Department of Environment and Conservation

Anoxic impacts at Bill's Bay, Ningaloo Marine Park associated with the 2008 coral spawning event

Marine Science Program Data Report

MSPDR2 January 2009

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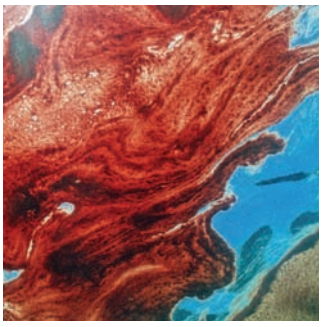


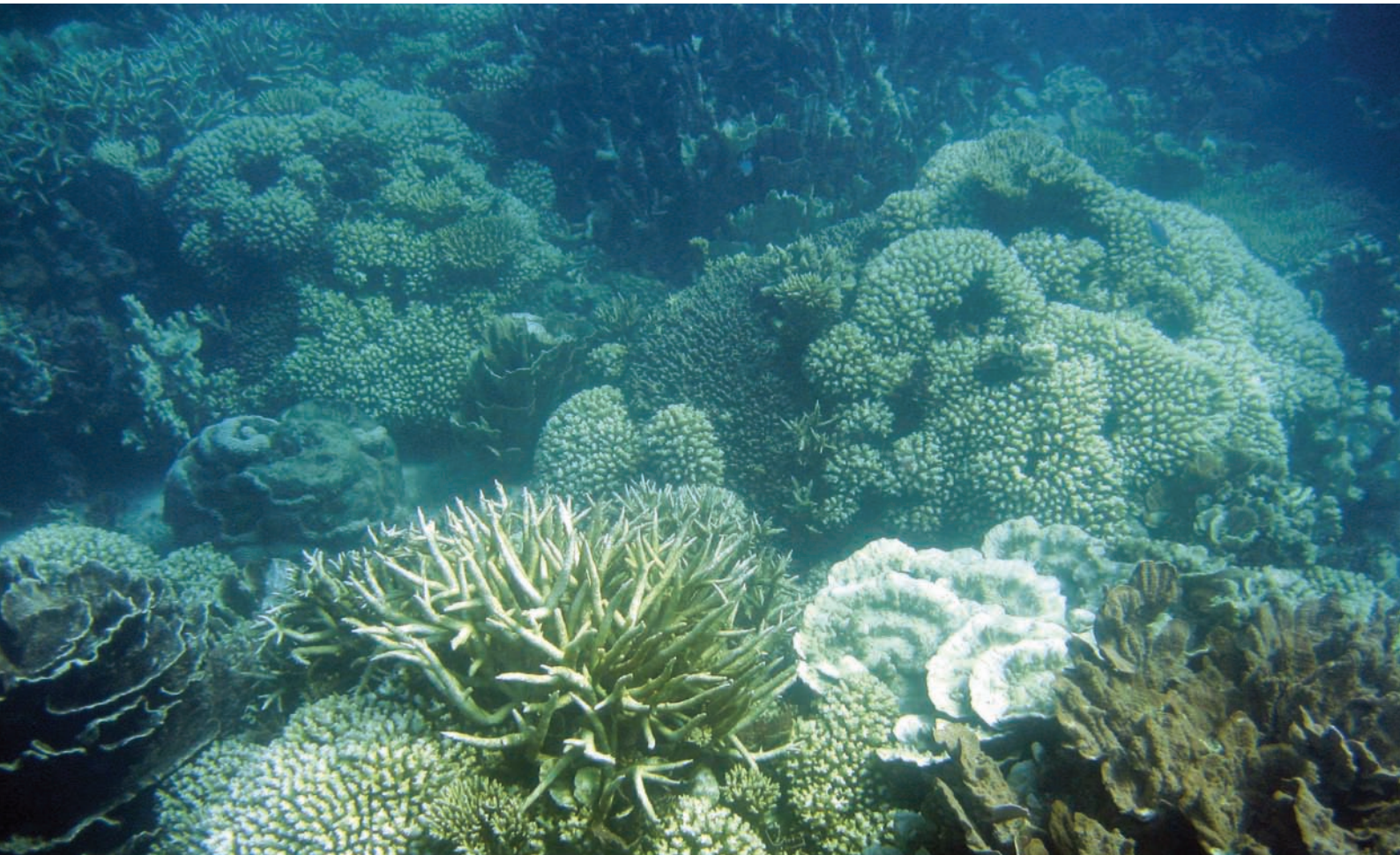

Department of
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ISSN 1836-5809 (Print) 1836-5817 (Online)

This report can be cited as:
Armstrong SJ, Syme R (2009). Anoxic impacts at Bill's Bay, Ningaloo Marine Park associated with the 2008 coral spawning event. Marine Science Program Data Report Series: MSPDR2. January 2009. Marine Science Program, Department of Environment and Conservation, Perth, Western Australia. 19p.

Cover images: (small images, left to right) Coral spawn slick in Bill's Bay in 1989 (subsurface view) during the mass mortality event that killed up to 100 per cent of fish, corals and other invertebrates; Bleached corals photographed from the air during the 2008 anoxic coral spawning event; Some coral colonies, such as this *Montipora* coral, completely bleached during the 2008 anoxic coral spawning event at Bill's Bay; Numerous fish were killed and washed up along the shore of Bill's Bay during the 2008 anoxic spawning event and (large image) Bleached coral community at Bill's Bay, Western Australia associated with the 2008 anoxic coral spawning event. Photos - Department of Environment and Conservation/Marine Science Program and Exmouth District.

SUMMARY

Coral spawning in 2008 coincided with northerly winds and small swell conditions causing the accumulation of coral spawn in inner Bill's Bay for up to nine days. Observations suggest that the respiratory demand of the coral spawn and further biological oxygen demand of its decomposition caused anoxic conditions within inner Bill's Bay resulting in the mass mortality of reef organisms including fish and corals. The spatial extent of coral bleaching at Bill's Bay was mapped approximately 12 days after the commencement of coral spawning. Observations suggest 20 to 40% of corals were killed within a 1.2 square km area of inner Bill's Bay. In addition photographs and descriptive observations of corals at existing long-term reef recovery monitoring sites at Bill's Bay were taken. The area where dead fish washed up along the shore was mapped and information regarding the type and condition of these fish were also recorded immediately after the event. The climatic and oceanographic factors that occurred leading up to the event are also recorded herein. To quantify the mortality and recovery of corals from this event, the long-term reef recovery monitoring sites established after the 1989 anoxic spawning event at Bill's Bay were re-surveyed in September 2008. Data from the survey will be prepared into a subsequent Marine Science Program data report.

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1 INTRODUCTION

The Ningaloo Reef is located approximately 1000 km north of Perth in Western Australia, and runs parallel to the coastline as a discontinuous barrier for approximately 300 km. It is the largest fringing coral reef system in Australia and the only coral reef in the world fringing the west coast of a continent (Taylor & Pearce, 1999). Temperate and tropical currents converge in the Ningaloo region, resulting in a diversity of marine life including more than 500 species of fish, 250 known species of corals and approximately 600 species of molluscs (The Department of Conservation and Land Management, 2005). The area has very high ecological and social conservation significance and was gazetted as a marine park in 1987. In 2005, the park boundary was amended to include the southern section of the Ningaloo Reef and the Muiron Islands Marine Management Area was also gazetted.

