Cairns Shipping Development Project

Ports North

APPENDIX D.13

Draft : Environmental Impact Statement

Appendix D.13

Marine Ecology Supporting Information

Appendix D13 Marine Ecology Supporting Information.

D13.1 Detailed Methodology for Baseline Surveys

Acoustic Habitat Mapping

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

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

The QTC suite of programs was used to process acoustic data (Lockerand Wright 2003; Riegland Purkis 2005; Preston et al. 2006). During data acquisition, QTC Real-Time was used show preliminary classifications which allowed sampling effort to be adjusted based on the heterogeneity of the seafloor. Raw data files were also post-processed using the QTC IMPACT software package and all data were checked for correct time stamps, correct depths and correct signal strengths. Acoustic records from the potential and existing DMRAs and the area between these locations were combined for the backscatter analysis using the QTC Impact seabed classification software. This allowed comparison of sediments (and eventually habitat classes) between these areas.

In the QTC IMPACT software (version R3.40) the acoustic echoes were digitised and normalised to a range between 0 and one, before being subjected to further analysis. These data were then reduced by generating Full Feature Vectors, referred to hereafter as acoustic records. Acoustic records were displayed on a bathymetry plot where the recorded depth was checked against the blanking (minimum recordable) depth and the maximum depths expected for the study area, based upon existing bathymetric information.

QTC IMPACT was used to classify acoustic signals (echograms) that returned from the seabed into statistically different acoustic classes. All acoustic records were subjected to Principal Components Analysis (PCA) to eliminate redundancies and noise. The first three principal components of each echo (called Q values) were retained, according to the theory that these typically describe 95 percent of the information within each echo. Data points were then projected into three dimensional space along these three components (Figure A), where they were then subjected to cluster analysis to determine echoes of similar signature. QTC Impact’s Auto Clustering Engine was used to determine the most probable number of habitat classes out of a maximum of 30 classes. This maximum number of potential classes was selected (conservatively) based on similar work in Cleveland Bay where up to eight classes have been observed.

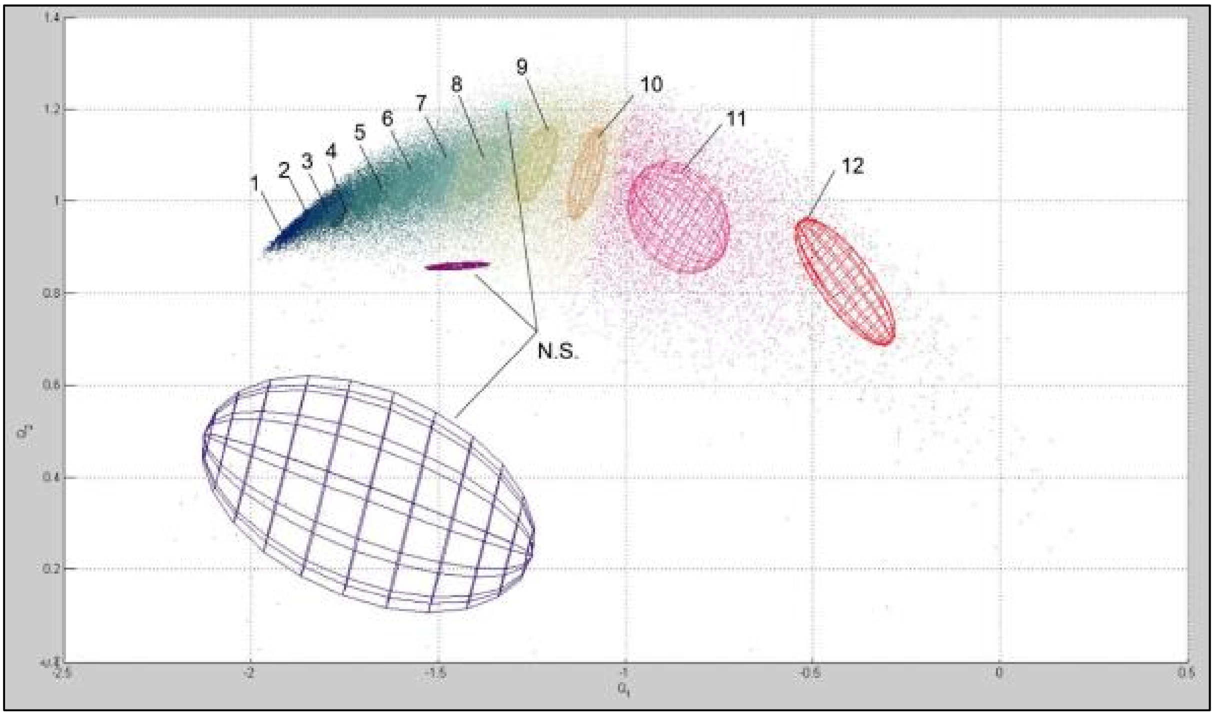

Figure D13.1.1a PCA Ordination of Acoustic Returns Showing 12 Legitimate Classes and Three Classes Consisting of Sampling Anomalies or Non-significant Classifications

For each individual signal, the following data were exported from QTC IMPACT: latitude and longitude; depth (uncorrected for tidal or wave states); three PCA axes (called Q axes); a class category; a class assignment confidence value and a class probability value, which both range from 0 to 100 percent. These indices may be useful for further determining the overall ‘quality’ of individual data points and classes. Records with confidence less than 95 percent were removed from the analysis.

Three classes consisted of either entirely non-significant classifications (classifications with less than 95 percent confidence) or were sampling anomalies (Figure A). Sampling anomalies corresponded to the sounding over propeller wash; where the vessel needed to reverse, or crossed the wake of another vessel. These events were recorded during data capture and corresponded to the time-stamp of anomalous classifications. For the purposes of data presentation and interpolation, each dataset has been reduced to a three column matrix consisting of a single x, y and geo-referenced seabed class category. The locations of 54,010 “cleaned” acoustic records used in this study are shown in **Figure D13.1.1b.**

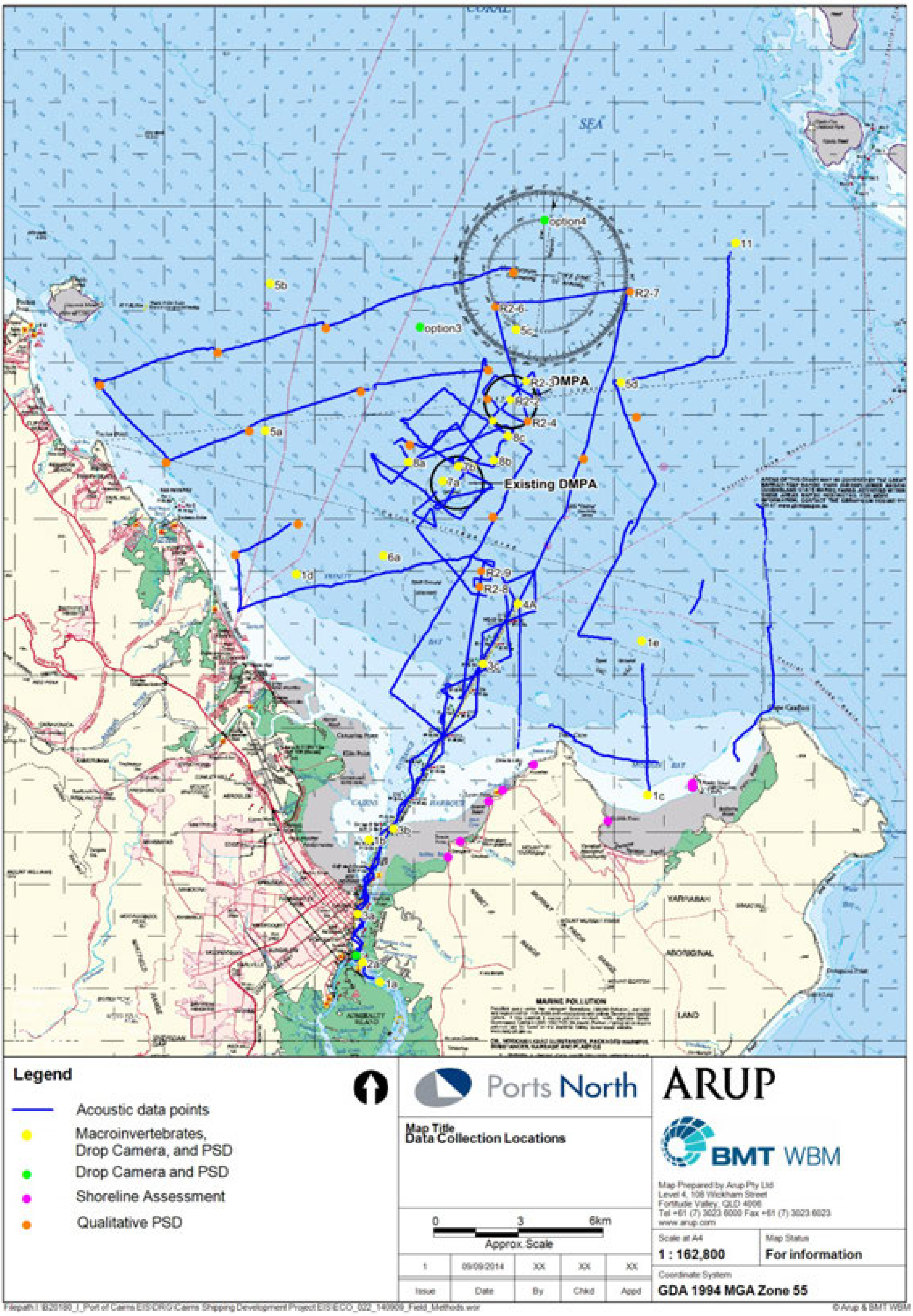

Figure D13.1.1b Data Collection Locations

A natural neighbour interpolation with mean values was used to create benthic habitat maps using Vertical Mapper v3.1 through the MapInfo 10.5 platform.

Natural-neighbour interpolations use a Voronoi tessellation, which is a grid-mesh drawn between existing "real" data points used to fill in data between "missing" data points (Figure C). In the example shown below, the central black data point (cell) is interpolated by calculating the relative input from surrounding points. The relative contributions of neighbouring points are shown as green circles, and relate to how much of their respective areas fall within the search radius. The search radius is shown as a blue polygon surrounding the cell (**Figure D13.1.1c**).

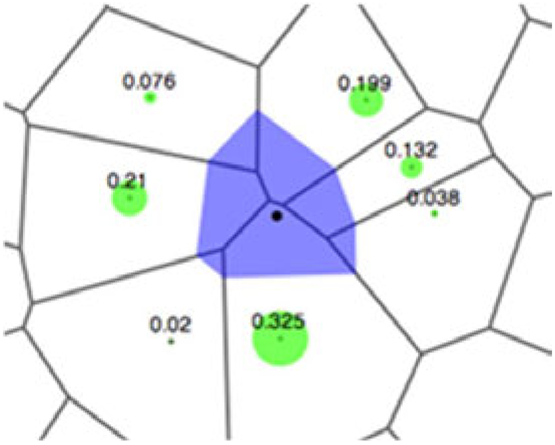

Figure D13.1.1c Example Natural Neighbour Interpolation; the Voronoi Tessellation is shown as a Black Grid, Relative Weighting is shown in Green, the Cell Size (Pixel Width) is shown as a Central Black Dot, and the Radial Aggregation Distance is shown in Blue.

Mean values were interpolated because acoustic classes agreed well with reference sediment types from the broad-scale mapping, and classes showed serial ordination (**Figure D13.1.1a**). For example, class two and four habitats were separated by class three habitats existing between them.

<u>Ground Truthing</u>

Ground truthing was carried out in a selection of acoustic habitat classes; one and classes five-12. Colours and proximity in two dimensional space depict the relatively differences of acoustic records shown in Figure A. That is, points that are close together, and coloured similarly are more similar than points which are farther apart and coloured more disparately. Ground truthing conducted at acoustic class one is considered highly representative of classes two-four, given their proximity and colouration in q-space.

At each validation point, a 0.028 m^2 van Veen grab was used to collect material for particle size distributional (PSD) analysis, or for qualitative examination. The PSD samples were analysed by Golder Associates using sieve and hydrometer testing with Australian Standard AS1726 size fractions. Qualitative grab samples were photographed, examined, and particle size fractions were estimated. Locations of these qualitative and quantitative validation points are shown in **Figure D13.1.1b**.

<u>Soft Sediment Epifauna</u>

At locations shown in **Figure D13.1.1b**, a combination of infra-red standard definition (low light) and wide angle high definition drop cameras were used to assess soft sediment epifauna communities.

This was done during calm conditions (winds below 8knts) between 20 and 23 July 2013. Despite excellent meteorological conditions (no rain and prolonged light winds) many of the inshore sites experienced zero visibility conditions due to mobilised surface silts. Effective video validation was not possible at sites 1a, 1b, 1c, 1d, 2a, 3a, 3b, 3c, 4a, and 5a. Benthic validation information for these areas was gathered instead from McKenna et al. (2013). Four-minute video recordings behind a passively drifting vessel were made at each site. Burrows (from video only) and taxa were enumerated for each useable four minute transect.

Benthic Infauna Communities

A total of 21 sites were sampled at representative areas within the potential DMPAs, dredged channel areas and from additional ‘control’ areas outside the disturbance footprint but within the study area. Replicate 0.028 m^2 van Veen grab samples were collected at each site, sieved through a 0.5 mm screen and preserved in a 10 percent buffered formalin solution. Samples were sent to Stephen Cook (Dardanus Scientific) for identification and enumeration of each taxa. Summary statistics for abundance and taxa richness were derived, and multivariate statistical analyses (n-MDS ordinations ANOSIM, and SIMPER) were used to explore spatial patterns in community structure using Primer 6.16. The locations of macroinvertebrate samples are shown in **Figure D13.1.1b**.

Shoreline Assessment

Intertidal communities were surveyed during spring low-tide periods on 23 and 24 July 2013 to assess the major community constituents of rocky shores at East Trinity, False Cape, and Rocky Island (**Figure D13.1.1b**). Rocky Island was accessed using a small kayak deployed from the back of *MV Viking*, while all other sites were accessed from public roads. Communities at Rocky Island were surveyed along 250 m of reef edge along the western reef platform, as this area appeared to have the highest coral cover during the survey, and based on Google Earth imagery. Rocky shores at other locations at East Trinity and False Cape were assessed over 50-200 m depending on the availability of habitat.

Coral Surveys

Surveys were performed at Double Island and Rocky Island on 13 and 14 December 2013, respectively. Locations of the coral survey transects are shown in **Figures D13.1.1d** and **D13.1.1e** respectively. Figures Surveys were conducted after three consecutive calm days, where wind speeds did not exceed 10kts, creating excellent inshore visibility conditions varying between two and four m.

At Double Island, dive surveys were completed at five sites around the reef, starting at southern end (DI1), going counter clockwise around to finish along SW shore (DI5). CJ did first three locations, DTM did last two. At each site, 30 m dive transects were performed at -5 and -3 LAT, (or as close as possible to these profiles). The northern site (DI3) was only approximately -4 LAT at the deepest part of the reef slope. At the NW site (DI4), the reef slope was shallower again, and the deeper transect was performed at approximately -3 m LAT, with a shallower transect performed at -2 m LAT. The deeper transect was always performed first, and transects were always performed along depth contour.

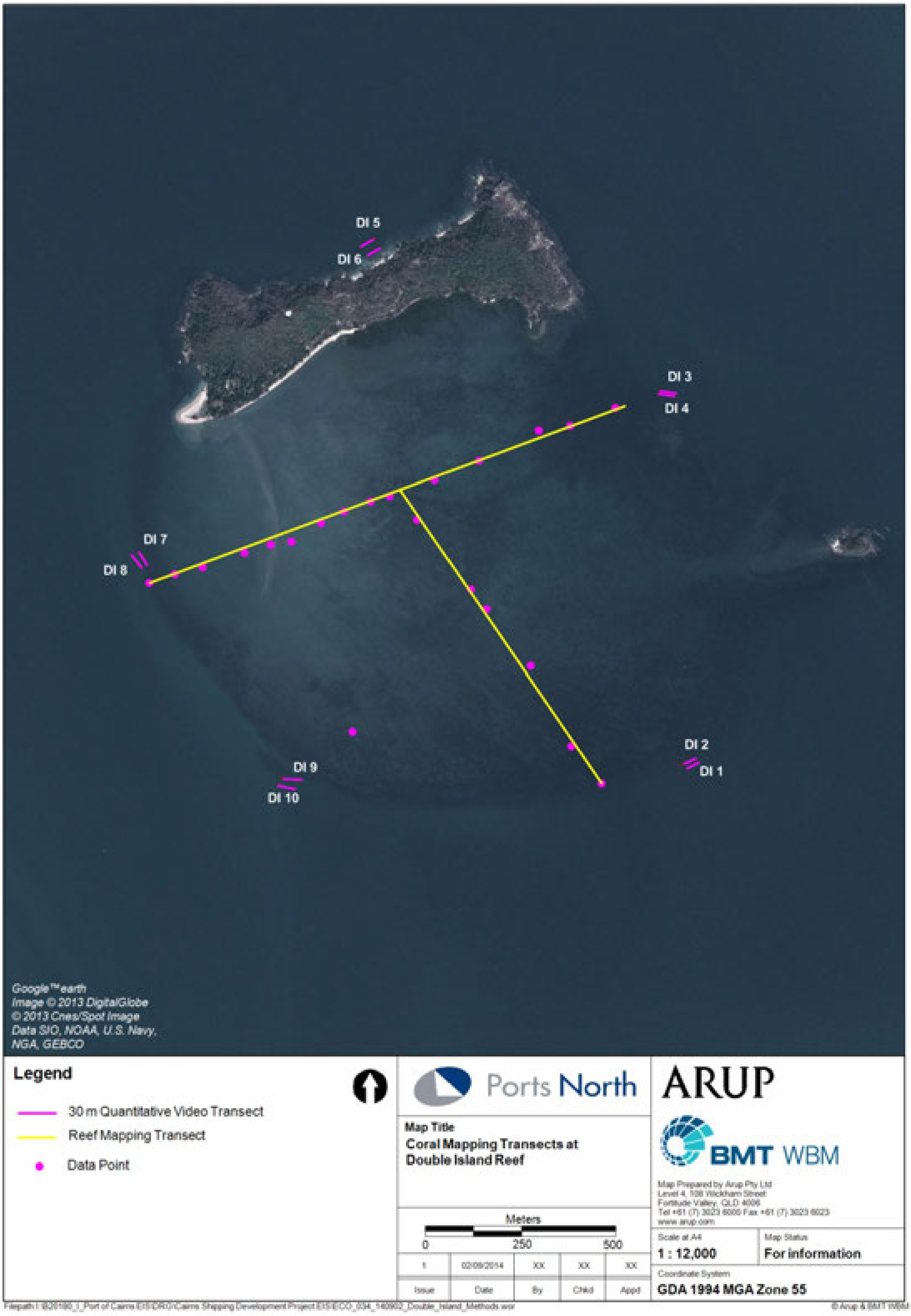

Figure D13.1.1d Coral Mapping Transect at Double Island Reef

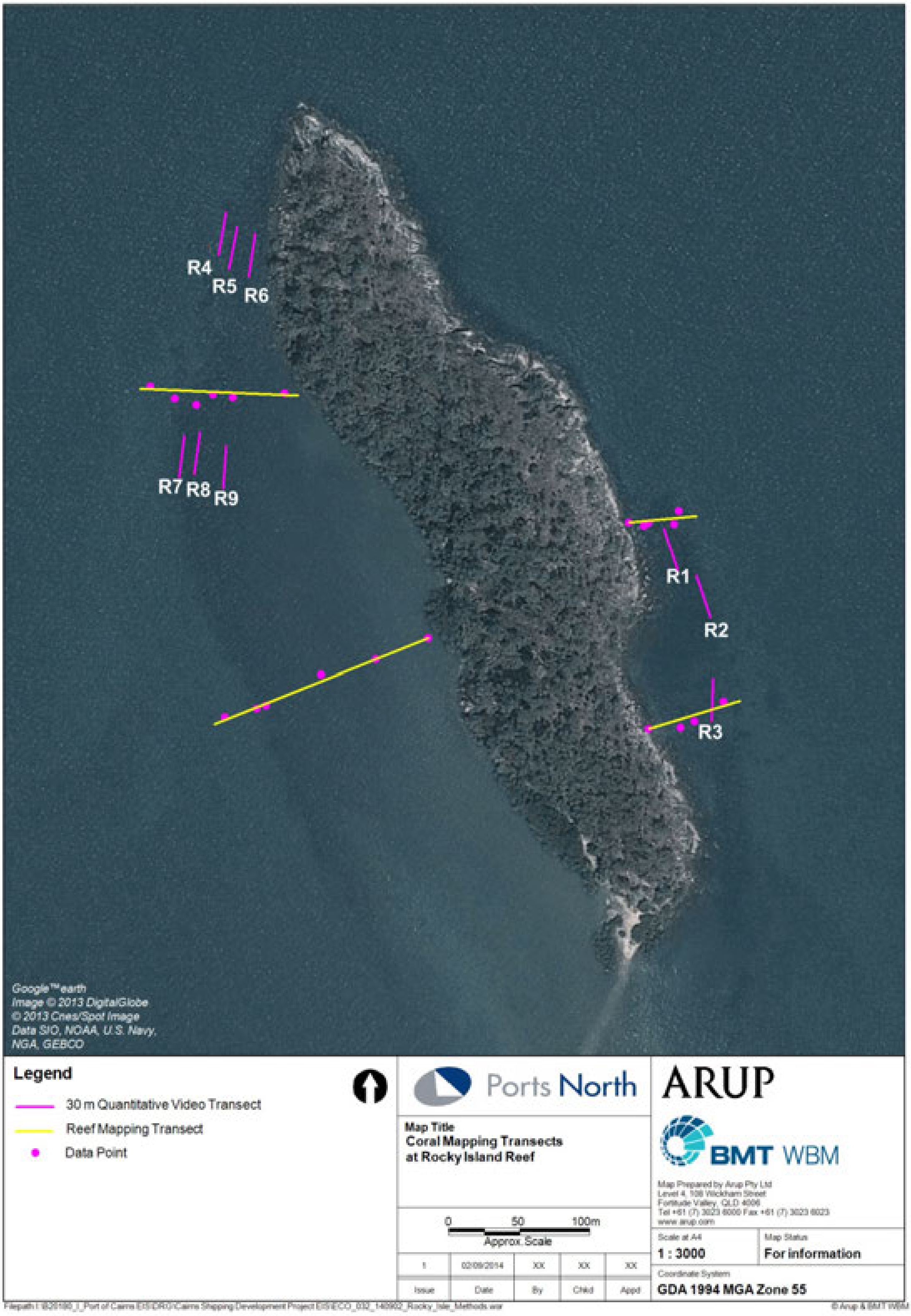

Figure D13.1.1e Coral Mapping Transect at Rocky Island Reef

Appendix D13.2 Seagrass Habitat of Cairns Harbour and Trinity Inlet: Annual and Quarterly Monitoring Report 2013

SEAGRASS HABITAT OF CAIRNS HARBOUR AND TRINITY INLET:

Annual and Quarterly Monitoring Report 2013

Jarvis, JC, Rasheed MA, McKenna SA & Sankey, T.

Report No. 14/09

April 2014

SEAGRASS HABITAT OF CAIRNS HARBOUR AND TRINITY INLET:

Annual and Quarterly Monitoring Report 2013

A Report for Far North Queensland Ports Corporation Limited (Ports North)

Report No. 14/09

April 2014

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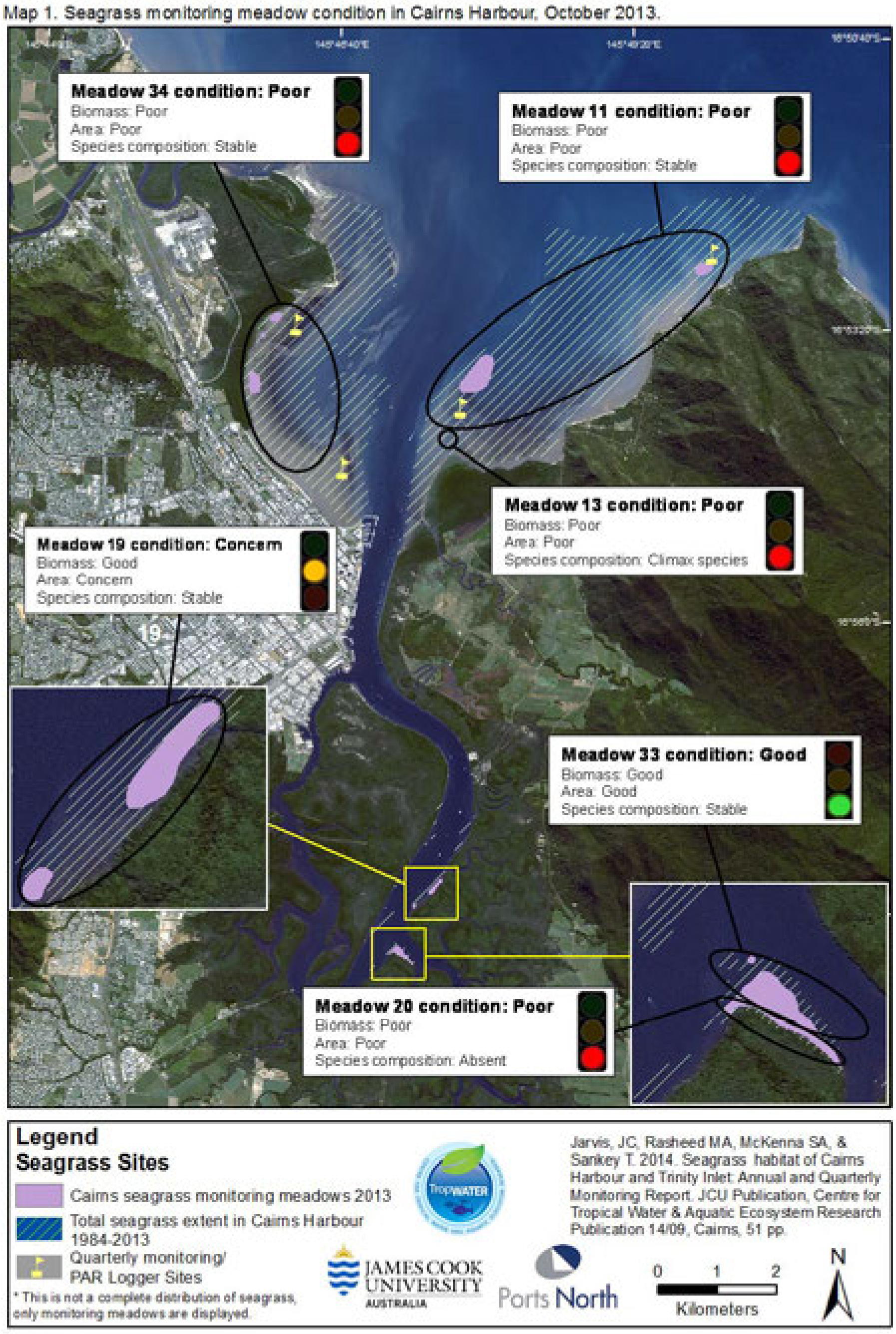
KEY FINDINGS

1. Seagrasses in Cairns Harbour and Trinity inlet were in a poor condition in 2013 with remnant meadows highly vulnerable to further impacts.
2. Positive signs were increases in biomass and area in most meadows from 2012; however they remained significantly below the long term average.
3. A seed bank remained for most areas that could facilitate further recovery, however density was low compared to similar meadows in northern Queensland and seed bank densities were declining over time for most sites. A reduced seed bank may limit the capacity for natural recovery of the system.
4. Light and climate conditions appeared to be favourable for seagrass growth at most sites in 2013 and the low levels of recovery observed are likely a reflection of previous catastrophic declines limiting the availability of propagules from which recovery could be initiated and sustained.
5. The deployment of light (PAR) and temperature loggers in Cairns in 2013 enhanced the monitoring program and improved interpretation of meadow-scale change and the ability of the program to assess future seagrass declines and recovery. Continued light monitoring will also allow the development local light requirements for Cairns seagrass as they continue to recover.

IN BRIEF

Seagrasses have been monitored annually in Cairns Harbour and Trinity Inlet since 2001. Each year all seagrass monitoring meadows representing the range of different seagrass community types found in Cairns are mapped and assessed for changes in biomass and species composition. These metrics are then used to develop a seagrass condition index (see sections 2.4 & 3.2 of this report for further details). Baseline surveys mapping all seagrasses within the port limits were conducted in 2001 and 2012. In addition to the established monitoring program, quarterly assessments of seagrass condition, seed bank density and light were conducted at four key locations in Cairns Harbour during 2013.

Map 1. Seagrass monitoring meadow condition in Cairns Harbour, October 2013.



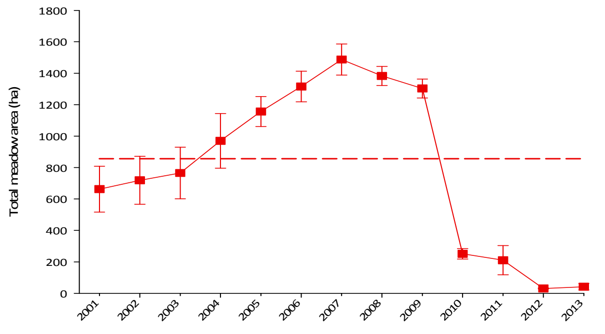


Figure 1. Total area of seagrass within all Cairns monitoring meadows from 2001 to 2013 (error bars = "R" reliability estimate). Red dashed line indicates 13-year mean of total meadow area.

Seagrasses in Cairns Harbour were in a poor condition in 2013, with biomass and area significantly below the long term average (Map 1). The total area of all seagrass monitoring meadows within Cairns Harbour has also dramatically declined since peaking in 2007 (Figure 1). The only meadow classified as "good" was the small *Halophila ovalis* meadow in the Redbank area of Trinity inlet.

Large scale declines across Cairns Harbour began in 2009 and continued through 2012. Declines were associated with multiple years of above average rainfall and severe storm and cyclone activity that have left seagrasses with a greatly reduced capacity for recovery and the potential for complete loss of meadows. Meadow area and biomass increased slightly in 2013, however meadows remain well below the 13 year average.

Monitoring of light available to seagrasses in Cairns during 2013 indicates that light availability was likely to be favourable for seagrass growth in at least three of the four monitoring locations. However a true local light requirement for seagrasses in Cairns was unable to be determined during 2013 due to the lack of seagrass recovery at monitoring sites. It is likely that seagrass meadows expanding during recovery following large scale declines may require more light than similar seagrass communities in established meadows. If further seagrasses recovery occurs then local light requirements will be able to be assessed at the established light monitoring sites.

The next 12 months will be critical for Cairns seagrasses. If the recovering patches of seagrass remain through the senescent season and some seeds remain viable then continued recovery in 2014 could occur. However these remnant seagrass patches are small and highly vulnerable and seed bank density and viability has been decreasing in the absence of replenishment.

The Cairns Harbour Trinity Inlet seagrass monitoring program forms part of a broader program that examines condition of seagrasses in the majority of Queensland commercial ports and a component of JCU's broader seagrass assessment and research program. Seagrasses on Western Cape York, Torres Strait and the Gulf of Carpentaria were generally in a good condition which is in stark contrast to seagrasses on the east coast of Queensland that were severely impacted by unfavourable climate events and cyclones and remained in a vulnerable condition in 2013/14 such as Mourilyan Harbour, Abbot Point and Townsville. For full details of the Queensland ports seagrass monitoring program see www.jcu.edu.au/portseagrassqld.

