Australian Government

Australian Institute of Marine Science

Port of Abbot Point Ambient Coral Monitoring Program: Monitoring plan

18 August 2016

AIMS: Australia's tropical marine research agency

Australian Institute of Marine Science www.aims.gov.au

Townsville, Queensland:

PMB No 3
Townsville MC Qld 4810
Telephone: (07) 4753 4444

ABN: 789 61616 230

Contact person for this report:

Angus Thompson
Coordinator Inshore Monitoring
Email: a.thompson@aims.gov.au
Telephone: (07) 4753 4329

This report should be cited as:
Costello P, Davidson J, Thompson A (2016) Port of Abbot Point Ambient Coral Monitoring Program: Monitoring Plan- June 2016. 14 pp

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Revision History:		*Name*	*Date*	*Comments*
1	Prepared by:	Angus Thompson	15/08/2016	
	Approved by:	Britta Schaffelke	18/08/2016	Approved for submission
2	Reviewed by:	Nicola Stokes	23/05/2017	
	Revised by:	Angus Thompson	25/05/2017	Minor revision required

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Preface

Coral communities are an iconic component of the marine ecosystems in Northern Australia. Inshore coral reefs of the Great Barrier Reef are impacted by multiple pressures including large scale disturbances such as cyclones, through to more localised issues such as elevated levels of nutrients or suspended sediments as a result of activities in the coastal zone and in adjacent catchments.

The successful management of activities potentially harmful to coral communities requires the ability to disentangle the impacts of local, manageable, pressures from larger-scale processes. To achieve this goal, baseline information relating to the dynamics of coral reef communities exposed to ambient environmental conditions is an essential precursor to assessing the response of communities exposed to potentially damaging conditions.

The Port of Abbot Point Ambient Coral Monitoring Program (the program) has been initiated by the Australian Institute of Marine Science (AIMS) under contract to North Queensland Bulk Ports (NQBP). The overarching goal of this program is to develop an understanding of the condition of coral communities on fringing reefs in the vicinity of Abbot Point and of the key environmental factors influencing that condition. This understanding will benefit port master-planning and inform the design and interpretation of future impact assessments.

Specific objectives of the program are:

- To assess and report the condition of coral communities at Holbourne Island and Camp Island
- To identify key environmental factors influencing coral community condition

This document outlines the monitoring plan that has been initiated to meet the specific objectives and general goal of the program.

Executive Summary

The monitoring plan for Port of Abbot Point Ambient Coral Monitoring Program (the program) was initiated in May 2016. This report outlines the sampling design and methods suggested for the ongoing monitoring of fringing reef community condition and dynamics in the vicinity of the Port of Abbot Point. The sampling design and sampling methods are consistent with those used by the Australian Institute of Marine Science to monitor and report the condition of inshore coral reef communities between Rockhampton and the Daintree under the Marine Monitoring Program. The compatibility between these programs affords standard reporting and analysis tools used by the MMP to be utilised by the program. In addition, the ability to interpret observed condition and trends in benthic communities will be enhanced as they will be comparable to those occurring at larger spatial and temporal scales or under exposure to differing levels of pressure elsewhere on the Great Barrier Reef. Conversely, the program has the potential to feed information back into the wider assessment of inshore coral communities of the GBR such as state and regional level reef report cards.

Key points of the design include the selection of a pair of sites on both the windward and leeward aspects of both Holbourne and Camp Islands. Within each site a set of five 20 m long transects are permanently marked with steel markers at 1.5 m to 2 m depths below low tide datum. Additional transects at 5 m depths are included at Holbourne Island. The distribution of sampling includes replication across gradients of: water-quality, exposure to wave energy and depth that are known to influence the composition and dynamics of benthic communities as well as potential exposure to a range of acute and chronic pressures. Within sites benthic communities are monitored along sets of five, permanently marked, 20m long transects using a combination of photo point intercept and belt transects to describe a time-series of benthic community cover, composition and juvenile coral densities. The program also maintains loggers to monitor water temperature at both islands.

