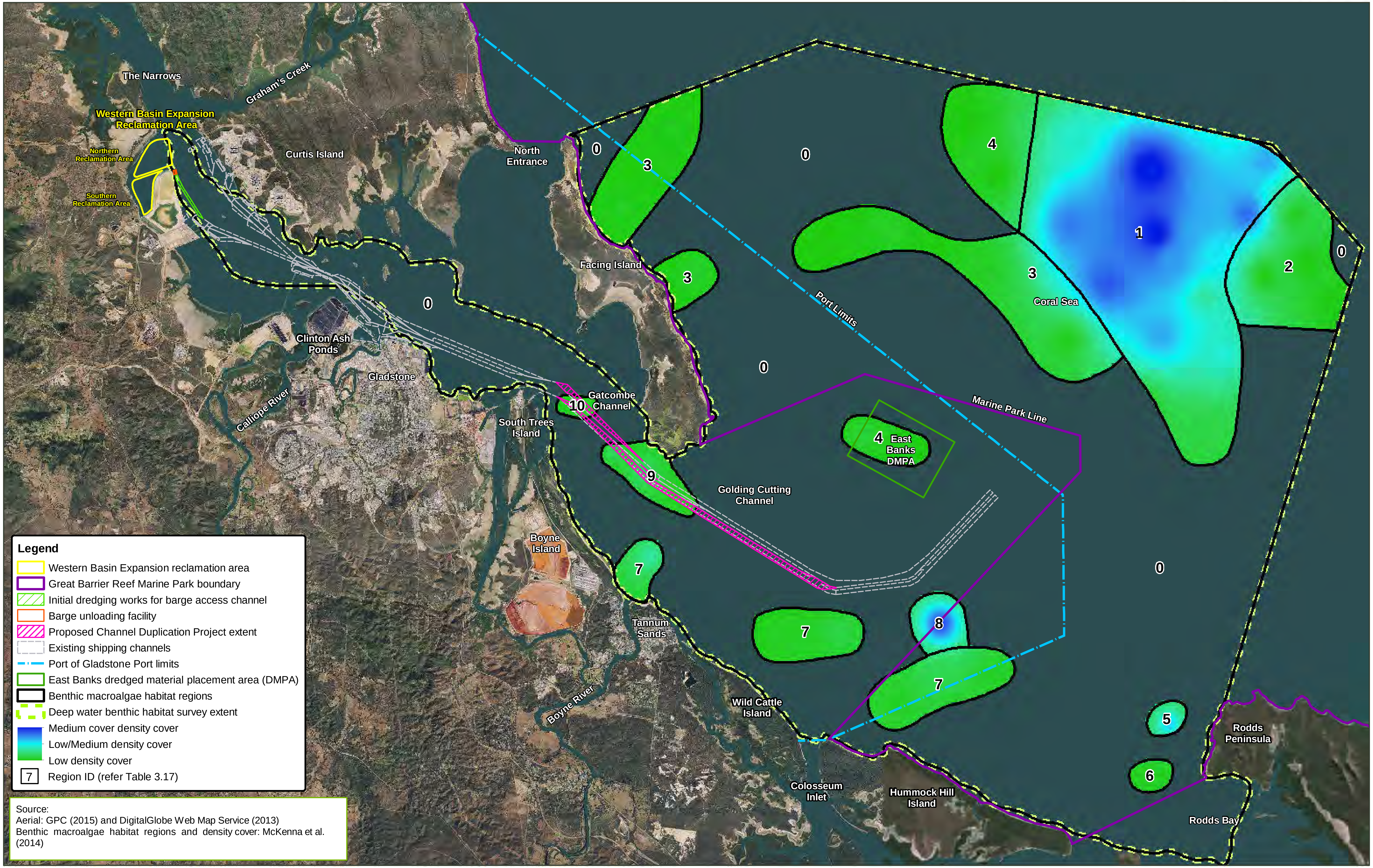

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Coordinate system: GDA_1994_MGA_Zone_56

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Figure 7.21: Location, density and distribution of benthic macroalgae within the Port Curtis region (November 2013)

Density category	Community type	Description
Low density macroalgae communities		▪ There were four community types in this density category that collectively covered approximately 8,715ha ▪ These community types occurred in both offshore and near shore areas
	Region 3: Mostly open substrate dominated by sand/shell with low densities of erect macrophytic, erect calcareous and filamentous algae	▪ This community type occurred in three areas on the offshore side of Facing Island ▪ Video footage of these regions featured large areas of sand dominated by erect macrophytic algae such as *Sargassum* and the calcareous algae *Halimeda*
	Region 4: Mostly open substrate dominated by rubble/rock with low densities of erect macrophytic and erect calcareous algae	▪ This community type covered approximately 2,412ha of the survey area and was located offshore on the northeast boundary of the survey area ▪ Video transects of this region featured relatively large areas of rubble and 'live' and dead rock from which erect macrophytes and erect calcareous algae were attached
	Region 6: Mostly open substrate dominated by mud with low densities of erect macrophytic algae	▪ This habitat type was found in the entrance to Rodds Bay and only consisted of erect macrophytic algae
	Region 10: Mostly open substrate dominated by rock with low densities of erect macrophytic and filamentous algae	▪ This community type occurred as a small area (approximately 150ha) in the areas to be dredged ▪ The community here was dominated by *Sargassum* and green filamentous algae attached to rock which was dominant in the area
Low/medium density macroalgae communities		▪ These four community types were located near shore between Tannum Sands and Rodds Bay
	Region 7: Patches of low/medium density erect macrophytic, erect calcareous and filamentous algae	▪ This community type occurred over three areas between Tannum Sands and Hummock Hill Island that collectively covered approximately 2,746ha ▪ The dominant algae in these areas was erect macrophytic algae which contributed to 65% of the algae taxa present
	Region 9: Patches of low/medium density erect macrophytic, filamentous, encrusting and erect calcareous algae; rock/rubble areas	▪ This community type was one of two areas that fell within the areas to be dredged ▪ This algal community type was associated with rock/rubble areas and covered 722ha ▪ Four of the five algae taxa were found in region 9
Medium density macroalgae communities		▪ There were three community types in this density category that collectively covered approximately 11,340ha ▪ The algal habitat in these regions consistently covered 20 to 80% of the total bottom area in the video transect ▪ These regions consisted of large areas of rubble, coral and 'live' and dead rock that formed significant benthic habitats
	Region 1: Medium density algae habitat dominated by erect macrophytic, erect calcareous and filamentous algae	▪ This community type was one of the largest community types in the survey area (approximately 10,598ha) and was found in the offshore areas east of Facing Island ▪ Region 1 occurred in the same area as medium density benthic macroinvertebrate communities

Density category	Community type	Description
	Region 5: Medium density algae habitat dominated by erect calcareous and encrusting algae	▪ This community type occurred at Rodds Peninsula and was one of the smallest community types in the survey area covering approximately 205ha ▪ The dominant algae in this region were erect calcareous algae mainly from the taxa *Halimeda*
	Region 8: Medium density algae habitat dominated by erect macrophytic and filamentous algae	▪ This community type was found in a relatively small area approximately 5km from Hummock Hill Island ▪ Erect macrophytic algae made up 65% of the algae taxa present with filamentous and encrusting algae making up the minor component of the taxa present

Table note:

Appendix D (Table 3) contains further details on the mean percent cover and percent of each algae type within the community type.

Source: Adapted from McKenna et al. (2014)

Many macroalgae species make important contributions to the construction of reef framework and are significant framework builders and framework 'cementers' on coral reefs (Diaz-Pulido et al. 2007). Coral reef surveys undertaken at five individual reef areas as part of the Project EIS baseline marine ecology data collection, surveyed approximately 424.3ha of reef area around Facing Island and Seal Rocks (Vision Environment 2015a). Among the 10 major substrate classes identified at all locations, the highest average cover was dominated by sediments (i.e. sand, pavement and rock: 55 ± 4.6%), followed by macroalgae (29 ± 3.5%), which was also identified as the dominant live form cover (Vision Environment 2015a).

Studies undertaken by BMT WBM (2013), albeit at different survey locations, found that reefs along Facing Island had up to 30% hard coral cover along with macroalgae cover between 19% to 45%. The highest percent of living substrate among reefs surveyed for the Project EIS comprised the macrolagae, *Sargassum* sp. (21%), while other macroalgae species included the brown algae genera (*Lobophora* sp.) (2.4%), and the red algae genera (*Asparagopsis* sp.) (1.9%). Similar findings were also reported by Ayling et al. (2012). Hard coral substrate was found to be the best correlation to explain fish community assemblages among survey locations in Port Curtis. Macroalgae was also correlated with fish assemblages between monitoring periods. A summary of Port Curtis reef community surveys and associated macroalgae are provided in Section 8 and Appendix J of this report.

7.7.3 Comparison between 2002 and 2013 macroalgae surveys

There has been one previous Port-wide survey of benthic communities to describe the presence or absence, percent cover and algal types, in terms of community density for benthic algae habitat (Rasheed et al. 2003) in Port Curtis. This survey was confined to the Port limits and Rodds Bay, and did not include the deep water offshore areas that were examined as part of the 2013 assessment. In the 2002 and 2013 benthic surveys, algae within the comparable survey area contributed only a minor component of the benthic communities. However, the occurrence and distribution of macroalgae within the comparable 2002 survey area was higher in 2013 than 2002 (McKenna et al. 2014; Rasheed et al. 2003). In 2002, macroalgae cover was low and did not form distinct community regions, as they did in 2013 (refer Figure 7.21) and were therefore not mapped in 2002 (Rasheed et al. 2003). In 2002, only two sites adjacent to Seal Rocks had significant macroalgae cover (5% and 10% cover), and these two sites incorporated sections of reef associated with Seal Rocks (Rasheed et al. 2003). These two sites were located in a similar area to Region 8 in the 2013 survey (refer Figure 7.21).

8 Reef communities

8.1 Background

Coral reefs are topographically complex structures created from the accumulation of calcium carbonate material, which provide microhabitats for a diverse assemblage of marine benthic flora and fauna (Hoegh-Guldberg et al. 2007). Scleractinian corals, also known as hard corals, are marine invertebrates which are the key building blocks of coral reefs and are typically the key calcium carbonate producers (Hoegh-Guldberg et al. 2007). Over 400 species of scleractinian corals are present in the Great Barrier Reef region, with typically between 30 and 90 species per reef (DeVantier et al. 2006). Those reefs situated inshore tend to be characterised by lower levels of diversity and dominated by the more sediment tolerant species. However, the combined size and diversity of the Great Barrier Reef is fundamental to its ecological integrity (DHI 2013).

The wider GBRWHA contains the world's most extensive coral reef ecosystem, with approximately 2,900 reefs. The Great Barrier Reef extends 2,000km along Queensland's coastline and covers an area of 345,000km^2 (Lucas et al. 1997). The Great Barrier Reef consists of a range of habitats and reef types from subtropical to tropical reefs, and extends across the continental shelf from inshore to offshore (Hopley et al. 2007). In 1981, the Great Barrier Reef became a world heritage site due to its high habitat and species diversity, and is protected by Commonwealth and Queensland Government legislation, policies and a comprehensive zoning system (Lucas et al. 1997). Despite high levels of protection, inshore reefs situated within 20km of the mainland are threatened by reductions in water quality, which has been linked to the recent degradation of a number of inshore reefs along the Great Barrier Reef (De'ath et al. 2012; Thompson et al. 2011).

The Port Curtis region (including the Port of Gladstone) is located within the GBRWHA designated by UNESCO. It is also located near the GBRMP which is managed by the Commonwealth Government statutory authority, the GBRMPA. 'Fringing Reefs', 'Inshore Turbid Reefs', and 'Coral species – diversity and extent' are each listed as OUV attributes of Port Curtis (Commonwealth of Australia 2013).

The Port Curtis region supports a wide range of reef habitat types, including fringing, platform, and headland reefs, as well as rubble fields (BMT WBM 2014a). Based on mapping from GBRMPA Gazetteer, Port Curtis contains 19 reefs made up of predominantly intertidal rocky shores or shallow subtidal reefs (BMT WBM 2014a).

Given that existing mapping significantly under-estimates the extent of subtidal reefs in the Port Curtis region (BMT WBM 2014a), spatial data provided by GBRMPA Gazetteer together with fine-scale, ground-truthed survey data from BMT WBM (2014a) and Vision Environment (2015a), have been combined to present the current known extents of coastal fringing reefs in the Port Curtis region (refer Figure 8.1) and in relation to the Project impact areas (refer Figure 8.2).

Table 8.1 outlines the reefs mapped in the Port Curtis region by the Great Barrier Reef Gazetteer along with names, individual reef numbers. The total area of reef habitat (those comprising reasonably developed hard structures), according to GBRMPA Gazetteer in the area is approximately 953ha.

Table 8.1 Locations of reefs mapped within Port Curtis region

Port Curtis zone/locality	Reef name	Reef number	Area (ha)
Inner harbour	Turtle Island	23-085	20.27
Mid Harbour	North Point Reef (Facing Island #1)	23-061A	58.08
	Facing Island Reef (#2)	23-061B	30.69
	Farmer's Reef	23-084	6.21

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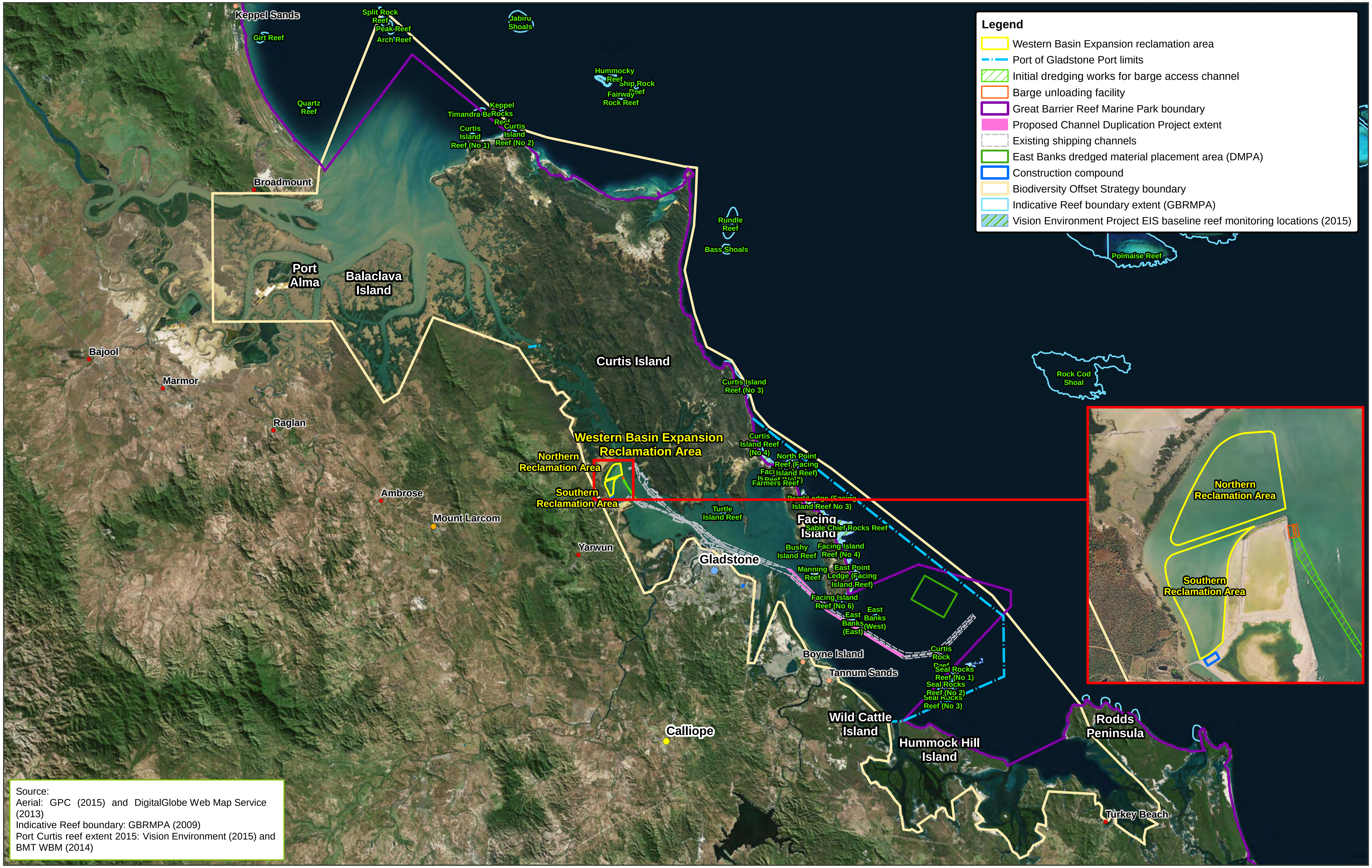

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Figure 8.1: Reefs of Port Curtis, Port Alma and offshore areas

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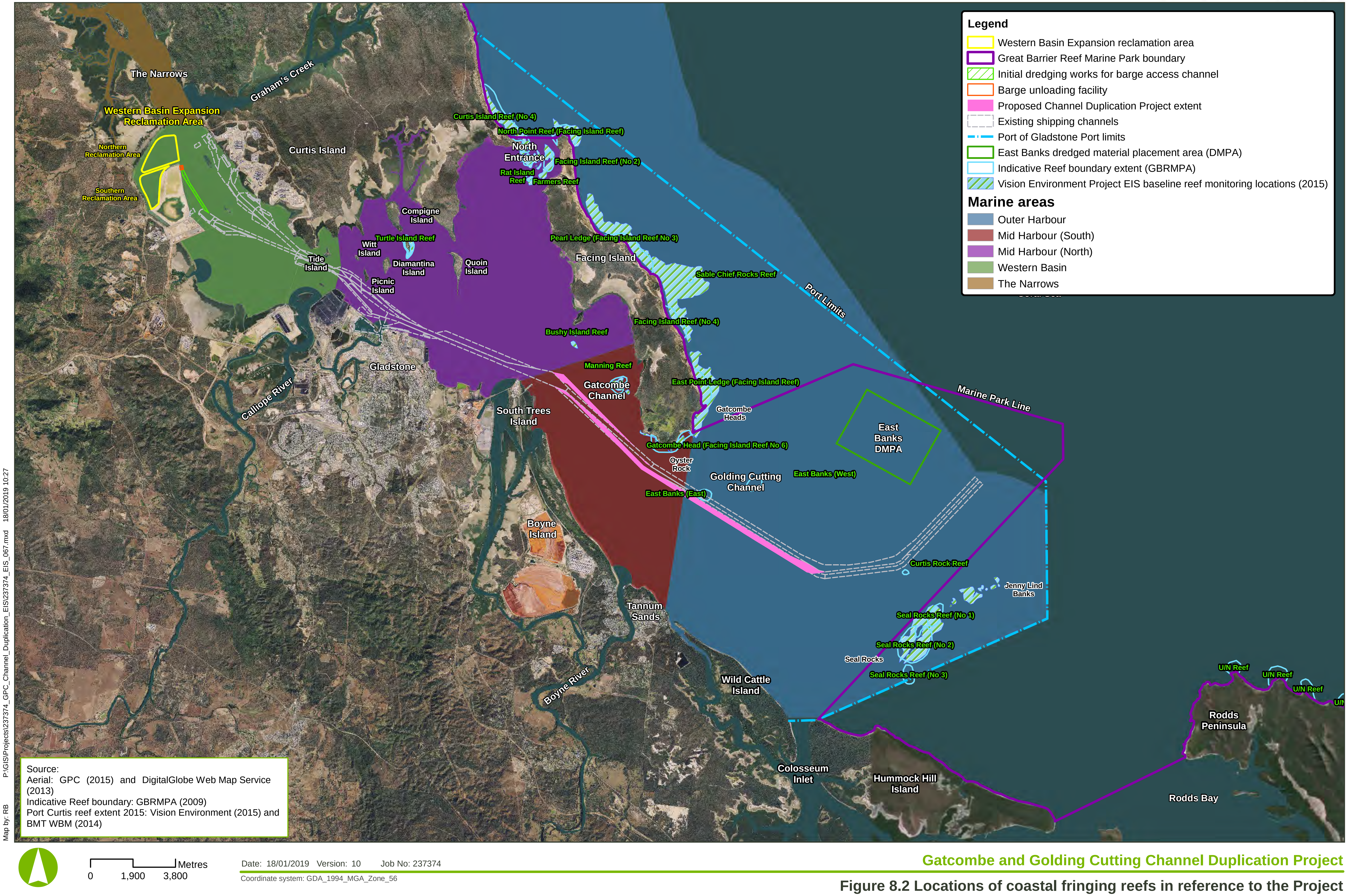

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Coordinate system: GDA_1994_MGA_Zone_56

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Figure 8.2 Locations of coastal fringing reefs in reference to the Project

Port Curtis zone/locality	Reef name	Reef number	Area (ha)
	Rat Island Reef	23-060	15.81
	Manning Reef	23-062	39.11
	Bushy Island Reef	23-086	2.09
	Curtis Island Reef #3	23-059C	166.31
Outer Harbour	Seal Rocks Reef #1	23-067A	45.35
	Seal Rocks Reef #2	23-067B	179.68
	Seal Rocks Reef #3	23-067C	34.74
	Curtis Rock Reef	23-066	4.4
	East Banks (East)	23-065A	24.42
	East Banks (West)	23-065B	29.17
	Facing Island Reef (#6)	23-061F	66.54
Eastern shore of Facing Island	Pearl Ledge (Facing Island Reef #3)	23-061C	104.01
	Sable Chief Rocks	23-064	4.71
	East Point Ledge (Facing Island Reef)	23-061E	70.06
	Facing Island Reef #4	23-061D	51.06
Total			**952.71**

Table note:

Areas are indicative only based on GBRMPA Gazetter mapping in BMT WBM (2014a)

It should be noted that the western shore of Facing Island has several unnamed reefs, and while several other rocky outcroppings exist in the Inner Harbour zone at the southern end of Curtis Island, around Diamantina Island and Witt Island, these locations have low to zero hard coral cover and have not been mapped by GBRMPA (BMT WBM 2014a). Reef communities with lower hard substrate cover made up of live and dead rubble/rock reef are also described in this section.

To the north of Port Curtis, reefs are located on the eastern shore of Curtis Island at Curtis Island Reef #3 (i.e. Black Head), and further north in Port Alma within Port limits at Timandra Bank and Curtis Island Reef #1 (BMT WBM 2014a). These reefs, along with other surrounding reefs, have been subject to surveys as part of BOS studies (refer section below for further detail).

8.2 Methodology

This section provides a description of the methodologies employed as part of these studies and investigations, with Section 8.3 outlining the findings and describing the current reef values within Port Curtis.

Several baseline desktop studies and ground-truthing investigations have been undertaken within the Gladstone region, and wider bioregion, to document the distribution and ecological values of hard benthic substrata and associated communities, including coral reef communities (refer Table 8.2). Desktop and field studies recently completed as part of GPC's Port Curtis and Port Alma ERMP and BOS also provide a substantial amount of up to date baseline information on reef communities in the Port Curtis region (refer Table 8.3).

Existing information sources and studies have been referenced to describe the reef community values within the Project direct impact areas (e.g. WB and WBE reclamation areas, barge access channel, BUF and areas to be dredged) and potential indirect impact areas (e.g. areas adjacent to the direct impact areas likely to be impacted as a result of the Project activities) (Project impact areas).

Along with a desktop review of available studies, targeted Project EIS baseline monitoring surveys were also undertaken in 2014 and 2015 at five reef locations in proximity to the Project impact areas.

Table 8.2 Information sources for coral and reef community values

Survey	Reference
Technical Report, Gladstone Harbour Report Card 2017	Gladstone Healthy Harbour Partnership (2017b)
Technical Report, Gladstone Harbour Report Card 2016	Gladstone Healthy Harbour Partnership (2016b)
Technical Report, Gladstone Harbour Report Card 2015	Gladstone Healthy Harbour Partnership (2015b)
Baseline Assessment of Benthic Communities (algae and macro-invertebrates) in the Port Curtis Region	McKenna et al. (2013)
Changes in Benthic Communities on Fringing Coral Reefs around Facing Island: August 2013	Ayling et al. (2013)
Development of Coral Indicators for the Gladstone Harbour Report Card, ISP014: Coral	Thompson et al. (2015)
GBRMPA Port of Gladstone Field Trip (23 to 24 September 2013) Site Inspection Report (Sable Chief Rocks Survey)	Baker (2014)
The Impact of Dredge Spoil Dumping on Fringing Coral Reefs Around Facing Island, August 2012	Ayling et al. (2012)
Mapping and Assessment of Seagrass and Coral Reefs for the Gladstone Ports Corporation Limited	Oceania Maritime Consultants Pty Ltd (2011)
Port Curtis Reef Assessment Report prepared for Queensland Gas Company	BMT WBM (2009)
Report for the Western Basin Dredging and Disposal Project: Marine Ecology Assessment. Appendix Q of the Port of Gladstone Western Basin Dredging and Disposal Project Environment Impact Statement	GHD (2009c)
Facing Island Reef Surveys	BMT WBM (2018)

Table 8.3 Reef studies undertaken as part of the Ecosystem Research and Monitoring Program and Biodiversity Offset Strategy

Survey	Reference
Prioritisation of reef restoration and enhancement sites – Phase 2 and 3 Report	BMT WBM (2015)
Identification of coral reef sites for Restoration and Enhancement – Phase 1	BMT WBM (2014a)
Central Queensland Corals and Associated Benthos: Monitoring Review and Gap Analysis	BMT WBM (2013)
Gladstone Coral Desktop Study: Distribution and Ecological Value of Corals and Coral Reef in the Gladstone and Wider Bioregion	DHI (2013)

8.2.1 Port Curtis and Port Alma Ecosystem Research and Monitoring Program study approach

BMT WBM (2013) conducted a review of existing information to identify trends in existing data and identify potential data gaps for reef environments between the Keppel group and Port Curtis, with a particular focus on the waters within and adjacent to Port Curtis and Port Alma (refer Figure 8.3).

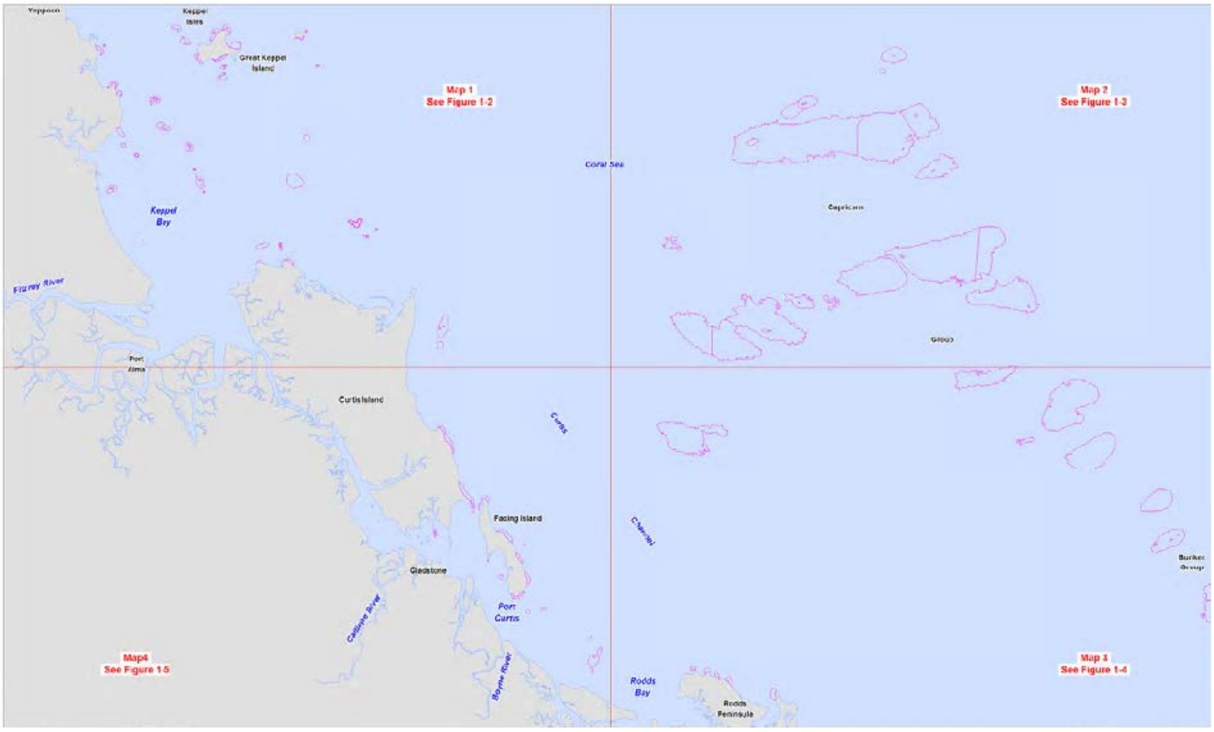

Figure 8.3 **BMT WBM (2013) study area for the Ecosystem Research and Monitoring Program report on Central Queensland corals and associated benthos**

Source: BMT WBM (2013)

The purpose of the report was to provide a basis for describing management aims and the subsequent development and application of monitoring programs in Port Curtis for the ERMP and BOS. A wide range of existing data sources were examined as part of the review, including:

- Searches of the Aquatic Sciences and Fisheries Abstracts bibliographic database
- A review of charts and other spatial data
- Internet-based searches for published and grey literature, and associated data
- Communications and data requests to researchers from Central Queensland University (CQU) and the Australian Institute of Marine Science (AIMS) who work within and adjacent to the study area.

The spatial data sources utilised by BMT WBM (2013) to provide a basis for mapping of the reef locations within the ERMP and BOS study area included:

- Navigation Chart 819 from the Australian Hydrographic Service showing known reefs
- Bathymetry and typography – Digital Elevation Models (DEMs) with 10m resolution for the surrounding area (BMT WBM 2013) and from Ryan et al. (2006) for Port Alma
- Gazetteer of Australia Reefs (Geoscience Australia 2013)
- Spatial data from Rasheed et al. (2002), which was rectified to coastline using MapInfo 10 software
- Location of survey points (e.g. observations, transect points) based on literature review, including past EISs for the LNG projects on Curtis Island.

These data sources were reviewed in GIS to show major bathymetric features, the extent of known reefs and areas of high density epibenthos, as well as the locations of previous surveys (BMT WBM 2013).

8.2.2 Prioritisation of reef restoration and enhancement

The summarised data from BMT WBM (2013) were used in the identification of potential reef restoration sites (BMT WBM 2014a) and subsequent prioritisation (BMT WBM 2015). These studies involved identification of a range of reef sites throughout Port Curtis and the wider BOS region as potential areas for restoration. Sites with known positions (where quantitative coral cover data existed) were revisited to investigate changes in community and health since prior survey. Sites with high-living coral cover investigated by BMT WBM (2009) and Ayling et al. (2012) were revisited.

Transect data (three replicate 25m transects) was taken from a selection of 15 sites. From each transect, 200 point identifications were made, consisting of 20 points each from 10 randomly selected photos. Cover and community data were analysed to show similarities among communities and changes in cover over time.

Broad-scale mapping of coral habitat was performed using ground-truthing from an additional 53 locations, aerial imagery from Google Earth, and data from BMT WBM (2013).

Catchment and hydrodynamic modelling were also performed for the Calliope and Boyne Rivers to examine the main drivers of change in coral cover and the effects of flood events in 2010-11 and 2013 to better inform the selection of potential sites for restoration.

8.2.3 Project reef baseline data collection

8.2.3.1 Targeted reef monitoring

Project EIS baseline monitoring was conducted by Vision Environment in 2014 (dry season) and 2015 (wet season) at five reef locations in Port Curtis. Reef monitoring sites were established in 2014 through a desktop assessment of historical information (e.g. Ayling et al. (2012) and Oceania Maritime Consultants (2011)), and information gained through Project EIS field studies for broad-scale benthic habitat mapping, undertaken by JCU TropWATER in November 2013 (McKenna et al. 2013).

Preliminary hydrodynamic modelling for the Project direct impact areas (BMT WBM 2014c) was used to generate a composite plot that provided a semi-quantitative indication of potential plume dispersion under a number of given dredging scenarios and assumptions. Targeted reef monitoring locations were established taking into account this preliminary modelling and maritime constraints (e.g. shipping channels). The reef communities selected for Project EIS targeted monitoring were:

- Oyster Rocks/Gatcombe Heads (East Point)
- Sable Chief Rocks
- Jenny Lind Banks
- Seal Rocks.

Surveys of these reefs were undertaken to record:

- Reef area and boundaries
- Reef attributes (i.e. species composition, percentage of cover, and substrate type)
- General reef health.

Permanent monitoring transects were established at four of the reef locations for subsequent repeat surveys, which have the potential to contribute to a Before, After, Control, Impact (BACI) design, to enable an assessment of potential impacts associated with the Project. High current and low visibility restraints at Oyster Rocks meant that a permanent transect was not established at this site.

Multiple 50m long belt transects were randomly established in the 2014 dry season. Photographic quadrats used to record information in the field and to be analysed in the lab. A number of transects (between 6 and 15 per location) were revisited during the 2015 wet season (January to March 2015) in order to determine if substrate communities had changed seasonally. Further information on sampling approach, data capture and analysis techniques (i.e. statistical analysis, community mapping and health assessments) are provided in Appendix J.

8.2.3.2 Baseline assessment of benthic communities in the Port Curtis region

A baseline epibenthic macroalgae and benthic macroinvertebrate habitat survey was conducted for the Project EIS by the JCU research entity TropWATER in November 2013. This survey used methods adapted from the original Port Curtis benthic habitat survey conducted by Rasheed et al. (2003). The full report, including detailed methodology, is provided in Appendix D.

8.2.4 Gladstone Healthy Harbour Partnership

The AIMS (2016) undertook surveys in July 2015 to assess the condition of coral communities in Port Curtis. Surveys were undertaken within the Inner Harbour, Mid Harbour and Outer Harbour zones aimed at locating suitable areas of coral habitat for the establishment, and baseline survey of permanent long term coral monitoring sites for future use in the GHHP Report Card. These surveys were conducted after the Project EIS reef surveys in January and March 2015.

In the Mid Harbour zone, monitoring locations were established at reefs around the North Entrance (Farmer's Reef, Rat Island and Facing Island reef #2) and off the southwest side of Facing Island at Manning Reef (refer Figure 8.2). In the Outer Harbour zone, two locations were established at Seal Rocks around Seal Rocks Reef #2 (refer Figure 8.2). Spot checks were also conducted around each of these areas to document reef characteristics.

No suitable areas for long term coral monitoring were found in the Inner Harbour zone due to limited hard coral communities and consistently poor visibility which would hinder any future survey efforts.

The methods used to monitor coral communities are consistent with those used by the Great Barrier Reef Report Card with a grading from A ('Very good') to E ('Very poor'). The scoring criteria considers the following indicators to calculate the coral score for the GHHP Report Card:

1. Coral cover (%): the combined cover of hard and soft corals relative to a baseline determined by the AIMS Reef Plan Marine Monitoring Program
2. Macroalgal cover (%): the cover of macroalgae relative to a baseline consistent with the MMP
3. Juvenile coral density (number per m^2): relative to the MMP baseline.

In 2017, a new indicator to monitor potential changes in hard coral cover, averaged over three years to give the rate at which hard coral cover increases (GHHP 2017b). This new indicator was included to provide a measure of the rate of coral recovery in Port Curtis.

8.3 Reef values

8.3.1 General context

The Port of Gladstone is a deep estuarine embayment, bounded by Curtis Island in the north and Facing Island in the east. Component estuaries, including the larger estuaries of the Calliope and Boyne Rivers, as well as The Narrows and Auckland Creek, merge with deeper waters to form a naturally sheltered, 30km long deep water harbour. The coastal region encompasses three broad shoreline types of rocky cliffs and shore platforms, sand beaches, and mudflats and mangroves which support a range of benthic communities, including intertidal soft sediments, rocky and coral reefs, seagrasses and soft corals.

The Port has three naturally formed connections with the sea being; the south channel between Facing Island and Boyne Island, the North Entrance between Facing Island and Curtis Island, and The Narrows between the mainland and Curtis Island (BMT WBM 2014a). The water exchange that occurs in the Port through these entrances is significant to the local coral communities because they allow seawater into, and fresher estuarine water out of, the natural harbour (BMT WBM 2014a).

Combined with very large deposits of silt from the hinterland in times of flood, the estuary maintains an existing highly turbid character. The areas of Port Curtis, Rodds Bay and the northern end of The Narrows are commonly described as having ‘naturally high turbidity’ with generally higher turbidity found within the shallow muddy environments adjacent to the coast line. This is largely evident during local tidal cycles with ebb tides typically containing increased turbidity levels and flood tides containing clearer waters (GPC 2012).

Higher turbidity can also be a result of resuspension by wind and wave action, and heavy rain/flood events. Port Curtis is a macro tidal estuary subject to a large tidal range (i.e. 4m to 5m), which ensures that the water column is vertically well mixed for most of the time, resulting in the natural resuspension of fine sediment (BMT WBM 2013). The estuary receives freshwater flows from the Boyne and Calliope Rivers, along with occasional flows through The Narrows from the Fitzroy River. As detailed in BMT WBM (2014a): ‘patterns in turbidity, sedimentation and salinity are major drivers of reef community structure within and adjacent to Port Curtis, reflecting the salinity tolerances and light requirements of reef biota’.

8.3.2 Reef distribution and extent

A wide range of reef and hard substrate habitat types exist within and adjacent to Port Curtis, including fringing, platform, and headland reefs, as well as rubble fields (BMT WBM 2013).

Map 17 of GBRMPA (2016) Marine Park Zoning identifies 19 reefs, which include subtidal reefs and intertidal rocky shores collectively, within Port Curtis (refer Figure 8.1 and Table 8.1). These reefs consist of Turtle Island in the Inner Harbour zone, Facing Island #2, North Point (Facing Island #1), Curtis Island Reef #3, Farmer’s Reef, and Rat Island Reef in the north of the Mid Harbour zone surrounding the North Entrance, and Manning Reef and Bushy Island Reef in the southern part of the Mid Harbour zone.

The Outer Harbour zone comprises various reefs around Seal Rocks Reef (including reef numbers 1, 2, and 3), Curtis Rock, East Banks (East) and East Banks (West) and Gatcombe Head (Facing Island Reef #6) at the southern tip of Facing Island. On the eastern side of Facing Island in coastal waters, significant reef assemblages are present at Pearl Ledge (Facing Island Reef #3), Sable Chief Rocks, East Point Ledge (Facing Island Reef #5), and Facing Island Reef #4 along with various other unnamed reefs (BMT WBM 2014a).

Various other reefs in and around Port limits exist to the north of Port Curtis, including reefs along the eastern shore of Curtis Island and in Port Alma (refer Figure 8.1). Some of these reefs have been subject to recent surveys as part of the BOS and, although outside of the Project impact areas, are useful in outlining the differing reef assemblages in the wider region.

Rock substrate, combined with clear oceanic water off Facing Island and Curtis Island, and the mouth of the Boyne River, provide conditions which support algal reef complexes often dominated by Phaeophyta (brown) and Rhondophyta (red) algae (GPC 2012). In some areas these combine with coral species to form complex reef systems (GPC 2012).

Coral reef distribution in Port Curtis is mostly limited to areas harbouring suitable substrate along with sufficient light penetration, such as the shallow intertidal zones surrounding Facing Island and Seal Rocks (DHI 2013; BMT WBM 2013). Coral communities are also abundant within deeper Port channels (> 5m), The Narrows and Passage Islands that are dominated by heterotrophic filter feeders and are believed to be the result of strong tidal currents which provide a food supply for filter feeders (BMT WBM 2013).

8.3.3 Community structure

Generally, the coral reef communities in Port Curtis are typical of fringing coral reefs on the southern inshore Great Barrier Reef, but also contain platform, headland and rubble field reefs, with both hard and soft corals (BMT WBM 2013). When compared to reefs in the northern Great Barrier Reef, or at mid-shelf or outer shelf areas, reefs in this region are generally lower in coral species richness, and tend to be made up of corals along with other benthic organisms (e.g. algae, sponges) growing on rocks or boulders (Ayling et al. 2012; GBRMPA 2007; DeVantier et al. 2006).

In an assessment of fringing coral reefs around Facing Island, Ayling et al. (2012) reported that sites from reefs along the eastern and southern extremities of Facing Island clustered together and were dominated by taxa known to tolerate turbid conditions, such as faviids, *Turbinaria*, poritids and soft corals (refer multi-dimensional scaling plot of coral communities in Figure 8.4) (BMT WBM 2014a). Taxa such as *Montipora, Acropora* and *Pocillopora,* found at Rundle Island, were reported as clustered to the far right of the plot in Figure 8.4. Curtis Island sites at Black Head were dominated by sponges and had extremely low hard coral cover (BMT WBM 2014a).

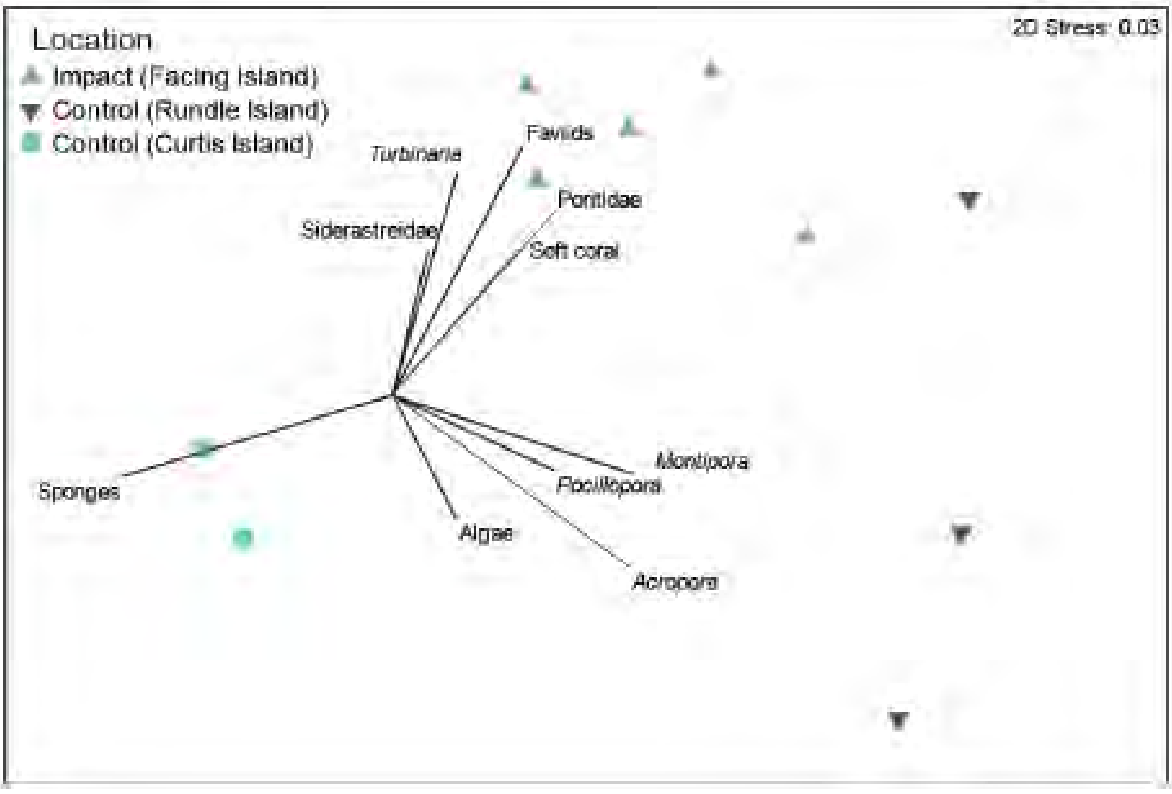

Figure 8.4 **Multi-dimensional scaling plot of coral communities**

Figure note: The plot represents Bray-Curtis Resemblance and data are log (x+1) transformed.

Source: Ayling et al. (2012)

Figure 8.5 displays the differences in broad cover categories (i.e. hard coral, soft coral, algae and other invertebrates) in a multi-dimensional scaling plot of Euclidean distances among site-averaged reef communities of Port Curtis, from sites surveyed by Ayling et al. (2012) and BMT WBM (2009). While the main window in Figure 8.5 describes communities based on distances (i.e. points that are close together represent similar communities and points that are far apart represent different communities), the bubble plots below the main window illustrate relative differences in cover at each of these reefs. The area of each bubble is scaled to show average percent cover (BMT WBM 2014a).

The results of these analyses indicate that the majority of the reefs surrounding Facing Island were similar in terms of the cover of broad community types (i.e. they had moderate hard coral cover, moderate algal cover, low soft coral and other invertebrate cover (BMT WBM 2014a)). Sites at Manning Reef and Farmer's Reef on the western side of Facing Island were exceptions to this, exhibiting a high cover of hard coral and soft coral, respectively. On the eastern side of Curtis Island, the reef at Black Head exhibited a large number of sponges, but very little hard or soft corals. Reef communities at Turtle and Diamantina Islands differed from most other sites, although they were similar to one another, as they had little coral cover and large algal cover (BMT WBM 2014a).

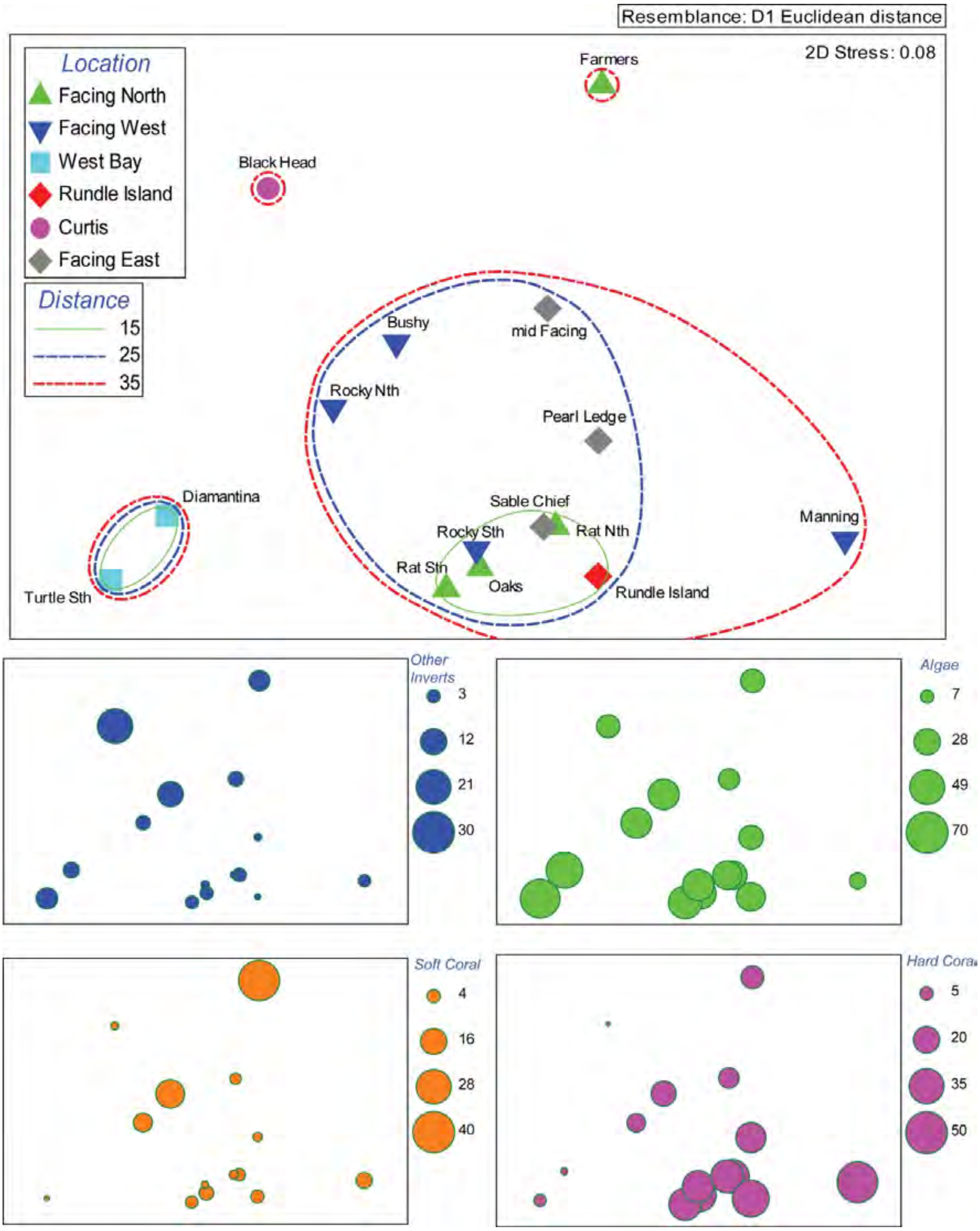

Figure 8.5 **Multi-dimensional scaling plot of Euclidean distances among site-averaged reef communities of Port Curtis**

Figure notes:

Reefs in close proximity tend to have similar communities.
Bubble plots below the main ordination show relative percent cover values with larger bubbles indicating higher cover.

Source: BMT WBM (2013)

8.3.4 Coral cover and condition (2009)

The study for the *Port Curtis Reef Assessment Report* (BMT WBM 2009) conducted subtidal assessments at 10 reefs within Port Curtis, representing the majority of reefs west of Facing Island. As outlined in BMT WBM (2014a), the key findings of the 2009 Port Curtis reef assessment report were:

- The benthic coral reef fauna assemblages of Port Curtis generally occur from the lower intertidal limit to a depth not usually exceeding 2m below the low water mark/datum
- Reefs located in North Entrance and along the western side of Facing Island typically comprise of a high proportion of hard coral cover, with a maximum value of > 47% cover (mean = 39%)
- At the two nearshore, turbid fringing reef sites (i.e. Turtle and Diamantina Islands) hard coral was low (average = 4%), and incidental observations indicated that coral colony size was typically small (< 15cm diameter)
- Coral cover within Port Curtis was consistent with patterns observed at other fringing reefs within the broader region (e.g. Shoalwater, Percy Islands, Prudhoe Island) (BMT WBM 2014a).

8.3.5 Coral cover and condition (2012 and 2013)

Ayling et al. (2012) assessed the potential impact of offshore dredged material placement on reef communities at five sites east of Facing Island (i.e. Gatcombe Head (Rocky Point), Curtis reef #4, Sable Chief Rocks and Pearl ledge); two sites at Black Head on Curtis Island (control sites); and three sites at Rundle Island (control sites) (BMT WBM 2014a). Four replicate transects were sampled at each site in 2011 and 2012 both before and after the placement of the dredged material placement at the existing East Banks DMPA (refer Figure 8.2). The methodology adopted for the study was comparable to BMT WBM (2009), utilising diver-based line intercept or point-intercept calculations (BMT WBM 2014a).

The results of Ayling et al. (2012) identified that hard coral cover was highest at Rundle Island (39.5%) and lowest at Black Head on Curtis Island (0.4%), with reefs along the eastern side of Facing Island averaging approximately 20% cover (BMT WBM 2014a). In addition to this, no significant difference in hard or soft coral cover between the two time periods could be observed, therefore suggesting that no impact was observed (BMT WBM 2014a).

Available coral cover data for Port Curtis reefs were summarised in BMT WBM (2013) from quantitative surveys conducted by BMT WBM (2009) and Ayling et al. (2012). The study found hard coral cover was highest at reefs along the southwest tip of Facing Island (Gatcombe Reef and Manning Reef), Seal Rocks, and Rat Island near the North Entrance between Facing Island and Curtis Island. Hard coral cover was lowest at Black Head Reef on Curtis, Island, followed by Turtle Island (BMT WBM 2014a). Living hard coral cover data over these reefs was presented as an interpolation over the GBRMPA Gazetteer reef layer in Figure 8.6.

Reef sites were again surveyed in 2013 as part of dredged material placement impact studies which found high coral cover on Rundle Island sites (50% cover) and moderate cover on Facing Island sites (28%) (Ayling et al. 2013). A rapid increase in macroalgal cover at Facing Island sites was recorded from 2011 to 2013, compared to macroalgae at control sites which only increased from 2011 to 2012, but not over 2013 (Ayling et al. 2013). Overall coral cover increased at most impact and control sites over the three year survey period with a higher average rate of increase at Rundle Island sites (43%) than Facing Island sites (11%) (Ayling et al. 2013).