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1 INTRODUCTION

Seagrasses provide a range of critically important and economically valuable ecosystem services including coastal protection, support of fisheries production, nutrient cycling and particle trapping (Hemminga and Duarte 2000; Costanza et al. 1997). Seagrass meadows show measurable responses to changes in water quality, making them ideal candidates for monitoring the long-term health of marine environments (Orth et al. 2006;Dennison et al. 1993).

1.1 Queensland Ports Seagrass Monitoring Program

A long-term seagrass monitoring and assessment program has been established in the majority of Queensland commercial ports and catchments. The program was developed by the Seagrass Ecology Group at James Cook University's Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) (Formally part of Fisheries Queensland/DAFF) in partnership with the various Queensland port authorities. While each location is funded separately and they have a range of requirements for use of the information, a common methodology and rationale is utilised to provide a network of seagrass monitoring locations throughout the state (Map 2).

Map 2 Location of Queensland Port Seagrass assessment sites (red – long term monitoring; blue - baseline mapping only)

A strategic long term assessment and monitoring program for seagrasses in port locations and surrounding catchments provides managers and regulators with the key information to demonstrate that seagrasses and ports can co-exist as well as information to plan and implement port development and maintenance programs that will have a minimal impact on seagrasses. In addition, as an excellent integrator of impacts to water quality, seagrasses provide an ideal indicator of overall marine environmental health of the port (Dennison et al. 1993). The program also provides an ongoing assessment of many of the most threatened seagrass communities in the state.

The program not only delivers key information for the management of port (e.g. dredging) and catchment (e.g. urban and agricultural runoff) activities to minimise impacts on seagrasses but has also resulted in significant advances in the science and knowledge of tropical seagrass ecology. It has been instrumental in developing tools, indicators and thresholds for the protection and management of seagrasses and an understanding of the drivers of tropical seagrass change. It provides a measure of the marine environmental health of the ports as well as feeding into regional assessments of the status of seagrasses.

For more information on the program and reports from the other monitoring locations see www.jcu.edu.au/portseagrassqld

1.2 Cairns Harbour and Trinity Inlet Seagrasses

The first surveys of seagrass distribution, species diversity and abundance in Cairns Harbour were undertaken as part of a broad scale state wide seagrass survey in 1984 (Coles et al. 1985). In 1988 and 1993, Cairns Harbour and Trinity Inlet seagrasses were re-surveyed (Coles et al. 1993; Lee Long et al. 1996) and subsequent detailed mapping of Ellie Point seagrasses occurred in December 1996 (Rasheed and Roelofs 1996). The Trinity Inlet Management Program then commissioned the Queensland Department of Primary Industries to conduct a baseline survey of seagrass in the region in 2001 (Campbell et al. 2002). In 2012 Ports North commissioned the JCU/TropWATER Seagrass Group to conduct a baseline survey of the seagrass in the greater port limits of the Port of Cairns as part of the Cairns Shipping Development Project (CSDP) EIS (Rasheed et al. 2013). Over 800 hectares of seagrass habitat was mapped in each of these surveys and these meadows represent the only major coastal seagrass resource between Hinchinbrook Island and Cooktown (Lee Long et al. 1993, 1996; Campbell et al. 2002, 2003). In 2013 Ports North implemented the quarterly monitoring surveys to gather further data on the condition and resilience of seagrass for the CSDP EIS.

The State of Trinity Inlet Report (1997) recognised seagrasses as crucial to maintaining biodiversity and fisheries productivity in the Inlet and identified seagrasses as a key habitat type for long-term monitoring. These meadows are mostly within the Trinity Inlet Fish Habitat Area but are vulnerable to scouring from vessel movements, downstream effects of urban, industrial and agricultural land-use (declining water quality), and potential changes in hydrology associated with port development and maintenance. Urban and industrial expansions were identified as major threats to the environmental health of Trinity Inlet (WBM 1997). As seagrasses show measurable responses to changes in water quality they can also be used as an effective tool to monitor marine environmental health (eg. Dennison et al. 1993).

1.3 Port of Cairns

The Port of Cairns is located within Trinity Bay and Trinity Inlet, and operated by Ports North. It is one of Queensland's busiest ports and handles bulk and general cargo, cruise ships, fishing fleets and passenger ferries. Existing port infrastructure includes twelve operational wharves, commercial fishing bases, a barge ramp, marina and mooring facilities, swing basins and a 10km long channel which is subject to annual maintenance dredging (Ports North, 2013).

Ports North is investigating the potential to improve shipping access to the Port of Cairns and accommodate a larger class of cruise vessels. The Cairns Shipping Development Project (CSDP) would involve:

- Widening and deepening of the existing shipping channel and basins;
- Expansion of the existing dredge material placement area (DMPA) and/or provision of a new DMPA to accommodate dredge spoil from capital and maintenance dredging.

This development will require approvals from State and Federal Government and the Great Barrier Reef Marine Park Authority. In preparation for the EIS, Ports North have recognised that seagrasses make up an ecologically important and environmentally sensitive habitat in the Port of Cairns and recognise their value as a tool for monitoring water quality and the marine environmental health of the port. Therefore as part of these investigations seagrass monitoring activities were expanded during 2013 to incorporate a quarterly assessment program at four key representative seagrass sites to assess seagrass condition, benthic light (PAR) levels and seed bank assessments. Results of these quarterly assessments have been included in this report.

1.4 Seagrass Monitoring Program

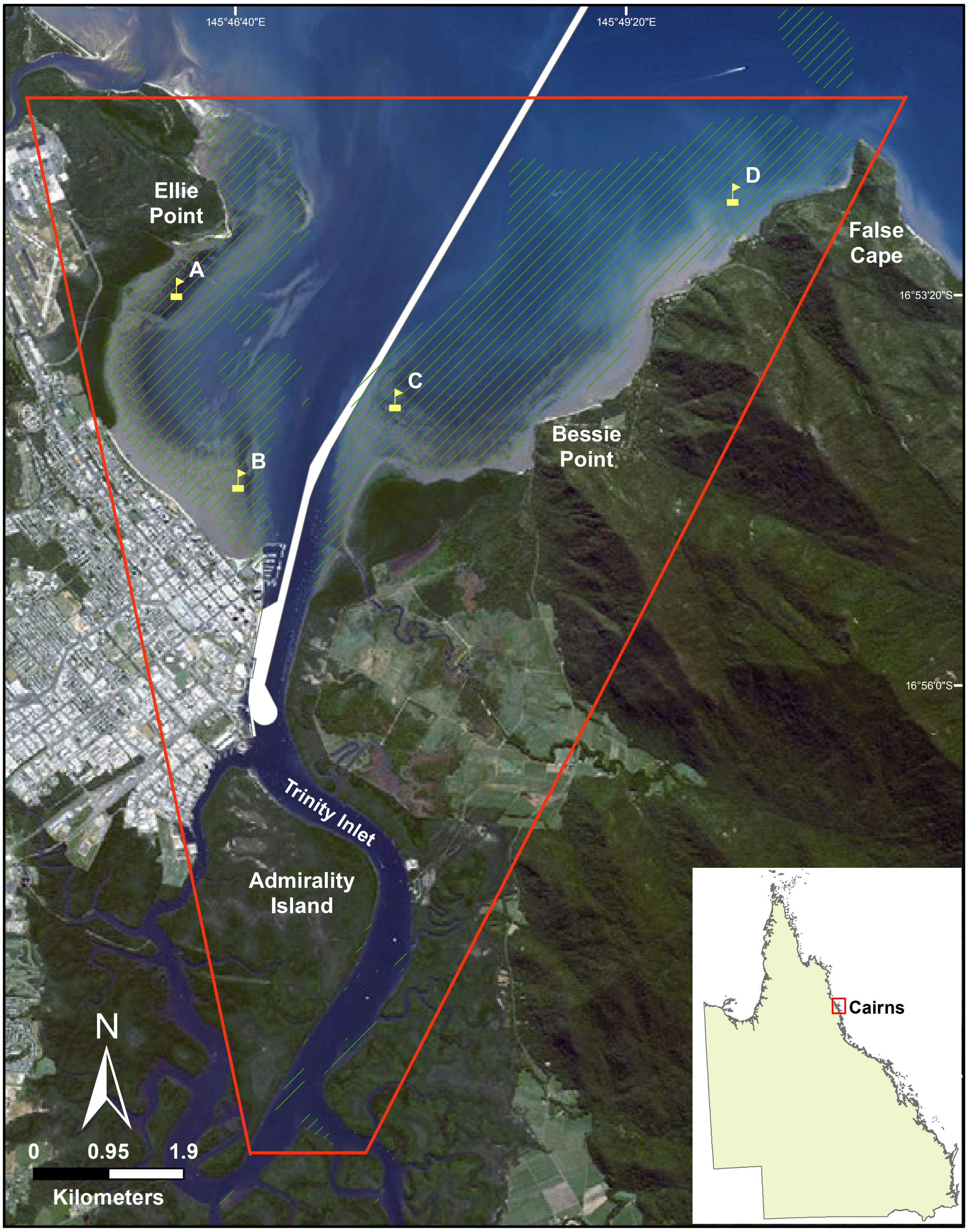
In partnership with the James Cook University - Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) and following the baseline survey conducted in 2001 (Campbell et al. 2002), Ports North established an annual seagrass monitoring program which helped define the natural variation for seagrass communities and some of the links between seagrass change and climate. The annual monitoring program conducted between October and December each year provides a regular update of the marine environmental health of Trinity Bay and Trinity Inlet and an assessment of seagrass condition and resilience to inform port management. As the annual monitoring program only examines a sub-set of representative seagrass meadows in Trinity Bay and Trinity Inlet, an updated baseline survey of all of the seagrass in the system was conducted in 2012 as part of the Cairns Shipping Development Project (CSDP) EIS (Rasheed et al. 2013). The baseline survey was conducted in conjunction with the annual monitoring program and found the smallest ever recorded area of seagrass with substantial declines occurring in previously robust and expansive meadows (Rasheed et al., 2013). This unprecedented loss occurred over the previous three years and left only small remnant patches of seagrass that were likely to be highly vulnerable to further natural and anthropogenic impacts. These declines were associated with multiple years of above average rainfall and severe storm and cyclone activity that likely left seagrasses with a greatly reduced capacity for recovery and the potential for complete loss of meadows. In 2013 Ports North implemented the quarterly monitoring surveys to gather further data on the condition and resilience of seagrass for the CSDP EIS. These sites would also be used as the sensitive receptor monitoring sites for the proposed CSDP.

The quarterly surveys were conducted in March, July, September, and December 2013 at four permanent sites established in areas previously known to have good seagrass coverage representing the key seagrass meadow types found in Cairns Harbour (Map 3). Queensland seagrass communities are seasonal, with maximum distribution and abundance usually occurring in late spring/early summer and quarterly monitoring has been used to effectively describe the nature of seasonal change while allowing for assessments of the links between seagrass change and light.

This report discusses the findings of the 2013 annual and quarterly monitoring surveys and the implications for the overall health of Cairns Harbour and Trinity Inlet's marine environment and places observed changes within a regional and state-wide context. The overall objectives of the 2013 annual and quarterly seagrass monitoring were to:

1. Map and quantify the distribution and abundance of selected seagrass monitoring meadows;
2. Compare monitoring results with previous seagrass surveys and assess changes in relation to natural events, port and catchment activities;
3. Assess seagrass condition and recolonisation quarterly at four key locations to assess seasonal changes and act as sensitive receptor monitoring sites for the proposed Cairns Shipping Development Project;
4. Measure and analyse benthic light (Photosynthetic Active Radiation (PAR) and temperature and how these change with seagrass condition;
5. Assess the capacity for seagrass recovery and recolonisation through assessment of seed-banks and reproductive effort;
6. Use the information collected to assist in determining drivers of seagrass change and quantifying local seagrass light thresholds for use in appropriate dredge management strategies and;
7. Based on the results of the first year of quarterly assessments determine if any restoration or assisted recovery may be warranted for Cairns seagrasses.

Map 3. Extent of 2013 seagrass annual monitoring survey area.



Legend

- Survey area 2013
- Total seagrass extent in Cairns Harbour 1984-2013
- Existing channel
- Quarterly Monitoring/ PAR Logger Sites

Source:
Jarvis, JC, Rasheed MA, McKenna SA, & Sankey T. 2014. Seagrass habitat of Cairns Harbour and Trinity Inlet: Annual and Quarterly Monitoring Report. JCU Publication, Centre for Tropical Water & Aquatic Ecosystem Research Publication 14/09, Cairns, 51 pp.

2 METHODOLOGY

2.1 Annual Monitoring Program

The sampling approach for the annual survey followed those in the established Cairns seagrass monitoring program as well as for seagrass baseline and monitoring programs in other Queensland Ports such as in Townsville, Mourilyan Harbour, Gladstone, Mackay, Weipa, Karumba, Thursday Island and Abbot Point (see McKenzie et al. 1996; Rasheed & Taylor 2008; Rasheed et al. 1996; Rasheed et al. 2001; Rasheed et al. 2003a; Rasheed et al. 2003b; Rasheed et al. 2005; Roelofs et al. 2001, 2003).

The annual seagrass surveys were conducted between October and December 2013. The survey area included intertidal and subtidal areas extending from north Ellie Point across to False Cape, and south to Redbank Creek in Trinity Inlet (Map 3).

A variety of sampling methods were used to survey the seagrass meadows. Methods applied were based on existing knowledge of seagrass distribution and physical characteristics of the area such as depth, visibility and logistical and safety constraints. Three sampling techniques were used:

1. Intertidal areas: Helicopter survey
2. Shallow subtidal areas: Boat based underwater CCTV drop camera
3. Deep water areas: Boat based CCTV camera sled tows

2.1.1 Intertidal areas

Exposed areas were surveyed using a helicopter at spring low tide to determine seagrass presence, abundance, species composition and meadow boundaries. Seagrass meadow characteristics were collected at sites scattered within the seagrass meadow as the helicopter hovered within two metres above the seagrass (Figure 2). Above-ground biomass, seagrass species composition, algal cover and sediment types were determined from three random placements of a 0.25 m^2 quadrat out the side of the helicopter (Figure 2). Positions of all sites were fixed and recorded using GPS.

Figure 2. Helicopter intertidal mapping of exposed seagrass meadows at spring low tide.

2.1.2 Shallow subtidal areas

Assessments of shallow subtidal meadows were conducted from a small research vessel. An underwater CCTV camera system with real-time monitor was mounted to a 0.25 m^2 quadrat which provided live images allowing researchers to record seagrass above-ground biomass, species composition, algal cover and sediment type from three random placements of the quadrat (Figure 3). A Van Veen sediment grab (grab area 0.0625 m^2) was used at each camera site to confirm sediment type and species viewed on the video screen (Figure 3). Survey sites were located along transects perpendicular to the shoreline extending to the offshore edge of seagrass meadows with random sites used to measure continuity of bottom habitat between transects. Sampling intensity was at approximately 50 to 100m intervals along each transect or where major changes in bottom topography occurred. Transects continued to at least the seaward edge any seagrass meadows that were encountered.

Figure 3. Shallow subtidal mapping of seagrass meadows using CCTV system and Van Veen sediment grab.

2.1.4 Habitat characterisation sites and seagrass above-ground biomass

Seagrass biomass (above-ground) was determined using a "visual estimates of biomass" technique (as described by Kirkman 1978 and Mellors 1991). This technique involves an observer ranking seagrass biomass in the field in three random placements of a 0.25m^2 quadrat at each site. Ranks are made in reference to a series of quadrat photographs of similar seagrass habitats for which the above-ground biomass has previously been measured. The relative proportion of the above-ground biomass (percentage) of each seagrass species within each survey quadrat was also recorded. Field biomass ranks are then converted into above-ground biomass estimates in grams dry weight per square metre (g DW m^2). At the completion of sampling each observer ranks a series of calibration quadrats that represented the range of seagrass biomass in the survey. After ranking, seagrass in these quadrats are harvested and the actual biomass determined in the laboratory. A separate regression of ranks and biomass from these calibration quadrats is then generated for each observer and applied to the field survey data to determine above-ground biomass estimates.

Data collected and recorded at each site included:

1. *Seagrass species composition* - Seagrass identifications in the field and from video according to Kuo and McComb (1989). Species composition measured from the sled net sample and from the video screen when species are distinct.
2. *Seagrass biomass* - Estimates of seagrass biomass from video images using a calibrated visual estimates technique as described by Kirkman (1978) and Mellors (1991) (and described above).
3. *Algae* - Presence/absence, algae type and per cent cover (identified according to Cribb 1996). Per cent cover was estimated from a video grab. Algae collected in the sled net and grab provided a taxa list.
4. *Sediment type* - A Van Veen grab (area 0.0625 m^2) was used to obtain a sediment sample at each site. Grain size categories were identified visually as: shell grit, rock, gravel (>2000µm), coarse sand (>500µm), sand (>250µm), fine sand (>63µm) and mud (<63µm).
5. *Site location* - by GPS including weather conditions at the time of sampling.

2.1.5 Habitat Mapping and Geographic Information System

All survey data was entered into a Geographic Information System (GIS) for presentation of seagrass species distribution and abundance. Satellite imagery of the Cairns area with information recorded during the monitoring surveys was combined to assist with mapping seagrass meadows. Three seagrass GIS layers were created in ArcMap:

- ***Habitat characterisation sites*** – site data containing above-ground biomass (for each species), dbMSL, sediment type, time, latitude and longitude from GPS fixes, sampling method and any comments.
- ***Seagrass meadow biomass and community types*** – area data for seagrass meadows with summary information on meadow characteristics. Seagrass community types were determined according to species composition from nomenclature developed for seagrass meadows of Queensland (Table 1). Abundance categories (light, moderate, dense) were assigned to community types according to above-ground biomass of the dominant species (Tables 1, 2).
- ***Seagrass landscape category*** – area data showing the seagrass landscape category determined for each meadow.

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

Aggregated seagrass patches
Meadows are comprised of numerous seagrass patches but still feature substantial gaps of un-vegetated sediment within the meadow boundaries

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

Table 1. Nomenclature for community types Cairns Harbour and Trinity Inlet.

Community type	Species composition
Species A	Species A is 90-100% of composition
Species A with Species B	Species A is 60-90% of composition
Species A with Species B/Species C	Species A is 50% of composition
Species A/Species B	Species A is 40-60% of composition

Table 2. Density categories and mean above-ground biomass ranges for each species used in determining seagrass community density Cairns Harbour and Trinity Inlet.

Density	Mean above ground biomass (g DW m^2)				
	H. uninervis (narrow)	*H. ovalis* *H. decipiens*	*H. uninervis* (wide) *C. serrulata/rotundata*	*H. spinulosa*	*Z. capricorni*
Light	< 1	< 1	< 5	< 15	< 20
Moderate	1 - 4	1 - 5	5 - 25	15 - 35	20 - 60
Dense	> 4	> 5	> 25	> 35	> 60

Each seagrass meadow was assigned a mapping precision estimate (±m) based on the mapping methodology utilised for that meadow (Table 3). Mapping precision estimates ranged from 3m for small isolated seagrass meadows, to 50m for larger subtidal meadows. The mapping precision estimate was used to calculate a range of meadow area for each meadow and was expressed as a meadow reliability estimate (R) in hectares. Additional sources of mapping error associated with digitising aerial photographs onto base maps and with GPS fixes for survey sites were embedded within the meadow reliability estimates.

Table 3. Mapping precision and methodology for seagrass meadows Cairns Harbour and Trinity Inlet.

Mapping precision	Mapping methodology
3-20m	Meadow boundaries determined from a combination of helicopter and camera/grab surveys; Exposed inshore boundaries mapped from helicopter; Offshore boundaries interpreted from subtidal survey sites and aerial photography; Patchy cover of seagrass throughout meadow; Relatively high density of mapping and survey sites; Small subtidal meadows in Trinity Inlet
50m	Subtidal meadow boundaries determined from camera/grab surveys only; All meadows subtidal; Patchy cover of seagrass throughout meadow; Moderate density of survey sites; Recent aerial photography aided in mapping.

2.2 Quarterly Seagrass Monitoring Program

Seagrass was assed quarterly at four permanent sites established in areas previously known to have good seagrass coverage (Map 3). These sites represent the key seagrass meadow types found in Cairns Harbour (*Z. capricorni* sites A and B, *H. uninervis* with mixed species site C, and *H. uninervis* only site D). Queensland seagrass communities are seasonal, with maximum distribution and abundance usually occurring in late spring/early summer. Quarterly monitoring has been used to effectively describe the nature of seasonal change and will also allow for assessments of the links between seagrass change and light.

At each of the intertidal sites three permanent 50m transects were established based on the seagrass-watch protocols (http://seagrasswatch.org/home.html) and recently adapted for the Gladstone Western Basin seagrass assessments by the group (McCormack et al. 2013). For the subtidal sites, 3 replicate permanent blocks were established and seagrass assessed in at least 10 randomly located quadrats within each block.

The key information collected for seagrass at the quarterly assessment sites was:

- Percent cover
- Above-ground biomass
- Species composition
- Seed bank status

In addition Photosynthetically Active Radiation (PAR) available to the seagrasses was collected at each of the four sites, with additional PAR data also collected at the spoil ground where deepwater seagrasses have previously been known to occur.

Sampling methods for the program followed Seagrass-Watch methodology (McKenzie et al. 2007; see also www.seagrasswatch.org). To avoid damaging seagrass from repeated sampling in highly muddy sites such as Cairns, the methodology was adapted to use helicopters to sample the intertidal sites (see McCormack et al 2013). Each site comprises a 50m x 50m area of a relatively homogenous section of the seagrass meadow. The intertidal sites contain three 50m transects which were monitored to determine per cent seagrass cover, above ground biomass, species composition and algae cover. The 50m x 50m subtidal sites were sampled using a real-time camera system from a boat with sampling randomly distributed within each of three replicate blocks. In addition to the Seagrass-Watch standard methodology, seagrass above-ground biomass was determined using a "visual estimates of biomass" technique as described previously (See section 2.1.4).

2.2.1 Intertidal seagrass sampling

Intertidal monitoring meadows were sampled using a helicopter when exposed at spring low tide. Three transects at each site were assessed with eleven 0.25 m^2 quadrats examined on each transect as per Seagrass-Watch protocols. Photos of each quadrat were also taken for further assessment.

2.2.2 Subtidal seagrass sampling

Three permanent replicate blocks were sampled from a small boat at the subtidal sites. Within each block 10 random placements of a 0.25 m^2 quadrat were assessed. A real-time underwater video camera mounted to a 0.25 m^2 quadrat provided live images that were viewed and ranked from a colour monitor aboard the research vessel. Images will also be recorded for later analysis.

2.2.4 Seed Bank assessment

Seed-bank density for *Zostera capricorni* and *Halodule uninervis* seeds was quantified at each of the four locations to assess the capacity for seagrass recovery and recolonisation. Ten samples per site were collected with a van Veen sediment grab (grab area 0.0625 m^2). Samples were then sieved in the laboratory and seeds removed, and identified (Figure 4).

2.2.5 Temperature and Light PAR Loggers

At each of the four seagrass monitoring sites and at an additional deepwater site near the spoil ground benthic light (Photosynthetically Active Radiation or PAR) and temperature was continuously recorded from April to December 2013 (data collection continued beyond the time frame of this report). Monitoring of within seagrass canopy temperature (°C) was recorded every 15 minutes using autonomous iBTag submersible temperature loggers. Temperature loggers were replaced at each location quarterly.

Submersible OdysseyTM photosynthetic irradiance autonomous loggers (light loggers) were also deployed at the quarterly monitoring locations to assess PAR. Continuous measurements were conducted and recorded by the logger every 15 minutes. Automatic wiper brushes cleaned the optical surface of the sensor every 15 minutes to prevent marine organisms fouling the sensors. Light loggers were replaced and downloaded every month.

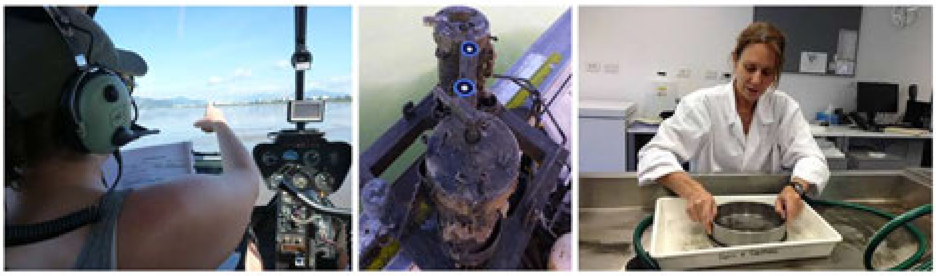


Figure 4. Helicopter survey, PAR loggers and processing of sediment seed bank samples from Cairns Harbour monitoring sites.

2.3 Statistical analyses

Seagrass above-ground biomass was compared between years with a one-way analysis of variance (ANOVA) in the statistical package program R (R Core Team, 2013). The one-way ANOVA was performed only on those habitat characterisation sites where seagrass was present, because the inclusion of sites where seagrass was absent (zero values) in the data set violated the assumption of ANOVA. Each meadow's data was examined for normality and homogeneous variance and data transformations applied to meet these assumptions (all meadows were fourth root transformed; Quinn and Keo, 2002). Tukey's post hoc analysis was used to test for significant differences in biomass between years (multcomp package, Hothorn et al., 2008). Detailed statistical results are presented in Appendix 1.

Sediment seed bank density data from each of the quarterly monitoring sites were also analysed in the statistical package program R using negative binomial regression with month (March, July, September, December) and species (*Z. capricorni* and *H. uninervis*) when applicable (lme4 package, Bates et al. 2013). Negative binomial regression is a type of logistic regression and was selected due to the use of non-negative count data, the large number of observations (160 total), and a high number of zeros recorded in the survey (Zuur et al. 2012). Each site was analysed independently based on the assumption that the density of the seed bank at each site did not affect the density at all other sites. Site C was the only site where both species (*Z. capricorni* and *H. uninervis*) were found, therefore this site was analysed for species, month, and all interactions. Tukey's post hoc analysis was used to test for significant differences in seed bank density between month or species when applicable for each site (multcomp package, Hothorn et al., 2008). Detailed statistical results are presented in Appendix A.1.

2.4 Seagrass meadow condition index

This is the first year of applying and testing the condition index and there is scope for future modifications of the classifications and approach as it is rolled out and tested across the ports monitoring program. This initial index was developed for each of the monitoring meadows based on mean above ground biomass, meadow area and species composition. The index integrates this information to give each meadow a condition rating of “good”, “concern” or “poor”. For biomass and area the current value for each meadow was compared with the meadow’s long term average and categorised into a range that corresponded to the three index categories (Table 4). Ranges for each component of the condition index were selected based on the historical variability within the monitoring meadow representing seagrass condition in a stable meadow (good), in a meadow with reduced resilience to disturbance (concern) and in a meadow with limited resilience and loss of ecosystem function (poor). Two different ranges were used recognising that some monitoring meadows are relatively stable (higher cover meadows dominated by larger species) and other meadow types are naturally variable (patchy meadows dominated by smaller often colonising species) (Table 4).

Species composition was assessed qualitatively as “good” when the species composition has remained relatively stable; of “concern” when there has been a substantial shift (approximately 20% or greater) in species toward colonising species indicating disturbance or stress; or “poor” when the meadow has shifted to become clearly dominated (>80%) by colonising species. It is important to note that species shifts are relative and determined on a meadow by meadow basis taking into account both the current year’s species composition and historical trends. Some monitoring meadows in their stable state are always dominated by colonising species. As a result the presence of colonising species in these meadows results in a condition rating of “good” for species composition in the condition index (Table 4).

The final condition of the monitoring meadow is determined by looking at all three factors (biomass, area and species composition), with the lowest of any of the three factors determining the overall condition index. Where additional information is available, such as seagrass seed-bank status, light and temperature stress or other measures of resilience such as flowering and fruiting and carbohydrate stores may be used to modify the overall condition score if they indicate the meadow may be under increased stress.

Table 4. Determination of seagrass condition index for Cairns seagrass monitoring meadows.

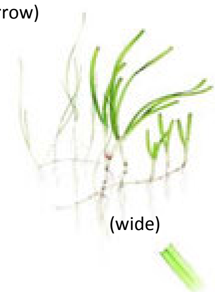
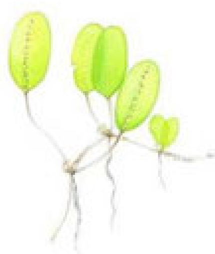
Condition Index	**Biomass**		**Area**		**Species Composition**
	Stable higher cover meadows	Patchy highly variable meadows	Stable higher cover meadows	Patchy highly variable meadows	
Good	Less than 20% below the long term average	Less than 50% below the long term average	Less than 10% below the long term average	Less than 20% below the long term average	Relatively stable species composition
Concern	Between 20% and 50% below the long term average	Between 50% and 80% below the long term average	Between 10% and 20% below the long term average	Between 20% and 50% below the long term average	Shift in species composition towards colonisers
Poor	Greater than 50% below the long term average	Greater than 80% below the long term average	Greater than 20% below the long term average	Greater than 50% below the long term average	Colonising species have become dominant

3 RESULTS

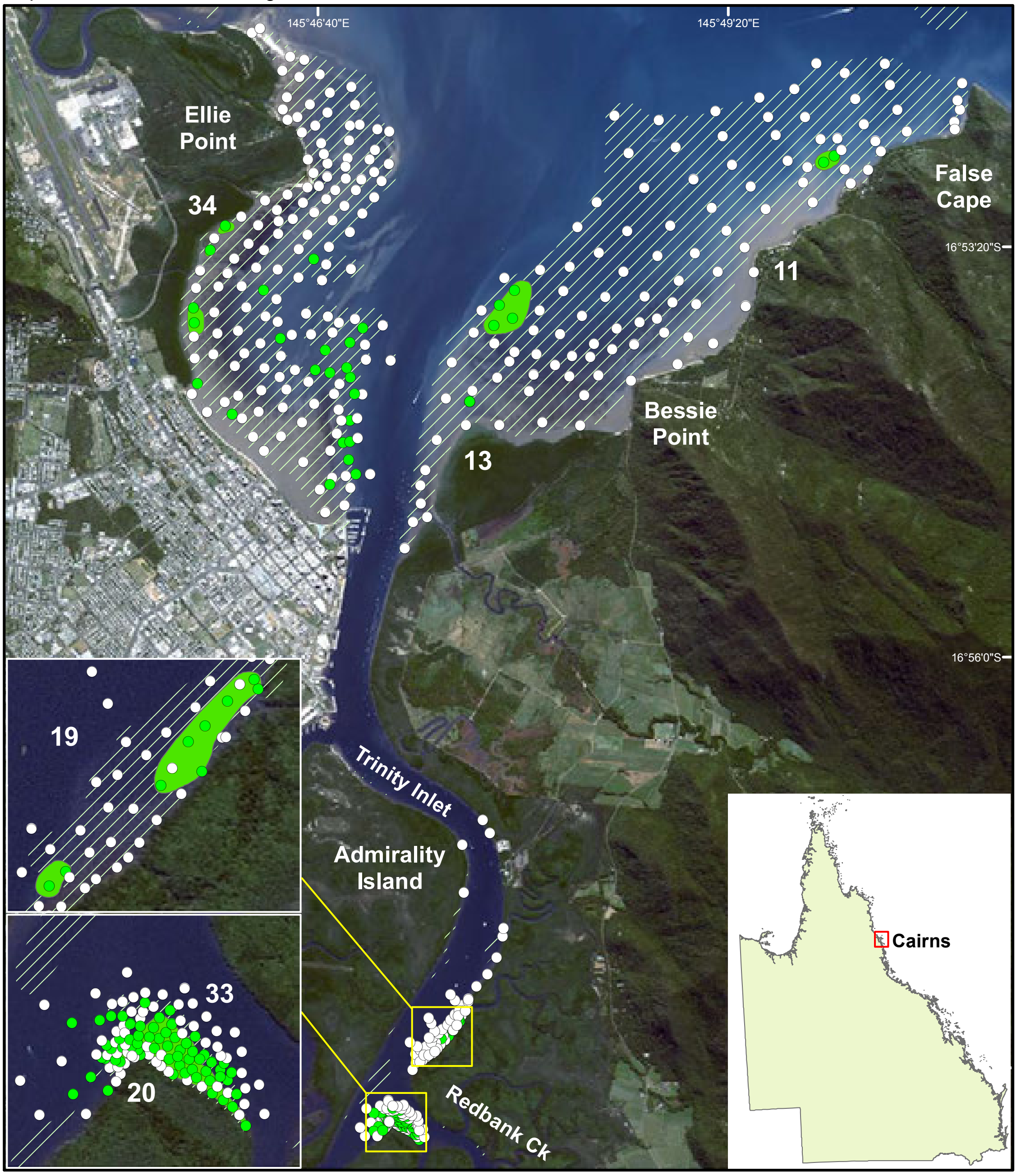
3.1 Seagrass Species in Cairns Harbour and Trinity Inlet

A total of 464 habitat characterisation sites were surveyed in the 2013 annual monitoring seagrass surveys, with seagrass present at 22% of sites (Map 4). A total of seven seagrass species have been recorded in Cairns Harbour and Trinity Inlet across all surveys (1984, 1988, 1993, 2001- 2012), five of which were identified in 2013. *Cymodocea rotundata* and *Thalassia hemprichii* were the two species that have been found in the past but were not present in the monitoring meadows in 2013 (Table 5).