Bill's Bay, an embayment within the shallow coastal lagoon of Ningaloo Reef is situated near the township of Coral Bay. The lagoon at Bill's Bay is 2 – 2.5 km wide and has an average depth of about 3 m. Lagoonal flushing at Bill's Bay is likely to be predominantly controlled by wave-forcing mechanisms and also less predominantly by wind and tidal forcing. Results from a study at Osprey/Sandy Bay (located approx. 60 km further north along the Ningaloo Reef tract than Bill's Bay) indicate lagoonal flushing times of five to eight hours under typical offshore wave conditions (Lowe *et al.* 2008). The lagoon volume is much greater at Bill's Bay and is likely to be much less wave influenced. It is possible that lagoonal flushing times at Bill's Bay are longer than at Osprey/Sandy Bay (Lowe pers. comm. 2008).

In March 1989, corals within Bill's Bay spawned several nights earlier than usual. Incoming tides, light north-westerly winds and low swell conditions coincided with the time of spawning and restricted the dispersal of the coral spawn. As a result, large amounts of coral spawn were trapped in the bay, forming extensive slicks. The respiratory demand of the coral spawn, followed by the biological oxygen demand of its decomposition, depleted available oxygen in the water column and sediments. This hypoxic environment caused many marine organisms to die almost immediately and, within a few days, over one million fish, of at least 80 species, were washed ashore (Simpson *et al.* 1993). Extensive mortality of corals and other reef organisms also occurred over an area of approximately 3 km^2. Live coral cover decreased from 42.9% to 9.4% and several large colonies up to 50 years old were killed, indicating that a mass mortality of this magnitude had not occurred at Bill's Bay for at least four to five decades (Simpson *et al.* 1993). Since 1989, the Department of Environment and Conservation (DEC) and the Australian Institute of Marine Science (AIMS) has monitored the recovery of corals within Bill's Bay on a periodic basis: 1994 (Simpson & Field 1995), 1995/96 (AIMS, unpubl.), 2000 (Grubba & Cary 2000), 2001 (AIMS, unpubl.), 2004 (AIMS, unpubl.) and 2006 (Long, 2007). In summary, the recovery of pre-disturbance levels of coral cover occurred within 10 years, and recovery of pre-disturbance type acroporid-dominated coral communities was achieved at one site (Site 1) within 17 years. Most recovering near-shore sites had not yet reached this successional stage by the time of the last major survey in October 2006 (Long, 2007).

Anecdotal reports of mortality of corals and other organisms from less severe anoxic events at Bill's Bay coincident with coral spawning on several occasions since 1989 indicate that such events are relatively common at this location (van Schoubroeck & Long, 2007). Reports of fish washed ashore and observations of bleached corals indicate that a major anoxic event occurred at Bill's Bay in March/April 2008. This report documents the observations made during this event.

Objectives of the survey were to:

- Map the spatial extent of coral bleaching that occurred within Bill's Bay during the 2008 anoxic bleaching event.
- Record the severity of coral bleaching at the 17 long-term monitoring sites within Bill's Bay.

2 METHODS

2.1 Fish kill observations

Between 30 March and 2 April 2008, the area where fish were washed ashore was mapped (Figure 2). Photographs were taken approximately every 100 m along a 1 km length of beach starting from the northern end of Skeleton Bay and heading in a southerly direction (Figure 2). No emphasis was made on targeting large aggregations of dead fish. As many of the photographs looked very similar only a selection of the photographs is presented in this report. The selection of photographs was chosen to reflect both the general abundance of dead fish and the variety of species. Additional information including the length and condition of fish washed ashore was also recorded and is presented in this report (Table 2).

2.2 Coral bleaching observations

The spatial extent of coral bleaching at Bill's Bay was mapped approximately 12 days after the commencement of coral spawning. A snorkel diver was towed (manta-tow) behind a small zodiac and hand signals were used to indicate where bleaching was present or absent whilst a person in the vessel recorded the information. A grided search pattern was undertaken starting at DEC long-term monitoring Site 1 (located at the SE corner of Bill's Bay) and ending at Site 14 (located near Point Maud at the NW corner of Bill's Bay) (Figure 4). The GPS coordinate for the eastern end of the northern transect at each site was used to locate the sites. At each site the snorkel diver took several photographs of the condition of corals. An emphasis was made to get panoramic photos rather than close-up photos of individual corals.

To record the spatial extent of the bleaching from the air, an aerial flight over Bill's Bay was undertaken approximately 17 days after the commencement of coral spawning. Photographs of areas affected by bleaching were taken during the flight and are presented in this report.

Table 1. GPS coordinates (decimal degrees, datum WGS 84) of the 17 long-term monitoring sites in Bill's Bay. The coordinate for the eastern end of the northern transect is provided.

Site	Latitude	Longitude
1	S23.14090	E113.76967
2	S23.14132	E113.76648
3	S23.14177	E113.76264
4	S23.14231	E113.75875
5	S23.13635	E113.76959
6	S23.13672	E113.76595
7	S23.13685	E113.76189
8	S23.13773	E113.75749
9	S23.13032	E113.76800
10	S23.13030	E113.76478
11	S23.13048	E113.76017
12	S23.13086	E113.75438
13	S23.12461	E113.76568
14	S23.12540	E113.76063
15	S23.12538	E113.75751
16a	S23.12441	E113.75494
16b	S23.12441	E113.75537
17	S23.14665	E113.76349

2.3 Oceanic and climatic conditions information

A record of the oceanic and climatic conditions that occurred prior to and during the event were sourced from the AIMS Ningaloo Reef Weather Station (Milyering) and the Bureau of Meteorology (BOM). Additional information was collected through direct observations and measurements in the field.

3 DATA MANAGEMENT

3.1 Report archival

Hard copies of this report are held at the following locations:

1. Marine Science Program, Science Division, Department of Environment and Conservation, 17 Dick Perry Avenue, Western Australia, 6152. Ph: (08) 9334 0299 Fax: (08) 9334 0327.

2. Woodvale Library, Science Division, Department of Environment and Conservation, Ocean Reef Road, Woodvale, Western Australia, 6026. Ph: (08) 9405 5100 Fax: (08) 9306 1641.

3. Archives, Woodvale Library, Science Division, Department of Environment and Conservation, Ocean Reef Road, Woodvale, Western Australia, 6026. Ph: (08) 9405 5100 Fax: (08) 9306 1641.

4. Department of Environment and Conservation: District Office- Exmouth, 20 Nimitz St, Exmouth, WA, 6007. Ph: (08) 99478000 Fax: (08) 99478050.

5. Department of Environment and Conservation: Regional Office - Karratha, Lot 3 Anderson Rd, Karratha Industrial Estate, Karratha, WA, 6714. Ph: (08) 91431488 Fax: (08) 91441118.

6. Serials Section, State Library of Western Australia. Alexander Library Building, Perth Cultural Centre, Perth, Western Australia, 6000.

7. North West Research Association Field Station, Coral Bay, WA. Ph: (08) 99485136

Digital copies of this report are held at the following:

1. The Marine Science Program server

3.2 Digital video archival

All mini digital video (MDV) cassette footage collected during the surveys is held at two locations:

1. MDV masters have been archived in the 'Bill's Bay – Coral Bay – Long Term Monitoring Program – Video Archive – Marine Science Program' file no. 2008/001940 held at the Information Management Branch, Department of Environment and Conservation, 17 Dick Perry Avenue, Kensington, Western Australia. Ph: (08) 9334 0392.