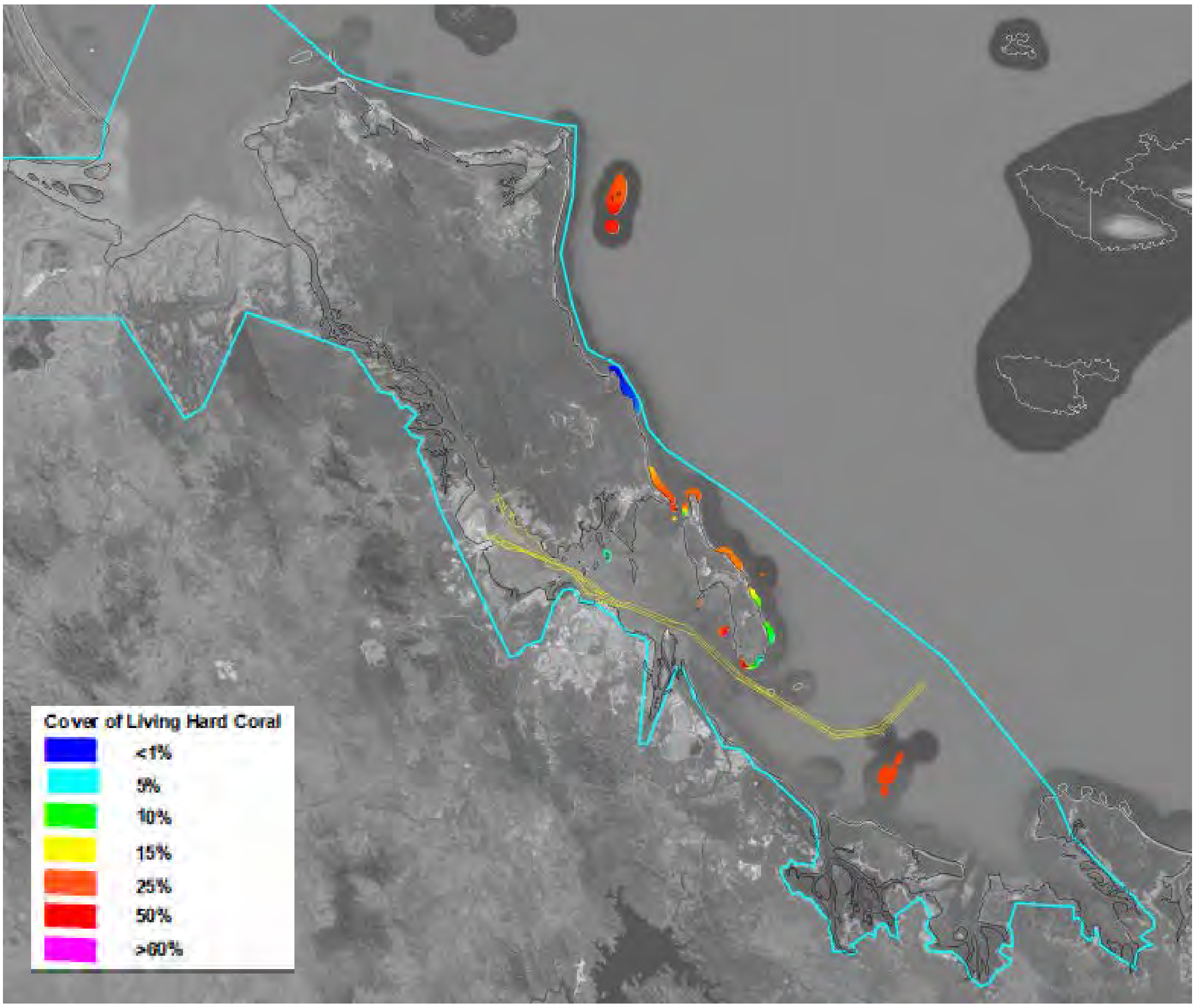

Figure 8.6 **Interpolated hard coral cover in Port Curtis and Biodiversity Offset Strategy boundary**

Source: BMT WBM (2014a)

8.3.6 Coral cover and condition (2014)

Field investigations by BMT WBM in 2014 showed that there had been dramatic reductions in hard and soft coral cover since 2009 in some parts of Port Curtis, particularly west of Facing Island (BMT WBM 2015). East of Facing Island (sites visited by Ayling et al. 2012), there were no noticeable changes in communities or cover (BMT WBM 2015). Examples of these changes are shown pictorially in Figure 8.7.

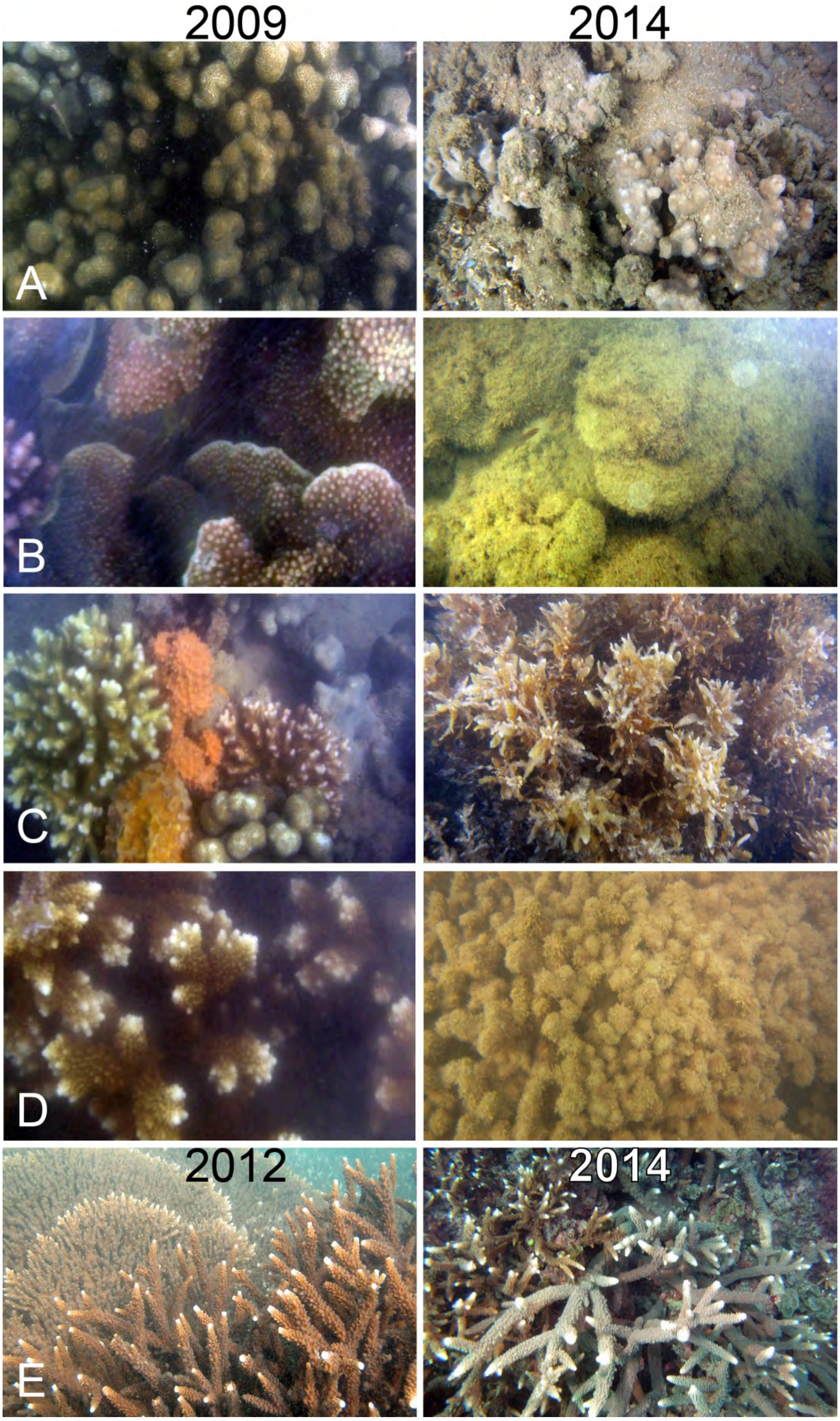

Figure 8.7 **Photographic examples of changes in condition between 2009 and 2014: (A) Oaks Reef (i.e. Facing Island #2); (B) Bushy Island; (C) Rat Island South; (D) Manning Reef; (E) Sable Chief Rocks Reef**

Source: BMT WBM (2015)

Some examples of these changes from BMT WBM (2015) include:

- Extensive *Porites* colonies at Facing Island #2 in 2009 were still present in 2014, but cover was greatly reduced and colony colour appeared lighter (Figure 8.7A)
- Significant reductions in coral cover were observed at Bushy Island (Figure 8.7B) where dense *Turbinaria* had been replaced by turfing algae
- Reefs in the vicinity of North Entrance, including Rat Island Reef south, had significantly more macroalgae (mostly *Sargassum*) than they did in 2009, and coral genera such as *Pocillopora* (Figure 8.7C) were absent in 2014
- Significant reductions in coral cover were widespread at Manning Reef (Figure 8.7D), including sites which had formerly had the highest coral cover of any reef in Port Curtis.

Sites east of Facing Island, such as Sable Chief Rocks Reef, had similar cover and community metrics to when they were last surveyed in 2012 (refer Figure 8.7E). The changes in community, specifically with respect to major benthic cover groups are shown in Figure 8.8.

Coral cover was substantially lower in 2014 than 2009 at many sites in Port Curtis (e.g. Bushy Island, Manning, Oaks, Rat South, Rat North, Rocky Point South and Turtle Island reefs). East Point Ledge also had slightly lower hard coral cover in 2014 than 2012. Changes in hard coral cover on the eastern side of Facing Island at Gatcombe (east), Facing Island #4, Pearl Ledge were within the range of standard error variability, suggesting that changes in cover over time were not likely to be statistically significant. Estimates of hard coral cover at Sable Chief Rocks Reef were very similar between 2012 and 2014 (BMT WBM 2015).

Reefs in Port Curtis that experienced large reductions in hard coral cover were located within a zone of impact predicted by hydrodynamic modelling (BMT WBM 2015). Salinity thresholds derived by Berkelmans et al. (2012) were overlain on modelled plume outputs from the 2013 flood and these were consistent with areas of impact. It is likely that reefs west of Facing Island and Seal Rocks Reef are in a state of recovery after major freshwater plume impacts from 2013 (BMT WBM 2015).

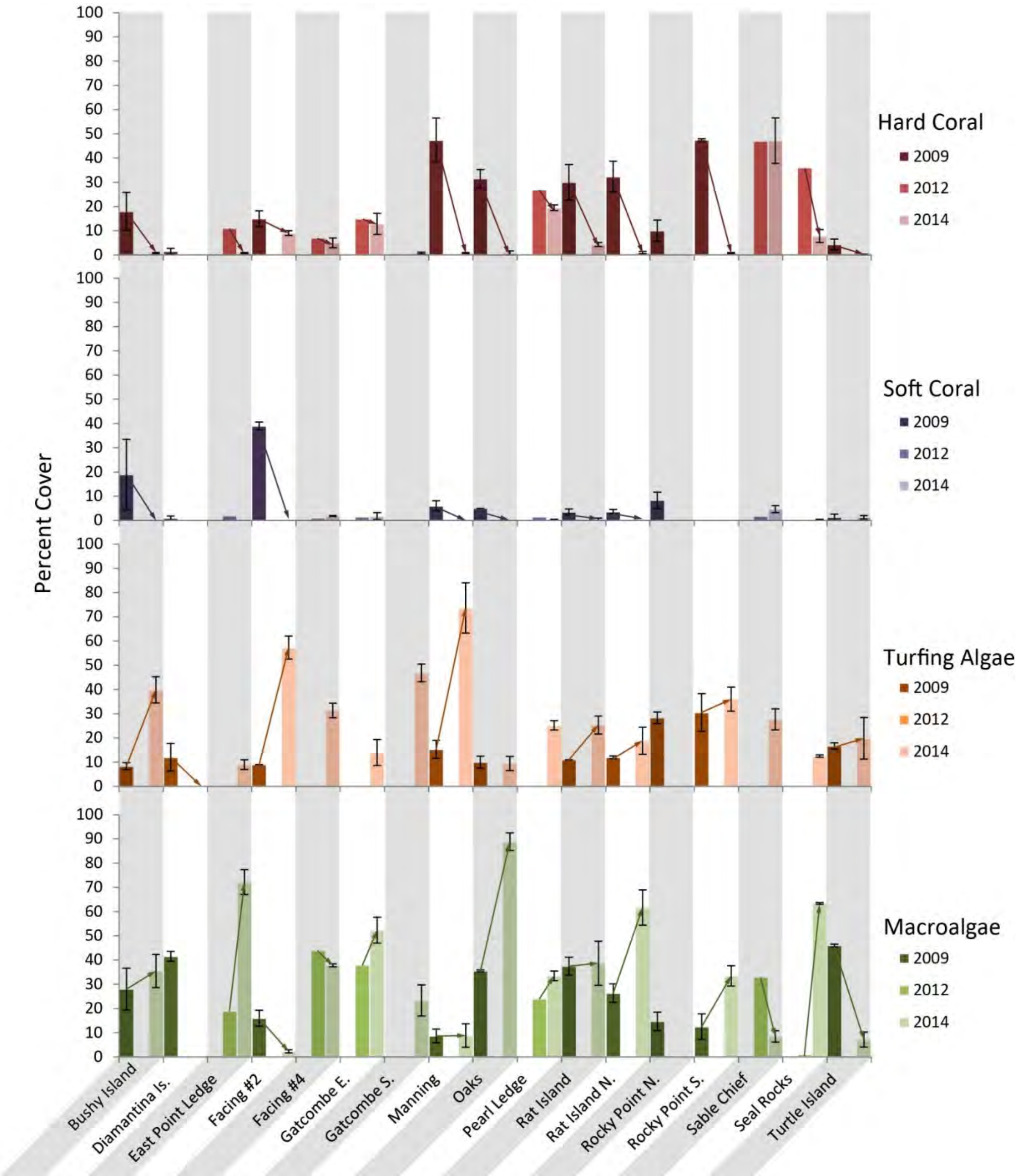

Figure 8.8 **Changes in mean (± se) percent cover for hard coral, soft coral, turfing algae and macroalgae**

Figure note: Means without error bars for Facing Island sites in 2012 have been estimated from Ayling et al. (2012), and Seal Rocks 2012 data is from Baker (2014)

Source: BMT WBM (2015)

8.3.7 Coral indicators for the Gladstone Harbour Report Card

8.3.7.1 Content of section

The surveys undertaken in July 2015 by AIMS to assess the condition of coral communities in Port Curtis characterised the coral environments within the Inner Harbour, Mid Harbour and Outer Harbour Zones. Sections 8.3.7.3 to 8.3.7.5 outline the results of these surveys for localities within these zones. Section 8.3.7.5 provides a summary of the GHHP coral monitoring results for 2015 through to 2017.

8.3.7.2 Inner Harbour

No suitable sites for long term coral monitoring could be found in the Inner Harbour zone with surveys around Quoin Island, Turtle Island and Diamantina Island, finding limited hard substrate *'primarily of broken rock and occasional small dead coral colonies colonised by a mixed community of macroalgae and small heterotrophic soft corals'* (Thompson et al. 2015). High turbidity and low visibility substantially restricts the ability to conduct coral surveys at these sites. At best any coral colonies at these sites would be small and patchily distributed (Thompson et al. 2015).

Quoin Island

There was no evidence of corals or hard substrates required to support coral communities. Anecdotal evidence suggests the northern end of Quoin Island adjacent to the spit has supported coral communities previously (Thompson et al. 2015).

Diamantina Island

Some small dead colonies of hard coral of the genus *Turbinaria* were found around the eastern and southwestern side of the island but no live hard corals were found. Some small heterotrophic Gorgonian like soft corals were observed in places. Macroalgae genus *Asparagopsis* and *Lobophora* were common amongst the rocky substrates. Substrate was mostly small rocks interspersed by silt deposits (Thompson et al. 2015).

Turtle Island

Similar substrate and communities to those described for Diamantina Island were recorded around the southwestern and southeastern sides of Turtle Island. No evidence of substantial dead or live coral communities was found. Water was highly turbid with limited visibility during inspections (Thompson et al. 2015).

8.3.7.3 Mid Harbour

Rat Island

A narrow fringing reef on the southern side of the island was identified as having the highest density of both living and dead standing corals and a baseline monitoring site was established here. Coral cover percentage was predominantly the coral family Faviidae with a small percentage of *Turbinaria* and Poritidae. Around the eastern and northern aspects of Rat Island were scoured hard rocky substrate interspersed with sand patches. Cover of live and dead coral was lower in these areas. The western face was rubbly and shallow with a strong current. The dead hard corals recorded were mostly *Acropora* and *Turbinaria* (Thompson et al. 2015).

In 2016, Rat Island Reef was the only reef that received a poor score compared to a very poor score for all the other surveyed reefs for the macroalgal cover (GHHP 2016b).

Farmer's Reef

A monitoring site was selected on the northern aspect of the reef with live and dead corals recorded on areas of hard substrate patchily distributed in a sandy area. Coral cover percentage was predominately Faviidae with a small percentage of Poritidae. Some live and dead corals were observed on the eastern side which runs through a channel. The south and west aspects were shallow and sandy. The dead corals recorded were mostly *Porites* and *Turbinaria* and the family Faviidae (Thompson et al. 2015).

In 2016, macroalgae cover at Farmer's Reef was predominantly composed of the red algae *Asparagopsis* (GHHP 2016b). There was an increase from 4% cover in 2015 to 36% cover in 2016 at Farmer's Reef (GHHP 2016b).

Facing Island #2

A monitoring site was selected on the southeastern face of the reef, an area characterised by a mix of dead and live coral community. Coral cover percentage was predominantly Poritidae with small percentages of Faviidae and Siderastreidae. The dead community was predominantly comprised of branching and corymbose forms of the genus *Acropora* and also the genera *Turbinaria* and *Porites*. The western aspect of the reef was hard rocky substrate and the northern aspect was a patchy rocky and sandy substrate with low cover of live and dead corals (Thompson et al. 2015).

There was also a high cover of macroalgae which was dominated by the large brown algae genera *Sargassum* and *Lobophora* in both 2015 and 2016 (GHHP 2015b; 2016b).

Manning Reef

A monitoring site was selected on the northern side which is characterised by an area of hard substrate. Dead coral colonies, mostly of the branching genus *Acropora* are present across the whole site suggesting previous high coral cover at this reef (Thompson et al. 2015).

Macroalgae cover at Manning Reef was predominantly composed of the red algae *Asparagopsis* (GHHP 2016b; 2017b).

Bushy Island

Coral communities were deemed too limited to conduct long term monitoring at this site with only one small (~ 20cm) living colony of *Porites* recorded. Spot checks identified dead corals over a narrow band of substrate between the intertidal and muddy subtidal area. Dead standing corals included the genus *Turbinaria*, *Porites,* and branching forms of *Acropora* and *Porites* (Thompson et al. 2015).

8.3.7.4 Outer Harbour

Seal Rocks

One monitoring site was established on the northern side of the reef which was composed of dead standing corals with moderate cover of macroalgae interspersed by patches of sand. Large amounts of dead branching, corymbose and tabulate forms of the genus *Acropora* and also *Turbinaria* were recorded suggesting previous high living coral cover at this reef (Thompson et al. 2015).

Another monitoring site was established on the southwestern aspect of the main rocky area of Seal Rocks. This location comprised an area of living corals mostly of the genus *Turbinaria* with small a percentage of *Pocillopora* and families Faviidae and Acroporidae. The substrate comprised dead standing coral and patches of sand (Thompson et al. 2015).

Other spot checks of the reef found rocky substrate with lower cover of live and dead corals and very high cover of the brown macroalgae *Sargassum* and *Lobophora* on the southeastern side of the main rocky area, consistent with Project EIS surveys completed by Vision Environment in 2014 and 2015. The location of Seal Rocks Reef (#3) as mapped by GBRMPA Gazetteer was found to be primarily a sand bank (Thompson et al. 2015).

In 2015 and 2017, the high cover of macroalgae at Seal Rocks was dominated by the large brown algae genera *Sargassum* and *Lobophora* (GHHP 2015b; 2017b).

East Banks

No signs of hard substrate that would serve as coral habitat were identified from surface observations and side scan sonar surveys at the locations mapped as reef by the GBRMPA Gazetteer as East Banks (East) and East Banks (West) (refer Figure 8.2). This area is composed of large sand banks that are washed by very strong currents on both falling and rising tides (Thompson et al. 2015).

8.3.7.5 Coral indicator monitoring results

Coral communities in both the Mid Harbour and Outer Harbour received a grade of ‘E’ (Very poor) for the 2015 survey (GHHP 2015b). ‘Poor’ or ‘Very poor’ gradings were given for most monitoring criteria reflecting low cover of living corals, low abundance of juvenile corals and high cover of macroalgae at most reefs surveyed (refer Figure 8.9 and Figure 8.10).

The current condition of coral communities in Port Curtis is thought to almost certainly be a result of the large freshwater influx caused by the flooding event in January 2013 (Thompson et al. 2015). Coral genera *Acropora* and *Pocillopora*, which are sensitive to disturbances such as low salinity, were present in dead coral communities at most sites surveyed. It is quite typical of nearshore reefs of the Great Barrier Reef to experience low coral cover and macroalgal dominance following a severe disturbance such as a flooding event (Thompson et al. 2015). While still quite low, the density and diversity of juvenile corals recorded indicates that recovery of coral communities is underway with *Acropora* and *Pocillopora* corals observed to be recruiting to most reefs (Thompson et al. 2015). A brief description of the reef areas in Port Curtis that were investigated by AIMS is provided below.

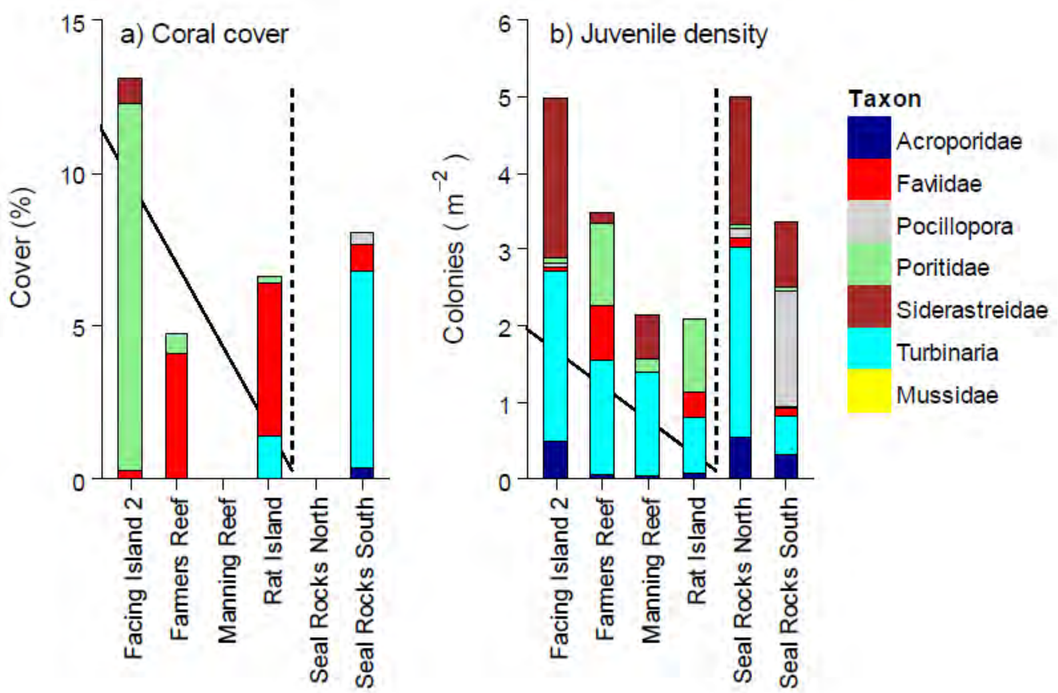

Figure 8.9 **Taxonomic composition of coral communities at monitoring locations represented by Proportional cover of the substrate (a) and Numbers of colonies < 10cm in diameter (b)**

Source: Thompson et al. (2015)

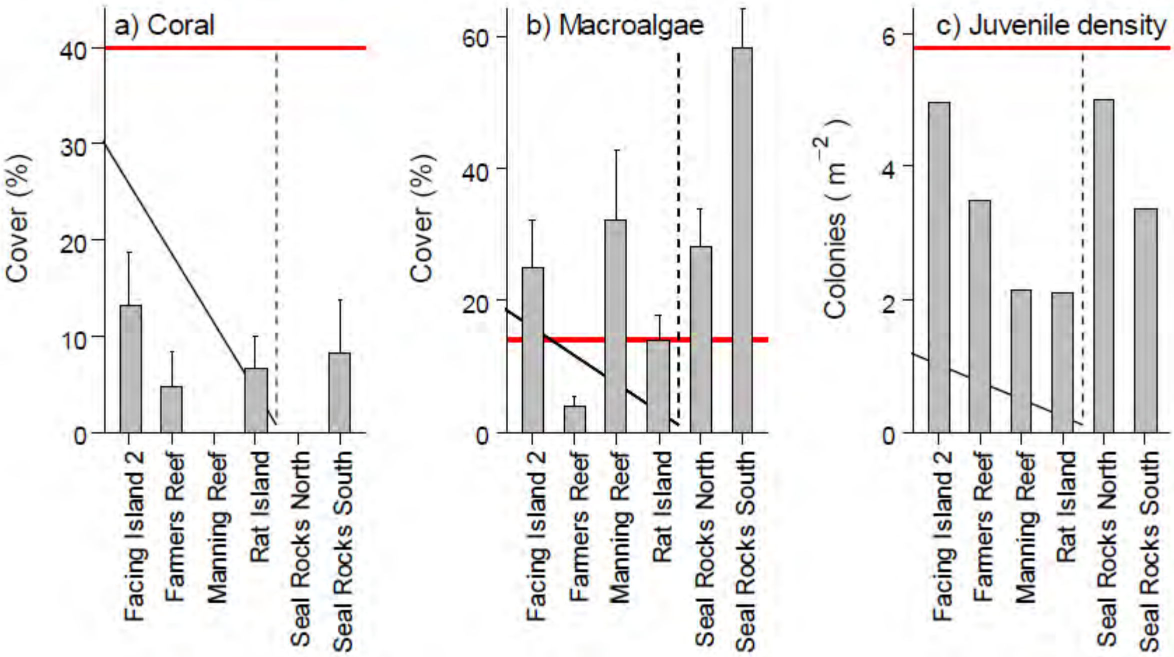

Figure 8.10 **Observations of each report card indicator Proportional cover of substrate occupied by corals (a), Proportion cover of substrate occupied by macroalgae (b) and Density of corals < 10cm in diameter standardised for available settlement substrate (c)**

Figure note: For each criterion the thresholds limit set at the C to D grade boundary is represented as a red horizontal line, noting that for coral cover and juvenile density values below the threshold are in worse condition while values of macroalgal cover higher than the threshold are considered to be in worse condition.

Source: Thompson et al. (2015)

In the 2016 report card, the overall coral grade was an 'E' (Very poor) (GHHP 2016a). This result was due to the low cover of living coral, low abundance of juvenile corals and high macroalgal cover at the majority of surveyed sites (GHHP 2016b). The overall score for coral in 2016 (0.12) was similar to the score for coral recorded in 2015 (0.15) (GHHP 2016b). The specific rating for the density of juvenile corals (i.e. based on a harbour-wide mean density) improved in 2016, with the 2015 grade being 'Very poor' to a score of 'Poor' in 2016 (GHHP 2016b). Macroalgal cover was high at all reefs in 2016 in comparison to the results from 2015, resulting in a grade of 'Very poor' in 2016 (GHHP 2016b).

In the 2017 report card, the overall coral grade was a 'D' (Poor), which is an improvement on the overall coral grade for 2016 ('E' (Very poor)) (GHHP 2017a). The coral cover received the same score as in 2016, and there were small improvements in the score for juvenile coral density and macroalgal cover (GHHP 2017b). Juvenile coral density and macroalgal cover recorded in 2017 are similar to those recorded in previous years (GHHP 2017b).

8.3.8 Project EIS baseline reef monitoring

8.3.8.1 Substrate cover

As part of the Project EIS, baseline reef monitoring occurred in 2014 and 2015 at five reef locations, which were selected for targeted analysis (refer Figure 8.11). The purpose of the Project EIS baseline reef monitoring is to understand and document the existing reef environment values within and adjacent to the Project impact areas, to enable an assessment of potential impacts associated with the Project (refer Appendix J).

A total area of 424.3ha was classified as potential reef area (based on visual map inspections) within the baseline reef monitoring area (Vision Environment 2015a). The largest area of reef was encountered at Sable Chief Rocks (~208ha or 49% of the total area observed) and the smallest area of reef (< 2ha or < 1%) at Oyster Rocks (refer Table 8.4). These surveys also demonstrate that GRMPA (2016) mapping underestimates the current areas of coral reefs in Port Curtis.

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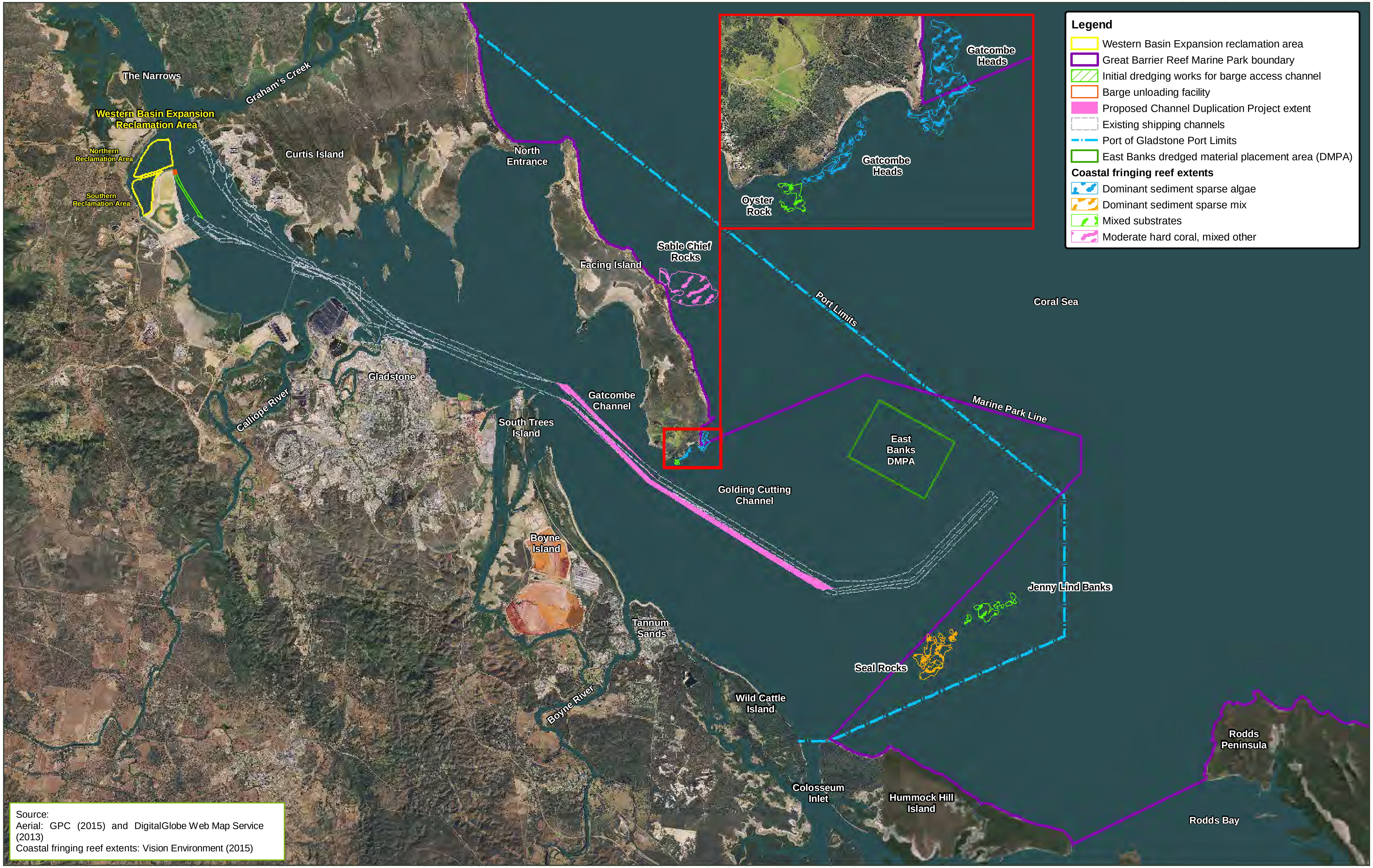

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Metres
0 1,900 3,800

Date: 17/01/2019 Version: 9 Job No: 237374

Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 8.11: Project EIS baseline reef monitoring areas

Table 8.4 **Total extent of reef area for each location included in Project EIS baseline reef monitoring**

Location	Area (ha)
Oyster Rocks	1.8
Gatcombe Heads	18.1
Jenny Lind Banks (Seal Rocks Reef #3)	66.7
Seal Rocks	130.1
Sable Chief Rocks	207.6
Total area	**424.3**

Source: Vision Environment (2015a)

Ten major substrate classes were identified among all locations with four classes pooled (turfing algae, seagrass, other biota and unknowns), due to low cover (Vision Environment 2015a). The highest average cover (with plus or minus standard error (± se)), was sediments (i.e. sand, pavement and rock: 55% ± 4.6%), followed by macroalgae (29% ± 3.5%), and hard corals (13% ± 6.4%), with the lowest major classes (< 2%) consisting of soft corals, sponges and ascidians, and other biota (refer Table 8.5 and Appendix J).

Pavement cover (i.e. rock, rubble and/or sediment) percentages identified in the baseline reef monitoring program were similar to results from a number of studies conducted to the south of the Project potential impact area, encompassing reefs from Elliott Heads to Rodds Bay (Alquezar and Boyd 2007; Alquezar et al. 2007; 2011). The studies found similar pavement cover (40% to 60%), however, dominant live substrate cover included soft corals (30% to 40%) and macroalgae, which was in contrast found in very small amounts at most study reefs for the baseline reef monitoring program (Vision Environment 2015a). The monitoring program identified macroalgae as the dominant live form cover (~29%), followed by hard coral cover (13%) (Vision Environment 2015a).

This suggests that coastal fringing reefs within Port Curtis are quite different to coastal reefs further south along the coast.

Table 8.5 **Mean percent dominant substrate cover among locations (June to August 2014 (dry season) and January to March 2015 (wet season))**

Major substrate classes	Jenny Lind Banks	Oyster Rocks	Gatcombe Heads	Sable Chief Rocks	Seal Rocks	All sites
Sediment (%)	56.4 ± 6.0	53.4 ± 11.0	61.2 ± 4.0	37.8 ± 4.6	67.6 ± 5.5	55.3 ± 4.6
Macroalgae (%)	32.6 ± 5.8	40.0 ± 12.2	29.9 ± 4.5	19.3 ± 2.8	20.8 ± 3.7	28.5 ± 3.5
Hard coral (%)	5.9 ± 1.2	4.1 ± 2.7	4.5 ± 1.2	41.0 ± 6.4	9.7 ± 2.7	13.1 ± 6.4
Soft coral (%)	4.4 ± 1.5	1.0 ± 0.4	0.7 ± 0.2	0.9 ± 0.3	1.5 ± 0.5	1.7 ± 0.6
Sponge and ascidians (%)	0.3 ± 0.1	1.0 ± 0.7	2.2 ± 0.7	0.6 ± 0.3	0.2 ± 0.1	0.9 ± 0.3
Other biota (%)	0.9 ± 0.5	0.5 ± 0.5	1.9 ± 1.4	1.6 ± 0.5	0.8 ± 0.4	1.2 ± 0.2

Source: Vision Environment (2015a)

Results of the broader (> 90,000ha) benthic habitat characterisation of Port Curtis and Rodds Bay undertaken by TropWATER, found that the dominant habitat feature was open substrate with a low to medium cover of benthic habitat, benthic fauna and algae (McKenna et al. 2014). BMT WBM (2013) found that reefs along Facing Island had up to 30% hard coral cover. Within the same reef areas, macroalgae cover was between 19% and 45% (BMT WBM 2013). Although the focused study areas were not identical, the results were consistent and within similar ranges found in the baseline reef monitoring program.

Significant (P < 0.05) differences in substrate types were observed among monitoring locations (refer Figure 8.12), which included sediments, soft corals, hard corals and sponges. The highest noticeable difference was hard coral, with over five times more hard coral observed at Sable Chief Rocks compared to all other locations (refer Photograph 8.1). There were no significant (P > 0.05) differences in substrate cover among locations for macroalgae or other biota.

The results were similar to those found in previous studies of fringing reefs in Port Curtis by Ayling et al. (2012), Oceania Maritime Consultants (2011) and BMT WBM (2014a), where Sable Chief Rocks was significantly different to other surrounding study sites along Gatcombe Heads and Facing Island. The authors found that the highest hard coral cover was at Sable Chief Rocks representing 31% cover, with the branching hard coral Acroporidae being the dominant family (~20%). Macroalgae ranged from 15 to 45% and soft coral was at 2% to 3% cover (Ayling et al. 2012). These results were similar to the baseline reef monitoring program, where hard coral at Sable Chief Rocks was found at ~40% cover, with *Acropora formosa* being the dominant hard coral species (refer Table 8.5 and Appendix J, Table 3.3). Macroalgae was at ~20% and soft corals at < 1% (refer Table 8.5) in this monitoring program.

Major substrate cover was significantly dissimilar (permutational multivariate analysis of variance (PERMANOVA); P (Perm) < 0.001; df 4; MS 26.3) among locations (refer Figure 8.13). Sable Chief Rocks had the greatest difference in substrate community composition compared to other locations. The major substrates driving the variation included hard corals, sediments and macroalgae. The findings were similar to those of Ayling et al. (2012) and BMT WBM (2013).

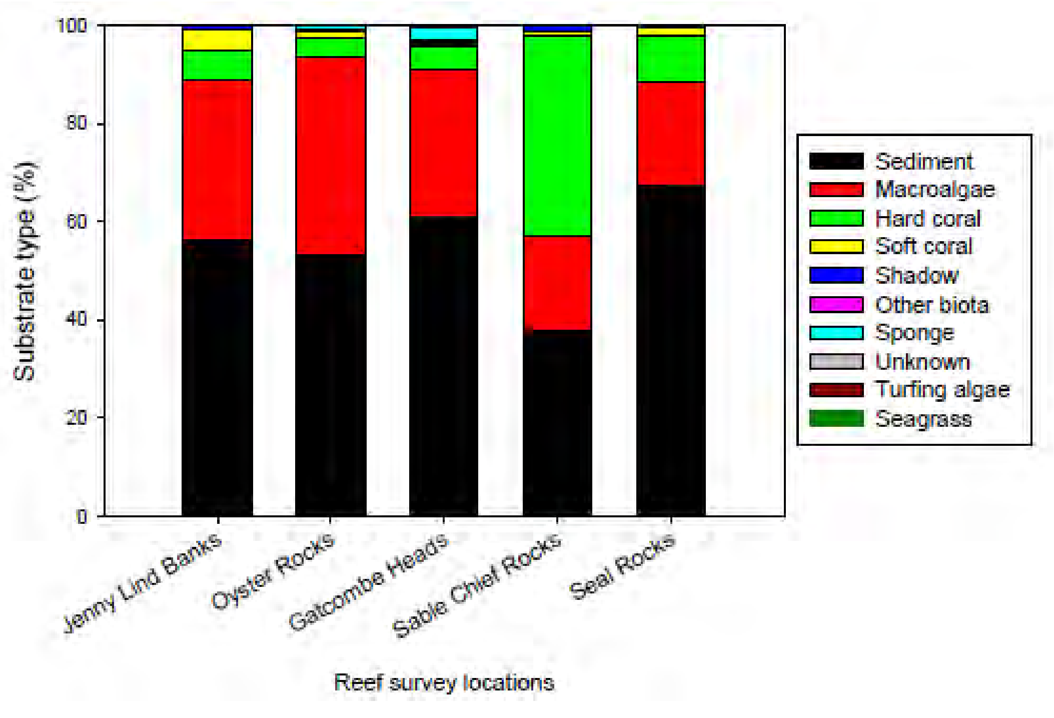


Figure 8.12 **Mean (± se) percent major substrate cover among locations**

Source: Vision Environment (2015a)

Photograph 8.1 Photograph of extensive hard coral cover at Sable Chief Rocks

Source: Vision Environment (2015a)

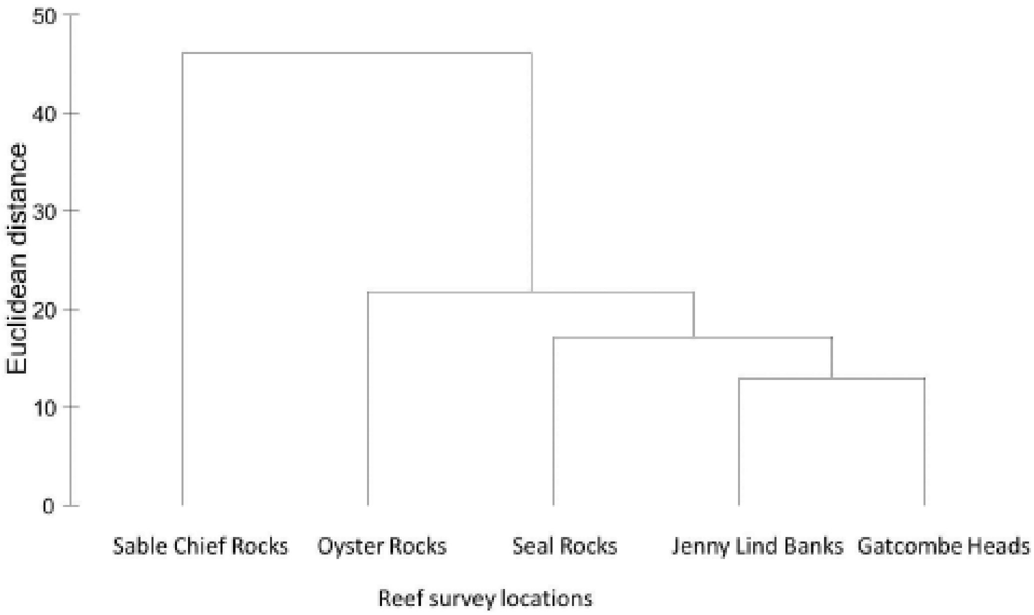
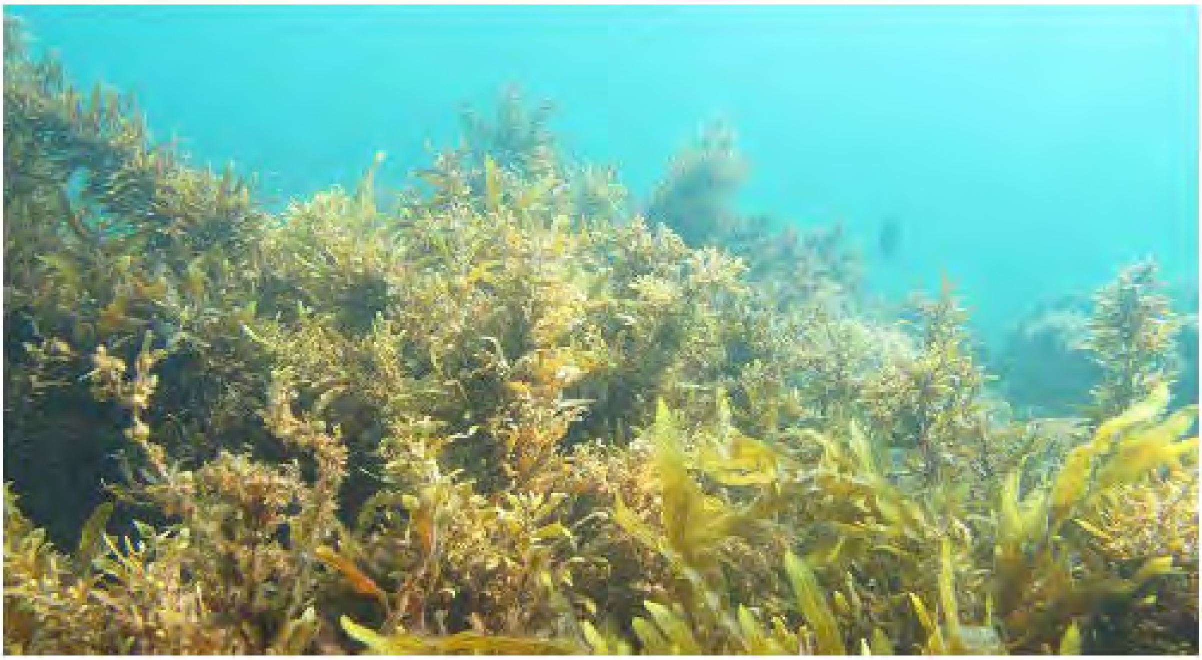


Figure 8.13 **Hierarchical cluster analysis using grouped averages of major substrate categories among locations**

Source: Vision Environment (2015a)

Substrate sub-categories were classified into 48 classes among all locations (refer Appendix J, Table 3.3). Sand and pavement substrates were the highest non-live classes from all locations (35% and 19%, respectively). Highest living substrate consisted of the macrolagae, *Sargassum* sp. (21%, refer Photograph 8.2), followed by the hard branching coral (*Acropora formosa*) (7%, refer Photograph 8.3), the brown algae genera (*Lobophora* sp.) (2.4%), and the red algae genera (*Asparagopsis* sp.) (1.9%, Photograph 8.4). Similar findings were reported by Ayling et al. (2012) indicating there has been little change in percent cover of substrates from 2012 to 2015.

The highest cover of the hard coral species, *Acropora formosa*, was observed at Sable Chief Rocks (> 30%), while Oyster Rocks and Gatcombe Heads exhibited the highest algae cover (*Sargassum* sp.) (38% and 23%, respectively). Lower proportions of the hard coral (Dendrophyllidae *Turbinaria* sp) (1.8%) and the wide flat plate coral (*Acropora hyacinthus*) (1.3%), were observed at most sites, with highest cover observed at Sable Chief Rocks (> 3%). Most other classes combined made up less than 1% cover over the whole area.



Photograph 8.2 Example of the brown algae (*Sargassum* sp.), abundant at Gatcombe Heads (photograph), Oyster Rocks and Seal Rocks

Source: Vision Environment (2015a)

Photograph 8.3 Branching coral (*Acropora formosa*) abundant at Sable Chief Rocks

Source: Vision Environment (2015a)

Similar to the major categories, small but significant (P < 0.001) dissimilarities in minor substrate classes were observed (PERMANOVA; P (Perm) < 0.001; df 4; MS 111.2) among locations. Sable Chief Rocks displayed the least similar substrate composition to all other locations (refer Figure 8.14), with hard corals driving the main difference between locations at Sable Chief Rocks (PCO1; x-axis), including the branching corals (i.e. *Acropora hyacinthus*, *Pocillopora damicornis*, *Acropora digitifera*, *Acropora formosa*, *Pocillopora verrucosa* and *Anacropora forbesi*). Turfing algae and sediment type also contributed to some differences among locations (PCO2; y-axis).

Photograph 8.4 Red algae (*Asparagopsis* sp.) abundant at Jenny Lind Banks

Source: Vision Environment (2015a)

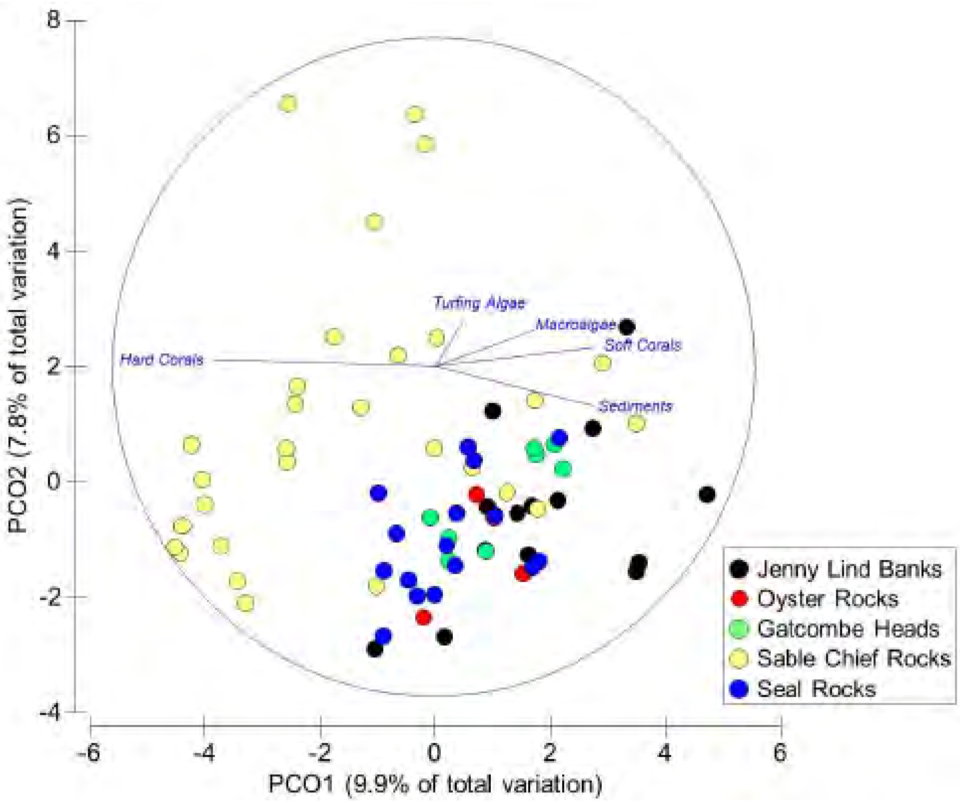


Figure 8.14 Principle coordinates ordination of minor substrate categories among locations

Figure note:

Major categories were overlaid to determine type of structure driving the variation among locations. Data were normalised and square root transformed using Euclidian distances.

Source: Vision Environment (2015a)

Coral bleaching is a stress response of corals and can be caused by an increase in ocean temperatures (Backer et al. 2008). An increase of 1°C can have a significant impact on the frequency of coral bleaching events (Baker et al. 2008; Berkelmans et al. 2004; Berkelmans and Oliver 1999; Glynn 1993). A number of freshwater bleaching events have also occurred at neighbouring northern inshore reefs of the Great Barrier Reef in the last five years (Thompson et al. 2011; Thompson and Dolman 2010; Thompson et al. 2010). Very little coral surveyed as part of the Project monitoring program demonstrated signs of stress, with less than 0.5% of corals showing pale colouration and less than 0.1% presenting bleached white colouration (refer Figure 8.15). The highest amounts of sediments on corals were observed at Seal Rocks, with approximately 0.5% of transects affected, followed by Sable Chief Rocks. The highest amounts of sediment on other biota were observed at Gatcombe Heads and Oyster Rocks (17% and 12%, respectively). There were no signs of diseased corals at any of the locations.

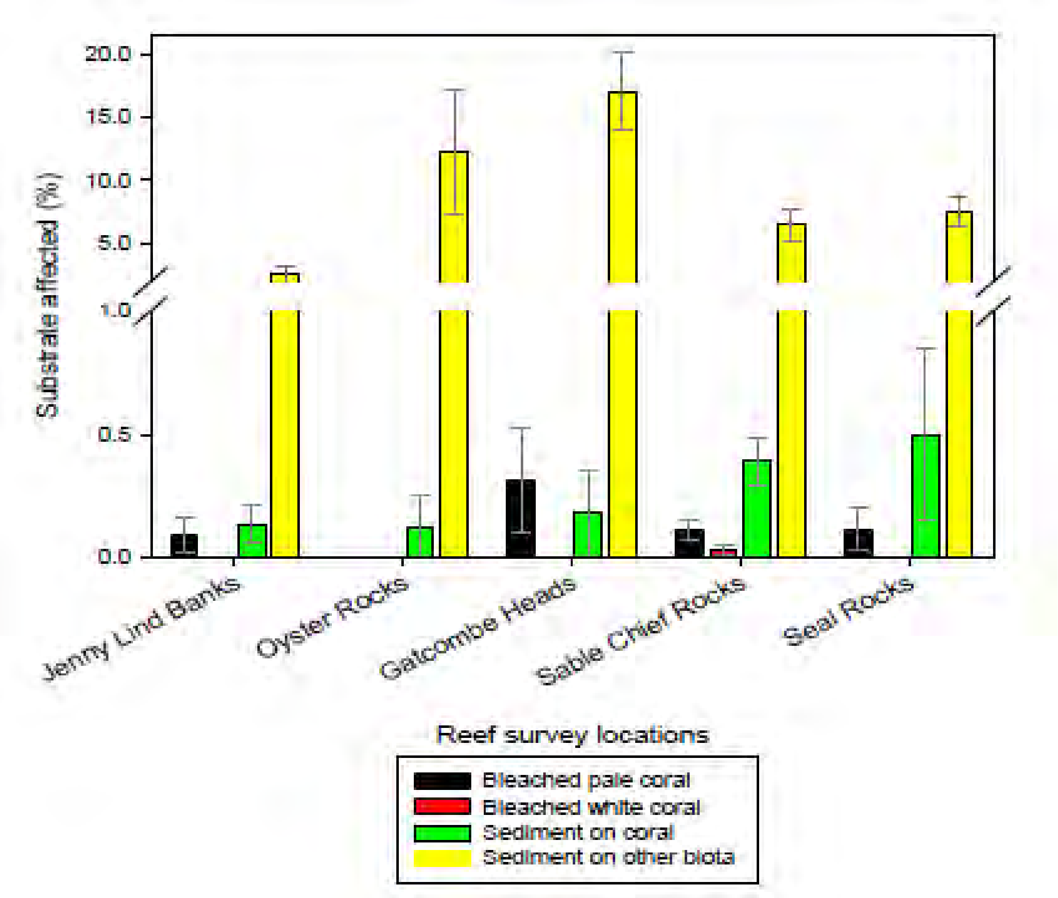


Figure 8.15 **Percent substrate affected per site, by stress (bleaching), disease or sediments**

Source: Vision Environment (2015a)

8.3.8.2 Mapping

Reef extent areas were mapped within the Project baseline reef monitoring area (refer Figure 8.11). Jenny Lind Banks and Oyster Rocks consisted mainly of mixed substrates with approximately 53% to 56% sediments, 32% to 40% algae, and 5 to 10% of hard and soft corals (refer Table 8.5 and Appendix J, Figures 3.6 and 3.7). Gatcombe Heads was classified as dominant sediments with sparse algae and comprised approximately 60% sediments, 30% algae and lower amounts (< 10%) of other classes (refer Table 8.5; Appendix J, Figure 3.7). Seal Rocks was classified as dominant sediment with sparse other (refer Appendix J, Figure 3.8), consisting mainly of approximately 68% sediments, 21% algae, 10% hard coral, and < 2% other classes. Sable Chief Rocks exhibited a slightly different classification consisting of moderate hard coral, mixed other classes, with 41% hard coral, 38% sediments, 19% algae and < 2% other classes (refer Table 8.5, Appendix J, Figure 3.9).