Sampling Design

Coral communities are spatially variable as a result of local population stochasticity and fine scale habitat variability combined with variable exposure to more determinate environmental drivers and disturbances. The ability to detect and interpret changes in coral communities requires a sampling design that includes replication at the primary scales of variability.

Within the inshore areas of the GBR there is a strong gradient of increasing nutrient concentration and turbidity with proximity to the coast that exerts selective pressures on benthic communities (De'ath & Fabricius 2010). Increased nutrient levels have been demonstrated to promote persistent stands of macroalgae (De'ath & Fabricius 2010, Thompson *et al.* 2015) while increased turbidity reduces light available to corals resulting in shifts in community composition as sensitive species are excluded (DeVantier *et al.* 2006, Thompson *et al.* 2014). In addition, exposure to low salinity flood plumes, that are lethal to corals, increases with proximity to major rivers (van Woesik 1999, Jones & Berkelmans 2014, Thompson *et al.* 2014). The sampling design developed for the Port of Abbot Point ambient coral monitoring program (the program) includes reefs surrounding Camp Island and Holbourne Island as representative of reefs at different locations along a water quality gradient. What was not possible to include in the program was a replication of reefs at similar locations along water quality gradients that would add to the ability to assess variability in condition as a result of differences in water quality in the face of confounding with some other environmental pressure or disturbance event. It is this issue that strongly supported the adoption of a within-reef sampling design consistent with that used for the monitoring of other inshore coral communities by the Reef Plan Marine Monitoring Program (MMP) as this effectively extends the sampling design to include reefs in other regions situated along similar gradients in water quality.

Within a reef the aspect of the reef relative to prevailing weather conditions and water depth can influence coral community condition both due to differences in exposure to chronic conditions resulting from turbidity but also differential exposure to disturbance events. Light, required for corals autotrophic acquisition of energy, attenuates exponentially with depth at a rate proportional to turbidity (Van Duin *et al.* 2001, Storlazzi *et al.* 2015) while sedimentation increases as a function of suspended sediment concentration, particle size and turbulence (Storlazzi *et al.* 2015). The sampling design for the program includes sites on both the windward (Eastern) and leeward (Western) aspects of both Camp Island and Holbourne Island (Figure 1). At Holbourne Island sites were replicated at both 2m and 5m depths below lowest astronomic tide datum (LAT) as predicted by Navionics electronic charts on the day of site construction. At Camp Island there was insufficient depth to include replication at the 5m depth. Further, at Camp Island East the reef slope did not consistently extend to 2m below LAT and as such transects were set at 1.5m below LAT only. At Camp Island West the reef slope extended to 2-3m below LAT and transects were set at 2m only (Table A1).

Within depth and location combinations, the design includes two sites each including five 20m long transects. The replication of sites allows an estimate of the consistency of community status within a location. The replicate transects are included to allow the averaging of status over what are typically spatially heterogeneous communities.

