Hay Point Maintenance Dredge: Coral Impact Monitoring Report

North Queensland Bulk Ports (NQBP)

VISION ENVIRONMENT

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CITATION

This report should be cited as: *Vision Environment (2019). Hay Point Maintenance Dredge Coral Impact Monitoring Report for North Queensland Bulk Ports.* Vision Environment, Gladstone, Australia.

DOCUMENT CONTROL

Document draft	*Originated by*	*Edit and review*	*Date*
Draft for internal review	RA	FM	11/08/2019
Draft 2 for internal review	FM	CW	15/08/2019
Draft issued to Client	FM	LA	16/08/2019
Final issued to client	NQBP	FM	30/08/2019

DISCLAIMER

FILE REFERENCE

30082019 FINALCoral Impact Monitoring Report_NQBP Hay Point Maintenance Dredge Monitoring _VE

EXECUTIVE SUMMARY

Maintenance dredging of the Port of Hay Point took place from 31 March to 2 May 2019. As per the NQBP Long-term Maintenance Dredge Management Plan, the Port of Hay Point Maintenance Dredging Environmental Monitoring Plan and the NQBP Marine Environmental Monitoring Program, impact monitoring of corals was required to determine if coral communities had been affected by maintenance dredging activities.

Monitoring of four locations (Round Top Island and Victor Island (water quality monitoring trigger sites), and Slade Islet and Keswick Island (water quality monitoring control and support sites) took place prior to, and after, maintenance dredging. These four locations are utilised in the ambient coral monitoring program, which has been undertaken since 2006. The ambient monitoring protocol was used as a basis of the impact monitoring but was altered slightly to focus on techniques which would more easily permit the detection of possible impacts. This included the use of a rapid coral health indicator technique, developed by VE, to determine if corals were stressed prior to physical damage being observed.

Examination of coral community demographics found that macroalgal assemblages were the most common substrates encountered at all locations during both the Pre- and Post-Dredge surveys, with *Sargassum* sp. being the most common macroalga taxon across all locations. Sediment covered around 1/3 of the monitored locations.

Hard and soft corals were recorded at all locations with coverage remaining similar during the Pre-Dredge and Post-Dredge surveys, indicating no apparent impact from dredging activities. Soft coral coverage was higher at Round Top Island and Keswick/St Bees Island in comparison with Slade Islet and Victor Island, similar to previous findings. *Montipora* spp., *Acropora* spp. and *Lobophytum* spp. were found to be the most common coral taxa.

Few hard corals across the transects demonstrated stress, with less than 4% of corals overall showing pale bleaching and less than 1% of corals presenting white bleaching or disease. These levels did not change between the Pre-Dredge and Post-Dredge surveys. Of note was the higher level of pale bleaching at Keswick/St Bees locations, which was located approximately 20 nm from any dredge activity.

Sediment was observed on corals at all locations, with a decrease of occurrence evident at two inshore sites (Victor Island and Slade Islet) from Pre- to Post-Dredge surveys. However, the depth of the sediment on the coral increased between 0.5 to 0.9 mm across all locations from the Pre- to Post-Dredge surveys. As this occurred at all locations, it is unlikely that dredging activities were responsible.

Consistent numbers of juvenile corals were evident in both surveys and across locations. Coral growth from the Pre- to Post-Dredge survey was also observed.

In general, a darkening of coral pigment colours was observed from the Pre- to Post-Dredge survey, showing an opposite pattern to coral bleaching. The pigment darkening was attributable to seasonal lower light availability. Higher levels of darkening were observed at Round Top Island which may be attributable to the deeper water at these coral monitoring sites, in addition to the differing variety of coral genera monitored at this location.

Overall, no apparent impact from maintenance dredge activities was evident on the monitored coral parameters. Any significant changes between the Pre-Dredge and Post-Dredge surveys could be attributable to seasonal variation or regional metocean influences.

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Acronyms

AIMS	Australian Institute of Marine Science
ANOSIM	Analysis of Similarity
ANOVA	Analysis of Variance
EMP	Environmental Management Plan
HSEQ	Health Safety Environment and Quality
LMDMP	Long-term Maintenance Dredge Management Plan
LSD	Least Significant Differences
MANOVA	Multivariate Analysis of Variance
MEMP	Marine Environmental Monitoring Program
MS	Management System
NQBP	North Queensland Bulk Ports
PAR	Photosynthetically Active Radiation
PCO	Principal Component Analysis
PERMANOVA	Permutational Analysis of Variance
QA/QC	Quality Assurance/Quality Control
RGB	Red Green Blue
VE	Vision Environment

1 INTRODUCTION

The Port of Hay Point is North Queensland Bulk Ports Corporation's (NQBP) southernmost port. The Port encompasses two coal terminals, which export in excess of over 100 million tonnes of coal per year. In order to maintain safe navigational depths necessary for the manoeuvring and transit of ships in and around the Port of Hay Point, regular maintenance dredging is required to remove naturally accumulated sediment impacting the required depths. As such, NQBP developed the Port of Hay Point Long-term Maintenance Dredge Management Plan (LMDMP) (NQBP, 2018c) and Port of Hay Point Maintenance Dredging Environmental Monitoring Plan (EMP) (NQBP, 2018a) in order to manage accumulated sediment within the port in the most sustainable way. Several state and federal approvals were gained before commencement of the 2019 Port of Hay Point maintenance dredging program, which included the implementation of the NQBP Marine Environmental Monitoring Program (MEMP) (NQBP, 2018b) linked to the LMDMP and EMP.

As per the MEMP, NQBP are required to conduct impact monitoring of corals during each maintenance dredge program to quantify if coral communities in the Hay Point region have been affected by maintenance dredging. The MEMP states that impact monitoring will be undertaken utilising the sites and methods used for the ambient coral monitoring program and is to take place approximately four weeks prior to dredging, and four weeks post dredge completion.

Corals have been monitored at four locations in the vicinity of Hay Point (Round Top Island and Victor Island (water quality monitoring trigger sites), and Slade Islet and Keswick Island (water quality monitoring control and support sites) since 2006 by a variety of service providers. Since January 2018, a biannual pre- and post-wet season ambient coral monitoring program has been carried out by TropWATER, a unit of James Cook University in association with Sea Research (Ayling *et al.*, 2018).

After discussion with NQBP, the proposed impact monitoring of the corals was altered slightly from the ambient monitoring protocol outlined in the MEMP, to focus on techniques which would more easily permit the detection of impacts from the maintenance dredge activities. This included the use of:

- Photographic quadrats to accurately compare Pre- and Post-Dredge measurements of coral species, the occurrence of coral damage (sediment deposition, bleaching or disease) and coral recruitment, which also functioned to reduce dive times;
- Methodology to enable objective measurements of substrate cover as opposed to field estimations;
- A rapid coral health indicator technique to determine if corals are stressed prior to physical damage being observed; and
- The use of univariate and multivariate statistical analyses to determine whether there has been a change in the coral community before and after maintenance dredging.

This report presents the results of the coral impact monitoring undertaken in response to the 2019 Port of Hay Point maintenance dredge program (31 March to 2 May 2019).

2 METHODOLOGY

The VE methodology was based on the Vision Environment (VE) Health, Safety, Environment and Quality (HSEQ) Management System (MS) protocols *VE191 Coral Reef Monitoring by Transect* and *VE 223 Coral Reef Monitoring using Timed Transects*, which is based on the Australian Institute of Marine Science (AIMS) standard operating procedures. Pre-Dredge surveys commenced in February (18th to 22nd) but were hampered by poor visibility during the prevailing king tides and were therefore completed in mid-March (13th to 15th). The Post-Dredge survey was undertaken from 13th to 17th June 2019, approximately six weeks after the completion of dredging. This was the first available suitable weather window after the four-week minimum post-dredge time requirement.

The MEMP listed outlined that monitoring should take place at six individual sites at each of the four locations: Keswick Island/St Bees Island; Slade Islet; Round Top Island; and Victor Island (Figure 1). At each site, four transects previously established by TropWATER were to be examined, totalling 96 transects in total.

However, modifications to this program were required during the Pre-Dredge survey as recommended by VE and agreed to by NQBP, with fewer sites monitored at all locations (except Round Top Island, the location closes to the dredge and placement activities) and fewer transects at most of the sites (Table 1), resulting in a total of 52 transects examined in this monitoring program.

The decrease in the number of transects examined was due to the poor water visibility during the king tides prevailing during the initial Pre-Dredge survey, and the need to install new permanent transects at all sites. Unfortunately, the previously established transects were not able to be located easily by the VE dive team, and thus new permanent transects were required to be established adjacent to the transect locations provided by TropWATER. The new transects of 20 m were established with 12 mm stakes driven into the seabed at 5 m intervals. Note that more than 1000 lineal metres of coral surveys across 51 transects at 17 sites around four islands was undertaken and determined to be sufficient for statistical analysis between Pre- and Post-Dredge surveys.

Table 1 Coral Monitoring Sites
Note that depth measurements are indicative and are the means of the recorded dive depths during monitoring.

Location	Mean Depth (m)	Site ID	Latitude	Longitude	No. of transects
Keswick Island/St Bees Island (control)	5.6	S1	-20.9150	149.4185	3
		S2	-20.9132	149.4171	3
		S4	-20.9290	149.4280	3
		S5	-20.9245	149.4102	4
Slade Island (control)	5.9	S1	-21.0989	149.2440	3
		S2	-21.0988	149.2450	3
		S6	-21.0994	149.2459	3
Round Top Island (trigger)	8.2	S1	-21.1699	149.2656	3
		S2	-21.1715	149.2636	3
		S3	-21.1702	149.2668	3
		S4	-21.1719	149.2675	3
		S5	-21.1749	149.2689	3
		S6	-21.1769	149.2665	3
Victor Island (trigger)	4.1	S1	-21.3189	149.3244	3
		S2	-21.3223	149.3267	3
		S5	-21.3197	149.3215	3
		S6	-21.3223	149.3191	3