Table 5. Seagrass species present in Cairns Harbour and Trinity Inlet 2013.

Family	Species			
CYMODOCEACEAE Taylor	*Halodule uninervis* (wide and narrow leaf morphology) (Forsk.) Aschers. in Boissier	(narrow)  (wide)	*Cymodocea serrulata* (R.Br.) Aschers and Magnus	
ZOSTERACEAE Drummortier	*Zostera capricorni* Aschers.		* Note *Zostera capricorni* has been re-classified as a sub-species of *Zostera mulleri* however for consistency purposes we will continue to name the seagrass as *capricorni*	
HYDROCHARITACEAE Jussieu	*Halophila decipiens* Ostenfield		*Halophila ovalis* (R. Br.) Hook. F.	

Map 4. Location of monitoring meadows in Cairns Harbour, October 2013.



Legend
Seagrass Sites

- Seagrass absent
- Seagrass present
- Cairns seagrass monitoring meadows 2013
- Total seagrass extent in Cairns Harbour 1984-2013

* This is not a complete distribution of seagrass, only monitoring meadows are displayed.

N

0 1 2
Kilometers

Jarvis, JC, Rasheed MA, McKenna SA, & Sankey T. 2014. Seagrass habitat of Cairns Harbour and Trinity Inlet: Annual and Quarterly Monitoring Report. JCU Publication, Centre for Tropical Water & Aquatic Ecosystem Research Publication 14/09, Cairns, 51 pp.

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3.2 Seagrass in the Annual Monitoring Meadows

3.2.1 Seagrass distribution and abundance within annual monitoring meadows

There has been a massive reduction in seagrass area and biomass for the monitoring meadows over the last five years (Figures 5 and 6). A total of 42.1 ± 21.0 ha of seagrass habitat was mapped in the six monitoring meadows in 2013 (Figure 6). While this was the first increase in total area since 2007, seagrass populations remained low at approximately 95% below the 13 year long-term average of 855.6 ha (Figures 6-12; Map 5; Appendix A.2). Traditionally the smallest monitoring meadows have been located in Trinity Inlet while the larger meadows have been located in the harbour along the Esplanade and the eastern side of the channel at Bessie Point. In 2012 however, the Esplanade and Bessie Point meadows were reduced to small isolated patches of seagrass (Figures 7-12). This trend continued in 2013; however, there was some minor expansion of area and a return of an isolated patch of seagrass in the South Bessie Pt. meadow (Figures 7-12; Map 5). Distribution of the monitoring meadows that were present in 2013 ranged from 0.03 ± 0.02 ha for the South Bessie Pt. *Cymodocea serrulata* meadow, to 27.1 ± 15.1 ha for the Bessie Point *Halodule uninervis* dominated meadow (Figures 7-12; Map 5; Appendix A.2).

Seagrass was only present in sufficient density to obtain mean meadow above-ground biomass in five of the monitoring meadows (Figure 5; Appendix A.2). The mean combined biomass of the monitoring meadows was 2.15 ± 0.37 g DW m^2. While this was an increase over the 2012 mean combined biomass (1.01 ± 0.17 g DW m^2), values remained low at approximately 88% below the 13 year long-term above-ground biomass average of 17.89 g DW m^2 (Figure 5). Based on the mean biomass of the dominant species in each meadow, the Esplande-Ellie Point (*Z. capricorni*), Bessie Point (*H. uninervis*) and South Bessie Point (*C. serruilata*) meadows were characterised has having a light cover of seagrass, while the Inlet and Redbank *Halophila* meadows were characterised has having moderate seagrass cover (Figure 6; Table 6). The seagrass landscape category was the same for all monitoring meadows; isolated to aggregated patches of seagrass (Figures 7-12; Table 6).

3.2.2 Comparison with previous annual monitoring surveys

The overall condition of the seagrass meadows in Cairns harbour in 2013 was poor (Map 1, Figures 7-12). The exceptions were the Redbank Halophila meadows 19 and 33 which were in the concern and good categories respectively (Figure 10 and 12). For all of the meadows ranked 'poor' in 2013 both biomass and area were reduced compared to the long term average reference values (Figures 7-9, 11). Species composition remained the same across all meadows with the exception of Bessie Point South (meadow 13) where *C. serrulata* was present for the first time since 2009 (Figure 9). In addition to low biomass and reduced area, the limited density and low overall viability of the sediment seed bank indicates a limited resilience to disturbance and a reduced ability to recover to pre-2009 levels (Figure 13). These results indicate that although there is some recovery in 2013 compared to 2012 the overall seagrass condition across Cairns Harbour and Trinity Inlet remains poor.

Following the La Niña-related events of 2010/11 and severe TC Yasi in February 2011, total seagrass meadow area and mean above-ground biomass in Cairns Harbour and Trinity Inlet declined in 2012 to the lowest recorded values since annual monitoring began in 2001 (Appendix A.2). In 2013 some recovery was noted; however both biomass and area remain well below the long term average for seagrass in Cairns Harbour. The previously extensive *Zostera capricorni* and *Halodule uninervis* seagrass meadows in Cairns Harbour have been reduced substantially to small remnant patches (Figures 7-8). The Inlet and Redbank *Halophila spp.* dominated meadows have fared better with meadow density and distribution over the last three years remaining within the range of previously recorded values (Figures 10-12; Appendix A.2).

A general trend of declining biomass has been observed in the *Zostera capricorni* dominated Esplanade meadow since a peak in 2004 (Figure 7). A similar trend has also been observed in the *Halodule uninervis* dominated Bessie Point meadow, after it peaked in 2005. The small intertidal *Zostera capricorni* dominated meadow at Redbank Creek dramatically declined in biomass from 2009 to 2010 and has been absent since 2011 (Figure 11). Similarly, no seagrass was found in the South Bessie Point *Zostera capricorni* meadow in 2012; however recovery was noted in 2013 with the presence of *C. serrulata* (Figure 9; Appendix A.2).

Species composition in the monitoring meadows that were present in 2013 generally followed similar trends to previous years with only small fluctuations in the minor species that make up the composition of the meadows (Figures 7-12). The only species shift to note was the change in dominant species in the Inlet meadow from *Halophila decipiens* to *Halophila ovalis* (Figure 10). The dominant species in this meadow has always fluctuated between the two *Halophila* species. In addition, *Cymodocea serrulata* was present in the Cairns Harbour monitoring meadows (Bessie Point South Meadow 13) for the first time since 2010.

Of the three meadows where depth was able to be determined, depth limits were reduced compared to previous years (Table 7). Depth was reduced at Meadow 19 from 5.6 to 3.0 m below mean sea level and from 2.9 to 2.3 m below mean sea level at Redbank meadow 33 (Table 7).

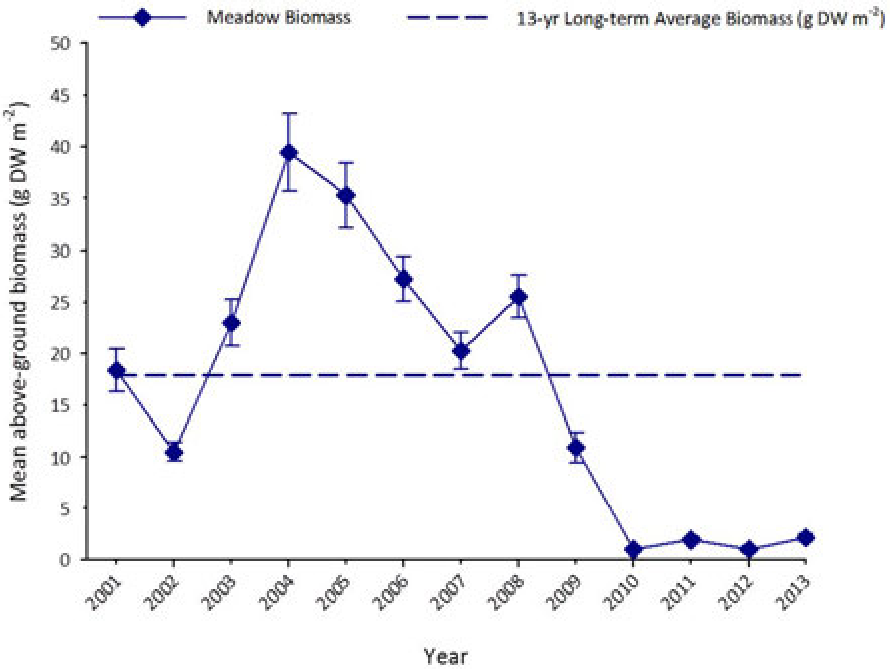


Figure 5. Mean above-ground biomass (g DW m^2) of all monitoring meadows combined in Cairns Harbour and Trinity Inlet from 2001 – 2013 (error bars – standard error). Dotted blue line indicates 13-year mean of meadow biomass.

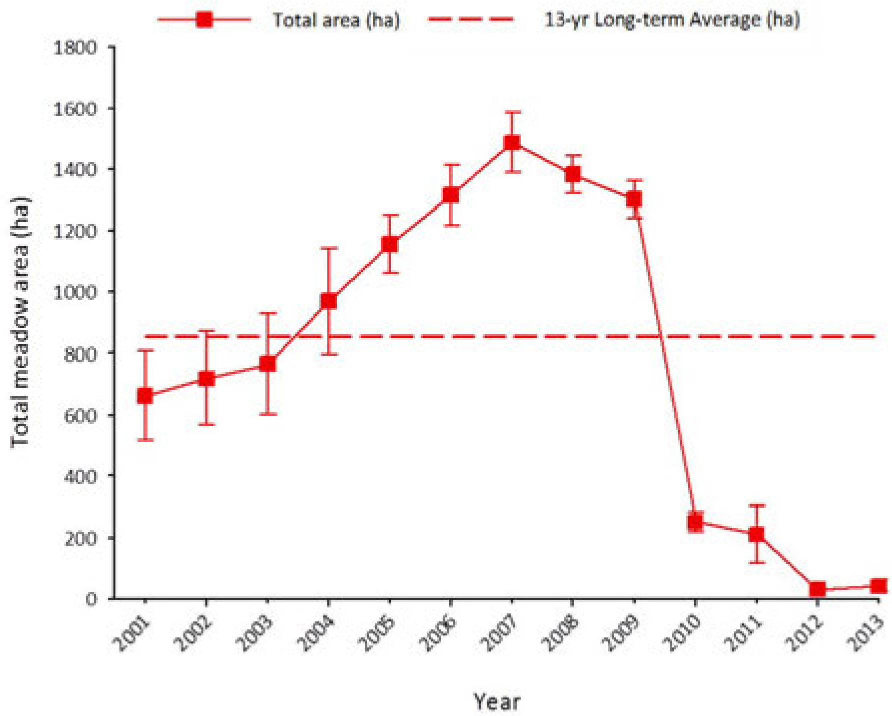


Figure 6. Total area of all monitoring meadows combined in Cairns Harbour and Trinity Inlet from 2001 – 2012 (error bars – "R" reliability estimated). Solid red line indicates 13-year mean of total meadow area.

Table 6. Description of Cairns Harbour and Trinity Inlet seagrass monitoring meadows from the 2013 monitoring survey.

Meadow	Location	Meadow ID	Number of Sites	Habitat Type	Meadow Cover	Meadow Description
Esplanade-Ellie Pt.	Cairns Harbour	34	6	Intertidal	Aggregated patches	Light *Zostera capricorni*
Bessie Point	Cairns Harbour	11	6	Subtidal to intertidal	Aggregated patches	Light *Halodule uninervis* (thin) with light *Halophila ovalis*
South Bessie Point	Cairns Harbour	13	1	Isolated patch	Isolated patch	Light *Cymodocea serrulata*
Inlet	Trinity Inlet	19	9	Subtidal	Aggregated patches	Moderate *Halophila decipiens* with light *Halophila ovalis*
Redbank (Zc)	Trinity Inlet	20	**NP**	Subtidal to intertidal	**NP**	**NP**
Redbank (Ho)	Trinity Inlet	33	28	Subtidal	Aggregated patches	Moderate *Halophila decipiens/ Halophila ovalis*

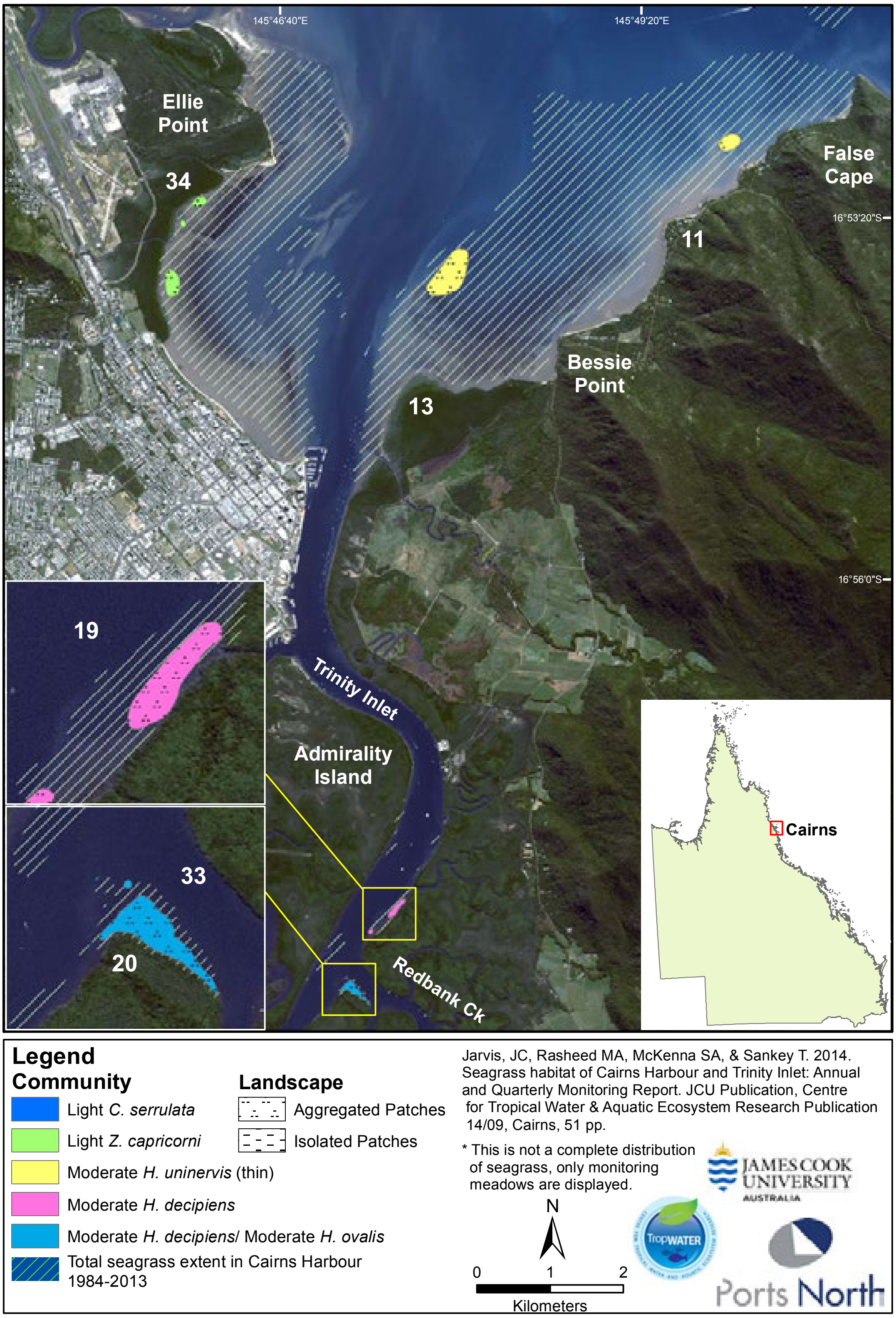
NP – No seagrass present

Table 7. Maximum depth penetration (depth below mean sea level) of monitoring meadows in Cairns Harbour and Trinity Inlet, 2001 – 2013.

Meadow location and ID number	Maximum Depth (depth below mean sea level (m)												
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Esplanade to Ellie Pt. (34)	NA	NA	NA	NA	NA	NA	NA	1.7	1.5	NA	NA	NA	NA
Bessie Pt. (11)	3.7	3.7	4	4.1	4	4.3	4.2	4.2	3.1	4.2	1.8	NA	2.1
Inlet (19)	NA	3.2	3.4	3.8	2.9	3.3	3.3	4.4	3.8	2.6	5.1	5.6	3.0
Redbank (20)	1.3	1.1	1.5	1.6	1.2	1.1	2	1.6	2.4	1.5	NP	NP	NP
Redbank (33)	NA	3.4	3.2	3.2	2.9	2.4	3	1.8	4.8	3.8	3.3	2.9	2.5

NP – No seagrass present
NA – Not applicable (meadow exposed at spring low tide)

Map 5. Location of monitoring meadows in Cairns Harbour, October 2013.



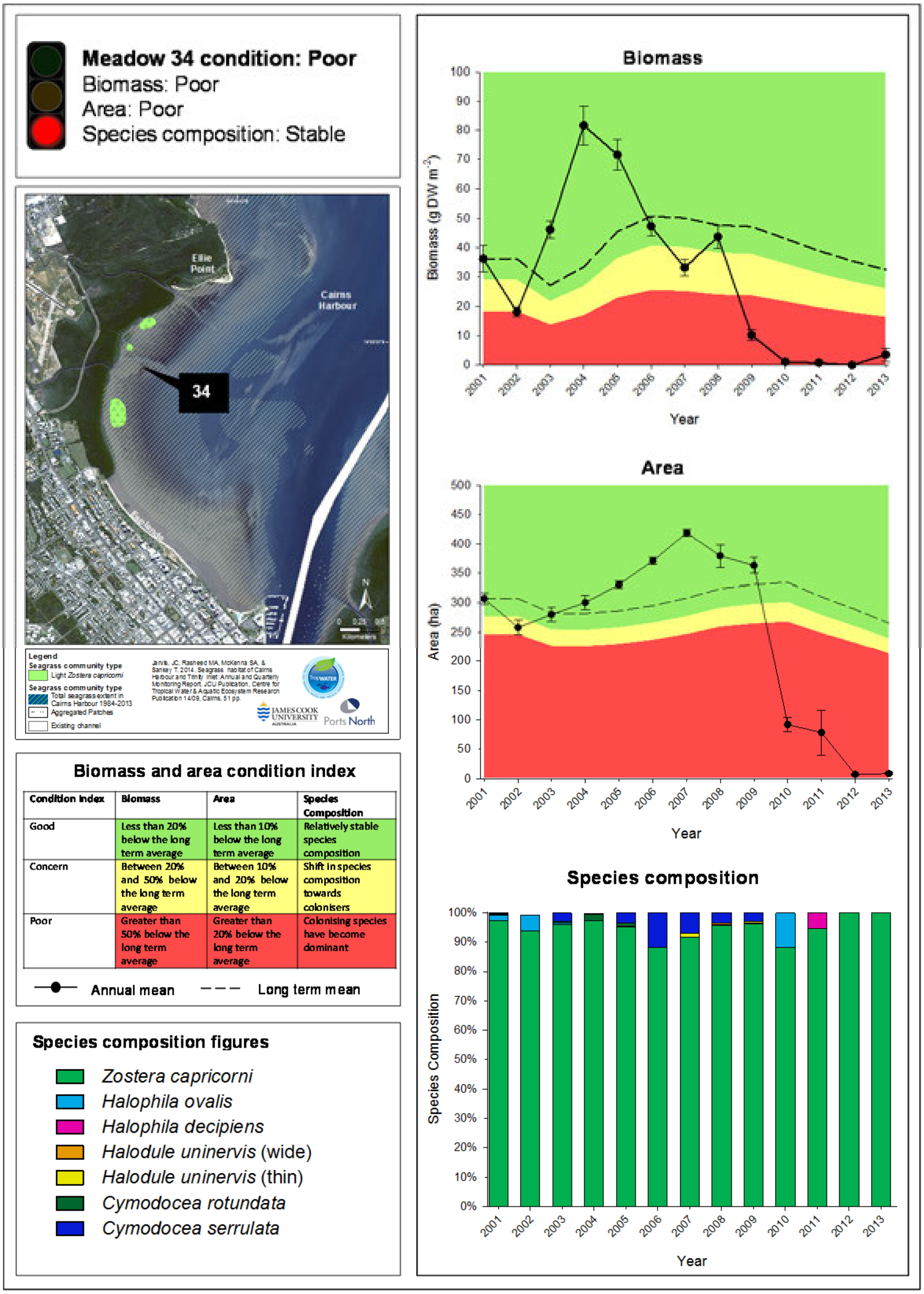
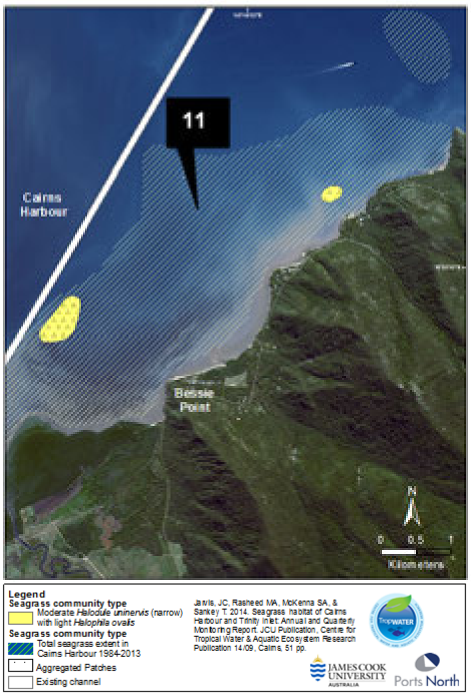


Figure 7. Changes in biomass, area and species composition for the Esplanade meadow (meadow no. 34) from 2001 – 2013 (biomass error bars = SE; area error bars = "R" reliability estimate).

Meadow 11 condition: Poor
Biomass: Poor
Area: Poor
Species composition: Stable



Biomass and area condition index

Condition index	Biomass	Area	Species Composition
Good	Less than 20% below the long term average	Less than 10% below the long term average	Relatively stable species composition
Concern	Between 20% and 50% below the long term average	Between 10% and 20% below the long term average	Shift in species composition towards colonisers
Poor	Greater than 50% below the long term average	Greater than 20% below the long term average	Colonising species have become dominant

—●— Annual mean — — — Long term mean

Species composition figures

- *Zostera capricorni*
- *Halophila ovalis*
- *Halodule uninervis* (thin)
- *Halodule uninervis* (wide)
- *Cymodocea serrulata*

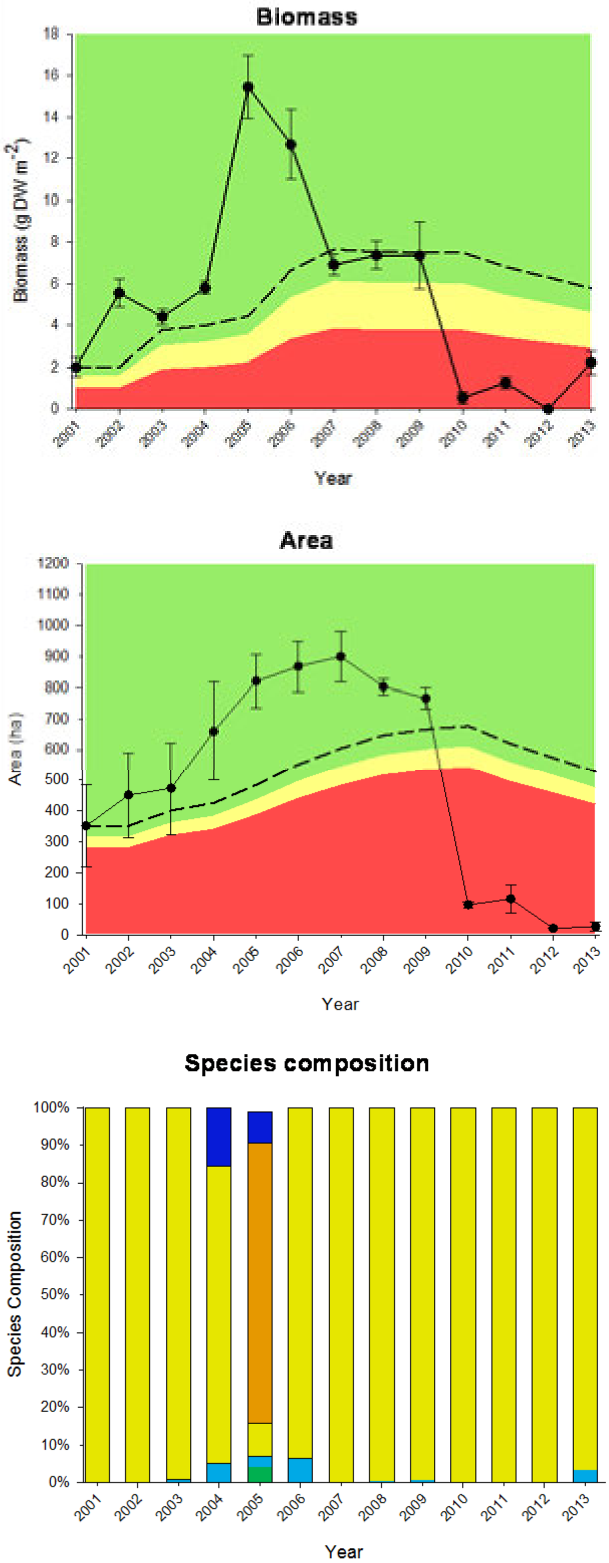


Figure 8. Changes in biomass, area and species composition for the Bessie Point (meadow no. 11) meadow from 2001 – 2013 (biomass error bars = SE; area error bars = “R” reliability estimate).