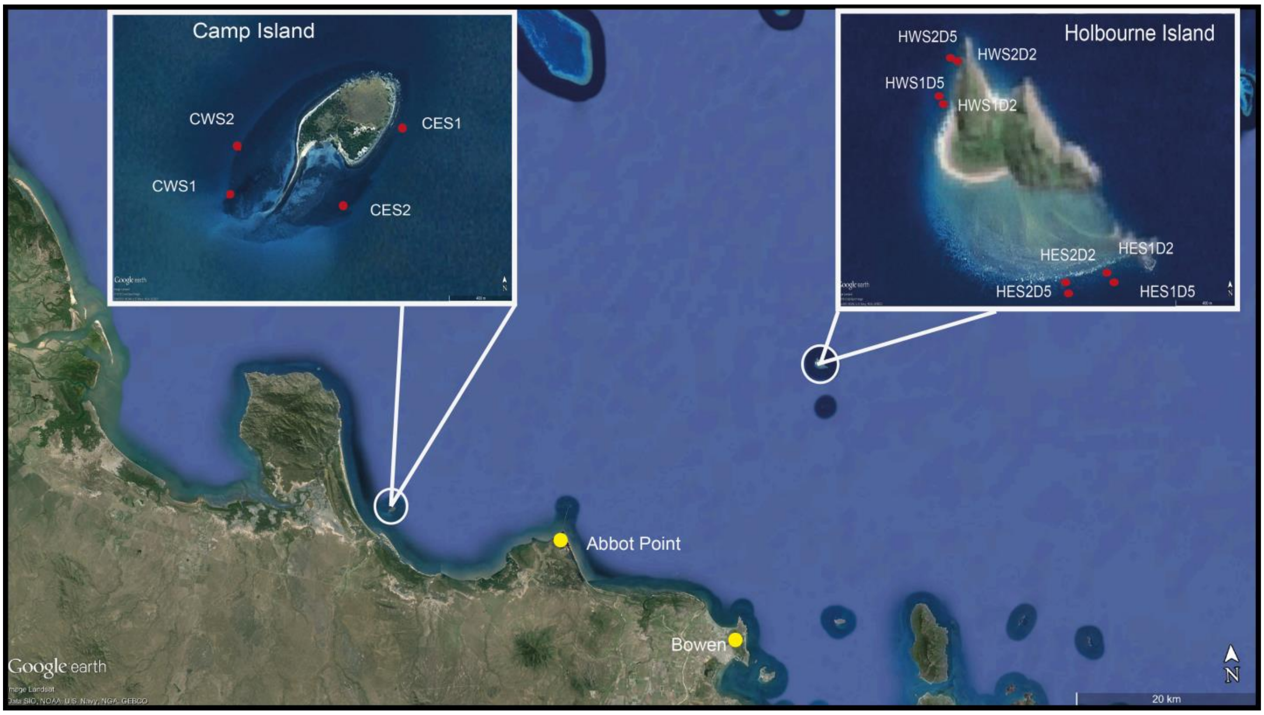

Figure 1: Coral monitoring locations at Camp Island and Holbourne Island. Site labels are abbreviated in the form; Reef –"H" for Holbourne Island and "C" for Camp Island, Aspect – "W" for West and "E" for East, Site number - S1 or S2 and Depth below low tide datum – "D2" for 2m and "D5" for 5m. No depths included at Camp Island as only 1 depth was sampled at each site.

Table 1: Coral monitoring site locations. Full transect directions included as Table A1.

Reef	Aspect	Site	Depth (m)	Figure 1 code	Latitude	Longitude
Camp Island	East	1	1.5	CES1	19.8508	147.90517
		2	1.5	CES2	19.85413	147.9012
	West	1	2	CEW1	19.85332	147.89423
		2	2	CEW2	19.8512	147.89502
Holbourne Island	East	1	2	HES1D2	19.73325	148.3644
			5	HES1D5	19.73377	148.36467
		2	2	HES2D2	19.73362	148.36182
			5	HES2D5	19.734	148.36183
	West	1	2	HWS1D2	19.72517	148.35473
			5	HWS1D5	19.7249	148.35447
		2	2	HWS2D2	19.72332	148.35562
			5	HWS2D5	19.72318	148.35527

Location of transects

At each combination of site and depth a 120m long site was constructed along the depth contour. This 120 m long site was divided into five, 20 m long, transects each separated by a space of 5 m. The start of each transect is marked with a steel "star picket" with additional transect markers consisting of lengths of 10 mm steel rod placed at the midpoint (10m) and end (20m) of each transect. The location of the start of the 1st transect is recorded as a GPS waypoint based on WGS84 datum. From this location compass bearings are recorded along each transect to aid future surveys (Table A1) and facilitate relocation of markers lost during storms or any other unforeseen event.

Regular maintenance of sites should be conducted as required to ensure transect placement remains consistent over consecutive surveys.