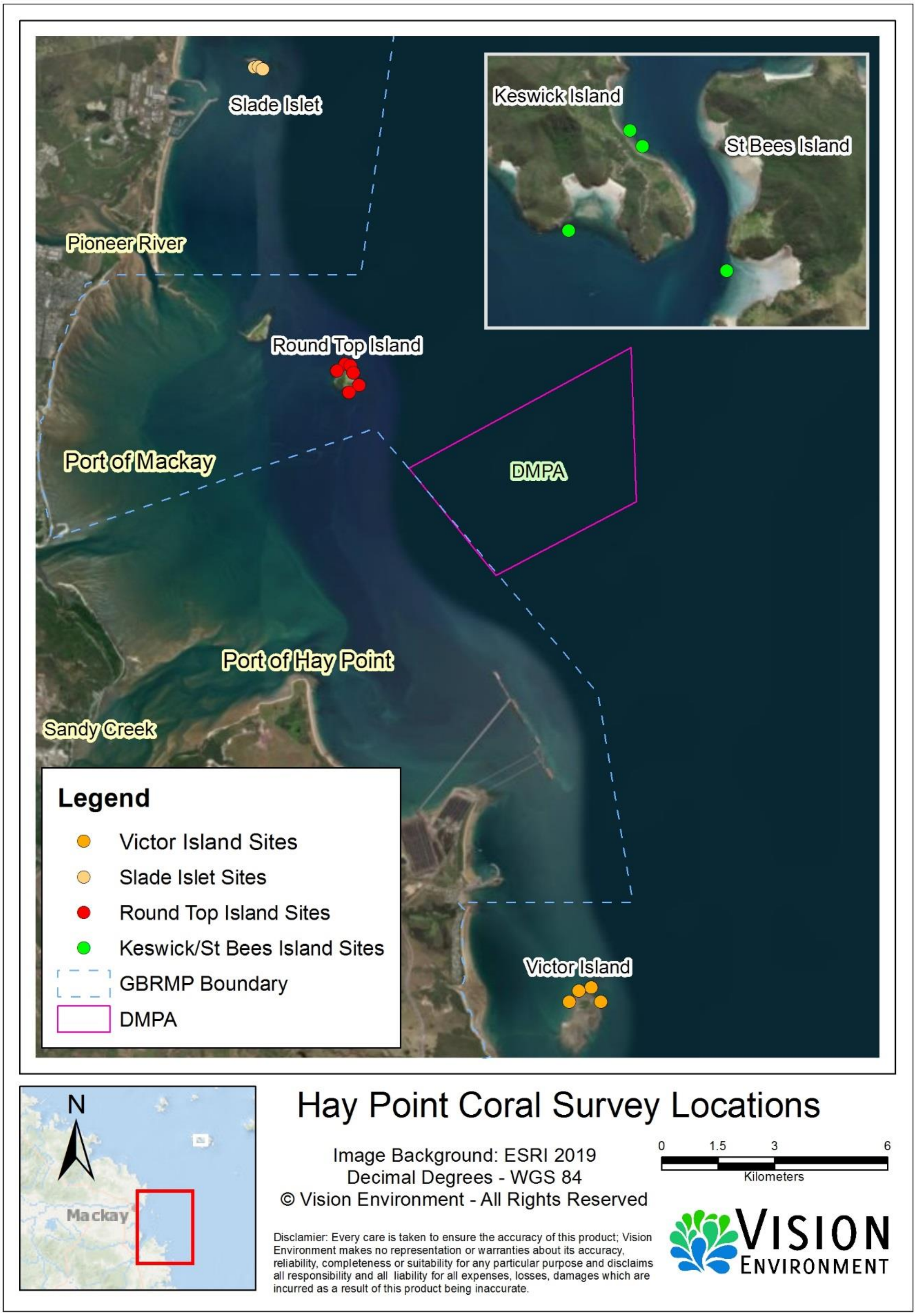

Figure 1 Hay Point coral impact monitoring locations.
Map background: ESRI 2019.

During the Pre-Dredge survey, GPS locations were recorded at each end of the transects. Thin marking line was deployed along the transect (tied to start, mid and end stakes) to remain in place during both surveys to ensure continuity of the monitoring. The marking line was removed after the Post-Dredge survey.

2.1 Coral Cover and Community Demographics

Along each transect, photographic quadrats were captured at 1 m intervals using a still camera in an underwater housing set on the lowest wide-angle setting (28 mm full frame equivalent, behind a flat port, giving an approximate diagonal angle of view of about 60° underwater). Each image was captured at 1 m above the benthos using a reference bar to standardise each photograph (Figure 2). Images were captured parallel to the seafloor to minimise parallax error, and depth was recorded to within +/- 0.1 m using a dive computer. Photographs were taken at the same location within each transect during each survey to ensure accurate Pre- and Post-Dredge comparisons.

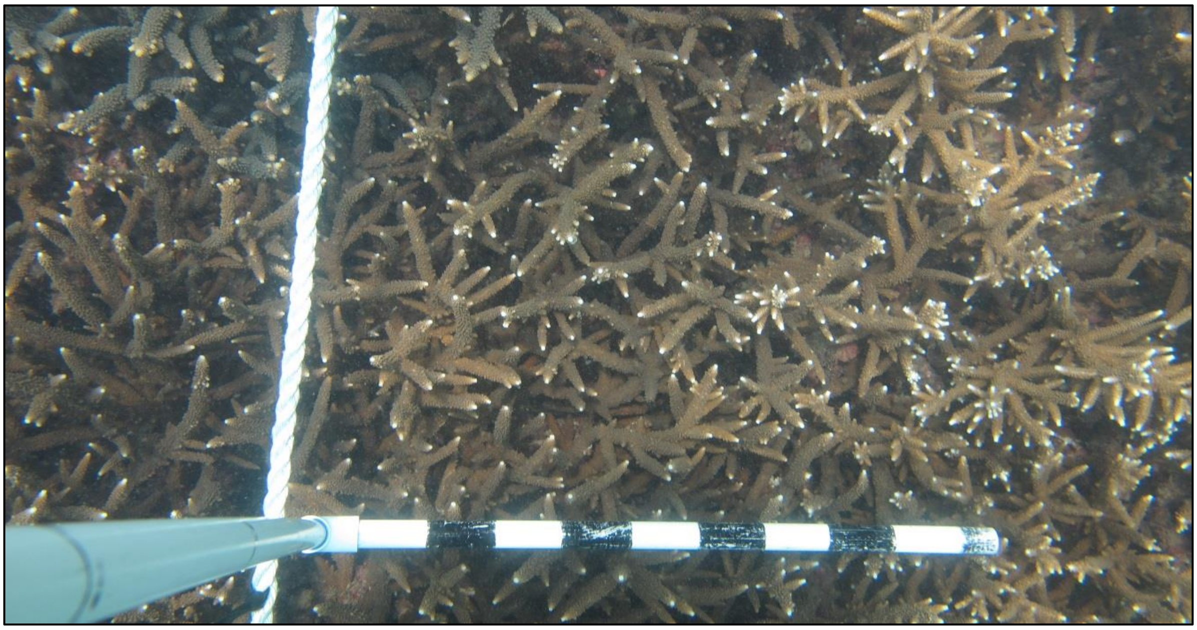

Figure 2 Example of line intercept method with standardised scale bar along a transect line.

Images were analysed by means of point count methodology by an experienced taxonomist, where a minimum of 20 randomly selected points were overlayed on each image to determine community demographics of sessile benthic organisms, pavements and other non-lining substrates (Figure 3).

Major community categories included:

- Turfing algae;
- Hard corals;
- Soft corals;
- Macroalgae;
- Sponges and ascidians;
- Sediment (e.g. sands, pavement and rock); and
- Other living biota, including hydroids, bryozoans and zoanthids.

A second taxonomist analysed 10% of images for quality assurance/quality control (QA/QC) purposes as per VE HSEQ MS protocols. If the transect accuracy was lower than 95% between the two taxonomists, transects were re-examined and results discussed.

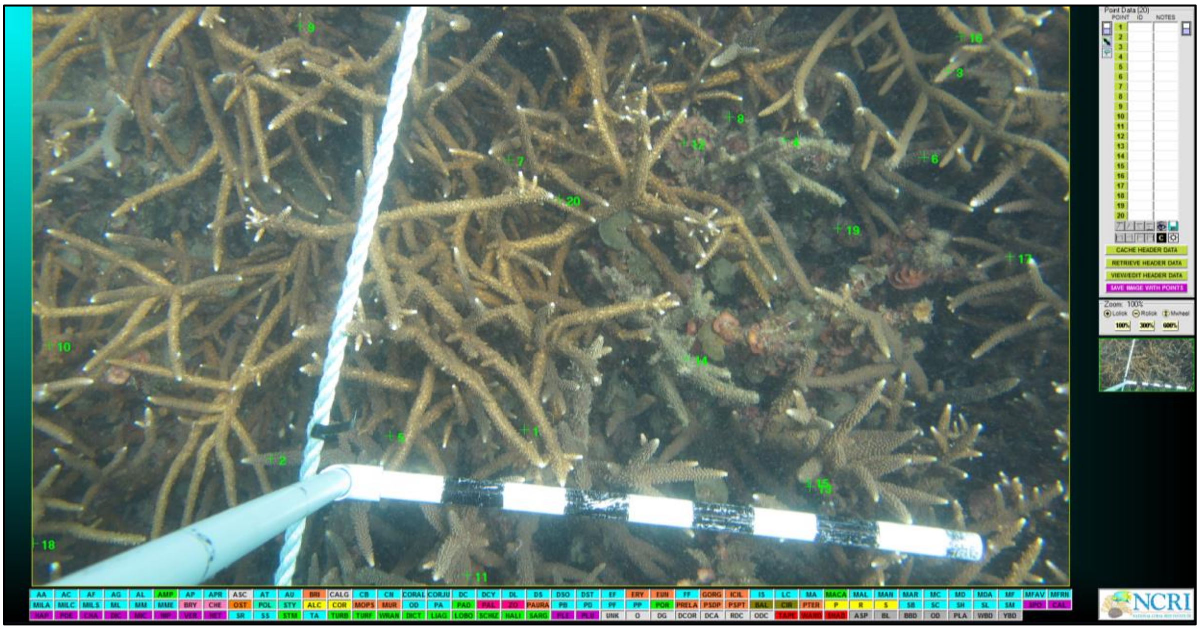

Figure 3 Example of point intercept area with 20 random points, dominant coral species and disease, bleaching, sediment cover analysis.

2.2 Bleaching, Disease and Sediment Deposition

In addition to measuring coral community demographics using point intercept techniques, the same images were used to determine the occurrence per transect of:

- Sediment deposition on corals;
- Coral bleaching; and
- Diseased coral.

Additionally, when sediment covered corals were observed during the fieldwork, sediment depth on the colony surface of up to 20 corals per transect was measured.

2.3 Coral Recruitment

Using the same images as above, all new recruits across three size classes (0-2 cm diameter, 2-5 cm diameter and 5-10 cm diameter) were recorded.

2.4 Rapid Coral Health Indicator Technique

Once coral disease and/or bleaching is observed, significant irreparable damage may have occurred to individual coral colonies. Being able to measure stress in corals before physical damage is observed, may allow management strategies to reduce the risk of further damage. As such, VE has developed a rapid response coral health indicator technique as an early warning indicator of potential anthropogenic pressures.

The methodology is based on measuring the luminance/reflectance and the Red Green Blue (RGB) colour channels of coral images in response to reduced light thresholds, which can be experienced during dredge events, prolonged low light climatic conditions, sediment deposition and turbidity stressors. The technique determines light thresholds required to change the pigment concentrations and colour of corals when subjected to reduced ambient light. Previous studies conducted by VE (Alquezar *et al.*, in prep) have found that these endpoints are typically sensitive enough (dependent on the coral species) to indicate whether impacts have occurred. Hence, change in coral colour pigment among sites and surveys was utilised in this project as an early detection indicator.

During the Pre-Dredge survey, up to four individual coral colonies from commonly occurring species were selected in each transect and photographed using a custom designed quadrat frame which incorporated a white reference colour bar. The same coral colonies were photographed on the same plane during the Post-Dredge survey, and data compared across the surveys. While ideally the same coral species would be monitored at each site, the variation in coral species present across the sites did not enable this to occur. As such, the most common corals occurring at each site were the ones that were selected for analysis, thus randomising species.

Colour information attained from frequency histograms, including RGB and luminosity channels, were selected and standardised against the white reference colour bar included in each photograph. Luminosity is a measure of perceived brightness in an image and is described as the amount of light absorbed, emitted, or reflected from an area.

Luminosity was used as the colour channel indicator and was compared in the selected corals across transects, sites, locations and surveys and standardised as a percentage of luminance to the scale bar of each photograph. This allowed for correction of colour shifts during differing ambient conditions (e.g. alterations in light, depth and turbidity). This non-invasive technique indicates the amount of potential coral bleaching that could occur based on the increase or decrease in coral pigments. Temporal (Pre- and Post-Dredge) and spatial (sites/locations) changes in pigment colour were examined.