Meadow 13 condition: Poor
Biomass: Poor
Area: Poor
Species composition: Climax species

Biomass and area condition index

Condition Index	Biomass	Area	Species Composition
Good	Less than 20% below the long term average	Less than 10% below the long term average	Relatively stable species composition
Concern	Between 20% and 50% below the long term average	Between 10% and 20% below the long term average	Shift in species composition towards colonisers
Poor	Greater than 50% below the long term average	Greater than 20% below the long term average	Colonising species have become dominant

Annual mean — Long term mean

Species composition figures

Zostera capricorni
Halophila ovalis
Halodule uninervis (thin)
Cymodocea serrulata
Cymodocea rotunda

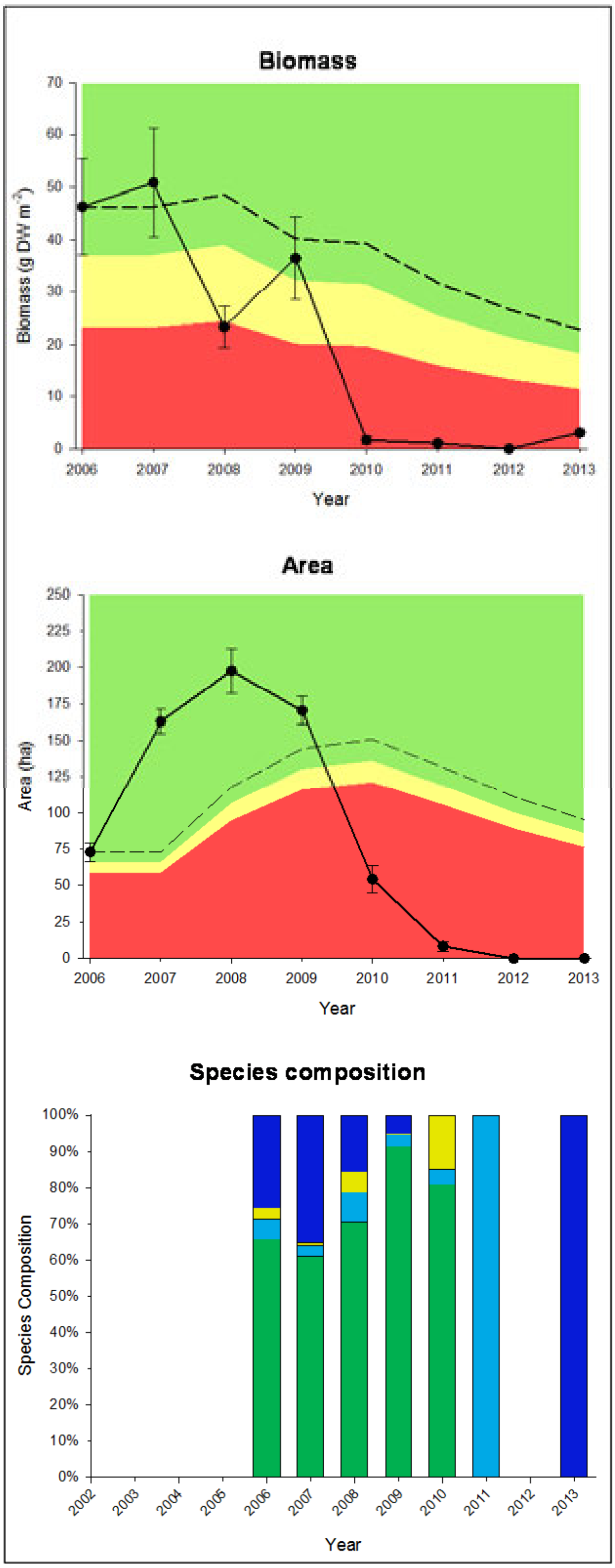
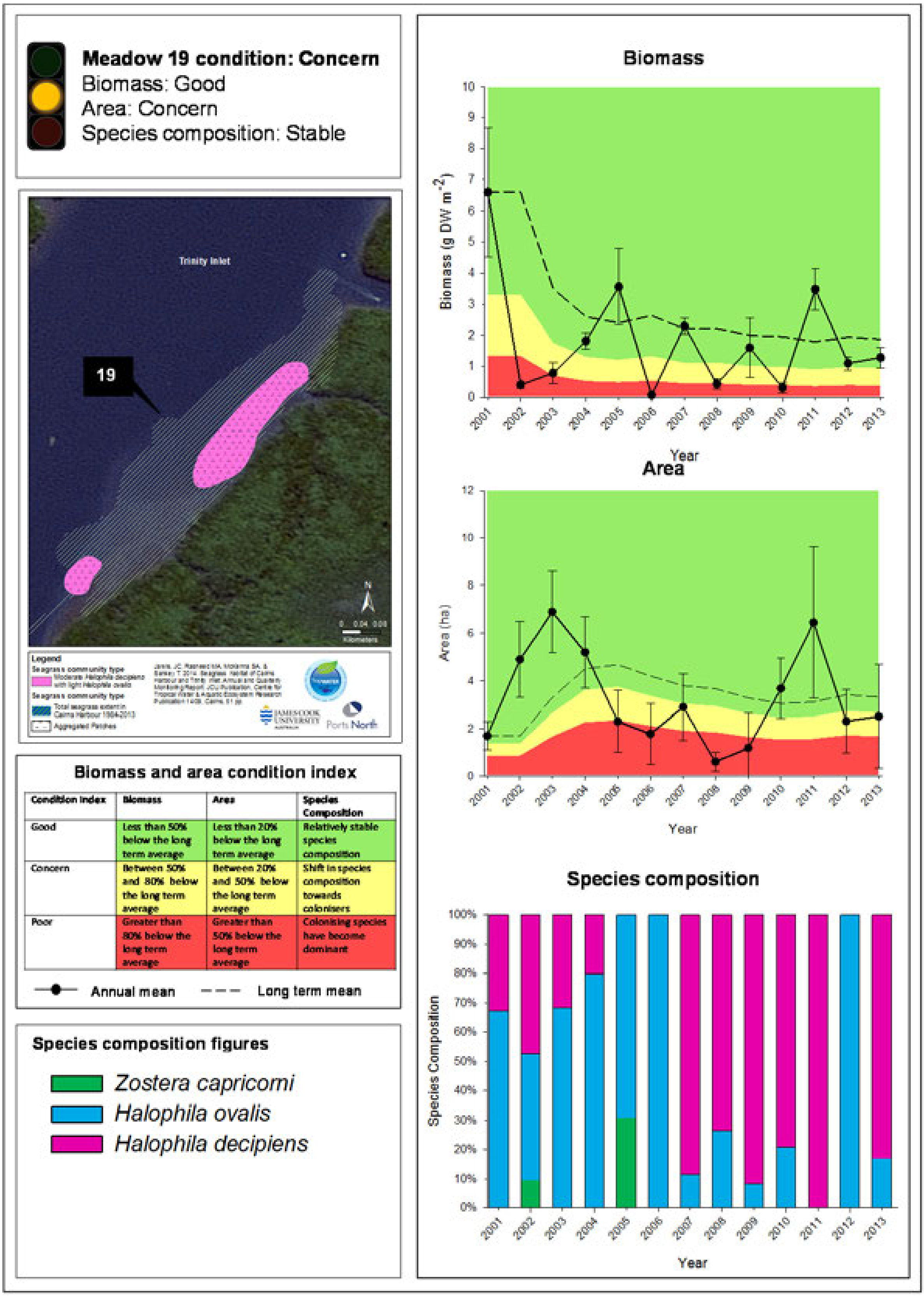


Figure 9. Changes in biomass, area and species composition for the South Bessie Point (meadow no. 13) meadow from 2001 – 2013 (biomass error bars = SE; area error bars = "R" reliability estimate).



Condition Index	Biomass	Area	Species Composition
Good	Less than 50% below the long term average	Less than 20% below the long term average	Relatively stable species composition
Concern	Between 50% and 80% below the long term average	Between 20% and 50% below the long term average	Shift in species composition towards colonisers
Poor	Greater than 80% below the long term average	Greater than 50% below the long term average	Colonising species have become dominant

Figure 10. Changes in biomass, area and species composition for the Trinity Inlet *Halophila* meadow (meadow 19) from 2001 – 2013 (biomass error bars = SE; area error bars = “R” reliability estimate).

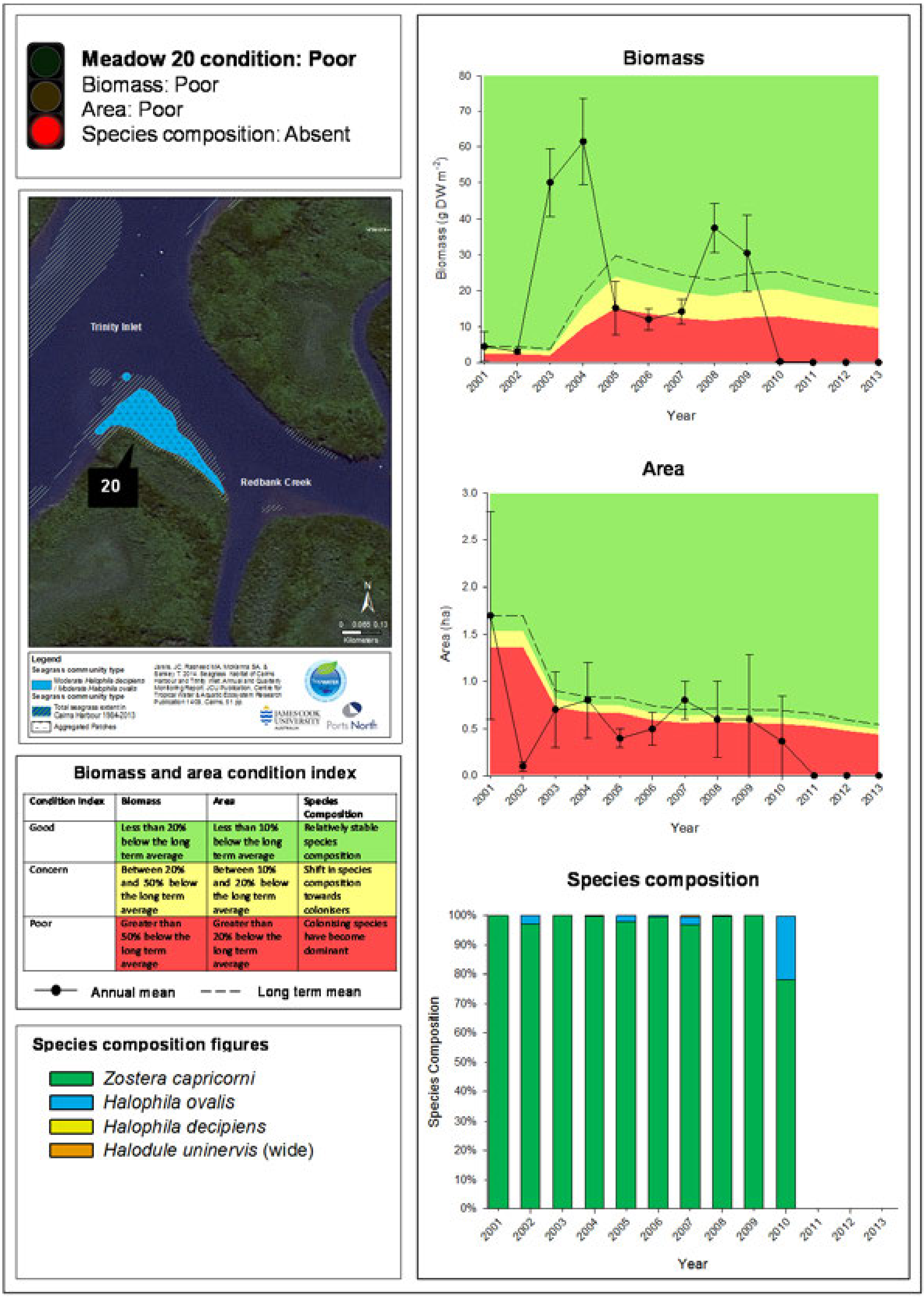


Figure 11. Changes in biomass, area and species composition for the Trinity Inlet *Zostera* meadow (meadow no. 20) from 2001 – 2013 (biomass error bars = SE; area error bars = "R" reliability estimate).

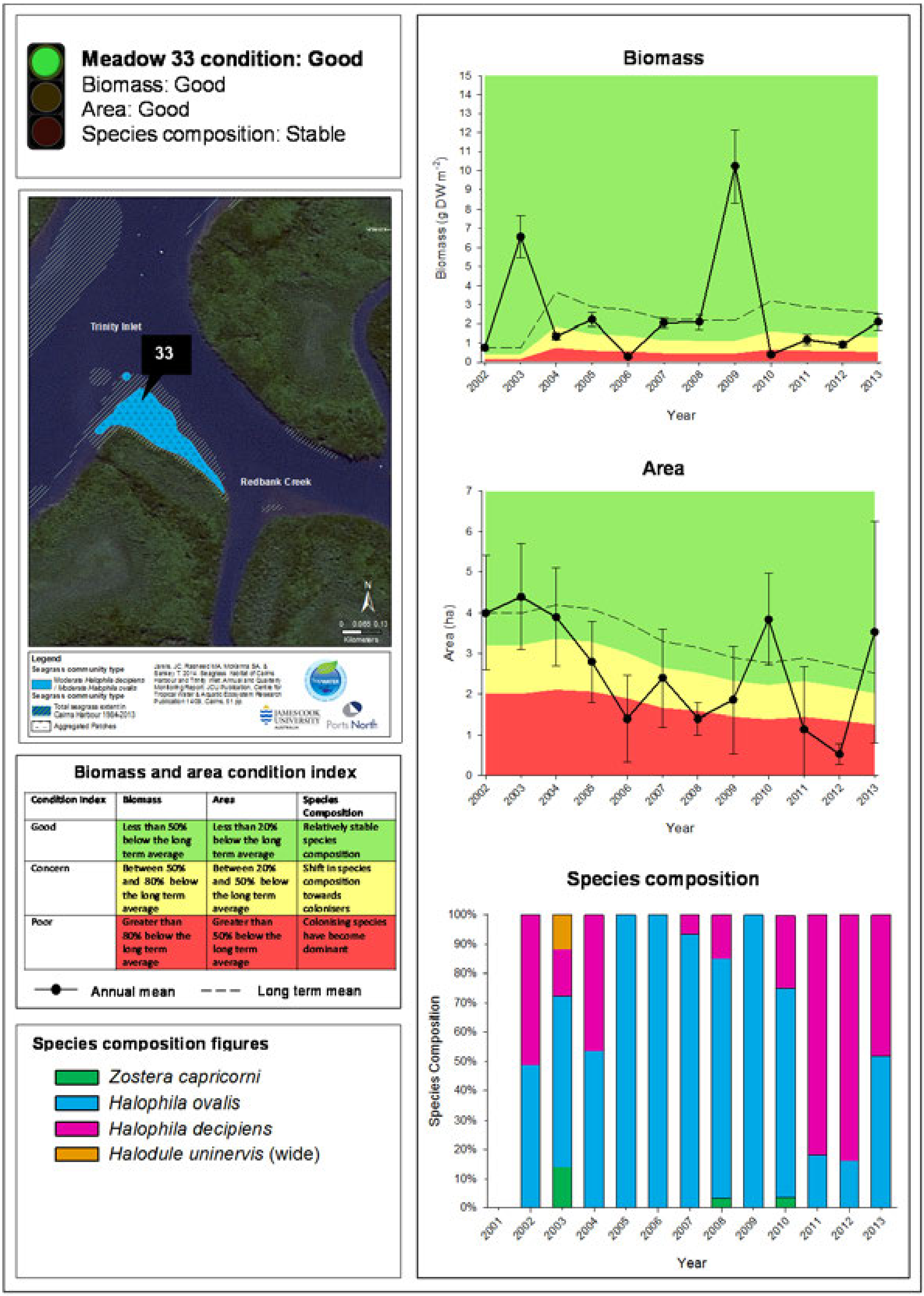


Figure 12. Changes in biomass, area and species composition for the Trinity Inlet *Halophila* meadow (meadow 33) from 2001 – 2013 (biomass error bars = SE; area error bars = "R" reliability estimate).

3.3 Quarterly Seagrass Monitoring

3.3.1 Intertidal and Subtidal Seagrass Sampling

All four sampling sites (A-D) for quarterly monitoring of seagrass condition in Cairns Harbour were established in April 2013 (Map 3). Although all of the transects were established within areas historically supporting four of the main types of seagrass communities found in Cairns Harbour, no seagrass was observed during the transect monitoring at any sites throughout the quarterly sampling effort. The limited recovery noted in the annual survey occurred in isolated patches that did not arise along any of the quarterly monitoring transects.

3.3.2 Seed Bank

Seeds were found at all quarterly monitoring sites in Cairns Harbour (Figure 13). Mean total seed bank density (averaged across all times and species) was similar between sites A, B, and C and ranged from 28 ± 7 seeds m^{-2} to 36 ± 10 seeds m^{-2} (Table 8). Site D had a significantly lower mean total seed bank density at 3 ± 1 seeds m^{-2}. Across time, the greatest density of seeds (averaged across all sites and species) occurred in July (41 ± 9 seeds m^{-2}) and the lowest in September and December (13 ± 3 seeds m^{-2} for both months) (Table 9).

Table 8. Mean Cairns Harbour and Trinity Inlet 2013 quarterly seagrass monitoring seed bank density (seeds m^{-2}) per site.

Site	Mean Total seeds m^{-2}
A	31 ± 5
B	28 ± 7
C	36 ± 10
D	3 ± 1

Table 9. Mean Cairns Harbour and Trinity Inlet 2013 quarterly seagrass monitoring seed bank density (seeds m^{-2}) per month.

Month	Mean Total seeds m^{-2}
April	31 ± 8
July	41 ± 9
September	13 ± 3
December	13 ± 3

Seed bank density changed significantly with time for each site with maximum density found in April for sites A (*Z. capricorni* 52 ± 13 seeds m^{-2}) and D (*H. uninervis* 6 ± 5 seeds m^{-2}) and in July for sites B (*Z. capricorni* 75 ± 22 seeds m^{-2}) and C (*H. uninervis* 42 ± 23 seeds m^{-2}) (Figure 13; Appendix A.1.2). Lowest seed densities were reported in September for site A (20 ± 9 seeds m^{-2}) and C (3 ± 2 seeds m^{-2}) and in December for site B (14 ± 6 seeds m^{-2}) and D (2 ± 2 seeds m^{-2}).

Sites A and B were dominated by *Z. capricorni* seeds representing >96% of all seeds collected at these sites (Figure 13). Both *Z. capricorni* and *H. uninervis* were collected during all sampling periods at site C while only *H. uninervis* was found at site D. Unexpectedly *C. serrulata* seeds were also found at site A in December and in site C in September (Figure 13).

In addition to the quarterly seed bank sampling, Intensive spatial sampling of the viable seed bank across Cairns Harbour was completed in July 2013. Spatial patterns indicate that *Z. capricorni* seeds are greater in the in-shore areas of the monitoring meadows while *H. uninervis* is greater along the deeper edge of the intertidal sites, particularly in the Esplanade meadow (Jarvis et al 2013).

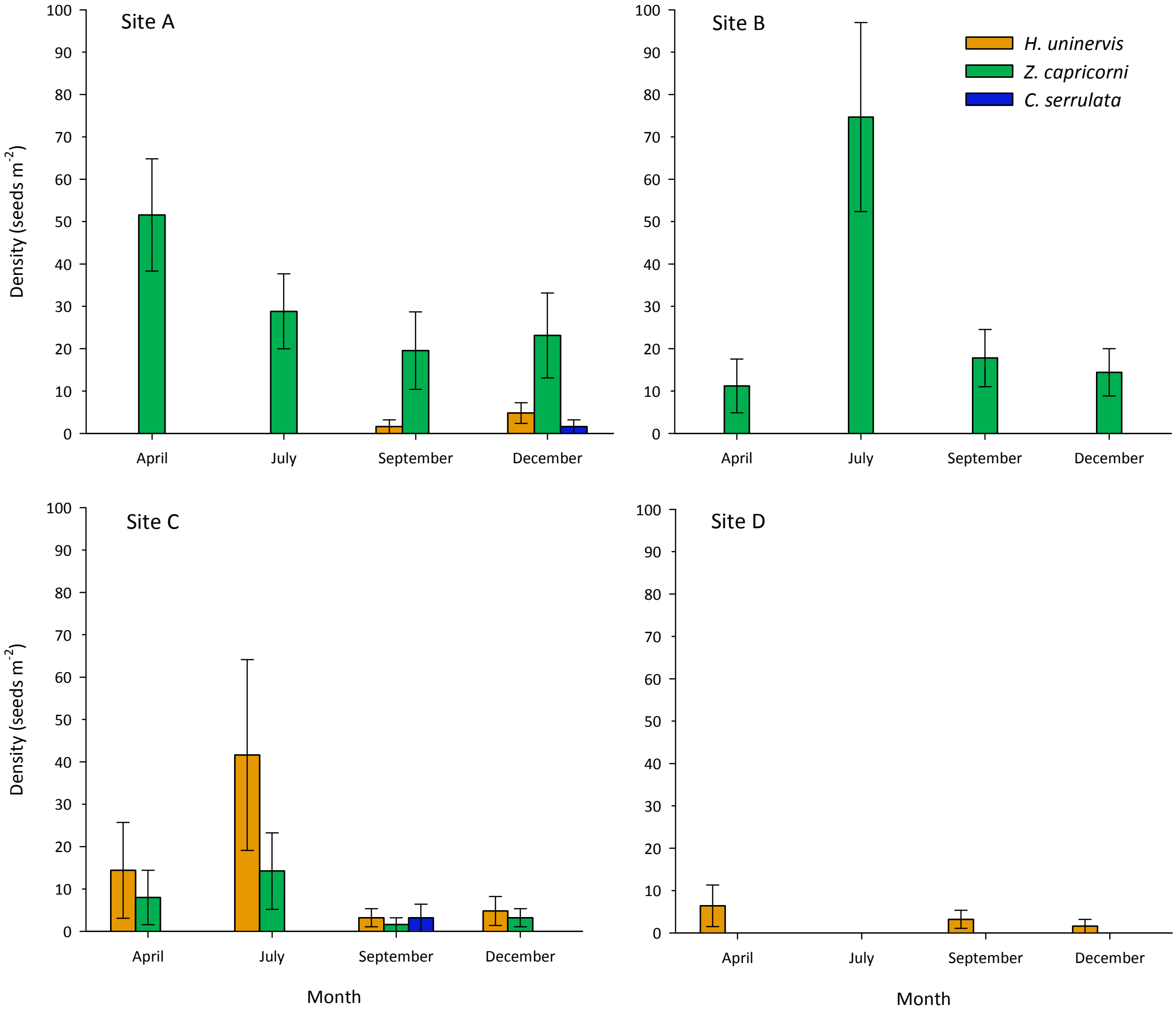


Figure 13. Changes in sediment seed bank density for all Cairns Harbour Quarterly monitoring sites (seed density error bars = SE).

3.3.3 Temperature and Light PAR Assessment

Benthic light and temperature was measured continuously from April to December 2013. Light levels, measured as total daily irradiance (mol m^{-2} day^{-1}), were consistently greater at site B on the intertidal bank at the southern end of the Esplanade and lowest for the subtidal site D at False Cape (Figure 14). Light levels were similar between the other two intertidal sites A and C. Light showed a limited seasonal effect with light decreasing slightly in the wet (December - May) compared to dry (June - November) seasons. Site D near False Cape is a completely subtidal site so lower light levels are to be expected. In addition a deep layer of extremely fine silty sediments covered the site which at times was likely to have completely buried the loggers further reducing light levels at this site.

Recent research investigating *Zostera capricorni* response to light suggests that intertidal communities in Gladstone Harbour require 6 mol m^{-2} day^{-1} over a 2 week average during the growing season (June-December) (Chartrand et al. 2012). Two of the three intertidal monitoring sites in Cairns that have previously supported *Zostera capricorni* (B & C) received in excess of 6 mol m^{-2} day^{-1} over a 2 week average for much of the 2013 growing season with minimal light stress events (> 3 consecutive days with 2 week average <6 mol m^{-2} day^{-1}). On 5 occasions during the 2013 growing season Site A had periods of light below the Gladstone threshold, with the longest event lasting 32 days during November/December.

Water temperatures fluctuated seasonally and were similar across all sites. Benthic water temperatures ranged from 20.6 ± 0.1 °C to 30.6 ± 0.1 °C at Site A, from 21.2 ± 0.2 °C to 30.4 ± 0.3 °C at site B, from 21.4 ± 0.4°C to 30.0 ± 0.1 °C at site C, and from 21.3 ± 0.1 °C to 30.6 ± 0.1 °C at Site D (Figure 14).

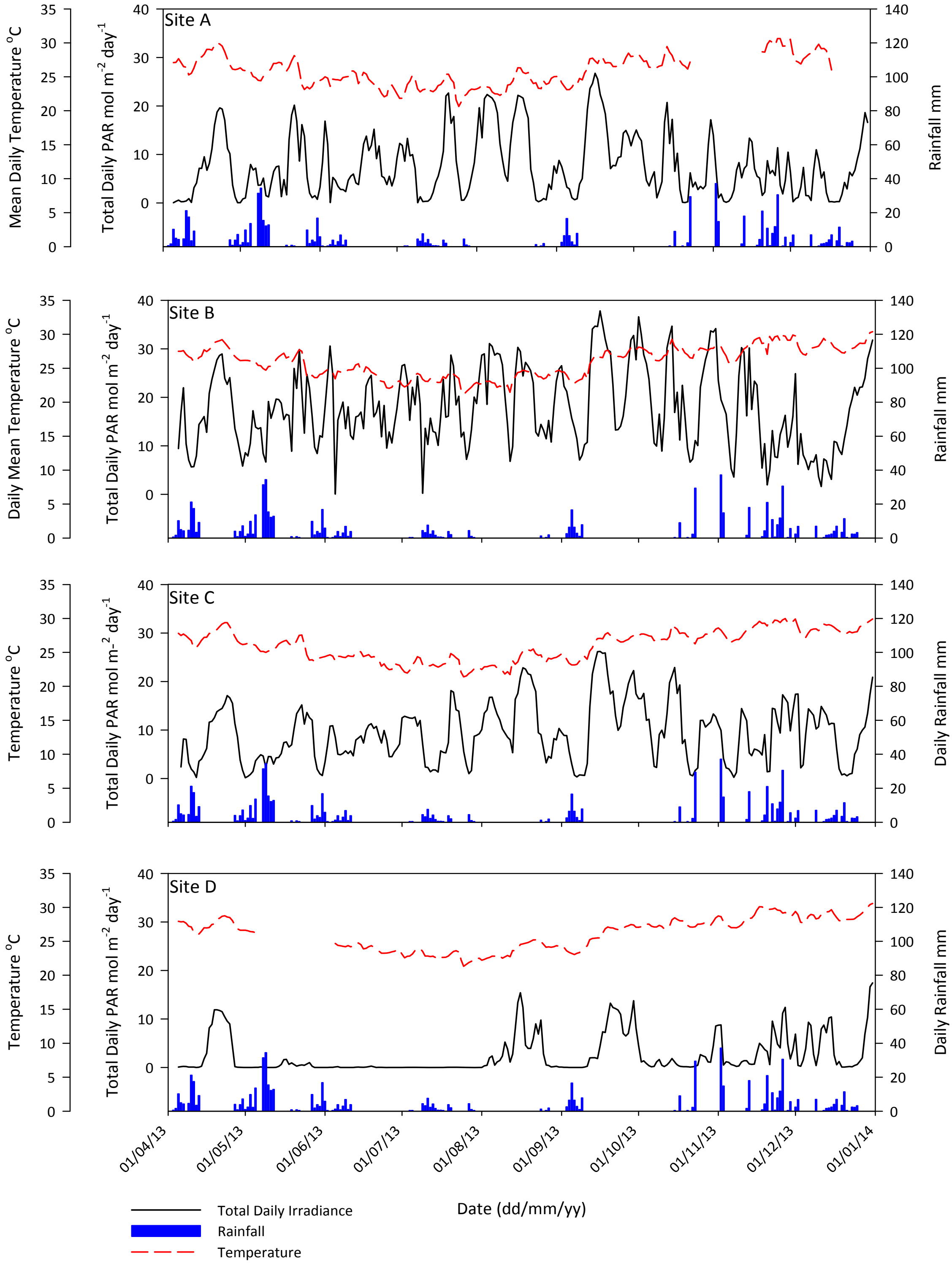


Figure 14. Total daily irradiance (mol m^{-2} day^{-1}), mean daily temperature (° C), and total daily rainfall (mm) for all Cairns Harbour quarterly monitoring sites. All data is from April to December 2013. Daily rainfall data source: Bureau of Meteorology, Station 31011, available at: www.bom.gov.au.

3.4 Cairns Climate Patterns Prior to 2013 Monitoring

3.4.1 Rainfall

Total annual rainfall in the Cairns region was below the long-term average (2086.5 mm) for first time in five years (Figure 15). The majority of rainfall in the twelve months prior to the 2013 survey fell in January 2013 (326.8 mm) and was below the long-term average of 427.7 mm for the month of March (Figure 16). For all other months, rainfall in the Cairns area generally remained below average leading up to the 2013 survey (Figure 16).

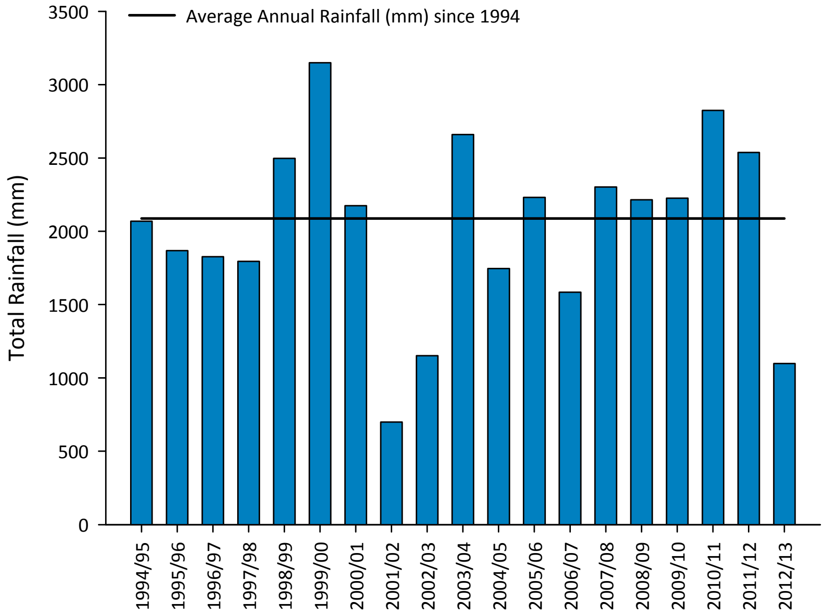


Figure 15. Total annual rainfall (mm) recorded at Cairns Airport, 1994 – 2013. Twelve month year (2012/13) is 12 months prior to survey. Source: Bureau of Meteorology, Station 31011, available at: www.bom.gov.au.

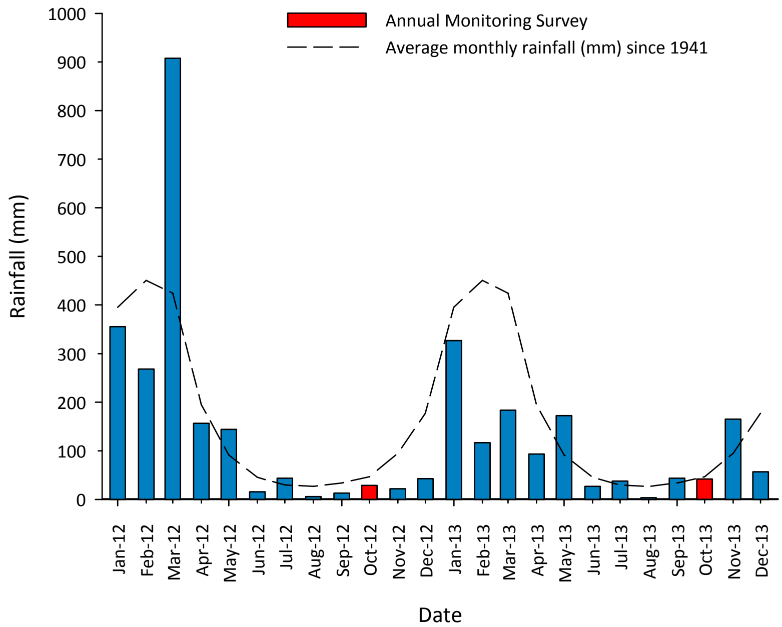


Figure 16. Total monthly rainfall (mm) recorded at Cairns Airport, January 2012 – December 2013. Source: Bureau of Meteorology, Station 31011, available at: www.bom.gov.au.

3.4.2 River Flow (Barron River)

River flow of the Barron River in 2012/2013 (294,009 ML) was also below the long-term average of 756,173 ML (Figure 17). In the twelve months prior to the 2013 survey the Barron River flow exceeded monthly averages in March only (Figure 18).