8.3.8.3 Seasonal comparisons

Results from transects surveyed in 2014 were compared to results from those undertaken during the 2015 wet season. Although there were significant ($P < 0.05$) differences among locations, there were no significant ($P > 0.05$) differences in any of the major category substrates (Vision Environment 2015a). This included hard coral, soft coral, macroalgae and sediment cover within locations, between the 2014 dry season and the 2015 wet season (refer Appendix J) (Vision Environment 2015a). The exception was sponges, which had higher cover in the 2014 dry season compared to the 2015 wet season. However, sponges made up less than 1% of the total cover for all sites (refer Appendix J) (Vision Environment 2015a).

Slight, but significant dissimilarities in species composition (minor categories) were observed among locations but not between seasons, with highest dissimilarities observed at Jenny Lind Banks (PERMANOVA; P (Perm-Location) < 0.001; df 3; MS 129.1). The main classes that influenced the variations among locations were macroalgae and hard coral, particularly for Gatcombe Heads and Sable Chief, respectively (analysis of similarity (ANOSIM); R-statistic 0.513, P < 0.1%), and to a lower extent, Gatcombe Heads and Jenny Lind Banks (ANOSIM; R-statistic 0.444, P < 0.1%) (refer Appendix J and Figure 8.16).

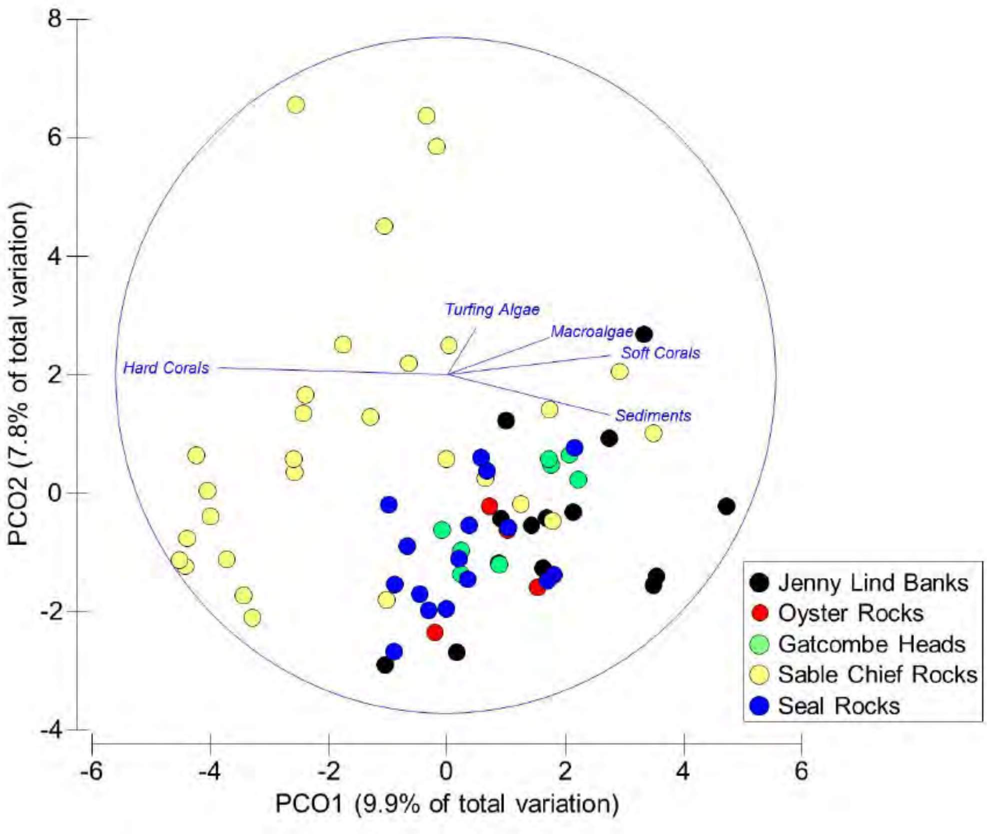


Figure 8.16 Principle Coordinates Ordination of minor substrate categories among seasons for select repeat transects

Figure notes:
Major categories were overlaid to determine type of structure driving the variation among locations. Data were normalised and standardised using Euclidian distances; circles denote Dry season 2014; and triangles denote 2015 wet season.

Source: Vision Environment (2015a)

Results of the baseline reef monitoring program were similar to that of Ayling et al. (2012), who found in a survey of fringing reefs adjacent to Facing Island, that although hard and soft coral cover did not change significantly, temporally macroalgae cover did. However, the study by Ayling et al. (2012) was conducted twice over the same seasonal period. The baseline reef monitoring program showed distinct wet season/dry season changes in macroalgae cover, particularly for Jenny Lind Banks (refer Appendix J and Figure 8.16). This may be attributed to a number of factors, including changes in temperature, light, nutrient enrichment and grazer activity (Coman et al. 2003; Costanzo et al. 2003; Lapointe et al. 2005; 2010), as many macroalgal species have demonstrated marked growth during short time periods when conditions are favourable (Burkholder et al. 2007; Costanzo et al. 2004; Lin and Fong 2008; Pihl et al. 1999).

8.3.8.4 Permanent transects

Permanent transects were established at four locations (Gatcombe Heads, Sable Chief Rocks, Jenny Lind Banks, and Seal Rocks). Transects were resurveyed after 12 months, from 3 of the 4 locations (Gatcombe Heads, Sable Chief Rocks and Jenny Lind Banks). Due to the relatively shallow depth of the colonies at Seal Rocks, all transect corals were severely damaged during the passing of TC Marcia in February 2015. Hence, no temporal data were able to be collected for this location.

There were no significant ($P > 0.05$) differences in coral growth per year among locations, with an average growth rate of 9.7 ± 1.2mm/year for the two species of Acroporidae at all sites (refer Figure 8.17) (Vision Environment 2015a). The growth rates were measurably lower (approximately 11% to 22%) than growth rates reported for the same corals in other experiments (Harriott 1998; Oliver 1984). However, the growth rate differences reported in other studies were most probably attributed to differences in temperature, geographic location and water quality, as these variables are known to have a large effect on coral growth (Baird and Marshall 2002; Harriott 1998; Koop et al. 2001; Rogers 1979).

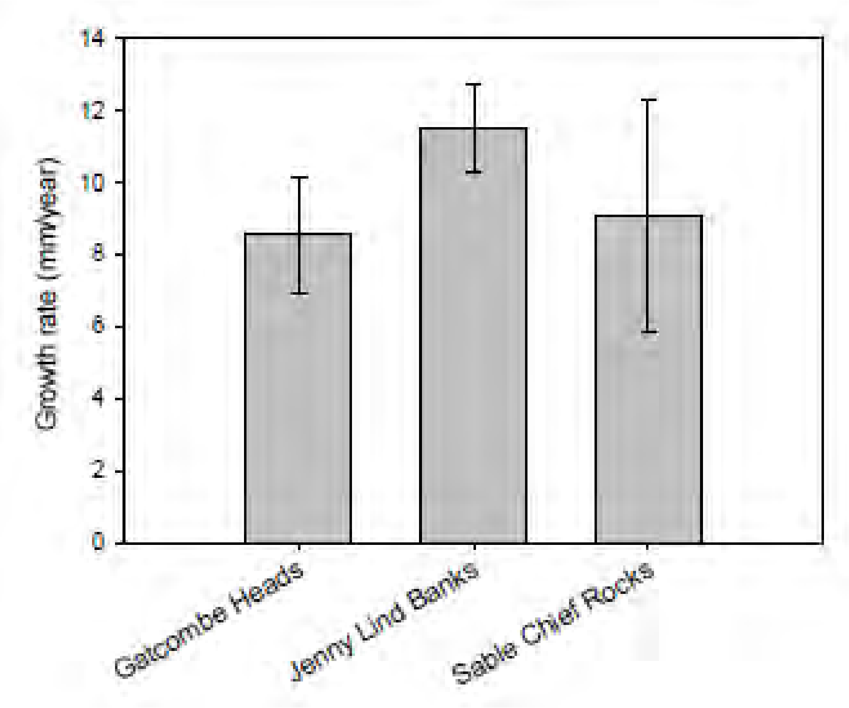


Figure 8.17 **Mean (± se) growth rate, per year, among locations in two *Acropora* sp.**

Source: Vision Environment (2015a)

Luminosity and pigmentation were measured at the three locations (refer Appendix J for full methodology). Branching corals from the Acroporidae family were slightly lighter in pigmentation compared to that measured the previous year at Gatcombe Heads and Sable Chief Rocks, but there was no significant (P > 0.05) difference between the two locations (Vision Environment 2015a). However, branching corals at Jenny Lind Banks had become significantly darker in pigmentation since the previous year and compared to Gatcombe Heads and Sable Chief Rocks (refer Table 8.6). Changes in pigment concentrations attributed to changes in concentrations of algae and/or zooxanthellae, can be affected by a number of stressors including, but not limited to, water clarity, light availability, temperature, ocean acidification and seasonal changes (Chen et al. 2005; Crawley et al. 2010; Fabricius 2006).

In general, ± 8% to 10% difference in luminosity was observed in pigment variation between June 2014 and June 2015 at all sites, however, no bleaching was observed in any of the colonies (Vision Environment 2015a).

Table 8.6 Mean (± se) percentage difference in coral pigment change for *Acropora* sp. (over 12 months)

Site	Red Green Blue (%)	Red (%)	Green (%)	Blue (%)	Luminosity (%)
Gatcombe Heads	-11.2 ± 4.8	-16.3 ± 6.0	-11.0 ± 5.1	-5.7 ± 3.7	-12.2 ± 5.2
Jenny Lind Banks	11.0 ± 3.3	16.6 ± 4.2	14.5 ± 8.9	22.5 ± 8.1	8.6 ± 2.6
Sable Chief	-4.8 ± 2.4	-5.2 ± 3.1	-8.2 ± 4.3	-0.2 ± 1.4	-6.6 ± 3.4
Seal Rocks	-	-	-	-	-

Table note:
Negative numbers denote corals have gone lighter compared to the previous year and positive numbers denote corals have gone darker compared to previous years.

Source: Vision Environment (2015a)

8.3.8.5 Benthic habitat regional baseline assessment

The Port Curtis region baseline assessment of benthic communities (algae and macroinvertebrates) undertaken in November 2013 found that the region supports a diverse range of benthic community types that are typical of communities found in offshore and near shore subtidal areas elsewhere in Queensland (McKenna et al. 2014). The benthic macroinvertebrate communities within the 2013 survey area were allocated into regions based on community composition and density. Three density categories were identified in the 2013 survey area: mostly open substrate; low density communities; and medium density communities (refer Figure 11.4 in Section 11).

Within these density categories a range of different community types were identified, including rock/reef communities, not necessarily representing developed hard coral structures (McKenna et al. 2014). Region 1 contained medium density benthic community with rock/reef areas, dominated by encrusting bryozoans, polychaetes, erect bryozoans, hydroids and bivalves. This region was located on the eastern side of the survey area off Facing Island and covered approximately 11,000ha of substrate (McKenna et al. 2014). Region 4 comprised medium density benthic community with rock/rubble/reef areas, dominated by encrusting bryozoans and bivalves (McKenna et al. 2014). This community occurred as five smaller areas throughout the baseline benthic survey area and encompassed the area to be dredged. These regions featured large areas of habitat forming 'live' and dead rock, rubble and reef and a large variety of taxa interspersed throughout the area (McKenna et al. 2014).

Overall the survey found that benthic macroinvertebrates and algae were concentrated around habitat forming 'live' and dead rock/rubble and reef and that this association was the driver behind the patches of higher biodiversity and density of benthic communities observed in the baseline benthic survey area (McKenna et al. 2014).

8.3.9 Facing Island Reef Surveys

The aim of the Facing Island Reef Surveys conducted in 2018 was to characterise and document patterns in the structure and condition of benthic reef communities along Facing Island and 'control' sites at Rundle Island (BMT WBM 2018). During the survey, three different approaches were used in assessing the health of the reef communities, including high-resolution multispectral satellite imagery, diver based quantitative sampling and a trial using 3D photogrammetry mapping. The full report, including detailed methodology and discussion of results, is provided in Appendix J2.

8.3.9.1 Remote sensing

The multispectral satellite imagery provided more accuracy in broad scale mapping of the reefs. The imagery was analysed by calculating the benthic reflective index (BRI), and the depth invariant index (DII) for Sentinel-2 satellite scenes. The DII is used for benthic classification of coral reef environments, while the BRI is known to have more classification efficacy in turbid water environments (Sagawa et al. 2010). Scenes of the survey area were taken from 11 August and 15 September 2017. Approximately 21.71km^2 of reefs were mapped, compared with 13.90km^2 previously mapped during the 2014 survey (BMT WBM 2014).

According to the BRI maximum likelihood classification mapping of Facing Island, the eastern side has coral and macroalgal dominated reefs along its length (refer Figure 8.18). Reefs from the south of East Point Ledge and within North Entrance are macroalgal dominated, while communities between Sable Chief Rocks and North Entrance are dominated by coral. These results largely agree with ground-truthing observations conducted in 2014 and 2018, however, several anomalies also occurred, including patches of macroalgal dominated reef inside Port Curtis and patches of coral-dominated habitat on East Banks which may have been a result of turbidity and/or seagrass (BMT WBM 2018). Furthermore, DII and BRI classifications suggested that there was coral dominated reef where reef had not been ground-truthed in the 2014 report recorded between Pearl Ledge and North Entrance (BMT WBM 2018).

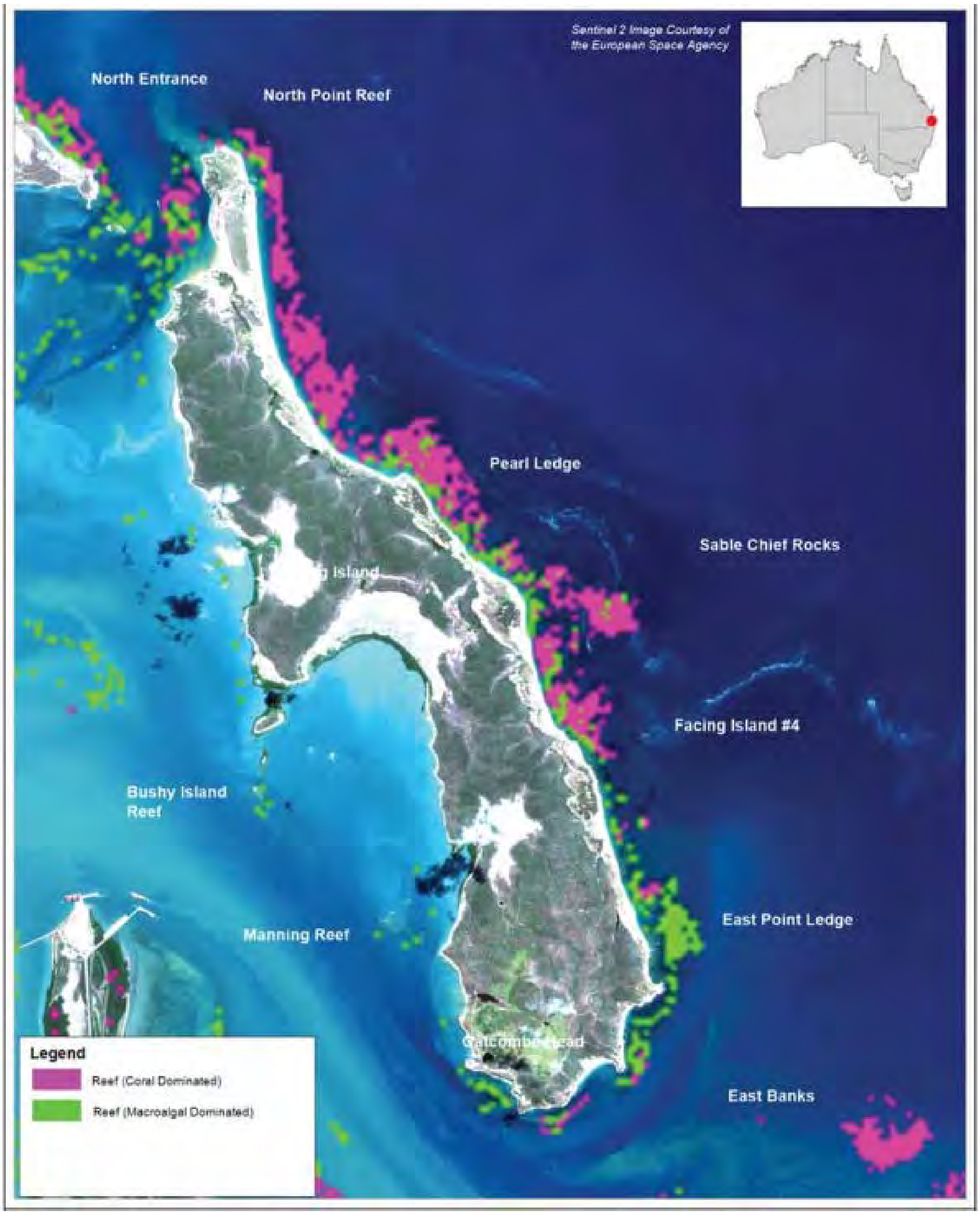


Figure 8.18 **Facing Island benthic reflective index (maximum likelihood classification)**

Source: BMT WBM (2018)

The reef extent of Rundle Island and Seal Rocks was found to be consistent with ground-truthed surveys. The BRI maximum likelihood classification mapping of Rundle Island demonstrated coral and macroalgal dominated reefs over some parts of the reef, but also mis-classified large sections (refer Figure 8.19. The BRI maximum likelihood classification mapping of Seal Rocks demonstrated scattered coral and macroalgal dominated reef along its length (refer Figure 8.20). According to the mapping, the reef in the northeast extremity is more coral-dominated, while the reef surrounding Seal Rocks is a mixture of substrates. It appears that there was a mis-classification of the reef as sandy substrates along in the deeper and northern sections of the reef, however ground-truthing surveys were not conducted at Seal Rocks to the same extent as at Facing and Rundle Islands (BMT WBM 2018).

Figure 8.19 **Rundle Island benthic reflective index (maximum likelihood classification)**

Source: BMT WBM (2018)

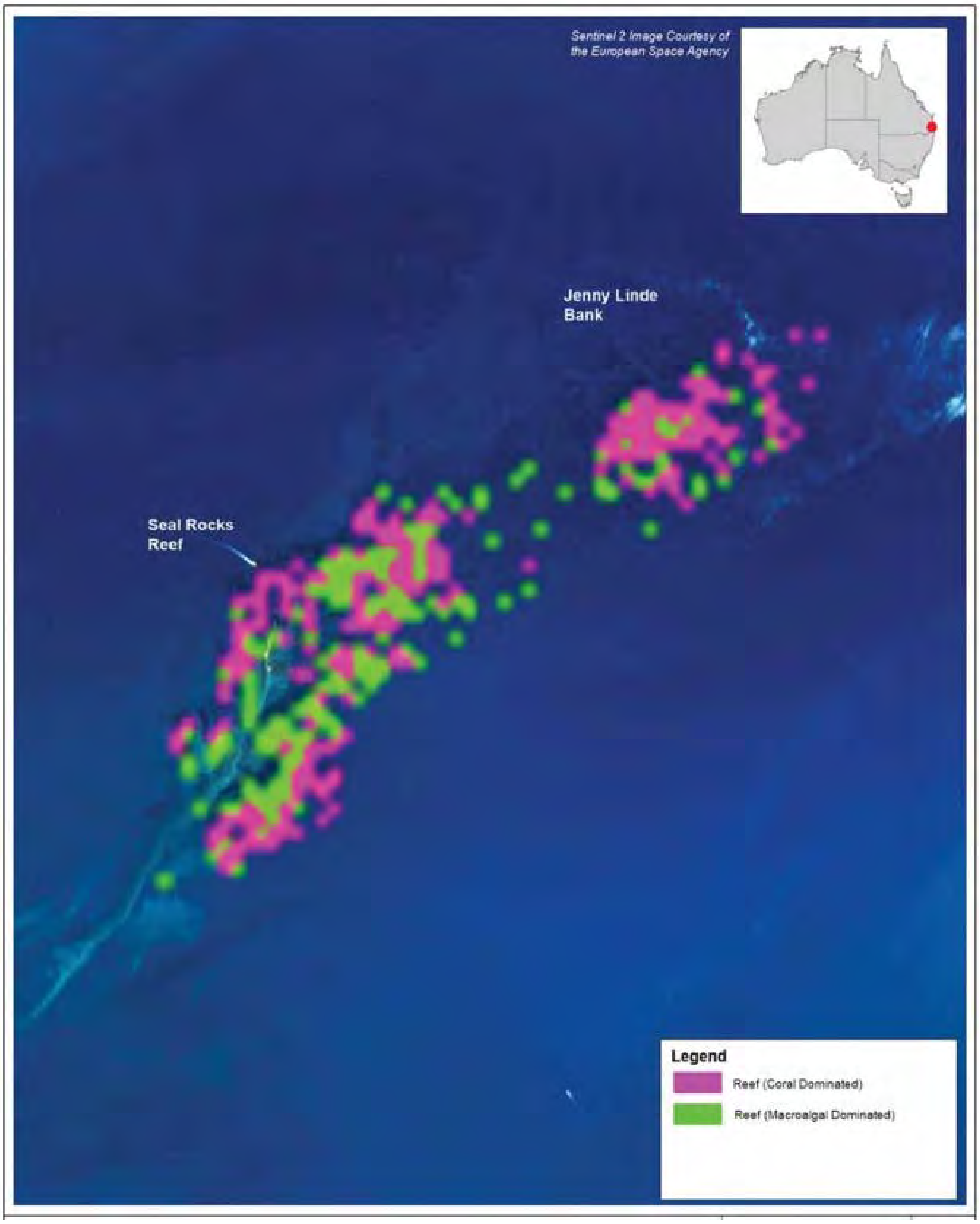


Figure 8.20 **Seal Rocks benthic reflective index (maximum likelihood classification)**

Source: BMT WBM (2018)

A revised reef layer was created from these findings, demonstrating that a larger extent of reef occurs within the survey area and reef classification from the BRI results for Facing Island are accurate representations (refer Figure 8.21). BRI mapping of Seal Rocks and Rundle Island was considered to be too anomalous (BMT WBM 2018).

Figure 8.21 Adjusted reef layer 2018

Source: BMT WBM (2018)

8.3.9.2 Coral monitoring

Diver based sampling was used to characterise the benthic community structure and condition of the Facing Island reefs for comparisons with previous surveys. Ten sites that were surveyed by Sea Research (2013) were revisited between 31 May and 4 June 2018. A 20m transect tape was laid down and a diver swam over the substrate using paired high-definition underwater cameras capturing still images and video footage. The still imagery and video footage was used to determine benthic cover and community composition, and assist in identification, coral health, recruitment counts, and general observation purposes (BMT WBM 2018).

Results found that hard coral cover was greatest at Rundle Island and along the eastern side of Facing Island, and the lowest in the harbour entrance sites. Harbour entrance sites had greatly decreased in coral cover between 2013 and 2014, and did not appear to have recovered significantly between 2014 and 2018 (refer Figure 8.22). Although consistent with catchment disturbances, it was considered extremely unlikely that sediment plumes created by Port of Gladstone maintenance dredging was contributing to these patterns based on monitoring, modelling and 2018 cover data (BMT WBM 2018).

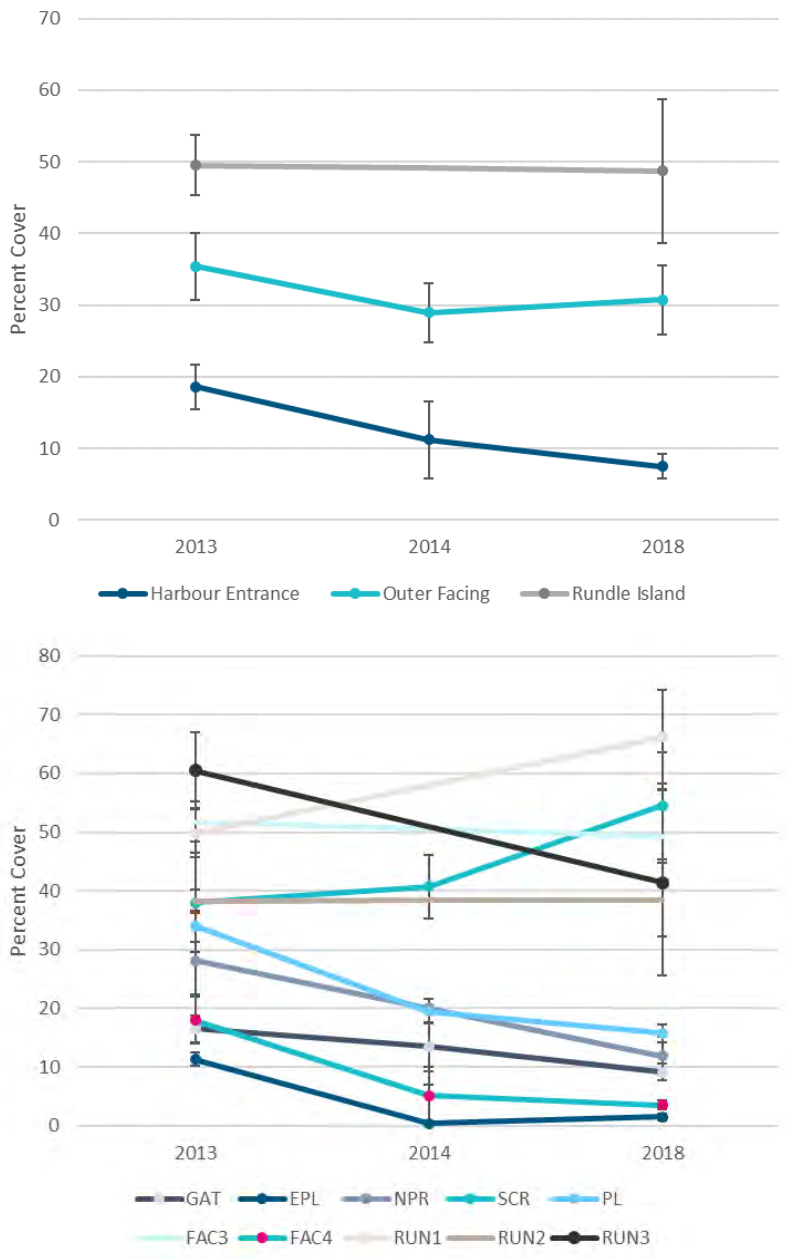


Figure 8.22 **Temporal changes in hard coral cover among treatments (above) and individual sites (below)**

Source: BMT WBM (2018)

Communities at Rundle Island appeared to have recently experienced substantial dieback which may have been the result of coral disease that was evident at many sites and/or thermal bleaching. Dieback is also known to lead to an increase in algal cover which was demonstrated at several sites which had low coral cover and the high algae cover. Bleaching tended to occur in individual colonies or as partial colony bleaching, rather than widespread bleaching which is often the case with major thermal related events. It was noted that partial colony bleaching and coral disease can also be difficult to distinguish and so can be misidentified (BMT WBM 2018).

9 Fish and fisheries values

9.1 Background

The Port Curtis region contains a range of high value natural habitat types important to fish and fisheries species, including seagrasses meadows, reefs, hard and soft benthic substrates, through to shallow inshore areas including tidal mudflats, mangrove forests and mangrove lined creeks and estuaries (Lucas et al. 1997). The region supports a variety of marine species, many of which are significant for their Indigenous, recreational and commercial value. The region also contains three FHAs declared under the provisions of the Fisheries Act.

This section provides an overview of the existing fish and fisheries values present within the Port Curtis region, including the Project impact areas. Fisheries values presented in this section, include a variety of non-fish species, including nektobenthic invertebrates which refer to larger benthic invertebrates capable of moving in water independent of currents (e.g. crabs, prawns, cuttlefish).

9.2 Methodology

9.2.1 General

The purpose of the Project baseline fish and fisheries values information is to understand the existing fish and fisheries values present within the Port Curtis region and to assess the potential direct and indirect impacts associated with the Project activities. Section 15 (megafauna) provides information on other nekton, including dolphins, dugongs and whales; while Section 14 (marine turtles) provides information on marine turtles.

Several studies have previously been conducted examining fish assemblages and habitats within the Project impact areas and Port Curtis region. The relevant studies and publicly accessible databases consulted as part of this assessment process are listed in Table 9.1. For the purposes of the database review, the search area was defined on a regional basis and included Port Curtis and adjoining marine areas to ensure that transient species were captured in the assessment (refer Figure 9.1).

The GHHP 2016 and 2017 report includes fish and crab indicators for the 2016 and 2017 GHHP Report Card, and committed to a fish health research program in 2016 following a workshop with the Fisheries Research and Development Corporation (FRDC) in 2015.

Table 9.1 Existing information sources for fish and fisheries values

Title	Reference
Reports	
Gladstone Harbour Report Card 2014, 2015, 2016 and 2017 *Technical Report, Gladstone Harbour Report Card 2014, 2015, 2016 and 2017*	GHHP (2014a; 2014b; 2015a; 2015b; 2016a; 2016b; 2017a and 2017b)
Developing a fish recruitment indicator for the Pilot Gladstone Healthy Harbour Report Card in 2015	Sawynok et al. (2015)
Shell Australia LNG Project: Estuarine and Marine Field Investigations	Alquezar (2010)
Fish habitat assessment of the Narrows pipeline crossing	Alquezar and Scannell (2010)
Arrow Energy LNG Plant: Estuarine and Marine Ecology Field Investigations (Phase I & II)	Alquezar (2011)
Distribution and assemblage composition of demersal fish in shallow, nearshore waters of Port Curtis	Currie and Connolly (2004)

Title	Reference
Intertidal wetlands of Port Curtis: Ecological patterns and processes, and their implications	Connolly et al. (2006)
Analysis of Water Quality in Relation to Fish Health in Gladstone Harbour and Waterways September 2011 – September 2012	EHP (2013)
Report for Western Basin Dredging and Disposal Project: Marine Ecology Assessment	GHD (2009c)
Fisheries Resources of Calliope River, Gladstone Central Queensland 2014	DNPRSR (2014a)
Gladstone Recreational Fishing Project – Gladfish	Sawynok et al. (2014)
Fish fauna of dry tropical and subtropical estuarine floodplain wetlands	Sheaves et al. (2007)
Fish communities of a subtropical mangrove forest, with comparisons to adjacent mudflats and seagrass beds	Small (1997)
Fisheries Resources of the Port Curtis and Capricorn Regions. A report prepared for the Queensland Fisheries Management Authority.	Walker (1997)
Databases	
EPBC Act PMST (refer Figure 9.1 for search area)	DoEE (2019)
Fisheries catch data (QFish) from data grid reference: S30 (2008/2009 to 2017/2018)	DAF (2018)
Wildnet database (refer Figure 9.1 for search area)	DES (2019)
Infofish commercial and recreational fish catch data (2014 to 2018)	Infofish Australia (2018)

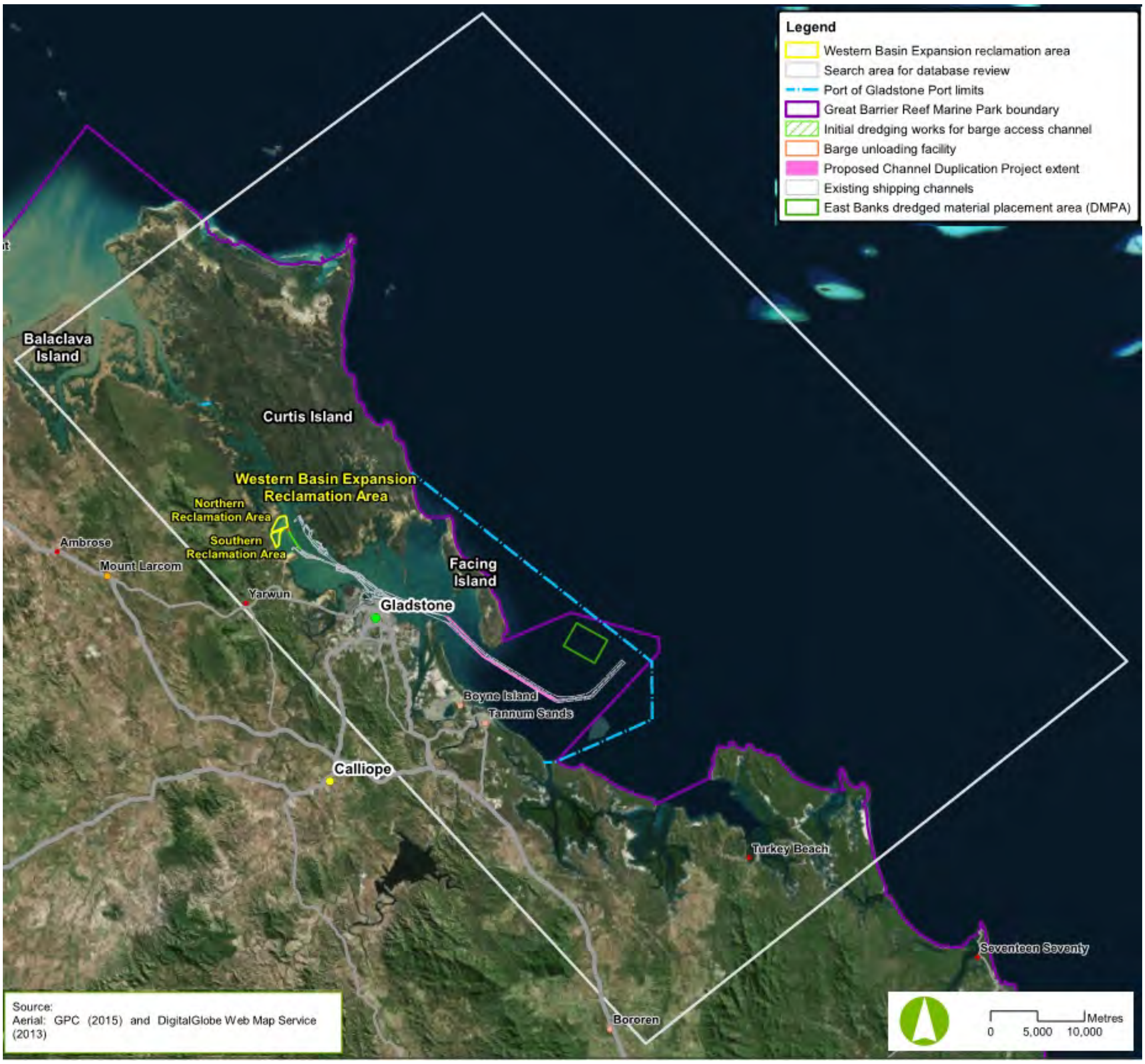


Figure 9.1 **Search area for database review**

Analysis of QFish datasets (DAF 2018) for the S30 Commercial Fishery, 30 minute Reporting Grid (referred to as the fishing activity area), for the 2008/2009 to 2017/2018 period was undertaken to determine trends associated with species diversity, abundance and yields. The fishing activity area is shown in Figure 9.2.

9.2.2 Project fish and fisheries values baseline data collection

A baseline monitoring program was undertaken by Vision Environment (2015a) as part of the Project EIS. This monitoring was designed to provide baseline information on fish and fisheries values at the potential impact area (i.e. areas to be dredged and the WB and WBE reclamation areas) and reference sites (refer Figure 9.3).

Fish assemblages can vary depending on marine, coastal, estuarine and freshwater habitats. For example, coral reef habitats, mangroves and estuarine areas typically contain a high diversity of fish and nektonic invertebrates while seagrass meadows and inter-reef areas generally exhibit lower levels (Lucas et al. 1997). Fish assemblages in Port Curtis have historically shown spatial and temporal variability (DAF 2018; Sawynok et al. 2014).

Baseline data on fish communities was collected for the Project EIS during both wet and dry seasons to account for temporal and seasonal variability. Surveys were conducted on a variety of habitat types, including coastal, estuarine and reef environments across Port Curtis (Vision Environment 2015a).

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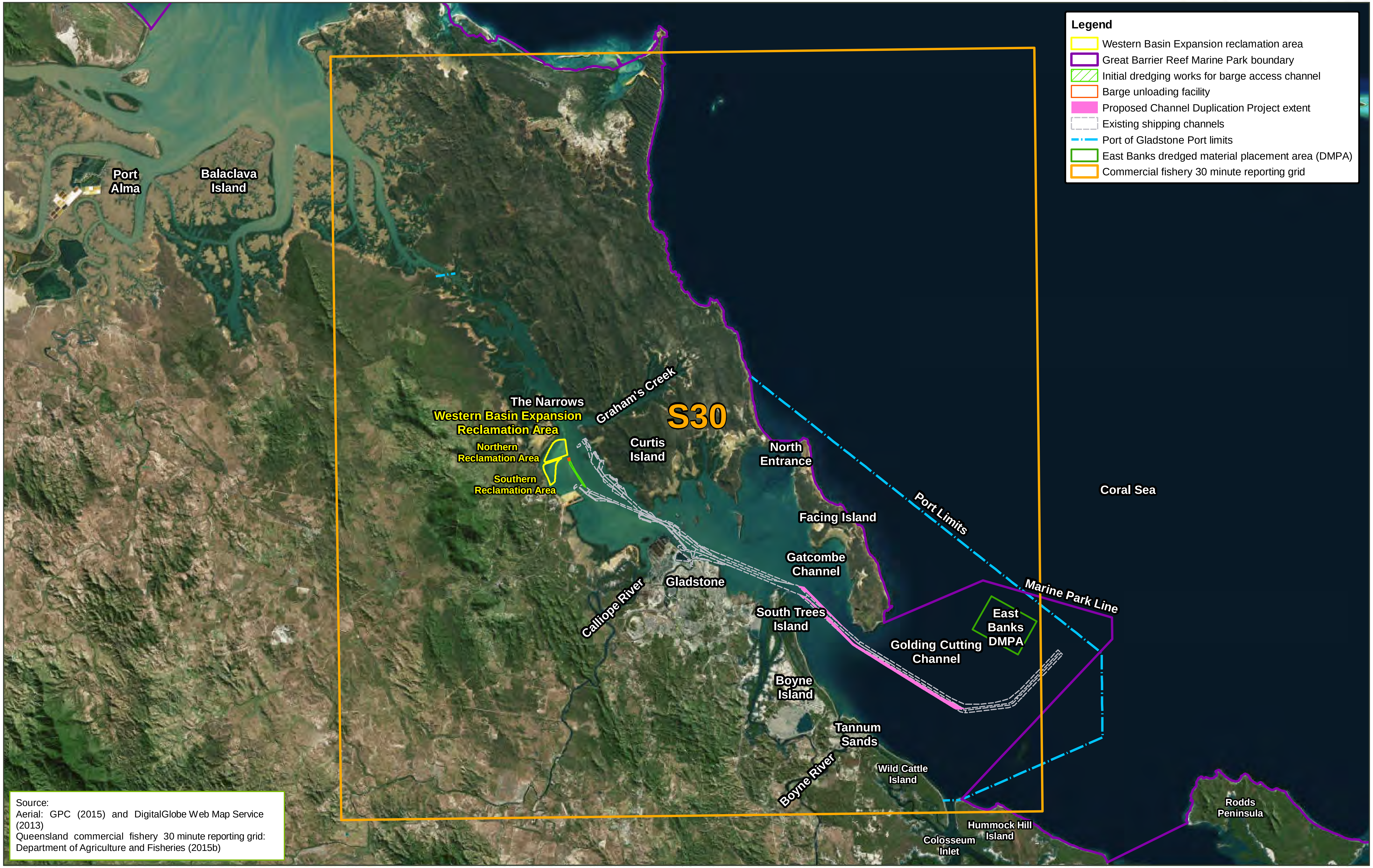

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Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 9.2: Commercial and recreational fishing activity area

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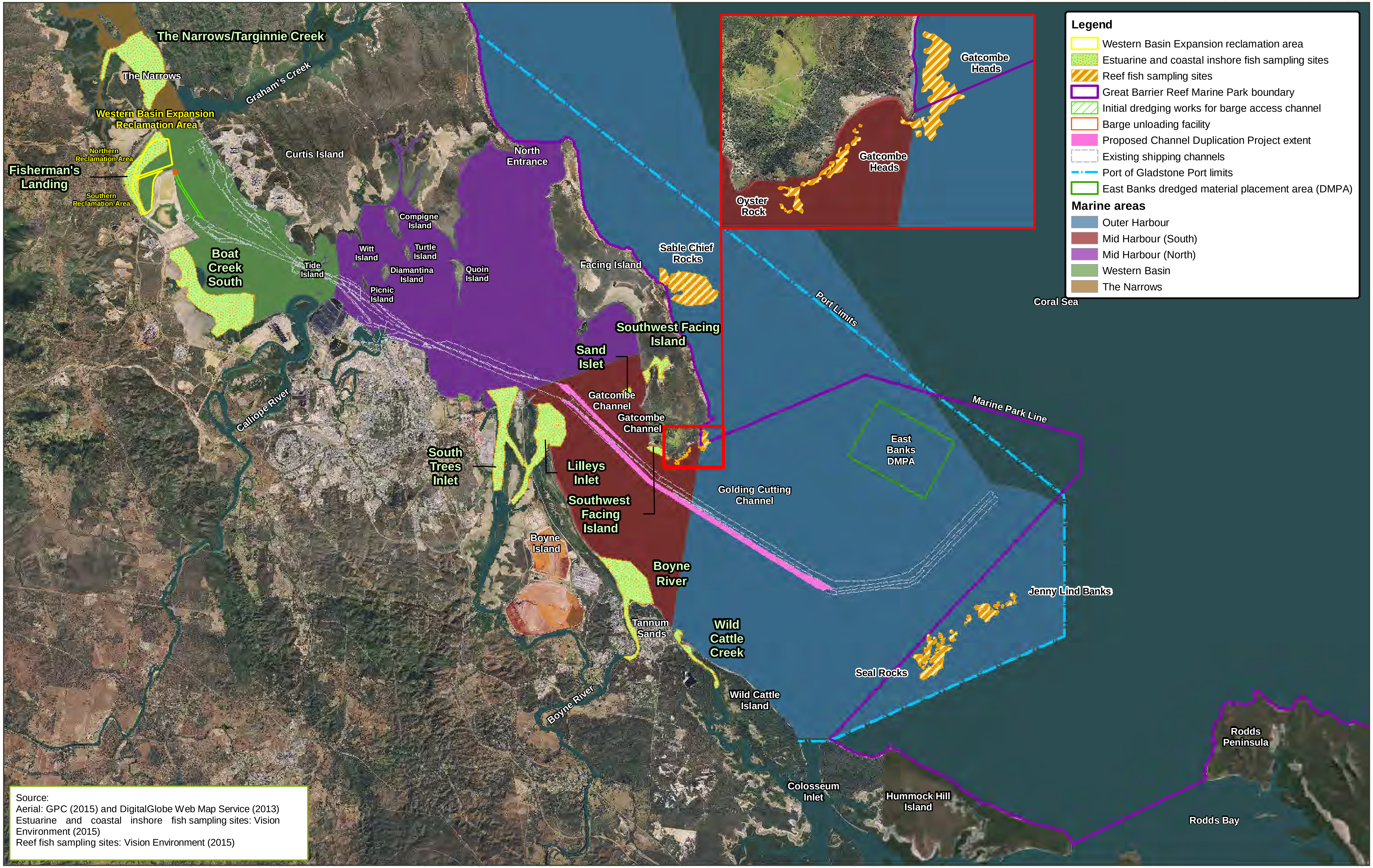

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Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 9.3: Project fish and nekton sampling sites

9.2.2.1 Estuarine and coastal fish surveys

The proposed areas to be dredged are located in relatively open waters across the Mid Harbour and Outer Harbour zones, adjacent to a number of beaches and fringing rocky reefs (refer Figure 9.3). As fish are mobile animals and have the potential to travel large distances, it can be difficult to collect sufficient data to discern fish communities along these open substrate areas.

Estuaries, creeks and rivers act as highways for fish and other nekton that commute from one system to another, especially along coastal beaches and fringing rocky reefs. Therefore, in order to determine an accurate estimate of fish communities within these habitats, sampling efforts were concentrated in estuarine and coastal inshore areas around the mouths of creeks, rivers, inlets and islets at nine locations around the areas to be dredged and the WB and WBE reclamation areas (refer Figure 9.3), including:

- Southwest Facing Island (including Gatcombe Heads)
- Sand Islet
- Wild Cattle Creek
- Boyne River
- Lilleys Inlet
- South Trees Inlet
- Fisherman's Landing
- The Narrows/Targinnie Creek
- Boat Creek South.

Cast netting and gill netting techniques (refer Photograph 9.1) were used to sample fish assemblages at each location. All fish collected were identified to species level and then released. Where identification of species was unable to be determined in the field, a voucher sample was taken for further analysis (refer Appendix J for detailed field survey and data analysis methods).

Photograph 9.1 Example of a gill net along a deep channel within South Trees Inlet

Source: Vision Environment (2015d)

9.2.2.2 Reef associated fish surveys

Baseline monitoring of reef communities in Port Curtis was undertaken as part of the Project EIS baseline data collection program (refer Section 8). Fish communities at these reef locations were also monitored during these surveys.

Preliminary hydrodynamic modelling for the Project impact areas (BMT WBM 2014c) was used to generate a composite plot that provided a semi-quantitative indication of potential plume dispersion. Reef monitoring locations were established taking into account preliminary plume modelling and maritime constraints (e.g. shipping channels) and included the following reef communities (refer Figure 9.3):

- Oyster Rocks
- Gatcombe Heads (East Point)
- Sable Chief Rocks
- Jenny Lind Banks
- Seal Rocks.

Seal Rocks, Gatcombe Heads and Oyster Rocks are reefs that have the potential to be impacted by the Project as they are located in proximity to the direct impact areas. Jenny Lind Banks and Sable Chief Rocks were selected as potential future control/reference monitoring locations as they are located at a greater distance from the potential direct impact areas.

Reef associated fish and other nekton were captured using multiple methods, including Baited Remote Underwater Video Stations (BRUVS) and diver surveys. Obligatory reef species were determined by diver surveys along fixed 50m transects, while deeper water and reef associated communities were surveyed using BRUVS (refer Appendix J for detailed field survey and data analysis methods).

9.2.2.3 Gladstone Healthy Harbour Partnership baseline surveys

The GHHP develops an annual report card on the health of the Gladstone Harbour. Indicators used to monitor harbour health are in four key areas, being: environmental, social, cultural, and economic. Each indicator is analysed and graded for inclusion in the annual report card.

Prior to 2016, environmental indicators did not include fish and crabs. GHHP determined that recruitment of key fish species has the potential to be an appropriate fish indicator, and a fish recruitment indicator was subsequently developed and included for the first time in the Gladstone Harbour Report Card 2016 (GHHP 2016a).

To assist with the development of a fish recruitment indicator for the annual report cards, an assessment of fish recruitment in the Gladstone area was undertaken, with a focus on Barramundi (*Lates calarifer*) and Bream species. The assessment was presented in *Developing a fish recruitment indicator for the Pilot Gladstone Healthy Harbour Report Card in 2015*, prepared by Infofish Australia (Sawynok et al. 2015).

The assessment of fish recruitment involved standardised castnet surveys, which were undertaken at 32 sites within the harbour, where habitat was considered suitable for juvenile fish of the target species (refer Figure 9.4). The survey involved 5, 10 or 20 casts at a site with the number of casts being determined by the size and characteristics of the site. These surveys were repeated monthly from November 2014 to December 2015 at most sites (Sawynok et al. 2015).

The assessment of fish recruitment survey indicated that Yellowfin bream (*Acanthopagrus australis*) used all parts of the estuaries ranging up to the top end of tidal influence, and into freshwater (Sawynok et al. 2015). Based on this study, and limited historical data available, it was considered that Yellowfin Bream is the most suitable species for long term monitoring of fish recruitment and the development of a fish recruitment indicator for the annual report card (Sawynok et al. 2015).

The Gladstone Harbour Report Card 2016 (GHHP 2016a) presented for the first time, an assessment of fish recruitment indicators, which included data captured monthly from 26 sites across 12 harbour zones between December 2015 and March 2016. The data for Gladstone Harbour Report Card 2017 was collected monthly from the same sites and harbour zones as 2016 between December 2016 and March 2017 (GHHP 2017a). The 2017 GHHP Report Card also included fish recruitment (bream species).

The Gladstone Harbour Report Card 2017 (GHHP 2017a) assessed three measures for Mud crab (*Scylla serrata)*, including abundance, prevalence of rust lesions and size (sex ratio). In the future, a fourth measure, biomass will be included when there is sufficient data accumulated to determine a biomass baseline.

The data included in the 2016 report (and its collection process), was reviewed by the GHHP Independent Science Panel and the GHHP Science Team to ensure scientific rigour (GHHP 2016b).

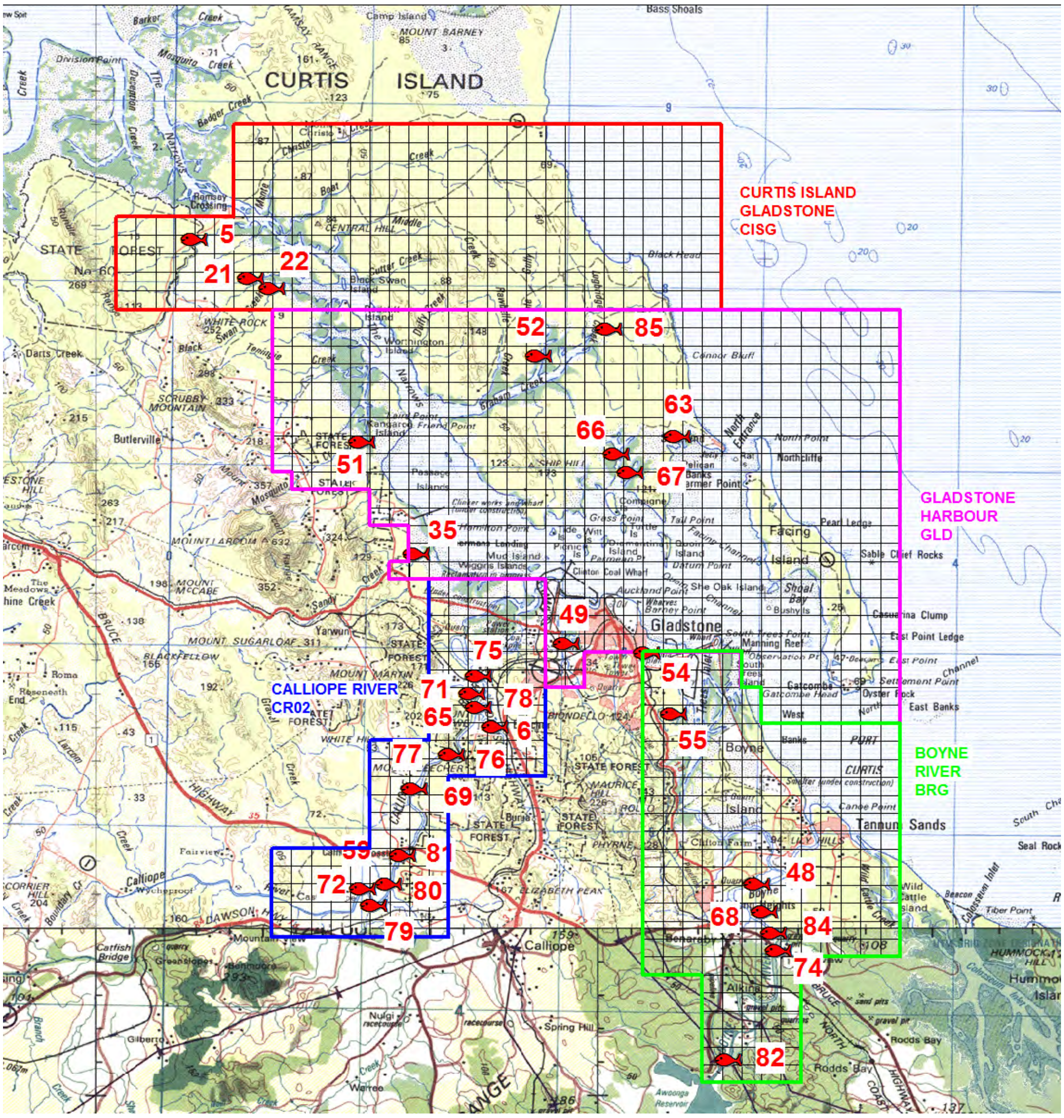

Figure 9.4 Site locations in the Gladstone study area and Suntag grid maps

Source: Infofish Australia (2018)

9.3 Existing fish and fisheries values

This section provides existing baseline information on the fish and fisheries values relevant to Port Curtis and associated waterways, including:

- Database search results (refer Section 9.3.1)
- Estuarine and coastal fish communities in Port Curtis (refer Section 9.3.2)
- Reef associated fish communities in Port Curtis (refer Section 9.3.3)
- Gladstone Healthy Harbour Partnership baseline survey (refer Section 9.3.4)
- Commercial and recreational fish catch data spatial distribution (refer Section 9.3.5)
- Commercial fisheries values (refer Section9.3.6)
- Recreational fisheries values (refer Section 9.3.7)
- Traditional fisheries values (refer Section 9.3.8).