2. Digital copies on DVDs have been stored at the Marine Science Program, Science Division, Department of Environment and Conservation, 17 Dick Perry Avenue, Kensington, Western Australia. Ph: (08) 9334 0299 Fax: (08) 9334 0327.

3.3 Digital still photographs archival

All digital still photographs taken during the survey are archived in the image library on the Marine Science Program server:

4 RESULTS

Observations suggest that the annual major coral spawning event at Coral Bay started on the night of 28 or 29 March 2008 approximately six to seven days after the full moon in March and four days after spring tide. This is within the predicted time period for the major coral spawning event at Ningaloo Reef to occur (seven to 10 days after the full moon in March).

The spawning event coincided with a prolonged period (six to seven days) of unsettled weather, dominated by rain events, light onshore winds (predominantly northerly) and occasional calm periods.

The conditions, related to a tropical cyclone (TC Pancho) located offshore at the time, caused the accumulation of coral spawn in Bill's Bay for up nine days (March 29 to April 7). It appears that the respiratory demand of the coral spawn and further biological oxygen demand of its decomposition depleted available oxygen in the water column and sediments. This caused a dystrophic crisis in Bill's Bay resulting in the mass mortality of reef organisms including fish and corals. Hundreds of dead fish washed up along the shore at Bill's Bay on 30 March one day after the commencement of coral spawning, and bleached corals were observed over a large area within Bill's Bay approximately 12 days after commencement of spawning (Figure 3).

Comparisons suggest that this event was the most significant in terms of area and severity of mortality of corals and other organisms to occur at Bill's Bay since 1989.

4.1 Oceanic conditions

Tides: Tidal variations during the event were relatively minor, heading into a period of neap tides with maximum ranges (March 29-April 2) no greater than 0.8 metres. Average tidal variation during this period was 0.4 m. Tides were semi-diurnal except for 1 April where it was diurnal.

Swell: The swell was very small and appeared to be influenced by passing cyclonic conditions during the time of the event. The swell decreased from 3.3 m on 28 March to 0.8 m on the morning of 1 April.

Circulation of coral spawn: There was a significant amount of coral spawn floating on the surface of the water, especially near shore (≤ 30 m). The spawn gradually dissipated with distance from the shoreline. The spawn was most concentrated at southern Bill's Bay, driven into the bay by north-westerly winds. There were also large mats of seagrass/seaweed floating on the surface at the time, much of which formed large, rotting banks on the shore.

Seawater temperature: Satellite data indicate that the sea surface temperature (SST) at Ningaloo Reef was not abnormal during the time of the bleaching event, i.e. within the range of SSTs recorded for Ningaloo Reef during March/April. This is consistent with *in situ* SST recordings made within Bill's Bay approximately 10 days after the event (28.3°C, 10 April at approx 2.30 pm near sites 1 and 2). These data help to eliminate SST abnormalities as the cause of the bleaching event.

4.2 Climatic Conditions

Wind: From 29 March 00hrs to 31 March 00hrs the winds were light (21 to 13 km/h (11 to 7 knots)) and from NW or WNW direction (Figure 2).

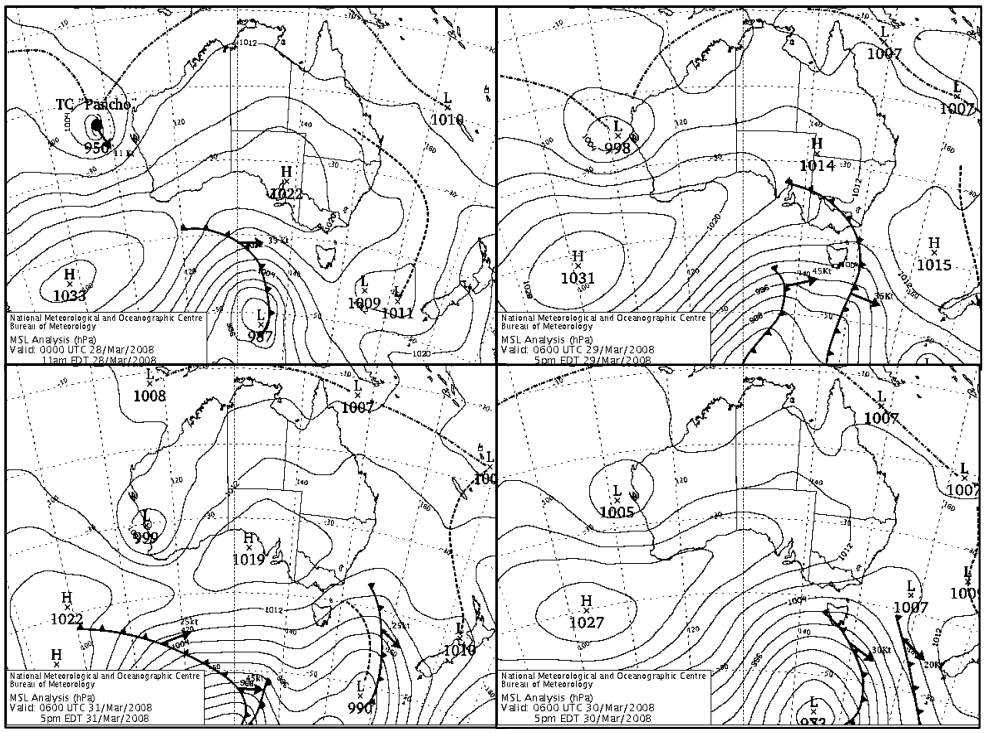


Figure 1. Synoptic charts from the time of the event. Clockwise from top left: 28/4/08, 9/4/08, 0/4/08, 31/4/08. (Source: Bureau of Meteorology).