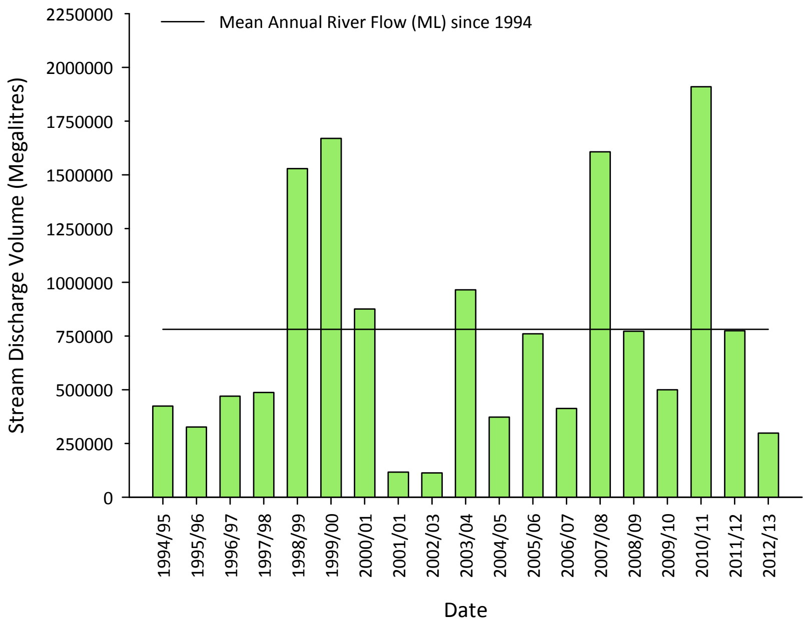


Figure 17. Annual water flow (mega litres) for the Barron River recorded at Myola, 1994 – 2013. Twelve month year (2012/13) is 12 months prior to survey. Source: Queensland Department of Environment and Resource Management, Station 110001D, available at: http://watermonitoring.derm.qld.gov.au/host.htm

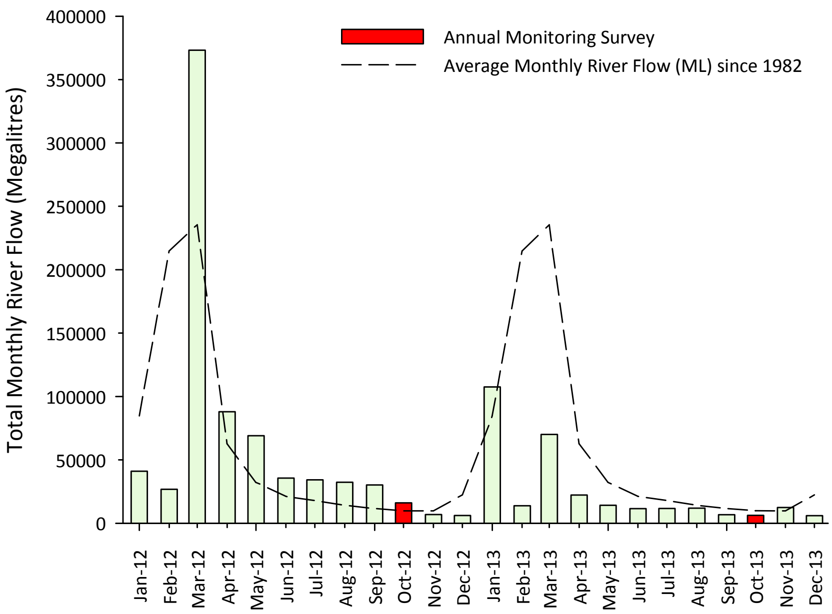


Figure 18. Monthly water flow (mega litres) for the Barron River recorded at Myola, January 2012 to December 2013. Source: Queensland Department of Environment and Resource Management, Station 916001B, available at: http://watermonitoring.derm.qld.gov.au/host.htm

3.4.3 Air Temperature

Mean annual maximum daily air temperature recorded at Cairns Airport in 2012-2013 (29.73°C) was 0.4°C warmer than the long term mean (29.33°C) (Figure 19). This followed two consecutive years of below average air temperature between 2010 and 2011. Mean monthly air temperature was at or slightly above the long-term monthly averages in the three months leading up to the start of the 2013 surveys (Figure 20).

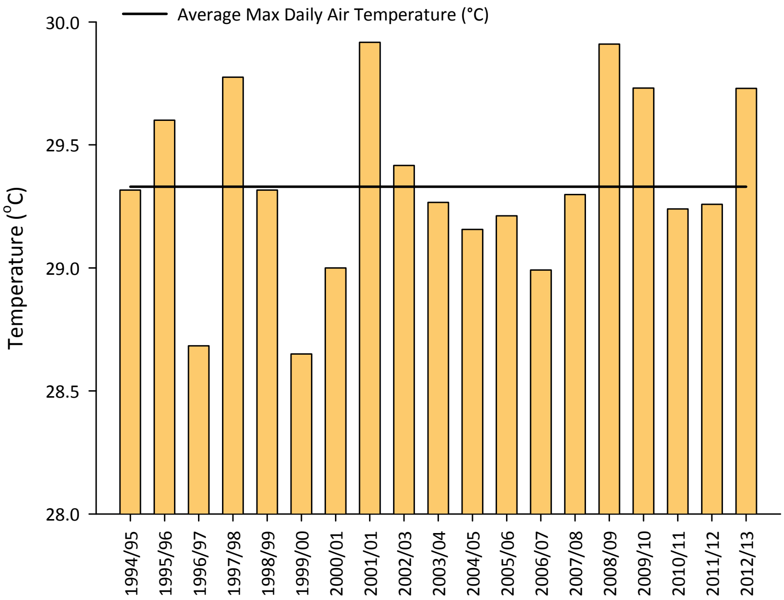


Figure 19. Mean annual maximum daily air temperature (°C) recorded at Cairns Airport, 1994 – 2013. Twelve month year (2012/13) is 12 months prior to survey. Source: Bureau of Meteorology, Station 031011, available at: www.bom.gov.au.

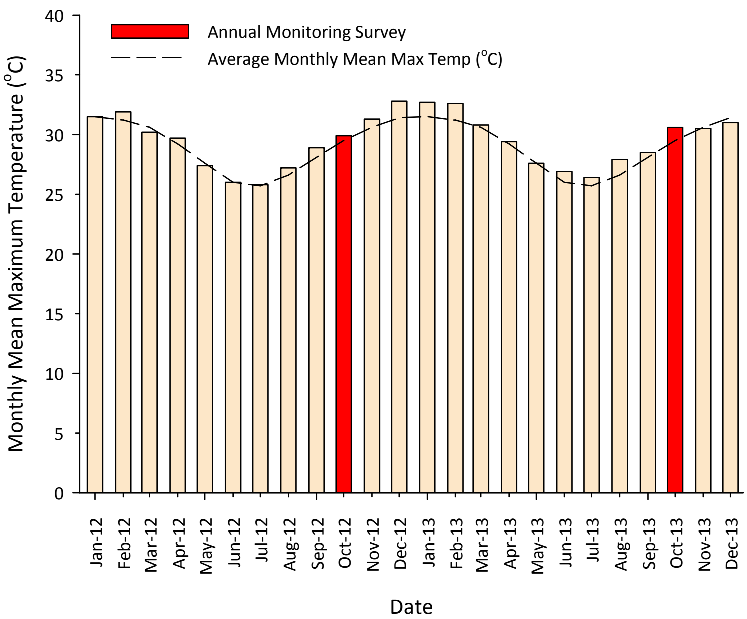


Figure 20. Monthly mean maximum daily air temperature (°C) recorded at Cairns Airport, January 2012 – December 2013. Source: Bureau of Meteorology, Station 31011, available at: www.bom.gov.au.

3.4.4 Daily Global Solar Exposure

Daily global solar exposure is a measure of the total amount of solar energy falling on a horizontal surface in one day. The values were usually highest in clear sun conditions during the spring/summer prior to the wet season beginning and lowest during winter (Bureau of Meteorology, 2013). Solar exposure in the Cairns area was above the long-term average (20.3 MJ m^2) after dropping below for the first time in five years (Figure 21). Solar exposure ranged between 17.6 MJ m^2 in July 2013 and 27.7 MJ m^2 in September 2013 (Figure 22). The monthly values leading up to the 2013 survey generally remained above the long-term monthly averages (Figure 22).

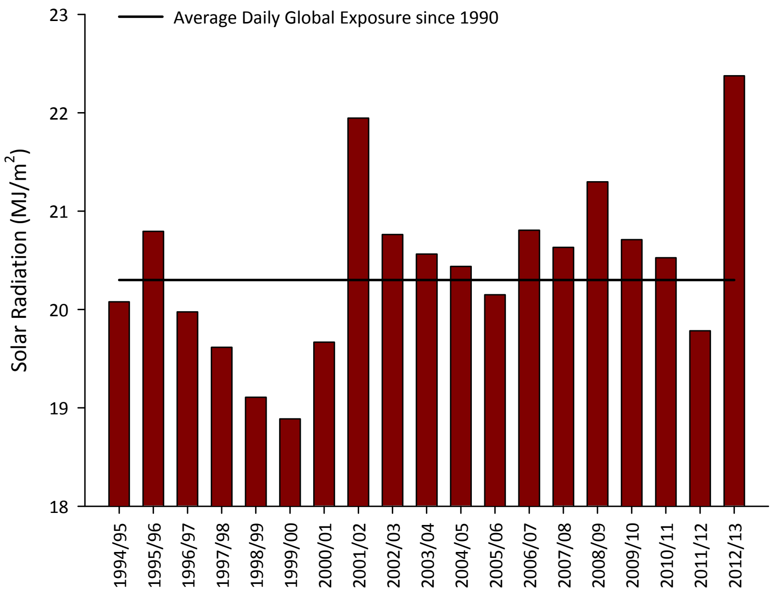


Figure 21. Mean annual daily global solar exposure (MJ m^2) recorded at Cairns Airport, 1994 – 2013. Twelve month year (2012/13) is 12 months prior to survey. Source: Bureau of Meteorology, Station. 031011, available at: www.bom.gov.au.

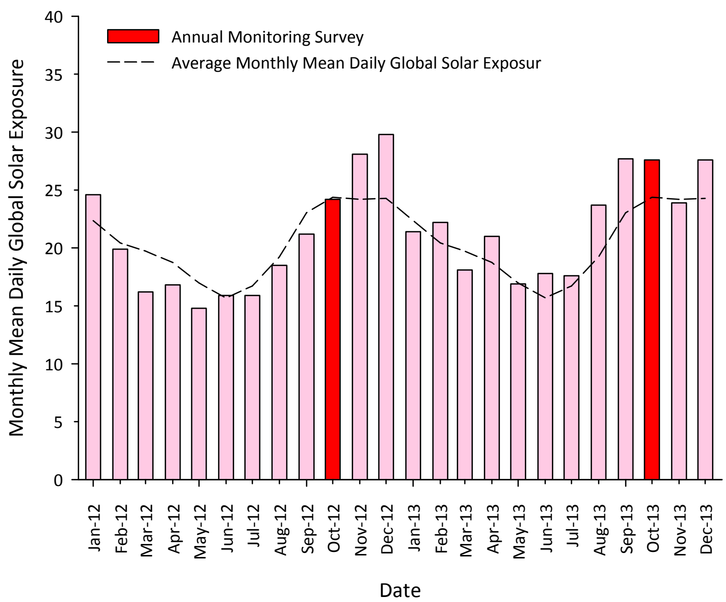


Figure22. Mean monthly daily global solar exposure (MJ m^{-2}) recorded at Cairns Airport, January 2012 – December 2013. Twelve month year (2012/13) is 12 months prior to survey. Source: Bureau of Meteorology, Station 031011, available at: www.bom.gov.au.

3.4.5 Tidal Exposure of Seagrass Meadows

Annual day time tidal air exposure of intertidal meadows has been below the 12-year long-term average (253.6 hrs) for the last five years (Figure 23). The intertidal areas in Cairns Harbour were exposed for the longest day time period in August 2013 (43 hrs) (Figure 24). In the month and three months prior to survey (the times that tidal exposure have been found to most affect seagrass meadows) the total number of hours that Cairns meadows were exposed decreased compared to 2012 (Figure 25).

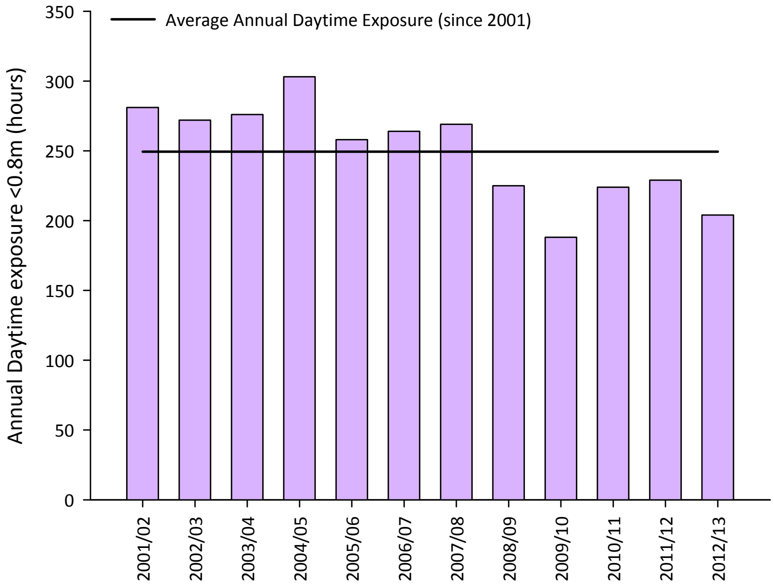


Figure 23. Annual daytime tidal exposure (total hours)* of seagrass meadows in Cairns Harbour; 2001 - 2013. Twelve month year is 12 months prior to survey. Source: Maritime Safety Queensland, 2013. *Assumes intertidal banks become exposed at a tide height of 0.8m above Lowest Astronomical Tide.

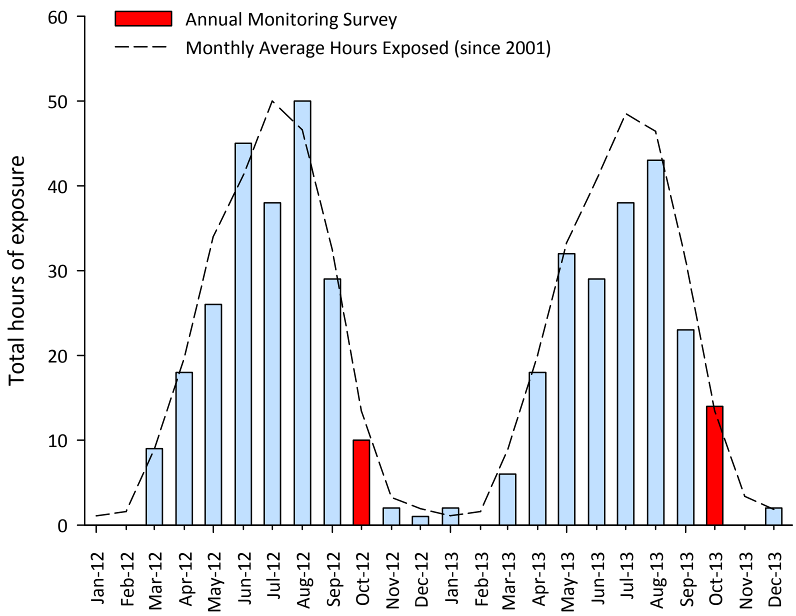


Figure 24. Total monthly daytime tidal exposure (total hours)* in Cairns Harbour; January 2012 – December 2013. Source: Maritime Safety Queensland, 2013. *Assumes intertidal banks become exposed at a tide height of 0.8m above Lowest Astronomical Tide.

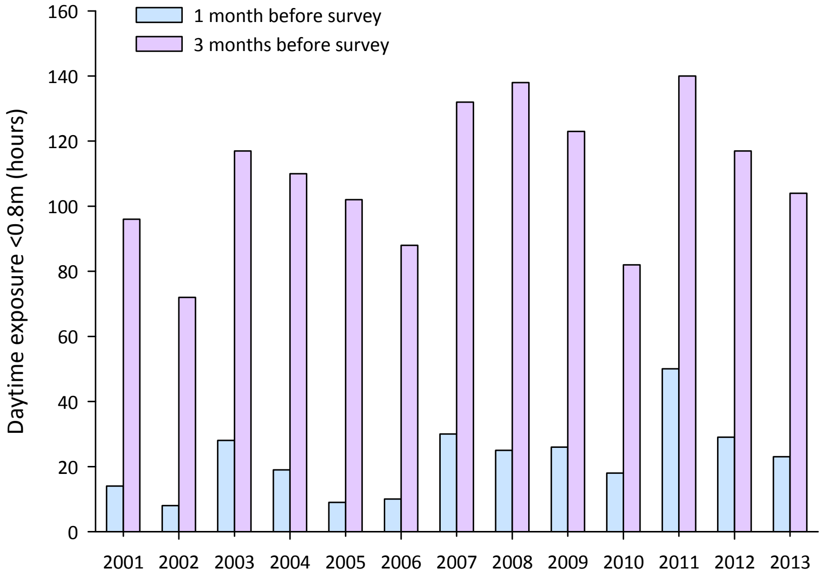


Figure 25. Total monthly daytime tidal exposure (total hours)* in Cairns Harbour in the one and three months prior to the annual survey 2001 – 2013. Source: Maritime Safety Queensland, 2013.
*Assumes intertidal banks become exposed at a tide height of 0.8m above Lowest Astronomical Tide.

4 DISCUSSION

The latest seagrass annual monitoring survey in Cairns Harbour and Trinity Inlet documented a modest increase in seagrass area and biomass from the historic lows recorded in 2012. However, the previously robust and expansive meadows are only found in small remnant patches that are likely to be highly vulnerable to further natural and anthropogenic impacts which could result in complete meadow loss. As a result the overall ranking of the Cairns Harbour and Trinity Inlet seagrass meadows with the seagrass meadow condition index remains ‘poor’. The limited recovery of seagrass in Cairns Harbour and Trinity inlet despite a return to favourable growing conditions in 2013 following multiple years of above average rainfall and severe storm and cyclone activity (2009-2011) highlights the reduced capacity for recovery in this system and its vulnerability.

The 2013 survey documents the first increase in seagrass area in Cairns Harbour and Trinity Inlet since 2009; however seagrass biomass and area remain well below the 13 year average. Monitoring meadows have undergone significant declines in biomass and distribution with substantial losses of seagrass observed after the 2010/11 La Niña events and TC Yasi. The large Esplanade and Bessie Point meadows have suffered major declines and have reduced to small remnant patches of seagrass. Since March 2012 conditions for seagrass growth have generally been much more favourable resulting in a slight increase in seagrass biomass and area observed in November 2013. The slow pace of recovery despite improving environmental conditions is most likely due to the near complete disappearance of meadows with little remaining seagrass from which recovery could occur.

The combination of high rainfall, high river flow and cyclones can negatively impact seagrass either physically (burial, scouring, direct removal of plants and seed-banks) (Preen et al. 1995; Bach et al. 1998; Campbell & McKenzie 2004) or physiologically (light limitation, excess nutrients and herbicides, and changes in salinity) (Björk et al. 1999; Ralph et al. 2007; Chartrand et al. 2012). We know that the quality and quantity of light is a critical determinant of seagrass growth and abundance (Ralph et al. 2007; Chartrand et al. 2012) and low light levels are thought to be the primary factor limiting the growth of many coastal seagrasses (Waycott et al. 2005). As low light conditions are prolonged, growth rates slow and plants drop leaves and shoots, thus reducing their abundance (Ralph et al. 2007; Collier et al. 2012). Studies of seagrasses in tropical regions have indicated that genera such as *Zostera* and *Halodule* have significantly greater light requirements (Grice et al. 1996; Bach et al. 1998; Longstaff & Dennison 1999; Longstaff 2003; Collier et al. 2009; Chartrand et al. 2012) than other genera such as *Halophila* species (Udy & Levy 2002; Fourqurean et al. 2003; Freeman et al. 2008). In Cairns it has been the higher light requiring species; *Zostera capricorni* and *Halodule uninervis* that have significantly declined in recent years with meadows dominated by these species either being lost or having reduced to small remnant patches since 2010.

Benthic light data collected as part of the 2013 quarterly monitoring program indicates that light levels were likely to be sufficient for *Z. capricorni* populations for much of the 2013 growing season at two of the sites where the species previously occurred. Until seagrass has recovered sufficiently at the quarterly monitoring sites the development of locally confirmed seagrass thresholds for light is not possible at Cairns Harbour. However, recent research investigating seagrass response to light in the Western Basin in Gladstone Harbour suggests that similar intertidal *Zostera capricorni* seagrass communities require 6 mol m^{-2} day^{-1} over a 2 week average during the growing season (June-December) (Chartrand et al., 2012). Although the response of seagrass to light conditions should be investigated on a site by site basis, the threshold value developed for the Western Basin can be used as an indication of how suitable the light environment may be for seagrass growth at the intertidal monitoring sites that have previously supported *Zostera capricorni* in Cairns (A, B & C) until a local value can be determined. Based on this value site A experienced five low light events where light levels were less than the light threshold from Gladstone. The longest event occurred at the end of the nominal growing season (November-December 2013).

It is likely that as the meadows in Cairns Harbour are in a recovery phase they may have a higher light requirement than for an established meadow. As part of this process the meadows are currently slowly expanding and therefore are expending energy on both persistence of the population and expansion into nearby areas (Shafer and Bergstrom, 2010). This may be additionally complicated by the fact that the meadows are now expanding into areas that have been unvegetated for several years and where sediment properties may have changed over time. As a result, the Cairns Harbour seagrass population may have a higher light requirement compared to established meadows that are expending most of their energy on bed maintenance only (Fonseca et al. 1998; Shafer and Bergstrom, 2010). A greater light requirement than similar seagrass populations in northern Queensland may explain some of the limited recovery in Cairns and highlights the need for the development of a localised light requirement.

In contrast the small *Halophila* dominated meadows in Trinity Inlet appear to have been less affected with increases in abundance and distribution recorded beginning in 2011. The *Halophila* dominated meadows in Trinity Inlet have been highly variable since monitoring began and this loss and recovery is typical for *Halophila* species which are well adapted to low light conditions (Udy & Levy 2002; Fourqurean et al. 2003) but are quick to decline when stressed by adverse conditions (Longstaff & Dennison 1999). The life history strategy of *Halophila* species means they are well adapted for recovery once conditions become favourable again as they are fast growing and rapid colonisers (Hammerstrom et al. 2006; Unsworth et al. 2010) producing large numbers of long lived seeds (McMillan 1991, Hammerstrom & Kenworthy 2003, Hammerstrom et al. 2006). These seeds can lie dormant in a sediment seed bank for at least two years.

There is little information available on the light requirements for *Halophila* species in subtidal meadows, although it is clear these species have a lower light requirement than the larger growing species such as *Zostera* and *Halodule* that dominate the shallower "higher light" areas of Cairns Harbour and Trinity Inlet. Estimates of light availability in *Halophila spinulosa* meadows in Moreton Bay indicate that the species can survive at light intensities of less than six per cent surface irradiance (Udy and Levy 2002). At Abbot Point light levels in subtidal seagrass meadows dominated by *Halophila* ranged between 0.28 – 4.5 mol m^{-2} d^{-1}). These ranges are well below the likely light requirements for *Zostera* (at least 4.5 mol m^{-2} d^{-1}; Chartrand et al. 2012) and *Halodule* (5.2 mol m^{-2} d^{-1}; Collier et al. 2012) yet were still capable of maintaining persistent *Halophila* meadows.

Of particular concern is the potentially limited capacity for the large *Zostera* and *Halodule* meadows to recover following the sustained declines, and almost complete loss of growing plants. Seagrasses are clonal plants and meadows can recover by vegetative means (asexual reproduction) through the extension of rhizomes (runners) as well through recruitment from propagules (seeds/sexual reproduction)(Rasheed 1999, Rasheed 2004; Inglis, 2000; Jarvis and Moore, 2010). Recovery by sexual reproduction is particularly important when there is complete loss of plants as has occurred in Cairns (Jarvis et al. 2010). Under these circumstances the meadows will be highly reliant on seeds stored in the sediments or recruitment of seeds or propagules through dispersal from elsewhere to re-establish.

Results of both the quarterly monitoring and a spatially comprehensive survey of the seagrass sediment seed bank in Cairns Harbour in July 2013 show that the mean total density of the seed bank was low across all sites and sampling times. Maximum density in 2013 was < 60 seeds m^{-2} significantly lower than other seagrass meadows that have been assessed previously in Queensland (*Zostera* 177 ± 28.4 seeds m^{-2}; Conacher et al. 1994a, Conacher et al. 1994b; *Halodule* 3,333 to 8,333 seeds m^{-2} Inglis, 2000). Seed viability was also low (Jarvis et al. 2013) and density continued to decline over time which indicates a potential bottleneck for the recovery of the Cairns Harbour seagrass populations from seed germination. While the area of seagrass in Cairns remains at historically reduced levels the *in situ* supply of seeds to replenish the sediment seed bank are also expected to remain low.

Although the existence of viable seeds in the Cairns area indicates the presence of a functioning sediment seed bank, it is not known how long the remaining viable seeds will persist under current conditions (Jarvis et al. 2013). Seed banks are characterised based on the length of time seeds remain viable in the sediment. Thompson et al. (1997) divided sediment seed banks into three main categories (1) transient (seeds persist in soil for less than 1 year); (2) short-term persistent (seeds that persist in the sediment for at least 1 but no more than 5 years); and (3) long-term persistent (seeds that persist in the sediment for > 5 years). Currently, the type of seed bank produced by *Zostera* and *Halodule* in Cairns is unknown.

The lack of a supply of new viable seeds in the seed bank combined with the gradual loss of viability of the existing seeds over time will further reduce the capacity of the seagrass meadows to recover to pre-2009 levels. With the significant and near complete loss of adult *Zostera* and *Halodule* plants in Cairns Harbour, and the low density of viable seeds remaining in the sediment seed bank, recovery and re-establishment of these meadows may be a slow process at current viable seed bank densities. These results paired with survey data collected as part of the annual and quarterly Cairns Harbour and Trinity Inlet seagrass monitoring program indicate that seagrass meadows in Cairns Harbour are in a 'poor' state with the remnant patches of seagrass highly susceptible to further stressors.

In summary, results of the 2013 monitoring indicate:

1. Seagrasses in Cairns Harbour and Trinity inlet were in a poor condition in 2013 with remnant meadows highly vulnerable to further impacts.
2. Positive signs were increases in biomass and area in most meadows from 2012; however they remained significantly below the long term average.
3. A seed bank remained for most areas that could facilitate further recovery, however density was low compared to similar meadows in northern Queensland and seed bank densities were declining over time for most sites. A reduced seed bank may limit the capacity for natural recovery of the system.
4. Light and climate conditions appeared to be favourable for seagrass growth at most sites in 2013 and the low levels of recovery observed are likely a reflection of previous catastrophic declines limiting the availability of propagules from which recovery could be initiated and sustained.
5. The deployment of light (PAR) and temperature logger in Cairns in 2013 enhanced the monitoring program and improved interpretation of meadow-scale change and the ability of the program to pinpoint the causes of seagrass declines and recovery.

4.1 Implications for Management

Results of the latest surveys show that seagrass meadows in Cairns Harbour and Trinity Inlet remain in a vulnerable state with the remnant patches of seagrass observed in 2013 having a reduced resilience to further stressors. The next 12 months will be critical for Cairns seagrasses. If the recovering patches of seagrass remain through the senescent season and some seeds remain viable then continued recovery in 2014 could occur. However these remnant seagrass patches are small and highly vulnerable and seed bank density and viability has been decreasing in the absence of replenishment. Future activities and development in the harbour and catchment should consider the state of seagrass resilience, and the vulnerability of these seagrasses as part of ongoing management strategies. In addition some consideration of what actions or research may be needed to assist recovery through restoration may be warranted in the event that natural recovery of these vital fisheries habitats fails.

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6 APPENDICES

A.1 Statistical Analysis

A.1.1. Summary of statistical results for mean above ground biomass versus year for monitoring meadows in the Cairns Harbour (2001 – 2012).

(A) One way ANOVA comparing seagrass mean above ground biomass between years (2001 – 2013) for the Cairns Harbour monitoring meadows 34, 11, 13, 19, 20 and 33. *** Significant difference at $p < 0.001$. Mean values for samples with seagrass present only.

	Esplanade to Ellie Point Meadow (34)					Bessie Point Meadow (11)				
	DF	SS	MS	F	Pr(>F)	DF	SS	MS	F	Pr(>F)
Year	11	127.5	11.59	25.34	***	11	19.46	1.769	10.09	***
Residuals	663	303.2	0.457			467	81.91	0.1754		

	South Bessie Point Meadow (13)					Inlet (Ho) Meadow (19)				
	DF	SS	MS	F	Pr(>F)	DF	SS	MS	F	Pr(>F)
Year	6	21.54	3.589	9.998	***	12	12.45	1.0378	12.58	***
Residuals	80	28.72	0.359			126	10.4	0.0825		

	Redbank (Zc) Meadow (20)					Redbank (Ho) Meadow (33)				
	DF	SS	MS	F	Pr(>F)	DF	SS	MS	F	Pr(>F)
Year	9	37.43	4.159	12.36	***	11	27.77	2.525	15.49	***
Residuals	86	28.94	0.337			245	39.94	0.163		

(B) Results of Tukey's post hoc comparison comparing mean above-ground seagrass biomass in the core monitoring meadows M34, M11, M13, M19, M20 and M33 at Cairns Harbour. Cells marked with a "Yes" indicates a significant difference in meadow biomass ($p < 0.05$) between comparison years and cells marked "No" indicates no significant difference in meadow biomass between years.   NP means there was not enough biomass to run the analysis and '--' means there was no data collected during that timeframe.

M34	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
2001													
2002	No												
2003	No	Yes											
2004	Yes	Yes	Yes										
2005	Yes	Yes	Yes	No									
2006	No	Yes	No	Yes	No								
2007	No	No	No	Yes	Yes	No							
2008	No	Yes	No	Yes	No	No	No						
2009	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes					
2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No				
2011	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No			
2012	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP		
2013	No	No	No	Yes	Yes	No	No	No	No	No	No	No	

M11	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
2001													
2002	No												
2003	No	No											
2004	No	No	No										
2005	Yes	Yes	Yes	Yes									
2006	Yes	Yes	Yes	No	No								
2007	Yes	No	No	No	No	No							
2008	Yes	No	Yes	No	No	No	No						
2009	Yes	No	Yes	No	No	No	No	No					
2010	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes				
2011	No	No	No	No	Yes	Yes	No	No	Yes	No			
2012	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP		
2013	No	No	No	No	Yes	No	No	No	No	No	No	No	

M13	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
2001													
2002	--												
2003	--	--											
2004	--	--	--										
2005	--	--	--	--									
2006	--	--	--	--	--								
2007	--	--	--	--	--	No							
2008	--	--	--	--	--	No	No						
2009	--	--	--	--	--	No	No	No					
2010	--	--	--	--	--	Yes	Yes	Yes	Yes				
2011	--	--	--	--	--	Yes	Yes	No	Yes	No			
2012	--	--	--	--	--	No	No	No	No	No	No		
2013	--	--	--	--	--	No	No	No	No	No	No	No	

M19	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
2001													
2002	Yes												
2003	No	No											
2004	Yes	Yes	No										
2005	No	Yes	No	No									
2006	Yes	No	Yes	Yes	Yes								
2007	No	Yes	No	No	No	No							
2008	Yes	No	No	No	No	No	No						
2009	Yes	No	No	No	No	No	Yes	No					
2010	Yes	No	Yes	Yes	No	No	Yes	Yes	No				
2011	No	Yes	No	No	No	Yes	No	No	Yes	Yes			
2012	Yes	No	No	No	No	No	No	No	No	Yes	No		
2013	No	No	No	No	No	No	No	No	No	Yes	No	No	

M20	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
2001													
2002	No												
2003	Yes	Yes											
2004	Yes	Yes	No										
2005	No	No	No	Yes									
2006	No	No	No	Yes	No								
2007	No	No	No	Yes	No	No							
2008	Yes	Yes	No	No	No	No	No						
2009	No	No	No	No	No	No	No	No					
2010	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes				
2011	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP			
2012	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP		
2013	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	

M33	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
2001													
2002	--												
2003	--	Yes											
2004	--	No	Yes										
2005	--	No	No	No									
2006	--	No	Yes	No	Yes								
2007	--	No	No	No	No	Yes							
2008	--	No	No	No	No	No	No						
2009	--	Yes	No	Yes	Yes	Yes	No	No					
2010	--	No	Yes	Yes	Yes	No	Yes	Yes	Yes				
2011	--	No	No	No	No	No	No	No	Yes	Yes			
2012	--	No	No	No	No	No	No	No	No	No	No		
2013	--	Yes	No	No	No	Yes	No	No	No	Yes	No	No	

A.1.2 Summary of statistical results for mean seed bank density versus month for quarterly monitoring sites in the Cairns Harbour (2001 – 2012).

