Interim Report on the continuing development of the toxic dinoflagellates atlas

Progress Report, Part 1, June 2009

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Background

Update on work associated with the development of the toxic dinoflagellates atlas of the Great Barrier Reef

The benthic toxic dinoflagellate atlas of the Great Barrier Reef (GBR) is a work in progress and will include high-resolution light micrographs of the dinoflagellates and images of macroalgae with high numbers of these epiphytic dinoflagellates. The final product will also include scanning electron microscopy images and information on the range of abundance of individual benthic toxic dinoflagellate species on a particular macroalga (if available), given in numbers of toxic dinoflagellates * g biomass $[ww]^{-1}$, seasonal fluctuations in abundances, and the geographical location where the samples were taken. Genbank accession numbers, primers, and genetic probes information will also be included. This information will be added as it becomes available. As many, in particular red macroalgal samples still require formal identification, which necessitates time-consuming sectioning of material, images of macroalgae and toxic dinoflagellates will be incorporated into the dinoflagellate atlas, as identification progresses, and are not included in this report.

The introduction to the dinoflagellate atlas, as far as information is available, has been included in this report (see below), however, the focus of this report is to present data of toxic dinoflagellate abundances, as far as analysed, for field trips to Magnetic Island (2008) and for the field trip to Orpheus Island in November, 2008. Analyses of seasonal surveys of reefs near Orpheus Island will form the basis of future reports as data analysis for the March 2009 field trip is too preliminary for inclusion here and the field trip planned for August 2009 has not yet been conducted. We have included a materials and methods section and a section on data analysis which will also be included in the benthic toxic dinoflagellate atlas of the GBR.

Introduction to the benthic toxic dinoflagellates atlas

Dinoflagellates are eukaryotic unicells often with distinct morphologies and many produce cysts (resting stages) to survive environmentally adverse conditions (e.g. nutrient limitation, rough weather, suboptimal temperatures, and reduced salinities due to freshwater influx), which sink to the sediments awaiting more suitable conditions before germinating. Resting cysts are often morphologically very different to the vegetative cell and therefore difficult to identify. These cysts incorporate a sporopollenin-like substance, dupped dinopollenin, in their thecal plates, which is resistant to digestion with hydrofluoric acid. Therefore the fossil record contains a good representation of armoured dinoflagellates cysts, those with thecal plates, which suggests that armoured dinoflagellates have existed for more than 800 million years. Dinoflagellates are incredibly diverse with more than 550 genera and 4,000 species (Graham and Wilcox, 2000), living in freshwater and marine habitats, as symbionts (e.g. in corals), parasites, in the plankton or on benthic substrata (e.g. macroalgal surfaces).

About fifty percent of the dinoflagellates are photosynthetic typically carrying chlorophylls a and c_2, and the unique xanthophyll peridinin and other characteristic carotenoids (e.g. gyroxanthin), which can be used as 'red tide' markers (Graham and Wilcox, 2000) and the non-photosynthetic dinoflagllates lack chloroplasts. Some marine dinoflagellates produce potent toxins and are known to affect human health. Dinoflagellates are an important part of marine food webs and are consumed by filter-feeding shellfish, large protozoa, rotifers and planktivorous fish and it is this chain of events that passes dinoflagellate toxins to humans leading to paralytic shellfish poisoning (PSP), diarrheic shellfish poisoning (DSP), and ciguatera (tropical reef fish poisoning, CFP), which has been recently reviewed by (Garrard *et al.* 2008). Dinoflagellates can bloom (sudden and uncharacteristic increase in the abundance of a species) and interestingly most of the 60 known toxin-producers are photosynthetic. The observed global increase in dinoflagellate blooms, and associated human impacts, has been attributed to the presence of cyst banks in regions, prone to blooms.

Dinoflagellates are swimming ‘champions’ moving with speeds of 200-500 µm s^{-1} (Graham and Wilcox, 2000). Most dinoflagellates bear two distinctly different flagella, which produce the characteristic swimming motion ‘whirl’ (Greek: dino), which has given this group of organisms its name. Even dinoflagellate genera that spend most of their life cycle as non-flagellate cysts, amoebae, or as filaments will form characteristically flagellated reproductive cells known as dinospores (zoospores). Two different types of flagellated dinoflagellates must be distinguished:

1. **Typical dinokont organisation**, where the flagella arise from the ventral side of the cells. Here the transverse flagellum lies in a cingulum, a groove which often encircles the cell’s equator, dividing the cell into two parts: the epitheca (apical part) and the hypotheca (antapical or posterior portion). The trailing longitudinal flagellum projects posteriorly and lies in a shallow body groove called the sulcus.
2. **Desmokont organisation**, where the transverse and longitudinal flagella arise apically and are not associated with specific body grooves. These cells are composed of two valves (prorocentroid thecal organisation). Regardless of flagellation type, the transverse flagellum has a characteristic coiled morphology, is associated with a contractile strand made of centrin, bears a single row of fine flagellar hairs, and always associates closely with the cell body. The longitudinal flagellum bears two rows of fine hairs, may also be associated with a paraflagellar rod, and is responsible for about fifty percent of the cell’s forward propulsion, but also provides the ability to stop and change swimming direction.

The atlas is composed of two parts, Part 1 depicting the toxic dinoflagellates and Part 2 showing the macroalgae bearing high numbers of these epiphytic toxin producers. Described toxic dinoflagellates are thought to cause or enhance the symptoms of ciguatera, while others are implicated in diarrheic and paralytic shellfish poisoning.

Analysis of epiphytic toxic dinoflagellate abundance and community structure in coastal, inshore and mid reefal habitats of the Great Barrier Reef

Abstract

Climate change-induced increases of natural disturbance events are predicted to cause range expansions and phase shifts to macroalgal dominance on coral reefs world-wide due to mass-mortalities of corals, resulting in an increase of substrate availability. Macroalgae and dead corals and coral rubble serve as substrates for toxic epiphytic and benthic dinoflagellates, known to cause ciguatera, paralytic – diarrhetic – and amnesic shellfish poisoning. Hence, as substrate availability increases, toxic dinoflagellates are likely to expand their ranges simultaneously with substrate availability. Information on the benthic toxic dinoflagellate abundance patterns and community composition for the Great Barrier Reef (GBR) are sparse. There is an urgent need to collect and collate these data in order to evaluate the impact of climate change on these toxin producers, as they affect human health. In this interim report, we are presenting preliminary data on abundance patterns and community composition of epiphytic toxic dinoflagellates in coastal, inshore – and mid-reefal habitats of the GBR. Macroalgal collections were conducted for Magnetic Island, one Cleveland Bay location (inshore reef), Backnumber Reef (mid-reef), and mid-reefs near Orpheus Island and coastal areas in Townsville and Orpheus Island.

The observed abundance patterns and community composition of epiphytic benthic dinoflagellates at the individual locations are described first in detail and will be compared to initial data on observed abundances and community composition for sites associated with surrounding mid-reefs and inshore locations at Orpheus Island. Major indicative trends of epiphytic toxic dinoflagellates abundances drawn from surveys carried out on Magnetic Island from March to August 2008 and for reefs near Orpheus Island in November 2008 are summarised here. Analyses of all data available for Magnetic Island indicate that toxic epiphytic dinoflagellate abundances on macroalgal substrates decreased in the following order: *Gracilaria textorii* > *Hypnea* sp. > *Chondria* sp. > *Portieria hornemannii* > *Centroceras* sp. It appears that the dominant toxic benthic dinoflagellates have highest abundances on red algal substrates, which might indicate a substrate preference. Nelly Bay in particular showed a dominance of *Ostreopsis* spp. which might indicate a preference for sheltered reefal habitats of this group of dinoflagellates. The dominance pattern of *Prorocentrum* species might indicate a generalist life style in relation to habitat choice; however, a species-specific analysis will be required to substantiate this hypothesis. In addition, epiphytic toxic dinoflagellate communities appear to be more species-rich on reefal macroalgal communities compared to coastal macroalgal communites.

In contrast to the dinoflagellate distribution and community composition results obtained for coastal communities on the mainland (Townsville), both sites in Pioneer Bay (Orpheus Island) show significant abundances of *Gambierdiscus* spp. While Pioneer Bay (site 2) shows a similar abundance pattern as coastal Townsville areas with the exception of the presence of *Gambierdiscus* spp, Pioneer Bay (site 1) is more species-rich and shows a low abundance of *Ostreopsis* spp. Interestingly, *Ostreopsis* spp present in Pioneer Bay at site 1 is absent at site 2. Pelorus Island (site 2) and Nelly Bay (Magnetic Island) share similar environmental conditions in terms of tidal inundation, being submerged at all times. This is reflected in the dominance of *Ostreopsis* spp and community composition similarities between both sites. The channel between Pelorus Island and Orpheus Island is a little more exposed compared to the inshore environment at Nelly Bay (Magnetic Island), which could explain the higher percentage of *Prorocentrum* spp observed at Pelorus Island. In summary, our preliminary analyses suggest that site similarities in terms of substrate and environmental

conditions are reflected in similarities of epiphytic toxic dinoflagellate abundances, community compositions, and species diversity across different sites.