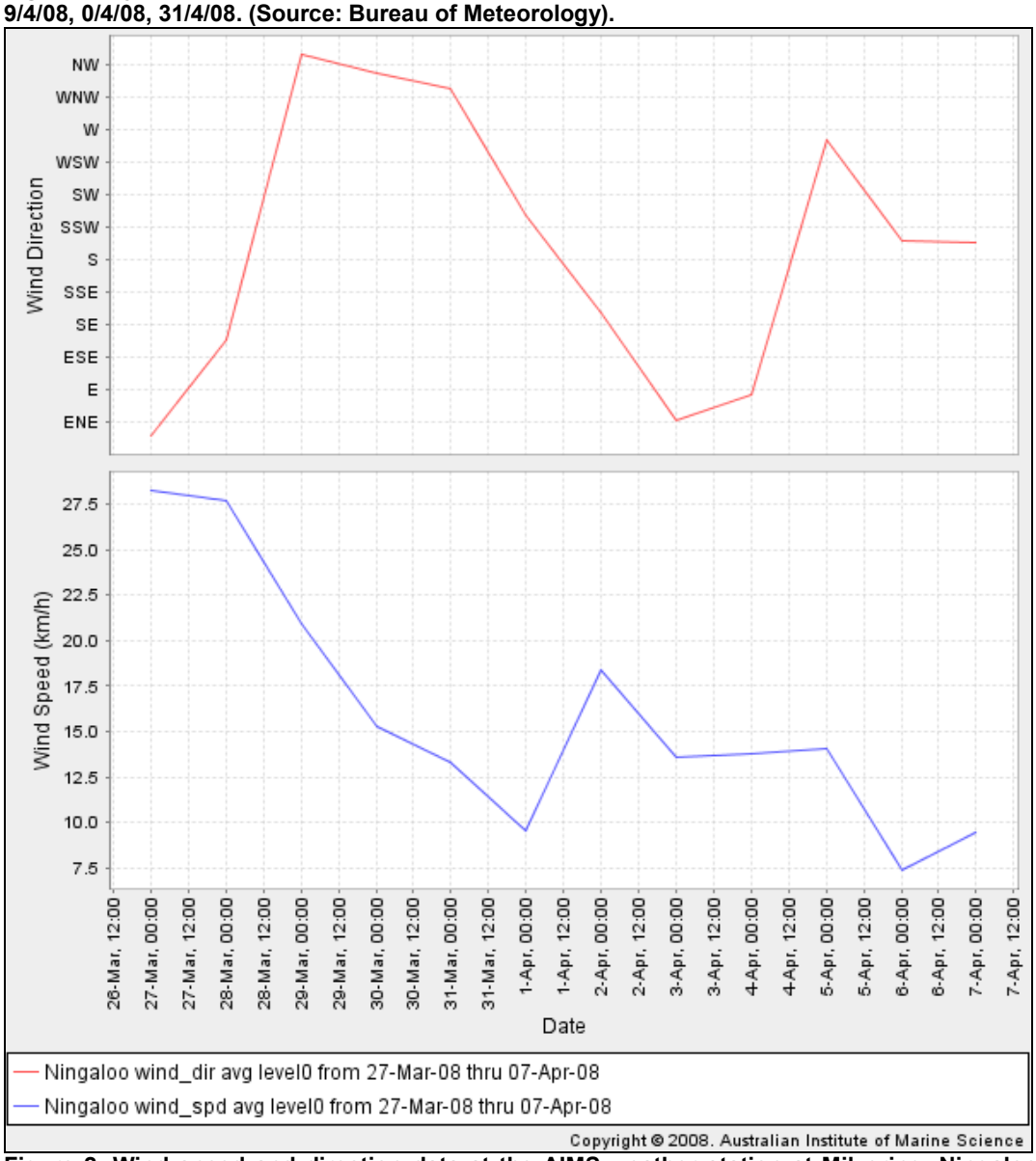


Figure 2. Wind speed and direction data at the AIMS weather station at Milyering, Ningaloo Reef during the time of the event. (Source: Australian Institute of Marine Science).

4.3 Observations of the fish kill

Approximately one day after the commencement of coral spawning various species of fish were observed either floating dead near shore, or washed up on the beach close to the main tourist beach at Coral Bay. By four days after the commencement of coral spawning, the number of dead fish had increased and dead fish had also washed up further north along the beach towards Skeleton Bay (Figure 3).

Figure 3. The fish kills observed were confined to the area known as Bill's Bay (of which Skeleton Bay is a small part located in the vicinity of where dead fish specimens were photographed).

4.3.1 Abundance of dead fish

31 March: An estimated 100-200 individual fish were observed dead on the beach and floating in the water (within 20 m from shore) along approximately 1 km of beach heading north from southern Bill's Bay.

1 April: Estimated high hundreds to possibly low thousands of individual fish were observed dead on the beach and floating in the water (within 20 m from the shore) in the vicinity of northern Bill's Bay and Skeleton Bay.

4.3.2 Condition of fish

31 March: All fish observed were dead. Many fish (across species) exhibited flayed gills and wide open/distended mouths, possibly indicating oxygen stress. No signs of decomposition were observed.

1 April: Some signs of decomposition were observed (e.g. loss of colour, weak or collapsed body structure, some bloating, yellowed eyes). A strong odour emanated from dead specimens. No lesions or bleeding were observed.

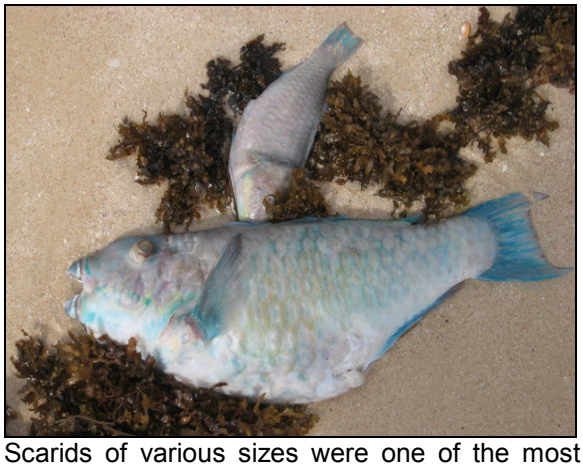
4.3.3 Fish types observed

Table 2. Information on the type, density (of dead fish washed up relative to other fish types), fork length, and condition of fish washed up at Bill's Bay during the anoxic spawning event.

Family	Density	Approximate fork length range (cm)	Condition	Injuries	Date/Time
Labridae	High	5-35	Decomposed	none visible	01/04/08 14:30
Scaridae	High	5-35	Decomposed	none visible	01/04/08 14:30
Pomacentridae	High	5-10	Slightly decomposed	none visible	01/04/08 14:30
Gobiidae	Low	5-10	Slightly decomposed	none visible	01/04/08 14:30
Plottosidae	Very Low	10-15	Recently decomposed	none visible	01/04/08 14:30

4.3.4 Photographs of the fish kill

The photographs below were taken near Skeleton Bay (Figure 3) on the 1/4/08. A variety of fish species was washed ashore during the event.



Scarids of various sizes were one of the most common families of fish washed ashore.

Other types of fish such as Pomacentrids were also washed ashore during the event.

Fish from the Gobiidae family were also washed ashore.

Fish from the Labridae family were also affected by the event.

4.4 Observations of coral bleaching

Coral bleaching was confined to inner Bill's Bay. The most severe and extensive bleaching was concentrated at the SE corner of Bill's Bay and adjacent to the shoreline heading north toward Skeleton Bay from Coral Bay township (Figure 4). *Acropora*, *Montipora*, *Echinopora* and *Pocillopora* corals appeared to be most affected by bleaching but some hardier corals such as massive Faviid sp. and *Porites* sp. were also bleached at some areas of Bill's Bay. Observations suggest that approximately 1.2 km^2 of the total area of Bill's Bay (approximately 5 km^2) was affected by bleaching (approximately 1/4 of Bill's Bay). Subsequent observations suggest that between approximately 20 to 40% of corals within the area described above were killed.