(A) Results of negative binomial regression comparing seagrass mean seed bank density between month (April-December 2013) and species (*Z. capricorni* and *H. uninervis*) when applicable for the Cairns Harbour monitoring sites, A, B, C, D. *** Significant difference at $p < 0.001$. Mean values for samples with seagrass present only.

	Site A				Site B			
	Est.	**SE**	**Z value**	**Pr(>Z)**	**Est.**	**SE**	**Z value**	**Pr(>Z)**
Intercept	3.94	0.05	84.92	***	2.42	0.09	25.57	***
April	--	--	--	--	--	--	--	--
July	-0.58	0.08	-7.76	***	1.79	0.10	17.56	***
September	-0.97	0.09	-10.95	***	0.46	0.12	3.75	***
December	-0.80	0.08	-9.62	***	0.25	0.13	2.00	0.05

	Site D			
	Est.	**SE**	**Z value**	**Pr(>Z)**
Intercept	1.86	0.13	14.85	***
April	--	--	--	--
July	--	--	--	--
September	-0.69	-0.22	-3.20	***
December	-1.39	0.28	-4.96	***

	Site C			
	Est.	**SE**	**Z value**	**Pr(>Z)**
Intercept	2.67	0.08	32.01	***
April	--	--	--	--
July	1.06	0.10	10.97	***
September	-1.50	0.20	7.70	***
December	-1.10	-1.10	-6.59	***
Species (HU)	--	--	--	--
Species (ZC)	-0.59	0.14	-4.22	***
July:ZC	0.42	0.16	2.68	***
September:ZC	-0.11	0.34	-0.31	0.75
December:ZC	0.18	0.27	0.68	0.50

(B) Results of Tukey's post hoc comparison comparing mean seed bank density the quarterly monitoring sites A-D at Cairns Harbour. Cells marked with a "Yes" indicates a significant difference in meadow biomass ($p < 0.05$) between comparison years and cells marked "No" indicates no significant difference in meadow biomass between years.

Site A	April	July	Sept	Dec
April				
July	Yes			
Sept	Yes	Yes		
Dec	Yes	No	No	

Site B	April	July	Sept	Dec
April				
July	Yes			
Sept	Yes	Yes		
Dec	No	Yes	No	

Site D	April	July	Sept	Dec
April				
July	No			
Sept	Yes	No		
Dec	Yes	No	No	

Site C**	April	July	Sept	Dec	ZC	HU
April						
July	Yes					
Sept	Yes	Yes				
Dec	Yes	Yes	No			
ZC						Yes
HU					Yes	

****There were no significant interaction terms in the Tukey's post hoc test for site C therefore the data is not included in this report.**

A.2 Above-Ground Biomass and Area changes: 2001 – 2013

Table 10a. Seagrass monitoring meadow area (ha) in Cairns Harbour and Trinity Inlet, 2001-2013 (% values indicate change in area from previous survey; ± R = reliability estimate).

Meadow	Area (ha) (R)												
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Esplanade to Ellie Pt. **(34)**	307.3 ± 10.0	258.5 ± 12.2 (-16%)	280.4 ± 11.7 (+8%)	300.8 ± 12.3 (+7%)	328.91 ± 6.47 (+9%)	370.8 ± 6.5 (+13%)	418.9 ± 6.4 (+13%)	379.3 ± 19.2 (-9.5%)	362.8 ± 13.37 (-4.3%)	92.1 ± 11.51 (-74%)	78.6 ± 37.93 (-15%)	7.4 ± 0.40 (-91%)	9.0 ± 1.0 (+21%)
Bessie Pt. **(11)**	351.8 ± 133.9	451.2 ± 137.3 (+28%)	473.5 ± 148.8 (+5%)	659.3 ± 158.5 (+39%)	820.4 ± 86.6 (+24%)	868.1 ± 81.6 (+6%)	899.7 ± 81.3 (+4%)	803.3 ± 25 (-11%)	766.2 ± 34.06 (-4.6%)	97.2 ± 9.33 (-87%)	116. 1± 46.47 (+19%)	20.7± 0.5 (+82%)	27.1 ± 15.1 (+31%)
South Bessie Pt. Meadow **(13)**	NP	NP	NP	Included in Meadow 11	Included in Meadow 11	73.0 ± 6.3	162.8 ± 8.4 (+123%)	197.7 ± 15.4 (+21%)	170.3 ± 9.63 (-13.8%)	54.2 ± 9.41 (-68%)	8.3 ± 3.42 (-84%)	NP	0.03 ± 0.02 (+100%)
Inlet **(19)**	1.7 ± 0.6	4.9 ± 1.6 (+195%)	6.9 ± 1.7 (+4%)	5.2 ± 1.5 (-25%)	2.3 ± 1.3 (-56%)	1. 8 ± 1.3 (-23%)	2.9 ± 1.4 (+60%)	0.6 ± 0.4 (-79%)	1.2 ± 1.46 (+100%)	3.68 ± 1.26 (+206%)	6.5 ± 3.17 (+76%)	2.3 ± 1.3 (-65%)	2.5 ± 2.2 (+9%)
Redbank (Zc) **(20)**	1.7 ± 1.1	0.1 ± 0.05 (-94%)	0.7 ± 0.4 (+600%)	0.8 ± 0.4 (+14%)	0.4 ± 0.1 (-50%)	0.5 ± 0.2 (+20%)	0.8 ± 0.2 (+60%)	0.6 ± 0.4 (-25%)	0.6 ± 0.68	0.37 ± 0.47 (-38%)	NP	NP	NP
Redbank (Ho) **(33)**	NA	4.0 ± 1.4[+]	4.4 ± 1.3 (+9%)	3.9 ± 1.2 (-11%)	2.8 ± 1.0 (-28%)	1.4 ± 1.1 (-50%)	2.4 ± 1.2 (+71%)	1.4 ± 0.4 (-42%)	1.9 ± 1.32 (+35.7%)	3.84 ± 1.13 (+102%)	1.1 ± 1.54 (-71%)	0.5 ± 0.3 (-55%)	3.5 ± 2.7 (+566%)
TOTAL **(monitoring meadows only)**	**662.5 ± 145.7**	**718.9 ± 152.6**	**765 ± 163.9**	**970 ± 173.9**	**1154.8 ± 95.5**	**1315.5 ± 96.9**	**1487.5 ± 98.9**	**1382.9 ± 60.8**	**1303 ± 60.52**	**254 ± 33.11**	**210.6 ± 92.50**	**30.9 ± 2.50**	**42.1 ± 21.0**

NP = meadow not present

Table 10b. Mean above-ground biomass (g DW m^2) of seagrass for monitoring meadows in Cairns Harbour and Trinity Inlet, 2001-2013.

Meadow	Mean biomass ± SE (g DW m^{-2})												
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Esplanade to Ellie Pt. (34)*	36.0 ± 3.2	18.0 ± 1.7	46.2 ± 4.1	81.6 ± 6.7	71.6 ± 5.3	47.4 ± 3.4	33.2 ± 2.9	48.4 ± 4	10.2 ± 3.3	1.1 ± 0.7	0.8± 0.1	NA	3.5 ± 2.3
Bessie Pt. (11)*	2.0 ± 0.4	6.4 ± 0.8	4.4 ± 0.4	5.8 ± 0.3^	15.6 ± 1.5	12.7 ± 1.7	6.9 ± 0.5	7.5 ± 0.4	7.3 ± 1.1	0.5 ± 0.2	1.8± 0.4	NA	2.2 ± 0.6
South Bessie Pt. Meadow (13)*	NP	NP	NP	Included in Meadow 11	Included in Meadow 11	46.3 ± 9.0	50.9 ± 10.4	24 ± 4	36.1 ± 7.6	1.7 ± 1.2^	1.1 ± 0.7	NP	3.1
Inlet (19)*	6.6 ± 2.1	0.4 ± 0.1	3 ± 0.5	1.8 ± 0.3	3.6 ± 1.2	0.1 ± 0.0	2.3 ± 0.3	0.4 ± 0.2	1.6 ± 0.3	0.1 ± 0.2	3.5 ± 0.4	1.1 ± 0.2	1.3 ± 0.3
Redbank (Ho)* (33)	4.5 ± 4.1	3.1 ± 0.6	50.1 ± 9.4	61.5 ± 12.1	15.1 ± 7.4	11.9 ± 2.9	14.1 ± 3.5	37.5 ± 6.8	30.4 ± 10.8	0.2 ± 0.2	1.2 ± 0.6	0.9 ± 0.2	1.2 ± 0.6
Redbank (Zc)* (20)	NA	0.8 ± 0.1	6.6 ± 1.1	1.3 ± 0.2	2.2 ± 0.4	0.3 ± 0.0	2.1± 0.3	2.1 ± 0.4	0.1 ± 0.04	0.4 ± 0.2	NP	NP	NP

Meadows indicated by an * had significant differences in biomass among years (see Appendix A.1).

^ The one site containing *Cymodocea serrulata* was omitted from Bessie Point biomass analysis and *Cymodocea rotunda* was omitted from South Bessie Point biomass analysis.

NP = meadow not present

NA = biomass values not available due to insufficient biomass samples

(Ho = *Halophila ovalis*; Zc = *Zostera capricorni*)

Appendix D13.3 Benthic Macro-Invertebrates of Cairns Harbour and Trinity Inlet: Survey – 2012/13

BENTHIC MACRO-INVERTEBRATES OF CAIRNS HARBOUR AND TRINITY INLET:

Survey – 2012/13

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Report No. 13/39

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BENTHIC MACRO-INVERTEBRATES OF CAIRNS HARBOUR AND TRINITY INLET:

Survey – 2012/13

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EXECUTIVE SUMMARY

This report details results of the algae and benthic macro-invertebrate component of the Cairns Harbour and Trinity Inlet baseline survey conducted between October 2012 and January 2013 as part of investigations for the Cairns Shipping Development Project EIS. The 2012/13 baseline survey of the Port of Cairns provided a comprehensive assessment of algae and benthic macro-invertebrates, and the most comprehensive assessment of seagrass distribution and abundance since 2001.

Results of the survey found that the Port of Cairns contained a diverse range of benthic community types that were typical of communities found in estuarine and deep water areas elsewhere in the tropical Queensland such as the Port of Abbot Point, Port of Hay Point, and Port Curtis. Typically the majority of these areas are dominated by open substrate with only a low density of benthic individuals.

In the Port of Cairns habitat forming benthic macro-invertebrates were predominantly found in the outer harbour area with little to no benthic macro-invertebrates occurring in the inner harbour or Trinity Inlet. This result contrasted the occurrence of macro algae which tended to occur in areas of the inner harbour and Trinity Inlet rather than the outer harbour area. While a diversity of taxa and community types were found, the dominant benthic habitat feature in the Port of Cairns was open substrate containing a low per cent cover of benthic life. There were no benthic communities that could be described as “high density” and there were no unique or unusual benthic macro-invertebrate or algal communities found within the survey area. Many of the algae and benthic macro-invertebrate communities described in this survey occurred in proximity to maintained channels, port facilities and the dredge spoil disposal site.

This was the first time that algae and benthic macro-invertebrate communities have been examined at this scale in the Port of Cairns and the 2012/13 survey provides a baseline from which future changes can be assessed. The survey provides a good indication of the location of significant benthic communities in the port but it is likely that many of the communities described would vary seasonally and between years and the potential for changes to distribution and density should be considered when interpreting the results.

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1 INTRODUCTION

The Port of Cairns is located within Trinity Bay and Trinity Inlet, and operated by Ports North. It is one of Queensland's busiest ports and handles bulk and general cargo, cruise ships, fishing fleets and passenger ferries. Existing port infrastructure includes twelve operational wharves, commercial fishing bases, a barge ramp, marina and mooring facilities, swing basins and a 10km long channel which is subject to annual maintenance dredging (Ports North, 2013).

Ports North is investigating the potential to improve shipping access to the Port of Cairns and accommodate a larger class of cruise vessels. The Cairns Shipping Development Project (CSDP) would involve:

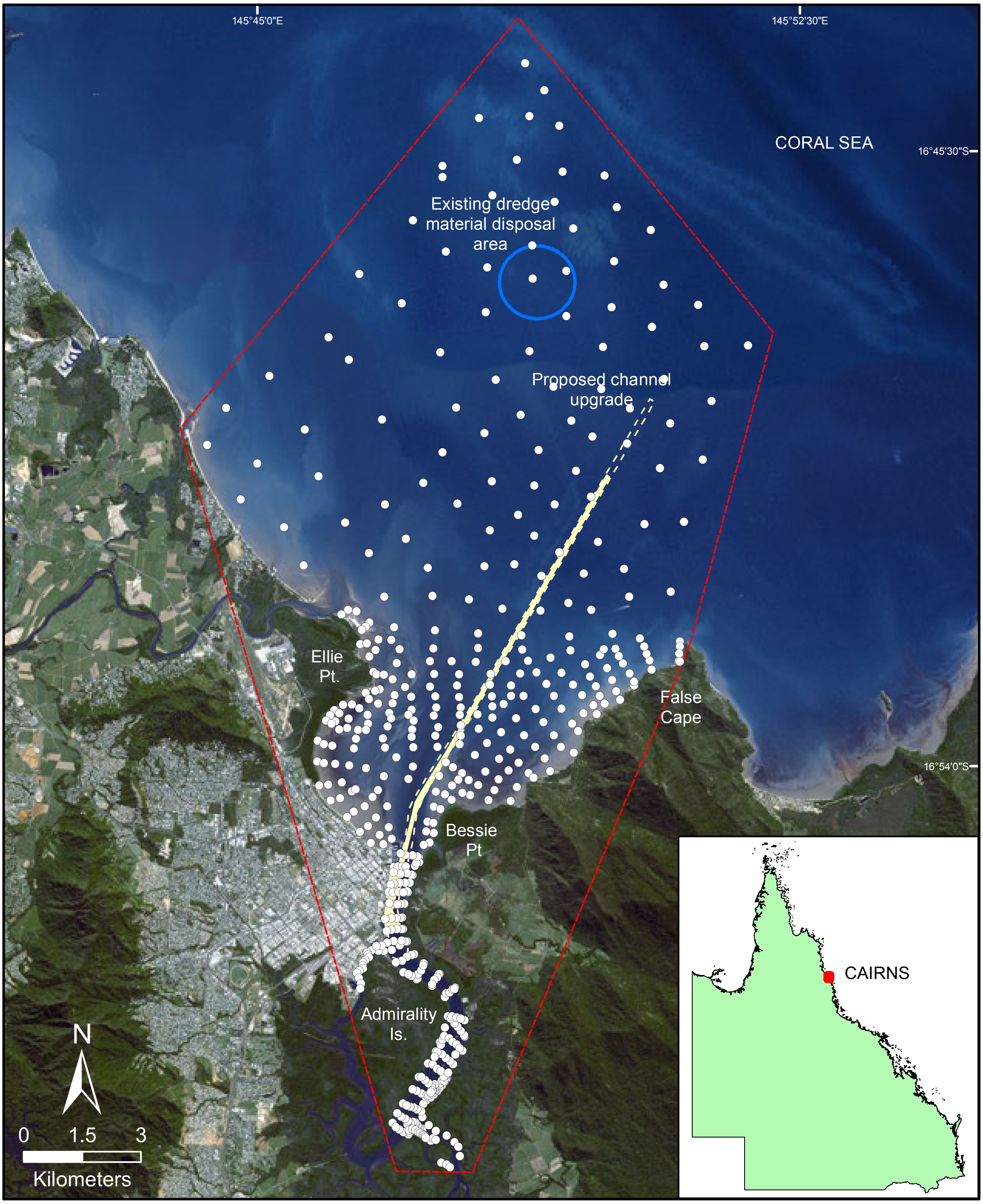
- Widening and deepening of the existing shipping channel and basins;
- Expansion of the existing dredge material placement area (DMPA) and/or provision of a new DMPA to accommodate dredge spoil from capital and maintenance dredging.

In partnership with the James Cook University - Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER), Ports North commissioned studies to identify and assess any significant benthic marine habitats and benthic macro-invertebrate communities within the port. These studies were commissioned in preparation for the planned capital dredging program associated with the CSDP to inform port management and project application processes.

As part of the annual seagrass monitoring exercise in 2012, the JCU/TropWATER Seagrass Group conducted a baseline survey of seagrass and other benthic habitats, and benthic macro-invertebrates (BMI) within the greater port limits of the Port of Cairns (Map 1). The sampling approach was based on the need to update data on seagrass communities, and establish baseline data on other significant habitat forming BMI communities.

This report details results of the algae and benthic macro-invertebrate component of the 2012/13 baseline survey in the Port of Cairns. For information on seagrass distribution and abundance please see Rasheed et al (2013).

Map 1. Port of Cairns baseline survey extent and survey sites 2012/13



Legend

- Survey Sites
- Survey area
- Existing channel

Source:
McKenna SA, Rasheed MA, Sankey T & Tol S.J 2013. 'Benthic macro-invertrbates of Cairns Harbour and Trinity Inlet: Baseline Survey - 2012/13'. JCU Publication, Centre for Tropical Water & Aquatic Ecosystem Research, Cairns.

2 METHODOLOGY

2.1 Survey Approach

Seagrass, algae and benthic macro-invertebrate communities within the limits outlined in Map 1 were surveyed between October 2012 and January 2013. The survey had two major components; a coastal intertidal to shallow subtidal survey, and an offshore (deep water) survey.

Sampling and mapping techniques applied were standard methodologies developed by the TropWATER Seagrass Group for assessing seagrass and, benthic marine habitats and macro-invertebrates in tropical environments. Techniques ensure that a large area of seafloor is integrated at each site to take into account the spatial variability and patchiness common for many tropical benthic communities as well as logistical issues associated with naturally high water turbidity and the presence of dangerous marine animals including saltwater crocodiles. The methods used in the CSDP baseline survey have been used as part of baseline and long term monitoring programs throughout Queensland including the Ports of Townsville, Mourilyan Harbour, Gladstone, Mackay, Weipa, Karumba, Thursday Island and Abbot Point (see McKenzie et al. 1996; Rasheed & Taylor 2008; Rasheed et al. 1996; Rasheed et al. 2001; Rasheed et al. 2003a; Rasheed et al. 2003b; Rasheed et al. 2005; Roelofs et al. 2001) as well as throughout the Great Barrier Reef Lagoon and other locations off the Queensland coast (Coles et al. 1996; 2000; 2002). Using standardised methods also enables direct comparisons of the results from Cairns with other Queensland locations.

2.2 Survey Methods

The survey area included intertidal and subtidal areas extending from north of the existing dredge material disposal area, and south to Redbank Creek in Trinity Inlet (Map 1). The survey area encompassed intertidal and subtidal areas with a focus on identifying benthic marine flora and fauna habitats and did not attempt to characterise the mangrove fringe found at the edges of the survey extent or the upper reaches of the rocky shoreline between Bessie Point and False Cape.

A variety of sampling methods were used to survey benthic habitats and benthic macro-invertebrates in the Port of Cairns. Methods applied were based on existing knowledge of benthic habitats and physical characteristics of the area such as depth, visibility and logistical and safety constraints. Three sampling techniques were used:

1. Intertidal areas: Helicopter survey
2. Shallow subtidal areas: Boat based underwater CCTV drop camera
3. Deep water areas: Boat based CCTV camera sled tows

2.2.1 Intertidal areas: Helicopter survey

Intertidal habitat boundaries and characteristics were determined using a helicopter around spring low tides when habitats were exposed. Habitat characteristics and composition were collected at sites scattered within the exposed survey area as the helicopter hovered within two metres above the sediment (Figure 1). The presence, density and composition of algae and benthic macro-invertebrates were determined within a 10m circular area out the side of the helicopter. The position of submerged areas likely to contain benthic communities was also noted to help focus efforts during subtidal surveys.

Figure 1. Helicopter survey of exposed benthic habitats.

2.2.2 Shallow subtidal areas: Boat based underwater CCTV drop camera

Assessments of shallow subtidal areas were conducted from a small research vessel. An underwater CCTV camera system with real-time monitor was mounted to a 0.25 m^2 quadrat which provided live images allowing researchers to record presence, density and composition of algae, benthic macro-invertebrates and sediment type from three random placements of the quadrat (Figure 2). A Van Veen grab (grab area 0.0625 m^2) was used in conjunction with the camera system to confirm species viewed on the video screen and sediment type (identified as shell grit, rock, gravel (>2000µm), coarse sand (>500µm), sand (>250µm), fine sand (>63µm) and mud (<63µm)). Survey sites were located along transects perpendicular to the shoreline extending to approximately 6m below mean sea level (MSL) with random sites used to measure continuity of bottom habitat between transects. Sampling intensity was at approximately 50 to 500m intervals along each transect or where major changes in bottom topography occurred.

Figure 2. Shallow subtidal mapping of seagrass meadows using CCTV system and Van Veen sediment grab.

2.2.3 Deep water areas: Boat based CCTV camera sled tows

Offshore sites (spoil ground and outer channel) were surveyed from a research vessel with stern winching capability. At each sampling site the real-time underwater camera system was towed for approximately 100 metres at drift speed (approx. one knot). Footage was observed on a TV monitor and recorded. The CCTV camera was mounted on a sled that incorporates a sled net 600 mm width and 250 mm deep with a net of 10 mm-mesh aperture (Figure 3). Surface benthos was captured in the net (semi-quantitative bottom sample) and used to confirm benthic habitat characteristics observed on the monitor (Figure 3). The Van Veen grab (grab area 0.0625 m^2) was used to confirm sediment type (identified as shell grit, rock, gravel (>2000µm), coarse sand (>500µm), sand (>250µm), fine sand (>63µm) and mud (<63µm)). Survey sites were scattered throughout the survey area with sampling intensity approximately 500m to 2km apart.

Figure 3. Deep water sled tows using CCTV system and sled net.

2.3 Habitat Characterisation

2.3.1 Benthic macro-invertebrates

At intertidal and shallow subtidal sites where habitat forming BMI were present, they were identified into the following four broad taxonomic groups:

- ***Hard corals -*** All massive, branching, tabular, digitate and mushroom scleractinian corals.
- ***Soft corals -*** All alcyonarian corals i.e. corals lacking a hard limestone skeleton.
- ***Sponges -*** All sponges were grouped together.
- ***Other BMI -*** Any other BMI identified e.g. oysters, ascidians, bivalves, gastropods and holothurians.

At deep water sites (spoil ground and outer channel) benthic macro-invertebrates visible on the monitor and those collected in the sled net and grab were identified into 13 taxonomic groups in the field (see Table 2). Counts were made of the number of taxa and individuals.

For all survey sites a benthic macro-invertebrate community density category was determined. Five community density categories were used:

- ***Open substrate*** - dominant feature was bare substrate with occasional isolated benthic macro-invertebrate individuals.
- ***Low density*** - benthic macro-invertebrates present in <10% of the 10m circular area from the helicopter or on the screen for < 10% of the site video record.
- ***Low/Medium density*** - benthic macro-invertebrates present in 10 - 20% of the of the 10m circular area from the helicopter or the site video record.
- ***Medium density*** – benthic macro-invertebrates present in 20-80% of the 10m circular area from the helicopter or the site video record.
- ***High density*** - benthic macro-invertebrates present in >80% of the 10m circular area from the helicopter or the site video record.

2.3.2 Macro Algae

At all sites within the survey area where macro algae were present, they were identified into the following five functional groups:

- ***Erect macrophytes -*** Macrophytic algae with an erect growth form and high level of cellular differentiation e.g. *Sargassum*, *Caulerpa* and *Galaxaura* species.
- ***Erect calcareous -*** Algae with erect growth form and high level of cellular differentiation containing calcified segments e.g. *Halimeda* species.
- ***Filamentous -*** Thin thread-like algae with little cellular differentiation.
- ***Encrusting -*** Algae growing in sheet like form attached to substrate or benthos e.g. coralline algae.
- ***Turf Mat -*** Algae that forms a dense mat or "turf" on the substrate.

For each site a macro algae density category was determined. Density categories were defined by the overall per cent cover of algae for each site. The relative proportion of the total cover made up of each of the algal functional groups for each site defined the community type. Four community density categories were used:

- ***Open substrate*** - dominant feature was bare substrate.
- ***Low density -*** algae covered <10% of the substrate.
- ***Medium density -*** algae covered between 10% and 50% of the substrate.
- ***High density -*** algae covered >50% of the substrate.

2.4 Habitat Mapping and Geographic Information System

All survey data was entered into a Geographic Information System (GIS) for presentation of benthic community distribution and abundance. Maps were generated in ArcGIS utilising recent aerial and satellite imagery. Other information including depth below MSL, substrate type and the shape of existing geographical features such as banks and channels were used to assist in mapping. A precision estimate (in metres) was assigned for the habitat regions mapped based on the mapping methodology used in determining the boundary. Boundaries were based on the mid-point between the last site where a particular habitat (seagrass/algae/benthic macro-invertebrate) type was present and the next site where it was absent. The precision estimate ranged from ±5m to ±500m dependent on the distance between sites and size of the region. The mapping precision estimate was used to calculate a range of area for each region and was expressed as a reliability estimate (R) in hectares. Additional sources of mapping error associated with digitising and rectifying base maps and with GPS fixes for survey sites were assumed to be embedded within the reliability estimates.

2.4.1 Benthic Macro-invertebrates

Two GIS layers were created in ArcGIS to describe the Port of Cairns benthic macro-invertebrate communities:

- ***Survey sites -*** GPS sites containing all benthic macro-invertebrate community data collected at benthic survey sites.

- ***Benthic community density and category -*** area data for benthic macro-invertebrate community regions. Community types within this layer were determine according to overall taxa composition observed on the video and collected in the sled net at sites within each region; and density was determined by the mean per cent time benthic macro-invertebrates were present in the 10m circular area from the helicopter and on the video record for sites within regions.

2.4.2 Macro Algae

Two GIS layers were created in ArcGIS to describe the Port of Hay Point macro-algae communities:

- ***Survey sites*** - GPS sites containing all algae data collected at benthic survey sites.
- ***Macro Algae community per cent cover and category*** - area data for macro-algae community regions. Algal community types within this layer were determined according to overall taxa composition observed in the helicopter area, on the video and collected in the sled net at sites within each region; and per cent cover category was determined by the mean per cent cover of macro-algae determined from the helicopter area and the video record for sites within regions.

3 RESULTS

A total of 572 habitat characterisation sites were surveyed for algae and benthic macro-invertebrates in the 2012/13 baseline survey. In general algae and benthic macro-invertebrate communities within the survey area were typical of estuarine habitats in the region. The dominant habitat feature was open mud/sand substrate with a low-medium percentage cover of benthic life.

3.1 Benthic macro-invertebrates

Benthic macro-invertebrates occurred throughout much of the outer harbour survey area and along the rocky intertidal/shallow subtidal regions between Bessie Point and False Cape and were comprised of a diverse suite of taxa (Maps 2 & 3). No significant areas of habitat forming benthic macro-invertebrates were found in the inner harbour or Trinity Inlet (Map 3). While there was a diversity of taxonomic groups identified in the outer harbour, the dominant community types in that area were those that had a low density of macro-invertebrates, with open substrate comprising the majority of the area (Map 2; Table 1 & 2). Benthic macro-invertebrate communities were divided into regions based on the community composition and density of individuals. There were three density categories; low, low/medium and medium, and a range of different community types within the density categories, combining to give thirteen different benthic macro-invertebrate region types (Maps 2 & 3; Table 1). There were three areas with communities of medium density benthic macro-invertebrates with the rest of the regions being classified as open, low or low/medium density communities (Maps 2 & 3; Table 1). There were no high density communities identified in the survey area.

Open substrate with occasional isolated benthic individuals

This was the lowest density category used to describe benthic macro-invertebrate regions and formed the majority of the survey area. There was one community type in this category (Maps 2 & 3; Tables 1 & 2). Although density of individuals was low, macro-invertebrate isolates within this region were from a wide range of taxonomic groups (Table 2). This region was found throughout the outer and inner harbour areas and Trinity Inlet (Maps 2 & 3).

Figure 4. Example of open substrate (frame taken from video footage in Jan 2013)

Low density benthic communities

Community types in this category were the most extensive and collectively covered 5336.5 ha of the survey area. There were five community types in this density category (Maps 2 & 3; Tables 1 & 2).

Region 2. *Mostly open substrate with patches of low density bivalves and low numbers of individual polychaetes.* This region formed part of a band of rocky oyster beds between Bessie Point and False Cape in the intertidal-shallow subtidal area.

Regions 3 & 6. *Mostly open substrate with patches of low density sea pens, hydroids and ascidians with low individual numbers of other taxa*. These low density communities occurred in the outer harbour. These benthic communities were found to be present in the footprint of the proposed channel expansion area of the outer harbour.

Regions 4 & 5. *Mostly open substrate with patches of low density bryozoans and hydroids and low individual numbers of other taxa.* These regions covered 2248.81 ha and occurred either side of the shipping channel in the outer harbour. Region 4 occurred as an isolated pocket on the east side of the shipping channel towards False Cape.

Region 7. *Mostly open substrate with patches of low density sea pens, hydroids and ascidians with moderate numbers of individual polychaetes & low numbers of other taxa*. This low density community occurred in the outer harbour at the northern extent of the survey area and overlapped with the current dredge material disposal area. Other taxa in this community included solitary and soft corals, sea pens, brachyurans, carid shrimps, stomatopods, bivalves and gastropods.

Region 8. *Mostly open substrate with patches of low density sea pens, hydroids and ascidians with moderate numbers of individual echinoids*. This region was one of the smaller areas in the outer harbour survey area and was bordered by region 13 a moderate density benthic community.

Low/Medium density benthic communities

There were two community types in this density category that collectively covered 95.42 ha of the survey area (Maps 2 & 3; Tables 1 & 2).

Region 10. *Mostly open substrate with patches of medium density bivalves & low numbers of individual polychaetes*. This region formed part of a band of rocky oyster beds between Bessie Point and False Cape in the intertidal-shallow subtidal area and covered 5.09 ha.

Region 12**.** *Mostly open substrate with patches of low/medium density hard and soft coral with sea pens, and low numbers of individual echinoids and bivalves*. This community occurred as a small area (90.33 ha) in the outer harbour to the west of the shipping channel. Video footage of this area featured a variety of hard and soft corals with sea pens interspersed throughout the area.