Introduction

Natural disturbances such as cyclones, heavy seasonal rainfall, storms, high seasonal temperatures and crown-of-thorn outbreaks contribute to the natural dynamic flux of coral reefs (Connell *et al.* 1997; McCook, 1999; Rogers and Miller, 2001). The initial recovery of coral reefs can be delayed by an influx of nutrients, primarily from disturbed sediments and freshwater plumes (Grimes and Kingsford, 1996), which leads to the temporary dominance of macroalgae on coral reefs (McCook, 1999; Walsh, 1983). Climate change is predicted to increase the occurrence of such natural disturbances as well as subject coral reefs to higher seasonal temperatures and irradiance, causing an increase in the occurrence and frequency of mass coral mortality and bleaching events (Berkelmans *et al.* 2004; McClanahan *et al.* 2004; McWilliams *et al.* 2005). The ability of coral reefs to recover between mass mortality events decreases with the increased frequency of disturbance events resulting in perhaps permanent macroalgal phase-shifts on coral reefs (Diaz-Pulido and McCook, 2002; McClanahan *et al.* 2005; McClanahan *et al.* 2001). An indirect effect of climate change on coral reefs, including the Great Barrier Reef (GBR), is the opportunity for the invasion of macroalgae into new habitats with the increased availability of substrates following mass coral mortality events (Shulman and Robertson, 1996).

Climate change-induced occurrence of macroalgal phase-shifts and expansion of macroalgae into new habitats on coral reefs could be a primary vector for the invasion of their epiphytic microalgal communities into new habitats within coral reefs. Toxic dinoflagellates are a common component of epiphytic microalgal communities and are associated with many macroalgal species. Epiphytic and benthic toxic dinoflagellates are also known to associate with bleached coral or coral rubble (Kohler and Kohler, 1992). *Gambierdiscus toxicus* as well as *Ostreopsis* spp and *Prorocentrum* spp are toxic epiphytic and benthic dinoflagellates known to cause or influence the severity of ciguatera. These organisms are likely to invade new habitats together with the expansion of macroalgae and increased availability of dead coral substrates. The implications following an invasion of ciguatera-causing toxic dinoflagellates could result in the expansion of existing ciguatera hotspots, possible increase in ciguateric high-risk fish species, and the creation of new ciguatera hotspots in habitats previously associated with low or no ciguatera risk.

Information on existing distribution and abundance patterns for epiphytic and benthic toxic dinoflagellates in the GBR is limited and sparse (Gillespie *et al.* 1985). This study will contribute new seasonal abundance patterns for epiphytic and benthic toxic dinoflagellates, particularly those associated with ciguatera. The impact of climate change in respect to temperature and pH tolerances, nutrient fluxes and substrate availability on the abundance and distribution patterns of epiphytic and benthic toxic dinoflagellates has not been investigated to date, in particular not for the GBR. This data is essential to improve protection of regional communities from long-term health and socio-economics impacts directly associated with ciguatera.

Materials and methods

Sampling strategy and processing

Magnetic Island and Townsville: Field collection for this project has been opportunistic, commencing at Picnic Bay, Magnetic Island on 16 March 2008. Samples were collected from three sites (Horseshoe Bay (04/06/08 and 26/09/08), Nelly Bay (18/05/08, 01/06/08, 27/07/08, 10/08/08 and 26/09/08) and Picnic Bay (16/03/08 and 26/09/08)) at Magnetic Island, three sites (Cleveland Bay (20/04/08), and Kissing Point (16/04/08 and 04/05/08 and 04/06/08) at Townsville and one site (Backnumber Reef (13/07/08)) at the mid-reef group, Slashers Reefs. Macroalgal samples were collected at low tide at 0-2 m on snorkel by inverting a zip-lock bag over the specimen. This procedure ensures minimising the collection of surrounding seawater. Samples were processed and analysed as described below for Orpheus Island.

Orpheus Island: The field trips in November 2008 and March 2009 collected macroalgal samples from Keeper, Lodestone, Ribb, Brewer, Bramble and Trunk Reefs, and Pioneer Bay at Orpheus Island, as well as Pelorus Island (Figure 1). Benthic toxic dinoflagellates are found on surfaces up to about ten metres' depth. Macroalgal samples were collected between zero to two metres on snorkel and two to ten metres on the back reefs by divers. Fifteen macroalgal samples were collected in separate bags at each site with two sites visited each trip. In total, 115 macroalgal samples were collected for November 2008 and 160 samples in March 2009, with three samples being sediment samples. Note: The March collection is awaiting completion of analysis and data are thus not presented in this interim report. Sediment samples were included in the March collection due to low macroalgal abundance at Pelorus Island and Pioneer Bay.

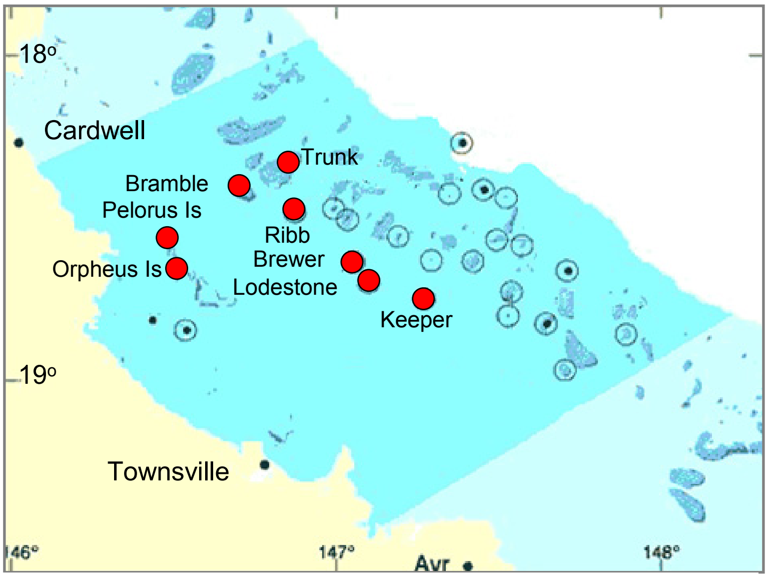


Figure 1: Macroalgal sampling sites near Orpheus Island. Three sites were sampled at Trunk Reef (November 2008), two sites were sampled at Pelorus Island, Bramble and Trunk Reefs and Pioneer Bay on both field trip occasions, while only one site was sampled at Brewer, Keeper, Lodestone, and Ribb Reefs due to reef size, limitations for sample processing (time) and distance from Orpheus Island. The latter sampling regime allowed sampling two reefs per trip.

Macroalgal samples were washed by shaking the samples in filtered seawater to collect the epiphytic toxic dinoflagellates within 24 hours after returning to Orpheus Island Research Station (OIRS). Macroalgal samples not processed directly on return were kept out of direct sunlight in collection bags in a tank with flow-through seawater for temperature control. Macroalgal samples were photographed, weighed and portions of processed macroalgal samples were frozen and dried on silica gel for genetic analysis. Representative portions were mounted on card board as herbarium specimens.

The washed-off dinoflagellate samples were concentrated by sequential filtration through 60µm and 20µm nylon mesh filters. Dinoflagellate concentrates were fixed in 3.7% paraformaldehyde in filtered seawater (final concentration). All samples were transported back to the North Queensland Algal Identification/Culturing Facility (NQAIF) at James Cook University (JCU) for identification and enumeration.

Sample analysis: The fixed washed-off concentrated material had a total volume of 13 mL which was further concentrated through natural gravity settlement for several days in the NQAIF laboratory. The resulting supernatant was carefully removed by pipette with the final sample volume depending on sediment content of the samples. 20 µL of sample was placed on a slide, covered with a cover slip; toxic dinoflagellates were identified and documented where necessary (i.e. a current high resolution image did not exist or a more appropriate angle for identification purposes could be obtained) on an Olympus BX51 high resolution microscope using Nomarski differential interference contrast at 40x magnification. Toxic dinoflagellate abundances were enumerated across the entire cover slip area using the same imaging equipment and numbers of species present were calculated as per equation 1 (eq. 1):

$$\mathbf{TNTDS = 20\ \mu L\ CV * 50 * FSV} \qquad \textbf{(eq. 1)}$$

Where TNTDS = total number of dinoflagellate species, CV = counted volume, FSV = final sample volume.

Data are presented either in percent of total toxic dinoflagellate abundance or as total number of toxic dinoflagellate genera or species * g macroalgal biomass wet weight $[\mathrm{ww}]^{-1}$.

Results and discussion

Magnetic Island and Townsville: To date, eleven separate field trips were undertaken to three sites (Picnic Bay, Horseshoe Bay, Nelly Bay) at Magnetic Island, three sites (Kissing Point, Rowes Bay, Cleveland Bay) at Townsville and one site (Backnumber Reef) at the mid-reef group, Slashers Reefs. A total of 55 macroalgal samples were collected (6 macroalgal samples from Horseshoe Bay (04/06/08), 14 samples from Nelly Bay (18/05/08, 6 samples; 01/06/08, 2 samples; 27/07/08, 4 samples; and 10/08/08, 2 samples) and 10 samples from Picnic Bay (16/03/08)) at Magnetic Island, 1 sample from Cleveland Bay (20/04/08), 9 samples from Kissing Point (16/04/08, 3 samples and 04/05/08, 6 samples), and 14 samples from Rowes Bay (04/06/08) at Townsville and 1 sample from Backnumber Reef (13/07/08)) (Appendix 1, Table 1).