9.3.1 Database search results

Database records for Port Curtis and the Gladstone region list 42 fish species under the EPBC Act as either migratory (8) or listed marine (34) species. The migratory species are all sharks and rays, while the listed marine species are all sygnathids (i.e. seahorse, pipehorse and pipefish). Four threatened fishes and sharks listed as Vulnerable under the EPBC Act were identified including Great white shark (*Carcharodon carcharias*), Whale shark (*Rhincodon typus*), Murray cod (*Maccullochella peelii*) and Green sawfish (*Pristis zijsron*) (refer Table 9.2). In addition, Estuary stingray (*Dasyatis fluviorum*), was identified from database searches of the Port Curtis region (refer Table 9.2). This species is listed as near threatened under the provisions of the NC Act, however, it is not a conservation significant species under the provisions of the EPBC Act.

Table 9.2 Listed marine fish species identified from database searches of the Port Curtis region

Scientific name	Common name	Management status (EPBC Act)	NC Act Status
Acentronura tentaculata	Shortpouch pygmy pipehorse	Listed marine species	-
Campichthys tryoni	Tryon's pipefish	Listed marine species	-
Carcharodon carcharias	Great white shark	Vulnerable/Migratory (Bonn Convention)	-
Choeroichthys brachysoma	Pacific short-bodied pipefish	Listed marine species	-
Corythoichthys amplexus	Fijian banded pipefish	Listed marine species	-
Corythoichthys flavofasciatus	Reticulate pipefish	Listed marine species	-
Corythoichthys haematopterus	Reef-top pipefish	Listed marine species	-
Corythoichthys intestinalis	Australian messmate pipefish	Listed marine species	-
Corythoichthys ocellatus	Orange-spotted pipefish	Listed marine species	-
Corythoichthys paxtoni	Paxton's pipefish	Listed marine species	-
Corythoichthys schultzi	Schultz's pipefish	Listed marine species	-
Dasyatis fluviorum[1]	Estuary stingray	-	Near threatened
Doryrhamphus excisus	Bluestripe pipefish	Listed marine species	-
Festucalex cinctus	Girdled pipefish	Listed marine species	-

Scientific name	Common name	Management status (EPBC Act)	NC Act Status
Filicampus tigris	Tiger pipefish	Listed marine species	-
Halicampus dunckeri	Red-hair pipefish	Listed marine species	-
Halicampus grayi	Mud pipefish	Listed marine species	-
Halicampus nitidus	Glittering pipefish	Listed marine species	-
Halicampus spinirostris	Spiny-snout pipefish	Listed marine species	-
Hippichthys cyanospilos	Blue-speckled pipefish	Listed marine species	-
Hippichthys heptagonus	Madura pipefish	Listed marine species	-
Hippichthys penicillus	Beady pipefish	Listed marine species	-
Hippocampus bargibanti	Pygmy seahorse	Listed marine species	-
Hippocampus kuda	Spotted seahorse	Listed marine species	-
Hippocampus planifrons	Flat-face seahorse	Listed marine species	-
Hippocampus zebra	Zebra seahorse	Listed marine species	-
Isurus oxyrinchus	Shortfin mako	Migratory (Bonn Convention)	-
Isurus paucus	Longfin mako	Migratory (Bonn Convention)	-
Lamna nasus	Porbeagle	Migratory (Bonn Convention)	-
Lissocampus runa	Javelin pipefish	Listed marine species	-
Maccullochella peelii	Murray cod	Vulnerable	-
Manta alfredi	Reef manta ray	Migratory (Bonn Convention)	-
Manta birostris	Giant manta ray	Migratory (Bonn Convention)	-
Micrognathus andersonii	Anderson's pipefish	Listed marine species	-
Micrognathus brevirostris	Thorn-tailed pipefish	Listed marine species	-
Nannocampus pictus	Painted pipefish	Listed marine species	-
Pristis zijsron	Green sawfish	Vulnerable/Migratory (Bonn Convention)	-
Rhincodon typus	Whale shark	Vulnerable/Migratory (Bonn Convention)	-
Solegnathus hardwickii	Pallid pipehorse	Listed marine species	-
Solenostomus cyanopterus	Robust ghostpipefish	Listed marine species	-
Solenostomus paegnius	Rough-snout ghost pipefish	Listed marine species	-
Solenostomus paradoxus	Ornate ghostpipefish	Listed marine species	-
Syngnathoides biaculeatus	Double-end pipehorse	Listed marine species	-
Trachyrhamphus bicoarctatus	Bentstick pipefish	Listed marine species	-

Table notes:

Listed marine species are not considered a MNES under provisions of the EPBC Act.

1 This species is also known as *Hemitrygon fluviorum*

Source: EPBC Act PMST (DoEE 2019), Wildnet (DES 2019)

Fish and other nekton included on the Fitzroy NRM BoT species prioritisation framework are listed in Appendix K (Table 2), including fish species historically found in the Port Curtis region such as the Green sawfish and the Grey nurse shark (*Carcharias taurus*) (east coast population) (Alquezar 2011; Currie and Connolly 2004; Graham et al. 2007). The Green sawfish is listed as vulnerable under provisions of EPBC Act however, this species has not been recorded in Port Curtis since the late 1960s.

The Grey nurse shark, listed as critically endangered under the provisions of the EPBC Act, has the potential to occur in waters to the south of Rodds Peninsula (DoEE 2019). While the closest record to the Project impact areas included in the ALA is situated off the coast of Byron Bay, New South Wales, approximately 600km southeast of Port Curtis (NCRIS 2015), there is published literature that has recorded the Grey nurse shark at Guthrie Shoal, Fraser Island, Moreton Island and North Stradbroke Island.

The Estuary stingray, Green sawfish and Great white shark are all ranked as high priority species by the BoT species prioritisation framework (DERM 2010a). The Estuary stingray utilises a range of shallow inshore habitats and is likely to frequent the Port Curtis region. The Green sawfish inhabits muddy bottom habitats and enters estuaries (DERM 2010a). It has been recorded in inshore marine waters, estuaries, river mouths, embankments and along sandy and muddy beaches. While Great white sharks can travel large distances offshore, they can also frequent inshore marine environments around rocky reefs, surf beaches and shallow coastal bays (DERM 2010a), all of which can be found in the Port Curtis region.

9.3.2 Estuarine and coastal fish communities

9.3.2.1 General context and existing information

Estuaries and coasts are complex environments that support a wide range of flora and fauna, and can comprise a number of subtidal and intertidal habitats, including seagrass meadows, mangrove forests, saltmarshes, soft muddy and sandy flats, sandy beaches and rocky outcrops (Faunce and Serafy 2006; Meynecke 2009; Sheaves et al. 2007). Fish communities can vary widely among these habitats.

Seagrass meadows have important economic value in terms of providing nursery and feeding habitats for commercial and recreational fisheries species (Watson et al. 1993; Unsworth and Cullen 2010), particularly the inshore and offshore prawn fisheries. Tiger prawn (e.g. *Penaeus esculentus, Penaeus monodon*), Endeavour prawn (*Metapenaeus endeavouri*), Banana prawn (*Fenneropenaeus merguiensis*) and Rainbow prawn (*Parapenaeopsis sculptilis*), all rely on the region’s seagrass communities at some stage of their lifecycle (Lee Long et al. 1992; GPC 2015a). While seagrass meadows are extensively used by juvenile fish, studies have also shown that large predatory fish inhabit seagrass beds at night (Alquezar 2011). Seagrass meadows are also recognised as important ecosystems for the maintenance of sea bed stability, water quality and biodiversity (DNPRSR 2014).

Mangrove environments are critical for creating an ecosystem to support fish and prawn species (including commercially and recreationally important species) as they rely on these environments during vulnerable stages of their lifecycle (Hutchinson et al. 2014). Mangroves provide an ideal protective environment, food and shelter, juvenile nursery grounds, and a place for estuarine and freshwater spawning fish (Alquezar 2011; Hutchinson et al. 2014).

Although fish utilisation of saltmarshes in the Port Curtis region is not well studied, investigations of saltmarsh-dependent organisms and adjacent mangrove habitats by GBRMPA (2006) found abundance and diversity of fish species increases with connection between habitat types. In the Great Barrier Reef region saltmarshes have been found to play a valuable role in the lifecycles of Red emperor (*Lutjanus sebae*), Sharks, Rays and other fish species (Goudkamp and Chin 2006; GPC 2015a).

A similar study by Sheaves et al. (2007) located at Munduran Creek which drains into The Narrows, found saltmarsh and saltpan habitats provide important habitat for fish species, including those of recreational and commercial significance, despite usually having lower species richness than other inshore habitats such as mangroves and seagrass (Sheaves et al. 2007).

Exposed mud and sand banks are the most common intertidal habitat within Port Curtis and generally are thought to be unproductive environments for fish compared to seagrass meadows or mangroves. Small (1997) found high proportions of economically important fish species in subtidal flats which are used by juvenile fish species, such as the Sea mullet (*Mugil cephalus*), seeking alternative habitat at low tide when adjacent seagrass meadows and mangroves become fully drained (Small 1997; DNPRSR 2014). Furthermore, these habitats contain high biodiversity and biomass of benthic invertebrates and algae that provide a direct food source for commercial and recreational fisheries species (QGC 2009; Long and McKinnon 2002). These environments are also critical habitat to nektonic invertebrate fisheries species, including the Banana prawn, Endeavour prawn and Mud crab.

Beach habitats made up of sand and pebble substrate are found around the Port Curtis coast and estuaries and support communities of algae which provide food sources for epifaunal and infaunal macroinvertebrates such as crustaceans, polychaete worms and molluscs. These species are a direct food source for fisheries species such as Whiting (*Sillaginidae*), Seabream (*Sparidae*), Flathead (*Platycephalus* spp.) and Mullet (*Mugilidae*) (DNPRSR 2014).

Estuaries, creeks and rivers act as highways for fish and other nekton that commute from one system to another, especially along coastal beaches and fringing rocky reefs during tidal movements, concentrating fish numbers in search for food and shelter (Jones and West 2005; Meynecke et al. 2008a; Meynecke et al. 2008b; Neira and Potter 1992; Rolls 2011; Sousa and Dangremond 2011 in Vision Environment 2015a). These estuarine environments are essential to the lifecycle of many recreational, Indigenous and commercially targeted fish species, including Mud crab, Barramundi, Flathead, Prawn species (Penaeidae), Mullet, and Bull shark (*Carcharhinus leucas*) (Walker 1997). Some local species such as Mangrove jack (*Lutjanus argentimaculatus*) use estuaries as juveniles and then move to offshore reefs as they mature (Sawynock et al. 2014).

Quinn (1992) estimates that more than 75% of all species harvested in Queensland's commercial fisheries rely on the variety of habitats found in healthy estuaries during some or all of their lifecycle (Quinn 1992; DNPRSR 2014).

Freshwater inputs in Port Curtis come from two major rivers, the Boyne River and the Calliope River, and the numerous creeks and tributaries that discharge into the Port and surrounding waters. The mean spring tidal range for the Port is 3.24m, the mean neap tidal range is 1.54m and the maximum tidal range is 4.69m (BMT WBM 2019). Due to the large tidal storage areas of the Port of Gladstone and the amplification effect on water levels, good tidal flushing and high tidal velocities generally exist within the main channels of Port Curtis (BMT WBM 2019).The importance of freshwater flows in Port Curtis on the productivity of the region has been shown through previous studies where years of large flows tend to result in higher benthic invertebrate productivity, resulting in higher growth rates in fish such as Whiting, which are then caught earlier in their life cycle than they would otherwise occur (Connelly et al. 2006).

Currie and Connelly (2004) found that demersal fish assemblages of Port Curtis are diverse and that assemblages were distinguishable in different habitats, particularly seagrass meadows, and at varying water depths. A trawl net survey of 105 intertidal and shallow subtidal sites (< 5m below mean low water springs) from The Narrows, Graham’s Creek, through to the Western Basin, Inner Harbour, Mid Harbour, and Outer Harbour zones, recorded 88 species of fish from 2,994 individuals collected.

Two small schooling species, the Common ponyfish (*Leiognathus equulus*) and Southern herring (*Herklotsichthys castelnaui*) were the most abundant species occurring at 50% and 36% of sites sampled, respectively. These species are common in inshore coastal waters elsewhere in tropical and subtropical waters of Australia (Currie and Connelly 2004). No significant differences in species abundance were found between the broad regions applied in the study (i.e. upper estuarine, central estuarine and open coastal), although mean richness suggested a general decline in diversity towards the coastal waters of the estuary (Currie and Connelly 2004).

An estuarine gradient was found to occur from The Narrows to open coastal waters, with fish assemblages changing gradually. A strong positive correlation between fish and turbidity was also identified and was considered the most noteworthy of all the water quality relationships investigated in the study (Connelly et al. 2006).

Currie and Connelly (2004) outlined five demersal fish assemblage groups (i.e. Groups I, II, III, IV and V) within Port Curtis using a cluster analysis of species abundance data, from each sampling site. These groups were found to reflect differences in habitat type and water depth (refer Figure 9.5 and Table 9.3). It is noted that the survey used a small trawl collection method over sedimentary habitats and therefore results are likely to exclude the abundance of larger species and those that associate with rock or reef habitat.

Group I was intimately associated with the seagrass meadows (Pelican Banks, South Trees Inlet and Tannum Sands) (Connelly et al. 2006). Group II was spread evenly across the sampling sites from The Narrows to Outer Harbour sites. Group III was highest for species richness and occurred predominantly in The Narrows, as well as in surrounding creeks, rivers and along shorelines. Group IV contained a similar abundance of species to Group III and had a strong presence in Graham's Creek, the Calliope River, and the Western Basin, Inner Harbour and Mid Harbour zones. Group V occurred in areas with stronger coastal water influences in the Outer Harbour and Mid Harbour zones such as adjacent to Hummock Hill Island and Boyne Island.

Table 9.3 Abundance (n/3000m^2) of demersal fish in five regions of Port Curtis identified from hierarchical classification of species/abundance data

Species	Common name	Sample site grouping				
		I	II	III	IV	V
Leiognathus decora	Common ponyfish	-	-	**28.28**	**9.47**	-
Herklotsichthys castelnaui	Southern herring	-	**1.43**	**12.40**	4.38	-
Ambassis marianus	Glass perch	-	-	7.68	1.53	-
Megalaspis cordyla	Finny scad	-	0.88	0.32	2.53	-
Siganus rivulatus	Happy moments	-	-	0.08	-	**6.75**
Saurida undosquamis	Large-scaled grinner	-	**0.29**	0.80	**1.15**	-
Apogon fasciatus	Striped cardinalfish	-	-	0.36	0.50	0.33
Liza dussumieri	Flat-tailed mullet	-	**0.62**	0.24	-	-
Tripodichthys angustifrons	Yellow-fin tripod fish	-	**0.29**	0.24	0.38	-
Pseudorhombus arsius	Large-toothed flounder	-	**0.29**	0.12	0.38	-
Sillago maculata maculata	Winter whiting	-	-	-	0.21	**0.67**
Scomberoides commersonianus	Giant leatherskin	**0.05**	-	0.24	-	-
Upeneus tragula	Bar-tailed goatfish	-	-	-	-	**0.50**
Hippocampus sp. 1	Seahorse	**0.50**	-	-	-	-

Table note:

Species listed were identified from similarity percentage test analyses as contributing ≥ 5% to the similarity within and dissimilarity between regional groupings. Species indicative of each regional grouping (contributing ≥ 5% to the total similarity within a group) are in **bold**. Species are ranked in order of decreasing abundance across all sample sites.

Source: Currie and Connelly (2004).

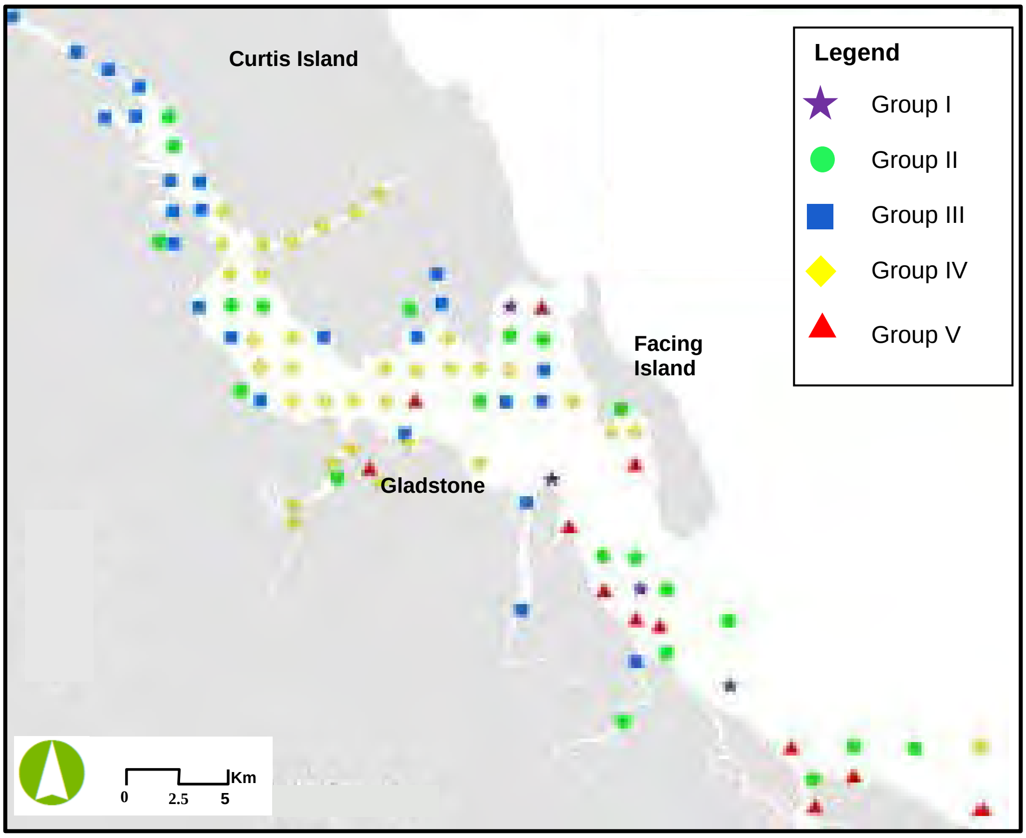

Figure 9.5 **Port Curtis demersal fish trawl survey community classification**

Figure note:

Map showing the locations of 105 demersal fish sampling sites and their classification into five groups following cluster analysis of species abundance data

Source: Currie and Connelly (2004)

Fish assemblages of Port Curtis were reported in Alquezar (2011) from targeted survey sites in the mangrove, seagrass and soft sediment habitats of The Narrows, Western Basin, Inner Harbour and Lower Calliope Estuary zones as part of Project EIS field investigations during 2010 to 2011. In total, 1,262 fish and nektonic invertebrates from 29 species were collected from all sites using a cast net sampling technique. The most common fish and nektonic invertebrate species representative of soft sediment shallow habitats, mangroves and other vegetation lined banks were the Banana prawn, Spottyface anchovy (*Stolephorus waitei*), Greenback mullet (*Liza subviridis*), Southern herring and Common ponyfish (Alquezar 2011). A further 11 species were collected using a gill net technique and consisted of 36 fish and mobile macroinvertebrate. The gill net technique was used to collect species representative of larger sized fish assemblages in deeper water channels. The most common species recorded were Diamondscale mullet (*Liza vaigiensis*), Giant queenfish (*Scomberoides commersonnianus*) and Blue catfish (*Ariopsis graeffei*). Other species recorded included the Beach salmon (*Leptobrama muelleri*), Blue threadfin (*Eleutheronema tetradactylum*) and Mud crab (Alquezar 2011).

9.3.2.2 Project Environmental Impact Statement cast net sampling results

Targeted cast net surveys conducted for the Project EIS recorded a total of 2,936 individuals representing 34 species of which 2 species (Blue swimmer crab (*Portunis armatus*) and Banana prawn) were invertebrates and the remaining species were fish (refer Appendix L (Table 1)). The most commonly observed species were Southern herring (38.7%), Estuary glassfish (*Ambassis marianus*) (21.3%) and Spottyface anchovy (14.3%), although Banana prawn were also frequently encountered (7.4%) (Vision Environment 2015a).

Significant differences in fish density, species richness, diversity and evenness were encountered among the locations sampled (refer Figure 9.6), with highest numbers of fish encountered at Lilleys Inlet, South Trees Inlet, Calliope River mouth and The Narrows/Targinnie Creek sites. Lowest numbers were encountered at Sand Islet and Southwest Facing Island sites (Vision Environment 2015a). Species richness was also significantly lower at Sand Islet, Fisherman's Landing and Wild Cattle Creek relative to all other sites (Vision Environment 2015a). In general, there were no significant differences in the biodiversity of the fish and other nekton encountered between the dry season and the wet season (Vision Environment 2015a). However, significant interactions among season and location were observed, suggesting that differences in biodiversity were encountered between seasons for some locations but not others (refer Figure 9.6) (Vision Environment 2015a).

Similar to biodiversity, fish community assemblages were also significantly dissimilar among locations, irrespective of season (refer Figure 9.6), with the largest differences observed between the South Trees Inlet and Sand Islet, in addition to Sand Islet and Lilleys Inlet (Vision Environment 2015a). Fish communities were similar in composition between Fisherman's Landing and The Narrows/Targinnie Creek, Wild Cattle Creek and Boyne River, and South Trees Inlet and Boyne River (refer Figure 9.7). There were no significant differences in fish communities recorded at each location during different seasons (refer Figure 9.7).

Differences in fish communities among locations can be attributed to a number of factors, including differences in habitat features (e.g. vegetated versus non-vegetated). In addition, physicochemical parameters, including turbidity and natural tidal flow, have been demonstrated to influence abundance of new recruits within Port Curtis and other locations around Queensland (Currie and Connolly 2004; Currie and Small 2005). Given the difference in the habitats surveyed as part of the EIS investigations, the observed variation in estuarine and coastal inshore fish communities is not unexpected.

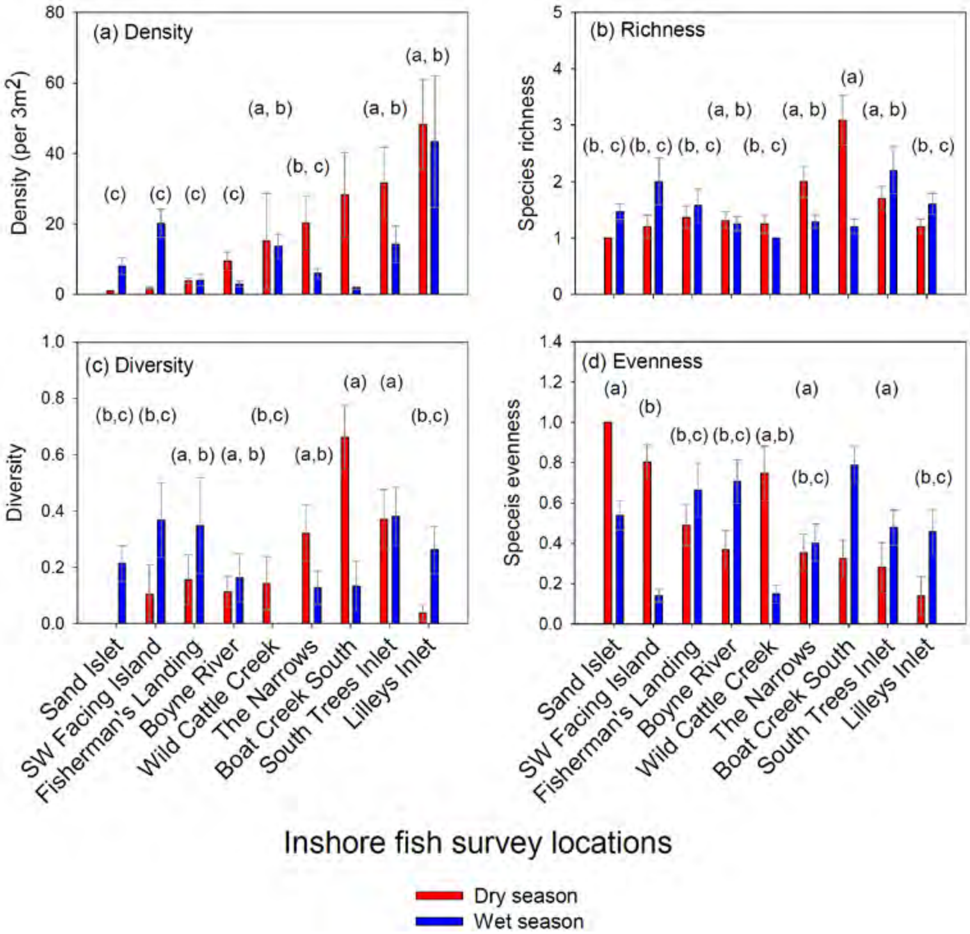

Figure 9.6 **Mean fish density (a), species richness (b), diversity (c), and species evenness (d) at nine estuarine and coastal inshore cast net sampling locations**

Source: Vision Environment (2015a)

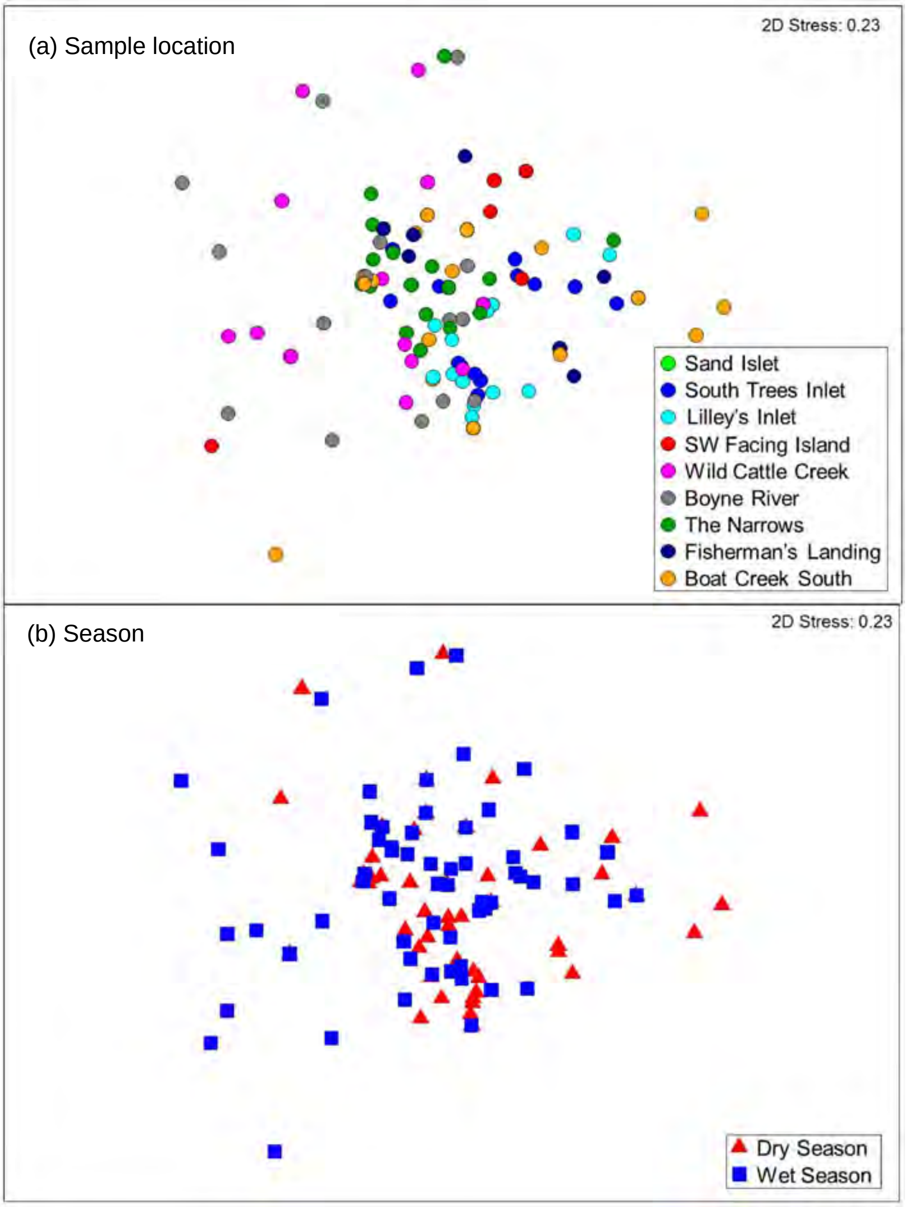

Figure 9.7 **Non-metric Multidimensional Scaling (nMDS) ordination plot (Bray-Curtis similarity) of fish community assemblages utilising shallow complex habitats among (a) locations, and (b) seasons**

Source: Vision Environment (2015a)

9.3.2.3 Project Environmental Impact Statement gill net sampling results

A total of 44 species of fish were identified during gill net sampling during the 2014 dry season and the 2015 wet season (Vision Environment 2015a). The most commonly caught species was the Giant queenfish (27%), Blue threadfin (11%), Beach salmon (11%), and Mud crab (11%). Species observed at each sampling location are presented in Table 9.4. Highest numbers of fish and other nekton caught in gill nets, irrespective of season, were encountered at Fisherman's Landing (12 individuals), followed by the Boyne River (10 individuals) and Lilleys Inlet (8 individuals). No fish or other nekton were collected by gill nets at Wild Cattle Creek or The Narrows/Targinnie Creek during both dry and wet season campaigns (Vision Environment 2015a). Species richness was also highest at Fisherman's Landing and Lilleys Inlet (refer Table 9.4).

Table 9.4 Species and abundance of fish associated estuarine and coastal habitats within Port Curtis during 2014 dry season and the 2015 wet season by gill net sampling

Location	Family name	Species name	Common name	Season		Total observed
				Dry	Wet	
Lilleys Inlet	Scatophagidae	*Scatophagus argus*	Spotted scat	3	0	**3**
	Carangidae	*Scomberoides commersonnianus*	Giant queenfish	1	1	**2**
	Terapontidae	*Amniataba percoides*	Barred grunter	1	0	**1**
	Scatophagidae	*Scatophagus argus*	Spotted scat	1	0	**1**
	Carangidae	*Carangoides humerosus*	Epaulette trevally	0	1	**1**
Fisherman's Landing	Leptobramidae	*Leptobrama muelleri*	Beach salmon	1	2	**3**
	Polynemidae	*Eleutheronema tetradactylum*	Blue threadfin salmon	3	0	**3**
	Portunidae	*Scylla serrata*	Mud crab	4	0	**4**
	Ariidae	*Ariopsis graeffei*	Blue catfish	1	0	**1**
	Rhinobatidae	*Aptychotrema rostrata*	Eastern shovelnose ray	0	1	**1**
Boat Creek South	Ariidae	*Ariopsis graeffei*	Blue catfish	2	0	**2**
	Leptobramidae	*Leptobrama muelleri*	Beach salmon	1	1	**2**
	Pomatomidae	*Pomatomus saltatri*	Tailor	0	1	**1**
South Trees Inlet	Polynemidae	*Eleutheronema tetradactylum*	Blue threadfin salmon	1	0	**1**
	Carangidae	*Scomberoides commersonnianus*	Giant queenfish	0	1	**1**
	Carangidae	*Carangoides humerosus*	Epaulette trevally	0	1	**1**
	Portunidae	*Scylla serrata*	Mud crab	0	1	**1**
Southwest Facing Island	Terapontidae	*Amniataba percoides*	Barred grunter	1	0	**1**
	Polynemidae	*Eleutheronema tetradactylum*	Blue threadfin salmon	1	0	**1**
Boyne River	Carangidae	*Scomberoides commersonnianus*	Giant queenfish	0	9	**9**
Sand Islet	Carcharhinidae	*Carcharhinus melanopterus*	Blacktip reef shark	0	1	**1**
Wild Cattle	-	-	-	0	0	**0**
The Narrows/ Targinnie Creek	-	-	-	0	0	**0**

Source: Vision Environment (2015a)

9.3.3 Reef associated fish communities

9.3.3.1 General context and existing information

Reef associated fish are important components of shallow water habitats, in that they form complex ecosystem functions. While fish are more mobile and can cover great distances compared to nektonic invertebrates, some fish such as Reef damselfish (*Pomacentrus* spp.) and Baitfish have restricted homing ranges (Alquezar 2011). For example, some reef associated fish species are obligate corallivores (species that feed primarily on coral), whereas other fish species are grazers, which rely on different types of algal growth thus preventing overgrowth of macroalgal habitats. Some species, such as Parrot fish (Scaridae), graze on the coral structure, contributing to links within the carbon cycle and reef re-formation (Fabricius et al. 2005; Glynn 1993; Hay 1984; Hughes 1994; Johansen and Jones 2013; Kavanagh 2000; Letourneur et al. 1998; Pratchett et al. 2011). It is suggested that up to 75% of fish found within a coral reef rely on live corals for food, shelter or settlement (Pratchett et al. 2011). Hence, there is a strong positive relationship between coral and other live substrate cover, and reef associated fish assemblages.

Based on mapping from GBRMPA (2016), Port Curtis contains 19 reefs made up of predominantly rocky shores or shallow subtidal reefs, although existing mapping is thought to significantly underestimate the extent of subtidal reefs in this area (BMT WBM 2014a). Coral reef communities in Port Curtis are typical of fringing coral reefs on the southern inshore Great Barrier Reef. When compared to reefs in the northern Great Barrier Reef region, or at mid-shelf or outer-shelf areas, reefs in the Port Curtis are generally lower in coral species richness and tend to be made up of corals along with other benthic organisms (e.g. algae, sponges) growing on rocks or boulders (Ayling et al. 2012; GBRMPA 2007; DeVantier et al. 2006). Section 8 provides a detailed overview of reef communities in the Port Curtis region.

There is a distinct lack of descriptive and quantitative data for reef associated fish species and assemblages in Port Curtis (BMT WBM 2013). Commercial fisheries provide compulsory monitoring data on catches which can indicate key trends in relative abundance of key fisheries species (BMT WBM 2013). However these data records are largely opportunistic and are relatively insufficient in determining trends in reef fish abundance given the limited frequency of data collection, the targeted nature of each fishery, and a general focus on estuarine (soft sediment) species (BMT WBM 2013). High turbidity and low visibility make collecting sufficient data in the reef areas of Port Curtis particularly difficult.

Commercial fisheries catch data for the Port Curtis region and neighbouring reporting grids was analysed in BMT WBM (2013) to provide an indication of species catch data for estuarine fish versus reef affiliated fish species. Species recorded in the S30 grid (refer Figure 9.2) described as having some reef association include Seabream, Blue swimmer crab, Mud crab, Cuttlefish (Sepiida), and Flathead, although Flathead, Mud crab, and Blue swimmer crabs are generally associated with soft sediment habitat.

Anecdotal evidence from online fishing forums and recreational fishing websites provide some indication on reef associated species found in Port Curtis. Information suggests that several reef associated species such as Tuskfish (*Choerodon* spp.), Grass emperor (Sweetlip) (*Lethrinus laticaudis*), Estuary cod (*Epinephelus coioides*) inhabit rocky outcroppings such as those located in the Inner Harbour zone at the southern end of Curtis Island and surrounding islands (e.g. Diamantina Island, Witt Island, Turtle Island, Picnic Island) (BMT WBM 2014a). Further south around Seal Rocks and Gatcombe Head, species such as Grass emperor, Coral cod (*Cephalopholis miniata*), Coral trout (*Plectropomus leopardus*), Silver bream (*Rhabdosargus sarba*) and Yellowfin bream have been reported.

Ecological studies of fish communities have been conducted at reefs in the wider region at the Capricorn Bunker group (approximately 50km from Port Curtis), however these locations are generally considered remote from the influences of Port Curtis (BMT WBM 2014a).

The Project EIS reef associated fish survey (refer Sections 9.2.2.2 and 9.3.3.2) is the first known study to focus on the relationship between fish assemblages and hard substrate reef communities in Port Curtis.

9.3.3.2 Project EIS reef associated fish survey results

A total of 6,037 fish from 59 species were encountered throughout the four monitoring locations during the 2014 dry season (37% of individuals recorded) and the 2015 wet season (63% of individuals recorded) (Vision Environment 2015a) (refer Appendix L (Table 2)). The most common fish species observed consisted of the Yellowtail demoiselle (*Neopomacentrus azysron*) (41%), followed by the Spotted-tail wrasse (*Coris caudimacula*) (11%), and Wards damsel (*Pomacentrus wardi*) (10%). The most common fish families throughout the monitoring program included Pomacentridae (Damsel fish) (73%), followed by Labridae (Wrasse) (21%), and Apogonidae (Cardinal fishes) (2%) (Vision Environment 2015a).

Significant differences in fish density, species richness, diversity and evenness were observed among sampling locations, with the highest quantities of fish and diversity of species encountered at Sable Chief Rocks and Jenny Lind Banks (refer Figure 9.8). Lowest numbers and species diversity were encountered at Seal Rocks and Gatcombe Heads. No significant differences were observed in fish biodiversity among seasons.

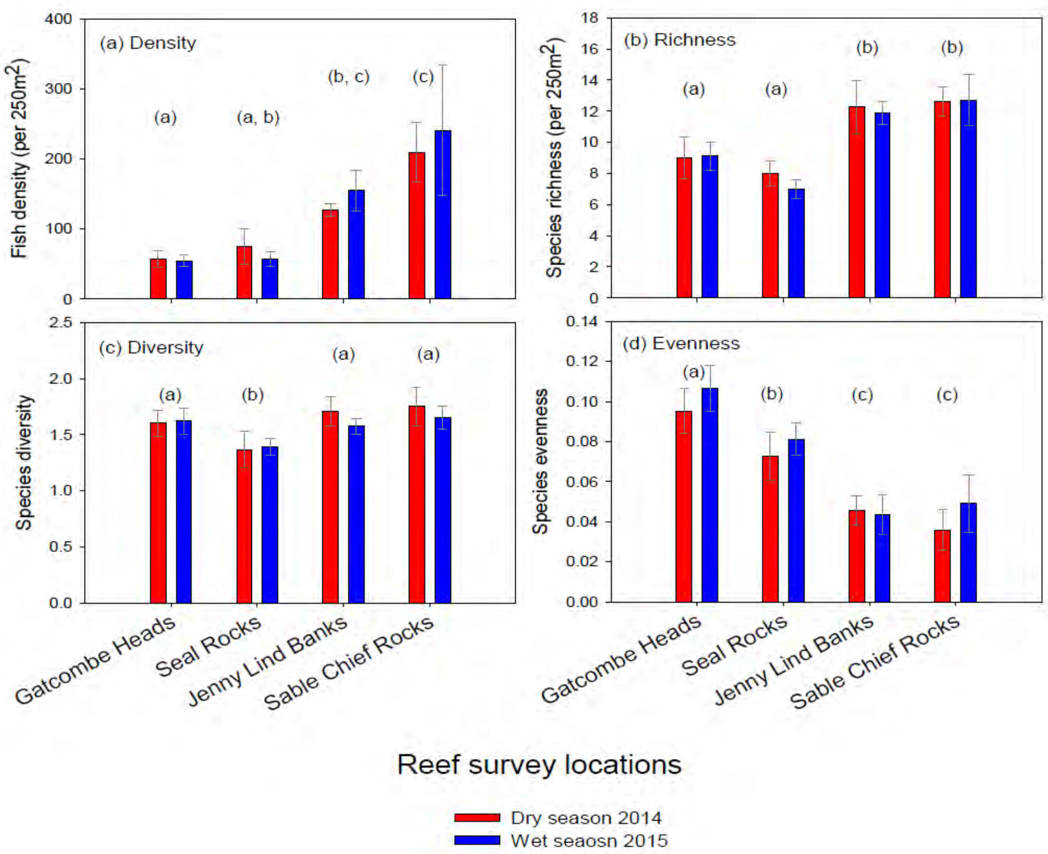

Figure 9.8 **Mean fish density (a), species richness (b), diversity (c), and species evenness (d) at four reef locations sampled**

Source: Vision Environment (2015a)

Reef obligate and associated fish communities tend to be territorial or have very limited homing ranges, hence they do not move large distances throughout their life time (Vision Environment 2015a). This is likely to explain why there were no differences in biodiversity observed between seasons (Vision Environment 2015a).

Significantly dissimilar reef associated fish assemblages were observed among locations, and season, with the highest differences in fish community structure encountered between Gatcombe Heads, Sable Chief Rocks and Seal Rocks (refer Figure 9.8). However, fish communities were similar between Jenny Lind Banks and Sable Chief Rocks, as well as Gatcombe Heads and Seal Rocks.

Minor correlations between substrate community matrices and fish assemblages were encountered, with hard coral substrate being the best fitting correlation to explain fish community assemblages among locations (refer Figure 9.9). However, reef macroalgae (refer Section 7) was highly correlated with fish assemblages between the wet and dry seasons. The results suggest that different fish communities may be governed by the type of reef structure present. Hence, a change in substrate type is likely to lead to a change in fish communities. Hard corals represented 16% of the total variation in the total data and macroalgae contributed to 45% of the total variation (refer Figure 9.9).

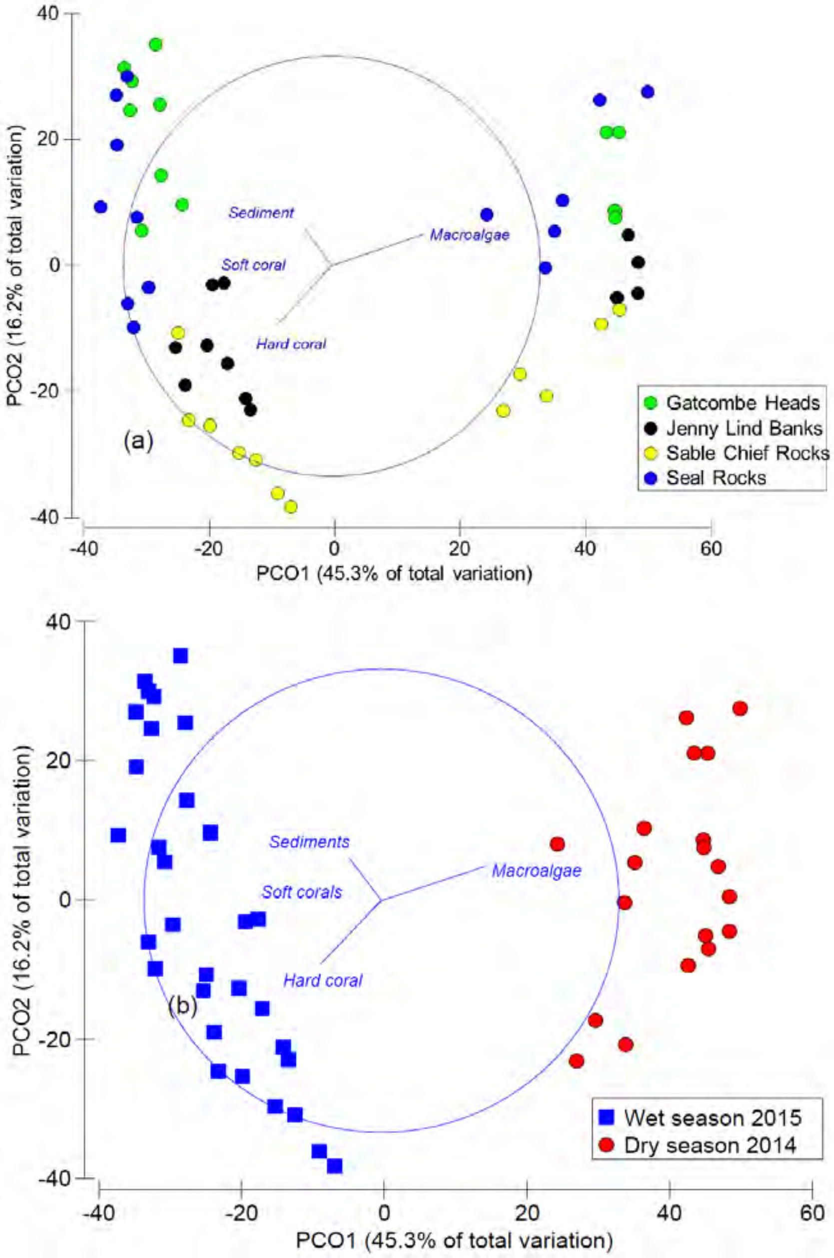

Figure 9.9 **Principle Coordinates Ordination of reef associated k=fish and other nekton among locations (a) and season (b)**

Source: Vision Environment (2015a)

Due to poor visibility conditions underwater, BRUVS deployed at Seal Rocks, Jenny Lind Banks, Gatcombe Heads and Sable Chief Rocks yielded limited data during the dry season of 2014 and no usable data was collected during the wet season of 2015 (Vision Environment 2015a).

Analysis of BRUVS data collected in 2014 indicated that the highest number of occurrences of fish in a one hour block was at Gatcombe Heads, followed by Jenny Lind Banks and Sable Chief Rocks, suggesting that fish resided in the vicinity of the BRUVS longer at Gatcombe Heads compared to other locations (Vision Environment 2015a). There were also significantly higher numbers of fish observed per frame at Gatcombe Heads compared to Jenny Lind Banks and Sable Chief Rocks, however there were no significant differences in species richness among locations (Vision Environment 2015a). The highest numbers of species were recorded at Jenny Lind Banks (refer Table 9.5).

Table 9.5 Species of fish identified at the BRUVS at each deployment location during the 2014 dry season sampling

Family	Species name	Common name	Species recorded at location		
			Gatcombe Heads	Sable Chief Rocks	Jenny Lind Banks
Balistidea	*Sufflamen* sp.	Black trigger fish	No	**Yes**	No
Chaetodontidae	*Chaetodon plebeius*	Blue-blotch butterflyfish	No	No	**Yes**
Chaetodontidae	*Chaetodon trifascialis*	Chevron butterflyfish	No	**Yes**	**Yes**
Labridae	*Pseudolabrus guentheri*	Gunther's wrasse	No	No	**Yes**
Labridae	*Thalassoma lunare*	Moon wrasse	**Yes**	No	**Yes**
Labridae	*Coris caudimacula*	Spotted-tail wrasse	No	No	**Yes**
Lutjanidae	*Lutjanus russellii*	Moses' snapper	**Yes**	No	No
Lutjanidae	*Lutjanus carponotatus*	Spanish flag/ Stripey snapper	**Yes**	**Yes**	**Yes**
Pomacentridae	*Chrysiptera rollandi*	Rolland's demoiselle	No	No	**Yes**
Pomacentridae	*Neopomacentrus azysron*	Yellowtail demoiselle	No	**Yes**	No
Pomacentridae	*Chromis nitida*	Yellowback puller	No	**Yes**	No
Sparidae	*Acanthopagrus australis*	Yellowfin bream	**Yes**	No	No
Sphyraenidae	*Sphyraena obtusata*	Yellowtail barracuda	**Yes**	No	**Yes**
Total species observed			**5**	**5**	**8**

Source: Adapted from Vision Environment (2015a)

9.3.4 Gladstone Healthy Harbour Partnership baseline surveys

9.3.4.1 Fish recruitment

Fish indicators within the harbour received an overall score of 0.40 (‘D’ grade, i.e. Poor) in the Gladstone Harbour Report Card 2016 (GHHP 2016a). This was measured in two Bream species (Yellowfin bream and Pikey bream [*Acanthopagrus pacificus*]). The Western Basin Harbour Zone and Inner Harbour Zone, applicable to the Project, were also assigned a ‘D’ grade.

The 2016 Gladstone Harbour Report Card fish recruitment score indicates a season with decreased catch rate, relative to the median reference level determined over that baseline period (GHHP 2016a). Statistical analysis identified large differences in fish recruitment between years (seasons) over this short time period, hence this result is regarded as provisional at this stage, and confidence in this indicator will improve as the data set increases (GHHP 2016a).

The overall score for fish recruitment in 2017 was 0.71 ('B' grade), indicating a good result. This was measured in two species as was the 2016 report card. The 2017 score for fish recruitment indicates a season with a higher recruitment rate (increased catch rate) relative to the median reference level determined over the baseline period.

9.3.4.2 Mud crabs

GHHP in 2017 produced a report card grading Mud crab health for 13 monitored sites (GHHP 2017b). The monitoring program required the development of relevant indicators to monitor Mud crab health and a methodology for allocating grades and scores.

The program revealed an overall grade of 'C' (0.55) for Mud crabs in the monitored sites with three of seven zones receiving a very good grade for abundance, whilst very poor and satisfactory were given to three zones and one zone respectively. Sex ratio also contributed to the low overall grading with six zones receiving poor to very poor gradings and a single site receiving a grading of good (GHHP 2017b).

9.3.5 Commercial and recreational fish catch data spatial distribution

The reported and documented catch rates of species within the Port of Gladstone and the associated intertidal and upstream environments have been consolidated within a database created by Infofish Australia (2018). For the purpose of the Project EIS, fish catch data was obtained for the period between 2014 and 2018. The Infofish Australia fish catch data has been derived from two sources:

- Suntaggers (2018)
- Gladstone Healthy Harbour Partnership (2017) recruitment survey data.

The consolidated Infofish Australia fish catch data has been used to show the spatial distribution of various fish catch species within the Port of Gladstone and its associated tributaries.

The data identifies that of the 32 fish species recorded, 18 were predominantly confined to being caught within the coastal bays, inlets and waterways. These species include Sand whiting, Banana prawns, Mangrove jack, Threadfin salmon, Coastal whiting and Flattail mullet. The remaining 14 species were recorded to be caught throughout the greater Port of Gladstone area and included fish species such as Yellowfin bream, Pikey bream, Barramundi, Gold-spotted rock cod and Dusky flathead (refer Appendix L (Figures L1 to L32) in Appendix I1 (Ecology Technical Report)).

The data obtained from Infofish Australia (2018) shows only two species, Gold-spotted rock cod and Barred javelin, being caught in proximity to the proposed channel duplication area to be dredged. Other fish species were recorded in the bays on the southwestern side of Facing Island.

The Infofish Australia (2018) data has been spatially summarised into general habitat types utilised by the fish species caught and recorded, including:

- Soft benthic habitat species (refer Figure 9.10)
- Intertidal/estuary habitat species (refer Figure 9.11)
- Reef associated habitat species (refer Figure 9.12)
- Sandy habitat species (refer Figure 9.13).

The data indicates that fish species utilising soft benthic habitats, intertidal/estuary habitat and reef associated habitat were primarily caught, identified and recorded in those areas to the north of the channel duplication area to be dredged and in the Port estuaries and bays to the east.

There was no clear differentiation observed between habitats utilised by certain species and their distribution within the Port of Gladstone area and surrounding waterways. Sandy habitat species were mostly confined to those sandy areas associated with bays and inlets, and not the larger expanses of open water associated with the Port.

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Growth, Prosperity, Community.

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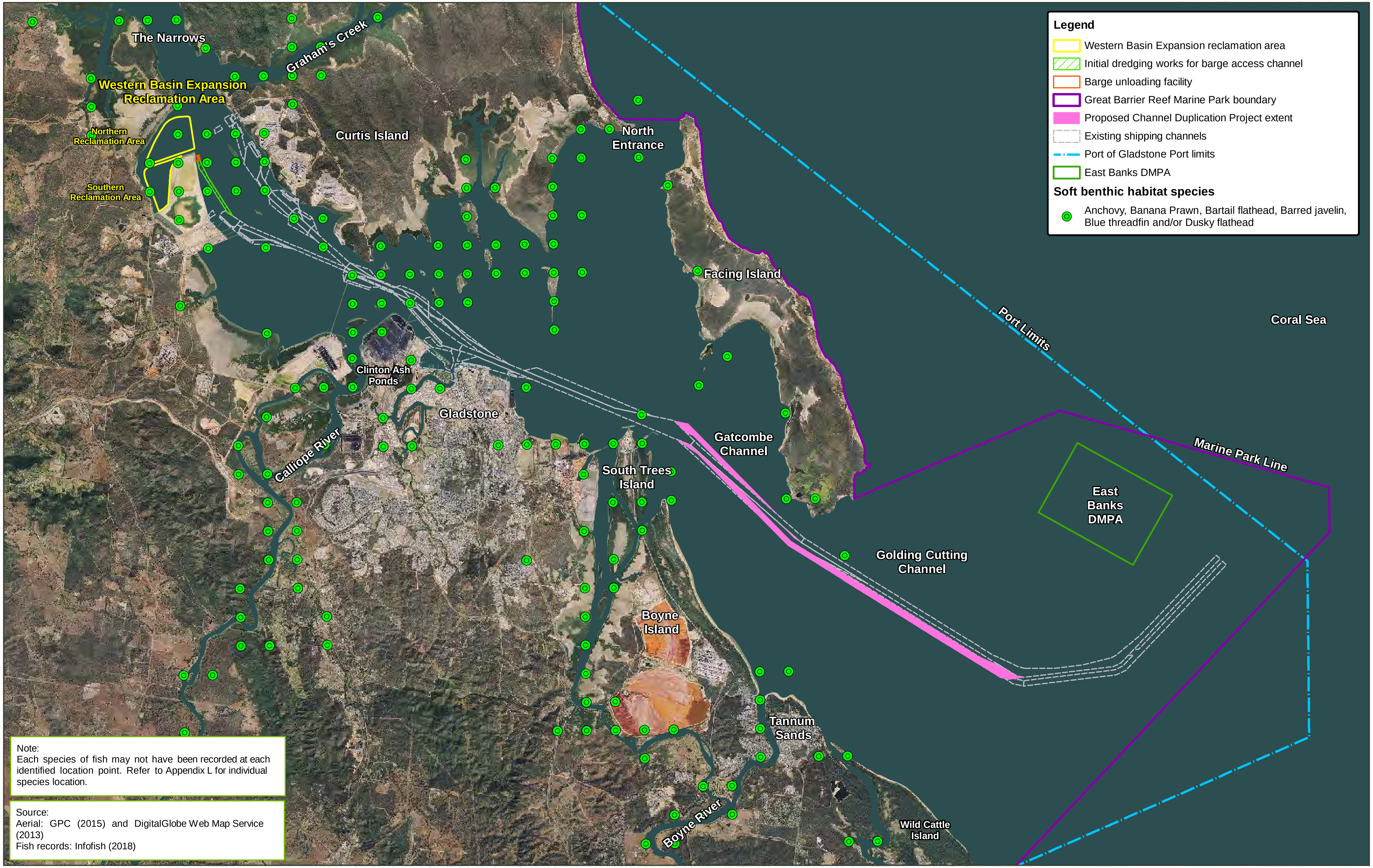

Note:
Each species of fish may not have been recorded at each identified location point. Refer to Appendix L for individual species location.