Timing of sampling

For the first year of the program sampling occurred late in the wet season (May) and will be repeated late in the dry season (October). This seasonal sampling will allow assessment of any seasonality in benthic communities and inform the future sampling frequency of the program. From existing MMP monitoring the dynamics of inshore communities can be seen to follow a predictable cycle of being impacted by acute disturbance events followed by periods of recovery. Disturbances typically occur over the summer months and include physical damage to communities caused by tropical cyclones, exposure to low salinity flood waters and thermal bleaching. As a result, an early dry season sample has proven sufficient to document the impact of the majority of disturbance events. In years that acute events do not impact coral communities documenting the recovery of reefs is of prime interest. Recovery is a function of recruitment; which for a majority of species occurs annually in November/December, and growth; which is relatively slow, making single annual sampling appropriate for assessing these resilience indicators. Because of the relatively slow rate that coral cover increases shorter than annual repeat survey frequencies will not improve estimates of recovery rate as the signal (trend in community condition) to noise (sampling error) ratio will be decrease. Conversely, longer than annual repeat sampling intervals detract from the ability to assign causation for reductions in indicator scores and produce difficulties in assigning lags to any environmental covariates that may be used to explain trends in coral community condition. The period May-July has proven an appropriate period for sampling inshore communities as the impacts of acute summer disturbance events have been fully realised and little recovery would be expected. Setting a consistent sampling period will also reduce variability in the macroalgae indicator resulting from seasonal variation in abundance of some species.

Survey methods

Photo point intercept transects

Estimates of the composition and percentage cover of corals, macroalgae and other benthic organisms are derived from the identification of organisms on digital photographs taken along the permanently marked transects. The method follows closely the standard procedure employed by AIMS to monitor benthic cover in the Long-Term Monitoring Program (LTMP), the Representative Areas Program (RAP) and the MMP (Jonker *et al.* 2008). Digital images are captured at a height of ~40cm from the substrate at 50 cm intervals along transects. Estimations of cover of benthic community components are derived from the identification of the benthos lying beneath five fixed points digitally overlaid onto these images. A total of 32 images (160 points) are analysed from each transect. For the majority of hard and soft corals, and some dominant macroalgae, identification to genus level is achieved. Identifications for each point are entered directly into a data entry front-end to an Oracle-database, developed by AIMS. This system allows the recall of stored transect images and facilitates the checking of all identified points by a second observer as well as providing a permanent record that could be further scrutinised should the need or desire arise.

Juvenile coral surveys

Along each transect, the number of juvenile colonies with a maximum dimension of <10cm that are within a 34cm band width (dive slate length) to the upslope side of the transect line are counted *in* *situ.* Corals are identified to genus-level and recorded into size categories of <2cm, 2 – 5cm, and 5-10cm. This method provides an estimate of the number of both hard and soft coral colonies that have successfully recruited and survived early post-settlement pressures. Small coral colonies considered to be the result of fragmentation or partial mortality of larger colonies are excluded.

Scuba search transects

Scuba search transects document incidence of coral disease and other sources of ongoing coral stress. This method follows closely the standard procedure used by AIMS LTMP, RAP and MMP (Miller *et al.* 2009) and serves to help identify probable causes of declines in coral community condition or ongoing stress. For each 20m transect a search is conducted within a 2m wide strip centred on the marked transect line within which the incidence of: coral disease, coral bleaching, coral predation by *Drupella* or crown-of-thorns seastars, overgrowth by sponges, smothering by sediments and physical damage to colonies is recorded. Any other points of interest that pertain to possible coral community condition are noted in the comments section of this database.

Additional environmental data

In addition to the monitoring of coral communities some basic environmental data are important covariates to be considered both in terms of identification and potential attribution of pressures but also to provide the contextual 'setting' of the coral communities.

Temperature

Thermal stress resulting in coral bleaching is an increasing threat to coral communities in a warming world. Temperature loggers have been deployed during the first survey event and are located on the Pickets marking the 1st transect at Site 1 at both Holbourne East (2m and 5m depths) and Camp East (2m only) to track ambient temperature profiles. These loggers are to be exchanged during each survey and will provide data invaluable in the identification of extreme temperature events likely to cause coral bleaching.