Samples collected in September from Horseshoe, Nelly and Picnic Bays are not yet fully analysed and are thus not included in this interim report. Twenty-one macroalgal genera were identified (Appendix 1, Table 1). *Caulerpa peltata* was only collected at one site (Backnumber Reef), as were *Dictyota* spp., *Polysiphonia* spp. and *Udotea* spp. (Kissing Point), *Hormophysa* spp., *Gracilaria textorii*, *Portieria hornemannii*, and *Tricleocarpa fragilis* (Nelly Bay), *Halimeda* spp. and *Turbinaria* spp. (Picnic Bay), and *Centroceros* spp., *Cystoseira* spp., *Hincksia* spp., and *Laurencia* spp. (Rowes Bay) (Appendix 1, Table 1). Two specimens were collected from the following sites: *Enteromorpha* spp (Horseshoe Bay and Rowes Bay), *Chondria* spp. (Cleveland Bay and Rowes Bay), *Jania* spp. (Kissing Point and Rowes Bay) (Appendix 1, Table 1), while three macroalgal specimens were collected for *Cladophora* spp. (Horseshoe Bay, Kissing Point and Rowes Bay), *Hypnea* spp. (Kissing Point, Nelly Bay and Rowes Bay), *Padina* spp. (Horseshoe Bay, Nelly Bay and Rowes Bay), and *Sargussum* spp. (Horseshoe Bay, Nelly Bay and Picnic Bay) (Appendix 1, Table 1). Five macroalgal samples were identified to species: *Caulerpa peltata*, *Gracilaria textorii*, *Hypnea cervicornis*, *Portieria hornemannii* and *Tricleocarpa fragilis* (Appendix 1, Table 1). The macroalgal samples from the September field trip to Horseshoe Bay, Nelly Bay and Picnic

Bay have been processed, but have not yet fully analysed. Over two hundred digital photos of the 55 macroalgal specimens collected to date have been obtained and processing is under way for incorporation into the dinoflagellate atlas.

Seven toxic dinoflagellates were identified to genus (Appendix 1, Table 1) and ten to species (*Coolia monotis*, *Dinophysis caudata*, *Gambierdiscus toxicus*, *Gymnodinium* sp., *Ostreopsis ovata, O. siamensis, O. lenticularis*, O. *heptagona* and *Prorocentrum lima, P. belizeanum, P. hoffmannianum*) by high resolution light microscopy, except four dinoflagellate cysts that remain unidentifiable.

Enumeration of identified dinoflagellate genera has been completed on 55 macroalgal specimens to date (Appendix 1, Table 1). In sequence of abundance from highest to lowest, the samples contained species of *Ostreopsis*, *Prorocentrum*, *Coolia*, *Gambierdiscus*, unknown dinoflagellates, *Dinophysis caudata* and *Gymnodinium* (Figure 2). *Dinophysis caudata* was only present in samples from Picnic Bay (5.2 cells * g biomass $[ww]^{-1}$) on *Sargussum* sp. and *Gymnodinium* sp. was only present at Horseshoe Bay (1.5 cells * g biomass $[ww]^{-1}$) on *Padina* sp. (Figure 2B). Both genera are classified as planktonic species and were most likely present due to strong onshore winds at the time of collection.

Species of *Ostreopsis* dominated the samples from Nelly Bay for all sampling occasions (Figure 3A) with numbers being highest in May, dropping off significantly in June, and gradually increasing again from July to August (Figure 2A). *Prorocentrum*, the next dominant species followed the same abundance pattern as observed for *Ostreopsis* (Figure 2A). *Gambierdiscus* species were only present in July in low abundances. Other sample locations showed no clear abundance pattern across sites (Figure 2B) but have a greater species diversity (Figure 3B) compared to Nelly Bay (Figures 2A and 3A).

Kissing Point samples taken in June 2008 had the highest toxic dinoflagellate abundance after Nelly Bay and it should be noted that Kissing Point samples thus far were void of *Ostreopsis* spp. Kissing Point samples were dominated by species of *Prorocentrum* and low numbers of unknown dinoflagellates (Figure 2B). Highest numbers of *Prorocentrum* spp. (1898.7 cells * g biomass $[ww]^{-1}$) were found on *Centrocerus* spp., followed by low numbers on *Jania* sp., *Padina* spp., and *Cladophora* sp. Unknown dinoflagellates were associated with all macroalgal samples that contained dinoflagellates. Seven macroalgal samples were void of dinoflagellates, *Chondria* sp., *Enteromorpha* sp., *Hincksia* sp., *Hypnea* spp. and *Laurencia* spp. (Appendix 1, Table 1). In contrast, Kissing Point samples collected in April 2008 contained only low numbers of *Prorocentrum* spp. on *Polysiphonia* sp. and unknowns on *Cladorphora* sp., while *Hypnea cervicornis* was dinoflagellate-free. Samples collected in May 2008 (*Dictyota* spp., *Jania* spp., *Polysiphonia* sp., and *Udotea* sp.) had no dinoflagellates associated with them (Appendix 1, Table 1; Figure 2B).

Cleveland Bay samples collected in April 2008 had the next highest numbers of toxic dinoflagellates and were dominated by *Coolia* spp. (1429.7 cells * g biomass $[ww]^{-1}$) and *Gambierdiscus* (873.7 cells * g biomass $[ww]^{-1}$) on *Chondria* sp. in April, 2008, present in fairly high abundances (Appendix 1, Table 1; Figure 2B). Horseshoe Bay samples followed and contained in order of abundance unknown dinoflagellates, *Prorocentrum* spp., *Ostreopsis* spp., *Gambierdiscus* spp., *Coolia* sp. and *Gymnodinium* sp. *Cladophora* spp. had the highest numbers of unknown dinoflagellates, *Prorocentrum* spp., *Ostreopsis* spp. and *Gambierdiscus* spp. (Appendix 1, Table 1). *Enteromorpha* sp., *Padina* spp. and *Sargassum* spp. carried low numbers of toxic dinoflagellates, e.g. *Padina* sp. harboured only 1.5 cells * g biomass $[ww]^{-1}$ for *Coolia* sp. and *Gymnodinium* sp. (Appendix 1, Table 1). Samples collected in Picnic Bay contained low numbers of *Ostreopsis* on *Turbinaria* spp. and *Sargassum* spp., the latter also contained 5.2 cells cells * g biomass $[ww]^{-1}$. Seven macroalgal samples were void of toxic dinoflagellates (Appendix 1, Table 1). The low numbers of toxic dinoflagellates found on this occasion was most likely due to strong onshore winds. Only one sample, *Caulerpa peltata*, was collected opportunistically from Backnumber Reef. It only contained low numbers of *Gambierdiscus* spp (Appendix 1, Table 1).