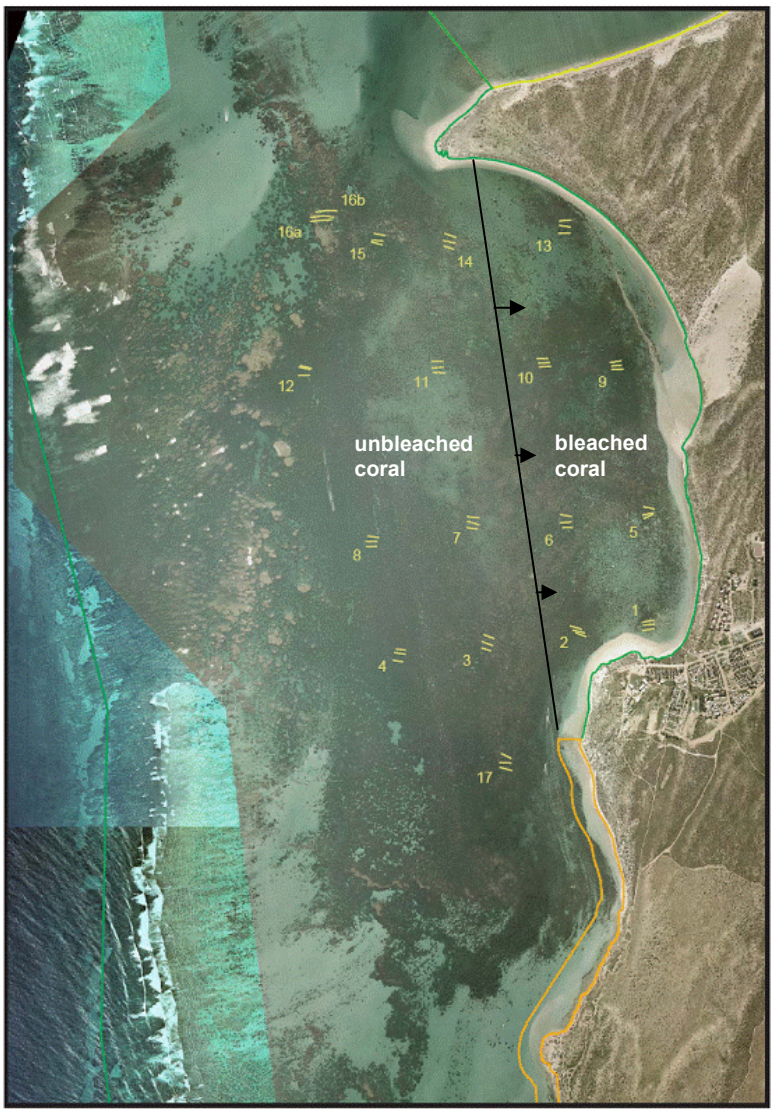
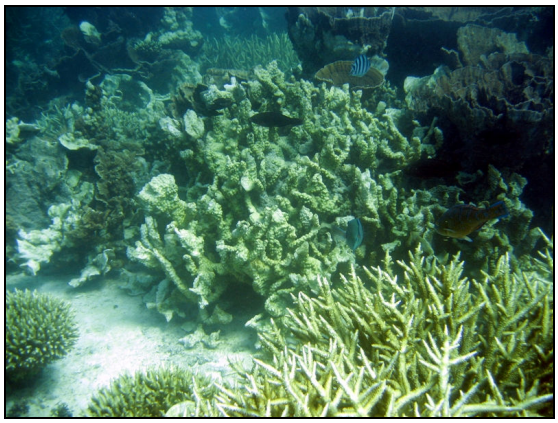


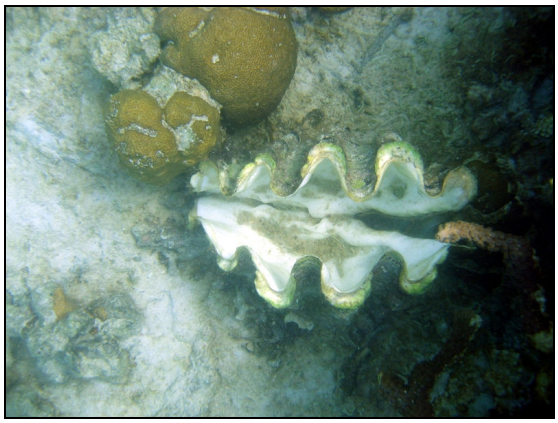
Figure 4. The general spatial extent of coral bleaching at Bill's Bay associated with the anoxic coral spawning event that occurred in March/April 2008. The positions of the 17 long-term reef recovery monitoring sites are shown.

4.4.1 Observations made at the Bill's Bay long-term monitoring sites

Site 1

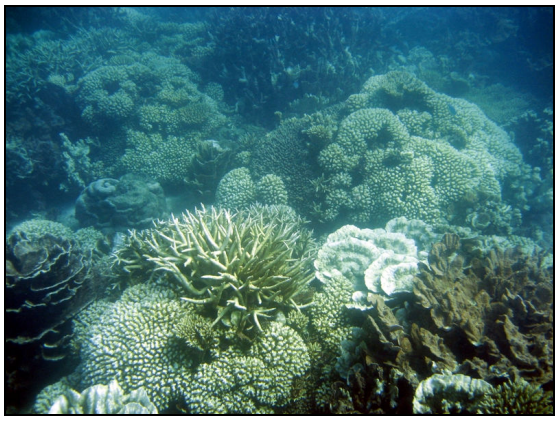
Corals at Site 1 were generally bleached. Coral cover was dominated by *Acropora*, *Montipora* and *Echinopora* corals all of which were affected by bleaching. Recently dead clams were also observed.

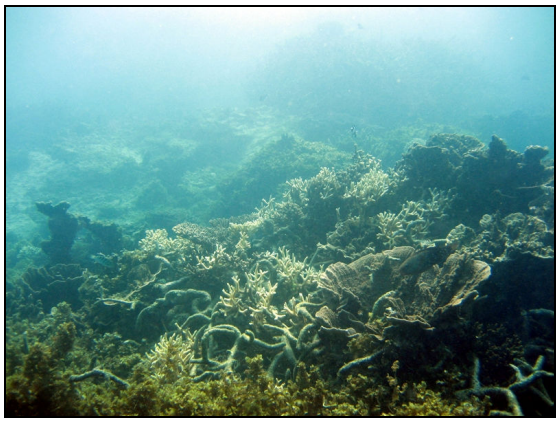


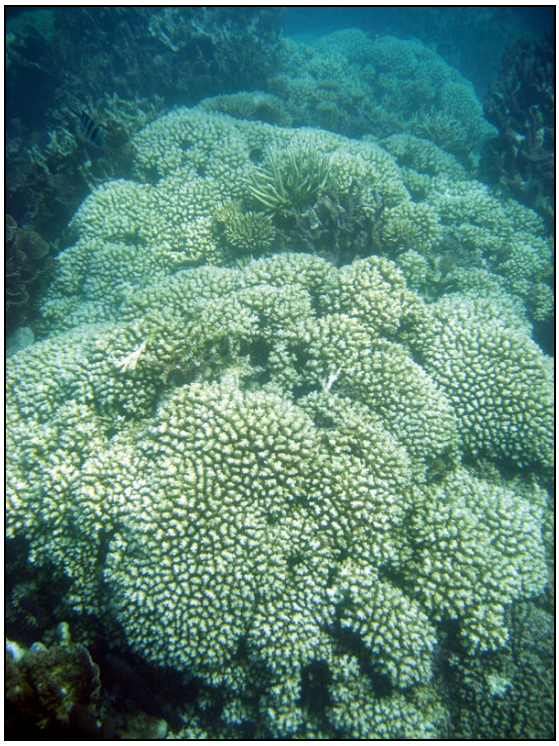


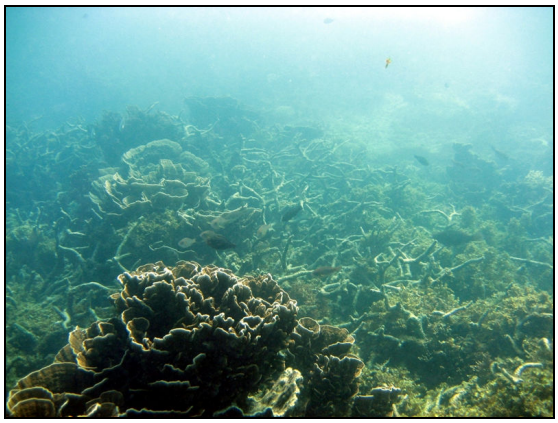
Site 2

Significant coral bleaching was observed at Site 2. Coral cover was dominated by *Pocillopora*, *Monitpora Acropora*, and *Echinopora* corals of which all were affected by bleaching. However, bleaching appeared patchy. Some corals were affected by bleaching whilst nearby corals, often of the same species, remained unbleached.