Water Quality

There is a steep gradient of improving water quality with distance from the coast in the GBR. The ambient conditions of turbidity and nutrient availability combine with exposure to wave activity to define the ambient conditions at any particular site that exert selective pressure on coral and algal communities.

Satellite derived estimates of total suspended sediments and Chlorophyll a for the entire Great Barrier Reef are available for download from the Bureau of Meteorology. These data provide a description of the ambient water quality condition of each Island allowing the conditions experienced by coral communities monitored by the program to be put in context with those monitored by the MMP. This contextual information is very important in determining the expectations for benthic community composition at the monitoring locations. In addition, relevant river discharge data obtained from the Queensland Department of Natural Resources and Mines (www.derm.qld.gov.au) will assist in identifying changes in ambient water quality conditions due to runoff that could potentially impact community condition.

Finally, NQ Bulk Ports undertakes ambient water quality monitoring that includes sites adjacent to both Camp and Holbourne Islands. It is expected that these direct measures of variability in local environmental conditions will provide important covariates allowing quantification of conditions leading to any water quality associated impacts to coral communities.

Sediment Composition

The grainsize distribution of sediments is a simple proxy for the hydrodynamic conditions of a location that govern the balance between fine sediment accumulation and resuspension. During the first survey AIMS collected 6 small sediment samples from each location from which the proportion of clay and silt sized particles was estimated by sieving.

Sediment samples were collected using a 100ml syringe tube from which the restricted end had been removed to take undisturbed plugs of the top 10mm of sediment from available deposits along 5m (Holbourne Island) and 2m (Camp Island) deep transects . Again, these data are collected at all MMP monitoring sites and will be used to place the communities along a gradient of wave exposure. In combination, satellite derived WQ and grainsize data are used to determine thresholds for the cover of Macroalgae at each reef that feed into the overall coral community condition index score used by the MMP and available to the program.

Data analysis and Presentation

A key feature of the sampling design described above is that the data collected can be integrated and synthesised into the report card format developed under the MMP (Thompson *et al.* 2015) and used to summarise coral community condition at state and regional levels. The report card is based on an inshore coral index that summarises the status of coral communities as measured by a set of indicators: coral cover, the density of juvenile corals corrected for substrate availability, the proportion of macroalgae in the algal communities, the rate of coral cover increase and more recently changes in coral community taxonomic composition, into a single score. This scoring system will be progressively implemented as the time-series allows: noting some indicators require several years of observation before being included. The coral index will provide a convenient, and broadly accessible, way to summarise coral community condition to user groups or target audiences with varying degrees of expertise, such as those targeted by the "Your Ports" environmental report series (North Queensland Bulk Ports 2015).

It is envisaged that information collected under this program will contribute to understanding the dynamics of coral communities in the vicinity of Port of Abbot Point exposed to natural environmental conditions (North Queensland Bulk Ports 2016). As the time series extends the quantification of impacts to coral communities from both acute and chronic environmental pressures will provide important information for the planning of future port activities.

Key pressures

Coral communities at Holbourne and Camp Islands are susceptible to a range of natural and anthropogenic pressures. Identifying these pressures and the associated drivers is essential in determining the cause of impacts to coral communities and developing an improved understanding of coral community responses that can then inform future management of Port activities. Following is a list of key pressures relevant to the program and the methods recommended for quantifying their potential impact on the coral communities monitored.

Thermal bleaching

Thermal stress resulting in coral bleaching is an increasing threat to coral communities in a warming world. Inshore areas between Mackay and Ingham were in the epicentre of thermal stress early in 2002 and suffered substantial loss of coral cover (Berkelmans *et al.* 2004, Sweatman *et al.* 2007). It is likely that coral communities at Camp and Holbourne Islands were affected by this event and remain susceptible to future events. In combination with global coral reef heat stress monitoring published by the Bureau of Meteorology (http://www.bom.gov.au/environment/activities/reeftemp/reeftemp.shtml) Scuba search surveys and monitoring of local water temperatures by *in situ* loggers will identify any future occurrence and impacts of thermal bleaching events at these sites.