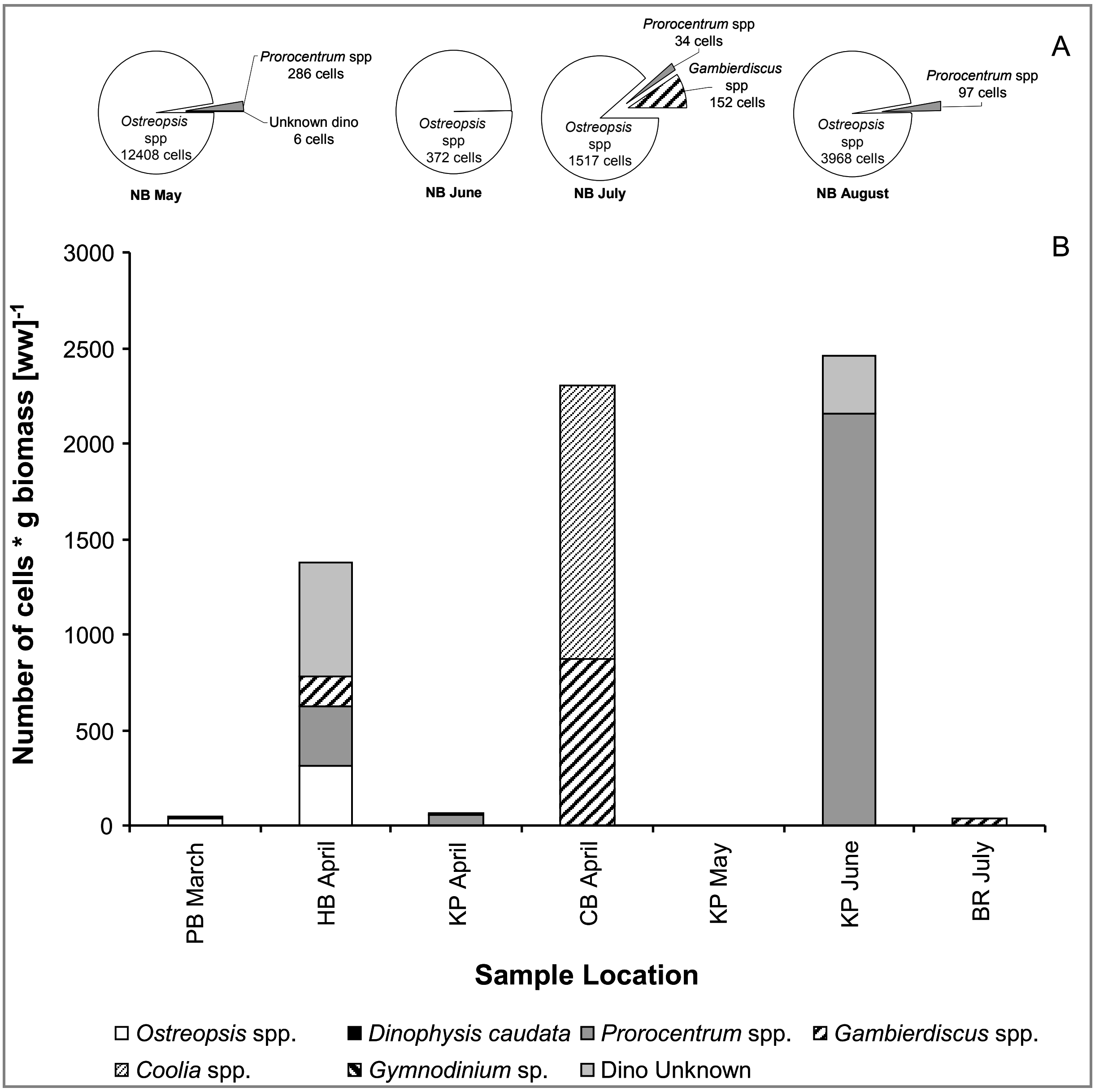


Figure 2: Total number of toxic dinoflagellate cells * g biomass wet weight [ww]$^{-1}$ at each sampling location from March to August 2008. (A) Toxic dinoflagellate abundance at Nelly Bay, Magnetic Island, from May to August. (B) Toxic dinoflagellate abundance for all other sampling locations at Townsville, Magnetic Island and Slasher Reefs. BR: Backnumber Reef; CB: Cleveland Bay; HB: Horseshoe Bay; KP: Kissing Point; NB: Nelly Bay; PB: Picnic Bay. Figure 2B Abundances of *Coolia* spp. and *Gymnodinium* spp. (1.5 cells * g biomass [ww]$^{-1}$; HB April), *Dinophysis caudata* (5.2 cells * g biomass [ww]$^{-1}$; PB March) and *Gambierdiscus* spp. (5.6 cells * g biomass [ww]$^{-1}$; BR July) were too low to be visible in the graph.

The red alga *Gracilaria textorii* collected from Nelly Bay has the highest number of *Ostreopsis* spp. per gram wet weight (*Ostreopsis* spp. 9780 cells * g biomass $[ww]^{-1}$). The lowest number of *Ostreopsis* spp. cells was associated with *Sargassum* sp. in Horseshoe Bay. While *Prorocentrum* spp. were associated with most macroalgal samples (Appendix 1, Table 1), highest abundance of *Prorocentrum* spp. (1898.7 cells* g biomass $[ww]^{-1}$) were detected on *Centroceras* spp. at Rowes Bay, Kissing Point. The red alga *Chondria* sp. collected from Cleveland Bay was associated with high numbers of *Coolia monotis* (1429.7 cells * g biomass $[ww]^{-1}$), which also had the highest numbers of *Gambierdiscus* spp. (873.7 cells * g^{-1}). The lowest number of *Gambierdiscus* spp. were detected on *Caulerpa peltata* (5.6 cells * g^{-1}) from Backnumber Reef (Appendix 1, Table 1). Macroalgal substrates in order of highest abundance of toxic dinoflagellates are the red algae *Gracilaria textorii* > *Hypnea* sp. > *Chondria* sp. > *Portieria hornemannii* > *Centroceras* sp. It appears that the dominant toxic benthic dinoflagellates have highest abundances on red algal substrates, which might indicate a substrate preference.

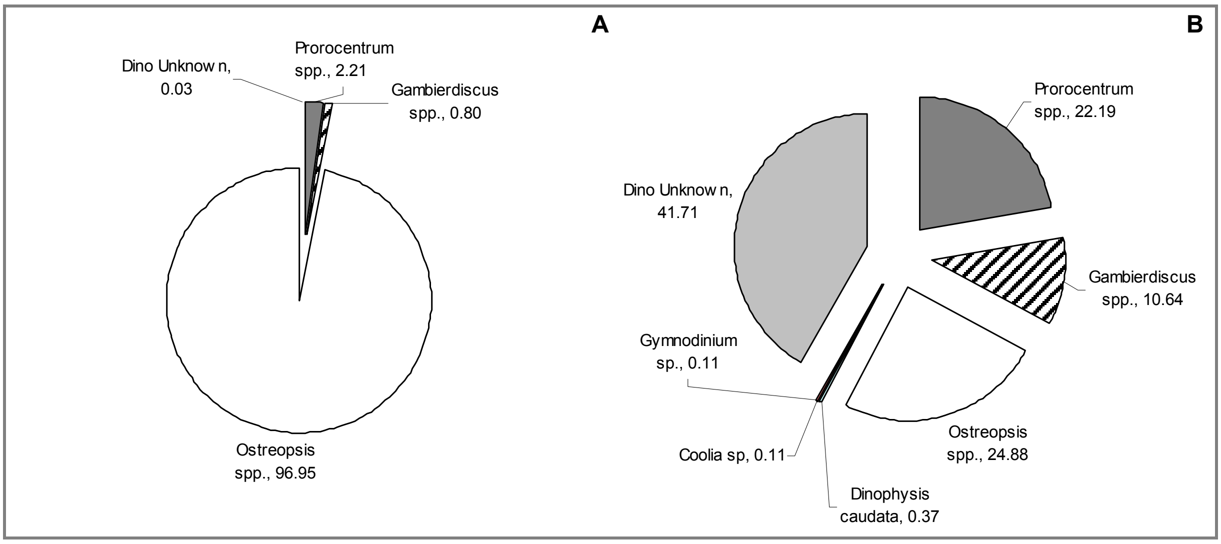


Figure 3: Comparison between toxic dinoflagellate species composition and abundance patterns in Nelly Bay (A) versus other sample locations on Magnetic Island (B). Data are presented in percent abundance.

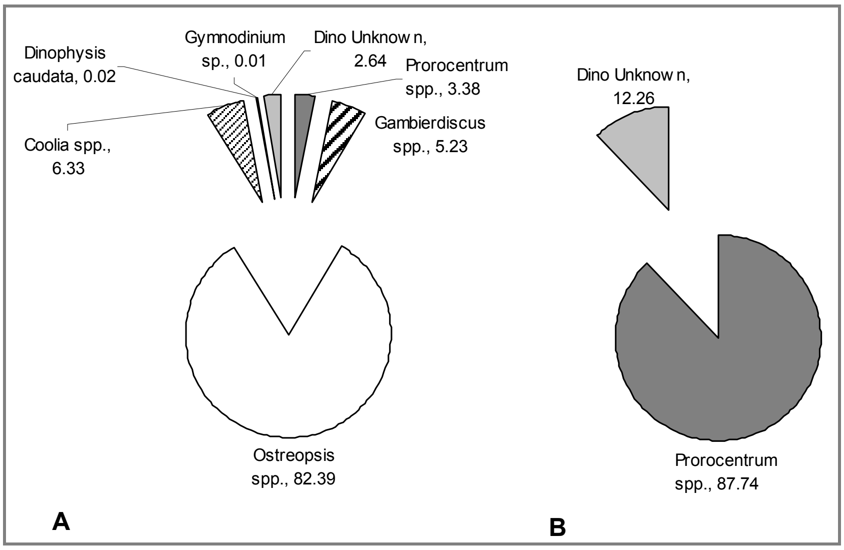


Figure 4: Comparison between toxic dinoflagellate species composition and abundance patterns in inshore reefal (A) versus coastal (B) sample locations. Data are presented as percent abundance.

Data analysed thus show the following indicative initial trends. The absence of *Ostreopsis* spp. and *Gambierdiscus* spp. and perhaps *Coolia* spp. in coastal macroalgal samples (Figure 4B) and its presence in samples from Magnetic Island inshore reefs (Figure 3B) suggests that these genera could have a preference for reef environments. In contrast to all other examined locations on Magnetic Island, Nelly Bay is always inundated at low tides, even spring low tides. This could explain the dominance and consistent presence of *Ostreopsis* spp. in fairly high to high numbers (Figure 3A). If this pattern proves true, *Ostreopsis* spp. seem to prefer sheltered reefal and always submerged substrata. This hypothesis can only be tested by continuing to sample Nelly Bay for all seasons. In contrast, *Prorocentrum* spp. associate with various macroalgal substrata collected from inshore reefal (Figure 4A) or sheltered coastal environments (Figure 4B). An examination at species level is required to identify potential preferences of particular species, or whether species of this genus could be classified as generalists with regards to environmental and substrata preferences. In contrast to reefal macroalgal substrata, which are dominated on many occasions by *Ostreopsis* spp. (82.39%) and appear to be species-rich (Figure 4A), coastal macroalgal substrata appear to be species-poor and dominated by *Prorocentrum* species (87.74%) and other yet to be identified benthic dinoflagellates (Figure 4B). The relatively high percentage of unidentified dinoflagellates (12.26%, Figure 4B) might suggest that these benthic dinoflagellates are unlikely to be significant toxin producers, as they should have been easily identifiable using the harmful algal identification literature.

Orpheus Island and surrounding reefs field collection, 1-11 November 2008: Thirteen separate sites were sampled by seven separate field trips over a ten-day period, with trips to six reefs (Bramble, Brewer, Keeper, Lodestone, Ribb and Trunk Reefs), and two islands (Pelorus and Orpheus Islands). A total of 115 macroalgal samples were collected of which 66 macroalgal samples from eight separate sites have been analysed (10 macroalgal samples from Pioneer Bay (site 1); 3 samples from Pioneer Bay (site 2) Orpheus Island; 9 samples from Pelorus Island (site 2); 6 samples from Bramble Reef (site 1); 8 samples from Bramble Reef (site 2); 14 samples from Keeper Reef; 10 samples from Lodestone Reef; and 6 samples from Trunk Reef (site 3)) (Appendix 1, Table 2). Samples collected from Brewer, Ribb and Trunk Reefs (site 1 and 2) as well as Pelorus Island (site 1) are not yet fully analysed and are thus not included in this interim report.