2.5 Data Analysis

Statistical analyses determined if changes in coral parameters were observed either temporally (between the two surveys) or spatially (among the four locations). One and two-way Analysis of Variance (ANOVA) was used to determine if there were any significant differences in major substrate cover or coral parameters (bleaching, disease, sediment deposition, coral recruitment and coral pigment change) between surveys (Pre- and Post-Dredge) or locations (Round Top Island, Victor Island, Slade Islet, and Keswick Island), with sites nested within each location.

Statistical interactions were used to determine if any significant spatial differences had occurred during both surveys, particularly for the sensitive substrates of hard and soft corals. Significance levels were increased ($P < 0.01$, 99 % confidence intervals) where data did not meet that criterion (O'Neill, 2000, Underwood, 1997). In order to determine where significant differences occurred Fisher's Least Significant Difference (LSD) *Post hoc* tests were used.

Due to the large number of minor category substrate types, multivariate statistical analyses were applied to examine any temporal or spatial changes in substrate cover. Permutational Multivariate Analysis of Variance (PERMANOVA) hypothesis testing was used to determine temporal and spatial significant dissimilarities (difference) in substrate community structure (multiple species and how they relate to each other based on percent cover). PERMANOVA was selected over other techniques because it is a permutational technique that does not require parametric assumptions unlike Multivariate Analysis of Variance (MANOVA) and ANOVA (Clarke and Gorley, 2006). Principal Coordinates Ordination (PCO), which is based on the PERMANOVA model, was used to graphically illustrate the data. Analysis of Similarity (ANOSIM) was also undertaken.

3 RESULTS & DISCUSSION

3.1 Cover and Community Demographics

Coral reefs are an important part of the marine ecosystem and to human populations. Coastal reefs are often located near estuaries and/or mangroves, making them important nursery habitats to many juvenile fish species (Birkeland, 1997, Blaber *et al.*, 2005, Harding *et al.*, 2006, Patterson and Swearer, 2007, Rönnbäck, 1999, Schaffelke *et al.*, 2005). Coastal fringing coral reefs in particular, are more susceptible to anthropogenic influences than offshore reefs, specifically because of their location. Hence, an understanding of reef habitat structure and condition is important in the management of future potential natural and man-made disturbances.

In the current study, major substrate community cover was used to determine if dredge activities had potentially changed community structure and health of the adjacent coastal fringing reefs. Major substrate/reef classes included turfing algae, hard corals, soft corals, macroalgae, sponges and ascidians, sediments and other biota (including hydroids, bryozoans and zoanthids).

Macroalgal assemblages were the most common substrate observed across the surveys and locations (mean transect cover = 35%); followed by sediments, including sand, pavements and rocks (32%); hard coral (17%); turfing algae (11%); and soft corals (2%). Sponges, ascidians, zoanthids, hydroids and bryozoans all contributed to ≤ 1% cover at each transect (Figure 4, Table 4 in Appendix). Similar proportions of the major categories were reported in January and July 2018 by TropWATER (Ayling *et al.*, 2018).

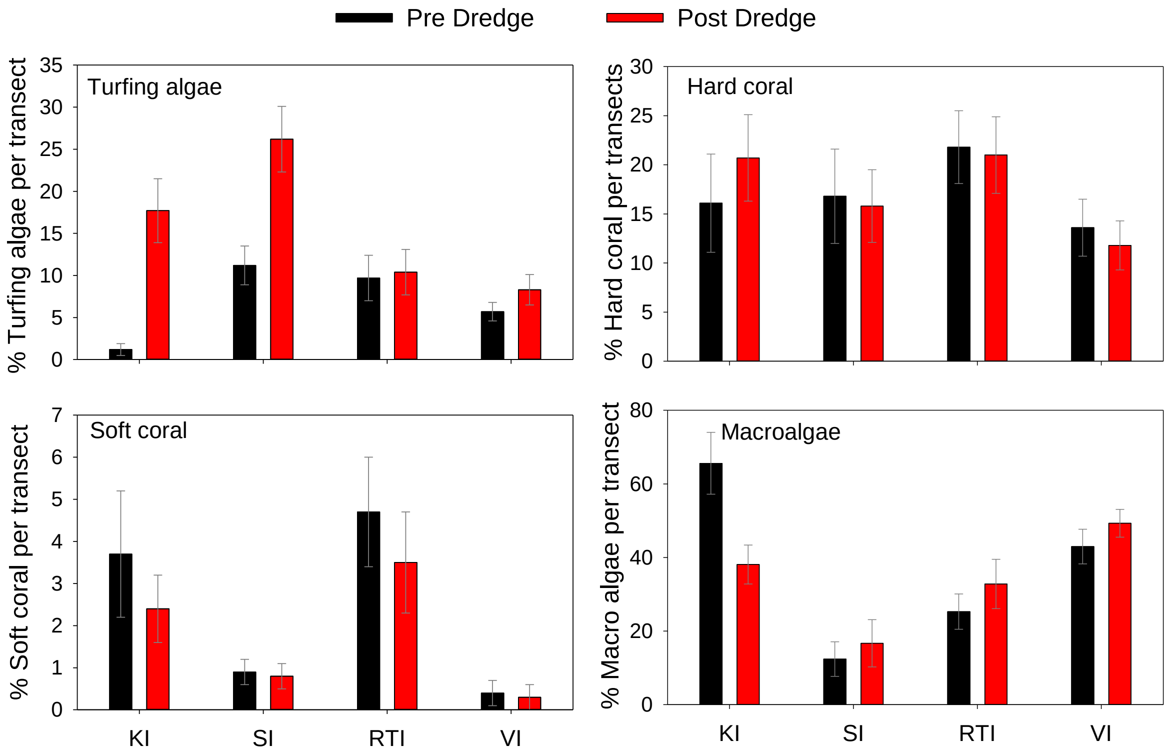

Figure 4 Mean transect substrate cover of turfing algae, hard corals, soft corals and macroalgae at locations during each survey.
Values are means ± se (n = 9 to 18).

Significant (P < 0.05) spatial differences between locations were evident for most major categories, including turfing algae, macroalgae, soft coral, sediment and hydroids and bryozoans (Table 2). Significant (P < 0.05) temporal differences between the Pre- and Post-Dredge surveys was evident only for turfing algae, with significantly higher coverage during the latter survey.

Of note were the significant (P < 0.05) spatial and temporal interactions for turfing algae and macroalgae cover, indicating that significant differences were evident in the coverage of the algae between the two surveys, but only at certain locations. Macroalgae coverage was significantly higher at Keswick/St Bees during the Pre-Dredge survey (mean transect cover = 66%), than during the Post-Dredge survey (38 %), while turfing algae coverage exhibited the opposite pattern (Pre-Dredge = 1.2%, Post-Dredge = 18%).

As this location was the greatest distance from the dredging activities (approximately 20 nautical miles from Port of Hay Point), the result was unlikely to be an impact of the dredge activities. TropWATER also recorded a similar decrease in macroalgal coverage from January to July 2018 at this location (Ayling *et al.*, 2018). The concurrent increase in turfing algae coverage at Keswick/St Bees is likely to be due to its increased visibility to divers with the reduction of macroalgal coverage.

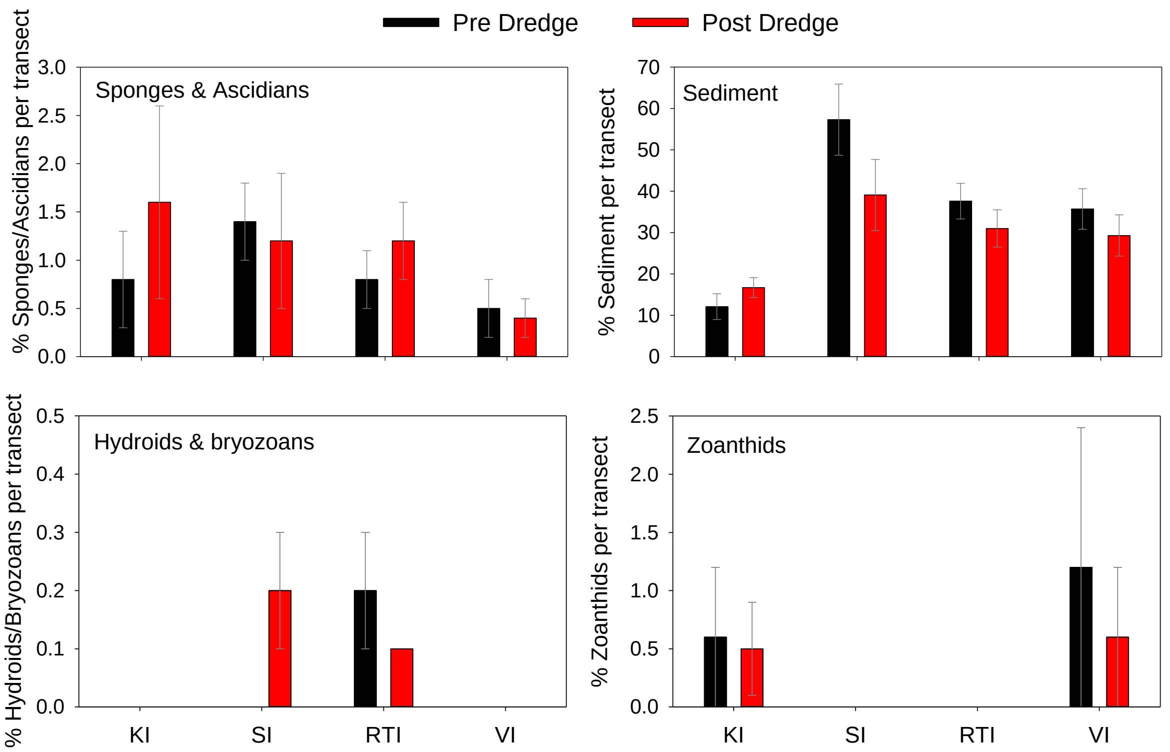

Figure 5 Mean transect substrate cover of sponges and ascidians, sediments, hydroids and bryozoans, and zoanthids at locations during each survey.
Values are means ± se (n = 9 to 18).

Regarding hard and soft coral coverage, no significant (P > 0.05) temporal differences between the Pre- and Post-Dredge surveys, or interactions, were evident. While no significant spatial variation between locations was evident for hard coral coverage, significantly (P < 0.05) higher soft coral coverage was evident at Round Top Island (mean transect cover = 4.1%) and Keswick/St Bees Island (3.4%), than Slade Island (0.9%) and Victor Island (0.4%). TropWATER also found soft corals to be more abundant on Round Top Island and Keswick/St Bees Islands during 2018 (Ayling *et al.*, 2018).

Table 2 Summary of one and two-way ANOVA's for major substrate cover and coral health indicators.
Red denotes significant (P < 0.05) differences observed. SS = sum of squares difference, P =probability.