Figure 5. Example of patches of soft coral in Region 12
(frame taken from video footage in Jan 2013)

Medium density benthic communities

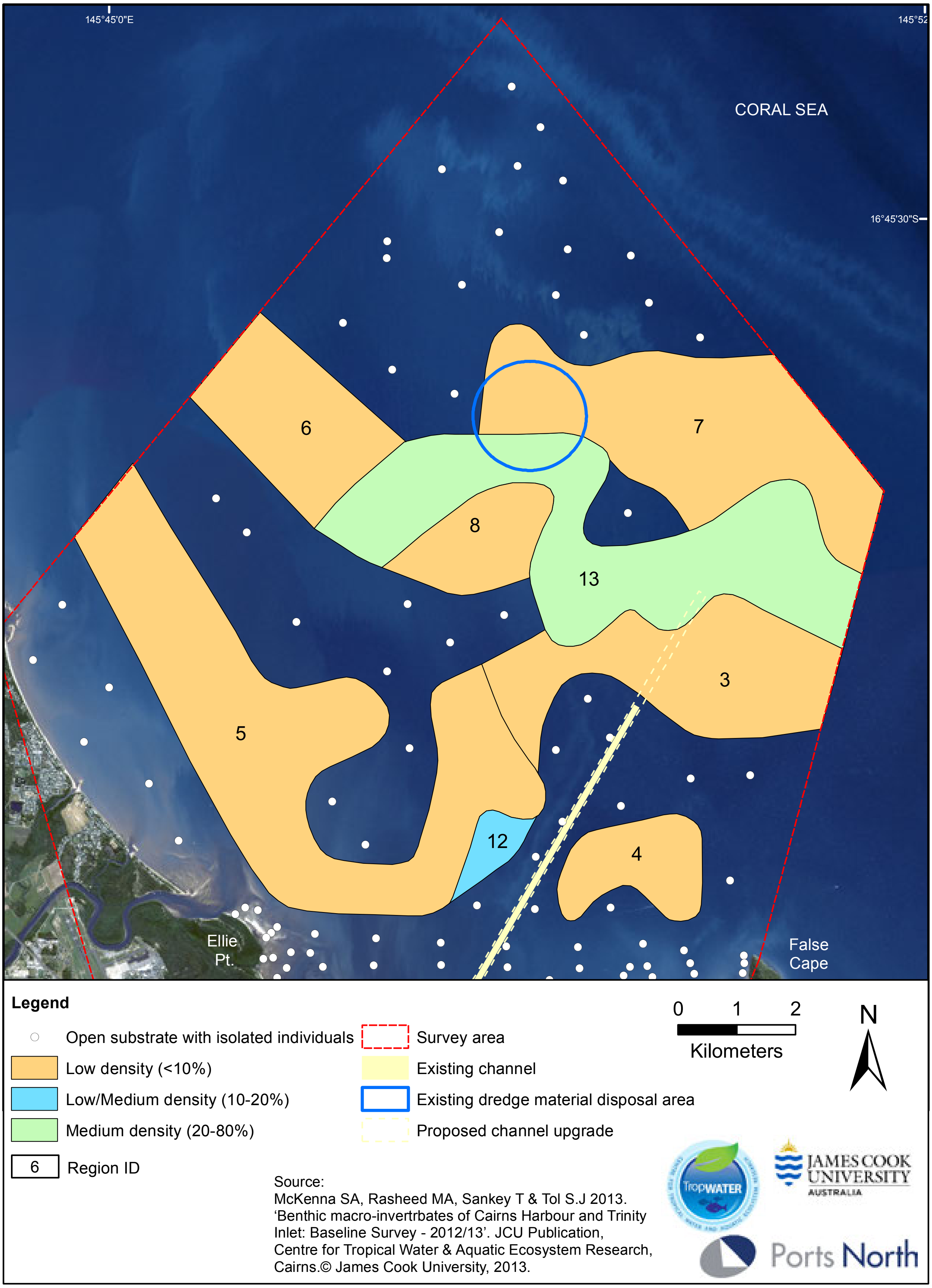
This was the highest density category present in the Port of Cairns and formed a large section of the outer harbour survey area. There were two community types in this category (Maps 2 & 3; Tables 1 & 2).

> ***Regions 9 & 11.*** *Patches of medium density bivalves & low numbers of individual polychaetes, with areas of open substrate.* These regions formed part of a band of rocky oyster beds between Bessie Point and False Cape in the intertidal-shallow subtidal area and encompassed the low density 'Region 2'. Collectively, these regions covered 11.83 ha.

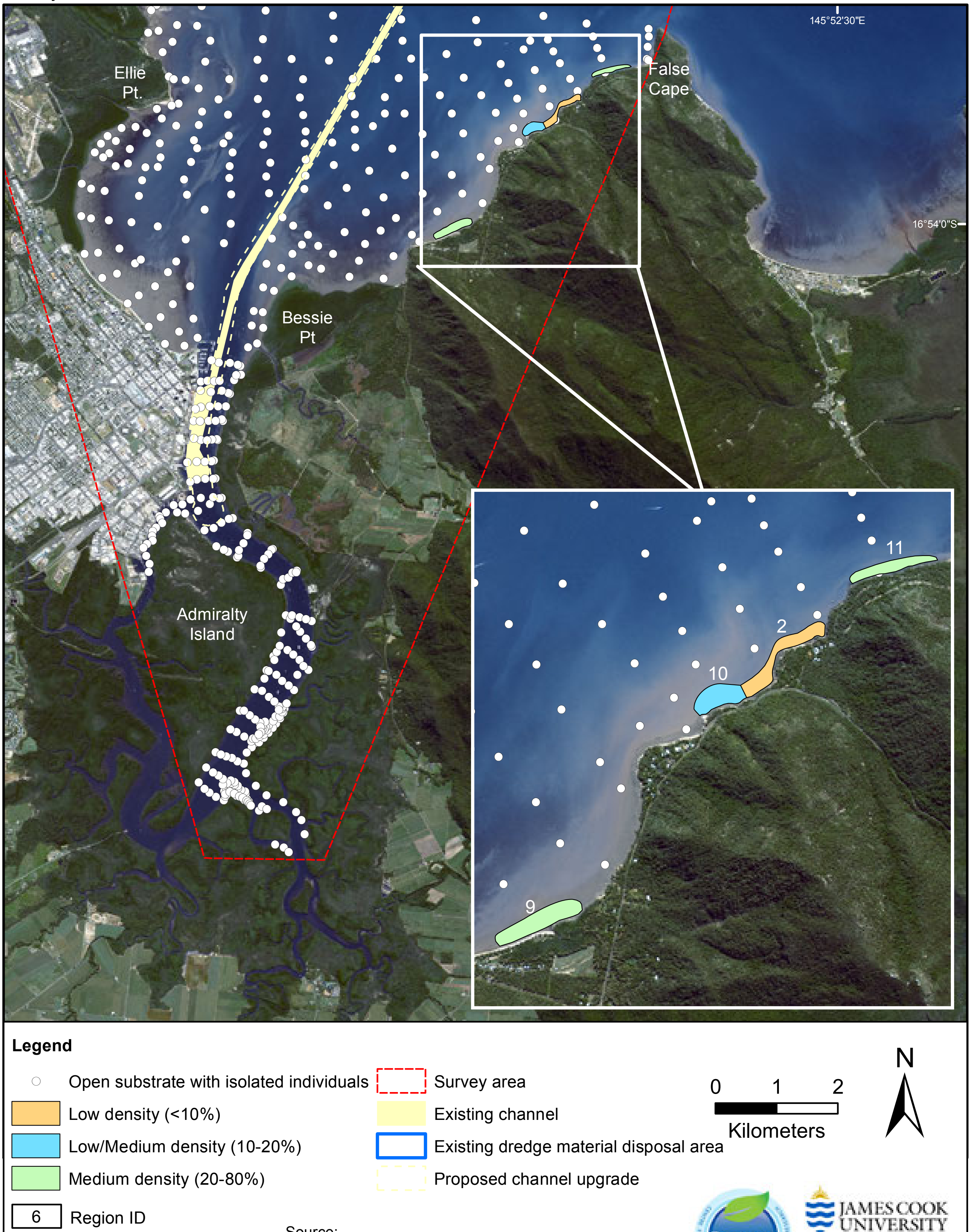
> ***Region 13.*** *Patches of medium density sea pens, hydroids & ascidians with areas of open substrate and low numbers of individual bryozoans, soft coral, echinoids, crustaceans & bivalves.* This region was the largest medium density region and covered 1454.56 ha of the outer harbour survey area. The benthic communities in this region overlapped with the southern edge of the current dredge material disposal area.

Figure 6. Example of patches of medium density sea pens
in Region 13 (frame taken from video footage in Jan 2013)

Map 2. Benthic macro-invertebrate (BMI) community regions in the outer harbour of the Port of Cairns, 2012/13



Map 3. Benthic macro-invertebrate (BMI) community regions in the inner harbour of the Port of Cairns & Trinity Inlet, 2012/13



Source:
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Table 1. Benthic macro-invertebrate regions in the Port of Cairns – density, region description, and number of sites in each region.

Density category	Benthic macro-invertebrate region description	Region ID (see maps 2 & 3)	No. of sites	Area ± R (ha)
Open substrate, occasional benthic individuals	Open substrate with isolated benthic individuals	1 (white survey sites on maps 2 & 3)	517	na
Low density benthic community	mostly open substrate with patches of low density bivalves & low numbers of individual polychaetes	2	2	6.59 ± 0.89
	mostly open substrate with patches of low density sea pens, hydroids and ascidians with low individual numbers of other taxa	3 & 6	9	1482.69 ± 561.99
	mostly open substrate with patches of low density bryozoans and hydroids and low individual numbers of other taxa	4 & 5	19	2248.81 ± 1730.27
	mostly open substrate with patches of low density sea pens, hydroids and ascidians with moderate numbers of individual polychaetes & low numbers of other taxa	7	9	1276.88 ± 604.34
	mostly open substrate with patches of low density sea pens, hydroids and ascidians with moderate numbers of individual echinoids	8	2	321.53 ± 76.96
Low/ Medium density benthic community	mostly open substrate with patches of medium density bivalves & low numbers of individual polychaetes	10	1	5.09 ± 0.48
	mostly open substrate with patches of low/medium density hard and soft coral with sea pens, and low numbers of individual echinoids and bivalves	12	1	90.33 ± 50
Medium density benthic community	patches of medium density bivalves & low numbers of individual polychaetes, with areas of open substrate	9 & 11	2	11.83 ± 1.41
	patches of medium density sea pens, hydroids & ascidians with areas of open substrate and low numbers of individual bryozoans, soft coral, echinoids, crustaceans & bivalves	13	10	1454.56 ± 837.26
Total		**13**	**572**	6898.29 ± 3863.60

Table 2. Benthic macro-invertebrate communities in the Port of Cairns – density and types of taxa present for each benthic community region.

Taxonomic Group		Benthic Community Region												
		Open Substrate	2	3	4	5	6	7	8	9	10	11	12	13
Annelidia	Polychaete	L	L					M		L	L	L		
Sipuncula	Unsegmented worm													
Ectoprocta	Encrusting bryozoan	L												
	Erect bryozoan	L		L		L								L
	Motile bryozoan													L
Cnidaria **Anthozoa**														
Zoantharia	Zoanthid													
	Anemone													
	Solitary coral	L			L	L		L						
Alcyonaria	Gorgonian													
	Sea pen	L		L				L						H
	Soft coral	L		L	L	L		L					H	L
Hydrozoa	Hydroid	L		L		L	L	L						L
Echinodermata	Asteroid	L				L								
	Crinoid	L												
	Echinoid	L		L	L	L	L		M				L	L
	Holothuroid	L												
	Ophiuroid	L												
Ctenophora	Jelly fish	L						L						
Urochordata	Ascidian	L		L				L	L					L
Porifera	Sponge	L												
Foraminiferida	Foram													
Arthropoda														
Crustacea	Brachyuran	L		L	L	L	L	L	L					L
	Penaeid prawn	L				L								L
	Carid shrimp	L		L		L		L						L
	Stomatopod							L						
	Barnacle													
	Other decapod													
Isopoda	Isopod (sea lice)							L						
Mollusca	Bivalve	L	L	L	L	L		L		M	M	M	L	L
	Gastropod	L		L		L	L	L						L
	Cephalopod			L										
	Nudibranch													
	Chiton													
	Sea hare													
Vertebrata	Fish	L		L		L	L	L						L
	Seahorse													
Other	Egg Mass													

(L = low, average of <4 individuals per site; M = medium, 4-10 individuals per site; H = high, average of >10 individuals per site)

3.2 Macro Algae

Macro algal communities occurred in isolated areas throughout the survey area and covered 675.28 ha (Maps 4 - 6). Despite their wide distribution the per cent cover of algae was typically low with 77% of the macro algae regions mapped having less than 10% cover of algae (Maps 4-6; Table 3). There were no high density macro algal communities identified in the survey area and only four of the five functional groups were identified. Erect macrophytic algae were the dominant algal types in the survey area and while not all species were identified the most common types of erect macrophytes present were species of the genus *Sargassum*. These algal communities generally occurred on open mud/sand sediment with other isolated benthic macro-invertebrates.

Macro algae communities were divided into categories based on the per cent cover of algae and their community composition. Macro algae regions fell into two density categories; low and medium, with ten different community types identified within these categories, combining to give twenty-one individual regions (Maps 4-6; Table 3).

Low density macro algal communities

The 'low' density category was the most common algal category and covered 593.22 ha throughout the survey area (Maps 4-6; Table 3). Six community types were identified within this category. Only two areas of low density algae were found in the outer harbour and these areas were dominated by erect macrophytic algae (Map 4; Table 3; Figure 7). Some erect calcareous algae of the genus *Halimeda* was found in region 14 of the outer harbour. This region also overlapped with a small patch of moderate density *Halophila decipiens* that was found as part of the seagrass component of this baseline survey. Region 5 in the outer harbour overlapped the southern edge of the current dredge material disposal area (Map 4).

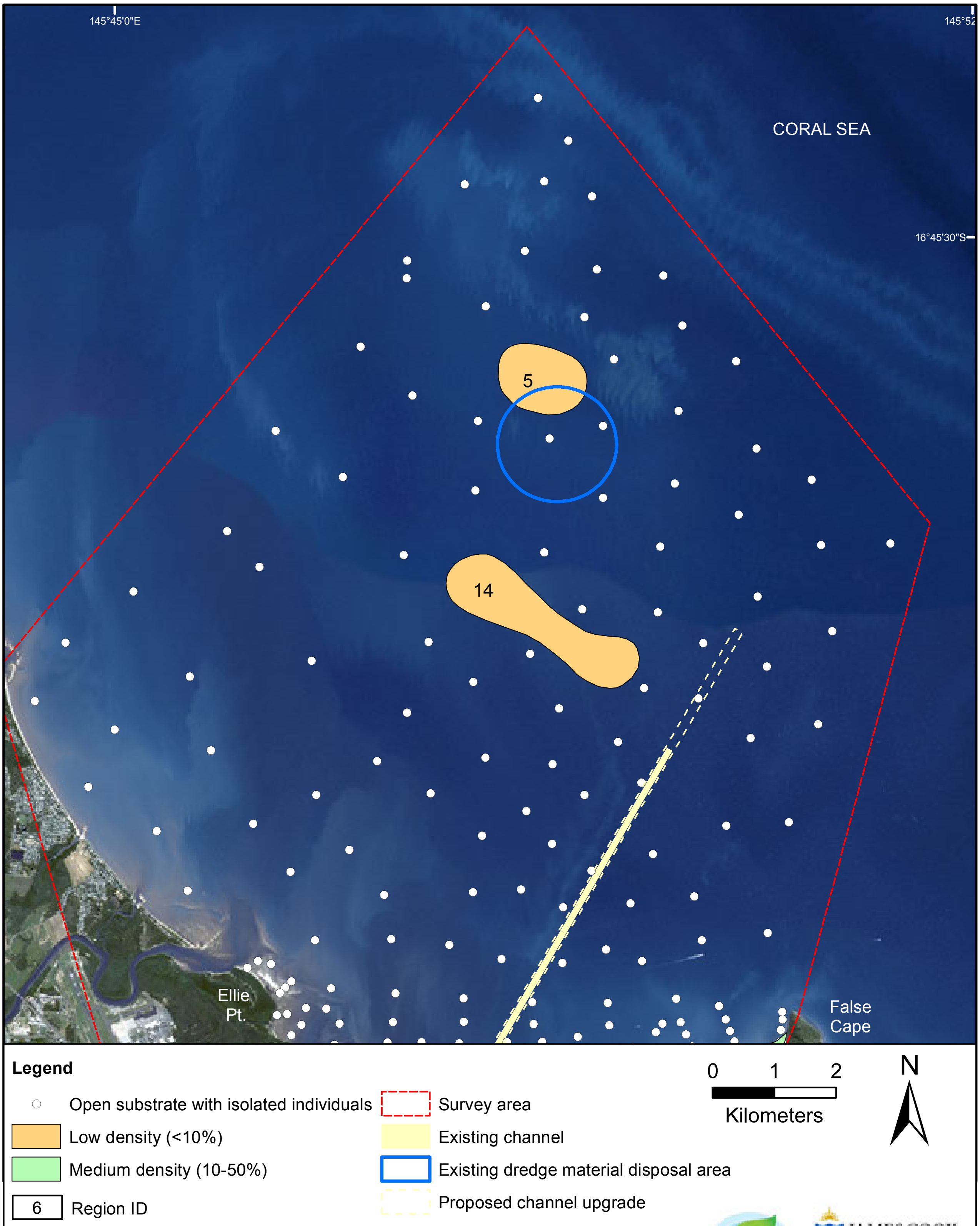
A large area (125.94 ha) of macro algae dominated by erect macrophytes with some filamentous algae was present along the Esplanade and was the second largest area of low density algae mapped (Map 5). Other smaller areas of low density algae was scattered throughout the inner harbour and Trinity Inlet (Map 5). The only region; Region 17, that was dominated by turf mat algae was located up the Inlet on the western side of Admiralty Island and abutting the developed area of the Inlet (Map 6). This region consisted of 90% turf mat algae and 10% filamentous algae (Table 3).

Figure 7. Example of patches of erect macrophyte algae in Region 5 (frame taken from video footage in Jan 2013)

Medium density macro algal communities

There were four community types in the survey area that had a medium density (10-80% cover) of algae cover (Maps 4-6; Table 3). Algal communities in this category covered 82.03 ha and were generally dominated by erect macrophytic algae (Maps 5 & 6; Table 3). Medium density algal communities were found along the Esplanade, near False Cape and in a small area on the western side of Admiralty Island abutting the developed area of the Inlet in Region 21 (Maps 5 & 6).

Map 4. Macro algae community regions in the outer harbour of the Port of Cairns, 2012/13



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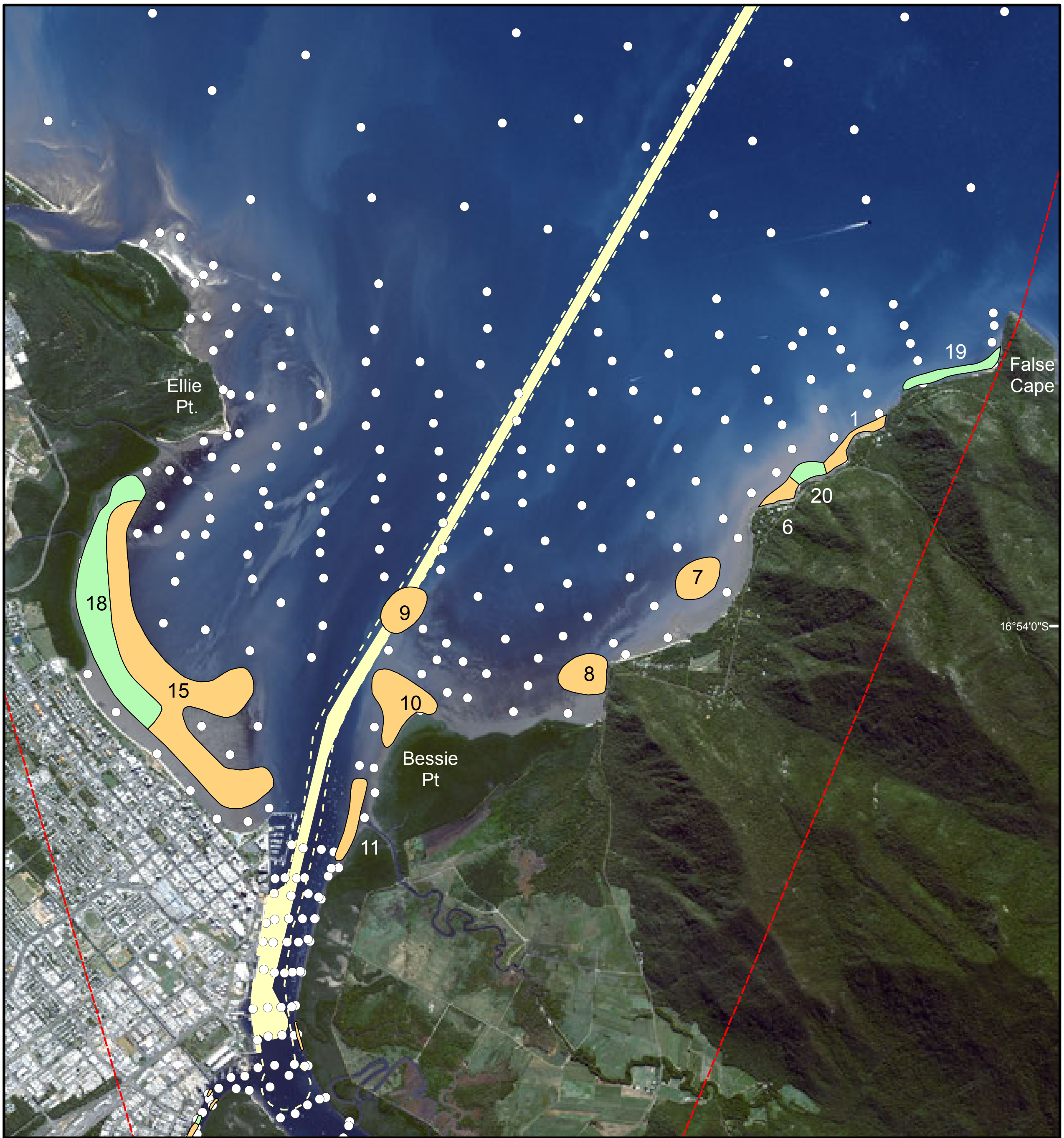
Map 5. Macro algae community regions in the inner harbour of the Port of Cairns , 2012/13



Legend

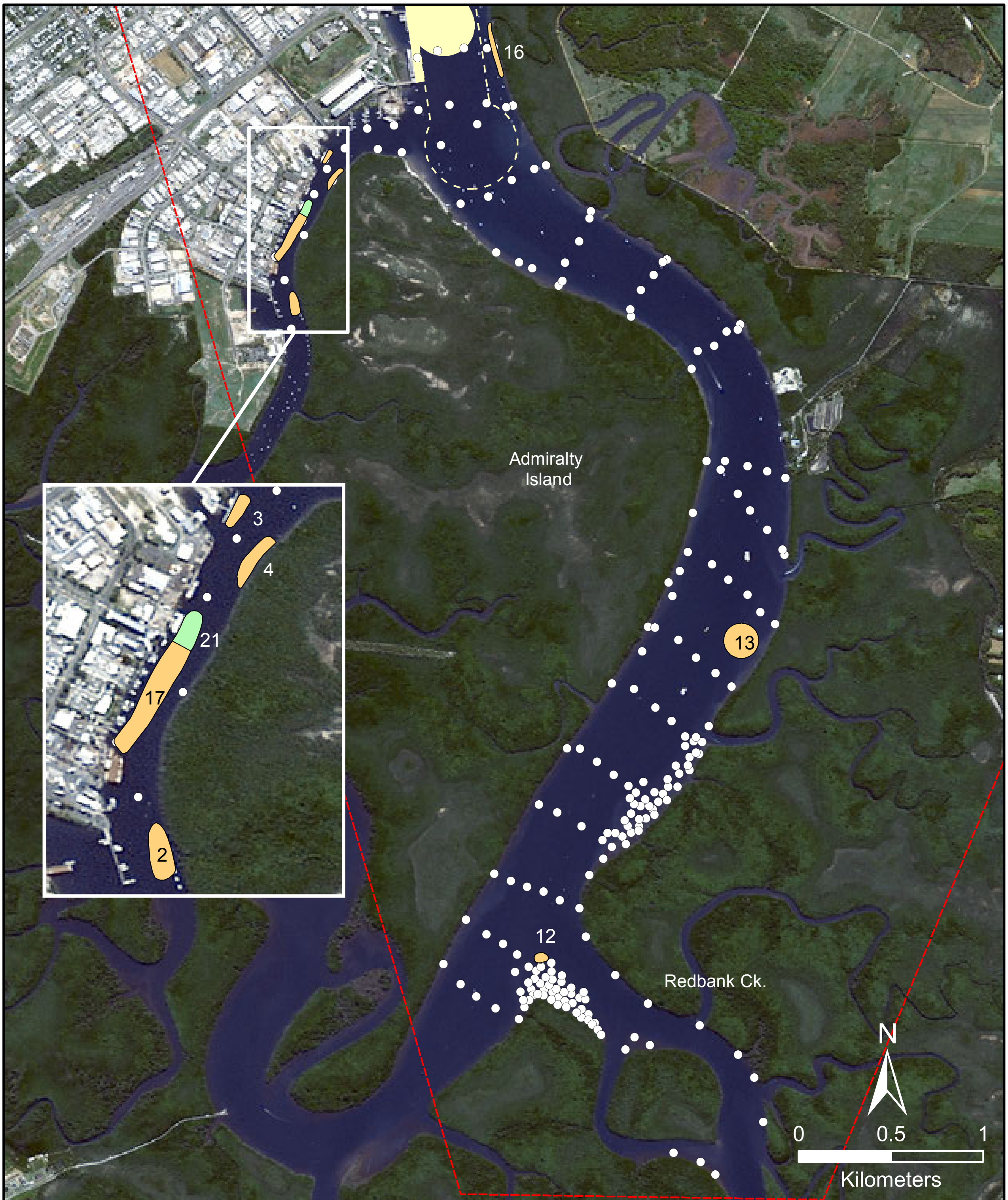
- Open substrate with isolated individuals
- Low density (<10%)
- Medium density (10-50%)
- 6 Region ID
- Survey area
- Existing channel
- Existing dredge material disposal area
- Proposed channel upgrade

0 0.8 1.6
Kilometers

N

Source:
McKenna SA, Rasheed MA, Sankey T & Tol S.J 2013.
‘Benthic macro-invertrbates of Cairns Harbour and Trinity Inlet: Baseline Survey - 2012/13’.
JCU Publication,
Centre for Tropical Water & Aquatic Ecosystem Research, Cairns.

Map 6. Macro algae community regions in Trinity Inlet Cairns , 2012/13



Legend

- Open substrate with isolated individuals
- Low density (<10%)
- Medium density (10-50%)
- Survey area
- 6 Region ID
- Existing dredge material disposal area
- Existing channel
- Proposed channel upgrade

Source: McKenna SA, Rasheed MA, Sankey T & Tol S.J 2013. 'Benthic macro-invertrbates of Cairns Harbour and Trinity Inlet: Baseline Survey - 2012/13'. JCU Publication, Centre for Tropical Water & Aquatic Ecosystem Research, Cairns. © James Cook University, 2013.

Table 3. Macro Algae community regions in the Port of Cairns – density, region description, and number of sites in each region.

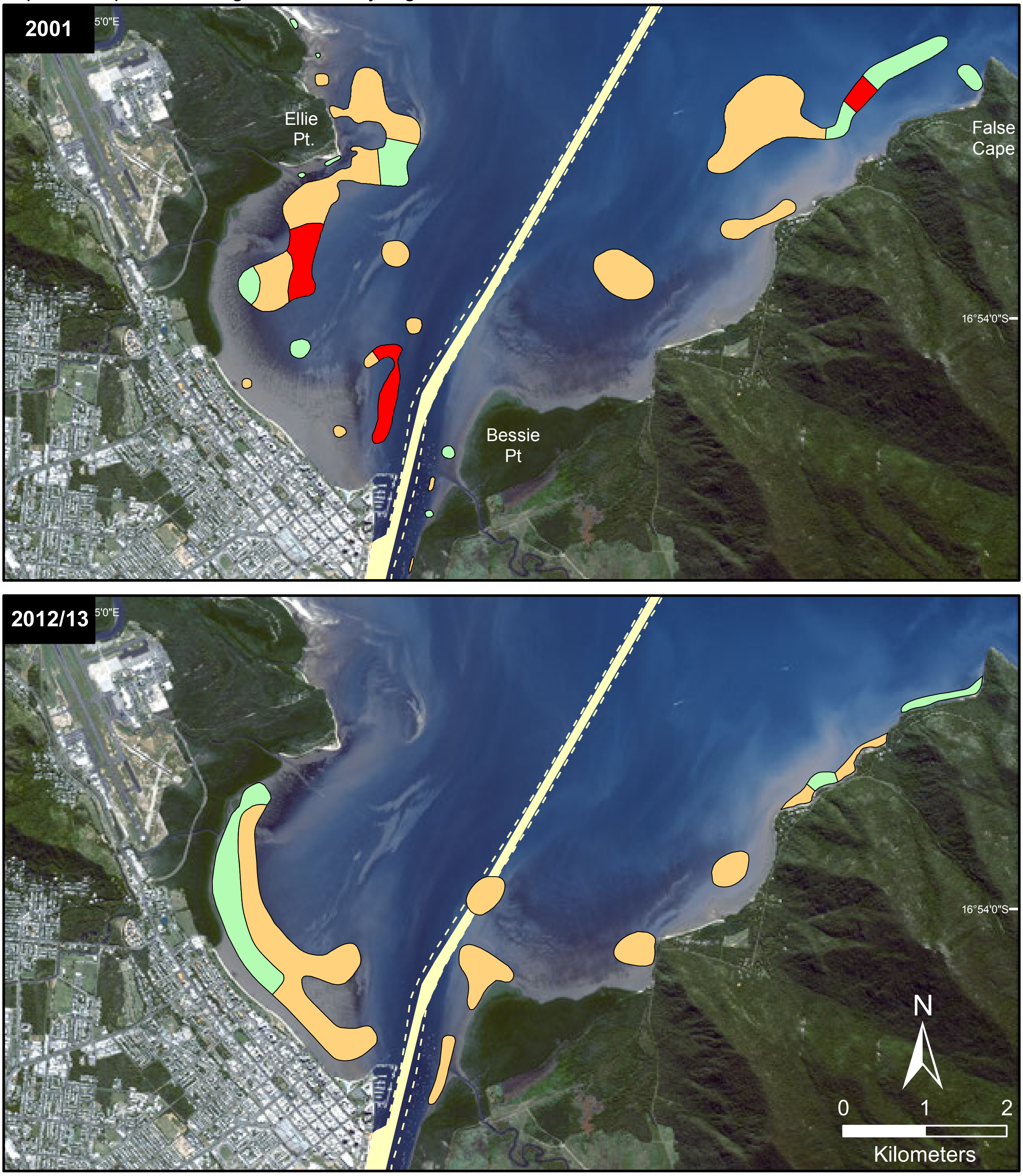
Density category	Algae region description	Region ID (see maps 4-6)	No. of sites	Mean % cover	Area ± R (ha)	% Algae Type			
						Erect Macrophyte	Turf mat	Filamentous	Erect calcareous
Open substrate	Open substrate with no algae present	(white survey sites on maps 4-6)	519	0	na	-	-	-	-
Low density algal community	mostly open substrate with patches of low density turf mat algae	1 2 3 4	2 1 1 1	3 2 1 1	8.28 ± 2.27	-	-	-	100
	mostly open substrate with low density erect macrophytic algae	5 6 7 8 9 10 11 12 13	1 1 1 1 1 4 3 1 1	0.40 2 1 2 5 4.25 2 3 1	215.26 ± 51.73	100	-	-	-
	mostly open substrate with low density erect macrophytic algae and erect calcareous algae	14	2	1.22	241.69 ± 169.17	80	-	-	20
	mostly open substrate with low density erect macrophytic algae and filamentous algae	15	13	4	125.94 ± 19.07	87.69	-	12.31	-
	mostly open substrate with low density filamentous algae and erect macrophytic	16	1	5	0.75 ± 0.32	20	-	80	-

	mostly open substrate with low density turf mat algae and filamentous algae	17	3	1.33	1.3 ± 0.67	-	90	10	-
Medium density algal community	patches of medium density erect macrophytic algae and filamentous algae with areas of open substrate	18	10	25	67.24 ± 3.03	93	-	7	-
	patches of medium density filamentous algae and turf algae with areas of open substrate and erect macrophytic algae	19	3	18.33	9.30 ± 1.13	5	31.67	63.63	-
	patches of medium density erect macrophytic algae/turf mat algae with areas of open substrate	20	1	50	5.12 ± 0.47	50	-	50	-
	patches of medium density turf mat algae with areas of open substrate	21	1	10	0.36 ± 0.28	-	100	-	-

Comparison with historical algal data

There has been one previous survey of Cairns Harbour and Trinity Inlet that examined the distribution of algae communities, conducted in 2001 (Campbell et al. 2002). This survey was confined to the area between the Barron River and False Cape and did not include the deeper offshore areas that were examined as part of the most recent 2012/13 assessment. Generally algae occurred in similar locations between the 2001 and 2012/13 surveys (Map 7). There were three areas of "high density" algae cover found in the 2001 survey, however these areas were not "macro" algae but consisted of benthic micro-algae that formes a film over muddy substrates (Map 7). Similar to 2012/13 no "high density" categories of "macro" algae were found in 2001. While there were generally similar patterns of algae distribution between the two surveys, there was an absence of algae in the deeper areas between Bessie Point and False Cape in 2012/13 compared to 2001. The algae communities that occurred in this area in 2001 consisted of a mix of benthic micro algae and turf mat algae.