Source:
Aerial: GPC (2015) and DigitalGlobe Web Map Service (2013)
Fish records: Infofish (2018)

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Map by: RB

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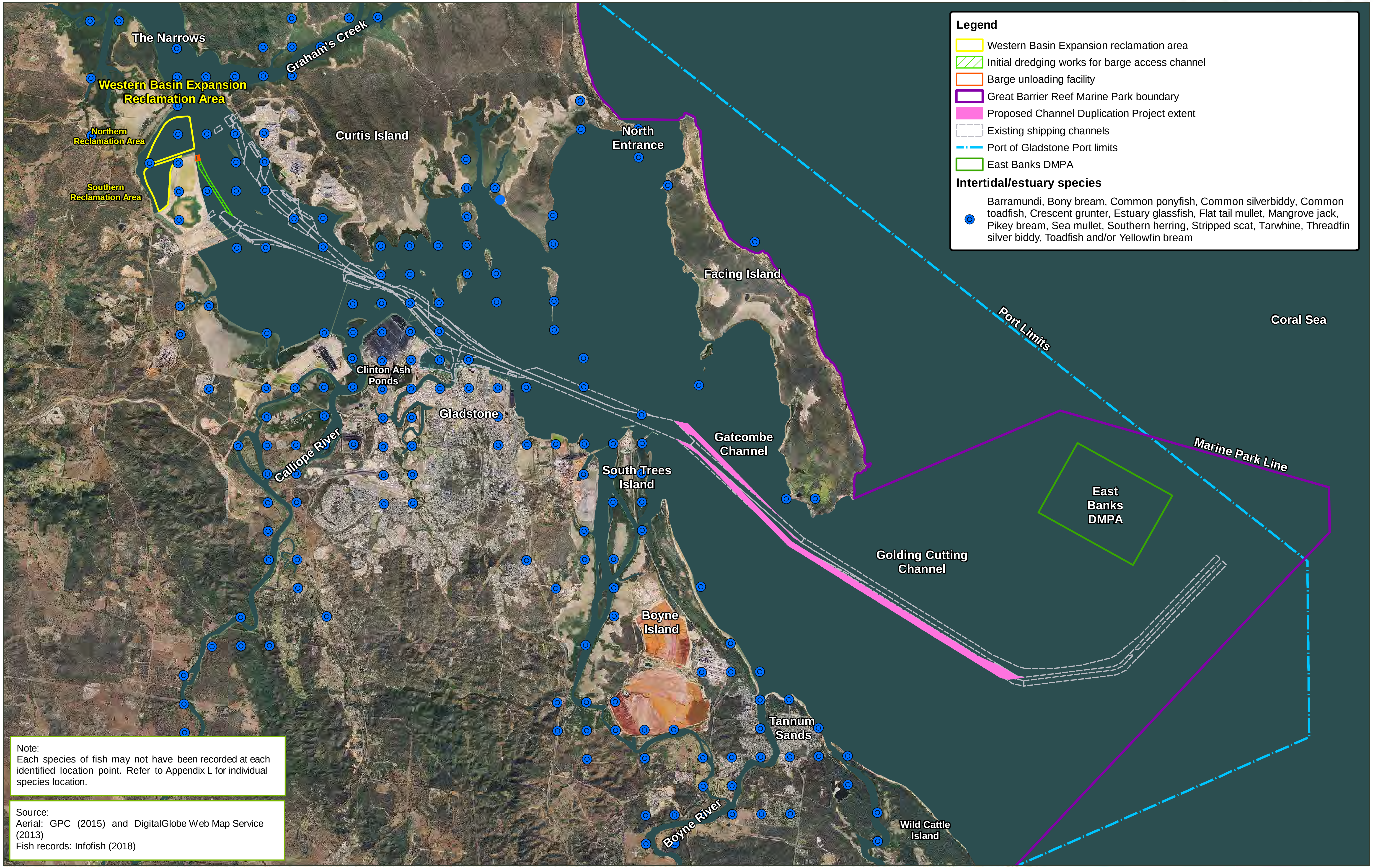
Date: 25/01/2019 Version: 0 Job No: 237374

Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 9.10: Recorded fish species for soft benthic habitat species



Note:
Each species of fish may not have been recorded at each identified location point. Refer to Appendix L for individual species location.

Source:
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Fish records: Infofish (2018)

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Gatcombe and Golding Cutting Channel Duplication Project

Figure 9.11: Recorded fish species for Intertidal/estuary species

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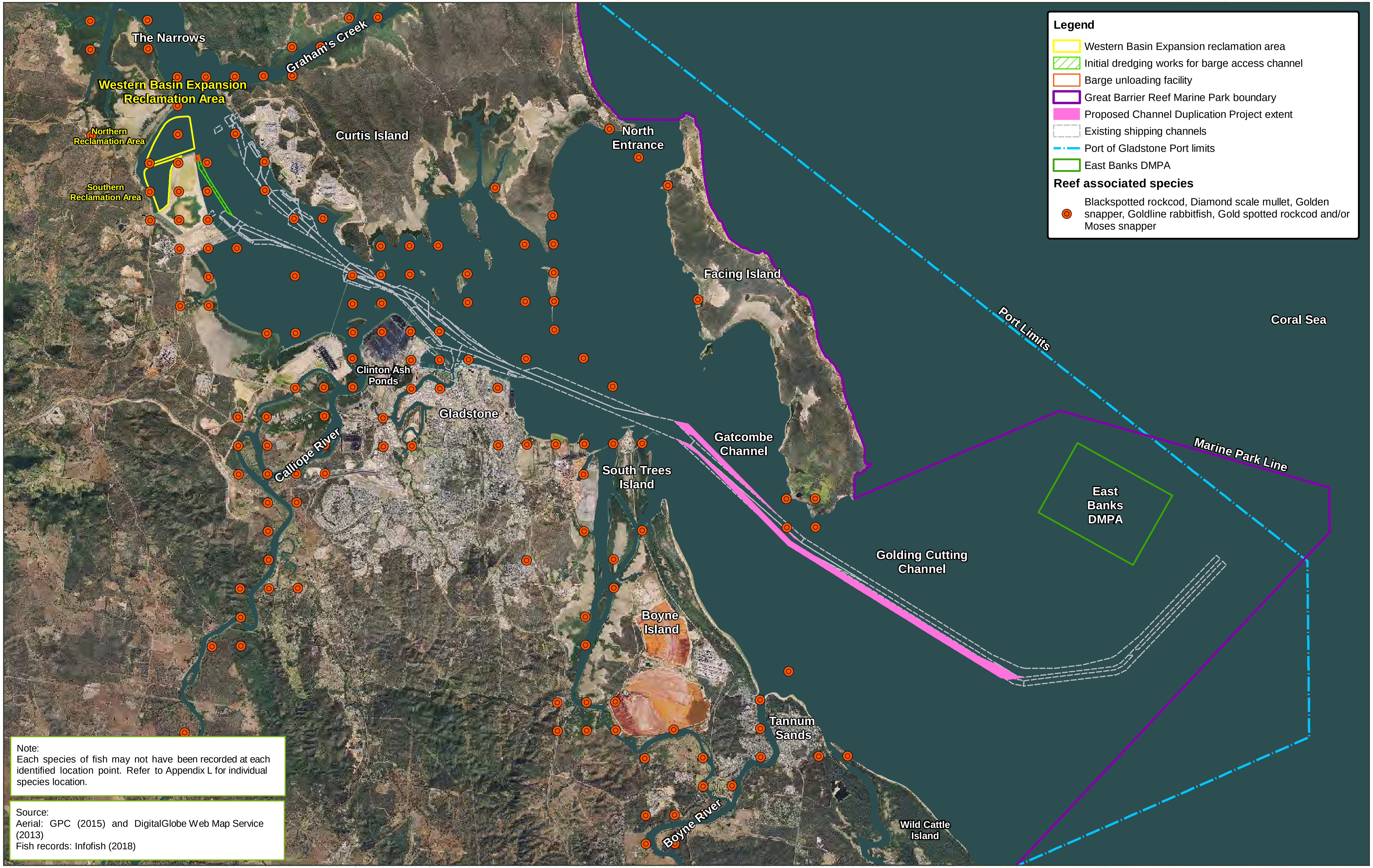

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Gatcombe and Golding Cutting Channel Duplication Project

Figure 9.12: Recorded fish species for reef associated species

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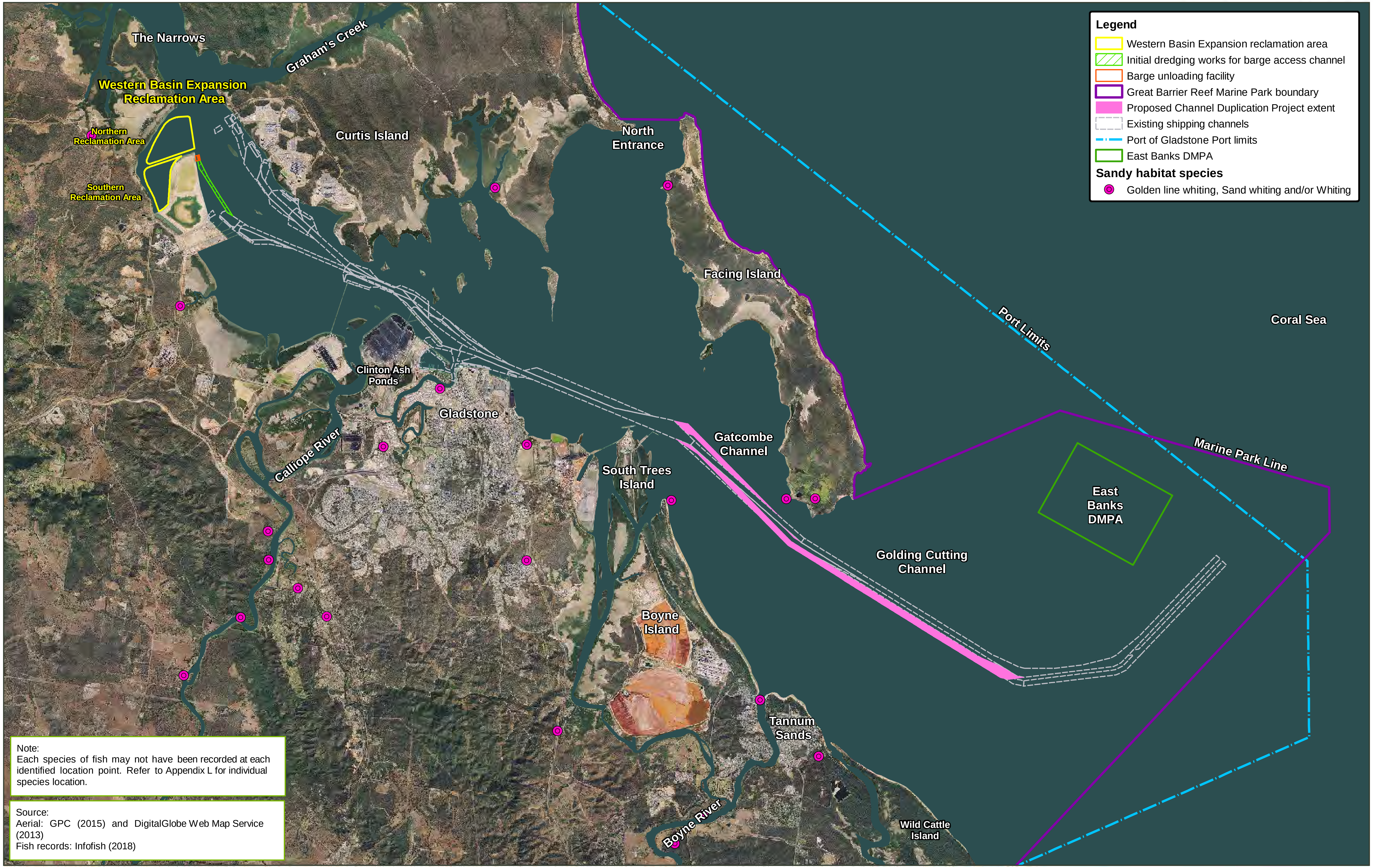

Note:
Each species of fish may not have been recorded at each identified location point. Refer to Appendix L for individual species location.

Source:
Aerial: GPC (2015) and DigitalGlobe Web Map Service (2013)
Fish records: Infofish (2018)

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Map by: RB

0 1,500 3,000 Metres

Date: 25/01/2019 Version: 0 Job No: 237374

Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 9.13: Recorded fish species for sandy habitat species

9.3.6 Commercial fisheries

At a State-wide scale, Port Curtis and the associated intertidal areas and upstream rivers and creeks represent an important resource for Queensland's commercial fisheries. Both inshore and offshore fisheries operate out of Port Curtis with commercial fishing activities in the area consisting of crabbing, trawling, net fishing, line fishing and tourist charters. Target species for commercial fisheries include a variety of fish and macroinvertebrates, including Barramundi, Mullet, Banana prawn, Mud crab, Bull shark and Queenfish. Inshore and offshore fisheries operate out of Gladstone Harbour (NPSR 2014). The existing WB reclamation area is known as a breeding ground for crab, shark, Blue salmon (*Eleutheronema tetradactylum*), prawns and estuary fish and is a common area to catch crabs (pers. comms. M McMillan et al. 2018).

Known areas within Port Curtis region of value to commercial fisheries include:

- Mangrove areas in The Narrows and estuarine inlets
- Seagrass meadows and intertidal wetlands in coastal areas
- Cape Capricorn on the northeastern headland of Curtis Island (wider area)
- Capricorn Bunker Group of offshore reefs (wider area).

9.3.6.1 Crab fisheries

Mud crabs are the principal target species for the Port Curtis region (DNPRSR 2014). Commercial operators set crab pots in estuaries or near-shore areas such as in the Calliope River, adjacent to Fisherman's Landing, The Narrows, Graham's Creek and South Trees Inlet (DNPRSR 2014; GPC 2012a). Most Mud crabs are caught between December and June.

9.3.6.2 Trawl fisheries

The trawl fishery is Queensland's largest commercial fishery (DAF 2013). The two basic types of trawling are otter trawling, which involves larger vessels typically in open coastal waters, and beam trawling, which is conducted in estuaries and shallow inshore waters (DAF 2013). The two licenced Queensland trawl fisheries that operate in the Port Curtis region are the East Coast Otter Trawl Fishery and the River and Inshore Beam Trawl Fishery (DNPRSR 2014). Trawlers are restricted from operating in specific areas of Port Curtis, such as the Inner Harbour and Western Basin zones.

Banana prawns are the main target species for trawler fisheries that operate in the Port Curtis region. Mangrove lined creeks provide nursery habitat for juvenile Banana prawns before moving into coastal waters as they mature. Banana prawn numbers are significantly influenced by rainfall and freshwater flows with increased catches positively correlated with high rainfall years (DAF 2013). Prawn species such as Endeavour, Tiger and coral species are also caught by trawlers, however catch totals are very low and these species have not been recorded since 2005 (DAF 2013). The amount of commercially harvested prawns within the fishing activity area from 2008/2009 to 2017/2018 was 819.79 tonnes (t) (refer Figure 9.14) (DAF 2018).

Other species caught and retained by trawlers in the Port Curtis region include the Saucer scallop (*Amusium balloti*), Moreton bay bug (*Thenus orientalis*), Balmain bug (*Ibacus peronei*) and Blue swimmer crab (DAF 2013). Common demersal fish species caught as bycatch by trawlers operating in the region include Grinner (*Saurida* sp.), Australian threadfin (*Polydactylus multiradiatus*) and Southern herring (DAF 2013).

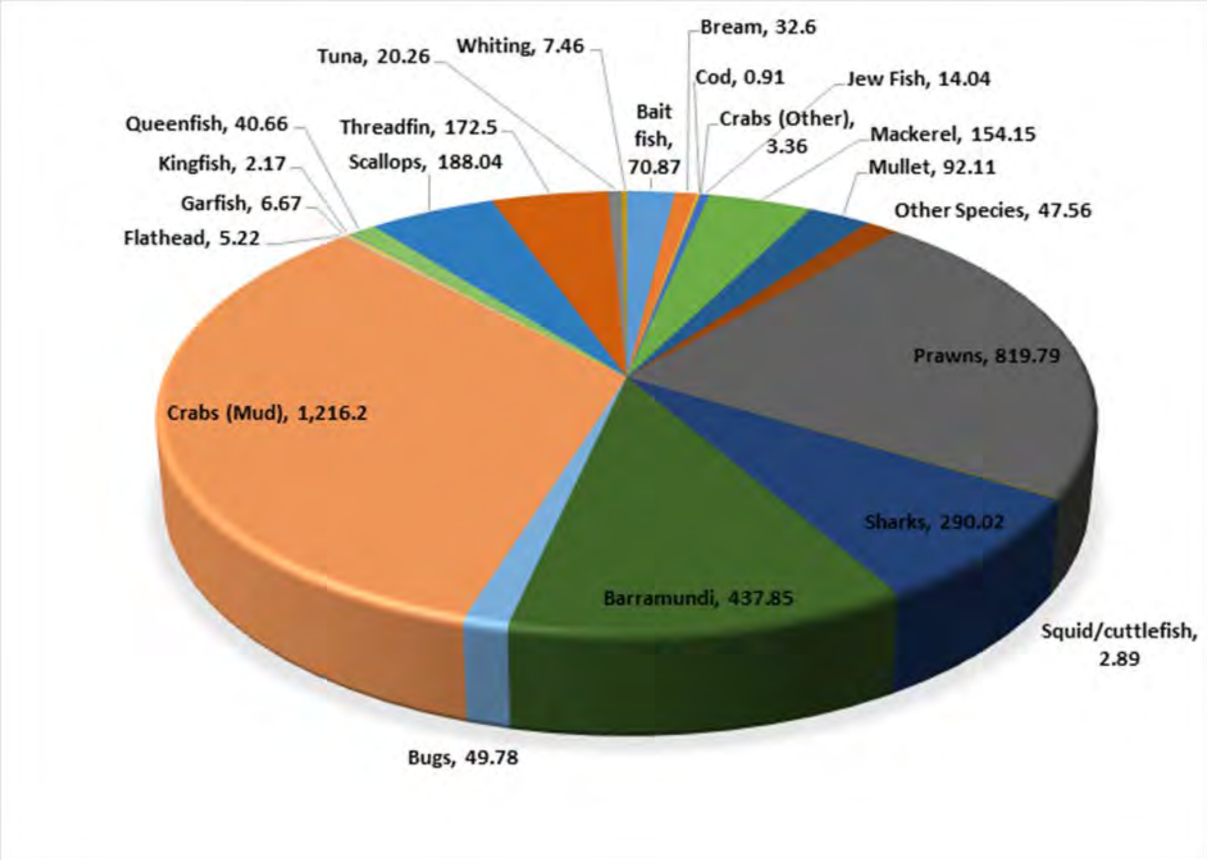

Figure 9.14 Commercially harvested species (in tonnes) within the fishing activity area (S30) (2008/2009 to 2017/2018)

Source: DAF (2018)

9.3.6.3 Inshore net fisheries

Net fisheries that operate in the Port Curtis region use a variety of mesh and seine net methods to target species such as Mullet, Shark, Blue threadfin, Barramundi and Mackerel species (Scombridae), among others (DAF 2018) (refer Figure 9.15 for percentage of individual species harvest in the fishing activity area from 2008/2009 to 2017/2018). The waters upstream of Farmer's Island in the Calliope River are closed to commercial net fishing and restrictions are placed on commercial net fisheries operating in Port Curtis as part of the Rodds Bay DPA.

In the context of Queensland's commercial fishing industry, the fishing activity area provided yields of Mud Crab and Baitfish that were greater than 5.0% of the State's reported commercial catch (refer Figure 9.16). All other species contributed less than 5% to Queensland's commercial fishing industry during the 2008/2009 to 2017/2018 period (refer Figure 9.16).

Analysis of species diversity reported for the fishing activity area during the 2008/2009 to 2017/2018 year period indicated that the species yields (i.e. retained catch weight) were greatest for Mud crab (33.09%), Prawn (22.31%) and Barramundi (11.91%), with lower retained catch rates reported for Sharks (7.89%), Mackerel (4.19%), scallops (5.12%) and Threadfin (4.69%). The remaining species account for approximately 11.8% of the reported catch (refer Figure 9.16).

Of the harvestable species within the fishing activity area, invertebrates accounted for approximately 2,280t (i.e. 62.1% of species), while finfish (including Shark) accounted for approximately 1,395 (i.e. 37.9% of species) during the 2008/2009 to 2017/2018 period (refer Figure 9.16).

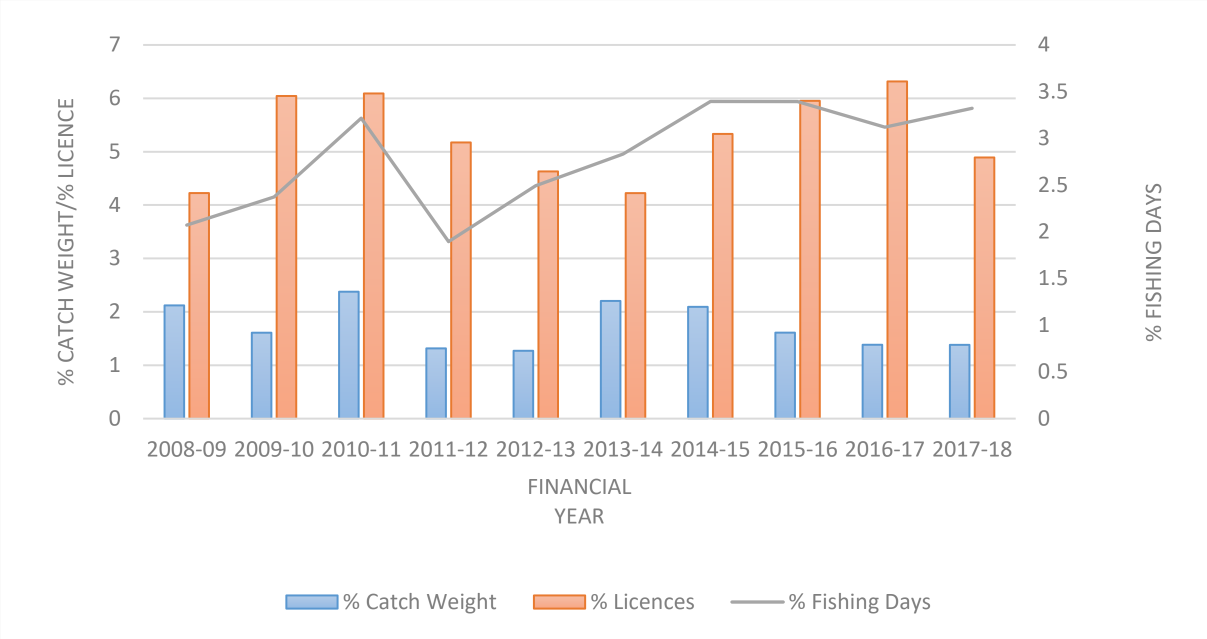

Figure 9.15 **Percentage of the Queensland commercial fishing industry that is provided by the fishing activity area (S30) (2008/2009 to 2017/2018)**

Source: DAF (2018)

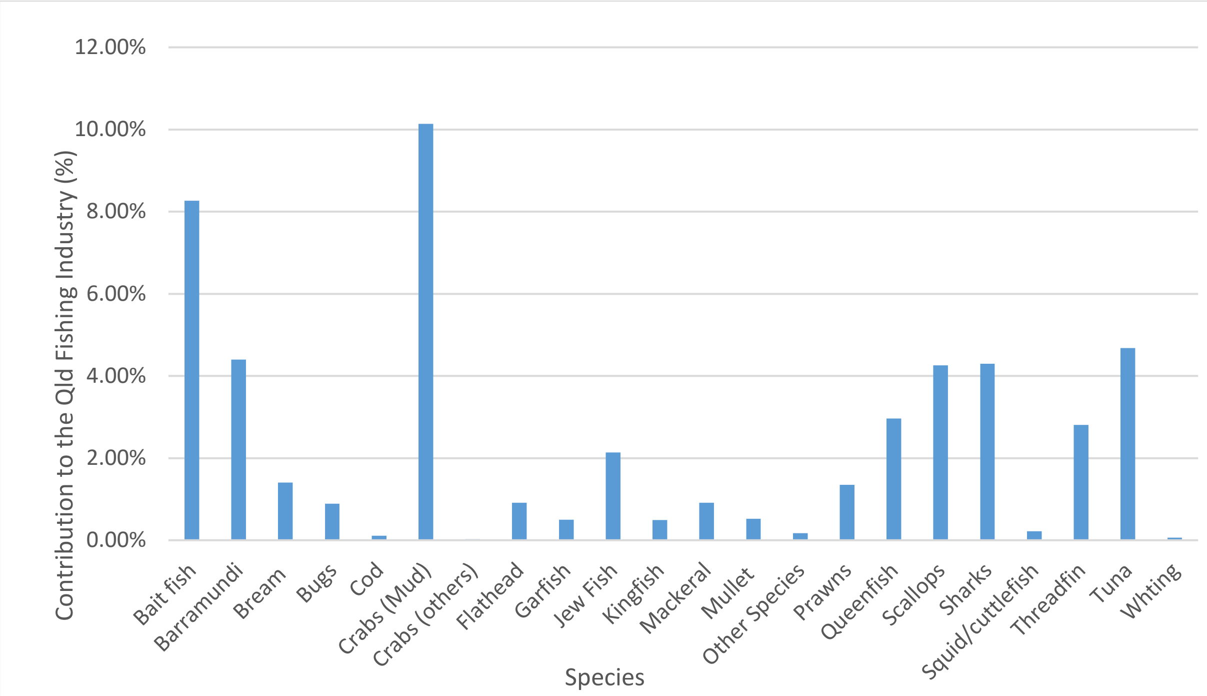

Figure 9.16 **Contribution of commercially harvested species within the fishing activity area (S30) to the Queensland commercial fishing industry (2008/2009 to 2017/2018)**

Source: DAF (2018)

9.3.6.4 Line fisheries

Line fisheries generally target a diverse range of fin fish species and use methods such as bottom handlines, trolling and droplines (offshore) (Queensland Government 2016b). Target fish in the region include a range of demersal and pelagic species, including Barramundi, Shark, Red throat emperor (*Lethrinus miniatus*), Tuskfish, Rockcod (*Ephinephelus* spp.), Coral trout, Grass emperor, Spanish mackerel (*Scomberomorus commerson*), Giant queenfish, Snapper (*Lutjanus* spp.) and Trevally species (Carangidae), among many others (Queensland Government 2016b).

9.3.6.5 Commercial catch data

Commercial fisheries in Queensland are monitored through a compulsory logbook program administered by DAF. Analysis of QFish datasets in the fishing activity area (i.e. the 'S30' Commercial Fishery 30 minute reporting grid) which encompasses the Project impact areas (refer Figure 9.2) for the 2008/2009 to 2017/2018 period indicates that highly variable yields among years occurred. This was due to a combination of varying fishing boats in operation, less fishing days, post flood impacts, a move from fishing vessels to ferries and barges in 2012, and variations in the crab catch which can utilise less fishing boats (refer Table 9.6).

Over the 10 year period assessed, on average, the fishing activity area yielded approximately 376.88t of commercial catch, utilised approximately 74 licences and encompassed approximately 4,407 fishing days per year (refer Figure 9.17) (DAF 2018). When assessed at the State level (refer Table 9.6 and Figure 9.15), the fishing activity area contributed approximately 1.7% of the commercial catch, utilised approximately 4.9% of the licences, and encompassed approximately 2.8% of the fishing days per year of Queensland's commercial fishing industry (DAF 2018).

Table 9.6 Annual commercial catches for all commercial fishing activities in the fishing activity area (S30)

Year ending June	S30 commercial fish yield (t)	% of Queensland yield	S30 commercial fishing licences	% of Queensland licences	S30 commercial fishing days	% of Queensland fishing days
2018	257.5091	1.38%	64	4.60%	4,894	3.31%
2017	274.10034	1.38%	82	5.82%	4,697	3.10%
2016	303.63538	1.61%	78	5.53%	5,264	3.38%
2015	404.46232	2.09%	72	5.05%	5,087	3.39%
2014	444.4323	2.20%	56	3.88%	4,399	2.82%
2013	281.20963	1.27%	67	4.50%	3,807	2.48%
2012	276.90113	1.32%	74	4.85%	3,017	1.88%
2011	554.41838	2.38%	90	5.71%	5,174	3.20%
2010	421.2483	1.61%	88	5.37%	4,145	2.35%
2009	550.95934	2.12%	69	4.05%	3,589	2.06%
Average over 10 years	376.88762	1.7%	74	4.9%	4,407	2.8%

Source: DAF (2018)

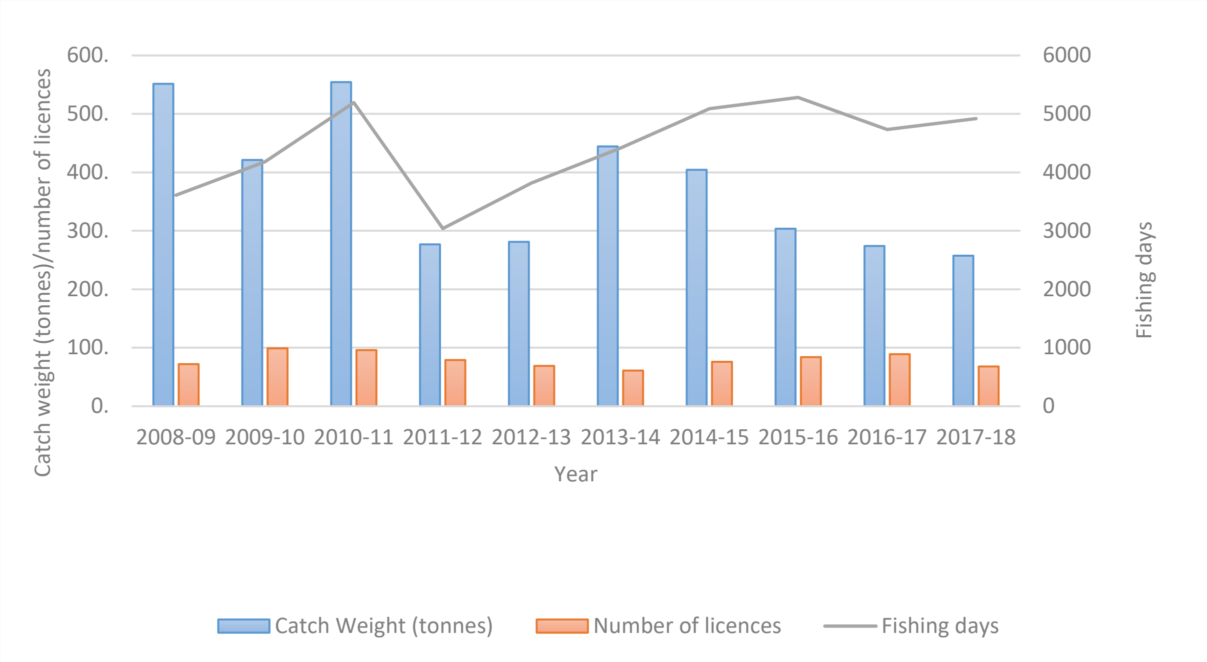

Figure 9.17 **Annual commercial catches for all commercial fishing activities in the fishing activity area (S30) (2008/2009 to 2017/2018)**

Source: DAF (2018)

9.3.7 Recreational fisheries

9.3.7.1 Target species

Port Curtis supports a very popular recreational fishing industry which is a key component of the region's tourism industry. Fishing activities predominantly include line fishing, crabbing and prawning. The majority of fishing is done by boat with a significant increase (36.1%) in boat registrations in the Gladstone Regional Council area recorded over the period of 2006 to 2014 from 5,396 to 7,342 (Sawynok et al. 2014). Generally, the main species caught within Gladstone Harbour include Bream, Barramundi, Cod, Flathead, Salmon and Mangrove jack (pers. comms. B Thomson 2018).

Based on an analysis of recreational fishing activities within Port Curtis and adjoining waterways from 2006 to 2014 the most commonly kept species (i.e. highest percent of species caught and retained) within the Gladstone region were Mud crab (20.7% (underestimated)), Seabream (Yellowfin bream and Pikey bream) (20.3%) and Barramundi (2.2%) (refer Figure 9.18 and Figure 9.19) (Sawynok et al. 2014).

Species that increased in total catch over the 2006 to 2014 period were Mud crab, Barramundi, Blue threadfin and King threadfin (*Polydactylus macrochir*). Species that decreased were School mackerel (*Scomberomorus queenslandicus*), Stripey snapper (*L. carponotatus*), and Longfin rockcod (*Epinephelus quoyanus)* (Sawynok et al. 2014).

Of the species that were retained during the 2006 to 2014 period, Blue threadfin was the most retained species when calculated against the total numbers caught (55.2%). This was followed by Grass emperor (53.0%) and Stripey snapper (53.0%) (refer Figure 9.18). Although not as high as the aforementioned species, retention rates of captured Mud crabs and Seabream approximated 21%. The least retained species during this period was the Longfin rockcod (1.6%). Barramundi was identified as the second most released species at 94.0%, however legal size limits are likely to be a contributing factor related to the released rates for both Longfin rockcod and Barramundi (Sawynok et al. 2014).

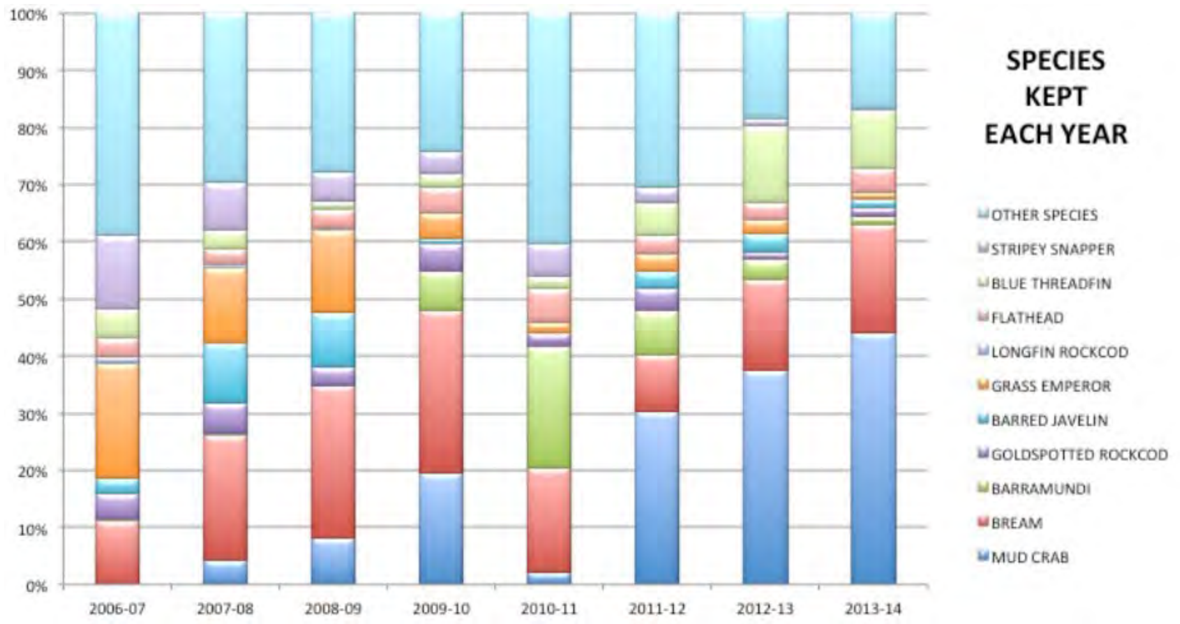

Figure 9.18 **Percentage of each target species kept from recreational fishing catches within Port Curtis (2006 to 2014)**

Source: Sawynok et al. (2014)

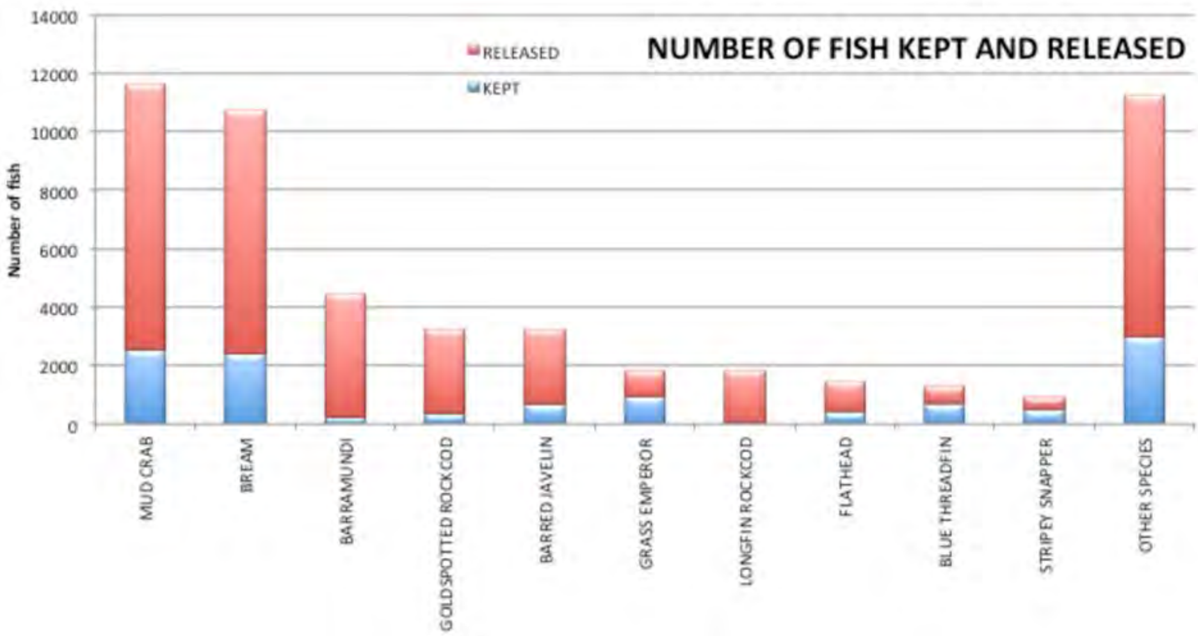

Figure 9.19 **Numbers of key species caught and kept from recreational fishing catches within Port Curtis (2006 to 2014)**

Source: Sawynok et al. (2014)

Recent trends suggest Barramundi and Mud crab remain the key target species for recreational fisheries in the area, however there has been a significant drop in Barramundi as the most caught species. The targeting of King threadfin has increased substantially in 2014, despite not being a key target species or amongst the most caught species in 2012. Seabream remain the most caught species with little change from 2012 to 2014 despite being a low priority target species according to survey data (Sawynok et al. 2014).

9.3.7.2 Target locations

From a recreational viewpoint, the most popular locations for recreational crabbing trips are the estuarine and inlet areas of Calliope River as well as Graham's Creek and The Narrows, followed by the Boyne River and South Trees Inlet (Gladstone Region 2018). For locations fished, the following areas are considered popular locations (Gladstone Region 2018):

- Barney Beach: Flathead, Salmon, Barramundi, Grunter and pelagic species
- Auckland Creek: Flathead, Barramundi, Fingermark (*Lutjanus johnii*), Mangrove jack, Salmon, Bream and Grunter
- Calliope River: Barramundi, Queen fish, Trevally, Salmon, Mangrove jack, Bream and Grunter
- Estuarine and inlet areas of Calliope River: Mud crabs, Barramundi, Mangrove jack, Bream, Fingermark, Salmon, Triple tail, Cod, Mulloway (*Argyrosomus japonicus*)
- Boyne River and South Trees Inlet: Barramundi, Flathead, Mud crabs, Whiting, Bream, Grunter, Diamond trevally (*Aclectus indica*) and Queen fish
- Gatcombe Head: Mackerel, Squire, Coral trout, Grass emperor (sweetlip), Redthroat emperor (sweetlip emperor) (*Lethrinus miniatus*), Parrot fish and Black spotted tusk fish
- Colosseum Inlet: Mud crabs, Mangrove jack, Bream, Whiting, Mackerel, Salmon and Barramundi.

Catch and effort data collected from the 'Boyne Tannum Hookup' annual fishing competition from 2005 to 2014 suggests that there has been a shift in trends in fishing effort from offshore trips from 2005 to 2009, to estuary/inshore trips from 2010 to 2014 (Sawynok et al. 2014). It should be noted some of these trends may be due to weather conditions at the time of the competition.

Anecdotal sources suggest popular beach fishing locations in the region are Lillie's Beach, Yellow Patch on the eastern side of Curtis Island, Turkey Beach at Rodds Bay and Farmer's Point on the northwest side of Facing Island (Battersby 2014; Tourism and Events Queensland 2016). Popular reef fishing locations include the southern end of Curtis Island and surrounding islands, Seal Rocks and Gatcombe Heads (Tourism and Events Queensland 2016; BMT WBM 2013).

Land based recreational fishing occurs from almost every location around Port Curtis where there is public access to the shore, with likely more than 100 locations (Sawynok et al. 2014).

9.3.7.3 Recreational catch data

Recreational fishing catch rates saw a steady decline since 1991 based on a median catch per person per a trip decline from 14 in 1991 to 9.5 for 2001 (Platten 2004; Sawynok et al. 2014). For the 2006 to 2013 period, catch rates of key recreational fishing target species varied, with a low of 8.5 fish per trip in summer 2006/2007 to a high of 25.9 fish per trip in autumn 2014. The greatest catch rates occurred from spring 2007 to autumn 2010 with lower catch rates from winter 2010 to winter 2012, and then increasing during the 2012 to 2013 period (Sawynok et al. 2014) (refer Figure 9.20).

Recent recreational fishing trends collated by Sawynok et al. (2014) suggests catch rates have been influenced by climatic conditions, the most extreme of which was associated with the flood event of 2010 where a significant increase in the take of Barramundi were observed. The rate of catch retention was lowest during summer 2011 through to 2012 (Sawynok et al. 2014).

Greatest catch retention of recreational fisheries was recorded during the autumn 2008 period (Sawynok et al. 2014). The highest annual 'total catch' rates for the 2006 to 2014 period occurred in 2009. The retained catch from recreational fisheries generally follows a pattern similar to that of the overall catch rate (refer Figure 9.20).

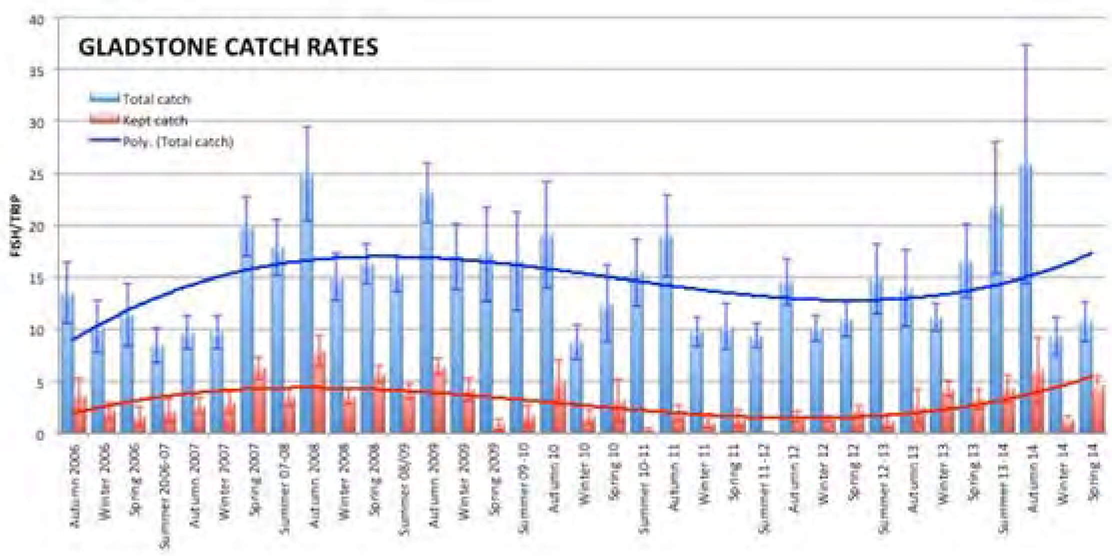

Figure 9.20 **Seasonal catch rates for recreational fisheries within Port Curtis (2006 to 2013)**

Source: Sawynok et al. (2014)

Number of small boat registrations is often used as an indicator of the size of recreational fishing activities in an area. Figure 9.21 depicts the trends in vessel registration (up to 8m, no sails) in Gladstone from 2006 to 2014. Between 2006 and 2014 the number of boat registrations rose from 5,396 to 7,342, representing a 36.1% increase during that time. Between 2013 and 2014, boat registrations increased by 1.9% (Sawynok et al. 2014). This increasing trend in registration is indicative of the increasing popularity of recreational fishing in the Gladstone area. Additionally, counts of boats trailers at key boat ramps were made across the Gladstone local government area (LGA) from spring 2011 to spring 2014. During this time, there was a total of 4,638 boat trailers across 906 days (Sawynok et al. 2014).

Figure 9.21 **Number of registered motorboats (up to 8m, no sails) in the Gladstone Local Government Area from 2006 to 2014**

Source: Sawynok et al. (2014)

9.3.8 Traditional fisheries

Traditional Use of Marine Resources Agreements (TUMRA) are developed by Traditional Owner groups in partnership with the Commonwealth and Queensland Governments, and describe how Traditional Owners intend to manage their take of natural marine resources (including protected species) within the GBRMP. The Port Curtis Coral Coast TUMRA is the largest agreement of its kind and covers an area of 26,386km^2 extending from Burrum Heads, south of Bundaberg, to the northern end of Curtis Island and the Fitzroy River mouth. Accredited in August 2011, the agreement represents the Gooreng Gooreng, Gurang, Bailai and Tarebilang Bunda Traditional Owners (DNPRSR 2014). EIS Chapter 16 (Aboriginal cultural heritage) provides further information on the Port Curtis Coral Coast TUMRA.

9.4 Fish Habitat Areas

9.4.1 Overview

FHAs are declared under provisions of the Fisheries Act and afford a level of protection to high value natural fish habitats in coastal areas. Rodds Harbour (i.e. Rodds Bay), Colosseum Inlet and the Calliope River, located south of the proposed Project impact areas (refer Figure 9.22), are declared FHAs.

FHAs are considered to be an important resource to support local commercially and recreationally important fisheries. FHAs seek to protect natural fish habitats by limiting coastal development and associated physical disturbance within and adjacent to a declared FHA, while still allowing for continued community use and access.

The declared FHA network in Queensland contributes to the lifestyle of residents and visitors through fishing, outdoor recreation and cultural activities. It also provides an estimated value of $40 billion per year in ecosystem services to the State economy (DEWHA 2010). The declared FHA network focuses on estuarine and coastal fish habitats, which support up to 75% of Queensland's commercial seafood catch (Quinn 1992) and most of the target recreational fish species in a given area. The network also includes small areas of fresh water at the upstream extent of some declared FHAs (DNPRSR 2014b).

9.4.2 Rodds Harbour Declared Fish Habitat Area

The Rodds Harbour FHA (FHA-036) covers an area of 11,619ha, and comprises Rodds Bay, Turkey Beach/Tannum Sands, Pancake Creek, Middle Creek and Jenny Lind Creek, 40km southeast of Gladstone and southeast of the Project areas to be dredged (refer Figure 9.22). The Rodds Harbour area was declared a FHA in 1983 (rezoned in 2003) and provides a conservation, protection, management and research area for essential fish habitat, important juvenile fish and prawn habitat, and is an important Mud crab recruitment area (NPSR 2016). The area is characterised by extensive habitat values, including mangrove zones bordering estuaries, samphire and claypan areas, seagrass meadows, island banks, bar zones, channels and deltaic areas (NPSR 2016).

The Rodds Harbour FHA supports commercial, recreational and Indigenous fisheries values, including Barramundi, Blue threadfin, Seabream, Estuary cod, Flathead, Mackerel, Grunter (Terapontidae), Jewfish (Sciaenidae), King Threadfin, Mangrove jack, Giant queenfish, Sea mullet, School mackerel, Whiting, Banana prawn, Endeavour prawn, Tiger prawn and Mud crab (NPSR 2016).

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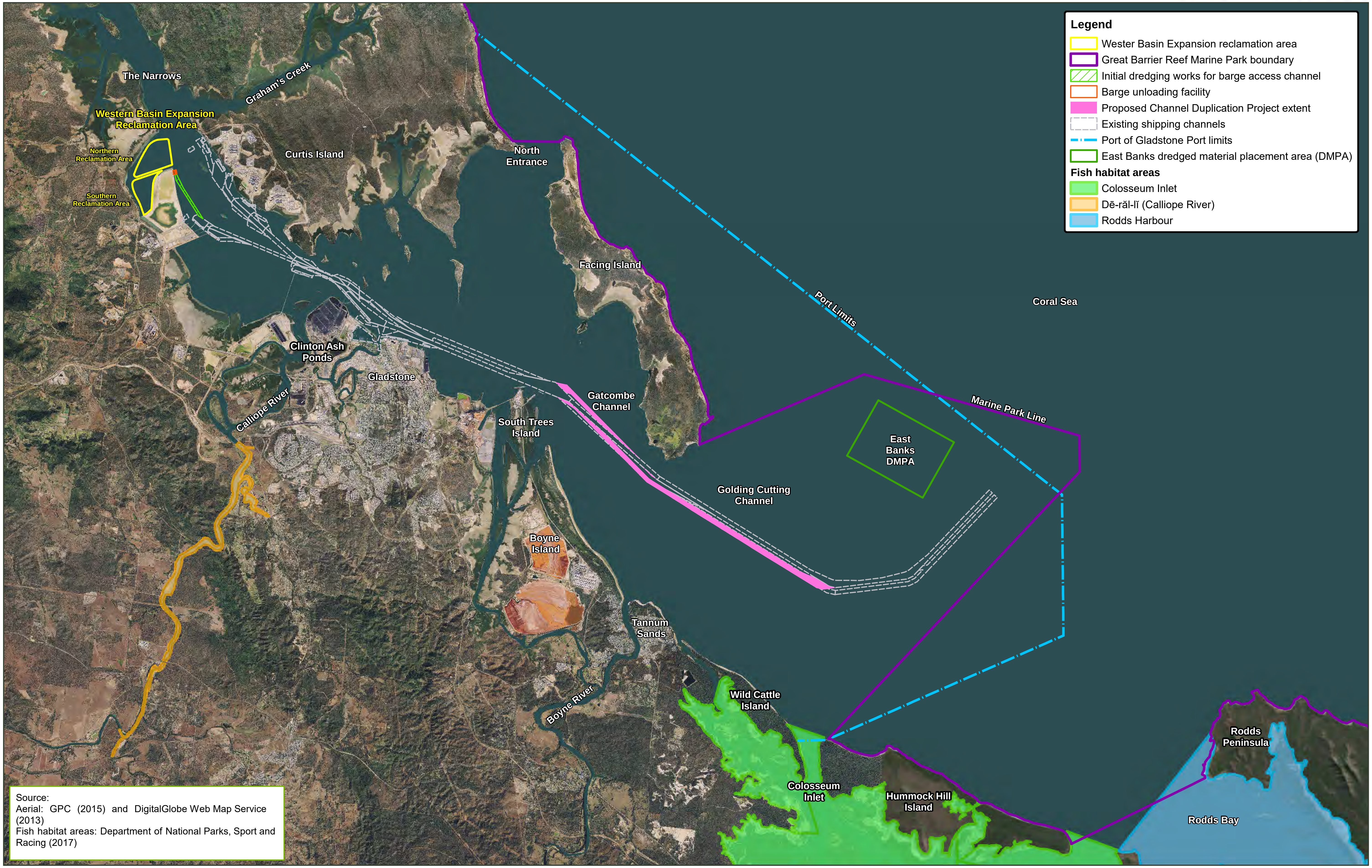

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Gatcombe and Golding Cutting Channel Duplication Project

Figure 9.22: Declared fish habitat areas in relation to the extent of the Project

9.4.3 Colosseum Inlet Declared Fish Habitat Area

The Colosseum Inlet FHA (FHA-037) covers an area of 11,816ha, and comprises the Colosseum Inlet, Wild Cattle Creek and Seven Mile Creek area, 24km southeast of Gladstone and south of the Project areas to be dredged (refer Figure 9.22). The area was declared a FHA in 1983 (rezoned in 2003) and provides important fish and juvenile prawn habitat (NPSR 2012). The area is characterised by extensive habitat values, including mangroves, bar zones, island banks, silty sand, channels, deltaic islands, samphire and clay pan areas, small coral community and seagrass meadows towards Tannum Sands (NPSR 2016).