	Turfing algae		Hard corals		Soft corals		Macroalgae	
Biodiversity % Substrate cover	SS	*P Value*	SS	*P Value*	SS	*P Value*	SS	*P Value*
Before / After "BA"	136.7425	*0.000000*	0.1150	0.735247	0.37631	0.541034	0.3927	0.532356
Locations "CI"	20.4963	*0.000017*	1.7998	0.152400	5.92898	*0.000938*	12.6644	*0.000000*
BA x CI "Locations"	4.9173	*0.003201*	0.5597	0.642927	0.10839	0.955010	4.3174	*0.006691*
Sites (locations)	7.4043	*0.000000*	15.9897	*0.000000*	6.32550	*0.000000*	10.1944	*0.000000*
BA x Sites (Locations)	4.7873	*0.000002*	0.4849	0.946693	0.20266	0.999549	2.8606	*0.001274*

	Sponges/ascidians		Sediments		Hydroids/Bryozoans		Zoanthids	
Biodiversity % Substrate cover	SS	*P Value*	SS	*P Value*	SS	*P Value*	SS	*P Value*
Before / After "BA"	0.62930	0.429569	3.2187	0.075952	0.04563	0.831311	0.674396	0.413558
Locations "CI"	0.96519	0.412506	12.9650	*0.000000*	4.87435	*0.003374*	1.469725	0.227661
BA x CI "Locations"	0.55625	0.645193	1.4668	0.228473	1.85688	0.142090	0.238356	0.869408
Sites (locations)	2.63510	*0.003855*	11.3606	*0.000000*	4.37472	*0.000013*	1.834755	0.050142
BA x Sites (Locations)	0.33727	0.990981	1.0381	0.429563	1.10711	0.365856	0.265970	0.997627

	Bleached Pale		Bleached White		Diseased Coral		Sediments on Corals	
Bleaching and sediments on corals	SS	*P Value*	SS	*P Value*	SS	*P Value*	SS	*P Value*
Before / After "BA"	1.64570	0.202634	1.838324	0.178328	2.295742	0.133015	15.02829	*0.000194*
Locations "CI"	4.84201	*0.003510*	2.450686	0.068150	0.656067	0.581089	6.83858	*0.000317*
BA x CI "Locations"	0.38742	0.762312	0.916768	0.435882	0.639540	0.591394	6.27000	*0.000623*
Sites (locations)	4.53739	*0.000008*	2.65767	*0.003578*	1.405145	0.173633	2.36323	*0.009397*
BA x Sites (Locations)	0.64472	0.836078	2.35315	*0.007450*	1.553658	0.105839	4.45752	*0.000006*

Significant (P < 0.05) spatial variation was evident for sediment coverage, which was significantly higher at Slade Islet (mean transect cover = 48 %), and significantly lower at Keswick/St Bees Island (15%). Hydroid/bryozoan coverage was significantly higher at Round Top Island (mean transect cover = 0.14%) than at all other locations (≤ 0.1 %). No significant temporal differences or interactions were recorded.

Within each of the major categories, recorded substrate was also designated into minor classes or categories (Table 6 in Appendix). For hard and soft corals and macroalgae, this meant classification into genus or species.

Of the macroalgae, the brown algae *Sargassum* sp. dominated (Figure 6), with mean transect coverage between 10 and 64%. TropWATER also found *Sargassum* sp. to be the most abundant macroalgae (Ayling *et al.*, 2018). The most common hard coral, particularly at the inshore sites of Round Top Island, Slade Islet and Victor Island, was *Montipora* spp. (Figure 6) with mean transect coverage of 2.0 to 7.6%. *Acropora* spp. was the next most common hard coral, and the dominant genus at Keswick/St Bees, with mean transect coverage ranging from 0.1 to 10% across the four locations. Similar hard coral demographics across the four locations was reported by TropWATER (Ayling *et al.*, 2018). *Lobophytum* spp. was the most common soft coral, with mean transect coverage ranging from 0.1 to 2.5% (Table 6 in Appendix).

Figure 6 Example of the common macroalgae *Sargassum* sp. and the hard coral *Montipora* sp. (center and right of image).

Due to the large number of minor category substrate types, multivariate statistical analyses were used to examine any temporal or spatial changes in substrate cover (Figure 7). Small but significant dissimilarities (differences) among minor category substrate communities were observed among the locations (ANOSIM R-statistic 0.037; P < 0.005; PERMANOVA P < 0.01), however, there were no significant dissimilarities in community assemblage between surveys (ANOSIM R-statistic 0.001; P > 0.05; PERMANOVA P > 0.01).

No significant interactions were observed between locations and surveys (ANOSIM R-statistic 0.036; P > 0.005; PERMANOVA P > 0.01). Like the univariate analyses, the results suggest that locations were composed of varying substrate communities, as would be expected. However, there were no significant temporal changes in overall community structure across surveys. Pairwise comparisons showed that there were no significant dissimilarities in minor substrate categories between Pre-dredge and Post-dredge at all locations (P > 0.005) (Figure 7).

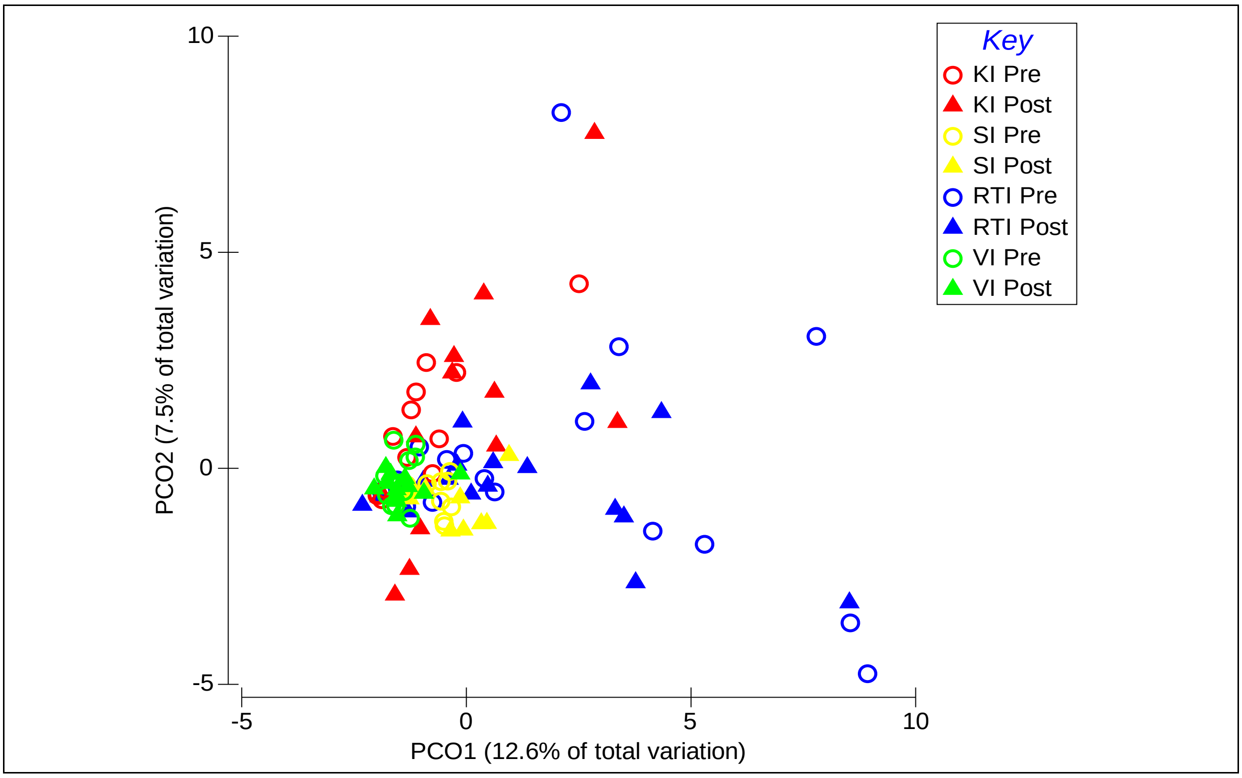

Figure 7 Principal Coordinates Ordination of minor substrate categories among locations over the two surveys.
Data were normalised and square root transformed using Euclidian distances. Locations coloured coded with Pre-Dredge data denoted by circles and Post-Dredge data denoted by triangles.

3.2 Bleaching, Disease and Sediment Deposition

Coral bleaching is facilitated by an increase in ocean temperatures, and an increase of 1°C can have a significant impact on the frequency of coral bleaching events (Baker *et al.*, 2008, Berkelmans and Oliver, 1999, Berkelmans *et al.*, 2004, Glynn, 1993). A number of bleaching events have also occurred in more northern reefs in the last ten years (Thompson *et al.*, 2010, Thompson *et al.*, 2011, Thompson and Dolman, 2010).

Very little coral substrate in the current study demonstrated signs of stress, with less than 4% of corals overall showing pale colouration and less than 1% presenting bleached white colouration (Figure 8, Table 5 in Appendix), similar to what was reported by TropWATER in 2018 (Ayling *et al.*, 2018). Moreover, less than 1% of corals showed any signs of disease.

There were no significant (P > 0.05) temporal differences in the occurrence of bleached pale corals, bleached white corals and diseased corals between the Pre- and Post-Dredge surveys (Table 2). However, significant (P < 0.05) spatial variation among locations was observed, with significantly higher occurrence of bleached pale corals at Keswick/St Bees (mean transect occurrence ~ 9%) than at the other locations (≤ 4 % occurrence). The higher level of bleached pale corals at Keswick/St Bees was consistent during both surveys.

Sediment deposition on corals was observed at each location during both surveys (Figures 8 and 10). Both significant (P < 0.05) spatial and temporal variation in the occurrence of sediment deposition was recorded, in addition to significant interactions. Victor Island and Slade Islet exhibited significantly higher occurrence of sediment deposition on corals during the Pre-Dredge survey (mean transect occurrence = 26 to 35%). However, occurrence decreased significantly during the Post-Dredge survey (3 to 6%) aligning with the Pre- and Post-Dredge survey occurrences recorded at Keswick/St Bees (2 to 4 % occurrence) and Round Top Island (4 to 5 % occurrence).

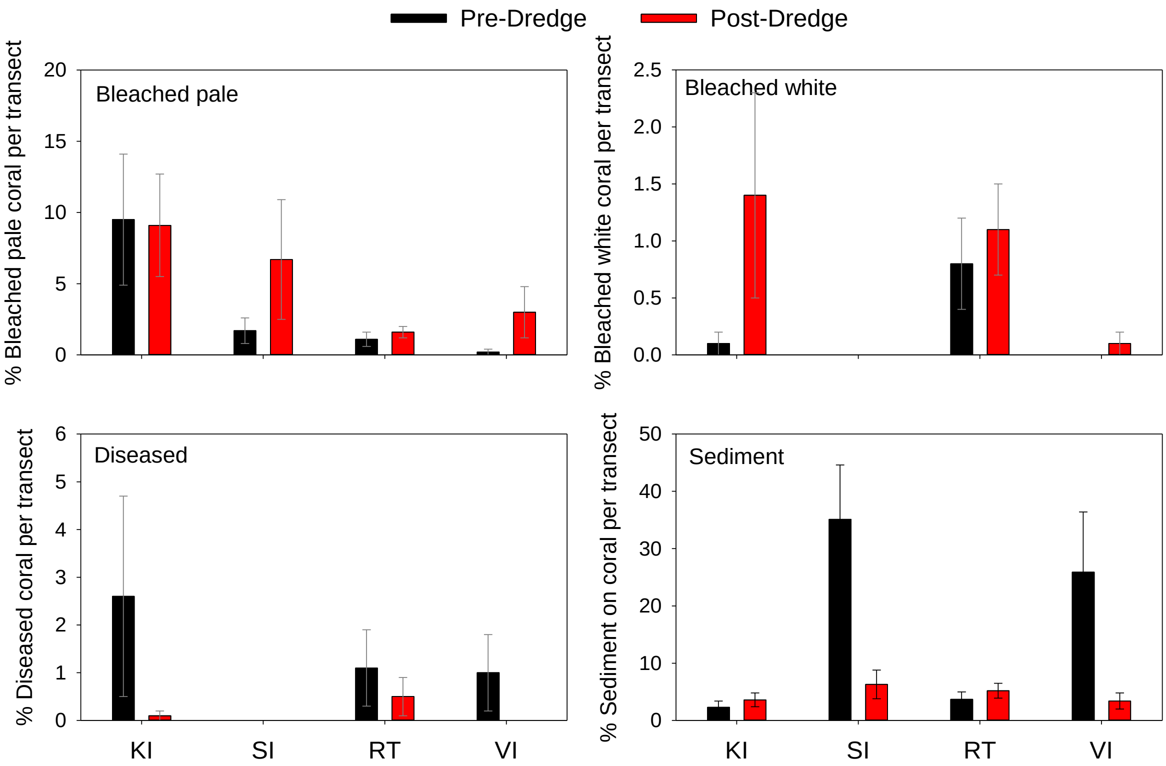

Figure 8 Mean transect cover of bleached pale corals, bleached white corals, diseased corals, and) presence of sediments on corals at locations during each survey.
Values are means ± se (n = 9 to 18).