Map 7. Comparison of algae community regions in the inner harbour of the Port of Cairns, 2001 and 2012/13



Legend

- Low density (<10%)
- Medium density (10-50%)
- High density (>50%)
- Existing channel
- Proposed channel upgrade

Source:
McKenna SA, Rasheed MA, Sankey T & Tol S.J 2013. 'Benthic macro-invertrbates of Cairns Harbour and Trinity Inlet: Baseline Survey - 2012/13'. JCU Publication, Centre for Tropical Water & Aquatic Ecosystem Research, Cairns.

4 DISCUSSION

The 2012/13 baseline survey of the Port of Cairns was the first comprehensive assessment of macro algae and benthic macro-invertebrates for the area, and the most comprehensive assessment of seagrass distribution and abundance since the 2001 baseline survey.

The Port of Cairns contained a diverse range of benthic community types that were typical of communities found in estuarine and deep water areas elsewhere in the region such as the Port of Abbot Point (Rasheed et al. 2005), Port of Hay Point (Thomas & Rasheed 2011) and Port Curtis (Rasheed et al. 2003b). Typically the majority of these areas are dominated by open substrate with only a low density of benthic community types.

In the Port of Cairns habitat forming benthic macro-invertebrates were predominantly found in the outer harbour area with few benthic macro-invertebrates occurring in the inner harbour or Trinity Inlet. This result contrasted the occurrence of macro algae which were more common in the inner harbour and Trinity Inlet than in the outer harbour area. While a diversity of taxa and community types were found, the dominant benthic habitat feature in the Port of Cairns was open substrate containing a low per cent cover of benthic life. There were no benthic communities that could be described as “high density” and there were no unique or unusual benthic macro-invertebrate or algal communities found within the Port of Cairns survey area.

The benthic communities in the outer harbour were dominated by filter feeding and suspension feeding species such as ascidians, sea pens, bryozoans and hydroids that tend to thrive in high current environments. Although only low to medium density regions of benthic macro-invertebrates occurred in the Port of Cairns, the value of these low density communities should not be underestimated. Benthic fauna are important as a source of food for many consumers (Miller et al. 2002). Benthic fauna also form a link between habitat substrata, detritus-based food chains and larger carnivores (Posey et al 1997; Henderson 1999). Similarly although the value of sparse algal communities to fisheries productivity and the marine environment in general is poorly quantified, algae provide food, habitat and shelter for macro benthic animals and other larger carnivores (Kulczycki et al 1981). Denser algae beds in the Gulf of Carpentaria are known to be important nursery grounds for juvenile prawns (Haywood et al. 1995). Macro algae also provide food for some species of marine turtles in Queensland (Limpus 1998). While the sparse beds that typified Cairns Harbour may not be providing the same level of services as denser algae communities it is likely that they do contribute some value to fisheries and the overall marine ecosystem for the area.

This was the first time that habitat forming benthic macro invertebrate communities have been examined at this scale in the Port of Cairns so direct historical or seasonal comparisons were not possible. The 2001 baseline survey did examine algae however, and between the 2001 and 2012/13 surveys algae generally occurred in similar locations.

Many of the algae and benthic macro-invertebrate communities described in this survey occurred in proximity to maintained channels, port facilities and the dredge spoil disposal site. The fact that these communities, particularly the medium density community type, occurred in the currently utilised spoil ground, indicates that benthic macro-invertebrates may be resilient to some level of spoil disposal, and potentially capable of recovering from the disturbance related to maintenance dredging and disposal conducted each year. However, without previous information or ongoing monitoring it is not possible to ascertain if the present distribution of algae and benthic macro-invertebrates reflects the historical extent of their abundance and distribution in the area.

This survey provides a baseline from which future changes can be assessed. The survey provides a good indication of the location of significant benthic communities in the port but it is likely that many of the communities described would be variable seasonally and between years and the potential for changes to distribution and density should be considered when interpreting the results.

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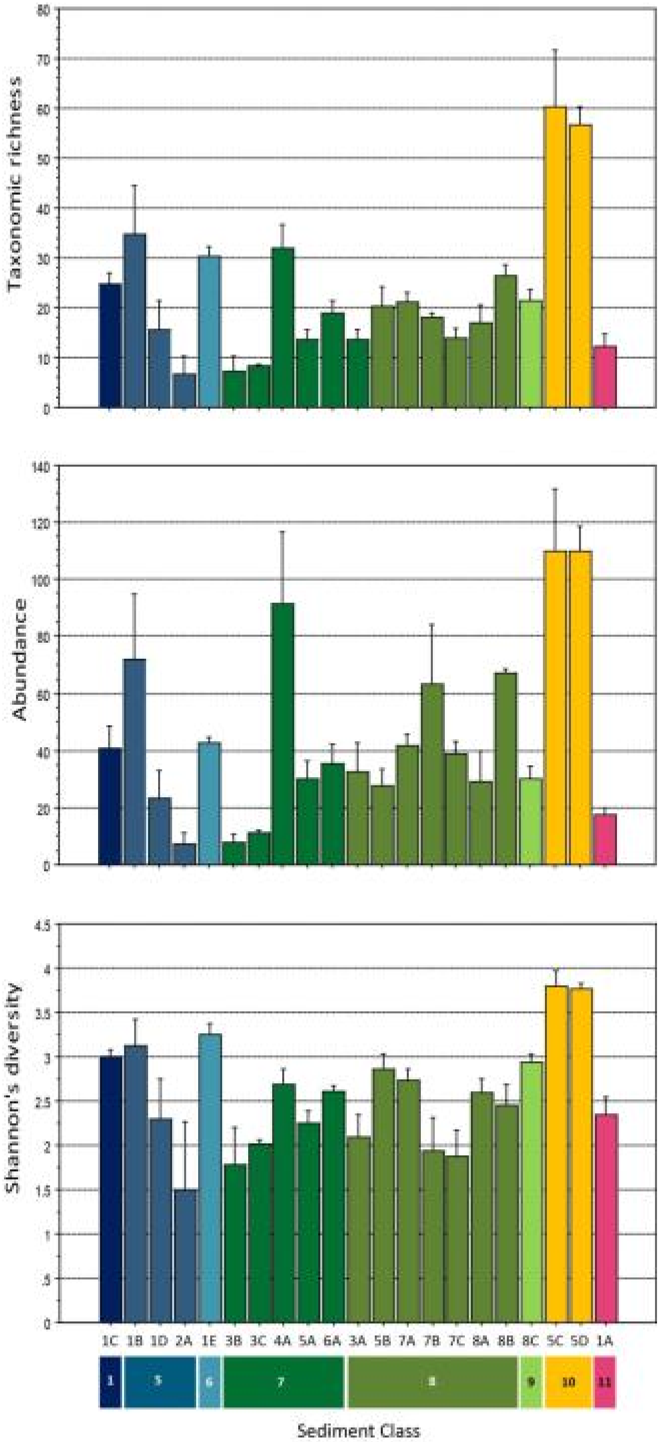


Figure D13.4a Dry Season – Mean (±S.E.) Taxonomic Richness (Upper Plot), Abundance (Middle) and Shannon's Diversity Index (Lower Plot) of Macroinvertebrate Infauna from Selected Sediment Classes

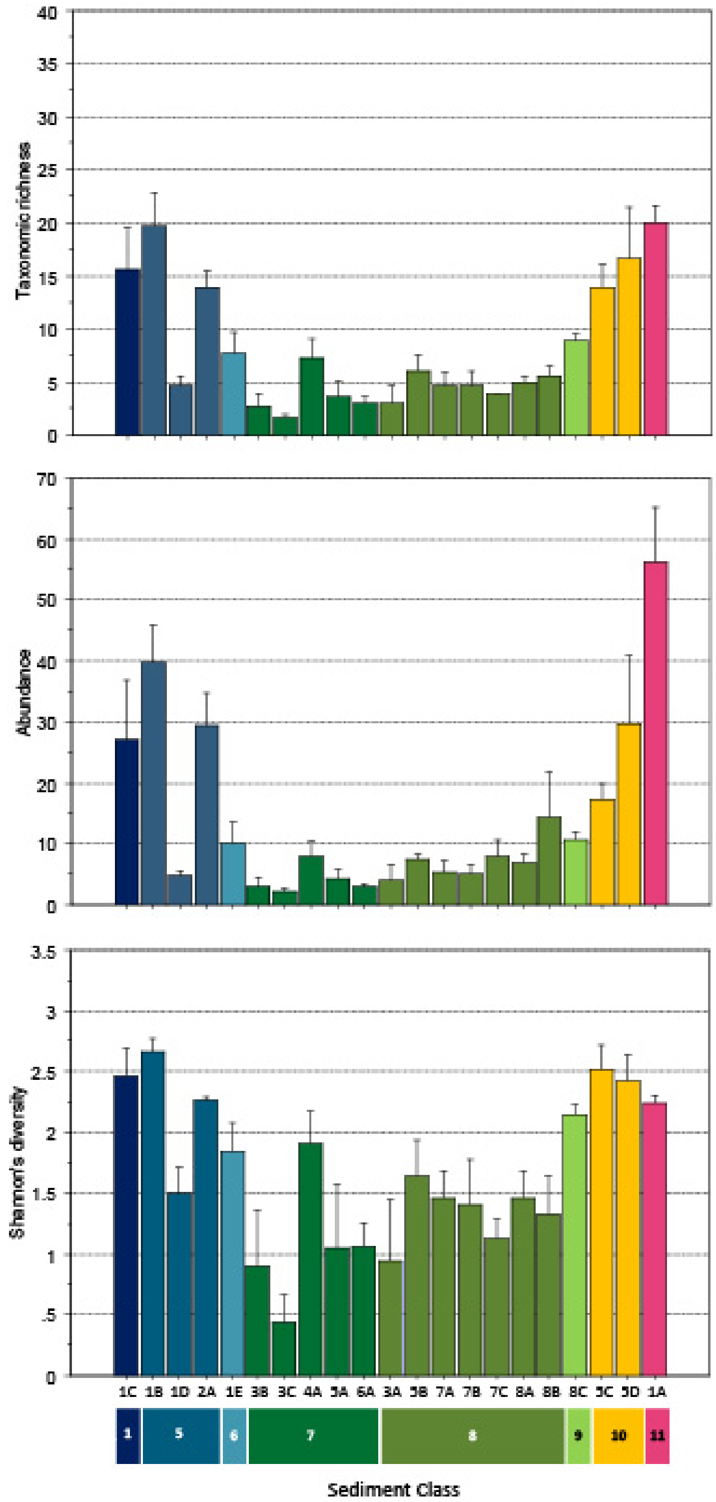


Figure D13.4b Wet Season – Mean (±S.E.) Taxonomic Richness (Upper Plot), Abundance (Middle) and Shannon's Diversity Index (Lower Plot) of Macroinvertebrate Infauna from Selected Sediment Classes

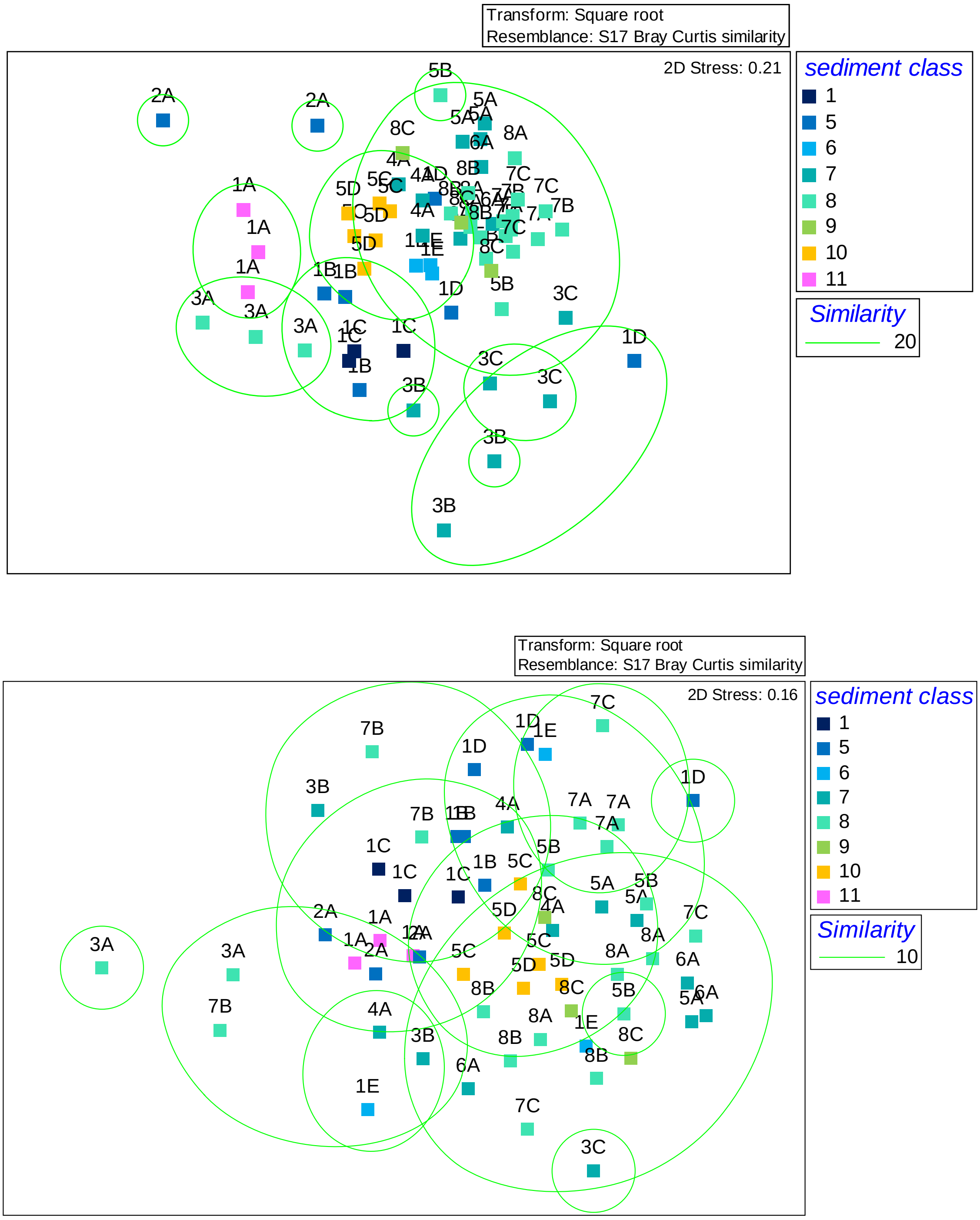
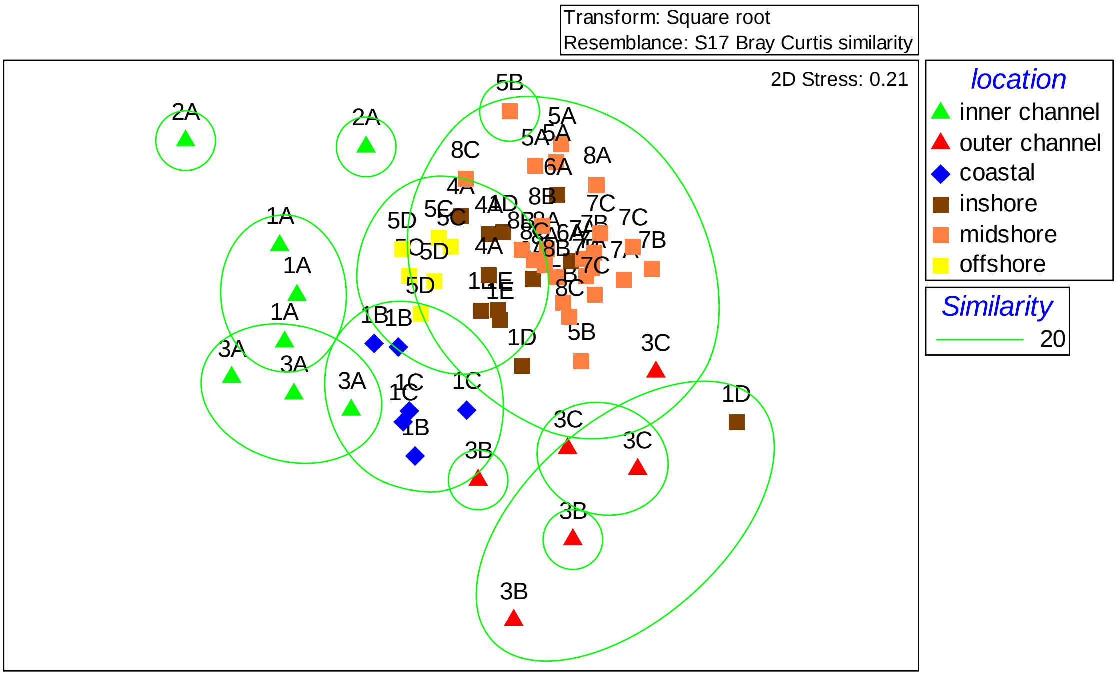


Figure D13.4c Two Dimensional n-MDS Ordinations showing Similarities of Macroinvertebrate Infauna Communities from Acoustically Defined Sediment Classes in Dry Season (Top) and Wet Season (Bottom) Surveys



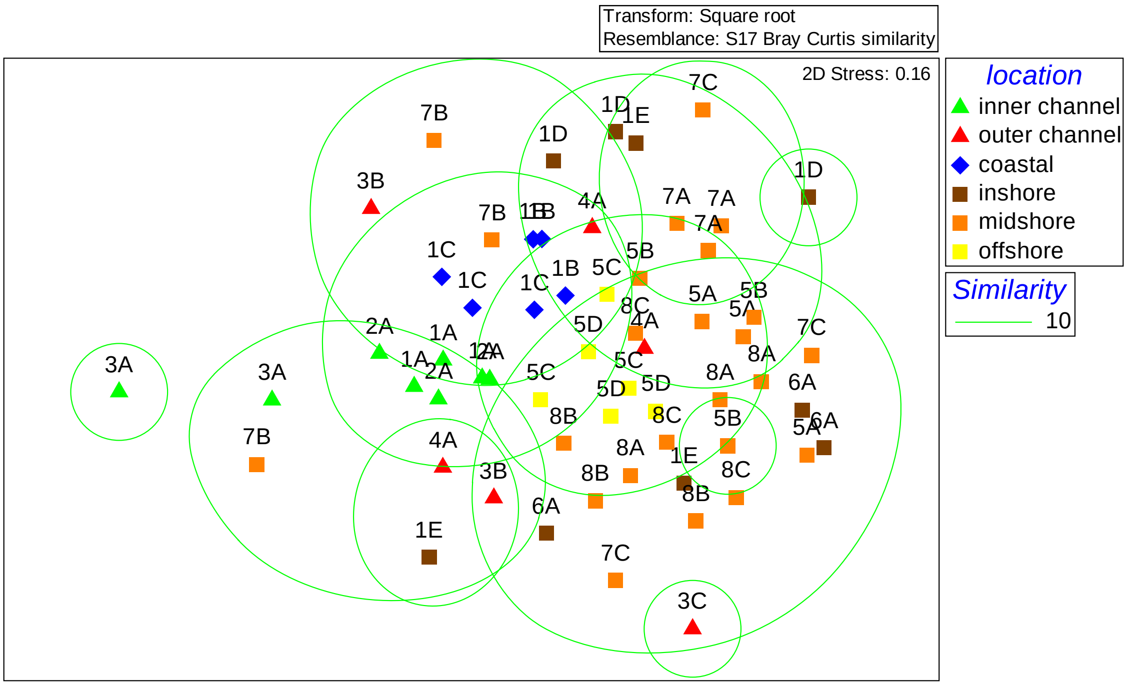
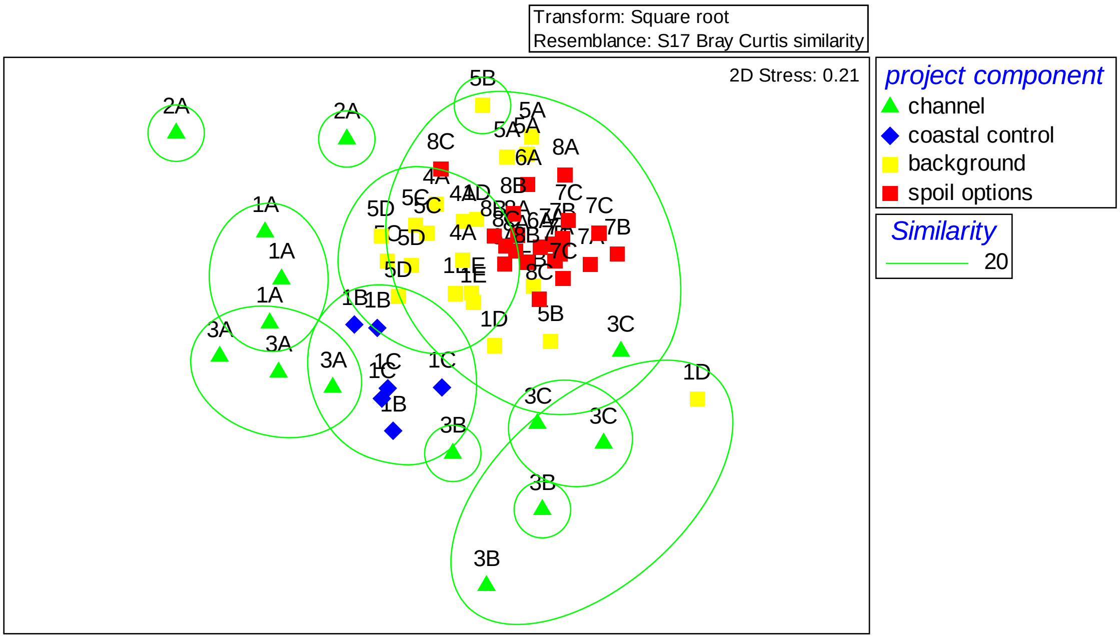


Figure D13.4d Two Dimensional n-MDS Ordinations Showing Similarities in the Macroinvertebrate Infauna Communities from Different Locations within the Study Area in Dry Season (Top) and Wet Season (Bottom) Surveys



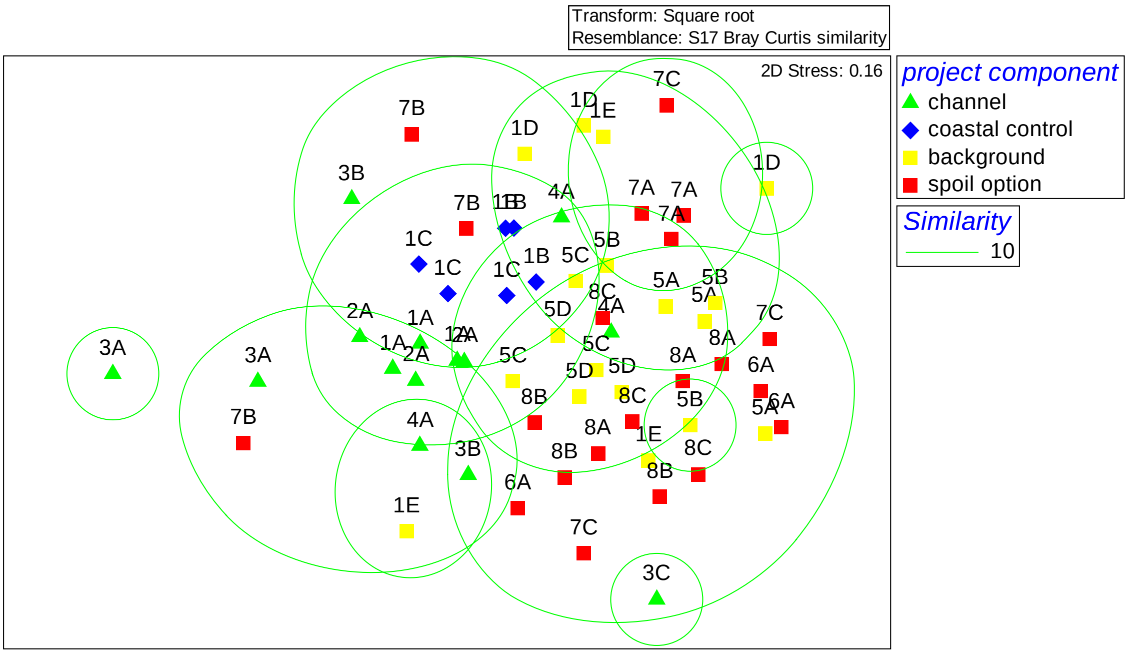
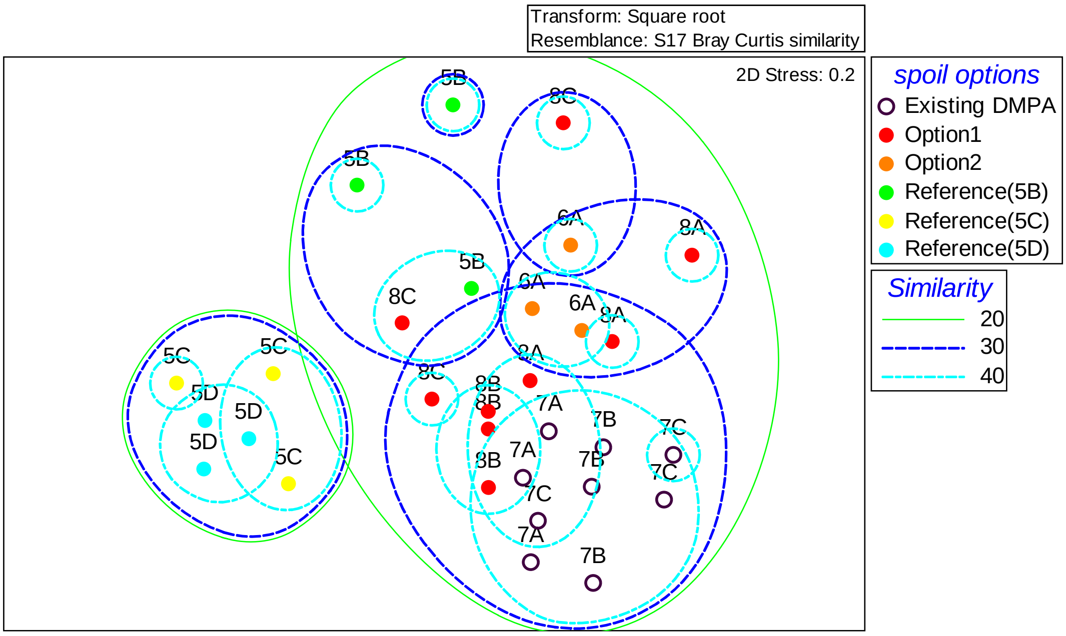


Figure D13.4e Two Dimensional n-MDS Ordinations showing Similarities in Macroinvertebrate Infauna Communities from areas affected by Different Project Components in Dry Season (Top) and Wet Season (Bottom) Surveys



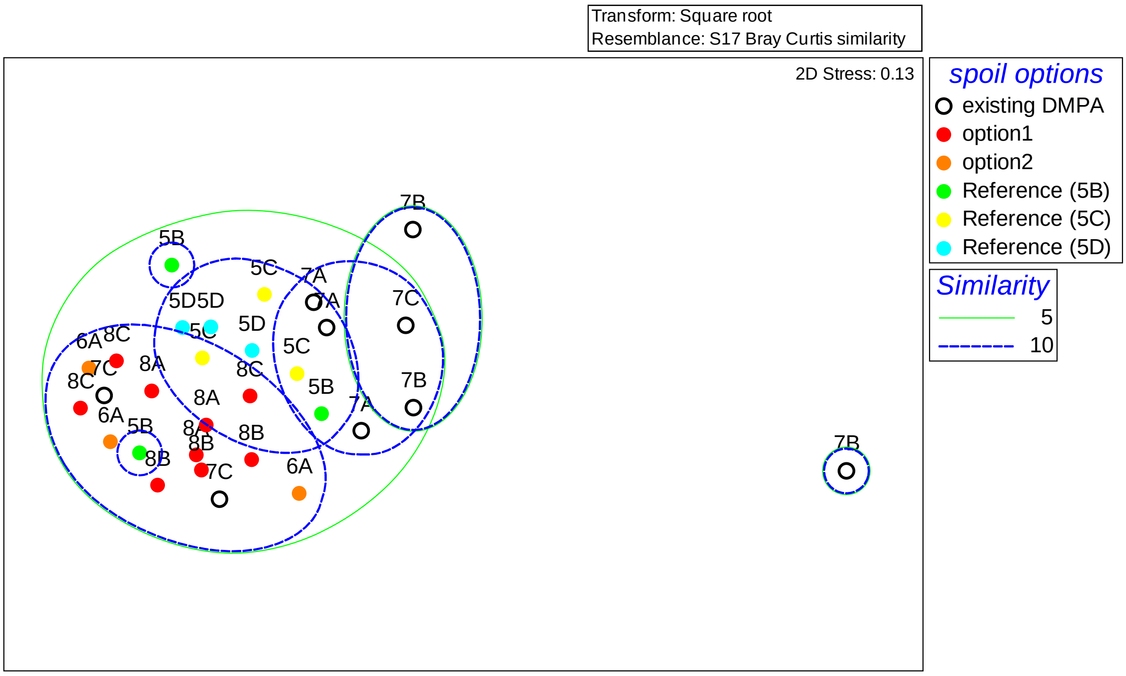


Figure D13.4f Two Dimensional n-MDS Ordinations showing Similarities in Macroinvertebrate Infauna Communities from the Existing and Proposed DMPAs as well as Midshore and Offshore Reference Sites in Dry Season (Top) and Wet Season (Bottom) Surveys

Appendix D13.5 Grid (H16) used for Acquisition of Commercial Catch Data