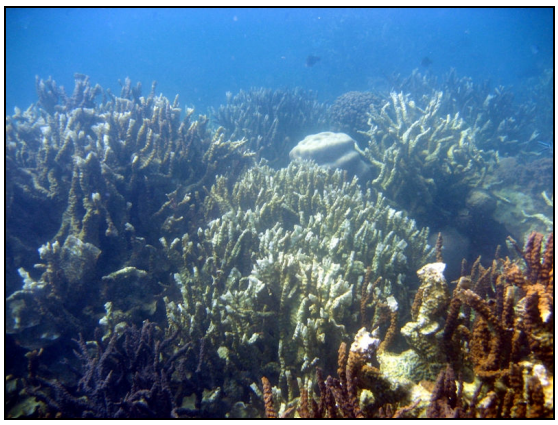
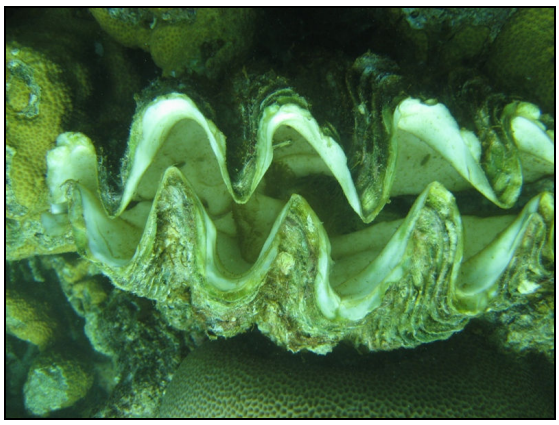






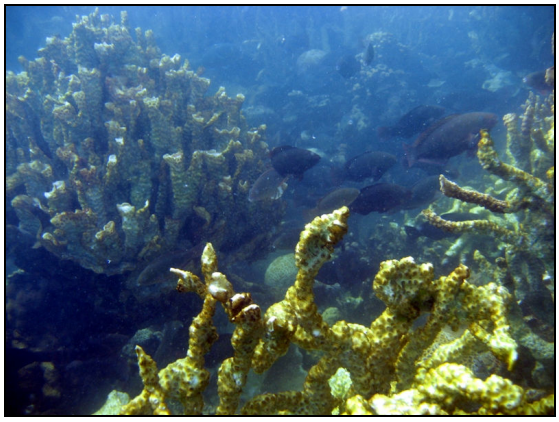
Site 5

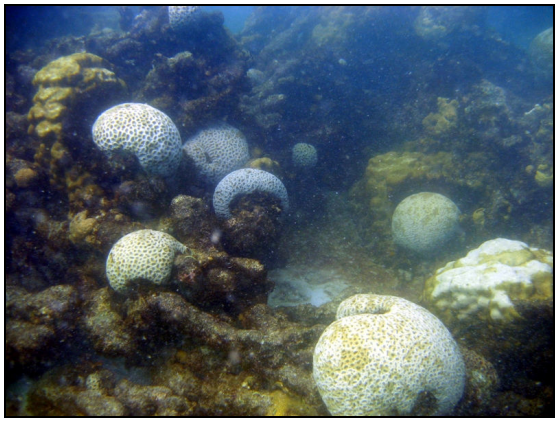
Corals at Site 5 were generally bleached. Coral cover was dominated by *Echinpora* sp. An estimated 40% of the existing live hard coral was bleached. Dead clams were observed at the site.

Site 9

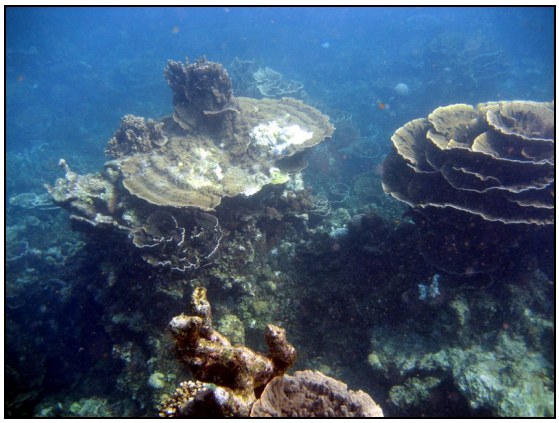
Corals at Site 9 were generally bleached. Coral cover was dominated by *Echinopora* and Faviid corals. All species of coral including Faviids and *Porites* appeared to be affected by bleaching however not all coral colonies were bleached. The impact observed at Site 9 was comparable to that at Site 5.

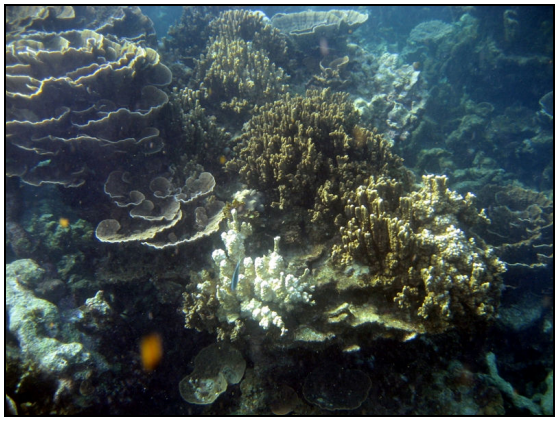





Site 10

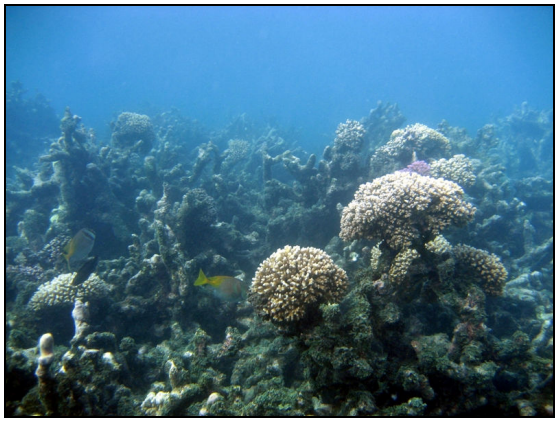
Minimal bleaching was observed at Site 10. Coral cover was dominated by *Monitpora* sp. Site 10 appeared to be near the borderline between where corals were generally bleached and where corals were generally unbleached. Bleaching starting approximately 30 m west of Site 10 and became progressively more severe in an eastward direction.