Figure 9 Example of bleached white coral at Round Top Island.

Figure 10 Examples of presence of sediments on coral tissues.

These results suggest that dredging activities did not appear to increase the occurrence of sediment deposition on corals. The decreased occurrence at the two inshore sites of Victor Island and Slade Islet may have been due to other regional metocean influences, such as winds, currents, storms and other weather events. As reported in the Hay Point Maintenance Dredge Water Quality Monitoring report (Vision Environment, 2019) flow events from the Pioneer River and Sandy Creek were recorded in response to rain events in March and April 2019, with winds greater than 15 kts recorded often during the monitoring project.

Significant ($P < 0.05$) temporal and spatial variation in sediment deposition depth was recorded, however no statistical interactions were observed (Table 2, Figure 11). Overall, sediment depth was significantly higher (1.1 mm) during the Post-Dredge survey than during the Pre-Dredge survey (0.5 mm). Spatially, Keswick/St Bees (1.1 mm) and Round Top Island (0.9 mm) exhibited significantly higher sediment depths than Victor Island (0.6 mm) and Slade Islet (0.5 mm).

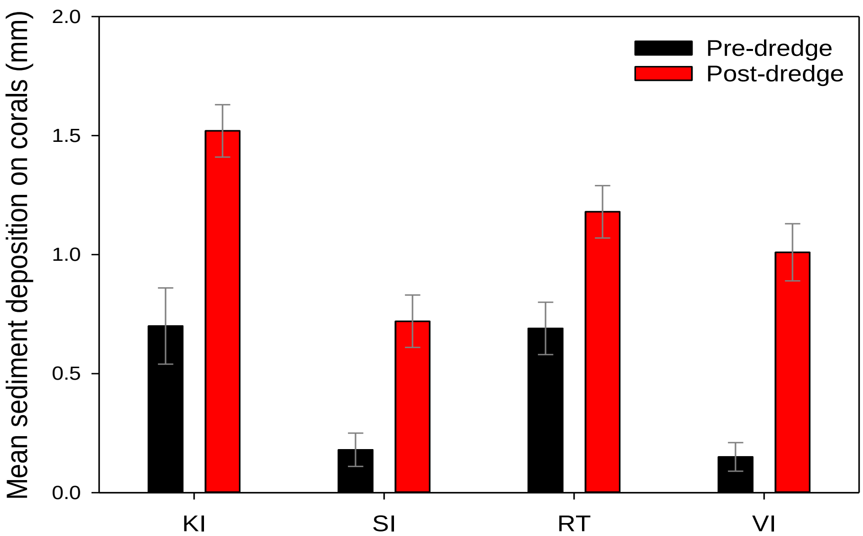

Figure 11 Mean sediment deposition on corals at locations during each survey.
Values are means ± se (n = 9 to 18).

Although sediment depths were higher Post-Dredge than during Pre-Dredge, increases were consistent across all locations (0.5 to 0.9 mm), including the Keswick/St Bees location which is located approximately 20 nm from the Port of Hay Point dredging activities. As such, it is unlikely that dredging activities were responsible for the increased depth of sediment between the two surveys.

3.3 Juvenile Coral

Approximately 882 juveniles from 18 coral species were recorded at the four locations across the two surveys (Tables 7 to 9 in Appendix). The most commonly occurring juvenile was *Turbinaria* spp. (29%) (Figure 12), followed by *Goniopora* spp. (23%), *Favia* spp. (10%), and *Acropora* spp. (8%). Some growth in mature corals was also observed over the two surveys, with some coral fragments increasing up to 50 mm in length between surveys (Figure 13).

As the number of sites and transects varied across the four locations, mean juvenile coral calculations were used for analysis as opposed to total numbers. Total numbers in each size class in each location and survey are listed in Table 8 in the Appendix.

There was no significant spatial or temporal difference in the total number of juveniles between the Pre- and Post-Dredge surveys, indicating no apparent impacts from dredging activities. The mean number of juveniles per transect during the Pre-Dredge survey ranged from 1.5 to 8.0, while ranging from 3.2 to 6.5 juveniles per transect during the Post-Dredge survey (Figure 14, Table 9 in Appendix).

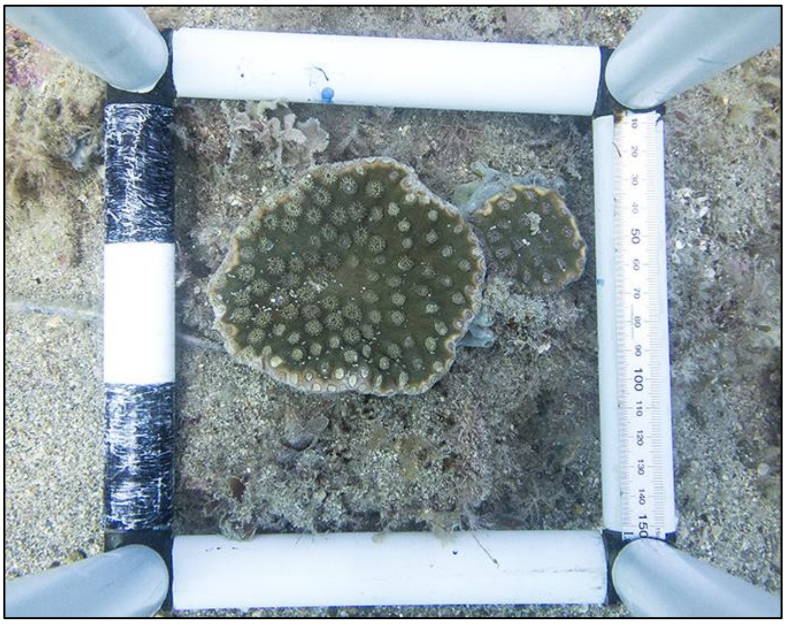

Figure 12 Examples of juvenile recruit coral *Turbinaria* sp.

Juveniles in the 5 to 10 cm size class generally made up the highest proportion of the juveniles at each location during each survey (37 to 76%), while the smallest size class (0 – 2cm) tended to have the fewest individuals (4 to 15%).

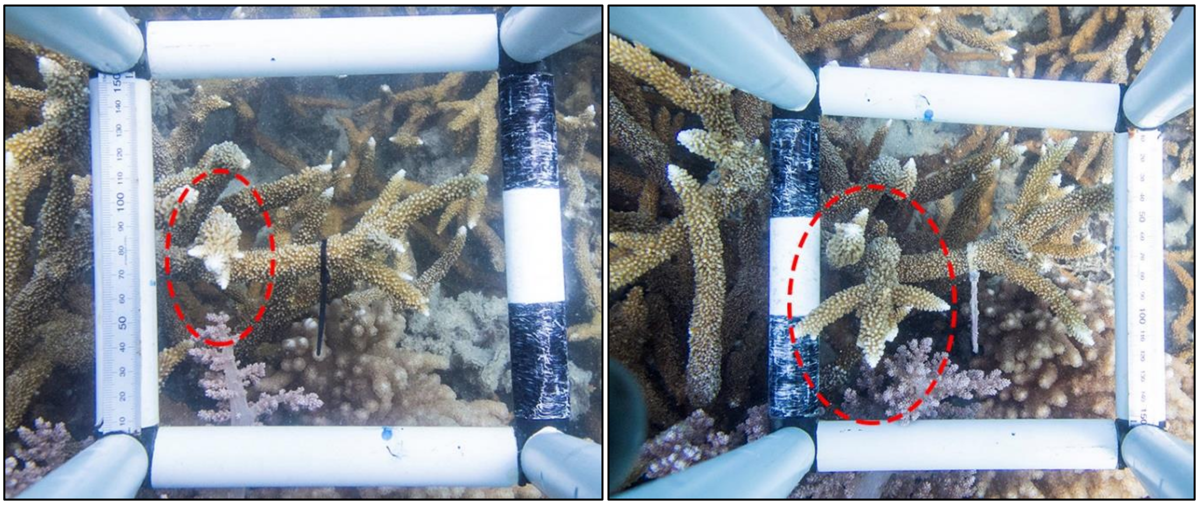

Figure 13 Examples of coral fragment growth (Red dotted line) between (a) Pre-dredge and (b) Post dredge surveys.

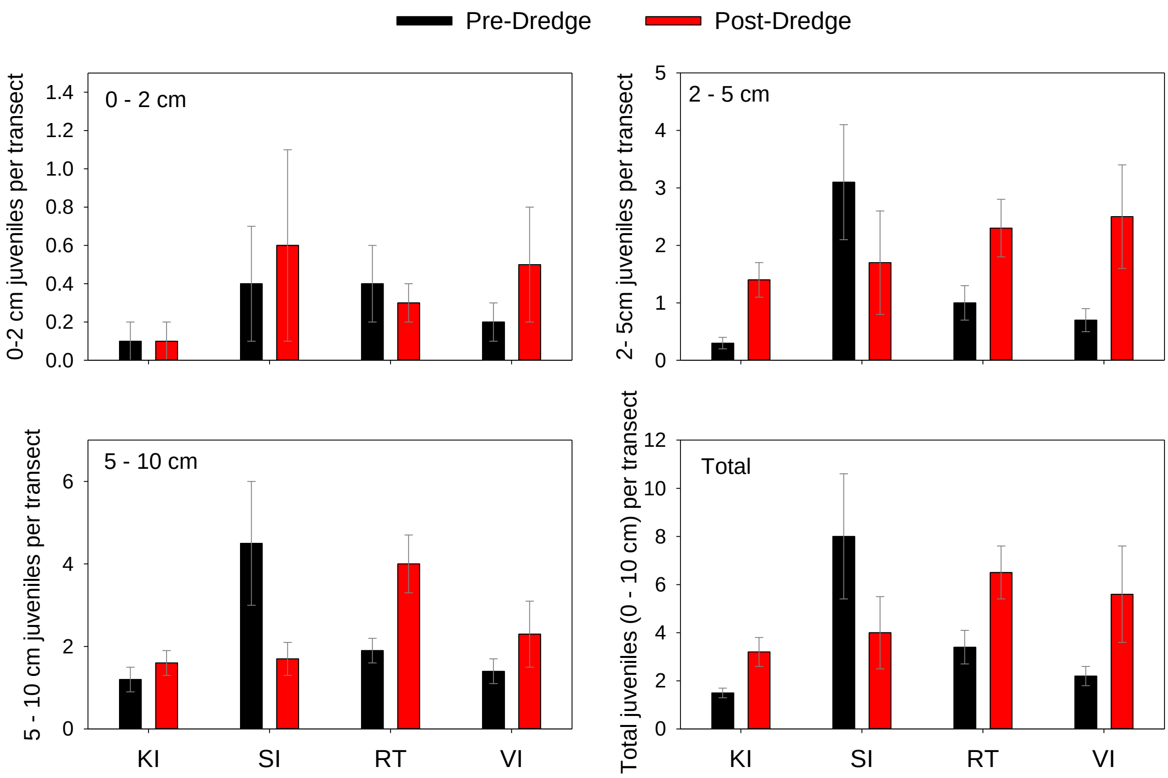

Figure 14 Mean juvenile corals in different size classes and total at locations during each survey *Values are means ± se (n = 9 to 18).*

3.4 Coral Colour Analysis

Corals and their algal symbionts have the ability to regulate changes in light availability through behavioural, morphological and physiological adaptation. This includes changes to polyp feeding regimes, changes in photosynthetic rates, coral skeletal light reflective and absorption properties, changes in algal densities, mucus production and energy shifts in physiology (Anthony and Fabricius, 2000, Ben-Zvi *et al.*, 2015, Chen *et al.*, 2005, Cruz *et al.*, 2015, Jones *et al.*, 2015, Nir *et al.*, 2011, Rodrigues and Grottoli, 2007, Wangpraseurt *et al.*, 2012).