Over five hundred digital photos of epiphytic dinoflagellates found on 66 macroalgal specimens analysed to date were taken and processing is under way for incorporation into the dinoflagellate atlas. Twenty-nine macroalgal samples were identified belonging to ten macroalgal genera (Appendix 1, Table 2). Of the ten macroalgal genera identified, *Hypnea* sp. was only collected at one site (Lodestone Reef), as were *Amphiroa* sp., *Hydroclathrus* sp. and *Padina* sp. (Pioneer Bay, Orpheus Island) (Appendix 1, Table 2). Two macroalgal specimens were collected from the following sites: *Dictyota* spp., *Gracilaria* spp. and *Sargassum* spp. (Pelorus Island and Pioneer Bay) and *Turbinaria* spp. (Bramble Reef and Pioneer Bay) (Appendix 1, Table 2), while three macroalgal specimens were collected for *Caulerpa* spp. (Lodestone Reef, Pelorus Island, and Trunk Reef), and *Halimeda* spp. (Bramble Reef, Keeper Reef, and Pelorus Island) (Appendix 1, Table 2). The macroalgal samples from the March (17-27) 2009 OIRS-based field trip have been processed, but not yet fully analysed.

Enumeration of identified dinoflagellate genera has been completed for 66 macroalgal specimens to date (Appendix 1, Table 2). *Ceratium* was only present on Red unknown 36 macroalga from Trunk Reef, site 3 (8.4 cells * g biomass $[ww]^{-1}$) (Figure 6H). In terms of general abundance, Keeper Reef (site 1) had the highest number of benthic dinoflagellates (6929.8 cells for 14 macroalgal specimens), followed by Pelorus Island (site 2) (4911.2 cells on 9 samples), Pioneer Bay (site 1) (4755.3 cells on 10 samples), Lodestone Reef (site 1) (3422.4 cells on 10 samples), Bramble Reef (site 1) (1466.7 cells on 6 samples), Trunk Reef (site 3) (931.1 cells on 6 samples), Bramble (site 2) (569 cells on 8 samples), and Pioneer Bay (site 2) (461 cells on 3 samples) (Figure 5). Benthic toxic dinoflagellate abundances at some locations, i.e. Keeper Reef (site 1) and Pelorus Island (site 2) and Lodestone Reef (site 1) could be a reflection of a current bias of analysis (more processed samples have been analysed). This is supported in terms of total dinoflagellate abundances for Pioneer Bay, as 3 samples from Pioneer Bay (site 2) show low numbers, but analyses of 10 samples from Pioneer Bay (site 1) with high numbers. In contrast, 8 samples were fully analysed for site 2 on Bramble Reef but had lower numbers of epiphytic toxic dinoflagellates than Bramble Reef (site 1), where 6 samples were analysed (Figure 5).Therefore, the low numbers of dinoflagellates encountered in particular on Bramble Reef (site 2) with 8 processed macroalgal samples (Figure 5) might indicate that there will be a trend in benthic toxic dinoflagellate abundances for particular locations and sites, once the full set of samples is completely analysed.

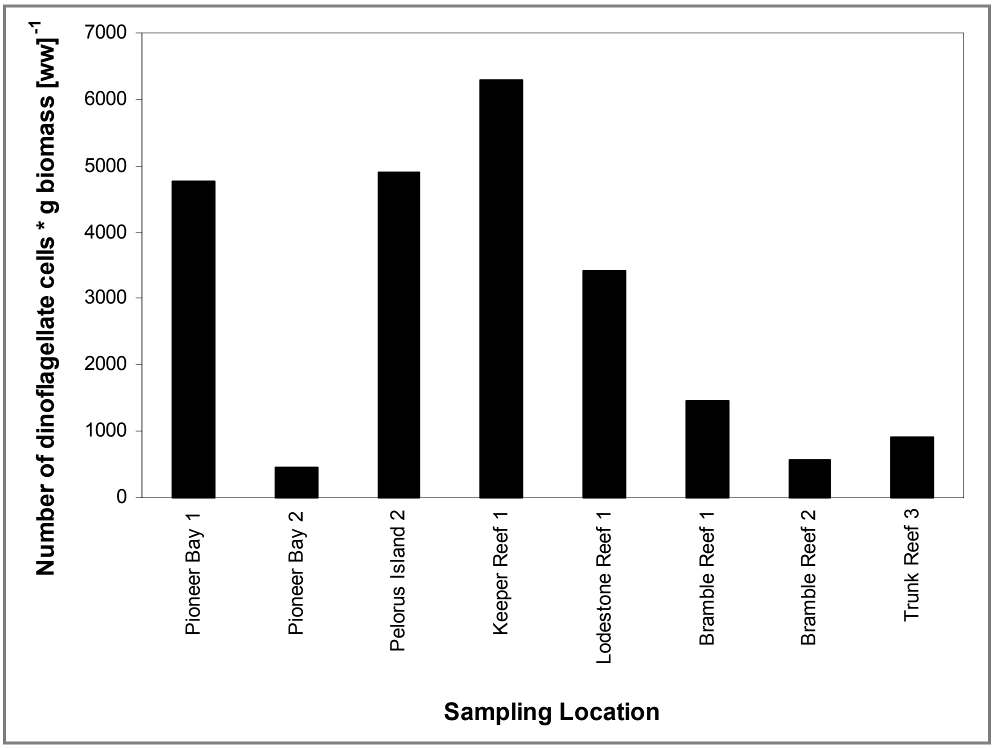
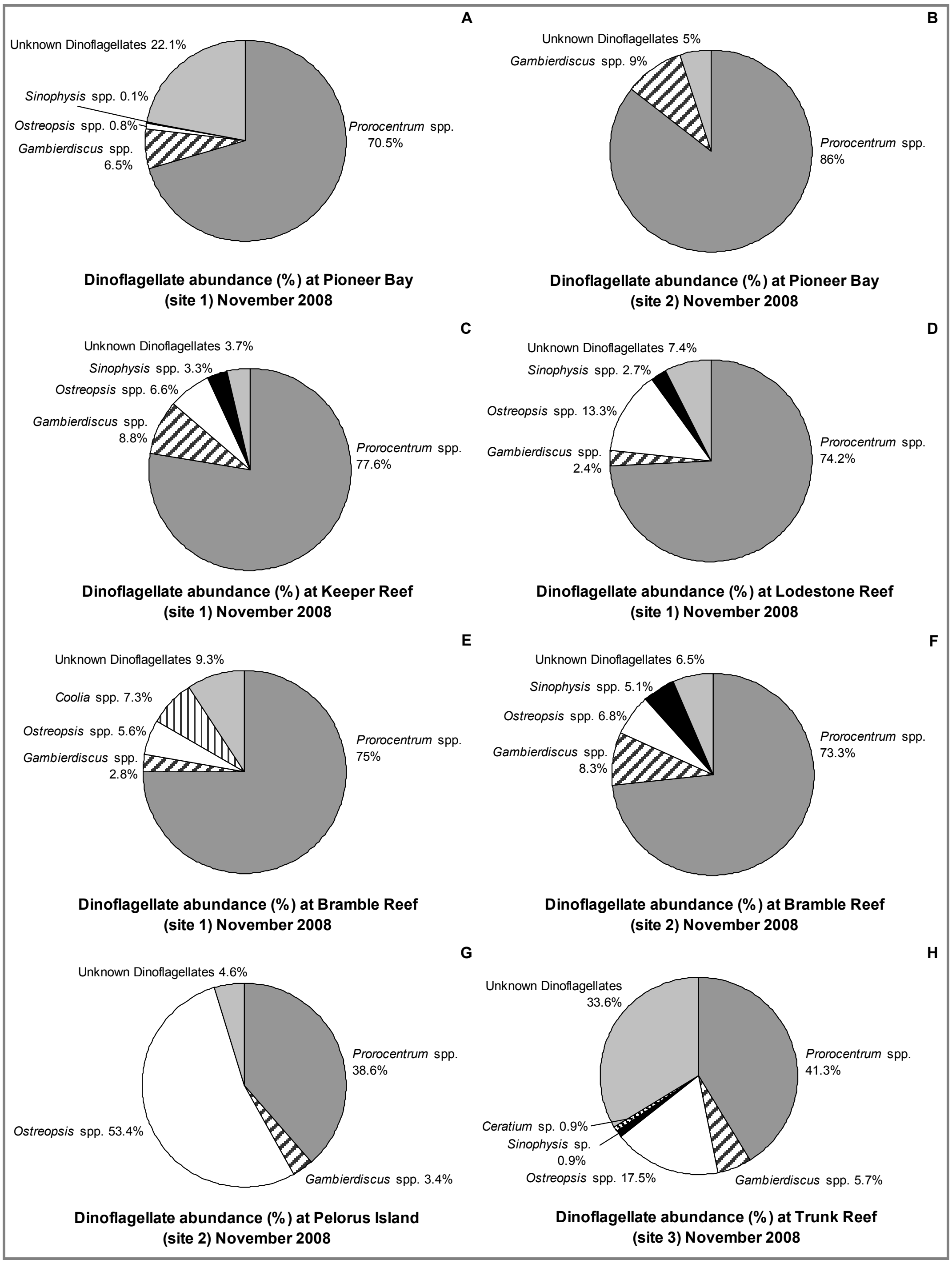


Figure 5: Total number of toxic dinoflagellate cells * g biomass wet weight [ww] $^{-1}$ at each sampling location in November 2008. Note that analysis is not complete and that sample analysis progress at present is uneven for different sites (see text for a detailed explanation).