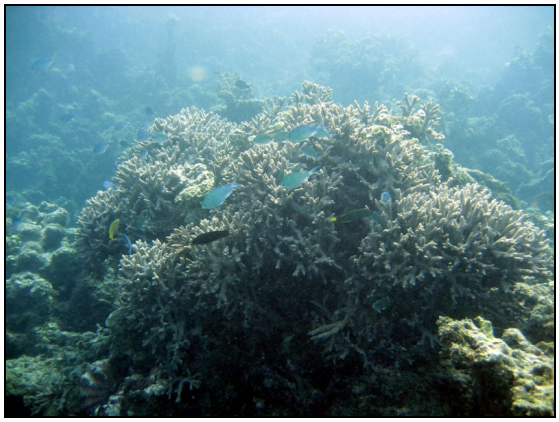


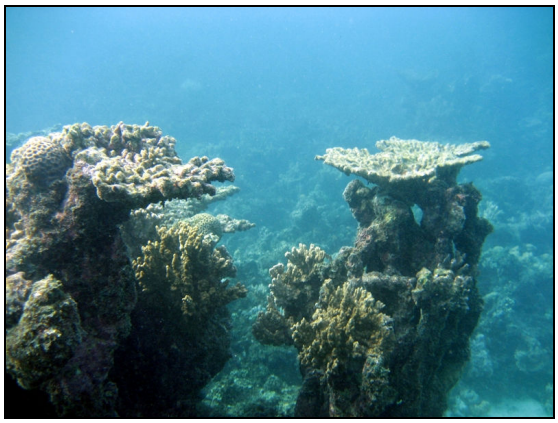


Site 11

No coral bleaching was observed at Site 11. Coral cover was dominated by *Pocillopora* and *Montipora* corals.

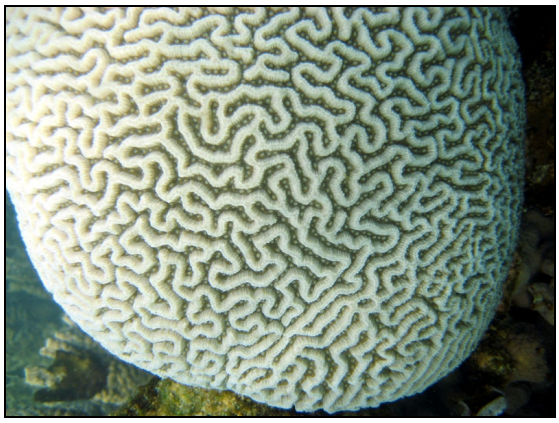


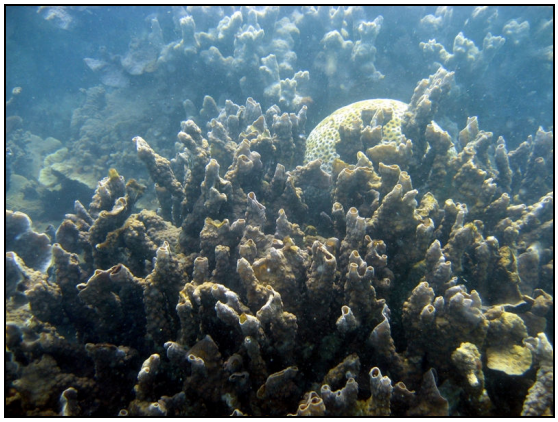


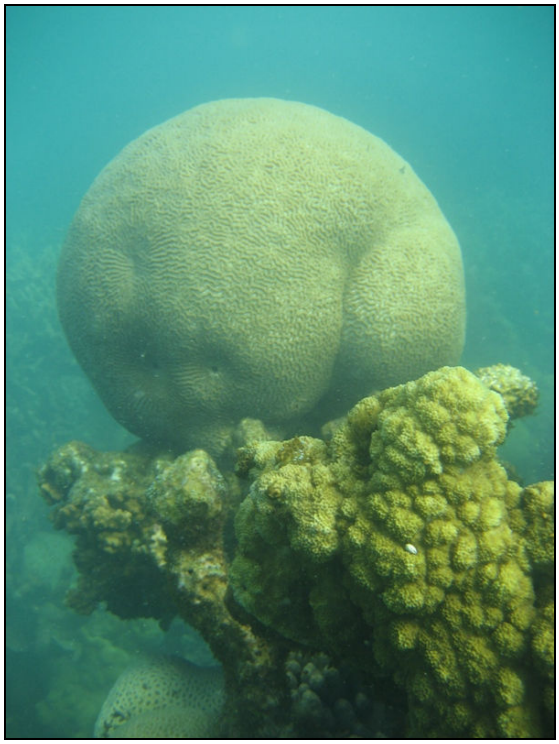


Site 13

Minimal to medium coral bleaching was observed at Site 13. Coral cover was dominated by *Echinopora* and Faviid corals. Some *Echinopora* corals were partially bleached but the majority remained unbleached. Some other Faviid corals were completely bleached, others partially bleached and others remained unbleached.

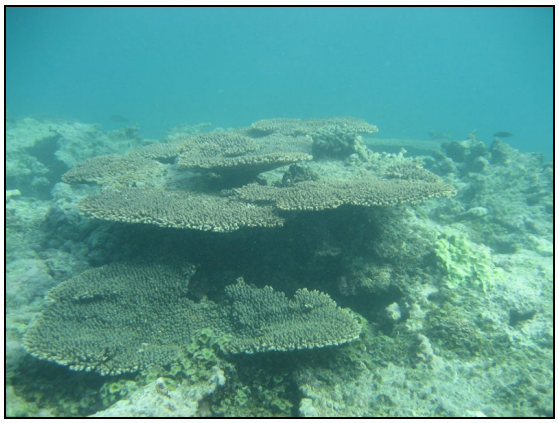


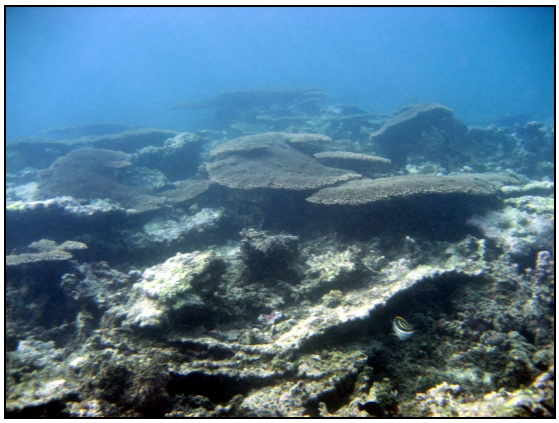


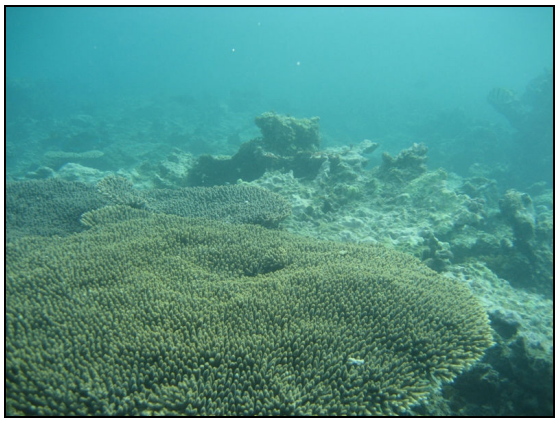


Site 14

No coral bleaching was observed at Site 14. Coral cover was dominated by plate *Acropora* sp.