In the current study, a measure of difference in colour luminance between the Pre-and Post-Dredge surveys was undertaken to determine if any physiological response of coral pigment production/reduction was evident between locations or across surveys. While ideally the same coral species would be monitored at each location, the variation in coral species present across the pre-established sites did not enable this to occur. As such, the most common corals occurring at each site were the ones that were selected for analysis, thus randomising species.

At the Keswick/St Bees location, a mix of *Acropora* spp., *Coscinaraea* spp. and *Montipora* spp., were utilised, in addition to a lesser proportion of *Gonipora* spp. and *Porites* spp. (Table 3). At Slade Island, *Porites* spp. and *Pocillipora* spp. were used, with one *Turbinaria* spp. individual analysed. At Victor Island, *Acropora* spp., *Montipora* spp. and *Turbinaria* spp. were used, with two individuals of *Pocillipora* spp. examined. At Round Top Island, approximately 75% of the corals examined were *Turbinaria* spp, with *Montipora* spp. and *Porites* spp. also analysed. No single coral type was examined at each of the four locations (Table 3).

Table 3 Mean percent colour change in monitored coral pigments between Pre-Dredge and Post-Dredge.
Values are means ± se (n). Positive numbers denote change to a darker colour, negative numbers denote change to a lighter colour (bleaching).

Coral	Mean percent (%) change in luminosity			
	Keswick/St Bees Islands	Slade Islet	Round Top Island	Victor Island
Acropora sp.	2.6 ± 2.0 (8)	-	-	7.7 ± 2.5 (12)
Acropora sp. / *Montipora* sp.	-	-	-	2.9 ± 0.5 (2)
Coscinaraea sp.	5.6 ± 3.1 (9)	-	-	-
Gonipora sp.	9.9 ± 13 (2)	-	-	-
Montipora sp.	6.4 ± 3.0 (8)	-	6.8 ± 4.7 (4)	1.1 ± 2.3 (10)
Pocillopora sp.	-	5.3 ± 2.2 (9)	-	16 ± 4 (2)
Porites sp.	0.7 ± 5.7 (2)	6.4 ± 1.0 (17)	12 ± 1 (8)	-
Turbinaria sp.	-	0.6 ± 0.0 (1)	11 ± 1 (41)	11 ± 4 (8)
Location Mean	**5.0 ± 1.6**	**5.8 ± 1.0**	**10.6 ± 1.0**	**6.7 ± 1.6**

Overall a positive colour change was recorded at each location, indicating an increase in pigment colour, and thus darker corals, between the two surveys (Table 3, Figures 15 and 16). Each coral taxon at each of the four locations also exhibited a positive colour change, ranging from a 0.6% pigment increase in *Turbinaria* spp. at Slade Islet to a 16% increase in *Pocillopora* spp. at Victor Island. Overall, significantly higher colour change (or darkening) was evident at Round Top Island (10.6%) in comparison with the other three locations (5.0 to 6.7%).

An increase in coral pigment is the opposite of coral bleaching. Decreased light availability to corals will lead to the coral's zooxanthellae to produce more pigment cells (e.g. chlorophyll) in order to increase photosynthesis (Dubinsky and Jokiel, 1994, Houlbrèque and Ferrier-Pagès, 2009, Nir *et al.*, 2011). Generally, the availability of light, or Photosynthetically Active Radiance (PAR), is higher during the summer months due to the longer day lengths, and lower during the winter months where day lengths are shorter (BOM, 2019). The overall darkening of the corals across all locations is likely to be attributable to the varying seasons in which the surveys were carried out (summer/early autumn to winter).

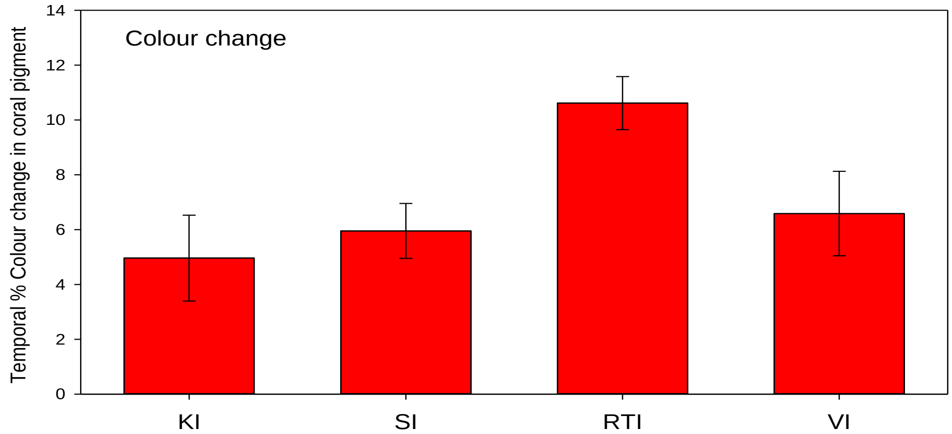

Figure 15 Mean percent colour change in coral pigments between Pre-dredge and Post-Dredge at each location.
Values are means ± se (n = 26 to 54).

Figure 16 Example of colour increase (darker) from Pre-Dredge to Post-Dredge surveys in *Porites* spp.

Benthic PAR (BPAR) can also be decreased by increased turbidity restricting the amount of light reaching the benthos. While measurements of benthic PAR and turbidity were not recorded at the coral monitoring sites during the maintenance dredge monitoring program, continuous benthic turbidity was recorded nearby at the Round Top Island and Victor Island water quality sites (Vision Environment, 2019). Mean benthic turbidity was similar at Victor Island and Round Top Island throughout the monitoring period, as was surface turbidity at these two sites and Slade Island. Therefore, the higher colour change at Round Top Island is unlikely to be a function of varying turbidity causing a reduction in available PAR.

However, differences in water depth can also affect the amount of PAR reaching the benthos. When water depth is greater, the amount of light attenuation through the water column is higher, and therefore less PAR is available at the benthos. The Round Top Island location was deeper (8.2 m) than the other three locations (4.1 to 5.9 m). It is likely that BPAR at the Round Top Island location was lower than Keswick/St Bees, Slade Islet and Victor Island, potentially resulting in the higher level of darkening at this location.

It is also may be possible that the increased darkening of the coral pigments at Round Top Island can be associated with the variety of corals examined at this location in comparison with the other three locations. Some coral taxon overall exhibited lower darkening, such as *Acropora* spp. (2.6% at Keswick/St Bees to 7.7% at Victor Island), and *Coscinaraea* spp. (5.6% at Keswick/St Bees).

However, the taxa examined at Round Top Island generally exhibited a higher level of darkening in multiple locations. Round Top Island *Montipora* spp. (6.8%) was similar to Keswick Island (6.4%), while Round Top Island *Turbinaria* spp. (11%) was similar to Victor Island (11%). Of note, was the higher darkening of the Round Top Island *Porites* spp. (12%) than Slade Islet (6.4%).

Unlike seagrass, little research has been undertaken on the effect of varying light regimes on coral, including pigmentation. However the results from the current monitoring, in addition to the preliminary research undertaken by VE (Alquezar *et al.*, in prep) suggests that several factors, including seasonality, water depth and coral taxon, appear to play a part in changes in colour pigmentation. Although not measured at the coral monitoring sites during the maintenance dredge monitoring program, small-scale physical and chemical differences between the locations may also have had some influence.

4 SUMMARY

Monitoring of the coral communities at the four selected locations was successfully carried out approximately two to six weeks prior to maintenance dredging and approximately six weeks after dredging completion. Overall, no impact on the coral communities was evident from the maintenance dredging activities. A summary of the key findings is provided below:

- Macroalgae was the most common substrate encountered at all locations during both the Pre- and Post-Dredge surveys. *Sargassum* spp. was the most common macroalgae across all locations;
- Sediments, including pavement, rubble and sand, was found to cover around 1/3 of the monitored locations;
- Hard coral, turfing algae and soft corals were the next most dominant substrate cover, with sponges, ascidians, zoanthids, hydroids and bryozoans found only in small amounts;

- At Keswick/St Bees, macroalgal cover declined from the Pre- to Post-Dredge survey, enabling turfing algae to become more discernible to divers, thus increasing its visible coverage. A similar pattern of macroalgal decrease from summer to winter at this location was reported by TropWATER in 2018;
- Hard coral coverage did not vary significantly between surveys or among locations, covering approximately 17% of the substrate examined. *Montipora* spp. was the most common taxon at Round Top Island, Slade Islet and Victor Island, while *Acropora* spp. was the dominant taxon at Keswick/St Bees Islands;
- Soft coral coverage did not vary between the surveys, but coverage was significantly higher at Round Top Island and Keswick/St Bees Islands in comparison with Slade Islet and Victor Island, similar to the 2018 TropWATER findings. *Lobophytum* spp. was the most common soft coral encountered across all locations;
- Few corals across the transects demonstrated stress, including bleaching and disease. No significant differences in the occurrence of bleaching was evident between the Pre- and Post-Dredge surveys. The Keswick/St Bees location exhibited the highest amount of bleach pale coral during both surveys;
- Sediment on coral was evident at all locations during both surveys. A decrease in occurrence was evident at Victor Island and Slade Islet during the Post-Dredge survey, with all locations exhibiting sediment on 2 to 6% of monitored corals. However, the depth of the sediment deposited on corals increased from the Pre-Dredge to Post-Dredge survey. As a consistent increase was evident across all locations, including Keswick/St Bees, it is unlikely that Hay Point dredging activities were responsible;
- Juvenile corals were evident in both surveys, and growth in mature corals from the initial survey was also observed. No significant spatial or temporal variation was evident in juvenile coral numbers. Juveniles in the 5 to 10 cm size class made up the highest proportion of recruits;
- Pigment colour in a variety of coral taxa across the four locations darkened from the Pre-Dredge survey to the Post-Dredge survey, showing an opposite pattern to coral bleaching. The pigment darkening across all locations is likely to be a seasonal influence with lower light availability due to decreasing daylight periods from February to June. A higher level of pigment darkening was evident at Round Top Island and may be due to the deeper water depths of the monitored coral communities at this location, which is a result of higher zooxanthellae density, in addition to the variety of coral genera examined at this location. Other localised physical and chemical differences between the locations may also have had some influence, although were not measured at the coral monitoring sites.
- Overall there appeared to be no discernible impact from dredging activities on the measured coral parameters.