Colosseum Inlet FHA supports commercial, recreational and Indigenous fisheries values, including Barramundi, Blue threadfin, Seabream, Estuary cod, Flathead, Grey mackerel, Grunter, Jewfish, King Threadfin, Mangrove jack, Giant queenfish, Sea mullet, School mackerel, Whiting, Banana prawn, Endeavour prawn, Tiger prawn and Mud crab (NPSR 2016).

9.4.4 Dē-răl-lĭ (Calliope River) Declared Fish Habitat Area

In September 2016, Dē-răl-lĭ (Calliope River) was declared a FHA (FHA-075). The Dē-răl-lĭ (Calliope River) FHA covers an area of 314ha within the Calliope River between the Moura Short Railway Line and the North Coast Line, and is located approximately 15km east of the Project areas to be dredged. DNPRSR (2014a) states that the Dē-răl-lĭ (Calliope River) FHA supports a valuable commercial fishery, providing habitats that are essential for the productive crab, beam trawl and net fisheries operating adjacent to the river. The Dē-răl-lĭ (Calliope River) FHA is also significant to recreational fisheries due to accessibility to the river and high catch rates (DNPRSR 2014a).

An assessment of the fisheries resources of the Calliope River published by DNPRSR (2014a) states the Calliope River supports high species diversity relative to other similar rivers in the wider area, with approximately 169 species historically recorded (refer Appendix L (Table 3)). The study primarily recorded fish species (90.5%) in addition to crustaceans and molluscs (7.1% and 2.4%, respectively). DNPRSR (2014a) indicated that of the species recorded in the Calliope River (refer Appendix L (Table 4)), 40% were considered to be of economic importance (i.e. they have direct local, regional and State economic significance). The remaining species recorded are known to provide food sources and links within the food chain supporting local fisheries (DNPRSR 2014a).

The study area for the 2014 assessment encompassed tidal, intertidal and some fresh waters of the Calliope River, from the river’s mouth to 32km upstream. The 2014 study used data from a variety of sources dating back to 1994, including previous EIS studies, DAFF surveys, DNRM, Queensland Museum, Gladstone Area Water Board (GAWB), Infofish Australia and the Cooperative Research Centre (CRC) Reef Research Centre.

10 Other marine reptiles

10.1 Background

Marine reptiles within Port Curtis include marine turtles (refer Section 14) and crocodiles and sea snakes (this section).

There are two species of crocodiles in Australia, the Freshwater crocodile (*Crocodylus johnstoni*) and the Saltwater crocodile (*Crocodylus porosus*). Both are listed as marine under the EPBC Act and the Saltwater crocodile is also listed as migratory under the EPBC Act and vulnerable under the NC Act. Freshwater crocodiles occur in inland rivers and wetlands in the Gulf of Carpentaria and as far south as the Ross River, which flows into the Coral Sea at Townsville (i.e. outside of the Project impact areas). Saltwater crocodiles are known to occur from the Gulf of Carpentaria and Cape York Peninsula to as far south as Gladstone (DoEE 2019). The primary habitat for Saltwater crocodiles is within swamps, and the tidal reaches of rivers, however Saltwater crocodiles are known to move out of rivers and along the coast or to islands within the GBRWHA, particularly following heavy rainfall (Lucas et al. 1997).

Sea snakes in Australia comprise of true sea snakes (Genus *Hydrophiidae*) and sea kraits (Genus *Laticauda*). True sea snakes are entirely marine based and never voluntarily leave the water, whereas the sea kraits venture onto land regularly to rest, hide and breed. True sea snakes have a distribution generally extending from southern Queensland northward, around to the central coast of Western Australia (GBRMPA 2012). There are approximately 32 species of true sea snakes in Australian waters, with 14 species maintaining permanent breeding populations in the Great Barrier Reef (GBRMPA 2012). Breeding populations of sea kraits are not thought to occur within the Great Barrier Reef (GBRMPA 2012). There are no species of sea snake or sea krait currently listed as conservation significant under Queensland or Commonwealth legislation.

10.2 Methodology

This assessment was informed by Government database resources, a review of existing literature and ecological surveys undertaken for marine reptiles (e.g. crocodiles and sea snakes) within Port Curtis. For the purposes of the database review, the search area was defined on a regional basis to include Port Curtis and adjoining marine areas, to ensure that transient species were captured in the assessment (refer Figure 10.1).

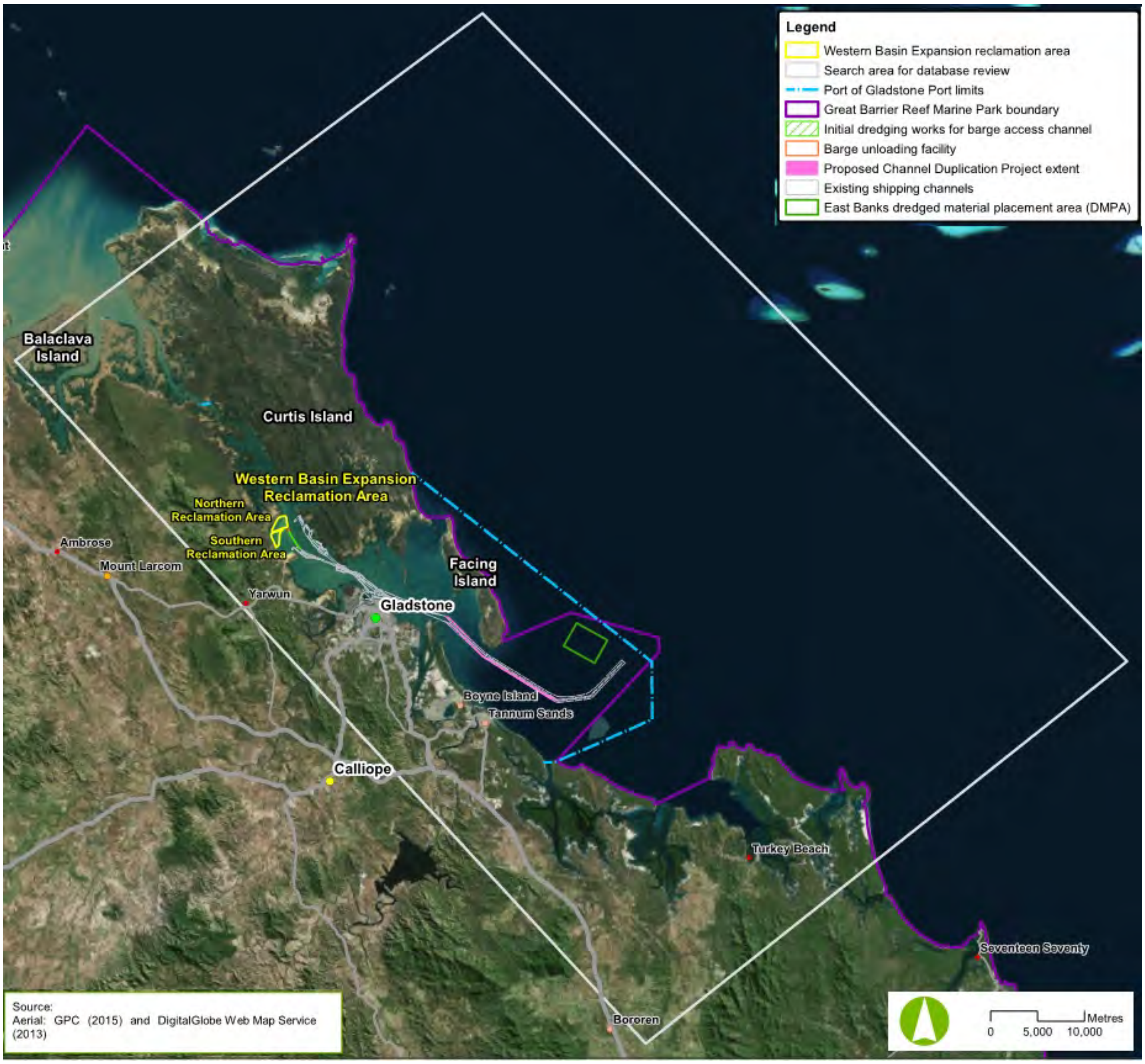

Figure 10.1 Search area for database review

The information sources that were reviewed as part of the desktop assessment are summarised in Table 10.1.

Table 10.1 Resources used for the assessment of other marine reptile values

Title	Reference
Reports	
Curtis Coast Coastal and Marine Resource Inventory Report	GPC (2012)
Report for Marine Megafauna and Acoustic Survey: Autumn Survey	GHD (2011a)
Report for Marine Megafauna and Acoustic Survey: Summer Survey	GHD (2011b)
Report for Western Basin Dredging and Disposal Project – Marine Megafauna Baseline and Impact Assessment	GHD (2009d)
Port of Gladstone Gatcombe and Golding Cutting Channel Duplication Project – Reef and Nekton Baseline Data Collection	Vision Environment (2015a)
Databases	
EPBC Act PMST (refer Figure 10.1 for search area)	DoEE (2019)
Wildnet database (refer Figure 10.1 for search area)	DES (2019)

10.3 Other marine reptile values

10.3.1 Crocodiles

Analysis of environmental databases indicates that one crocodile species, the Saltwater crocodile, is known, or is predicted to occur within Port Curtis and adjoining waters (refer Table 10.2). The Saltwater crocodile is a conservation significant species, listed as migratory (Bonn Convention) under the EPBC Act, and vulnerable under the provisions of the NC Act.

Table 10.2 Crocodile species known or predicted to occur within the Port Curtis region

Scientific name	Common name	Conservation status		
		EPBC Act	NC Act	IUCN
Crocodylus porosus	Saltwater crocodile	Marine migratory (Bonn Convention)	Vulnerable	Least concern

Source: EPBC Act protected matters search tool (DoEE 2016)

Saltwater crocodiles are known to inhabit tidal reaches of rivers, along beaches and offshore islands and in freshwater lagoons, rivers and swamps. Their habitat is typically north of the Tropic of Capricorn, although their habitat extends to the Gladstone region.

According to the Curtis Coast Coastal and Marine Resource Inventory Report (GPC 2012), the Saltwater crocodile (*Crocodylus porosus*) has been recorded within the Curtis Coast region, which is near the southern limit of its known range. Saltwater crocodiles have been sighted within Port Curtis at Fisherman's Landing, the Calliope River, The Narrows and in Pacific Creek on the northeastern corner of Curtis Island (GPC 2012). Saltwater crocodiles were not identified during Project field investigations.

10.3.2 Sea snakes

Analysis of environmental databases indicates that 13 sea snake species are known, or are predicted to occur, within Port Curtis and adjoining waters (refer Table 10.3).

Table 10.3 Sea snake species known or predicted to occur within the Port Curtis region

Scientific name	Common name	Conservation status		
		EPBC Act	NC Act	IUCN Red List
Acalyptophis peronei	Horned sea snake	Marine	-	Least concern
Aipysurus duboisii	Dubois' sea snake	Marine	-	Least concern
Aipysurus eydouxii	Spine-tailed sea snake	Marine	-	Least concern
Aipysurus laevis	Olive sea snake	Marine	-	Least concern
Astrotia stokesii	Stokes' sea snake	Marine	-	Least concern
Disteira kingii	Spectacled sea snake	Marine	-	Least concern
Disteira major	Olive-headed sea snake	Marine	-	Least concern
Emydocephalus annulatus	Turtle-headed sea snake	Marine	-	Least concern
Hydrophis elegans	Elegant sea snake	Marine	-	Least concern
Lapemis hardwickii	Spine-bellied sea snake	Marine	-	Least concern
Laticauda colubrina	Yellow-lipped sea krait	Marine	-	Least concern
Laticauda laticaudata	Blue-lipped sea krait	Marine	-	Least concern
Pelamis platurus	Yellow-bellied sea snake	Marine	-	Least concern

Source: EPBC Act protected matters search tool (DoEE 2016)

Limited information is available on sea snakes and their specific habitat requirements within Port Curtis, although they have been identified in a variety of areas from clear reef waters to turbid inshore estuaries, depending on the species (GPC 2012).

Opportunistic sightings of sea snakes within Port Curtis have been recorded in various investigations. During Project field investigations, an Olive sea snake (*Aipysurus laevis*) was encountered within a coral reef, though the specific location is not identified within the report (Vision Environment 2015a).

Aerial and boat-based surveys conducted by GHD (2011a; 2011b) within the Gladstone region recorded five sea snakes during the summer 2011 survey (one in Port Alma, one east of Curtis Island and four in The Narrows), and six sea snakes during the Autumn 2011 survey (two in Port Alma and three in The Narrows); however the identity of these species was not determined. In addition, a sea snake (possibly an Olive sea snake) was observed within the Western Basin zone during a benthic marine ecology survey undertaken in June 2009 (GHD 2009c).

11 Soft sediment habitats and benthic macroinvertebrates

11.1 Background

The benthic zone of the marine environment is generally defined as the surface and subsurface of the seafloor. Most of the benthic zone in the area of the GBRMP is comprised of soft sediment habitats lying in between coral reefs, between the coast and the barrier reefs (i.e. the 'lagoon'), and in benthic habitats of the continental slope (GBRMPA 2006). The majority of sediments in the inshore region of the lagoon originate from the land adjacent to the reef, and are generally dominated by very fine mud and sand particles. Conversely the sediments further offshore in the inter-reefal areas are comprised of coarser sands of marine origin (Chin 2003).

Throughout both the muddy and sandy substrates are scattered patches of hard substrate, including rubble, bedrock, deep reef and shoals. These different substrate types support varying communities of plants and animals, resulting in 'clear cross-shelf zonation of lagoonal and inter-reefal benthic communities related to the change in seabed sediments' (Chin 2003). The lagoonal and inter-reefal seabed habitats of the GBRMP are home to great biodiversity and are a critical part of the network of habitats that make up the Great Barrier Reef ecosystem (Chin 2003). These include flora and fauna such as microbes, invertebrates, seagrass and demersal fish. This section focuses on the 'macro-biota' inhabiting soft sediments in Port Curtis and the Project impact areas.

Macroinvertebrates are animals without backbones that can be observed by the naked eye (> 500 micrometres (µm)). Benthic macroinvertebrate communities within a marine estuary are made up of those organisms dwelling on the sediment surface (i.e. epifauna) and those which are buried within the sediment (i.e. infauna), which utilise the surface and subsurface sediment area for feeding and habitat. These communities encompass a diverse range of fauna comprising several types of feeding groups such as deposit-feeders, filter-feeders, grazers and predators, and include crustaceans (e.g. crabs; shrimp); gastropods (e.g. molluscs; clams); polychaetes (e.g. bristle worms); echinoderms (e.g. sea stars); ascidians (e.g. sea squirts); anemones (e.g. corals; sea pens); sponges; and bryozoans.

Benthic macroinvertebrate communities are an essential component of all estuarine ecosystems and play an important role in ecological processes such as nutrient recycling (enhancing nitrification and denitrification) and maintaining of water quality (Currie and Small 2005). They also serve as an important food source for higher trophic levels such as shorebirds and fish species (Currie and Small 2006).

The distribution of benthic macroinvertebrate species is controlled by a number of environmental variables, including sediment particle size, contaminant concentrations, water quality and biological factors such as competition and predation (Peeters et al. 2004). The dynamics of benthic fauna reflect the impacts of abiotic, biotic and anthropogenic influences (Currie and Small, 2005; 2006), therefore macroinvertebrate communities are commonly used in studies as biological indicators of ecological change (Stewart et al. 2000).

11.2 Methodology

11.2.1 General

The purpose of this section is to provide a description of the existing values of the soft sediment benthic communities in Port Curtis, particularly benthic macroinvertebrates, to allow the assessment of direct and potential indirect impacts associated with the Project activities. Note for the purposes of this report, macroinvertebrates associated with coral are reported separately in Section 8, and seagrass and benthic macroalgal communities are reported in Section 7.

Soft sediment habitat communities in Port Curtis have been well studied both spatially and temporally. These studies include impact assessments conducted before, during and after Port dredging and dredged material placement activities, as well as fine-scale baseline studies. Together with publicly accessible databases, these studies have been utilised to describe the existing soft sediment community values of Port Curtis, particularly macroinvertebrate assemblages. Relevant studies and database searches used to inform this section are listed in Table 11.1.

Table 11.1 Existing information sources for soft sediment habitats and benthic macroinvertebrates within Port Curtis

Title	Reference
Reports	
Macrobenthic Community Responses to Long-Term Environmental Change in an east Australian Sub-Tropical Estuary	Currie and Small (2005)
PCIMP Intertidal Monitoring 2007, North Harbour Zones	Melville and Andersen (2008)
PCIMP Intertidal and Coastal Monitoring 2009	Vision Environment (2010)
Port Curtis and Rodds Bay seagrass and benthic macro-invertebrate community baseline survey, November/December 2002	Rasheed et al. (2003)
Port Curtis Macrobenthic Monitoring Programme: Queensland Energy Resources Limited surveys: November 1995 – November 2005	Alquezar, Small and Stratford (2006)
Port of Gladstone Offshore Disposal Monitoring Program	BMT WBM (2012)
Surveys and reports for other project EISs in the Gladstone area (e.g. WBDDP EIS, LNG proponent EISs)	GHD (2009a) Alquezar (2008, 2010, 2011)
The influence of dry-season conditions on bottom dwelling fauna of an east Australian sub-tropical estuary	Currie and Small (2006)
Various environmental impact assessments for dredging and dredged material placement, 2002 to 2012	Shown in this section if relevant
Port of Gladstone East Banks Sea Disposal Site Macroinvertebrate Monitoring Project 2016/2017	Vision Environment (2017)
Databases	
Atlas of Living Australia (incorporates Queensland Museum Wildnet data and Queensland Herbarium HERBRECS data)	ALA (2019)
EPBC Act PMST (refer Figure 11.1 for search area)	DoEE (2019)
Wildnet database (refer Figure 11.1 for search area)	DES (2019)

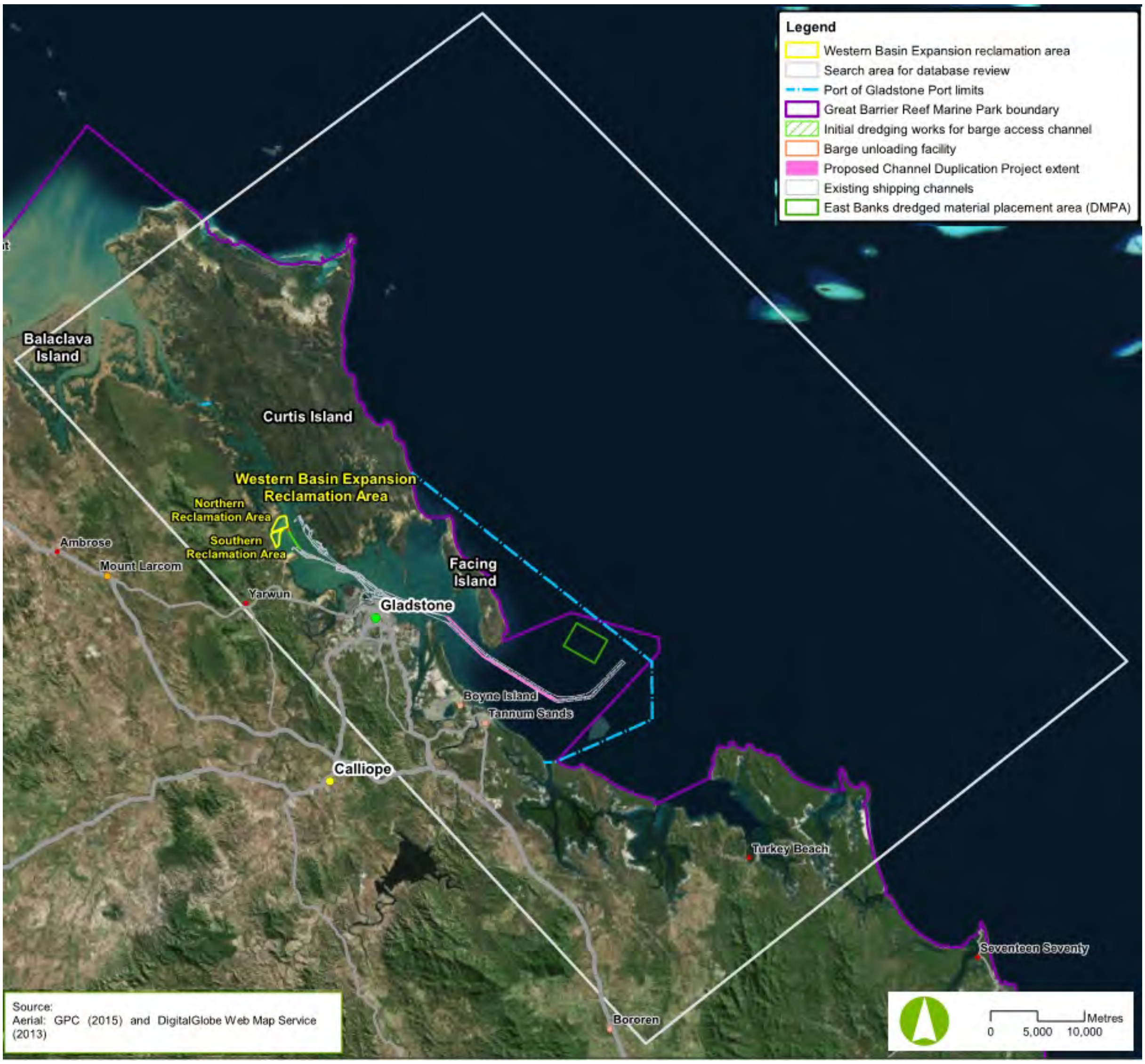

Figure 11.1 Search area for database review

Additional investigations of soft sediment macroinvertebrate and epibiota communities were also undertaken, specifically as part of the baseline surveys for the Project EIS. The methodologies are briefly outlined below for the:

- Key baseline Port Curtis studies undertaken by Rasheed et al. (2003) and McKenna et al. (2014) (refer Sections 11.2.2.1 and 11.2.2.2)
- Project EIS investigations (refer Section 11.2.2.4).

11.2.2 Field data collection

11.2.2.1 Port Curtis and Rodds Bay seagrass and benthic macroinvertebrate community baseline survey (Rasheed et al. 2003)

This study was undertaken as a joint collaboration between the (former) Gladstone Ports Authority (GPA), Queensland Fisheries Service and the CRC Reef Research Centre. The study was the first comprehensive study of seagrasses within Port Curtis since 1988, and the first survey to extend to coastal areas out to Port limits. The objective of the study was to establish baseline data on seagrass habitat within Port Curtis (including biomass, species composition and sediment characteristics) as well as other habitats, including benthic macroinvertebrate communities, against which potential (future) changes could be assessed.

Though conducted 16 years ago, the study provides a thorough, broad scale assessment of baseline conditions at the time of the survey, noting that numerous major development projects and other disturbances (e.g. floods) have occurred in Port Curtis since. In brief, the study surveyed seagrass, macroinvertebrates and epibiota at 143 sites throughout Port Curtis and Rodds Bay, as shown in Figure 11.2. Sites were typically positioned approximately 1km to 4km apart and a transect approximately 100m in length was sampled at each site.

The survey was conducted using a video camera and sled sampler (incorporated a sled net with of 600mm wide, 250mm deep, and a 10mm net mesh aperture) at sites where the water depth was greater than 5m below mean sea level. A van Veen grab (grab area 0.0625m^2) was also used to confirm sediment type and collect infaunal taxa (Rasheed et al. 2003). The analytical methodology implemented for this survey is provided in Appendix M.

An updated baseline survey of seagrass, benthic macroalgae and benthic communities was undertaken in November 2013 for the Project EIS (refer Section 11.2.2.2).

11.2.2.2 Baseline assessment of benthic communities in the Port Curtis region (McKenna et al. 2014)

The baseline epibenthic macroalgae and benthic macroinvertebrate survey conducted specifically for the Project EIS used methods adapted from Rasheed et al. (2003). It also collected visual (video) data on macroalgae communities, including the presence/absence, algal type and percent cover. This study was conducted by JCU's TropWATER in November 2013. The full report, including detailed methodology, is provided in Appendix D.

11.2.2.3 Benthic sampling program within Gladstone region (Choi et al. 2016, 2017)

A benthic sampling program was undertaken by Choi et al. (2016, 2017), which identified invertebrates living within the top 5cm of the sediment. Sampling was carried out during daylight hours at low tide. A total of 1,200 core samples were collected at 6 of the shorebird foraging sites across the ERMP area. A stratified random sampling approach was used to determine sample locations. Infaunal cores were collected where the core was driven into the sediment to a depth of 20cm and then retrieved and the top 5cm was separated from the rest of the core (Choi et al. 2017). Samples were passed through a 0.5mm mesh sieve as some infauna species can be 1mm in size. Samples were then sorted to a coarse taxonomic level. The abundance of all benthic invertebrates varied across the six sampled sites and elevations on the tidal flat, with bivalves, copepods, polychaetes and amphipods being the most dominant benthic organisms in the ERMP area (Choi et al. 2017). Section 12 provides further details regarding shorebird foraging sites across the ERMP area.

11.2.2.4 Project EIS macroinvertebrate transect surveys (Vision Environment 2015)

Detailed investigations of soft sediment benthic macroinvertebrate communities were undertaken by Vision Environment as part of the Project EIS. These investigations focussed on intensive sampling at locations likely/potentially affected by Project activities, including direct and potential indirect impact areas, nearby sensitive receptors and reference sites.

Macroinvertebrate assemblages were investigated twice over 12 months during the Project EIS baseline assessment (i.e. pre wet season (June to August 2014 and May to June 2015) and post wet season (January to March 2015)).

Fifteen benthic macroinvertebrate survey sites were sampled, including sites in the channel duplication area to be dredged and other Project direct impact areas (i.e. 'impact' sites). Sites adjacent to the direct impact areas or sensitive receptor habitats were considered 'near-field' or 'far-field/reference' sites, as appropriate. Table 11.2 provides a summary of the macroinvertebrate sampling locations which are depicted on Figure 11.2.

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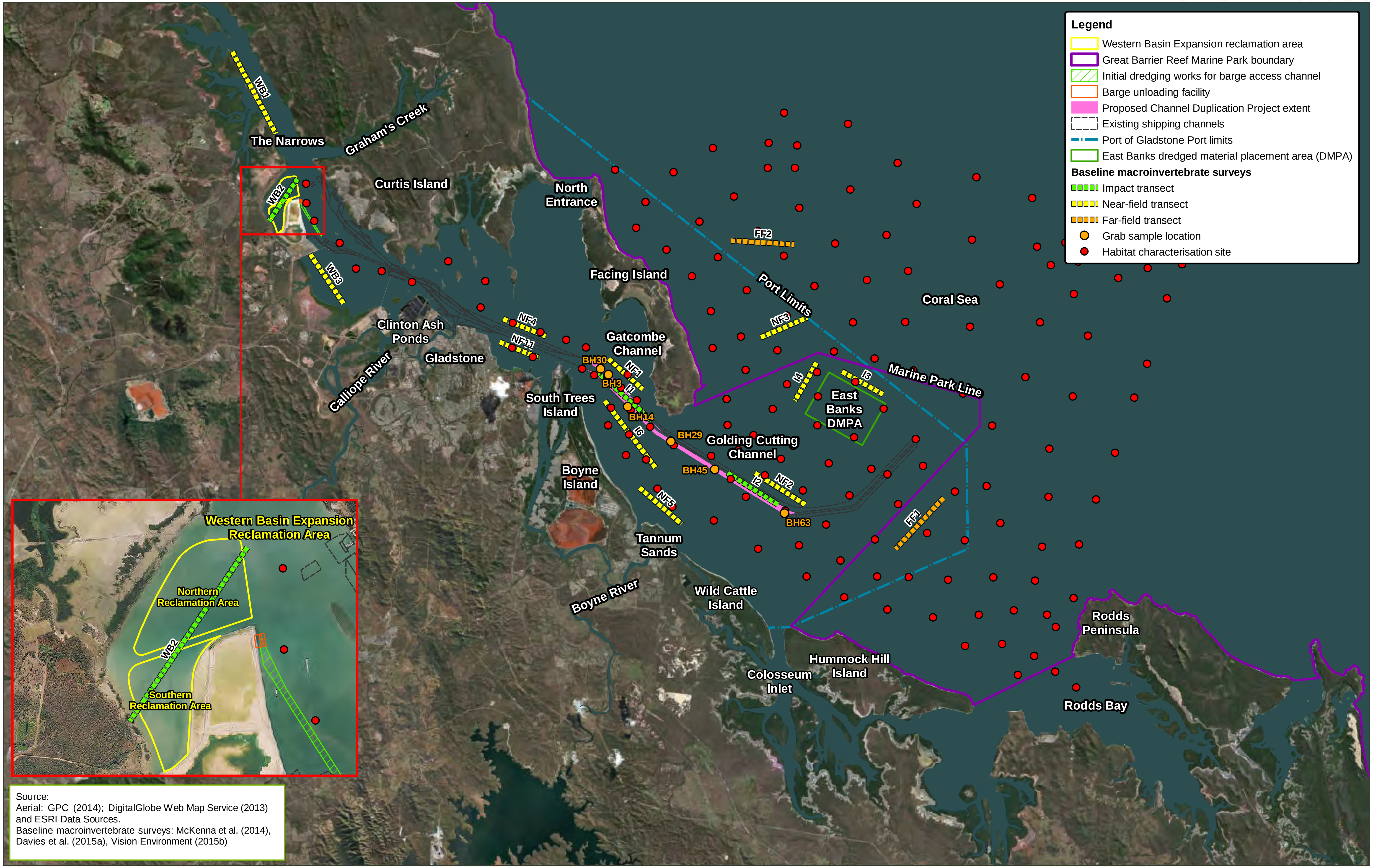

Source:
Aerial: GPC (2014); DigitalGlobe Web Map Service (2013) and ESRI Data Sources.
Baseline macroinvertebrate surveys: McKenna et al. (2014), Davies et al. (2015a), Vision Environment (2015b)

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Map by: RB

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Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 11.2: Survey locations for macroinvertebrates

Table 11.2 Baseline macroinvertebrate survey sites

Macroinvertebrate survey transect	Number of transects	Location of the survey sites
Impact sites	3	■ Two sites within the area to be dredged for duplication of the Gatcombe and Golding Cutting Channels ■ One site within the WBE reclamation area
Near-field sites	10	■ Five sites within the vicinity of the area to be dredged to for duplication of the Gatcombe and Golding Cutting Channels ■ Three sites within the vicinity of the East Banks DMPA ■ Two sites within the vicinity of the WBE reclamation area
Far-field/reference sites	2	■ One sensitive receptor site located near the Project EIS water quality monitoring site CD4 ■ One sensitive receptor site located near the Project EIS water quality monitoring site CD1

Sediments and associated macroinvertebrates were collected using a stainless steel Ponar grab sampler (volume 0.008m^3). Ten replicate samples were collected from each site, along with a further 10 samples for particle size distribution (PSD) and total organic carbon (TOC) analysis.

Sediment grabs were placed in 500µm mesh bags and sieved, in situ, before placing retained macroinvertebrate fauna in polyethylene bags for transport. In the laboratory, samples were preserved in 7% buffered seawater formalin for 24 hours and then placed in 70% ethanol for storage, until samples were sorted and identified. The report by Vision Environment (2015a) contains the analytical and statistical methodologies, and detailed survey findings (refer Appendix N).

11.2.2.5 Opportunistic Project EIS sampling – macrobenthic communities and sediment particle size (Davies et al. 2015)

Macroinvertebrate samples were opportunistically collected in February 2015 from six borehole locations within the area to be dredged (refer Figure 11.2) during geochemical sediment investigations for the Project EIS. Samples were collected with a grab (SEAS GS7L-SS Grab Sampler) at 10 replicate sites in each of the 6 locations, with a total of 60 samples collected.

The grab samples were frozen prior to being sent to the TropWATER lab in Cairns, where samples were sieved to 2mm. A representative sample of sediment was extracted from each sample. Organisms in the > 2mm fraction were sorted, identified and quantified.

Detailed PSD analysis was also conducted using a Malvern Mastersizer 2000 on appropriate samples or, for coarser sediments (two locations: boreholes BH14 and BH29), a Rapid Sediment Analyser which allows for coarser fraction analysis.

Details on the methods implemented for sample analysis are provided in Appendix O.

11.2.2.6 Port of Gladstone East Banks dredged material placement area macroinvertebrate monitoring project (Vision Environment 2017)

Macroinvertebrate and sediment monitoring was undertaken at sites within and adjacent to the existing East Banks dredged material placement area (East Banks DMPA) to address the monitoring requirements of the Sea Dumping Permit (SD2015/3002). Sampling was undertaken during the 2016/2017 wet season and 2017 dry season. Benthic soft-sediments were collected from each site using a stainless steel Ponar grab sampler (0.008m^3 grab volume).

Macroinvertebrate samples were sieved through a 1mm mesh as per APHA (2005), before being transferred to individually labelled polyethylene bags and placed on ice for transport to the laboratory. Samples were, fixed in 4% seawater-buffered formalin for at least 24 hours, followed by preservation in 70% ethanol as per the DERM Monitoring and Sampling Manual (2010b). Organisms were sorted and identified to the lowest taxonomic level using compound and dissecting microscopes.

Sediment samples were placed in individually labelled glass jars and polyethylene Ziploc bags, using pre-acid-washed and triple rinsed polypropylene scoops. The sediment samples were all analysed for particle size, nutrient concentrations and metal concentrations.

11.2.2.7 Gladstone Healthy Harbour Partnership

The Gladstone Harbour Report Cards for 2015, 2016 and 2017 included sediment quality sampling for six sediment metals and one metalloid (i.e. arsenic). The sediment samples were collected by PCIMP in June 2015, June 2016 and June 2017 from locations throughout Port Curtis, including areas adjacent to the WBE reclamation area (GHHP 2016b; 2017b).

The sediment grab samples were collected from the same sites used for water quality, and were collected using a stainless steel Ponar grab sampler, with four sub samples collected and analysed from each site. The samples were deposited into a collection tub that had been triple rinsed with seawater, and the samples were then photographed. The samples were not analysed for macroinvertebrates.

11.3 Soft sediment habitats and benthic macroinvertebrate values

11.3.1 General context

Soft sediment benthic habitats in Port Curtis are well studied both temporally and spatially. Surveys undertaken as part of the long term Port Curtis Macrobenthic Monitoring Program between 1995 and 2005 (Alquezar, Small and Stratford 2006) for the GPA and Queensland Energy Resources Limited (QERL), collected a total of 12,113 organisms from 418 taxa throughout the Port (Alquezar, Small and Stratford 2006). Results from sampling sites at Fisherman's Landing, The Narrows and Flying Fox Creek, indicated that the most abundant groups were molluscs, crustaceans and chordates which accounted for more than 97% of the individuals collected (Alquezar, Small and Stratford 2006). Other taxa collected in the surveys included echinoderms, cnidarians, sipunculids, nemerteans, branchiopods and pycnogonids (Alquezar, Small and Stratford 2006). Benthic communities were found to have higher species abundances, richness and diversity in the pre-wet season (November) compared to post-wet season (April) for all sites surveyed (Alquezar, Small and Stratford 2006).

Long term trends observed by Currie and Small (2005; 2006) throughout a six year study of benthic communities between The Narrows and the Inner Harbour zone, found that the distribution and abundance of soft sediment benthos was closely linked to water depth and sediment particle size, with species abundance and richness being lowest in the fine muddy substrates of the intertidal areas, and highest in the coarse, sandy sediments associated with the areas of the deeper channels (Currie and Small 2005). This ecological gradient was observed throughout seasonal and interannular changes in species dominance (Currie and Small 2005; 2006).

Currie and Small (2005; 2006) found temporal trends in abundance and richness were related to environmental variables with species richness and abundance positively correlated to influxes of freshwater and associated turbidity from runoff (Currie and Small 2005). High levels of turbidity appeared to indirectly promote recruitment and/or survival of benthic fauna in Port Curtis, indicating that long term declines and subsequent recovery of benthic communities could be attributed to long term climatic cycles, including El Nino southern oscillation events.

Infaunal communities, particularly at subtidal sites were found to be dominated by filter-feeding organisms in abundance and richness. The bivalve mollusc *Carditella torresi* was found to be the most abundant, followed by the ascidian *Ascidia sydneiensis.* A further eight species, including five bivalves (*Corbula tunicata, Mimachlamys gloriosa, Leionuculana superba, Mactra abbreviata* and *Placamen tiara*), one sea squirt (*Ascidiacea* sp.), one polychaete worm (*Eunice vittata*) and one shrimp (*Alpheus sp.*) contributed to a small percentage (2% to 3%) of the total abundance (Currie and Small 2005).

While relatively lower in abundance, intertidal areas in Port Curtis have been found to demonstrate diverse macroinvertebrate communities (Melville and Andersen 2008). Surveys undertaken for PCIMP in 2006 and 2007 in mangrove intertidal areas across Port Curtis found that molluscs and crustaceans were common on the rocky shores, and that the mangrove systems supported a range of taxa, including many gastropods that are common to mangrove stands and mud flats. Polychaetes were observed to have the highest species richness in the majority of survey areas, followed by molluscs and crustaceans (Melville and Andersen 2008).

Surveys undertaken by the CQU Centre for Environmental Management in 2010 to 2011 (Alquezar 2011) recorded 551 macroinvertebrate organisms from 124 species and from 7 different phyla from survey sites in The Narrows zone, Western Basin zone, and the Calliope River mouth. The most common phyla included polychaete worms (38%), molluscs (31%) and crustaceans (28%) with nemerteans and pycnogonids being the least common (< 1%). At each site, molluscs (*Mactra abbreviate*), crustaceans (*Corophium cf. Acutum* and *Ogyrides dellI*) and annelid worms (*Glycera* sp. and *Eunice vittata*) were the most abundant of all species. Diversity was observed to be higher at intertidal areas than subtidal areas and the highest species richness and diversity was observed in The Narrows (Alquezar 2011).

While a significant amount of macroinvertebrate survey data exists for the Inner Harbour areas of Port Curtis, the benthic macroinvertebrate communities of the Outer Harbour zone and coastal waters have also been well studied. Previous studies have predominately focused on monitoring to examine the impacts of dredged material placement at the existing East Banks DMPA. These studies have also identified broad patterns in benthic habitat structure, along with the key physical processes controlling benthic habitats and fauna communities at offshore sites adjacent to the existing East Banks DMPA (BMT WBM 2012).

Surveys conducted over a 15 month period in 2011 collected a total of 483 morpho-species comprising 182 families, 76 orders, 28 classes and 16 phyla. At all sampling locations, the most abundant phyla consisted of crustaceans, annelids and molluscs, although chordates (*Amphioxus* spp.) and echinoderms were also relatively abundant (BMT WBM 2012). Richness and abundance were higher during winter and spring, and lower in summer and autumn indicating a strong seasonal pattern. Lower abundance was particularly noticeable in the sampling event following the 2010/2011 Queensland flood event.

When compared to previous results in the area (i.e. study periods 2003 to 2005, and 2006), macroinvertebrate communities appear highly variable over time. The most prevalent taxa collected in the 2010 to 2011 survey differed substantially to those identified in 2006 with only three of the ten most prevalent taxa recorded in 2006 (elphidiid foramniferans, *Leptochela* sp. (comb shrimp), mysid shrimp, lumberinid polychaetes, microporid bryozoans, anemones, maldanid polychaetes, phoxocephalid amphipods, venerid bivalves and ampeliscid amphipods) recorded again in the 2011 survey (BMT WBM 2006; 2012). Similarly, foraminiferans, bryozoans and sea anemones were the numerically dominant taxa in 2006 surveys, but were rather absent in the 2003 to 2005, and 2010 to 2011 surveys (BMT WBM 2012).

Results from surveys conducted from 2003 to 2005 appeared similar to those of the 2010 to 2011 survey which found polychaete worms, crustaceans (e.g. ostracods; tanaids), bivalve molluscs and echinoderms represented the most abundant taxa (BMT WBM 2006).

The most recent macroinvertebrate and sediment monitoring undertaken at the East Banks DMPA in the 2016/2017 wet season and 2017 dry season recorded a total of 1,228 macroinvertebrates in the wet season and 1,044 species in the dry season, representing 158 taxa in total (Vision Environment 2017).

When compared to the surveys undertaken in the Outer Harbour zone in 2011 (BMT WBM 2012), the macroinvertebrate abundance, species richness and diversity values observed were lower in 2016/2017, however the results were not significantly different (i.e. no statistical significance was identified during analyses). This is reported as likely to be the result of regional environmental influences and differences in the depths of grab samples collected and analysed (i.e. Vision Environment 2017 samples were up to a depth of 89mm, whereas BMT WBM 2012 samples were to a depth of 120mm detecting species that burrow deeper into benthic sediments).

The overall variations observed in the macroinvertebrate communities of the East Banks DMPA during the 2016/2017 surveys were evident prior to the placement of dredged material at the site and is attributed to the higher gravel content in the East Banks DMPA sediments compared to reference sites (Vision Environment 2017).

11.3.2 Port Curtis and Rodds Bay historical baseline survey (2002)

The 2002 Port Curtis and Rodds Bay seagrass and benthic macroinvertebrate community baseline survey (Rasheed et al. 2003) was the first comprehensive study of Port Curtis benthic communities since 1988, and was the first survey to extend to coastal waters out to Port limits.

The baseline survey found that the survey area supported a range of benthic macroinvertebrates, and that there was an obvious distinction in the density and diversity of benthic macroinvertebrate communities between the inner Port area (inside Facing Island) and the Outer Harbour zone and coastal waters (refer Figure 11.3).

The most complex and diverse benthic macroinvertebrate communities occurred in the inner Port area around the maintained shipping channels. The Western Basin zone of the Port consisted of medium to high density macroinvertebrate communities comprising rubble reefs with a high abundance of bivalves, ascidians, bryozoans and hard corals. The maintained shipping channels from Targinie Channel up to Clinton Channel contained some of the highest density communities containing scallop and rubble reefs with a high abundance of bivalves and mixed reef taxa (e.g. sponges, soft coral, hard coral, hydroids, bryozoans and gorgonians). The higher diversity of benthic life in the shipping channels of the inner Port at the time of the 2002 study was attributed to the high currents flowing through these channels, compared with the open substrate areas outside of Facing Island. The benthic communities in these inner Port areas were dominated by filter feeding species such as sponges, gorgonians and bivalves, taxa which tend to thrive in high current environments (Rasheed et al. 2003).

The benthic environment of the Outer Harbour zone and coastal waters were dominated by open substrate and a low density of benthic taxa, consistent with open deep water sections of other Queensland ports, such as Mackay and Cairns (Neil et al. 2003; Rasheed et al. 2001; 2003). However, medium density benthic macroinvertebrate communities dominated by echinoids and gastropods, covered a large section of the existing East Banks DMPA. The high amount of rubble and coarser sediment material from dredged material (i.e. from dredged channels) at the reclamation area potentially provides a more suitable substrate for the settlement and recruitment of some benthic macroinvertebrates (Rasheed et al. 2003).

Overall, the large areas of high density benthic macroinvertebrate communities found in Port Curtis at the time of the 2002 survey were unusual compared to the results of other Queensland tropical and sub-tropical port surveys at the time of reporting (Rasheed et al. 2003).

Further details of the 2002 Port Curtis baseline benthic macroinvertebrate community survey are provided in Appendix M.

An updated baseline survey of Port Curtis benthic communities was undertaken in November 2013 for the Project EIS and is detailed in Section 11.3.3.

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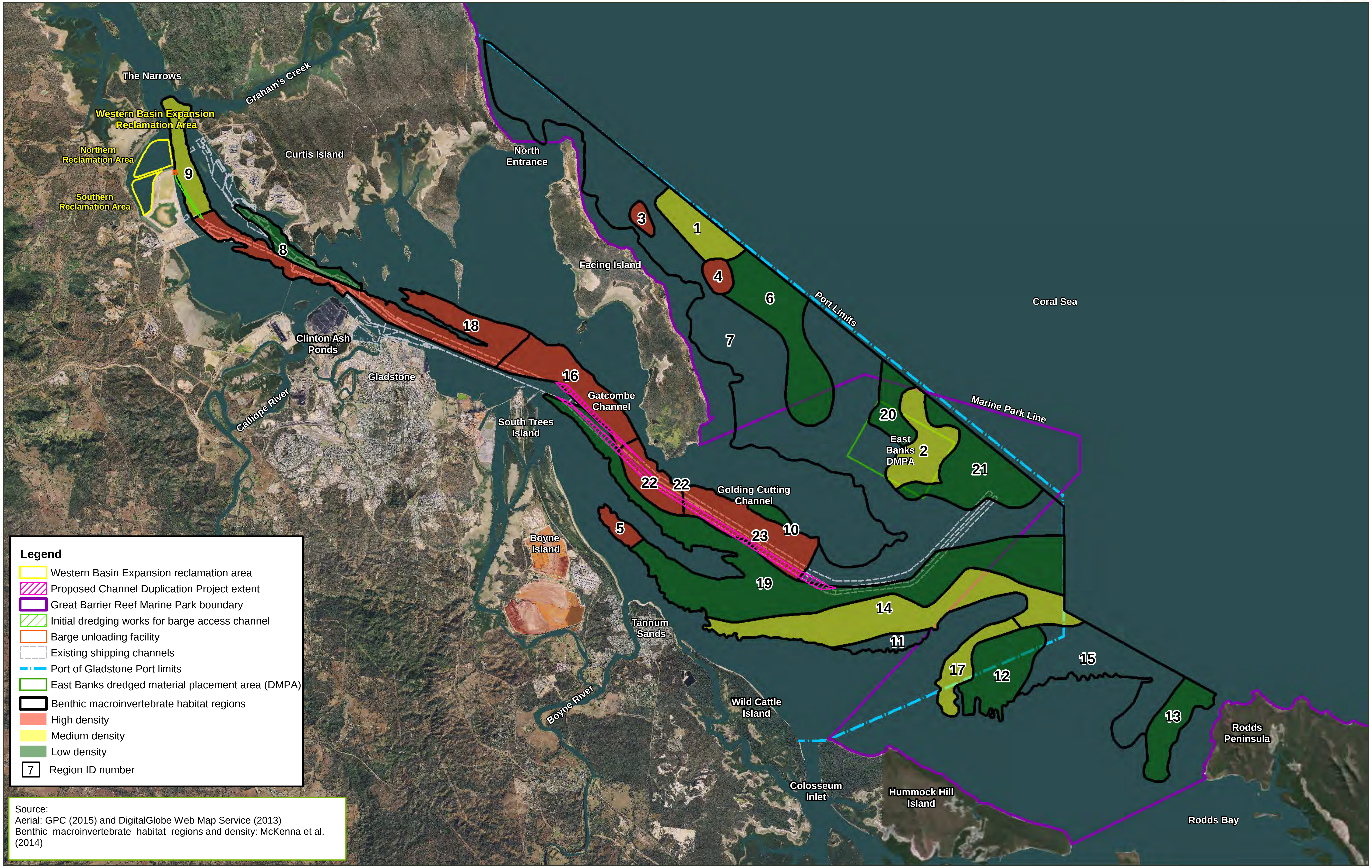

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Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 11.3: Location, density and distribution of benthic macroinvertebrates (November 2002)

11.3.3 Project EIS Port Curtis regional baseline assessment (2013)

The Port Curtis region benthic macroinvertebrate baseline assessment undertaken in November 2013 found that the region supports a diverse range of benthic community types that are typical of communities found in offshore and near shore subtidal areas elsewhere in Queensland such as Hay Point (Thomas and Rasheed 2011), Abbot Point (McKenna et al. 2013a) and Cairns (McKenna et al. 2013b). Typically, the majority of these areas are dominated by open substrate with a low to medium density of benthic communities, which differed from the 2002 survey. The diversity and density of benthic macroinvertebrates was similar between the inner Port area (inside Facing Island) and the outer Port (outside Facing Island) (McKenna et al. 2014).

Medium densities of habitat-forming benthos and benthic invertebrates were also found in the area to be dredged. Macroinvertebrates tended to be concentrated around habitat-forming 'live' and dead rock/rubble and reef. This association tended to be the driver behind the patches of higher biodiversity and density observed in the 2013 survey area.

The benthic macroinvertebrate communities in the 2013 survey area were dominated by filter feeding and suspension feeding species such as polychaetes, bryozoans, hydroids and bivalves. Elevated suspended material can result in the death of benthic fauna through congestion of feeding mechanisms and smothering, especially in filter-feeding organisms that occurred in the 2013 survey such as polychaetes, bivalves and bryozoans (Cruz-Motta and Collins 2004; Erftemeijer and Lewis 2006). Some species tend to be more sensitive than others to burial and increases in turbidity (Cruz-Motta and Collins 2004).

Photograph 11.1Sled with a closed circuit television camera system and benthic sample sorting process

Many of the benthic macroinvertebrate communities described in the 2013 and 2002 surveys, occur within or in proximity to maintained channels, port facilities and the existing East Banks DMPA. The presence of these communities, particularly the medium density community types that occurred in the East Banks DMPA in both the 2002 and 2013 surveys, indicates that benthic macroinvertebrates may be resilient to some level of dredged material placement and potentially capable of recovering from the disturbance related to capital and maintenance dredging and dredged material placement (McKenna et al. 2014).

Although only low to medium density regions of benthic macroinvertebrates occurred in the 2013 survey area, which differed from the 2002 survey, the value of these communities in supporting fisheries and biodiversity values should still be considered. Benthic fauna are a source of food for many consumers (Miller et al. 2003). Benthic fauna also forms a link between habitat substrata, detritus-based food chains and larger carnivores (Posey et al. 1997).

The benthic macroinvertebrate communities within the 2013 survey area were allocated into regions based on community composition and density. There were three density categories identified in the 2013 survey area; mostly open substrate, low density communities and medium density communities. Within these density categories a range of different community types were identified, with various combinations resulting in six different benthic macroinvertebrate region types (McKenna et al. 2014). These regions are outlined in Table 11.3 and Figure 11.4.

Table 11.3 Port Curtis 2013 deep water baseline survey area benthic macroinvertebrate regions

Density category	Benthic macroinvertebrate region description	Region ID	No. of sites	Area (ha)
Open substrate with isolated individuals	Open substrate with isolated benthic individuals	0	93	48,749
Low density benthic community	Mostly open substrate interspersed with polychaetes and encrusting bryozoans	2	27	19,411
	Mostly open substrate interspersed with brachyurans and low densities of most other taxa	3	7	4,530
Medium density benthic community	Medium density benthic community with rock/reef areas, dominated by encrusting bryozoans, polychaetes, erect bryozoans, hydroids and bivalves	1	15	11,321
	Medium density benthic community with rock/rubble/reef areas, dominated by encrusting bryozoans and bivalves	4	20	6,285
	Medium density benthic community dominated by mud/shell with medium densities of bivalves, polychaetes and bryozoans	5	1	396
Total		**15**	**163**	**90,692**

Source: McKenna et al. (2014)

Further details on the findings of the Port Curtis region baseline assessment undertaken in November 2013 are provided in Appendix D.

11.3.4 Project EIS baseline transects data collection (2014 wet season and 2015 dry season surveys)

Investigations undertaken by Vision Environment (2015b) indicate that a total of 5,043 macroinvertebrate infauna were collected at all locations sampled (refer to Figure 11.2). Sampled macroinvertebrates represented 162 different families and 18 phyla, 40% of which were identified during the dry season survey and 60% of which were identified during the wet season survey. The most common taxa sampled included the polychaete (*Maldane sarsi*) (11%), the brittle star (*Ophiuroidea* sp.) (6%), the unsegmented marine worm (*Sipuncula* sp.) (6%) the ascidian ball (*Ascidiacea*) (5%), and the polychaete worm (*Syllidae* sp.) (5%) (refer Photograph 11.2).