Runoff

Camp and Holbourne Islands lie adjacent to the Don River catchment and just south of the much larger Burdekin River. During flood events, runoff has the potential to impact coral communities both directly; due to inundation by freshwater and smothering by increased sedimentation (Brodie *et al* 2012), and indirectly through depletion of light due to increased turbidity, and subsequently through increased competition with macroalgae and increased prevalence of disease both of which are supported by increased nutrient levels (De'ath & Fabricius 2010, Haapkylä *et al.* 2011). Camp Island, located in close proximity to the coast, is particularly susceptible to drivers associated with runoff and flood events. In recent years severe flooding occurred in the region in 2008 potentially impacting the coral community at this location. In contrast Holbourne Island, located further offshore, is less vulnerable to the impacts of runoff and flood events. Referencing monitoring data against satellite derived water quality and river discharge data will assist in attributing any flood associated impacts to coral communities.

Cyclones and storms

Significant impacts to coral reefs in the GBR have been attributed to cyclone and storm damage (Osborne *et al.* 2010, De'ath *et al.* 2012). Recent cyclones that are likely to have damaged coral communities in the region of Abbot Point include Cyclone Yasi (2011) that caused widespread damage to nearshore reefs in the Palm group to the north of Abbot Point (Thompson *et al.* 2015), and cyclones Ului (2010), Anthony (2011) and Dylan (2014) that although much less severe that Cyclone Yasi crossed the coast between Bowen and the Whitsunday Islands. Impacts associated with cyclones and storms are readily identifiable during coral monitoring surveys allowing impacts to coral communities to be attributed accordingly.

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Table A1: Detailed transect locations

Reef	Site	Depth	Latitude	Longitude	Transect	Compass bearings
Holbourne Island East	1	2m	19.73325	148.3644	1	300
					2	205, 250@10m
					3	220, 250@10m
					4	270, 240@12m
					5	270, 230@7m
		5m	19.73377	148.36467	1	215, 150@13m
					2	240, 210@15m
					3	200, 260@10m
					4	270, 315@6m
					5	300
	2	2m	19.73362	148.36182	1	265, 300@5m, 230@15m
					2	260
					3	260, 250@10m
					4	270, 220@15m
					5	240, 330@4m, 270@10m, 280@14m
		5m	19.734	148.36183	1	210, 200@10m
					2	240, 270@5m, 255@10m
					3	240, 290@2m
					4	320, 0 toT5
					5	320, 290@10m
Holbourne Island West	1	2m	19.72517	148.35473	1	10, 50@6m, 30@10m
					2	10, 0@8m, 30@14m
					3	340
					4	20
					5	10, 340@5m
		5m	19.7249	148.35447	1	40, 320@10m, 50 to T2
					2	350, 0@8m, 300@15m
					3	30, 330@5m, 40@10m
					4	60, 40@3m, 300@5m, contour bommie
					5	340, 15@6m, 25@10m
	2	2m	19.72332	148.35562	1	345, 0@10m
					2	25, 75@10m
					3	10, 20@10m
					4	330, 20@5m, 100@15m
					5	50, 340@8m
		5m	19.72318	148.35527	1	30
					2	350, 10@9m, 60@16m
					3	30, 20@7m
					4	15
					5	40, 140@5m, 110@8m, 170@11m

Table A1 continued

Reef	Site	Depth	Latitude	Longitude	Transect	Compass bearings
Camp Island East	1	1.5m	19.8508	147.90517	1	170
					2	270
					3	225, 230@10m
					4	210, 220@10m
					5	200
	2	1.5m	19.85413	147.9012	1	230
					2	270
					3	235
					4	240
					5	170, 155@7m
Camp Island West	1	2m	19.85332	147.89423	1	0, 50 to T2
					2	0
					3	0, 35@11m
					4	345, 300@8m, 34@11m
					5	20, 10@7m
	2	2m	19.8512	147.89502	1	20, 30@10m
					2	345, 30@8m
					3	30
					4	130
					5	20