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6 APPENDIX

Table 4 Mean transect substrate cover of major category classes at locations during each survey.
Values are means ± se (n = 9 to 18)

Location	Survey	Mean percent cover per transect (%)							
		Turfing Algae	Hard Coral	Soft Coral	Macroalgae	Sponges/Ascidians	Sediment	Hydroids/Bryozoans	Zoanthids
Keswick/St Bees Islands	Pre-Dredge	1.2 ± 0.7	16 ± 5	3.7 ± 1.5	66 ± 8	0.8 ± 0.5	12 ± 3	-	0.6 ± 0.6
	Post-Dredge	18 ± 4	21 ± 4	2.4 ± 0.8	38 ± 5	1.6 ± 1.0	17 ± 2	-	0.5 ± 0.4
Slade Islet	Pre-Dredge	11 ± 2	17 ± 5	0.9 ± 0.3	12 ± 5	1.4 ± 0.4	57 ± 9	<0.1	-
	Post-Dredge	26 ± 4	16 ± 4	0.8 ± 0.3	17 ± 6	1.2 ± 0.7	39 ± 9	0.2 ± 0.1	-
Round Top Island	Pre-Dredge	9.7 ± 2.7	22 ± 4	4.7 ± 1.3	25 ± 5	0.8 ± 0.3	38 ± 4	0.2 ± 0.1	-
	Post-Dredge	10 ± 3	21 ± 4	3.5 ± 1.2	33 ± 7	1.2 ± 0.4	31 ± 5	0.1 ± 0.0	-
Victor Island	Pre-Dredge	5.7 ± 1.1	14 ± 3	0.4 ± 0.3	43 ± 5	0.5 ± 0.3	36 ± 5	-	1.2 ± 1.2
	Post-Dredge	8.3 ± 1.8	12 ± 3	0.3 ± 0.3	49 ± 4	0.4 ± 0.2	29 ± 5	-	0.6 ± 0.6

Table 5 Mean transect occurrence of bleach and diseased corals, and sediment on corals at locations during each survey.
Values are means ± se (n = 9 to 18)

Location	Survey	Mean Occurrence per transect (%)				Sediment Depth (mm)
		Bleached Pale Coral	Bleached White Coral	Diseased Coral	Sediment on Coral	
Keswick/St Bees Islands	Pre-Dredge	9.5 ± 4.6	0.1 ± 0.1	2.6 ± 2.1	2.3 ± 1.1	0.7 ± 0.2
	Post-Dredge	9.1 ± 3.6	1.4 ± 0.9	0.1 ± 0.1	3.6 ± 1.2	1.5 ± 0.1
Slade Islet	Pre-Dredge	1.7 ± 0.9	0	0	35 ± 10	0.2 ± 0.1
	Post-Dredge	6.7 ± 4.2	0	0	6.3 ± 2.5	0.7 ± 0.1
Round Top Island	Pre-Dredge	1.1 ± 0.5	0.8 ± 0.4	1.1 ± 0.8	3.7 ± 1.3	0.7 ± 0.1
	Post-Dredge	1.6 ± 0.4	1.1 ± 0.4	0.5 ± 0.4	5.2 ± 1.3	1.2 ± 0.1
Victor Island	Pre-Dredge	0.2 ± 0.2	0	1.0 ± 0.8	26 ± 11	0.1 ± 0.1
	Post-Dredge	3.0 ± 1.8	0.1 ± 0.1	0	3.4 ± 1.4	1.0 ± 0.1

Table 6 Cover of all minor classes/taxa at locations during each survey.

Major Category	Minor Category	KI		SI		RTI		VI	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Turfing Algae	Turfing Algae	1.2	17.7	11.2	26.2	9.7	10.4	5.7	8.3
Hard Coral	*Acropora digitifera*	0.7	0.5	<0.1	-	-	-	<0.1	0.1
	Acropora formosa	8.7	10.1	-	-	0.9	0.9	0.4	1.2
	Acropora hyacinthus	0.3	1.8	-	-	0.5	0.5	0.9	0.7
	Acropora spp.	0.5	0.9	<0.1	0.2	0.3	0.3	0.8	0.2
	Coscinaraea spp.	0.4	0.7	-	-	0.6	0.7	-	-
	Turbinaria spp.	0.1	0.5	1.0	1.3	5.8	5.1	0.6	0.3
	Faviidae echinopora	-	-	-	-	<0.1	-	-	-
	Faviidae spp.	0.5	0.9	0.7	0.8	0.2	0.1	0.2	0.2
	Faviidae goniastrea	-	-	-	-	<0.1	-	-	-
	Faviidae platygyra	0.1	0.2	-	-	0.7	1.0	-	0.1
	Hydnophora excesa			0.1	-	-	<0.1	-	0.1
	Lobophyllia hemprichii	0.1	0.4	0.1	-	0.6	<0.1	-	<0.1
	Merulina ampliata	0.1	0.1	-	-	-	-	-	-
	Montipora capricornis	-	<0.1	-	-	-	-	-	-
	Montipora spp.	2.0	2.4	6.0	5.1	5.0	4.5	7.6	6.6
	Montipora verrucosa	-	-	-	-	0.1	-	-	-
	Pachyseris speciosa	0.1	1.0	-	-	0.2	<0.1	-	-
	Pocillopora damicornis	0.2	0.8	2.1	2.2	0.2	0.4	2.1	1.4
	Poritidae goniopora	1.2	1.9	2.5	0.7	4.1	4.8	0.4	0.3
	Porites spp.	0.8	1.5	4.1	5.5	1.0	1.5	0.4	0.3
	Psammocora spp.	0.4	0.2	-	0.1	1.4	1.1	0.1	0.2
Soft Coral	*Alcyonium* spp.	-	-	-	0.1	0.3	-	-	-
	Gorgonian	-	-	0.3	0.2	0.3	0.7	-	-
	Lobophytum sp.	2.5	1.5	0.1	0.2	1.7	1.0	0.1	0.2
	Nephtheidae	-	-	<0.1	-	0.5	0.3	-	-
	Sarcophyton spp.	0.2	0.5	0.3	0.3	0.9	0.8	-	0.1
	Sinularia spp.	1.0	1.1	0.2	0.2	1.1	0.7	0.3	-
Macroalgae	*Caulerpa racemosa*	-	-	-	-	0.1	<0.1	-	-
	Codium spp.	-	<0.1	-	-	-	-	-	-
	Coraline Algae	0.1	1.8	0.3	0.2	1.0	2.0	0.1	<0.1
	Halimeda spp.	-	-	-	<0.1	-	0.1	0.1	0.2
	Lobophora spp.	0.1	0.1	1.7	0.3	1.6	1.2	0.2	0.4
	Other Green	-	0.1	1.1	1.7	0.7	0.3	-	1.5
	Padina spp.	0.1	2.0	-	-	-	0.2	-	0.1
	Sargassum spp.	65.4	32.4	9.4	14.5	21.8	29.0	42.6	47.2
Sponges/ Ascidians	Sponge/Ascidian	0.8	2.0	1.4	1.2	0.8	1.2	0.5	0.4
Bryozoa/ Hydroid	Bryzoa	-	-	-	-	0.1	-	-	-
	Hydroid	-	-	<0.1	0.2	0.1	0.1	-	-
Zoanthids	Zonanthid	0.6	<0.1	-	-	-	-	1.2	0.6
Sediment	Dead Coral with Algae	3.5	3.1	0.1	-	1.3	0.5	0.7	0.2
	Pavement	0.5	2.8	0.1	0.5	1.2	1.1	0.3	0.2
	Rubble	-	-	<0.1	-	3.1	0.9	-	-
	Sand	8.0	11.1	57.2	38.6	32.0	28.5	34.6	28.8

Table 7 Coral recruit taxon at locations during each survey.

Species	Keswick/St Bees Islands	Slade Islet	Round Top Island	Victor Island	Total
Acropora formosa	5	0	4	5	14
Acropora spp.	8	9	28	25	70
Coscinaraea spp.	14	0	0	0	14
Favia spp.	30	11	34	14	89
Goniopora spp.	11	64	115	12	202
Lobophora spp.	21	0	27	0	48
Lobophylia herprchii	2	0	2	0	4
Montipora spp.	3	13	26	14	56
Nephtheidae spp.	0	4	19	1	24
Pachyseris spp..	2	0	0	0	2
Platygyra spp..	2	0	3	0	5
Pocillopora damicornis	5	5	1	11	22
Porites spp.	2	4	4	0	10
Psammocora spp.	0	2	1	3	6
Sarcophyton spp.	1	2	19	4	26
Sinularia spp.	4	4	24	2	34
Turbinaria spp.	2	86	144	24	256
Total	112	204	451	115	882

Table 8 Number of coral recruits in size classes at locations during each survey.

Location	Survey	Number of Recruits			
		0 – 2 cm	2 – 5 cm	5 – 10 cm	Total
Keswick/St Bees Islands	Pre-Dredge	1	3	13	17
	Post-Dredge	4	42	49	95
Slade Islet	Pre-Dredge	6	47	67	120
	Post-Dredge	13	36	35	84
Round Top Island	Pre-Dredge	15	33	66	114
	Post-Dredge	13	118	206	337
Victor Island	Pre-Dredge	4	14	29	47
	Post-Dredge	9	34	25	68

Table 9 Mean number of coral recruits per transect at locations during each survey.
Values are means ± se (n = 9 to 18).

Location	Survey	Mean number of recruits			
		0 – 2 cm	2 – 5 cm	5 – 10 cm	Total
Keswick/St Bees Islands	Pre-Dredge	0.1 ± 0.1	0.3 ± 0.1	1.2 ± 0.3	1.5 ± 0.2
	Post-Dredge	0.1 ± 0.1	1.4 ± 0.3	1.6 ± 0.3	3.2 ± 0.6
Slade Islet	Pre-Dredge	0.4 ± 0.3	3.1 ± 1.0	4.5 ± 1.5	8.0 ± 2.6
	Post-Dredge	0.6 ± 0.5	1.7 ± 0.9	1.7 ± 0.4	4.0 ± 1.5
Round Top Island	Pre-Dredge	0.4 ± 0.2	1.0 ± 0.3	1.9 ± 0.3	3.4 ± 0.7
	Post-Dredge	0.3 ± 0.1	2.3 ± 0.5	4.0 ± 0.7	6.5 ± 1.1
Victor Island	Pre-Dredge	0.2 ± 0.1	0.7 ± 0.2	1.4 ± 0.3	2.2 ± 0.4
	Post-Dredge	0.5 ± 0.3	2.5 ± 0.9	2.3 ± 0.8	5.6 ± 2.0