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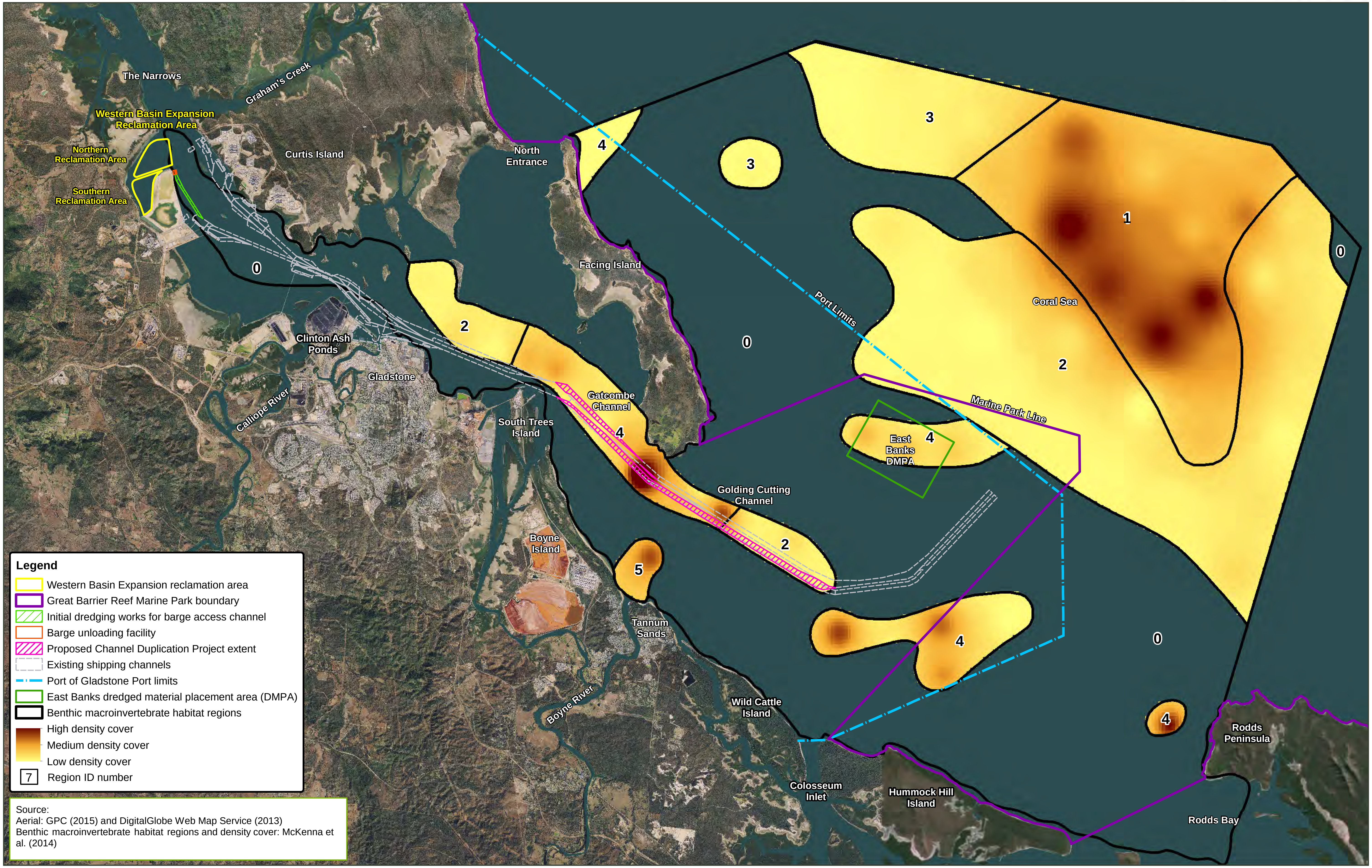

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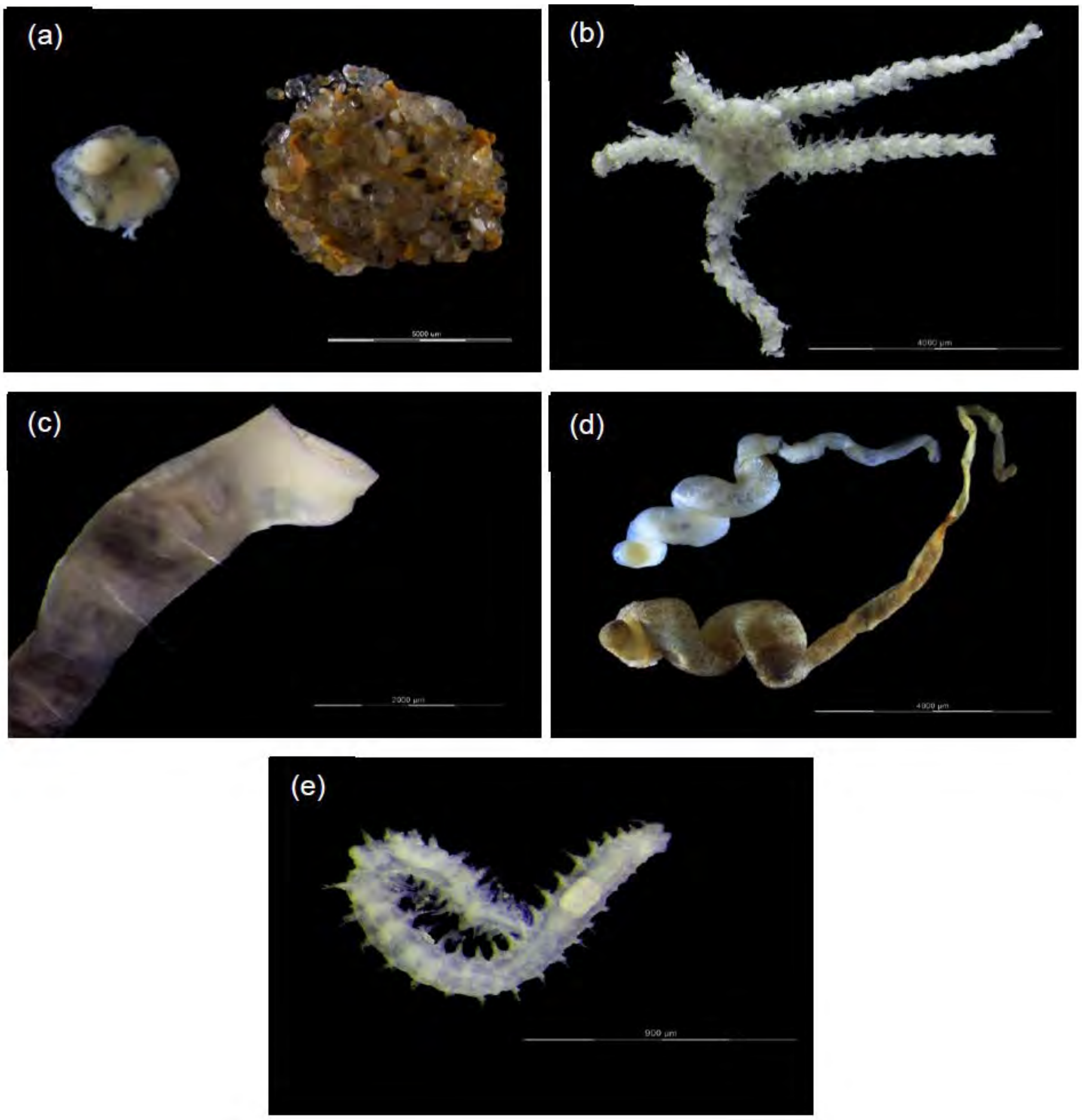
Gatcombe and Golding Cutting Channel Duplication Project

Figure 11.4: Location, density and distribution of benthic macroinvertebrates (November 2013)



Photograph 11.2 Photographs of the five most common macroinvertebrate species observed at all sites: (a) Ascidiacea, (b) *Ophiuroidea* sp., (c) *Maldane sarsi*, (d) *Sipuncula* sp., and (e) *Syllidae* sp.

Source: Vision Environment (2015b)

Vision Environment (2015b) noted that seasonal differences existed in macroinvertebrate abundance, richness and diversity. The wet season had significantly higher abundance, richness and diversity compared to the dry season, irrespective of sites. However, as there was no significant seasonal difference in evenness, the abundance spread among the taxa remained consistent across the baseline data collection period.

Consistent with the observations of Rasheed et al. (2003) and McKenna et al. (2014), Vision Environment (2015b) noted that significant differences in macroinvertebrate abundance, richness, and diversity occurred at different locations within Port Curtis. Highest abundance overall was evident at sites NF1 and NF11 in the Inner Harbour zone, and WB2 in the Western Basin zone adjacent Fisherman's Landing (8.7 to 64.5 organisms/0.008m^3) all which contained intermediate or high levels of TOC and fine sediment particle sizes. Lowest abundance was evident at I6 at the edge of the Mid Harbour/Outer Harbour zones (0.6 to 3.3 organisms/0.008m^3) which contained some of the lowest sediment TOC concentrations, in addition to low silt/clay content (Vision Environment 2015b) (refer Figure 11.2).

Macroinvertebrate species richness varied significantly across different sites with the highest richness overall, evident at NF1 in the Mid Harbour zone, followed by WB2 in the Western Basin zone, and FF2, a far-field reference site located in open coastal waters. FF2 was located east of Facing Island, and exhibited intermediate silt/clay and TOC content. Lowest richness was evident at I6 at the edge of the Mid Harbour/Outer Harbour zone, and Site I1, immediately north of I6, contained intermediate richness. Similar to species richness, the highest diversity was evident at NF1 in the Mid Harbour zone on the western side of Facing Island, WB2 in the Western Basin zone and FF2 in open coastal waters off Facing Island. Diversity at site I6 was significantly lower than all other sites. Site I1 contained intermediate levels of species diversity at the edge of the Mid Harbour/Outer Harbour zones.

A 2006 study of spatial distribution patterns of benthic macroinvertebrates within Port Curtis found that the number of species and individuals were typically highest in coarse-sand and gravel sediments, and were lowest in fine, well-sorted sands (Currie and Small 2006).

The Vision Environment (2015b) Project EIS macroinvertebrate baseline study (refer Appendix N) found that higher silt/clay fractions within the WBE reclamation area impact transects were found at sites closer to depositional zones, where lower tide/current movements occur. A summary of the benthic macroinvertebrate survey results recorded for the WBE reclamation areas impact transects is provided in Table 11.4 (Vision Environment 2015b).

Table 11.4 Overview of benthic macroinvertebrate survey results recorded for the Western Basin Expansion reclamation area impact and near field survey sites

Benthic macroinvertebrate value	Impact zone		Near field zone 1		Near field zone 2	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
Abundance (organisms/0.008m^3)	21.1 ± 6.0	32.8 ± 11.5	10.9 ± 5.6	6.0 ± 3.4	10.9 ± 4.6	9.5 ± 3.5
Species Richness (species/0.008m^3)	9.6 ± 1.9	12.1 ± 2.5	4.9 ± 1.5	3.6 ± 1.9	3.6 ± 0.8	4.7 ± 1.6
Diversity	1.8 ± 0.2	1.9 ± 0.3	1.1 ± 0.2	0.7 ± 0.3	0.8 ± 0.2	0.9 ± 0.3
Species Evenness	0.5 ± 0.1	0.6 ± 0.1	0.5 ± 0.1	0.6 ± 0.1	0.6 ± 0.1	0.4 ± 0.1

Source: Vision Environment (2015b)

A summary of the benthic macroinvertebrate survey results recorded for the dredging area impact transects are provided in Table 11.5 (Vision Environment 2015b).

Table 11.5 Overview of benthic macroinvertebrate survey results recorded for the dredging footprint impact and near field survey sites

Benthic macroinvertebrate value	Impact zone 1		Impact zone 2		Near field zone 1		Near field zone 2	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
Abundance (organisms/0.008m^3)	35.9 ± 17.3	11.9 ± 2.5	6.7 ± 1.8	6.2 ± 1.7	20.6 ± 4.0	64.5 ± 12.7	17.5 ± 6.5	15.8 ± 3.7
Species Richness (species/0.008m^3)	8.5 ± 2.1	5.0 ± 0.8	3.5 ± 0.8	4.6 ± 1.0	8.6 ± 1.3	23.7 ± 3.6	7.5 ± 2.1	6.9 ± 1.7
Diversity	1.3 ± 0.2	1.2 ± 0.2	0.9 ± 0.2	1.4 ± 0.2	1.7 ± 0.2	2.6 ± 0.1	1.3 ± 0.4	1.3 ± 0.3
Species Evenness	0.2 ± 0.1	0.4 ± 0.1	0.6 ± 0.1	0.8 ± 0.1	0.4 ± 0.1	0.3 ± 0.1	0.6 ± 0.1	0.4 ± 0.1

Source: Vision Environment (2015b)

The multivariate analysis (refer Figure 11.5) indicated that differences in macroinvertebrate assemblages were correlated with differences in sediment structure and carbon content (Vision Environment 2015b). This has also been observed by Currie and Small (2005) and BTM WBM (2014b). The depauperate macroinvertebrate community at I6 was identified to correlate with fine sands (63 to 500µm) which differed from most of the other sites. The inshore sites of WB1, WB2 and WB3 were grouped closely together indicating similarity and were correlated with TOC and dominant clay/silt content (< 63µm). The majority of near-field sites (NF1, NF2, NF3 and NF4), as well as both far-field sites (FF1 and FF2) and site I1, were also grouped, indicating similar macroinvertebrate communities, while impact sites I2, I3 and I4 also showed similarity among assemblages. Both groups were correlated with differing sediment parameters (e.g. no dominant particle size).

The univariate and multivariate analyses suggest that sediment parameters play an important role in shaping macroinvertebrate assemblages, as many invertebrate assemblages are specialist or obligates. These assemblages are suited or adapted to specific environments, utilising different feeding mechanisms specific to their habitat, such as filter/suspension feeding, deposit feeding, or predator/prey interactions.

Further details on the Project EIS baseline transects data collection and findings are provided in Appendix N.

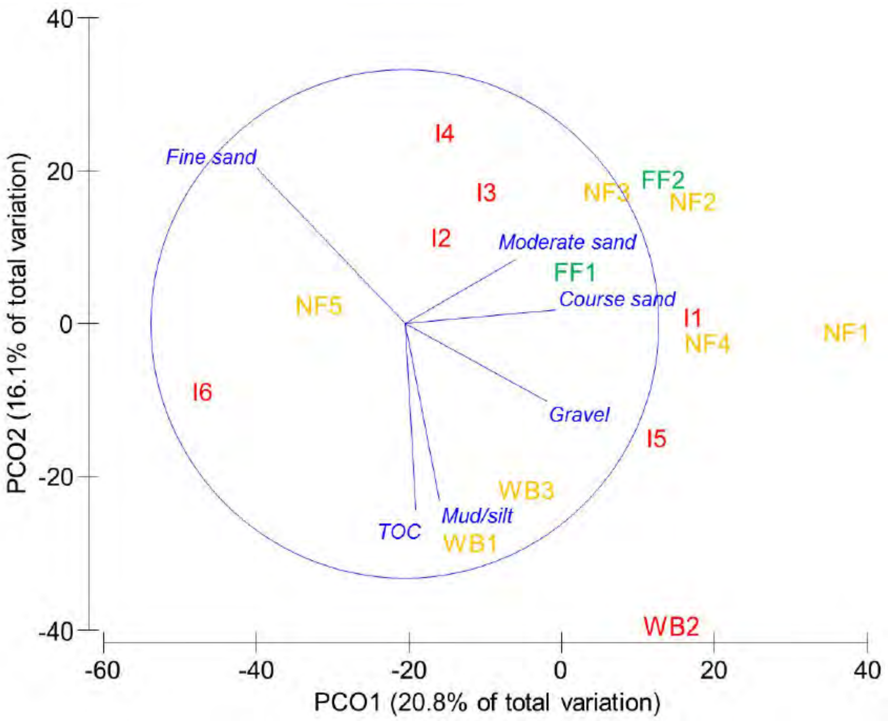


Figure 11.5 **Principle coordinates ordination of macroinvertebrate assemblages among sites**

Figure notes:

1. Sediment characteristics were overlaid to determine type of structure driving the variation among sites. Data were normalised and square root transformed using Bray-Curtis similarity (macroinvertebrate matrix) and Euclidian distances (sediment matrix)
2. Red text denotes Impact zones, orange text denotes near-field zones, green text denotes far-field zones

Source: Vision Environment (2015b)

Results from the baseline macroinvertebrate monitoring program for the Project conducted by Vision Environment (2015b) were similar to a number of historical studies conducted in Port Curtis (Alquezar 2008; Angonesi et al. 2006; BMT WBM 2012; 2014b; Vision Environment 2010).

The macroinvertebrate monitoring programs undertaken in Port Curtis have also informed whether marine pest species were present during surveys (refer Section 16).

11.3.5 Macrobenthic sampling as part of Project geochemical investigation

A total of 60 benthic habitat and sediment grabs were assessed from six locations within the area to be dredged (refer Figure 11.2). Macroinvertebrate infauna results were generally similar to a recent study of the deep water benthic macroinvertebrate community in the broader Gladstone region (McKenna et al. 2014). Reports from the field team during sample collection suggest the samples were taken primarily in areas with large amounts of rock and rubble. The presence of finer materials such as muds and silts may not have been detected in the samples due to limitations of the grab collection method in areas of high rubble and rock content. In areas where there are high amounts of rock and rubble, coarser sediment may wedge the grab open; allowing finer sediments to fall out of the grab on retrieval and hard surfaces will also limit the penetration of the grab once on the bottom (Davies et al. 2015c).

The benthic macroinvertebrate communities at all six sample locations were dominated by filter feeding and suspension feeding species such as polychaetes, bryozoans and bivalves (refer Photograph 11.3) similar to recent results from the broader Gladstone area and Abbot Point (McKenna et al. 2014; McKenna et al. 2013a).

Photograph 11.3 **Examples of the types of benthic macroinvertebrates found in grab samples**

Source: Davies et al. (2015c)

The majority of areas sampled in the broader Port Curtis region in November 2013 were dominated by open substrate with a low to medium density of benthic communities in both the inner Port area (inside Facing Island) and the outer Port (outside Facing Island) (McKenna et al. 2014). Medium densities of habitat-forming benthos and benthic invertebrates were also found in the area to be dredged during the 2013 survey (McKenna et al. 2014).

Previous studies of benthic communities in 2002 and 2013 have found benthic macroinvertebrates existing in proximity to shipping channels, Port facilities and the existing East Banks DMPA (McKenna et al. 2014; Rasheed et al. 2003). The continued presence of these assemblages in November 2013 following the WBDDP indicates that macroinvertebrate communities at these locations are somewhat resilient to previous dredging campaigns (McKenna et al. 2014).

11.3.6 Port of Gladstone East Banks dredged material placement macroinvertebrate monitoring project

These surveys were undertaken to meet the requirements of the Sea Dumping Permit SD2015/3002, with the aims of describing the characteristics of the East Banks DMPA sediments and to assess spatial and temporal patterns in macroinvertebrate communities and sediments (Vision Environment 2017). These surveys included sites within and adjacent to the East Banks DMPA as shown in Figure 11.6. Surveying sites both inside and outside of the East Banks DMPA was undertaken to assess the potential spatial extent of the 'near field' effects of dredged material placement at the East Banks DMPA, using a gradient approach to community and sediment comparisons (Vision Environment 2017).

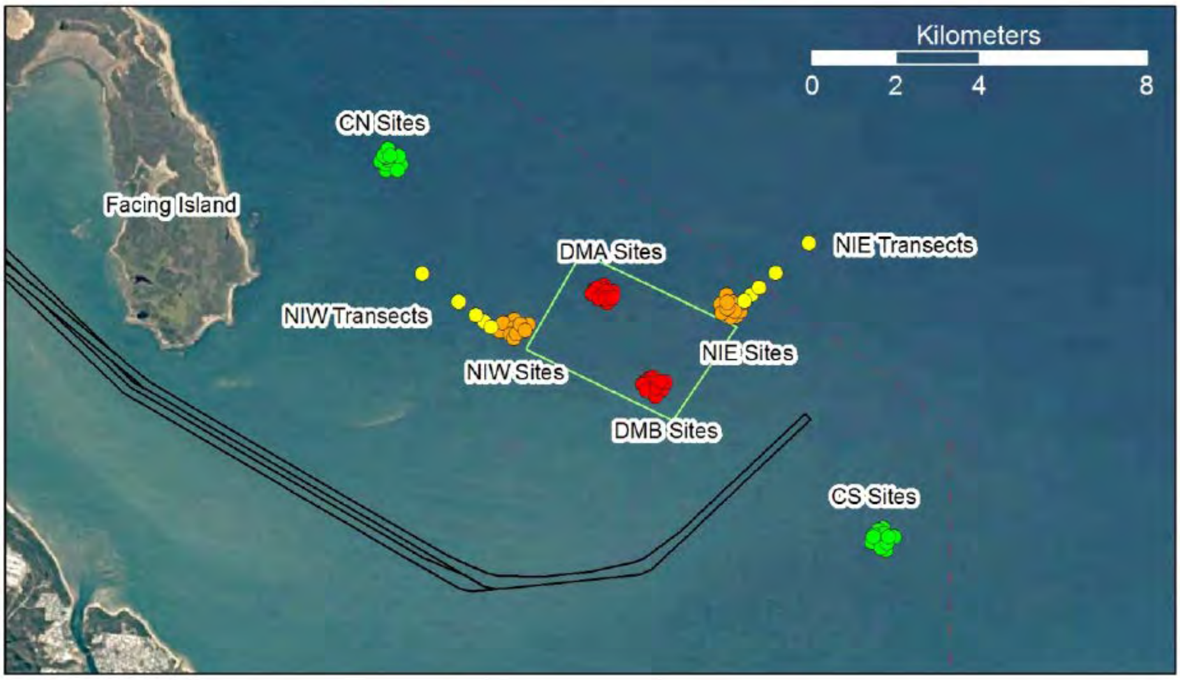


Figure 11.6 **East Banks dredged material placement area microbenthic**

Figure note:

Direct Impact sites (red), Potential Impact sites (orange), Transect sites (yellow) and Reference sites (green)

Source: Vision Environment (2017)

Eight of the survey sites (or primary survey sites) assessed as part of this monitoring project in 2016/2017 were also assessed in 2010/2011 (BMT WBM 2012). This enabled the direct comparison of macroinvertebrate assemblage data from the primary survey sites collected from the 2010/2011 surveys and the 2016/2017 surveys.

The data collected from the surveys in 2010/2011 and 2016/2017 was normalised for statistical analyses, and a two-way ANOVA was performed to determine significant spatial or temporal variation in macroinvertebrate indices of abundance, richness, diversity and evenness (significance levels were increase to $P < 0.01$, 99% confidence intervals) (Vision Environment 2017). The statistical comparisons with data collected in 2010/2011 were limited due differences in the data collected and laboratory analysis techniques utilised (Vision Environment 2017).

The 2016/2017 sediment and macroinvertebrate survey found similar results to the previous survey undertaken by BMT WBM (2012).

The 2010/2011 survey monitored particle size over a number of maintenance and capital dredging campaigns and did not identify any significant differences in particle size distribution in the East Banks DMPA during over during these dredging campaigns (BMT WBM 2012). BMT WBM (2012) concluded that due to low to moderate levels of bed-shear stress (i.e. a measurement of fluid force per unit area on the seabed, often related to sediment mobilisation and transportation), the finer sediment particles move into deeper water adjacent to the East Banks DMPA, leaving behind larger particles. The 2016/2017 transect data indicated that the silt content remains relatively high at sites within 250m to 500m of the potential impact sites (refer Figure 11.6), suggesting that particle settlement may occur within this range. Furthermore, there was a higher amount of coarser sediment particles at the direct impact sites compared to all the other sites, which is consistent with the conclusions of the BMT WBM (2012) report.

A total of 1,228 macroinvertebrates were collected during the 2016/2017 wet season and 1,044 macroinvertebrates collected during the 2017 dry season representing 158 taxa in total (Vision Environment 2017). Macroinvertebrate abundance, species richness and diversity were low in the East Banks DMPA, in comparison with most other monitoring sites. This is most likely due to the varying substrate characteristics where higher gravel content found in the East Banks DMPA (Vision Environment 2017). This spatial pattern was also recorded during the 2010/2011 surveys, prior to the placement of capital dredged material.

The 2016/2017 survey results identified significant spatial differences between survey sites, with the direct impact sites having significantly lower levels of organism abundance, species richness and diversity compared to many other sites (Vision Environment 2017). No discernible spatial pattern was evident along the transect sites for macroinvertebrate abundance, species richness or species diversity (Vision Environment 2017). Importantly, levels of abundance, species richness and species diversity did not differ significantly from one or more of the reference sites surveyed (refer Figure 11.6).

Species evenness was consistently high at the East Banks DMPA, indicating that macroinvertebrate abundance was spread evenly among the different taxa, suggesting good ecological health (Vision Environment 2017). The overall variations observed in the macroinvertebrate communities of the East Banks DMPA during the 2016/2017 surveys were evident prior to the placement of dredged material at the site and is attributed to the higher gravel content in the East Banks DMPA sediments compared to reference sites (Vision Environment 2017).

There were no introduced macroinvertebrate pest species recorded in either the wet or dry season surveys.

12 Migratory bird species

12.1 Background

In Australia, migratory species are those animals that migrate to Australia and its external territories, or pass through, or over, Australian waters during their annual migrations. Migratory species include some species of birds (e.g. petrels, albatrosses), marine mammals (e.g. dugongs, whales and dolphins) and reptiles (e.g. marine turtles, crocodiles).

There are a number of global conventions and agreements which have been established for the international coordination of conservation efforts for migratory species, including:

- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)
- China-Australia Migratory Bird Agreement (CAMBA)
- Japan-Australia Migratory Bird Agreement (JAMBA)
- Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA).

The EPBC Act lists migratory species as MNES, including species that are protected under the international conventions and agreements listed above. Actions likely to impact on migratory species are required to be assessed under the *Significant Impact Guidelines 1.1* (DoEE 2017a).

This section primarily focuses on migratory shorebird species for two reasons:

- The majority of the existing data from studies and reports is relevant to migratory shorebird species
- Project activities have greater potential to impact on migratory shorebirds and their habitat, due to the location of Project impact areas (direct and potential indirect impact areas).

It is noted, however, that other groupings of migratory birds are discussed where information is available.

12.2 Methodology

The purpose of this section is to document the existing migratory bird species populations and habitat areas within the Port Curtis region, providing a baseline for the assessment of direct impacts and potential indirect impacts associated with Project activities.

For the purposes of this section, assessment of migratory bird species includes migratory shorebirds, migratory aerial bird species, migratory terrestrial bird species, and migratory pelagic bird species. The migratory species that utilise terrestrial habitats are discussed in this section, with further on the habitat characteristics information provided in Section 13.

This section was informed by Government database resources and a review of existing literature and Project EIS ecological surveys. For the purposes of the database reviews, the Project EIS database search area was defined on a regional basis to ensure that transient species were captured in the assessment (refer Figure 12.1).

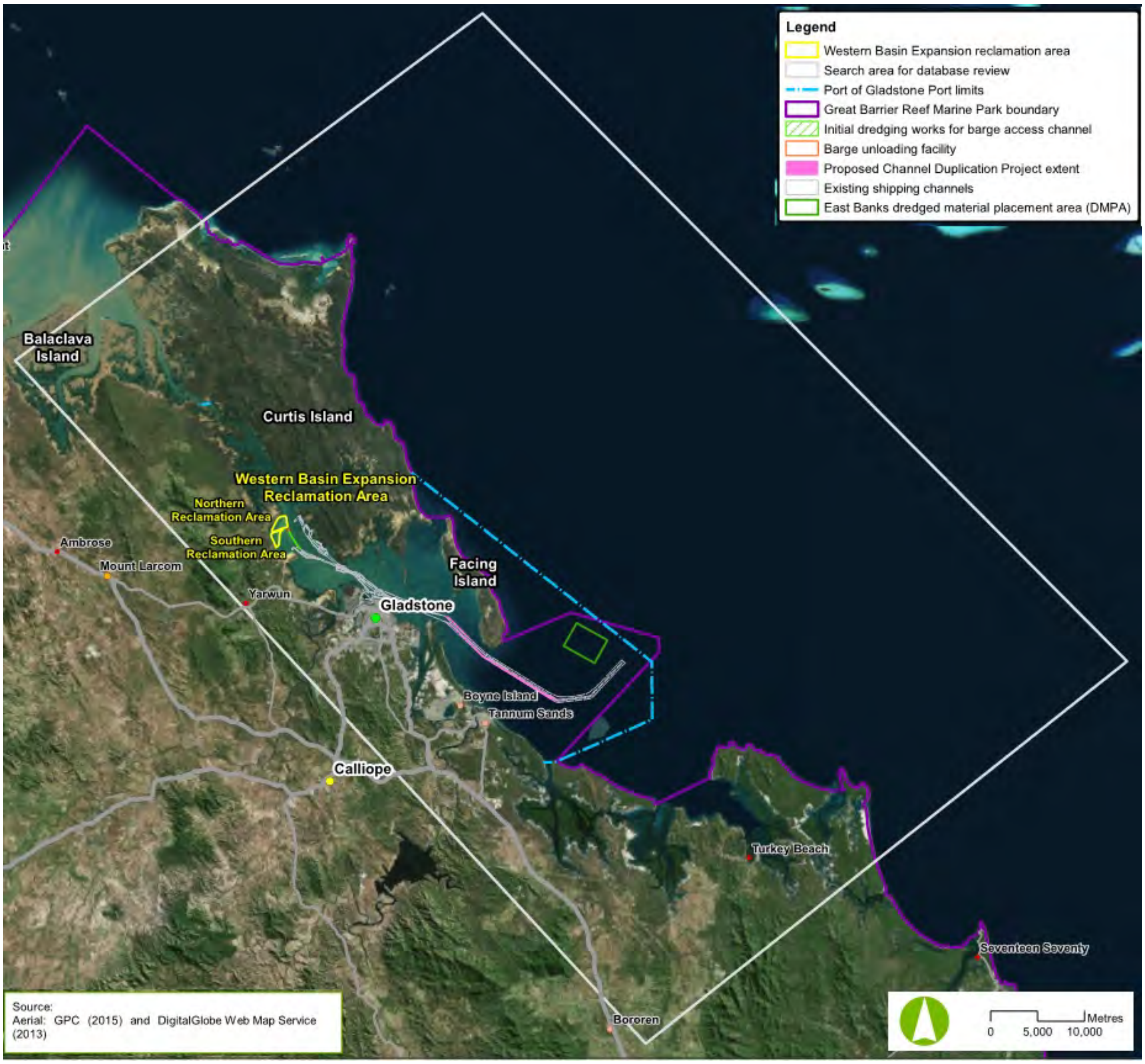


Figure 12.1 Search area for database reviews

The information sources which were reviewed and utilised as part of the assessment are summarised in Table 12.1.

Table 12.1 Key resources used for the assessment of migratory shorebird values

Title	Reference
Reports	
Arrow LNG Plant Supplementary Report to the EIS Addendum – Final Shorebird Technical Study	Ecosure (2013)
GLNG LNG Facility Curtis Island – Shorebird Surveys	URS (2015)
Migratory Shorebird Monitoring Review (This report summarises a range of monitoring events and includes information from nine comprehensive surveys conducted for GPC since 2011 and data from the Queensland Wader Study Group collected since 1993)	IMEMS (2013)
QCLNG Whole of Project Migratory Shorebird Management Plan	QGC (2013)
Report for Migratory Shorebird Monitoring Port Curtis and the Curtis Coast Annual Summer Survey – 2013	Wildlife Unlimited Pty Ltd (2013)
Report for Migratory Shorebird Monitoring Port Curtis to Port Alma, Survey One – January	GPC (2011a)
Report for Migratory Shorebird Monitoring Port Curtis to Port Alma Survey 3	GPC (2011b)

Title	Reference
The Action Plan for Australia Birds 2010	Garnett et al. (2011)
The distribution of shorebirds along the Queensland coastline	Driscoll (1997)
Gladstone Ports Corporation Report for Migratory Shorebird Monitoring Port Curtis and the Curtis Coast Annual Summer Survey – 2014	Wildlife Unlimited (2014)
Gladstone Ports Corporation Report for Migratory Shorebird Monitoring Port Curtis and the Curtis Coast Annual Summer Survey – 2015	Wildlife Unlimited (2015)
Gladstone Ports Corporation Report for Migratory Shorebird Monitoring, Port Curtis and the Curtis Coast Annual Summer Survey – 2016	Wildlife Unlimited (2016)
Gladstone Port Corporation Report for Migratory Shorebirds Monitoring, Port Curtis and the Curtis Coast Annual Summer Survey – 2017	Wildlife Unlimited (2017)
Gladstone Port Corporation Report for Migratory Shorebirds Monitoring, Port Curtis and the Curtis Coast Annual Summer Survey – 2018	Wildlife Unlimited (2018)
Annual Report: Migratory Shorebird Monitoring – Understanding Ecological Impact	Choi et al. (2015)
Annual Report: Migratory Shorebird Monitoring – Understanding Ecological Impact	Choi et al. (2016)
Final Report: Migratory Shorebird Monitoring – Understanding Ecological Impact	Choi et al. (2017)
Databases	
ALA (incorporates Queensland Museum Wildnet data)	ALA (2019)
EPBC Act PMST (refer Figure 12.1 for search area)	DoEE (2019)
Waterbird population estimates	Wetlands International (2006)
Wildnet database (refer Figure 12.1 for search area)	DES (2019)

12.2.1 Project migratory bird species baseline data collection

To supplement the existing information, two suitably qualified and experienced Aurecon ecologists conducted a summer migratory shorebird survey within the Project direct and potential indirect impact areas between 10 and 12 February 2015. This survey was supplemented by additional migratory shorebird sightings recorded during ecological assessments of the WBE reclamation area conducted by Aurecon between 4 March and 11 March 2015. The survey locations are shown in Figure 12.2. Incidental observations of avian species, including migratory birds, observed within the vicinity of Project activities were also recorded during the Project EIS water quality field inspections during August 2014, December 2014, April 2015 and June 2015.

The surveys at the WBE reclamation area, and the Boyne Island foreshore, typically commenced two hours before and after the high tide peak. Each area identified as potential habitat for migratory species were surveyed for a minimum period of four hours.

The Birds Australia Shorebirds 2020 Count Form was used to record shorebird data. Data recorded at each survey site included:

- Time and date
- GPS location (latitude/longitude)
- Observers
- Stage of tide (i.e. high rising and high falling)
- Wind direction
- Habitat type and quality

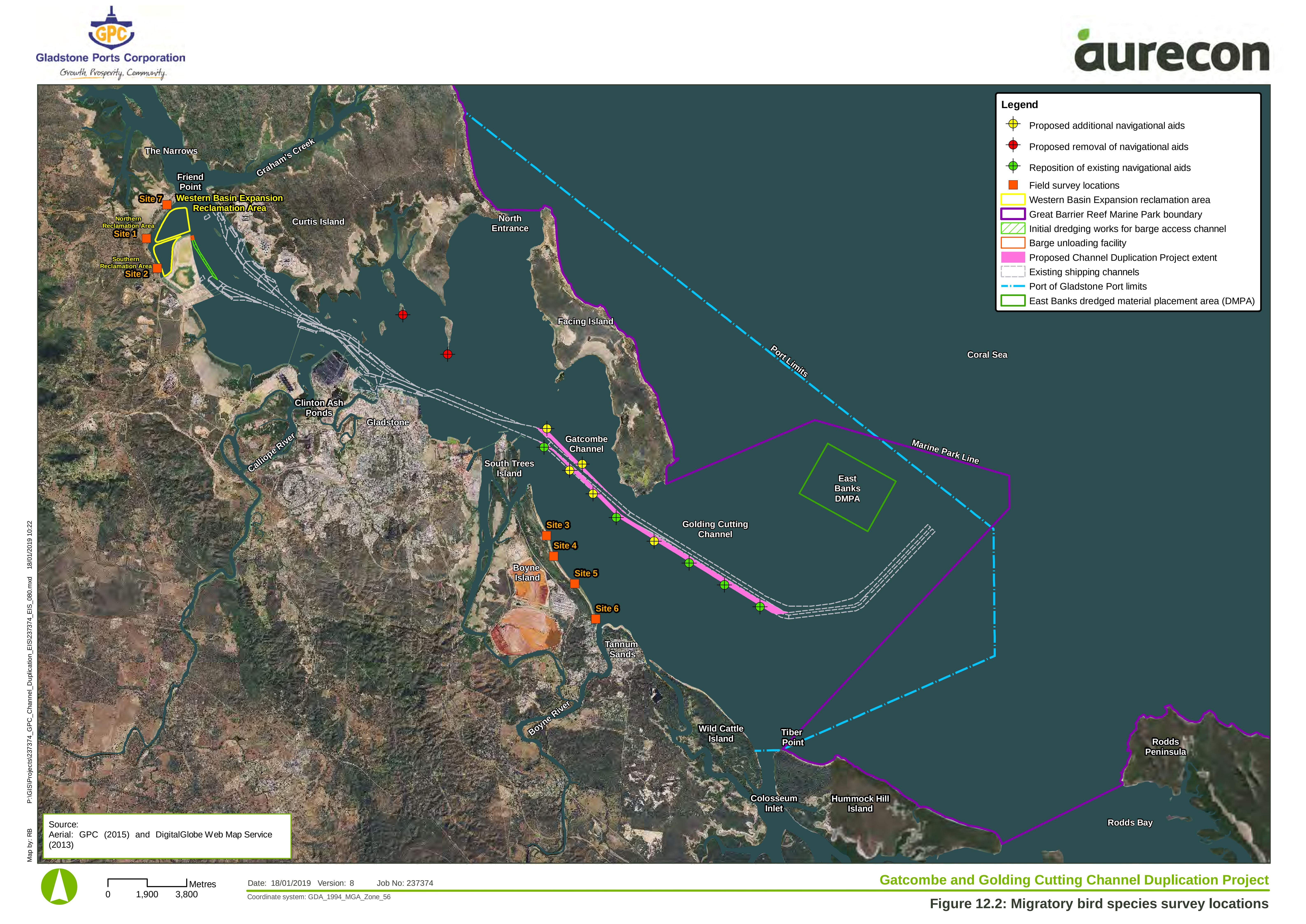


Figure 12.2: Migratory bird species survey locations

- Disturbances
- For observed individuals:
  - Species observed
  - Number of individuals observed
  - Age class of group (if known)
  - Any identifiable behaviours (e.g. feeding, foraging, roosting)
  - Photographs of the individuals where possible.

Weather parameters for the day of survey were accessed after the survey event using the Australia BoM website and data recorded at the Gladstone Radar weather station, ID 039123 (BoM 2018).

The migratory shorebirds were identified using a combination of accepted field guides, including Pizzey and Knight (2007) and Morcombe (2003). Nomenclature used in this report to describe migratory shorebirds has been taken from Christidis and Boles (2008). If an individual could not be identified to species level, the individual was grouped and described (e.g. Sand plover, Terek, Plover, Sandpiper, Knot, Tern, small wader, large wader).

The nature and quality of habitat value present at each monitoring location for migratory shorebirds was described during the field survey. The habitat values for foraging and roosting habitat for migratory shorebirds within the Project impact areas were mapped using a combination of field assessment data and existing data available for the Port Curtis region (refer Figure 12.3a).

12.3 Migratory bird species values

12.3.1 Database searches

Database searches identified the potential presence of 70 migratory birds within the database search area (refer Figure 12.1). The likelihood of occurrence assessment undertaken for the Project confirmed the presence of 21 migratory bird species within Project direct and/or potential indirect impact areas (i.e. Project impact areas) (refer Appendix B). An additional 43 migratory birds species were considered to have a moderate likelihood of occurrence and five species were considered to have a low likelihood of occurrence within the Project impact areas.

Appendix B provides the likelihood of occurrence assessments for all of the migratory species identified by the database searches, as well as identifying areas of known and potential habitat for these species within the Project impact areas. The database search results are provided in Appendix A, and Appendix K lists shorebirds included on the Fitzroy NRM BoT species prioritisation framework.

12.3.2 Review of existing information

A broad range of information sources were reviewed as part of this assessment (refer Table 12.1), including shorebird monitoring data and associated reporting from a range of development proponents within the Port Curtis region and government-maintained wildlife database records. The purpose of this review was to identify species likely to occur within the Project impact areas, including suitable foraging and roosting habitat, and population trends or significant populations recorded within the region.

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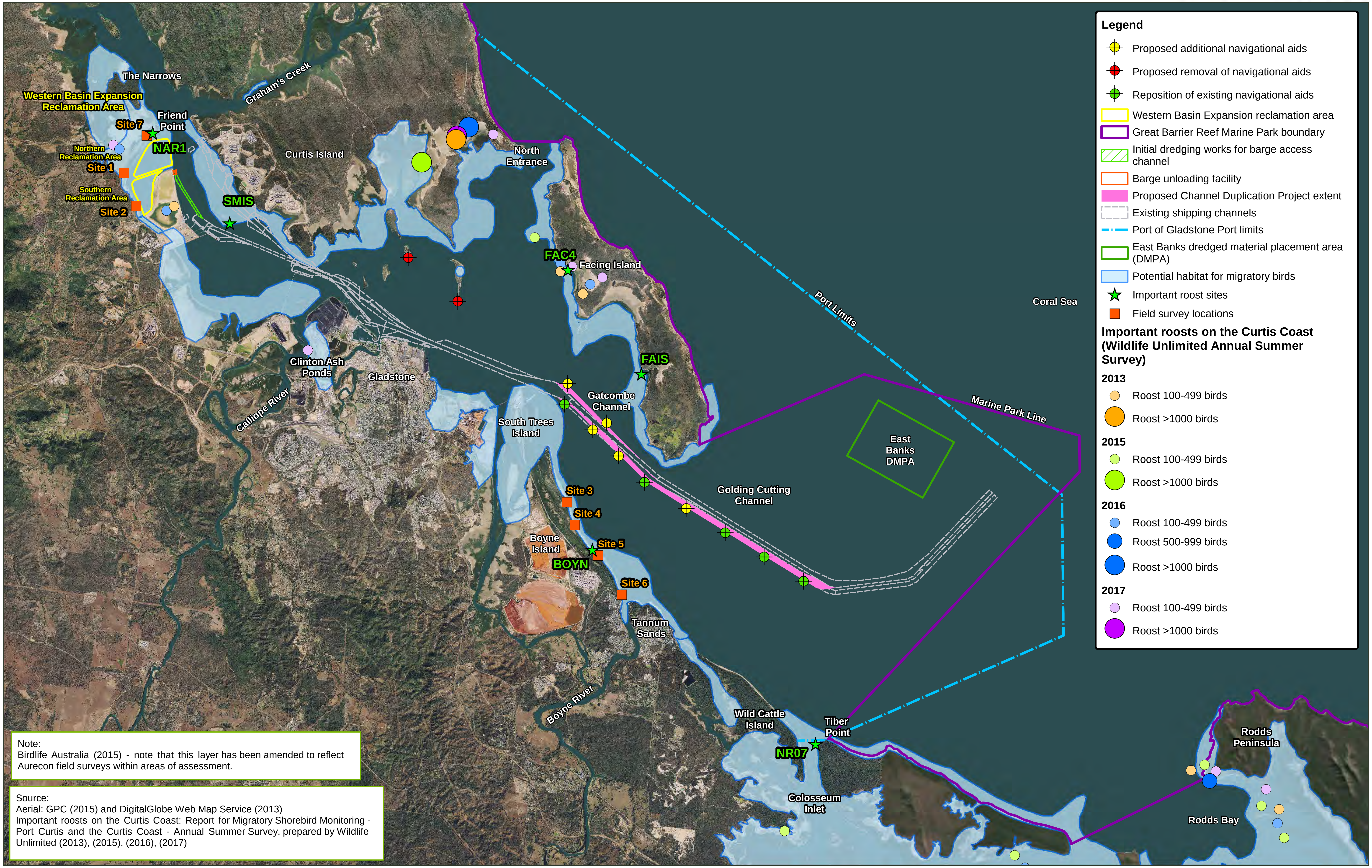

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Gatcombe and Golding Cutting Channel Duplication Project

Figure 12.3a: Potential habitat for migratory bird species (Overview)

One of the key information sources was a migratory shorebird monitoring review report prepared for GPC by IMEMS (2013). This review summarised results of a series of shorebird surveys in the Curtis Coast region (IMEMS 2013). These surveys targeted five key localities, including the Fitzroy Delta, North Curtis Island, Port Curtis, Colosseum inlet/Mundoolin Rock and Rodds Peninsula. This report reviewed survey data collected and records from the Queensland Wader Study Group (QWSG) from 1993 to 2013, from approximately 188 survey sites throughout the Curtis Coast region. The surveys focused predominantly on roosting migratory shorebirds at high tide, to be consistent with the majority of the shorebird data collected within the region and across Queensland.

The Curtis Coast region, including the Gladstone sub zone, contributes approximately 8% of the total population of migratory shorebirds in Queensland with an average population size during monitoring events in excess of 29,500 birds (population size calculated as a sum of the average counts over time for each species) (IMEMS 2013). Earlier estimates (Driscoll 1997) report a lower contribution for the Curtis Coast region of approximately 2.5% of the migratory shorebird population in Queensland; however at that time, the abundance of migratory shorebirds within the Fitzroy Delta and North Curtis Island had not yet been quantified. The Gladstone sub zone contributes approximately 6% of the total population of migratory shorebirds in Queensland, with an average population size during monitoring events in excess of 22,500 birds (IMEMS 2013).

Table 12.2 presents a summary of the species contribution for the Gladstone sub zone with respect to the State population total for migratory shorebird species (IMEMS 2013). The species presented in Table 12.2 are those which were subject to the IMEMS (2013) migratory shorebird monitoring review report.

Table 12.2 Percentage of migratory shorebird species State population occurring within the Gladstone sub zone

Migratory shorebird species	Scientific name	Percentage of State population within Gladstone sub zone
Bar-tailed godwit	*Limosa lapponica baueri*	5.5%
Black-tailed godwit	*Limosa limosa*	1.4%
Common greenshank	*Tringa nebularia*	10.3%
Curlew sandpiper	*Calidris ferruginea*	15.6%
Eastern curlew	*Numenius madagascariensis*	8.6%
Great knot	*Calidris tenuirostris*	2.8%
Greater sand plover	*Charadrius leschenaultii*	4.4%
Grey-tailed tattler	*Tringa brevipes*	7.6%
Lesser sand plover	*Charadrius mongolus*	10.9%
Red-necked stint	*Calidris ruficollis*	11.0%
Ruddy turnstone	*Arenaria interpres*	12.4%
Sanderling	*Calidris alba*	9.1%
Sharp-tailed sandpiper	*Calidris acuminata*	4.1%
Terek sandpiper	*Xenus cinereus*	13.7%
Whimbrel	*Numenius phaeopus*	8.9%

Source: IMEMS (2013)

As part of the Western Basin dredging approval conditions GPC are required to develop and implement the ERMP. As part of the ERMP, a study to determine the effect of port development activities on migratory shorebirds was conducted (as per Condition 33 of the EPBC Act approval). For the first two years of the ERMP, a comprehensive set of five surveys were required to be conducted in each year. Annual summer surveys (October to March) were required to fulfil Condition 33 of the EPBC Act approval, covering the high tide roost sites from years three to eight (Wildlife Unlimited 2016; 2017; 2018). Conditions 33 also required a repeat of the comprehensive surveys during years nine and ten.

12.3.2.1 Important habitat

Defining and identifying important habitat for migratory birds is critical to their ongoing survival to ensure habitat is appropriately managed. DoEE released industry guidelines in 2017 (i.e. *EPBC Act Policy Statement 3.21 – Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed species*). This guideline defines what important habitat for migratory shorebirds is, including at a national and international level (DoEE 2017a). As defined by the guideline, international important habitat is habitat that regularly supports:

- One percent of the individuals in a population of one species or subspecies of waterbird, or
- A total abundance of at least 20,000 waterbirds.

Furthermore, the guideline defines nationally important habitat for migratory shorebirds as habitat that regularly supports:

- 0.1 percent of the flyway population of a single species of migratory shorebird, or
- 2,000 migratory shorebirds, or
- 15 migratory shorebird species (DoEE 2017a).

One roost site within the Port Curtis region on North Curtis Island (Yellow Patch Estuary, approximately 29km north of the WBE reclamation area) has been recorded to host more than 1% of the flyway population of Whimbrels and is therefore considered internationally important habitat based on the above definition. This roost site will not be directly impacted by the Project activities.

To compare the relative importance of sites within the Curtis Coast region, and to identify sites that are important at a localised scale, IMEMS (2013) used a lower flyway population threshold of 0.1%. Within the Curtis Coast region, 44 roost sites met the flyway population threshold of 0.1% for at least one species. It is noted that this is similar to the definition of nationally important habitat under the DoEE (2017a) guidelines; however, as the IMEMS (2013) report was for a single migration season, it was not possible to state that this habitat ‘regularly’ supports these numbers of shorebirds. While the sites were not categorically defined as ‘nationally important’ for this reason, they are noted as having local importance, as is discussed in further detail below.

Between The Narrows and the Colosseum Inlet a total of seven sites were identified as important as they met the flyway population threshold of 0.1% for one or more shorebird species, as listed in Table 12.3. Two locations within proximity to the WB and WBE reclamation areas were identified as important roost sites for the Eastern curlew, with the NAR1 site situated approximately 400m north of the WBE reclamation area at Friend Point on Kangaroo Island (refer Figure 12.3b).

Within 5km of the proposed areas to be dredged, six locally important roost sites were identified, including two on Facing Island; one on Boyne Island; one at the entrance to the Colosseum Inlet; one at Six Mile Island; and one at Friend Point (refer Figure 12.3a and Table 12.3).

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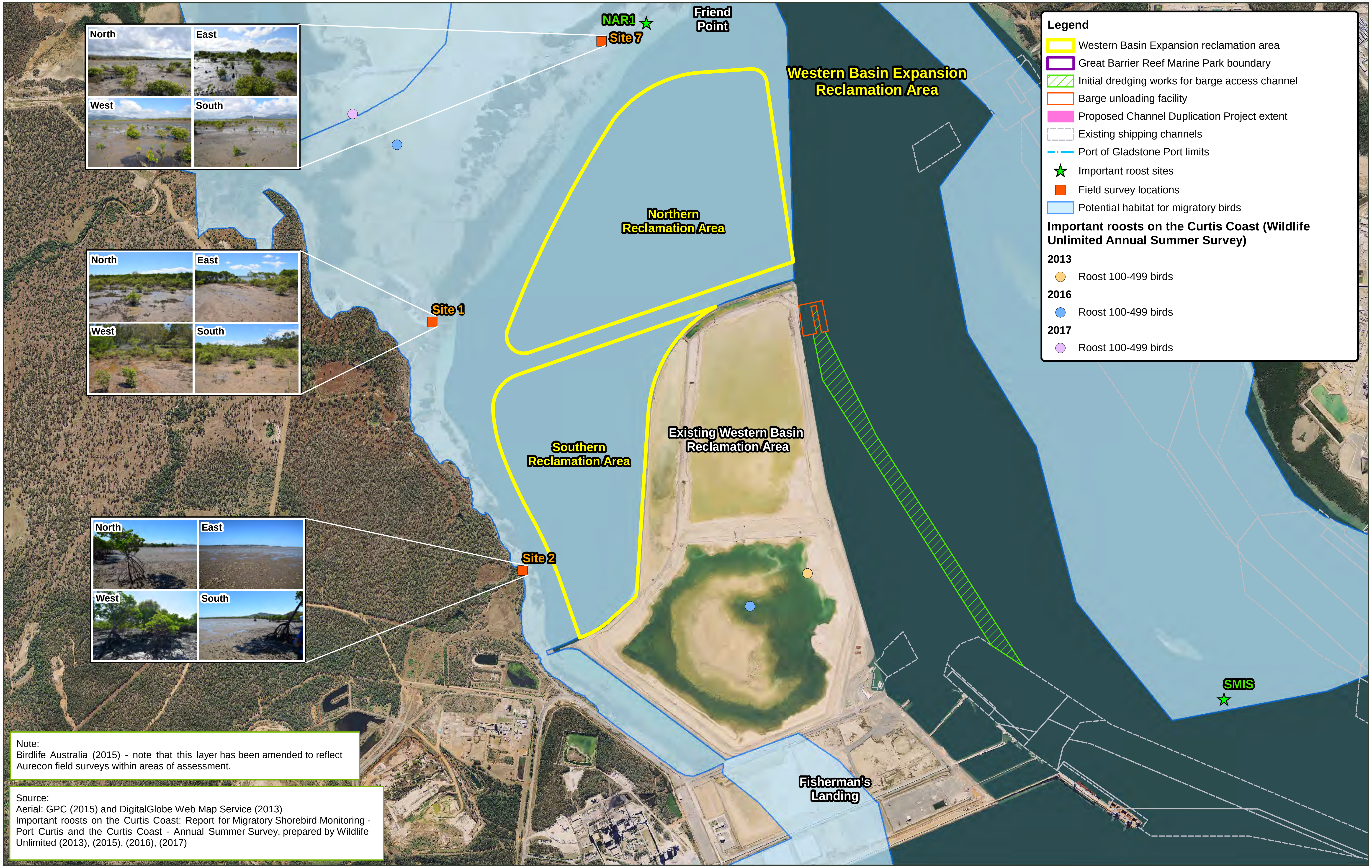

Note:
Birdlife Australia (2015) - note that this layer has been amended to reflect Aurecon field surveys within areas of assessment.