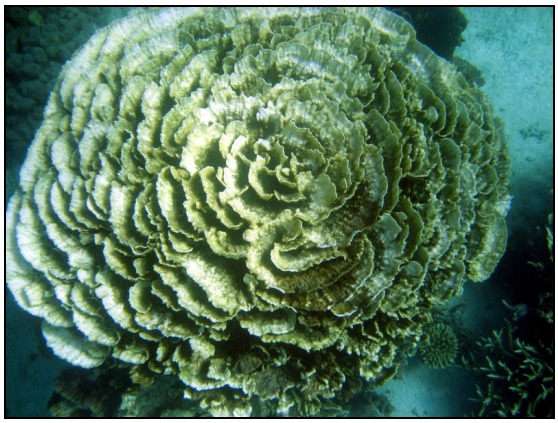




4.4.2 Additional information

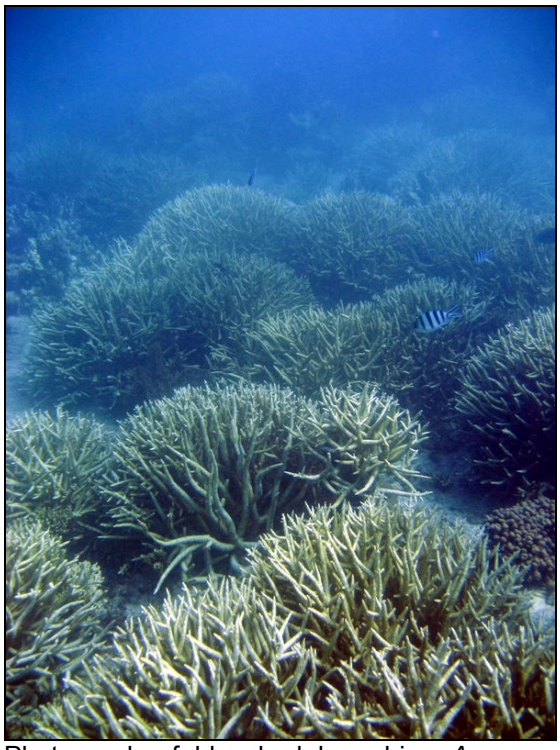
At Oyster Bridge, north of Point Maud, observations were made of bleached anemones (see images below). No other corals observed appeared to be bleached.

4.4.3 Additional photographs (taken in between sites)



Photograph of an almost completely bleached *Montipora* coral colony taken near Site 1.

Photograph showing bleached *Montipora* and branching *Acropora* corals taken opposite the main tourist beach at Coral Bay near Site 1.

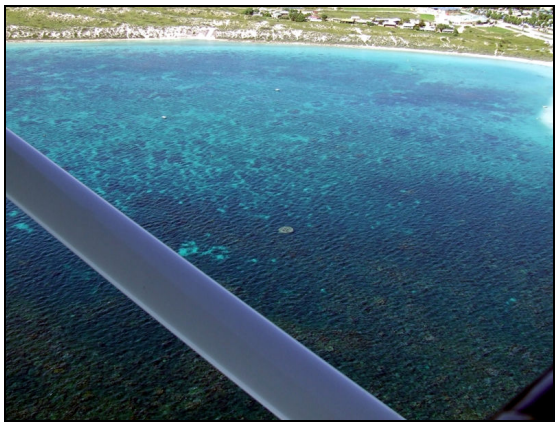


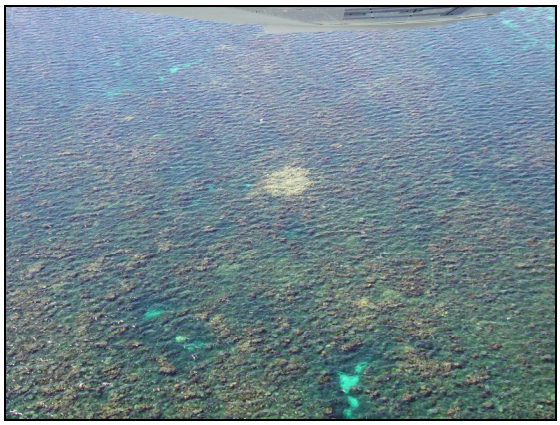
Photograph of bleached branching *Acropora* corals taken near Site 2.

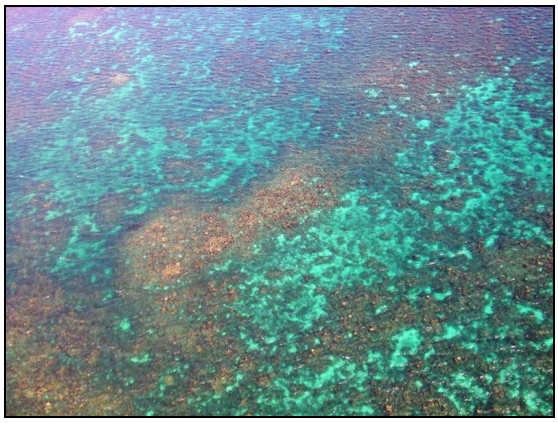
Photograph of bleached Faviid coral taken between Site 5 and Site 9.

4.4.4 Aerial photographs

The following photographs were taken during an aerial flight over Bill's Bay approximately 17 days after the commencement of coral spawning (15 April 2008). During the flight it was difficult to differentiate between bleached and unbleached areas of coral (Roger Syme, pers. comm.). It is likely that by this time the majority of bleached corals would have been covered in fine brown algae and from the air probably looked a similar colour to live coral.







5 RECOMMENDATIONS

- Develop a model to better understand lagoonal flushing times at Bill's Bay under varied climatic and oceanographic conditions.
  Note: Discussions are currently being made with Dr Ryan Lowe (UWA) in consultation with DEC's Marine Science Program to make this recommendation occur.

- An aerial flight needs to be undertaken as soon as possible after any future anoxic events to maximise the ability to distinguish between bleached and unbleached corals. An aerial flight could then provide more accurate information regarding the spatial extent of coral bleaching.

- Effort should be made to investigate potential ways of dispersing and circulating coral spawn within inner Bill's Bay to prevent anoxic conditions occurring in the future. The effect of such activities on other reef organisms, tourism activities, water quality etc would need to be thoroughly investigated.

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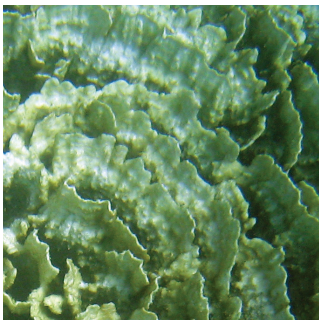

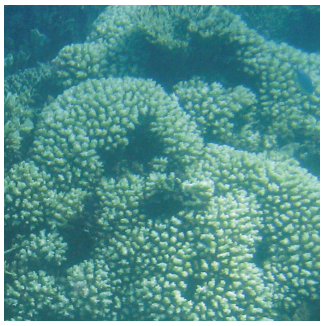

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