Four toxic benthic dinoflagellates (*Coolia* spp., *Gambierdiscus* spp., *Ostreopsis* spp. and *Prorocentrum* spp.) and two pelagic dinoflagellates (*Ceratium* sp. and *Sinophysis* sp.) were identified to genus (Appendix 1, Table 2) by high resolution light microscopy. Abundances of these and unknown dinoflagellates per location are shown in Figure 6. Note that the same sample completion bias applies as stated in the description for Figure 5, thus trends are most likely only indicative at this stage until the complete sample set is analysed.

In contrast to data obtained for sheltered inshore reefal locations (e.g. Nelly Bay (Magnetic Island), Cleveland Bay and Backnumber Reef), analysed reefal samples from locations near Orpheus Island show a dominance of *Prorocentrum* species comprising ~75% of the epiphytic toxic dinoflagellate communities (Figure 6C-6F), but are species-rich, as significant numbers of *Ostreopsis* spp., *Gambierdiscus* spp., *Sinophysis* sp., and unknown dinoflagellates are present in samples from Keeper Reef (site 1), Lodestone Reef (site 1), Bramble Reef (site 2) (Figures 6C, 6D, 6F). Bramble Reef (site 1) (Figure 6E) is also species-rich but *Sinophysis* sp. is absent and *Coolia* spp. is present instead in significant numbers. Interestingly, *Coolia* spp. is absent from Bramble Reef (site 2) (Figure 6F) and the other two sites (Figures 6C-6D). Samples analysed thus far for Trunk reef (site 3) differ from the mid-reefs described above by a reduced dominance of *Prorocentrum* spp., due to the presence of a high proportion of unknown dinoflagellates, but it is equally species-rich as the other mid-reef locations analysed thus far (Figure 6H).

In contrast to the dinoflagellate distribution and community composition results obtained for coastal communities on the mainland (Townsville), both sites in Pioneer Bay (Orpheus Island) show significant abundances of *Gambierdiscus* spp. and Pioneer Bay (site 1) is more species-rich and shows a low abundance of *Ostreopsis* spp. (Figures 6A-6B). Pioneer Bay (site 2) shows a similar abundance pattern as coastal Townsville areas, with the exception of the presence of *Gambierdiscus* spp. (Figure 6B). Interestingly, *Ostreopsis* spp present in Pioneer Bay at site 1 is absent at site 2 of Pioneer Bay (Figures 6A-6B).



Dinoflagellate abundance (%) at Pioneer Bay (site 1) November 2008

Dinoflagellate abundance (%) at Pioneer Bay (site 2) November 2008

Dinoflagellate abundance (%) at Keeper Reef (site 1) November 2008

Dinoflagellate abundance (%) at Lodestone Reef (site 1) November 2008

Dinoflagellate abundance (%) at Bramble Reef (site 1) November 2008

Dinoflagellate abundance (%) at Bramble Reef (site 2) November 2008

Dinoflagellate abundance (%) at Pelorus Island (site 2) November 2008

Dinoflagellate abundance (%) at Trunk Reef (site 3) November 2008

Figure 6: Abundance patterns for benthic toxic dinoflagellate genera for analysed samples from (A) Pioneer Bay (site 1), (B) Pioneer Bay (site 2), (C) Keeper Reef (site 1), (D) Lodestone Reef (site 1), (E) Bramble Reef (site 1), (F) Bramble Reef (site 2), (G) Pelorus Island (site 2) and (H) Trunk Reef (site 3).

Epiphytic toxic dinoflagellate abundances at Pelorus Island (site 2) are similar in terms of *Ostreopsis* spp dominance and community composition (Figure 6G) compared to Nelly Bay at Magnetic Island (Figure 2A). Both areas share similar environmental conditions in terms of tidal inundation, being submerged at all times. The channel between Pelorus Island and Orpheus Island is a little more exposed compared to the inshore environment at Nelly Bay (Magnetic Island), which could explain the higher percentage of *Prorocentrum* spp. observed at Pelorus Island (Figure 6G) compared to Nelly Bay (Figure 2A). In summary, site similarities in terms of substrate and environmental conditions appear to be reflected in similarities of epiphytic toxic dinoflagellate abundances, community compositions, and species diversity across different sites.

Initial composition for Magnetic Island and Orpheus Island data and seasonal abundance data for toxic dinoflagellates for Magnetic Island / Townsville and for reefs near Orpheus Island will be published in three manuscripts which will be submitted to peer-reviewed journals, once all collections are completed and fully analysed. The dinoflagellate atlas will contain summary data and references to these publications. It will also contain accession numbers of genetic sequences of the cultured dinoflagellates and, once accomplished, sequence accession numbers of single cell isolates from field samples, once these have been submitted to Genbank, while the analysed raw data will be published in peer-reviewed journals.

The development of a comprehensive atlas of toxic benthic dinoflagellates and macroalgal is an ongoing project, which requires time due to the spatial and temporal resolution of toxic dinoflagellates it will offer. The planned collection trip in August 2009 is essential to document seasonal distribution and abundance patterns of toxic dinoflagellates. It is planned that this atlas will be published in colour by the Reef and Rainforest Research Centre and the Great Barrier Reef Marine Park Authority.

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Appendix 1

Table 1: Collection, identification and abundance details for Magnetic Island and Townsville field trips in 2008.

Reef / Island	Site	Date	Macroalgae	Depth	Dinoflagellate ID	Number of cells/g wet biomass	Total number of cells/g wet biomass
Picnic Bay	MI	3/16/2008	*Turbinaria* sp. 1	surf zone	*Ostreopsis* spp.	4.0	43.2
Picnic Bay	MI	3/16/2008	*Halimeda* sp. 1	surf zone	None	0.0	
Picnic Bay	MI	3/16/2008	*Sargassum* sp. 1	surf zone	*Ostreopsis* spp.	28.7	
Picnic Bay	MI	3/16/2008	*Sargassum* sp. 5	surf zone	None	0.0	
Picnic Bay	MI	3/16/2008	*Sargassum* sp. 2	surf zone	None	0.0	
Picnic Bay	MI	3/16/2008	*Turbinaria* sp. 2	surf zone	None	0.0	
Picnic Bay	MI	3/16/2008	*Sargassum* sp. *6*	surf zone	*Ostreopsis* spp.	5.2	
				surf zone	*Dinophysis caudata*	5.2	
Picnic Bay	MI	3/16/2008	*Sargassum* sp. 3	surf zone	None	0.0	
Picnic Bay	MI	3/16/2008	*Sargassum* sp. 4	surf zone	None	0.0	
Picnic Bay	MI	3/16/2008	*Halimeda* sp. 2	surf zone	None	0.0	
Horseshoe Bay	MI	4/6/2008	*Sargassum* sp. 7	0-0.5m	*Ostreopsis* spp.	3.7	1,372.2
				0-0.5m	*Prorocentrum* spp.	9.4	
Horseshoe Bay	MI	4/6/2008	*Sargassum* sp. 8	0-0.5m	*Prorocentrum* spp.	6.8	
				0-0.5m	Dinoflagellate unknown	34.0	
Horseshoe Bay	MI	4/6/2008	*Padina* sp. 1	0-0.5m	*Coolia* sp.	1.5	
				0-0.5m	*Gambierdiscus* spp.	9.3	
				0-0.5m	*Gymnodinium* sp.	1.5	
				0-0.5m	*Prorocentrum* spp.	3.1	
Horseshoe Bay	MI	4/6/2008	*Padina* sp. 2	0-0.5m	Dinoflagellate unknown	36.3	
				0-0.5m	*Gambierdiscus* spp.	23.3	
				0-0.5m	*Ostreopsis* spp.	15.6	
Horseshoe Bay	MI	4/6/2008	*Enteromorpha* sp. 1	0-0.5m	Dinoflagellate unknown	48.4	
Horseshoe Bay	MI	4/6/2008	*Cladophora* sp. 1	0-0.5m	*Gambierdiscus* spp.	117.9	
				0-0.5m	*Ostreopsis* spp.	294.8	
				0-0.5m	*Prorocentrum* spp.	294.8	
				0-0.5m	Dinoflagellate unknown	471.7	
Kissing Point	TVLLE	4/16/2008	*Cladophora* sp. 2	0-0.5m	Dinoflagellate unknown	6.1	65.6
Kissing Point	TVLLE	4/16/2008	*Hypnea cervicornis* 1	0-0.5m	None	0.0	
Kissing Point	TVLLE	4/16/2008	*Polysiphonia* sp. *1*	0-0.5m	*Prorocentrum* spp.	59.5	
NQAIF tank	TVLLE	4/20/2008	*Chondria* sp. 1		*Coolia monotis*	1,429.7	2,303.4
					Gambierdiscus sp.	873.7	
Kissing Point	TVLLE	5/4/2008	*Jania* sp. *1*	0-0.5m	None	0.0	0.0
Kissing Point	TVLLE	5/4/2008	*Jania* sp. *2*	0-0.5m	None	0.0	
Kissing Point	TVLLE	5/4/2008	*Dictyota* sp. 1	0-0.5m	None	0.0	
Kissing Point	TVLLE	5/4/2008	*Dictyota* sp. 2	0-0.5m	None	0.0	
Kissing Point	TVLLE	5/4/2008	*Polysipohonia* sp. *2*	0-0.5m	None	0.0	
Kissing Point	TVLLE	5/4/2008	*Udotea* sp. 1	0-0.5m	None	0.0	
Nelly Bay	MI	5/18/2008	*Hormophysa* sp. 1	1-2m	*Ostreopsis* spp.	247.4	12,700.2
				1-2m	*Prorocentrum* spp.	8.6	
Nelly Bay	MI	5/18/2008	*Gracilaria textorii* 1	1-2m	*Ostreopsis* spp.	9,780.0	
				1-2m	*Prorocentrum* spp.	186.1	
Nelly Bay	MI	5/18/2008	*Portieria hornemannii* 1	1-2m	*Ostreopsis* spp.	2,102.1	
				1-2m	*Prorocentrum* spp.	75.1	
Nelly Bay	MI	5/18/2008	*Portieria hornemannii* 2	1-2m	*Ostreopsis* spp.	71.0	
Nelly Bay	MI	5/18/2008	*Portieria hornemannii* 3	1-2m	*Ostreopsis* spp.	29.5	
				1-2m	*Prorocentrum* spp.	4.5	
Nelly Bay	MI	5/18/2008	*Portieria hornemannii* 4	1-2m	*Ostreopsis* spp.	178.0	
				1-2m	*Prorocentrum* spp.	11.9	
				1-2m	Dinoflagellate unknown	5.9	
Nelly Bay	MI	6/1/2008	*Tricleocarpa fragilis* 1	1-2m	*Ostreopsis* spp.	277.0	372.2
Nelly Bay	MI	6/1/2008	*Portieria hornemannii* 5	1-2m	*Ostreopsis* spp.	95.2	
Rowes Bay (KP)	TVLLE	6/4/2008	*Cladophora* sp. 3	0-0.5m	*Prorocentrum* spp.	12.1	2,454.2
					Dinoflagellate unknown	36.2	
Rowes Bay (KP)	TVLLE	6/4/2008	*Jania* sp. 3	0-0.5m	*Prorocentrum* spp.	80.6	
					Dinoflagellate unknown	80.6	
Rowes Bay (KP)	TVLLE	6/4/2008	*Cystosiera* sp. 1	0-0.5m	Dinoflagellate unknown	64.2	
Rowes Bay (KP)	TVLLE	6/4/2008	*Padina* sp. 3	0-0.5m	Dinoflagellate unknown	43.7	
Rowes Bay (KP)	TVLLE	6/4/2008	*Padina* sp. 4	0-0.5m	*Prorocentrum* spp.	59.8	
					Dinoflagellate unknown	59.8	
Rowes Bay (KP)	TVLLE	6/4/2008	*Enteromorpha* sp. 2	0-0.5m	None	0.0	
Rowes Bay (KP)	TVLLE	6/4/2008	*Chondria* sp. 2	0-0.5m	None	0.0	
Rowes Bay (KP)	TVLLE	6/4/2008	*Laurencia* sp 1	0-0.5m	None	0.0	
Rowes Bay (KP)	TVLLE	6/4/2008	*Laurencia* sp. 2	0-0.5m	None	0.0	