Source:
Aerial: GPC (2015) and DigitalGlobe Web Map Service (2013)
Important roosts on the Curtis Coast: Report for Migratory Shorebird Monitoring - Port Curtis and the Curtis Coast - Annual Summer Survey, prepared by Wildlife Unlimited (2013), (2015), (2016), (2017)

Map by: RB P:\GIS\Projects\237374_GPC_Channel_Duplication_EIS\237374_EIS_065.mxd 18/01/2019 10:59

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Gatcombe and Golding Cutting Channel Duplication Project

Figure 12.3b: Potential habitat for migratory bird species (Western Basin Expansion reclamation area)

Based on the GPC and QWSG survey data, counts for five shorebird species have exceeded 0.1% of the flyway population on at least one occasion at a survey site (IMEMS 2013). These species are:

- Eastern curlew
- Grey-tailed tattler
- Terek sandpiper
- Lesser sand plover
- Ruddy turnstone.

Table 12.3 Locally important roost sites within proximity to Project activities as identified in IMEMS (2013) that contain at least 0.1% of a flyway population for one or more shorebird species

Project location	Location of important local roost sites with > 0.1% of a flyway population	Species for which counts of birds on least one occasion exceed > 0.1% of the flyway population
WBE reclamation area	▪ **NAR1** (1% to 2%) located on the shoreline at Friend Point on Kangaroo Island, approximately 400m from north of the WBE reclamation area	▪ Eastern curlew
	▪ **SMIS** (1% to 2%) located on Six Mile Island in The Narrows, approximately 2.75km southeast of the WBE reclamation area	▪ Eastern curlew
Areas to be dredged and the location of new navigational aids	▪ **FAC4** (7% to 10%) located on Facing Island: – Approximately 5km north of the area to be dredged: – From 5km to 17km from the Project navigational aid works	▪ Eastern curlew ▪ Grey-tailed tattler ▪ Lesser sand plover ▪ Terek sandpiper
	▪ **FAIS** (1% to 2%) located on Facing Island: – Approximately 2.6km north of the area to be dredged: – From 2.6km to 11.4km from the Project navigational aid works	▪ Terek sandpiper
	▪ **BOYN** (1% to 2%) located on Boyne Island Beach: – Located 3.7km southwest of the area to be dredged – From 3.7km to 9.2km from the Project navigational aid works	▪ Lesser sand plover
	▪ **NR07**(1% to 2%) located at Tiber Point at the entrance to Colosseum Inlet: – Located 4km south of the area to be dredged – From 7.1km to 19km north from Project navigational aid works	▪ Ruddy turnstone

No additional roost sites of local importance (based on the 0.1% flyway population threshold) were identified during annual shorebird surveys undertaken for GPC for the Port Curtis region in 2014 and 2015, 2016, 2017 and 2018 (Wildlife Unlimited 2014; 2015; 2016; 2017; 2018) compared to those identified in Table 12.3. However, the 2015 annual monitoring report indicates that the roost sites at Friend Point on Kangaroo Island may constitute ‘critical migratory shorebird habitat’ in the upper harbour area (Wildlife Unlimited 2015), which is located approximately 400m from the WBE reclamation area.

The IMEMS (2013) report identifies the NAR1 roost site on the shoreline at Friend Point as being locally important; and Wildlife Unlimited (2015) noted that previous survey work suggests that while migratory shorebirds will preferentially utilise the Friend Point shoreline roost, they have been recorded to move further inland to the claypan areas when the tide inundates the shoreline roost (Wildlife Unlimited 2015). Previous survey counts of the shoreline and claypan roost sites at Friend Point demonstrate the combined capacity of these sites is in excess of 150 birds (Wildlife Unlimited 2014). In 2018, Whimbrels were observed roosting for the first time on the bund wall of the WB reclamation area (Wildlife Unlimited 2018).

12.3.3 Population trends

12.3.3.1 Global populations

Estimating abundances of migratory shorebirds is particularly variable and logistically difficult as they are highly mobile, occur in different locations for different stages of their lifecycle, and have a wide spatial extent and often occur in large groups (Piersma and Baker 2000; Piersma 2007). These sources of variability make the detection of robust population trends difficult and can result in changes in abundance going undetected (Wilson et al. 2011). Furthermore, shorebirds are subject to threats both locally and across the East Asian-Australasian Flyway, such as loss of stopover sites, reduction in the area and quality of non-breeding habitat, changes to wetland breeding habitat (e.g. climate change). Data from Wetlands International (2006) identified that of the 237 populations of migrant shorebirds for which reliable abundance data exists, 52% of the populations are decreasing and only 8% are increasing.

Four shorebird species known to occur within the Port Curtis region and which have recently been listed under the EPBC Act as critically endangered, are the Eastern curlew, Curlew sandpiper, Great knot, and the Northern Siberian Bar-tailed Godwit. Garnett et al. (2011) identified in *The Action Plan for Australian Birds 2010* that the populations for these species had undergone recent and ongoing declines of up to 79% in the past three generations of these species (refer Table 12.4).

For the Eastern curlew, observed declines in numbers across Australia are reported to stem from ongoing loss of intertidal mudflat habitat at key migration staging sites in the Yellow Sea (TSSC 2015a). Curlew sandpipers are threatened by wetland degradation in East Asia at stopovers during their migration, with recorded threats to habitat, including environmental pollution, reduced river flow, sea level rise, human disturbance and reclamation for industrial uses (TSSC 2015b). Threats for migratory shorebirds are also occurring in Australia, including coastal development, land reclamation, alteration to surface and groundwater levels, recreational activities and impacts on food availability due to change in water quality (TSSC 2015a; 2015b).

Table 12.4 Population trends reported in the Action Plan for Australian Birds 2010 for species confirmed within the Project impact areas

Species	Population trends reported in *Action Plan for Australian Birds 2010*
Eastern curlew	Past, recent and ongoing declines of 30% to 49% in three generations (30 years) based on survey data and habitat loss
Grey-tailed tattler	Declines of 20% to 29% over three generations (25 years) based on survey data
Lesser sand plover	Past, current and anticipated declines of 50% to 79% over periods of three generations (24 years) based on survey data and habitat loss
Ruddy turnstone	Past decline in flyway estimated at 30% to 49% in three generations (25 years) based on survey data. However non-declining populations in other flyways are not phenotypically differentiated, suggesting genetic interchange, so downgraded to near threatened
Curlew sandpiper	Past, recent and ongoing declines of 50% to 79% in three generations (23 years) based on survey data and habitat loss
Great knot	Data not available
Northern Siberian bar-tailed godwit	Data not available

Source: Garnett et al. (2011)

12.3.3.2 Populations within the Curtis Coast region

The population dynamics and abundance of shorebirds within the Curtis Coast region are not understood well enough to draw statistically valid conclusions regarding trends in populations or abundance.

The IMEMS (2013) report identifies apparent changes in the abundance of migratory shorebirds at the Clinton Ash Ponds near the mouth of the Calliope River (not within the Project direct impact areas) which is a highly modified environment. The counts of shorebirds at this site have declined since the commencement of shorebird surveys in 1993 (IMEMS 2013). This site is highly disturbed and is primarily an artificial roosting site for shorebirds. As such, it is likely that the opportunities for local roosting within this site have decreased over time resulting in a decline in the abundance of shorebirds present at the site.

Due to variations in the methodologies used to count shorebirds within the Port Curtis region, there is not sufficient replicate datasets to determine the statistical significance of any apparent changes in shorebird abundance (IMEMS 2013).

Wildlife Unlimited (2016) found a reduction in the total abundance in shorebirds compared to the previous year, which was mostly due to a 42% reduction in the number of Red-necked stints recorded. Other species that returned a reduction in abundance compared to 2015 were Greater sand plover, Bar-tailed godwit, Great knot, Terek sandpiper and Grey plover. These decreases were offset by increases in the abundance of Grey-tailed tattlers and a number of the species which are relatively rare on the Curtis Island (Wildlife Unlimited 2016).

Wildlife Unlimited (2017) found a 21% increase of migratory shorebirds from February 2016, and 14% more than the summer average calculated from nine surveys conducted in January and February from 2011 to 2017. The increase in total abundance of migratory shorebirds was mostly due to the 229% increase in the number of Terek sandpipers (Wildlife Unlimited 2017). Other species that returned an increase in abundance compared to 2016 were Sand plover species, Red-necked stint and Whimbrel. The distribution of migratory shorebird was skewed to the north with the three highest abundance roosts all located there.

The total abundance of migratory shorebirds on the Curtis Coast does not appear to be declining however considerable variation in space and time has been documented for several species (Wildlife Unlimited 2016; 2017; 2018).

12.3.4 Carrying capacity of the Port Curtis/Port Alma area

Choi et al. (2016 and 2017) produced a migratory shorebird monitoring report for the ERMP area, based on estimating the carrying capacity of the Port Curtis/Port Alma region, and determining the size for the impacted population. It was found that approximately 20,000 migratory shorebirds use the ERMP area. Based on analysing the distribution, abundance and energy content of the shorebirds' invertebrate prey, Choi et al. (2017) determined that the ERMP area is functioning at or near carrying capacity. Satellite-based mapping showed that about 216km^2 of intertidal substratum is exposed in the ERMP area when the tide is in the bottom 10% of its range, resulting in a large foraging opportunity for shorebirds (Choi et al. 2016; 2017). However, these tidal flats are highly unevenly distributed across the area.

The ERMP area is ranked among the lowest in the world for the density of food available to shorebirds resulting in the areas near carrying capacity (Choi et al. 2017).

12.3.5 Species known or likely to be present

The desktop review of information identified a total of 66 migratory bird species as having the potential to occur within the Project database search area (refer Figure 12.1 and Table 12.6). Of these species, 62 were identified as having been previously confirmed within the Project database search area, or having a moderate likelihood of occurrence (based on the presence of suitable habitat and records of the species from nearby localities) (refer Table 12.5 and Table 12.6).

These 66 species can be grouped into the four broad categories provided below due to similar habitat requirements and general ecology, as per the category headings in Table 12.6:

- Shorebirds which utilise habitats along the shoreline
- Pelagic species which utilise open oceans for foraging and sub-Antarctic islands for roosting
- Aerial species which forage aerially
- Terrestrial species which utilise terrestrial habitats.

The likelihood of occurrence category definitions provided in Table 12.5 have been utilised in Table 12.6.

Table 12.5 Likelihood of occurrence category definitions

Likelihood of occurrence category	Definition
Confirmed	Multiple records for the species in the Project EIS database search area from a reliable data source (e.g. previous studies or specimen-backed database records) or confirmed during Project EIS field investigations, and suitable habitat exists within the Project impact areas
Moderate	Records for the species in the Project EIS database search area from a reliable data source but not specifically recorded within the Project impact areas. Suitable habitat for this species exists within the Project impact areas.
Low	Records for the species from the Project EIS database search area from a reliable data source but not specifically recorded within the Project impact areas. Suitable habitat for this species does not exist within the Project impact areas.
Negligible	Identified from database searches only and no suitable habitat exists within the Project impact areas

Table note:

Refer Section 2.2 for further details.

Table 12.6 Migratory birds confirmed or likely to be present within the Project impact areas

Family	Scientific name	Common name	EPBC Act status	Bonn	CAMBA	JAMBA	ROKAMBA	EPBC Act protected matters search tool	Wildnet	Likelihood of occurrence within the Project impact areas
Shorebirds (migratory)										
Threskiornithidae	*Plegadis falcinellus*	Glossy Ibis	Migratory/Marine	✓	-	-	-	-	✓	Low
Charadiidae	*Charadrius bicinctus*	Double-banded plover	Migratory/Marine	✓	-	-	-	✓	✓	Moderate
	Charadrius mongolus	Lesser sand plover	**Endangered** Migratory/Marine	✓	✓	✓	✓	✓	✓	Confirmed
	Charadrius leschenaultii	Greater sand plover	**Vulnerable** Migratory/Marine	✓	✓	✓	✓	✓	✓	Confirmed
	Pluvialis fulva	Pacific golden plover	Migratory/Marine	✓	✓	✓	✓	✓	✓	Confirmed
	Pluvialis squatarola	Grey plover	Migratory/Marine	✓	✓	✓	✓	✓	✓	Moderate
Scolopacidae	*Actitis hypoleucos*	Common sandpiper	Migratory/Marine	✓	✓	✓	✓	✓	✓	Moderate
	Calidris melanotos	Pectoral sandpiper	Migratory/Marine	✓	-	✓	✓	✓	-	Moderate
	Calidris alba	Sanderling	Migratory/Marine	✓	✓	✓	✓	-	✓	Moderate
	Arenaria interpres	Ruddy turnstone	Migratory/Marine	✓	✓	✓	✓	✓	✓	Confirmed
	Calidris acuminata	Sharp-tailed sandpiper	Migratory/Marine	✓	✓	✓	✓	✓	✓	Confirmed
	Calidris canutus	Red knot	**Endangered,** Migratory/Marine	✓	✓	✓	✓	✓	✓	Confirmed
	Calidris ferruginea	Curlew sandpiper	**Critically endangered** Migratory/Marine	✓	✓	✓	✓	✓	✓	Confirmed
	Calidris ruficollis	Red-necked stint	Migratory/Marine	✓	✓	✓	✓	✓	✓	Moderate
	Calidris tenuirostris	Great knot	**Critically endangered** Migratory/Marine	✓	✓	✓	✓	✓	✓	Confirmed
	Gallinago hardwickii	Latham's snipe	Migratory/Marine	✓	-	✓	✓	✓	✓	Confirmed
	Gallinago megala	Swinhoe's snipe	Migratory/Marine	✓	✓	✓	✓	✓	-	Low
	Gallinago stenura	Pin-tailed snipe	Migratory/Marine	✓	✓	✓	✓	✓	-	Low
	Limicola falcinellus	Broad-billed sandpiper	Migratory/Marine	✓	✓	✓	✓	✓	✓	Moderate

Family	Scientific name	Common name	EPBC Act status	Bonn	CAMBA	JAMBA	ROKAMBA	EPBC Act protected matters search tool	Wildnet	Likelihood of occurrence within the Project impact areas
	Limosa lapponica baueri	Bar-tailed godwit	**Vulnerable**, Migratory/Marine	✓	✓	✓	✓	✓	✓	Confirmed
	Limosa lapponica menzbieri	Northern Siberian bar-tailed godwit	**Critically endangered,** Migratory/Marine	✓	✓	✓	✓	✓	-	Confirmed
	Limosa limosa	Black-tailed godwit	Migratory/Marine	✓	✓	✓	✓	✓	-	Moderate
	Numenius madagascariensis	Eastern curlew	**Critically endangered** Migratory/Marine	✓	✓	✓	✓	✓	✓	Confirmed
	Numenius minutus	Little curlew	Migratory/Marine	✓	✓	✓	✓	✓	✓	Confirmed
	Numenius phaeopus	Whimbrel	Migratory/Marine	✓	✓	✓	✓	✓	✓	Confirmed
	Tringa brevipes	Grey-tailed tattler	Migratory/Marine	✓	✓	-	✓	✓	✓	Confirmed
	Tringa incana	Wandering tattler	Migratory/Marine	✓	-	✓	-	-	✓	Moderate
	Tringa nebularia	Common greenshank	Migratory/Marine	✓	✓	✓	✓	✓	✓	Confirmed
	Tringa stagnatilis	Marsh sandpiper	Migratory/Marine	✓	✓	✓	✓	✓	✓	Confirmed
	Xenus cinereus	Terek sandpiper	Migratory/Marine	✓	✓	✓	✓	✓	✓	Confirmed
Pelagic species										
Accipitridae	*Pandion haliaetus*	Eastern osprey[2]	Migratory/Marine	✓	-	-	-	✓	✓	Moderate
Sulidae	*Sula leucogaster*	Brown booby	Migratory/Marine	-	✓	✓	✓	-	✓	Moderate
Diomedeidae	*Phoebetria fusca*	Sooty albatross	**Vulnerable** Migratory/Marine	✓	-	-	-	✓	-	Moderate
	Phoebetria palpebrate	Light-mantled sooty albatross	Migratory/Marine	✓	-	-	-	✓	✓	Moderate
	Thalassarche cauta cauta	Shy albatross	**Vulnerable** Migratory/Marine	✓	-	-	-	✓	-	Moderate
	Thalassarche impavida	Campbell albatross	**Vulnerable** Migratory/Marine	✓	-	-	-	✓	-	Moderate
	Thalassarche salvini	Salvin's albatross	**Vulnerable** Migratory/Marine	✓	-	-	-	✓	-	Moderate

Family	Scientific name	Common name	EPBC Act status	Bonn	CAMBA	JAMBA	ROKAMBA	EPBC Act protected matters search tool	Wildnet	Likelihood of occurrence within the Project impact areas
	Thalassarche cauta steadi	White-capped albatross	**Vulnerable** Migratory/Marine	✓	-	-	-	✓	-	Moderate
	Thalassarche eremita	Chatham albatross	**Endangered** Migratory/Marine	✓	-	-	-	✓	-	Moderate
	Thalassarche melanophris	Black-browed albatross	**Vulnerable** Migratory/Marine	✓	-	-	-	✓	-	Moderate
Laridae	*Sterna albifrons*	Little tern[1]	Migratory/Marine	✓	✓	✓	✓	✓	✓	Moderate
	Sterna dougallii	Roseate tern	Migratory/Marine	-	✓	✓	-	-	✓	Moderate
	Sterna hirundo	Common tern	Migratory/Marine	-	✓	✓	✓	-	✓	Moderate
	Anous stolidus	Common noddy	Migratory/Marine	-	✓	✓	-	✓	✓	Moderate
	Chlidonias leucopterus	White-winged black tern	Migratory/Marine	-	✓	✓	✓	-	✓	Moderate
	Gelochelidon nilotica	Gull-billed tern	Migratory/Marine	-	✓	-	-	-	✓	Moderate
	Hydroprogne caspia	Caspian tern	Migratory/Marine	-	-	✓	-	-	✓	Confirmed
	Onychoprion anaethetus	Bridled tern	Migratory/Marine	-	✓	✓	-	-	✓	Moderate
	Sterna sumatrana	Black-naped tern	Migratory/Marine	-	✓	✓	-	-	✓	Moderate
	Thalasseus bergii	Crested tern	Migratory/Marine	-	-	✓	-	-	✓	Confirmed
	Macronectes giganteus	Southern giant petrel	**Endangered** Migratory/Marine	✓	-	-	-	✓	✓	Moderate
	Pterodroma neglecta neglecta	Kermadec petrel (western)	**Vulnerable**	-	-	-	-	✓	-	Moderate
	Ardenna carneipes	Flesh-footed shearwater	Migratory/Marine	-	-	✓	✓	✓	-	Moderate
	Ardenna grisea	Sooty shearwater	Migratory/Marine	-	-	✓	-	-	-	Moderate
	Ardenna pacifica	Wedge-tailed shearwater	Migratory/Marine	-	-	✓	-	-	✓	Moderate
	Ardenna tenuirostris	Short-tailed shearwater	Migratory/Marine	-	✓	✓	✓	-	✓	Moderate
Hydrobatidae	*Fregetta grallaria grallaria*	White-bellied storm-petrel	**Vulnerable**	-	-	-	-	✓		Moderate
	Oceanites oceanicus	Wilson's storm-petrel	Migratory/Marine	-	-	✓	-	-	✓	Moderate

Family	Scientific name	Common name	EPBC Act status	Bonn	CAMBA	JAMBA	ROKAMBA	EPBC Act protected matters search tool	Wildnet	Likelihood of occurrence within the Project impact areas
Fregatidae	*Fregata ariel*	Lesser frigatebird	Migratory/Marine	-	✓	✓	✓	✓	✓	Moderate
	Fregata minor	Giant frigatebird	Migratory/Marine	-	✓	✓	-	✓	-	Moderate
Phaethontidae	*Phaethon rubricauda*	Red-tailed tropicbird	Migratory/Marine	-	✓	✓	-	-	-	Moderate
Stercorariidae	*Stercorarius maccormicki*	South polar skua	Migratory/Marine	-	-	✓	-	-	✓	Moderate
Procellariidae	*Pachyptila turtur subantarctica*	Fairy prion (southern)	**Vulnerable**	-	-	-	-	✓	-	Low
Aerial species										
Apodidae	*Apus pacificus*	Fork-tailed swift	Migratory/Marine	-	✓	✓	✓	✓	✓	Moderate
	Hirundapus caudacutus	White-throated needletail	Migratory/Marine	-	✓	✓	✓	✓	✓	Moderate
Terrestrial species										
Cuculidae	*Cuculus opatus*	Oriental cuckoo	Migratory/Marine	-	✓	✓	✓	✓	✓	Moderate
Monarchidae	*Monarcha melanopsis*	Black-faced monarch	Migratory/Marine	✓	-	-	-	✓	✓	Moderate
Monarchidae	*Monarcha trivirgatus*	Spectacled monarch	Migratory/Marine	✓	-	-	-	✓	✓	Low
Monarchidae	*Myiagra cyanoleuca*	Satin flycatcher	Migratory/Marine	✓	-	-	-	✓	✓	Moderate
Rhipiduridae	*Rhipidura rufifrons*	Rufous fantail	Migratory/Marine	✓	-	-	-	✓	✓	Moderate

Table notes:

- Not listed Bonn Bonn Convention

1 Little tern is listed as high on the Queensland Government's BoT species prioritisation framework (refer Appendix K).

2 The Eastern osprey (*Pandion haliaetus*) has been included as a pelagic species for the purposes of this assessment. As a coastal species, the Eastern osprey shares similar habitat requirements to pelagic seabirds and as such, has been grouped with seabirds for the purposes of this assessment.

3 It is noted that some species in the above table are not specifically listed as 'migratory' or 'marine' under the provisions of the EPBC Act, however have been retained in this assessment as they are known to have migratory movement patterns.

12.3.6 Project EIS field survey sites

The migratory bird field survey site locations for the Project EIS are shown in Figure 12.3a and Figure 12.3b, and the species list is provided in Appendix C.

12.3.7 Habitat within the Project impact areas

Based on the results of the Project EIS field surveys, the indicative areas of shorebird habitat within the Project impact areas, are shown in Figure 12.3a and Figure 12.3b.

A diverse range of habitat types occur within the Project impact areas providing foraging and roosting habitat for a range of migratory bird species. General habitat present within the Project impact areas for the five categories of migratory birds are outlined in Table 12.7. It is also noted that these areas are likely to provide habitat for non-migratory bird species (e.g. non-migratory shorebirds).

Table 12.7 Habitat for migratory birds within the Project impact areas

Migratory bird category	General description of habitat types within the Project impact areas	Habitat type present (direct impact area (potential indirect impact area))	
		Areas to be dredged and new navigational aids	Western Basin Expansion reclamation area
Shorebirds (migratory)	▪ Intertidal saltmarshes and mangrove communities ▪ Beaches and shorelines ▪ Coastal mudflats and claypans ▪ Artificial environments such as coastal ponds or drains	X (✓)	✓ (✓)
Pelagic species	▪ Open water foraging habitat	✓ (✓)	✓ (✓)
Aerial species	▪ Air space above all Project impact areas	✓ (✓)	✓ (✓)
Terrestrial species	▪ Mangrove forests and woodlands for foraging and breeding habitat ▪ Terrestrial vegetation communities for foraging and nesting and breeding habitat ▪ Marine areas for foraging	X (✓)	X (✓)
Water birds (other than shorebirds)	▪ Natural and artificial waterbodies such as watercourses, drainage lines and ponds for foraging and breeding habitat	X (X)	X (✓)

Table notes:

✓(✓) = habitat type present within the direct impact area and the potential indirect impact area
X (✓) = habitat type not present within the direct impact area, habitat type present within the potential indirect impact area
X (X) = habitat type not present within the direct impact area and the potential indirect impact area

Predictive habitat mapping was prepared for terrestrial migratory species which were considered to have a moderate likelihood of occurrence within the Project impact area (refer Appendix B). The assumptions utilised to map potential habitat are outlined in Table 12.8. The potential habitat maps for migratory bird species are shown in Figure 12.4 to Figure 12.9.

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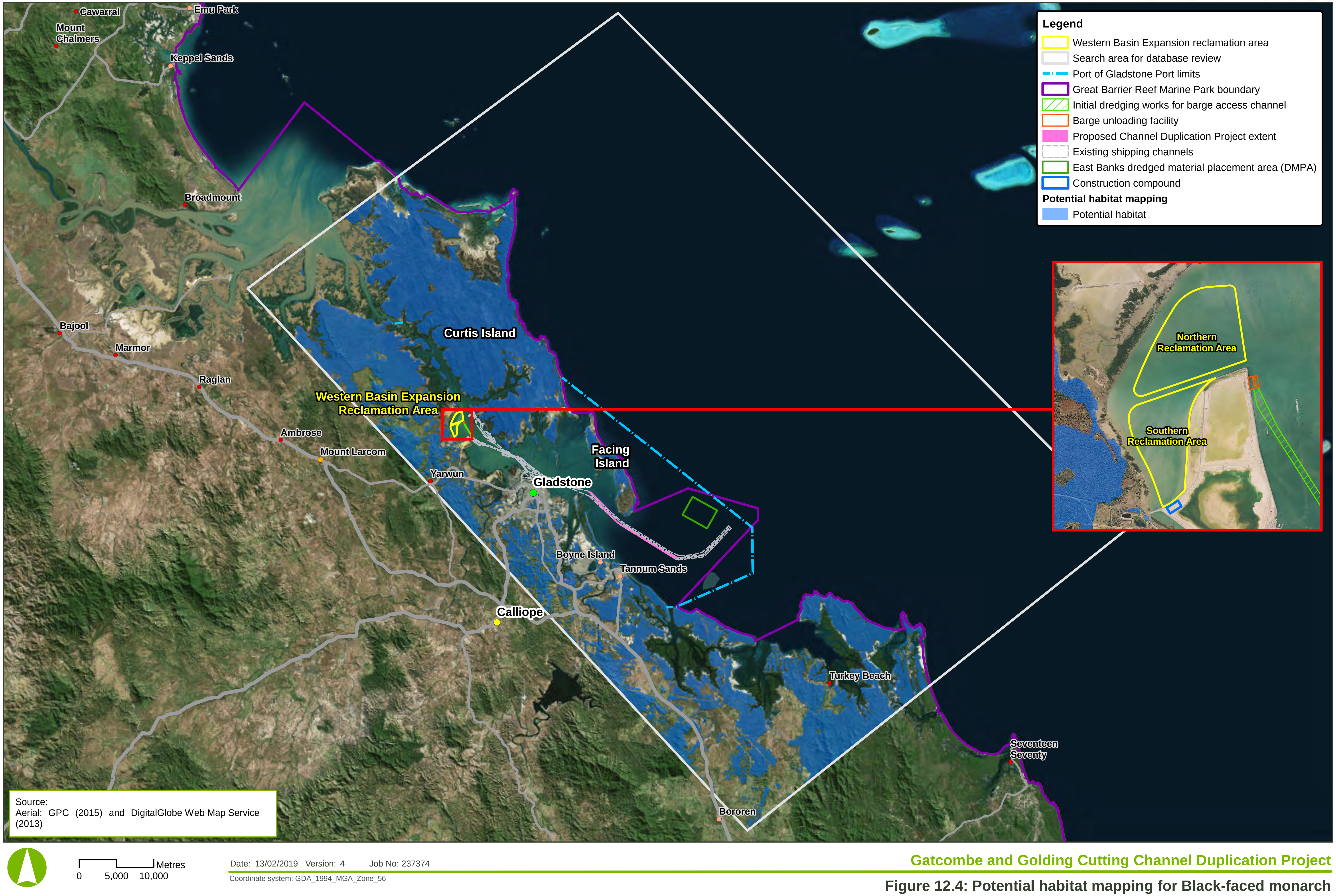

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Figure 12.4: Potential habitat mapping for Black-faced monarch

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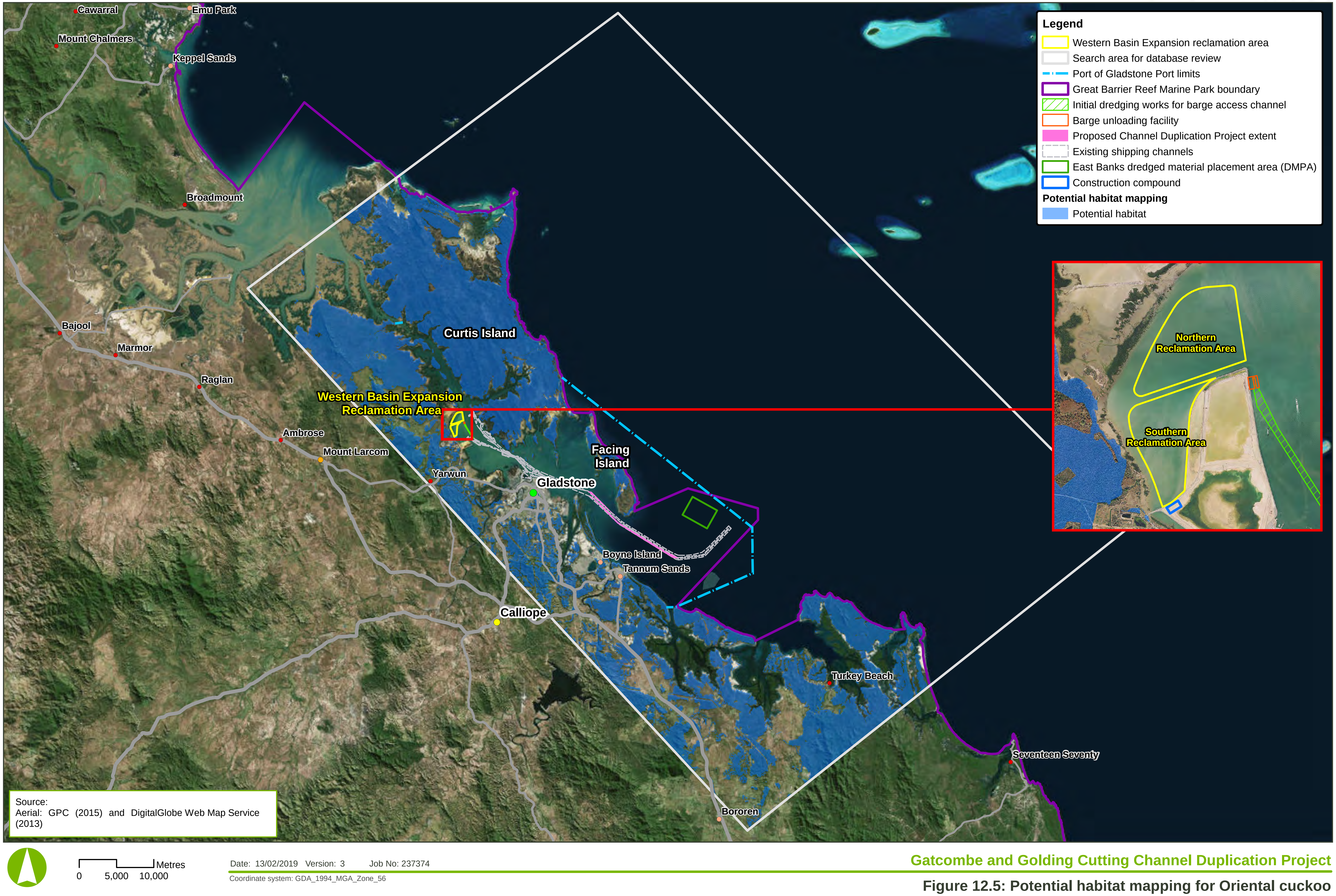

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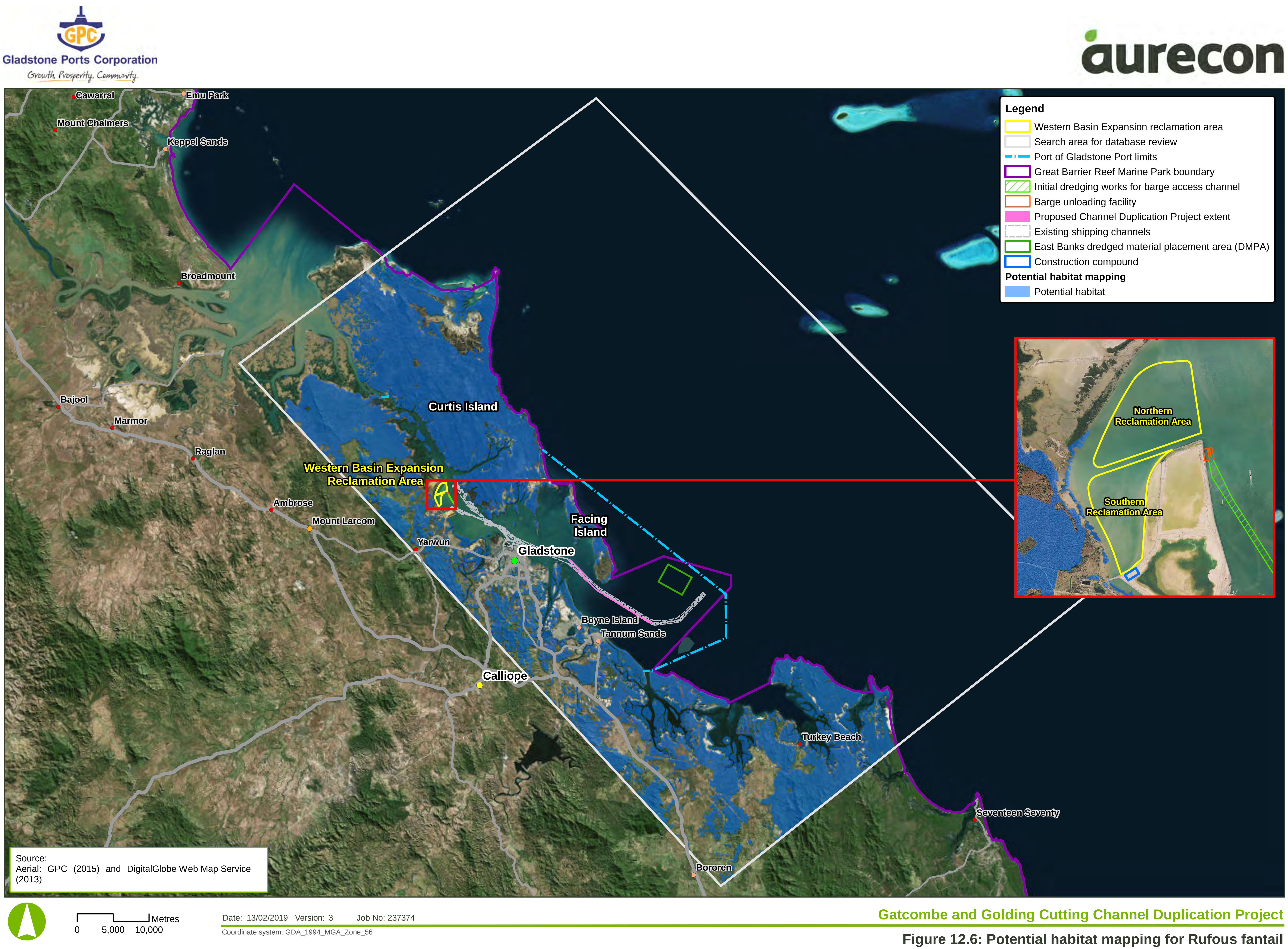
Date: 13/02/2019 Version: 3 Job No: 237374

Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 12.5: Potential habitat mapping for Oriental cuckoo



Date: 13/02/2019 Version: 3 Job No: 237374

Coordinate system: GDA_1994_MGA_Zone_56

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Figure 12.6: Potential habitat mapping for Rufous fantail

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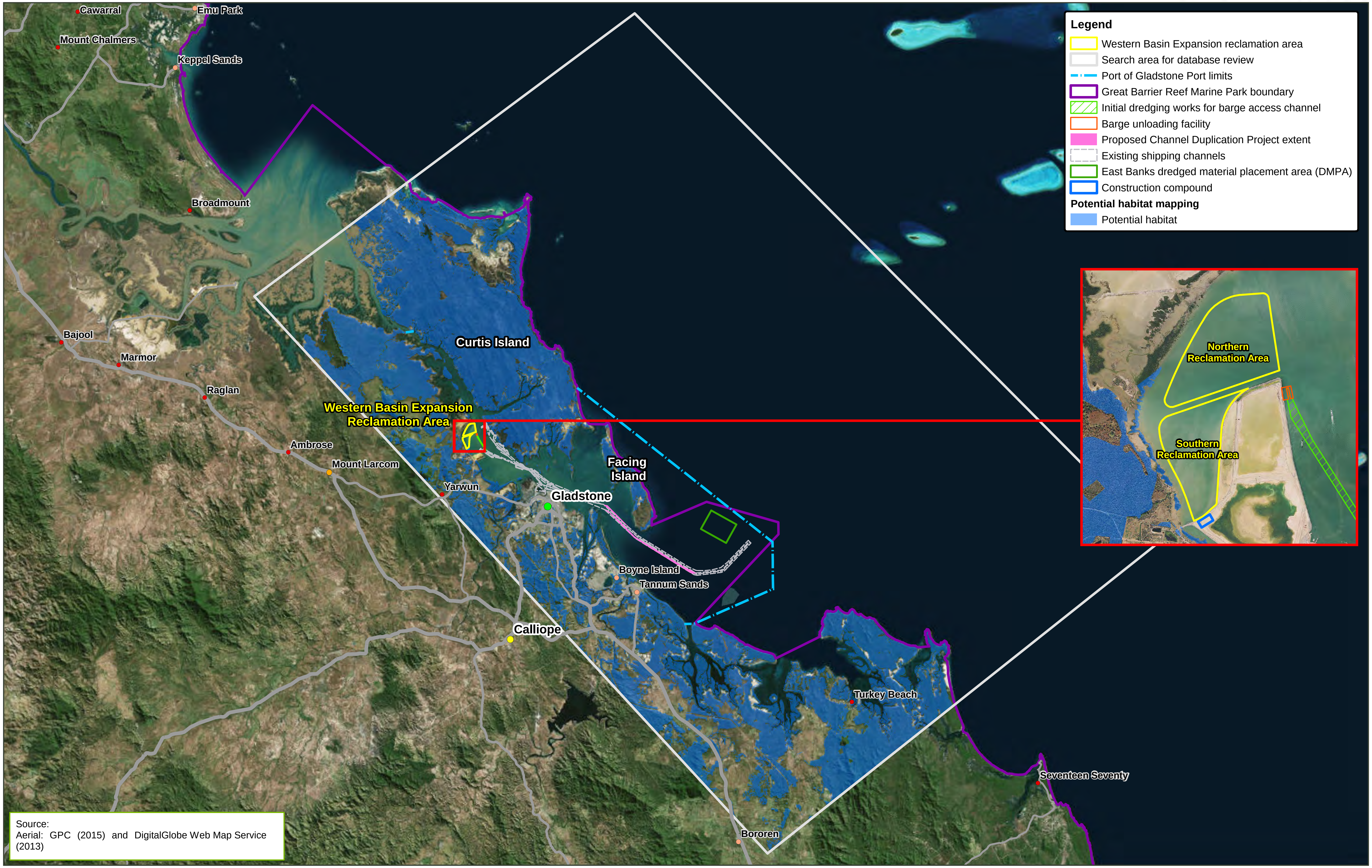

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0 5,000 10,000 Metres

Date: 13/02/2019 Version: 3 Job No: 237374

Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 12.7: Potential habitat mapping for Satin flycatcher

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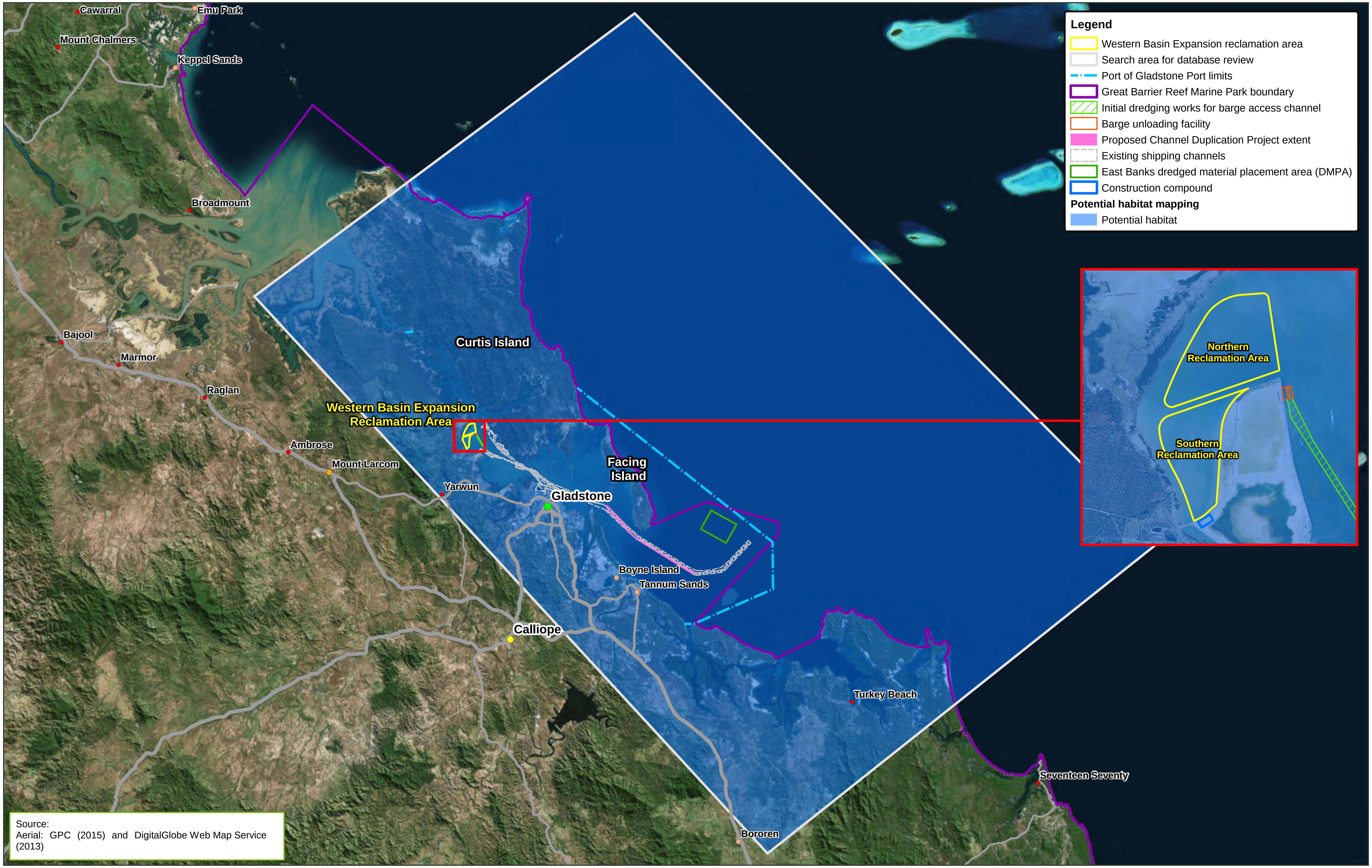
Growth, Prosperity, Community.

aurecon



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Date: 13/02/2019 Version: 3 Job No: 237374
Coordinate system: GDA_1994_MGA_Zone_56

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Figure 12.8: Potential habitat mapping for Fork-tailed swift

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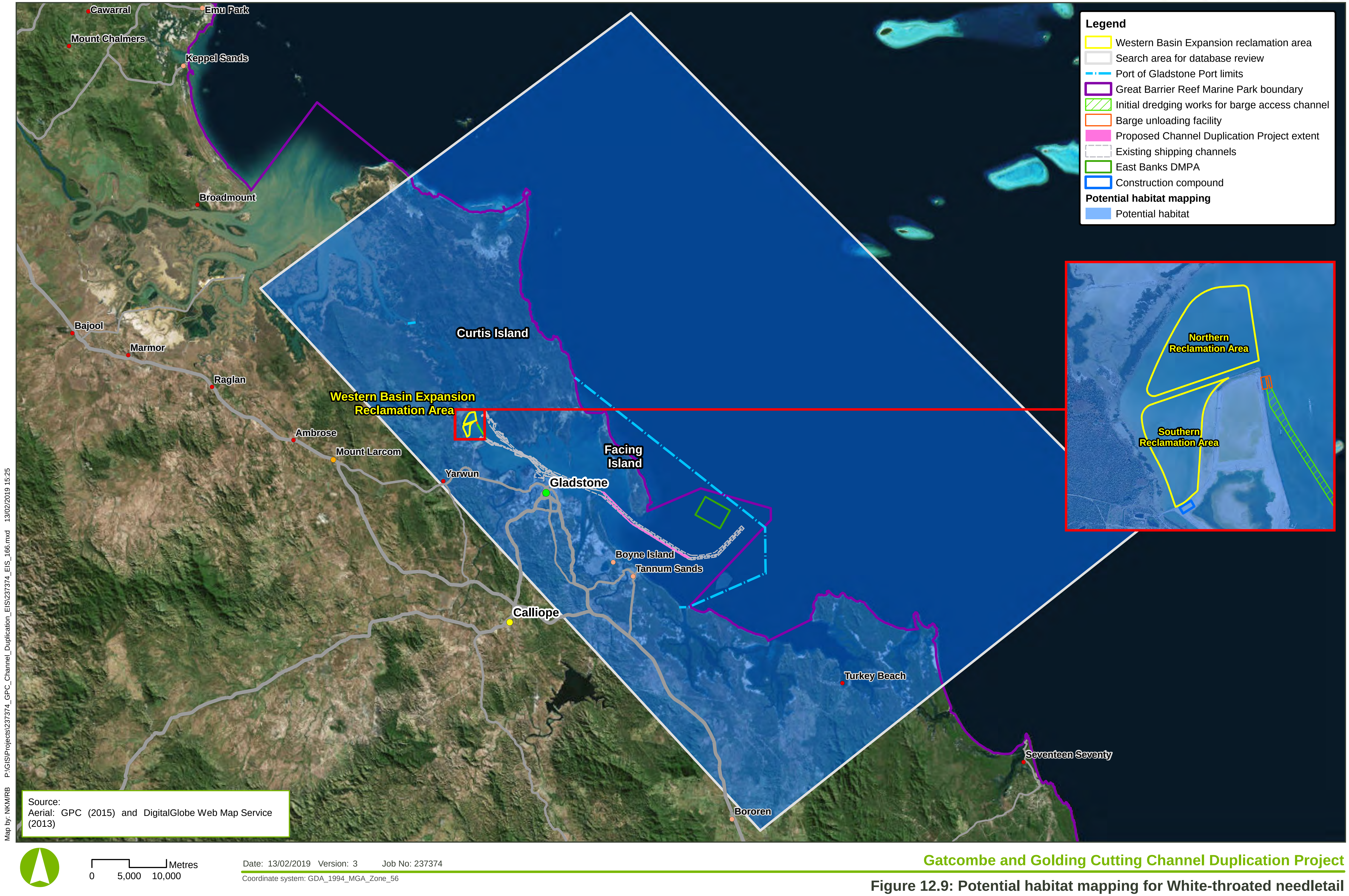

Date: 13/02/2019 Version: 3 Job No: 237374

Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 12.9: Potential habitat mapping for White-throated needletail

Table 12.8 Migratory terrestrial birds for which potential habitat areas were modelled using available GIS layers

Species name	Likelihood of occurrence within Project impact areas	General assumptions for mapping potential habitat	Results of potential habitat mapping
Black-faced monarch (*Monarcha melanopsis*)	Moderate	Areas of remnant vegetation that contain rainforest, vine thicket, Eucalypt forests and Eucalypt woodland communities	The WBE reclamation area is located approximately 230m east of the mapped potential habitat for this species
Oriental cuckoo (*Cuculus optatus*)	Moderate	Areas of remnant vegetation that contain rainforest, vine thicket, Eucalypt forest, Eucalypt woodland, Brigalow, Acacia woodland and Casuarina woodland communities	The WBE reclamation area is located approximately 230m east of the mapped potential habitat for this species
Rufous fantail (*Rhipidura rufifrons*)	Moderate	Areas of remnant vegetation that contain mangrove, rainforest, vine thicket, Eucalypt forest, Eucalypt woodland, Brigalow, Melaleuca forests and Melaleuca woodland communities	The WBE reclamation area is located approximately 115m east of the mapped potential habitat for this species
Satin flycatcher (*Myiagra cyanoleuca*)	Moderate	Areas of remnant vegetation that contain Eucalypt forests, Eucalypt woodland, mangroves, Melaleuca forests and Melaleuca woodland communities	The WBE reclamation area is located approximately 105m east of the mapped potential habitat for this species

As shown in Figure 12.8 and Figure 12.9, air spaces above all of the Project impact areas are considered to provide habitat for the aerial migratory species (i.e. Fork-tailed swift [*Apus pacificus*] and White-throated needletail [*Hirundapus caudacutus*]). As such, they are not specifically discussed within each of the Project impact area sections below.

12.3.7.1 Areas to be dredged for the channel duplication and new navigational aids

This section utilises the outcomes of the desktop assessment and Project EIS field surveys to provide further detail regarding the Project impact areas (as defined in Section 1.2.6) and their value for migratory bird species.

Direct impact areas

The areas to be dredged and the new navigational aids are within open marine waters between Boyne Island and Facing Island. This provides potential foraging habitat for pelagic and aerial species, and potential foraging habitat for the White-bellied sea eagle ([*Haliaeetus leucogaster*], listed as Marine under the provisions of the EPBC Act) and Eastern osprey.

Potential indirect impact areas

Open marine waters which are likely to provide habitat for migratory bird species, as is described for the direct impact areas, are also relevant for the potential indirect impact areas.

Additionally, there are extensive areas of shorebird habitat located on the coastal areas of Facing Island (refer Figure 12.3a). A roosting site on the Port Curtis side of Facing Island (Facing Island Inlet site) has been reported to contain more than 0.1% of the flyway population of Terek sandpipers, and is a locally important roosting site. This site is situated approximately 2.6km north of the area to be dredged and the closest new navigational aid, and is mapped as an estuarine wetland dominated by mangroves. Other shorebird habitat present along the Facing Island coast includes coastal claypans, sandbars, rocky outcrops, and sandy/rocky beaches (Sandpiper 2012).

Habitat along Boyne Island was assessed during Project EIS field surveys and confirmed to contain habitat for a range of shorebirds and migratory bird species. The habitat along the coastline, in proximity to EIS field survey Sites 3 through to 6 on Figure 12.3c, was characterised by sandy or rocky beaches with vegetated coastal dunes. Terrestrial vegetation present behind the dunes was also recorded as potential breeding habitat for terrestrial migratory species as it contained mature, woody vegetation suitable for nesting. Boyne Island beach has also been recorded as a locally important roost site for the Lesser sand plover (IMEMS 2013). During EIS field surveys, an Eastern osprey was recorded taking flight from this terrestrial vegetation behind the coastline on Boyne Island. Anecdotal records have noted the Eastern osprey nesting on pylons within the Port of Gladstone.

During EIS field surveys it was noted that this beach was accessed by vehicles and was a popular walking beach (including people with off-leash dogs). These activities are considered to reduce the overall quality of habitat for some species.

A locally important roost site for the Ruddy turnstone is known approximately 4km southwest of the area to be dredged and 7.1km to the closest new navigational aid, at Tiber Point at the entrance to the Colosseum Inlet (refer Figure 12.3a). A diverse range of habitat is present within the Colosseum Inlet/Mundoolin Rocks area, including claypans, lagoons, estuarine wetlands, coastal saltmarsh, sandy beaches and mangrove communities (IMEMS 2013). This area is likely to be important for migratory shorebirds and terrestrial bird species.

12.3.7.2 Western Basin Expansion reclamation area, barge access channel and barge unloading facility

Direct impact areas

The direct impact areas are situated largely in intertidal areas that become exposed mudflats during low tide. This area is therefore suitable foraging habitat for a range of migratory shorebirds. During EIS field surveys in and adjacent to the WBE reclamation area the Eastern curlew, Sharp-tailed sandpiper, Little curlew, Whimbrel and Caspian tern were recorded utilising habitat in this area. Habitat for shorebirds within this area is mapped in Figure 12.3b. It is also noted that in the 2015 annual shorebird monitoring survey, three Eastern curlews were observed utilising areas analogous to claypans within the existing Western Basin reclamation area. In the 2016 annual shorebird monitoring survey, 327 Red-necked stints were recorded foraging on the WB reclamation area (Wildlife Unlimited 2016). In the 2017 annual shorebird monitoring survey, a total of three Curlew sandpipers and one Whimbrel were recorded on the WB reclamation area (Wildlife Unlimited 2017). In the 2018 annual shorebird monitoring survey, 707 Red-necked stints, four Whimbrels and three Eastern curlews were recorded on the WB reclamation area (Wildlife Unlimited 2018).

These marine areas represent suitable foraging habitat for the Eastern osprey and White-bellied sea eagle (i.e. the barge access channel and the BUF).

Potential indirect impact areas

Areas directly adjacent to the WB and WBE reclamation areas contain suitable foraging habitat for shorebirds, as described for the direct impact areas. There are known foraging and roosting habitats for shorebirds within 400m of the direct impact area, associated with the shoreline and claypans on Kangaroo Island. These habitats have been identified in the 2015 annual migratory shorebird monitoring report as roosts which may constitute 'critical migratory shorebird habitat in the upper harbour' (Wildlife Unlimited 2015). The Friend Point roost site is also a locally significant roost site for the Eastern curlew, with another locally important roost site for this species located approximately 2.75km from the direct impact area on Six Mile Island in The Narrows (refer Figure 12.3a).

The mangrove communities on Kangaroo Island represent potential foraging and breeding habitat for terrestrial migratory birds.