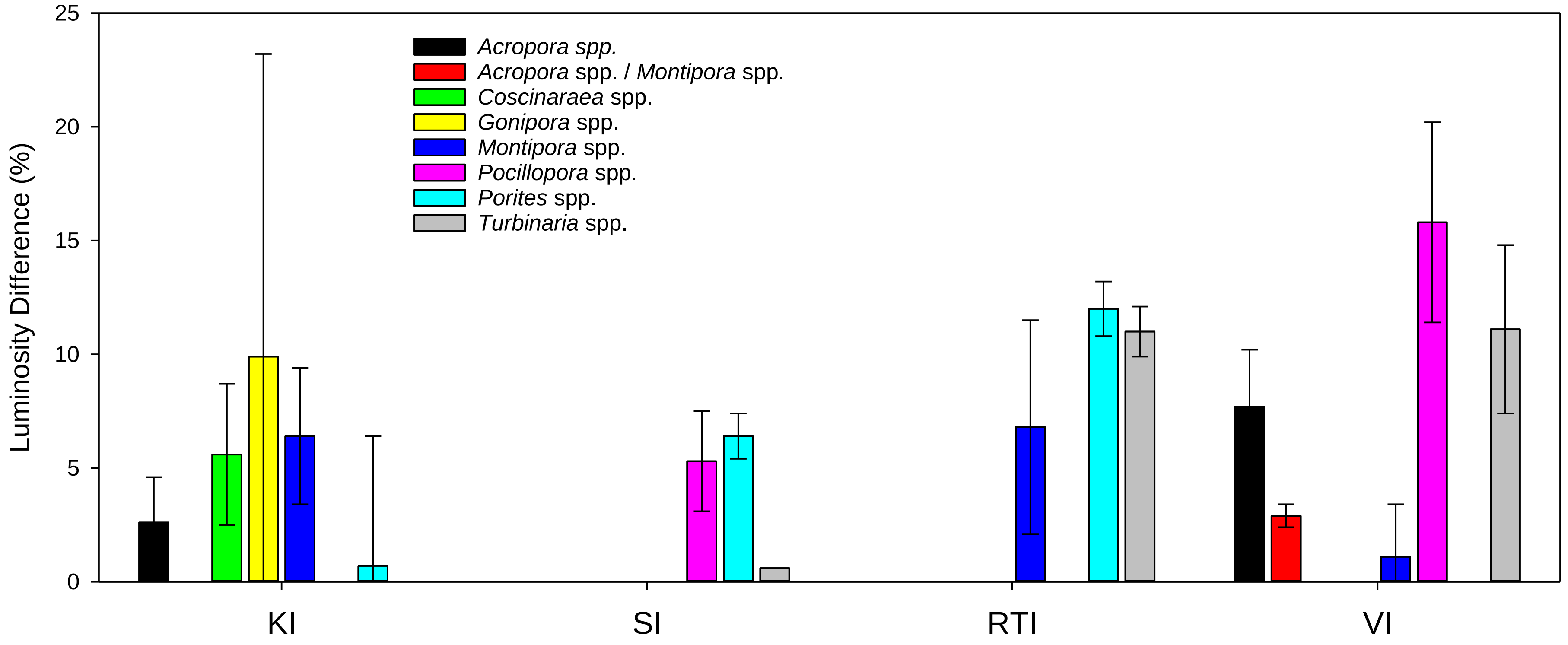

Figure 17 Mean percent (%) colour change in different coral genera at monitoring locations between Pre-dredge and Post-Dredge at each location.

Figure 18 Coral community at Round Top Island, including *Montipora* spp, and turfing algae.

Figure 19 Coral community at Slade Islet. *Favia* spp., and *Montipora* spp., exhibited in the middle surrounded by the soft coral *Pocillopora* spp.

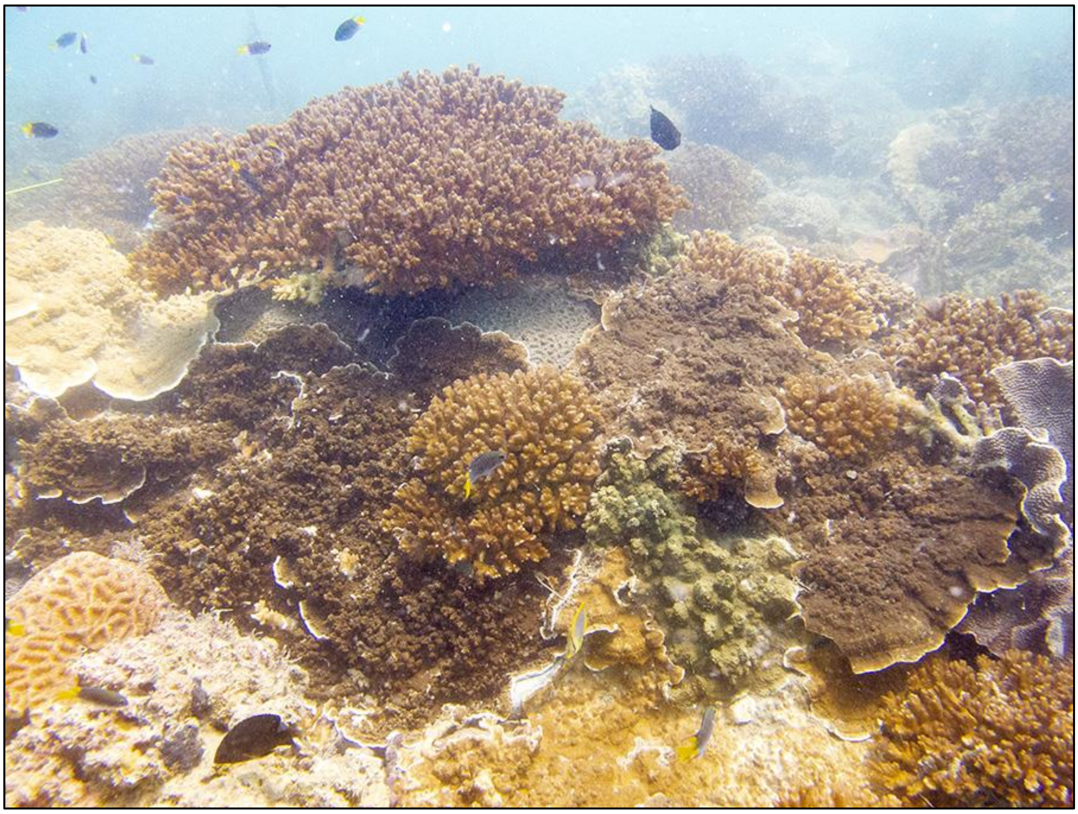

Figure 20 Healthy coral community at Slade Islet.

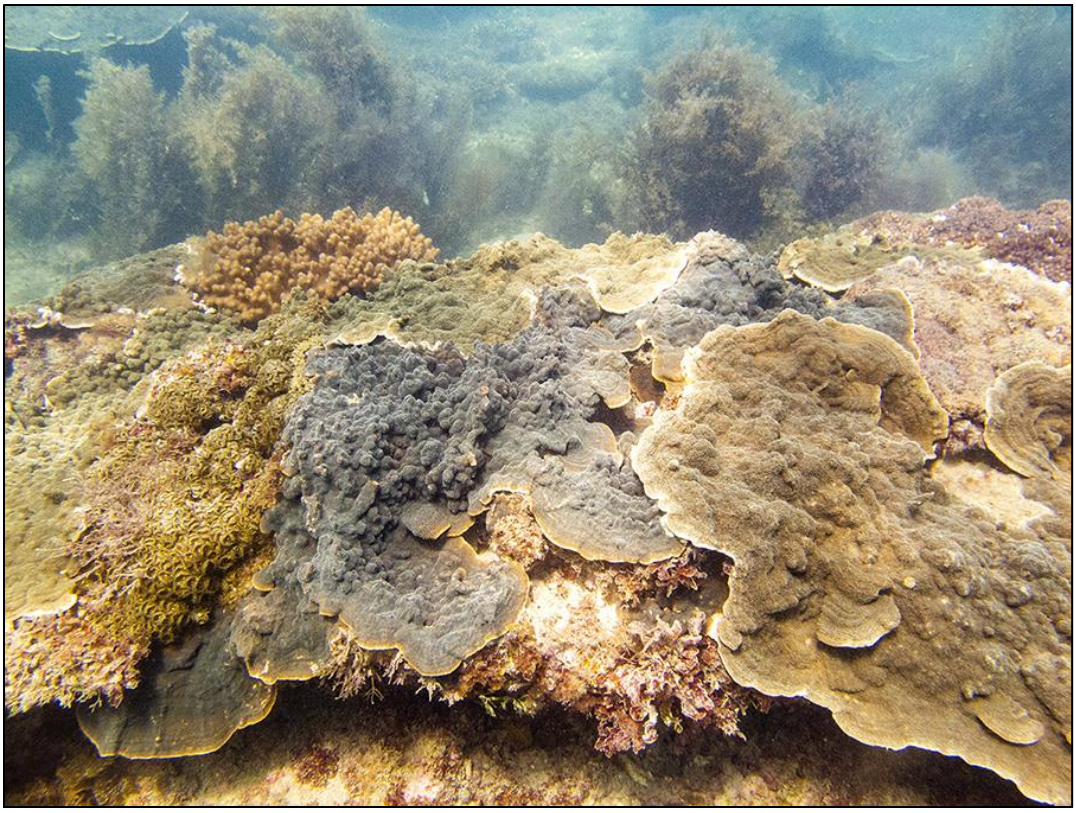

Figure 21 Healthy coral community at Victor Island, with *Montipora* spp. in the foreground and *Sargassum* spp. at the rear.

Figure 22 A school of Yellowtail demoiselle, *Neopomacentrus azysron*, seeking shelter among *Montipora* spp. corals at Round Top Island.

Figure 23 Dominant macroalgae, *Sargassum* spp., encountered at Victor Island with a resident Olive sea snake, *Aipysurus laevis*.

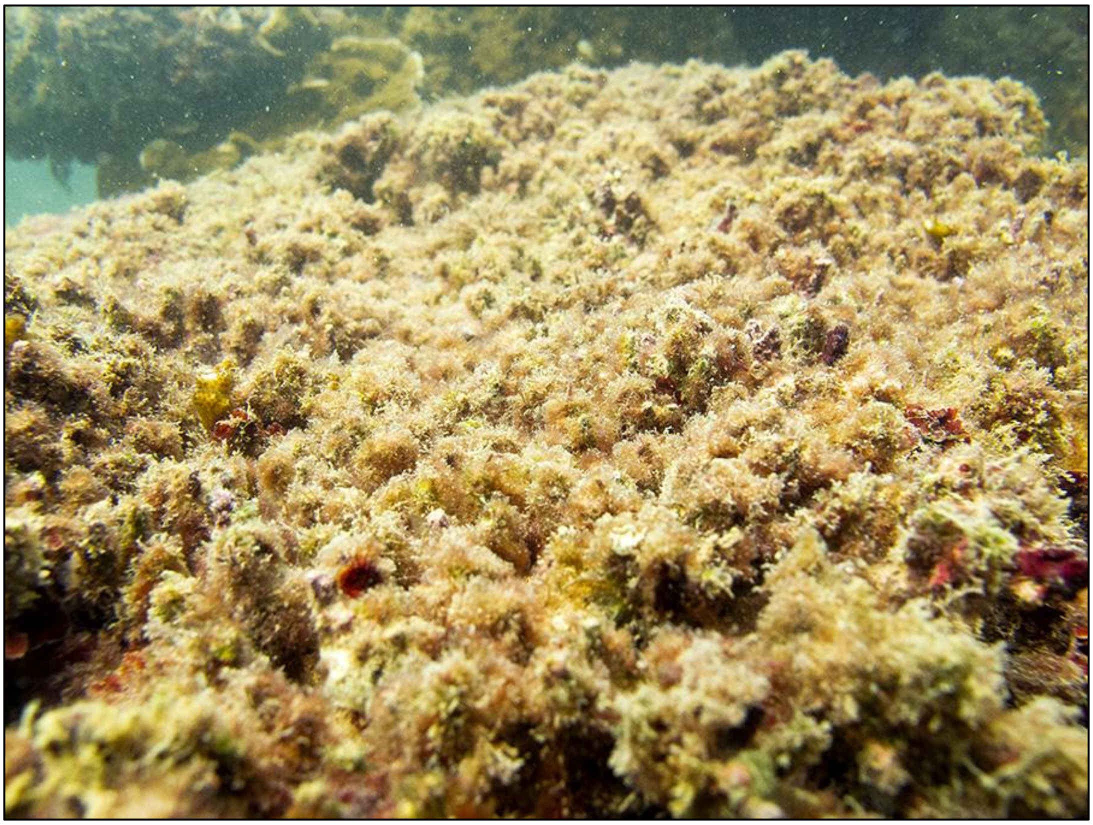

Figure 24 Example of turfing algae encountered at Victor Island.

Figure 25 *Montipora* spp., and *Acropora* spp., encountered at Victor Island.