(Table 1 continues to page 16)

Table 1 (cont'd): Collection, identification and abundance details for Magnetic Island and Townsville field trips in 2008.

Rowes Bay (KP)	TVLLE	6/4/2008	*Hypnea* sp. 2	0-0.5m	None	0.0	
Rowes Bay (KP)	TVLLE	6/4/2008	*Hypnea* sp. 3	0-0.5m	None	0.0	
Rowes Bay (KP)	TVLLE	6/4/2008	*Centroceras* sp. 1	0-0.5m	*Prorocentrum* spp.	100.1	
Rowes Bay (KP)	TVLLE	6/4/2008	*Centroceras* sp. 2	0-0.5m	Dinoflagellate unknown *Prorocentrum* spp.	18.2 1,898.7	
Rowes Bay (KP)	TVLLE	6/4/2008	*Hincksia* sp. 1	0-0.5m	None	0.0	
Backnumber Reef	1	7/13/2008	*Caulerpa peltata* 1	2-10m	*Gambierdiscus toxicus* *Prorocentrum* spp.	5.6 33.8	39.4
Nelly Bay	MI	7/27/2008	*Gracilaria textorii* 2	1-2m	*Ostreopsis* spp. Gambierdiscus sp.	778.5 35.4	1,702.5
Nelly Bay	MI	7/27/2008	*Gracilaria textorii* 3	1-2m	*Ostreopsis* spp. Gambierdiscus sp.	356.2 13.2	
Nelly Bay	MI	7/27/2008	*Sargassum* sp. 9	1-2m	*Ostreopsis* spp. Gambierdiscus sp.	211.1 17.6	
Nelly Bay	MI	7/27/2008	*Portieria hornemannii* 6	1-2m	*Ostreopsis* spp. *Gambierdiscus* sp. *Prorocentrum* spp.	170.9 85.5 34.2	
Nelly Bay	MI	8/10/2008	*Padina* sp. 5	1-2m	*Ostreopsis* spp.	278.2	4,064.9
Nelly Bay	MI	8/10/2008	*Hypnea* sp. 4	1-2m	*Ostreopsis* spp. *Prorocentrum* sp.	3,690.1 96.6	

Table 2: Collection, identification and abundance details for Orpheus reef field trips in November 2008.

Reef / Island	Date	Macroalgae	Depth	Dinoflagellate ID	Number of cells/g wet biomass	Total number of cells/g wet biomass
Pioneer Bay	2/11/2008	*Hydroclathrus* sp. 2	F	*Prorocentrum* spp.	306.8	4817.9
				Gambierdiscus spp.	12.0	
				Ostreopsis spp.	6.0	
				Dinoflagellate unknown spp.	12.0	
Pioneer Bay	2/11/2008	Unknown	F	*Prorocentrum* spp.	227.0	
				Gambierdiscus spp.	27.3	
				Dinoflagellate unknown spp.	44.3	
Pioneer Bay	2/11/2008	*Padina* sp. 7 (mix)	F	*Prorocentrum* spp.	166.3	
				Gambierdiscus spp.	10.1	
				Ostreopsis spp.	5.0	
				Sinophysis sp.	5.0	
				Dinoflagellate unknown spp.	10.1	
Pioneer Bay	2/11/2008	*Turbinaria* sp. 3	F	*Prorocentrum* spp.	14.7	
				Ostreopsis spp.	8.8	
				Dinoflagellate unknown spp.	14.7	
Pioneer Bay	2/11/2008	Red unknown sp. 1 (Mix)	S	*Prorocentrum* spp.	120.3	
				Gambierdiscus spp.	47.1	
				Dinoflagellate unknown spp.	20.9	
Pioneer Bay	2/11/2008	*Gracilaria* sp. 6 (c.f. *Rhodymenia* sp.)	S	*Prorocentrum* spp.	270.7	
				Gambierdiscus spp.	62.5	
Pioneer Bay	2/11/2008	*Sargassum* sp. 11	F	*Prorocentrum* spp.	928.4	
				Gambierdiscus spp.	35.7	
				Dinoflagellate unknown spp.	142.8	
Pioneer Bay	2/11/2008	*Hydroclathrus* sp. 3	F	*Prorocentrum* spp.	441.1	
				Gambierdiscus spp.	105.9	
				Ostreopsis spp.	17.6	
				Dinoflagellate unknown spp.	405.8	
Pioneer Bay	2/11/2008	*Amphiroa* sp. 1	F	*Prorocentrum* spp.	113.4	
				Gambierdiscus spp.	8.1	
				Dinoflagellate unknown spp.	24.3	
Pioneer Bay	2/11/2008	*Padina* sp. 8	F	*Prorocentrum* spp.	765.6	
				Gambierdiscus spp.	62.5	
				Dinoflagellate unknown spp.	375.0	
Pioneer Bay	10/11/2008	*Hydroclathrus* sp. 4	F	*Prorocentrum* spp.	133.9	461.0
Pioneer Bay	10/11/2008	*Dictyota* sp. 5	F	*Prorocentrum* spp.	96.0	
				Gambierdiscus spp.	3.8	
				Dinoflagellate unknown spp.	11.5	

Pioneer Bay	10/11/2008	Brown unknown sp. 4	F	*Prorocentrum* spp.	164.6	
				Gambierdiscus spp.	39.7	
				Dinoflagellate unknown spp.	11.4	
Pelorus	3/11/2008	Green unknown sp. 2	Flat	*Prorocentrum* spp.	166.7	4911.2
Pelorus	3/11/2008	*Sargassum* sp. 13	Flat	*Prorocentrum* spp.	937.5	
				Gambierdiscus spp.	62.5	
				Ostreopsis spp.	2187.5	
Pelorus	3/11/2008	Brown unknown sp. 1 (coral reef mix)	Flat	*Prorocentrum* spp.	708.3	
				Gambierdiscus spp.	83.3	
				Ostreopsis spp.	333.3	
				Dinoflagellate unknown spp.	208.3	
Pelorus	3/11/2008	*Dictyota* sp. 4	Flat	*Prorocentrum* spp.	17.5	
				Ostreopsis spp.	87.5	
				Dinoflagellate unknown spp.	4.4	
Pelorus	3/11/2008	*Halimeda* sp. 3	Slope	*Prorocentrum* spp.	52.3	
Pelorus	3/11/2008	*Caulerpa* spp. 2	Slope	None	0	
Pelorus	3/11/2008	*Gracilaria* sp. 8 mix(c.f. *Rhodymenia)*	Slope	*Gambierdiscus* spp.	21.7	
Pelorus	3/11/2008	Red unknown sp. 2	Slope	*Prorocentrum* spp.	13.5	
				Ostreopsis spp.	13.5	
				Dinoflagellate unknown spp.	13.5	
Pelorus	3/11/2008	Calcified Red unknown sp. 3	Slope			
Keeper	4/11/2008	Brown unknown sp. 2	Slope	*Prorocentrum* spp.	524.6	6334.7
				Gambierdiscus spp.	65.6	
				Dinoflagellate unknown spp.	16.4	
Keeper	4/11/2008	Brown unknown sp. 3	F	*Prorocentrum* spp.	3160.0	
				Gambierdiscus spp.	280.0	
				Ostreopsis spp.	200.0	
				Dinoflagellate unknown spp.	80.0	
Keeper	4/11/2008	*Halimeda* sp. 4	Slope	*Prorocentrum* spp.	2.9	
				Gambierdiscus spp.	10.0	
Keeper	4/11/2008	*Halimeda* sp. 5	Slope	*Prorocentrum* spp.	26.8	
				Ostreopsis spp.	13.4	
Keeper	4/11/2008	*Halimeda* sp. 6	Slope	None	0.0	
Keeper	4/11/2008	*Halimeda* sp. 7	Flat	*Prorocentrum* spp.	67.8	
				Gambierdiscus spp.	15.6	
				Dinoflagellate unknown spp.	15.6	
Keeper	4/11/2008	Red unknown sp. 6	Slope	None	0.0	
Keeper	4/11/2008	Red unknown sp. 7	Flat	*Prorocentrum* spp.	556.5	

				Gambierdiscus spp.	9.6	
				Ostreopsis spp.	9.6	
				Sinophysis spp.	19.2	
				Dinoflagellate unknown spp.	57.6	
Keeper	4/11/2008	Red unknown sp. 8	Slope	*Prorocentrum* spp.	160.2	
				Dinoflagellate unknown spp.	63.6	
Keeper	4/11/2008	Red unknown sp. 10	F	*Prorocentrum* spp.	378.8	
				Ostreopsis spp.	189.4	
				Sinophysis spp.	189.4	
Keeper	4/11/2008	Red unknown sp. 14	Slope	*Prorocentrum* spp.	33.0	
Keeper	4/11/2008	Red unknown sp. 23	Slope	*Prorocentrum* spp.	0.0	
				Gambierdiscus spp.	174.2	
				Dinoflagellate cyst sp.	15.2	
Keeper	4/11/2008	Red unknown sp. 24	Slope	None	0.0	
Keeper	4/11/2008	Red unknown sp. 25	Slope	None	0.0	
Lodestone	4/11/2008	*Hypnea* sp. 6	Slope	None	0.0	3422.4
Lodestone	4/11/2008	Red unknown sp. 3	Slope	*Prorocentrum* spp.	453.5	
				Ostreopsis spp.	226.7	
				Dinoflagellate unknown spp.	151.2	
Lodestone	4/11/2008	Red unknown sp. 4	Slope	*Prorocentrum* spp.	83.1	
				Dinoflagellate unknown spp.	24.9	
Lodestone	4/11/2008	Red unknown sp. 5	Slope	*Prorocentrum* spp.	548.8	
				Gambierdiscus spp.	29.5	
				Ostreopsis spp.	23.6	
				Synophysis sp.	11.8	
				Dinoflagellate unknown spp.	47.2	
Lodestone	4/11/2008	Red unknown sp. 9	Slope	*Prorocentrum* spp.	57.5	
				Ostreopsis spp.	19.2	
Lodestone	4/11/2008	Red unknown sp. 11	Slope	*Prorocentrum* spp.	1.8	
				Ostreopsis ovata	1.8	
Lodestone	4/11/2008	Red unknown sp. 12	Slope	*Prorocentrum* spp.	1.4	
				Dinoflagellate unknown spp.	1.4	
Lodestone	4/11/2008	Red unknown sp. 13	Flat	*Prorocentrum* spp.	920.4	
				Gambierdiscus spp.	17.7	
				Ostreopsis spp.	150.4	
				Synophysis spp.	26.5	
				Dinoflagellate unknown spp.	17.7	

Lodestone	4/11/2008	Red unknown sp. 15	Flat	*Prorocentrum* spp.	472.2	
				Gambierdiscus spp.	36.2	
				Ostreopsis spp.	32.1	
				Synophysis spp.	52.2	
				Dinoflagellate unknown spp.	12.1	
Lodestone	4/11/2008	*Caulerpa* sp. 3 (mix *Halimeda* sp.)	Slope	*Prorocentrum* spp.	1.6	
Bramble	5/11/2008	Green unknown sp. 3	Slope	*Prorocentrum* spp.	84.2	1465.7
				Gambierdiscus spp.	19.9	
				Ostreopsis spp.	15.3	
				Dinoflagellate unknown spp.	22.7	
Bramble	5/11/2008	Red unknown sp. 17	Slope	*Prorocentrum* spp.	126.5	
				Coolia spp.	10.1	
				Ostreopsis spp.	10.1	
				Dinoflagellate unknown spp.	20.2	
Bramble	5/11/2008	Red unknown sp. 18	Slope	*Prorocentrum* spp.	316.9	
				Gambierdiscus spp.	6.5	
				Ostreopsis spp.	6.5	
				Dinoflagellate unknown spp.	45.3	
Bramble	5/11/2008	Red unknown sp. 19	Slope	*Prorocentrum* spp.	393.1	
				Gambierdiscus spp.	4.3	
				Ostreopsis spp.	25.6	
				*Coolia*spp.	96.1	
				Dinoflagellate unknown spp.	17.1	
Bramble	5/11/2008	Red unknown sp. 21	Slope	*Prorocentrum* spp.	144.6	
				Gambierdiscus spp.	10.0	
				Ostreopsis spp.	24.9	
				Dinoflagellate unknown spp.	10.0	
Bramble	5/11/2008	*Turbinaria* sp. 4	Slope	*Prorocentrum* spp.	34.8	
				Dinoflagellate unknown spp.	20.9	
Bramble	5/11/2008	*Halimeda* sp. 8		*Prorocentrum* spp.	59.1	569.0
				Gambierdiscus spp.	11.8	
				Sinophysis sp.	5.9	
				Dinoflagellate unknown spp.	11.8	
Bramble	5/11/2008	*Halimeda* sp. 9		*Prorocentrum* spp.	12.7	
				Dinoflagellate unknown spp.	4.2	
Bramble	5/11/2008	*Halimeda* sp. 10		*Prorocentrum* spp.	10.0	
				Ostreopsis spp.	2.5	
Bramble	5/11/2008	*Halimeda* sp. 11		*Prorocentrum* spp.	12.7	
Bramble	5/11/2008	*Halimeda* sp. 12		*Prorocentrum* spp.	51.2	
				Gambierdiscus spp.	12.2	
				Ostreopsis spp.	4.9	

				Sinophysis spp.	12.2	
				Dinoflagellate unknown spp.	2.4	
Bramble	5/11/2008	Red unknown sp. 16		*Prorocentrum* spp.	230.4	
				Gambierdiscus spp.	2.9	
				Ostreopsis spp.	30.4	
				Sinophysis sp.	8.7	
				Dinoflagellate unknown spp.	17.4	
Bramble	5/11/2008	Red unknown sp. 20		*Prorocentrum* spp.	20.8	
				Gambierdiscus spp.	4.2	
				Ostreopsis spp.	0.9	
				Sinophysis sp.	0.9	
				Dinoflagellate unknown spp.	0.9	
Bramble	5/11/2008	Red unknown sp. 22		*Prorocentrum* spp.	20.4	
				Gambierdiscus spp.	15.8	
				Sinophysis sp.	1.5	
Trunk	9/11/2008	*Caulerpa* sp. 5	F	*Prorocentrum* spp.	15.1	931.1
				Gambierdiscus spp.	3	
				Ostreopsis spp.	0	
				Dinoflagellate unknown spp.	4.5	
Trunk	9/11/2008	*Caulerpa* sp. 6	F	*Prorocentrum* spp.	16.9	
				Gambierdiscus spp.	5.6	
				Dinoflagellate unknown spp.	16.9	
Trunk	9/11/2008	Red unknown sp. 36	F	*Prorocentrum* spp.	92.7	
				Sinophysis sp.	8.4	
				Ostreopsis spp.	67.4	
				Ceratium sp.	8.4	
Trunk	9/11/2008	Red unknown sp. 37	F	*Prorocentrum* spp.	185	
				Gambierdiscus spp.	44.4	
				Ostreopsis spp.	30	
				Dinoflagellate unknown spp.	281.3	
Trunk	9/11/2008	Red unknown sp. 38	F	*Prorocentrum* spp.	69.3	
				Ostreopsis spp.	65.9	
				Dinoflagellate unknown spp.	10.4	
Trunk	9/11/2008	Red unknown sp. 51	F	*Prorocentrum* spp.	5.9	