Patterns of mortality from natural and anthropogenic influences in Dampier corals: 2004 cyclone and dredging impacts.

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Abstract

Understanding patterns of coral mortality and recovery at Dampier is essential in assessing the potential impacts of industrial development on the coast and hinterland. Monitoring coral communities in the eastern Dampier Harbour over a period of 20 years has revealed a general pattern of constant or gradually increasing coral cover for several years, interrupted by occasional events that significantly reduce live coral cover.

Two significant mortality events were recorded by coral health monitoring conducted for dredging programs within the harbour in 2004. The first was a massive reduction in live coral cover in communities on the southern shore of West Lewis Island (up to 95% at site WLI2) attributed to cyclonic freshwater inundation. The second was an 80% reduction in live coral cover at one site (SUPB) on the western shore of the Burrup Peninsula attributed to dredge-generated sedimentation when dredging came within a few hundred metres of coral communities.

Sedimentation at SUPB impacted most species and most colonies. Acroporids and faviids were apparently most susceptible to sedimentation while species of *Turbinaria*, *Pavona decussata*, *Diploastrea heliopora* and *Porites solida* were most resilient. Freshwater stress at WLI2 caused total mortality of all corals shallower than approximately 3m below mean lower low water. Most other sessile invertebrates, including *Tridacna* clams, were also killed. The shallowest live corals recorded post-flooding were *Porites lutea* and *Pavona decussata*, possibly indicating their greater resilience to freshwater stress.

Both SUPB and WLI2 are likely to regain their coral cover over the following 10-20 years. The predominance of partial mortality over whole-colony mortality at SUPB should be advantageous to recovery, as the remnant colonies should persist and provide a focus for regrowth without the need for recruitment of new corals. However, residual fine sediment is likely to hinder successful recruitment for some time. The reef top at WLI2, in contrast, is now essentially a blank slate, which can only be colonised by recruitment. The dead coral skeletons are a good substrate for recruitment, however, and should be colonised relatively quickly if the supply of larval corals and other invertebrates is adequate and in the absence of further natural or anthropogenic disturbance.

Keywords: coral mortality, salinity, sedimentation, turbidity,

Introduction

Mortality in scleractinian corals

An unusual and important aspect of coral life history is that corals do not senesce and die of old age like most other organisms. Consequently there is no theoretical upper limit on coral lifespan. Despite this, dead coral colonies can be found on virtually all reefs, even those considered to be in pristine natural condition. Coral mortality results from a range of natural and anthropogenic causes including wave impact, sedimentation, thermal stress, salinity stress, desiccation, overexposure or underexposure to light, oxygen depletion, pollution, predation, competition, parasitism and disease. Several of these processes, particularly the biological ones, operate continuously on most reefs, resulting in a chronic background level of coral mortality. In undisturbed communities, this background loss of coral is usually more or less balanced by recruitment of new colonies and growth of existing colonies, such that the overall percentage of live coral cover on the reef (the value typically measured in field surveys) remains relatively constant (eg. Hughes and Jackson 1985).

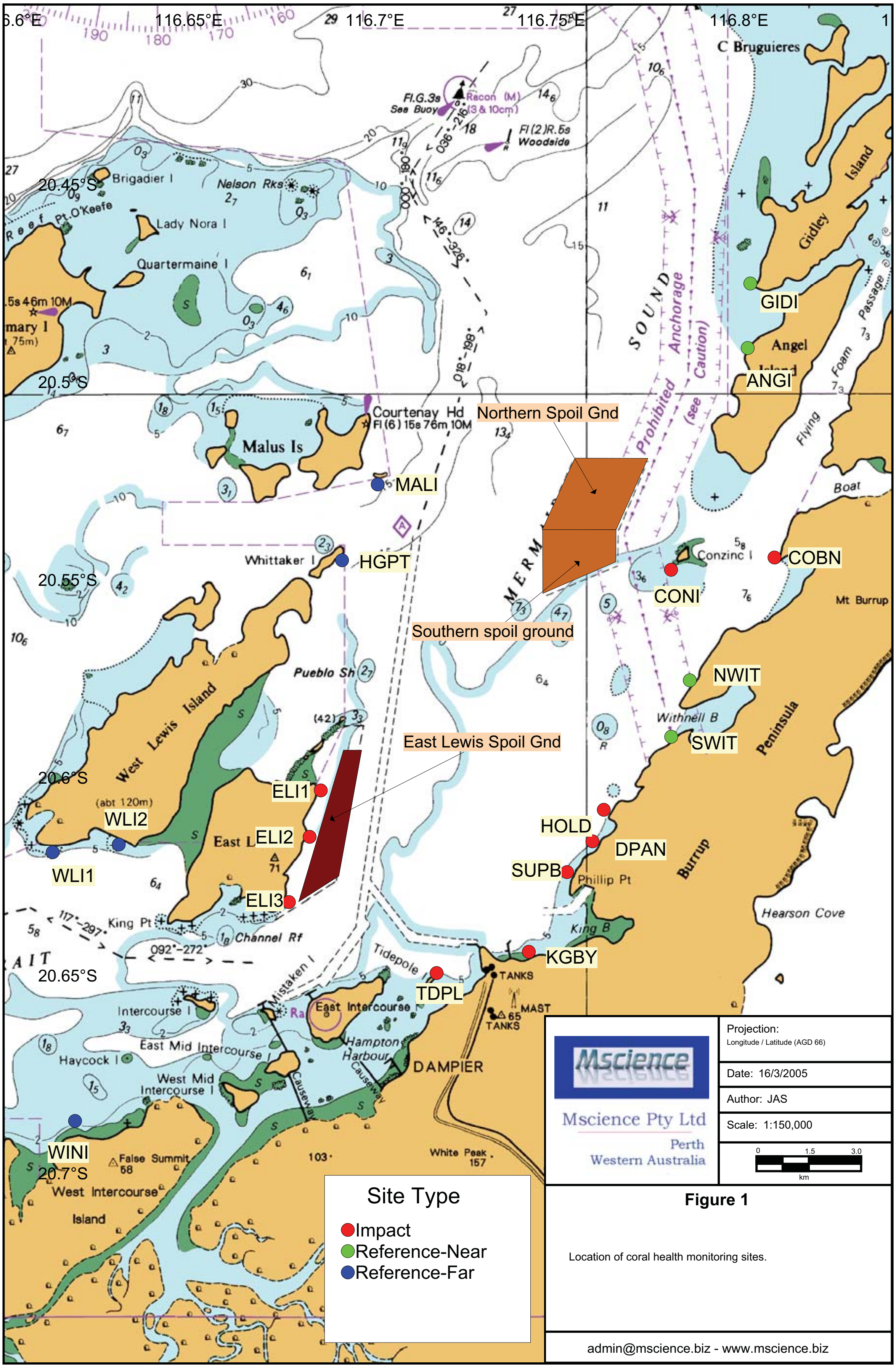
Several types of physical and biological events can result in rapid and extensive coral mortality, often well above background levels. These include cyclones, storms, floods, extreme high or low surface water temperatures, and outbreaks of predators, competitors, parasites or pathogens. Reef recovery following such events may take years to decades, or may be delayed indefinitely if the agent of mortality remains in place or if the community settles into an alternative stable state (eg. Knowlton 1992).

Coral mortality at Dampier

From a management perspective, understanding patterns in coral mortality and recovery at Dampier is essential in assessing the potential impacts of industrial development on the coast and hinterland. Maintenance of coral health and diversity is one of the fundamental requirements stipulated by the Western Australian Environmental Protection Authority (EPA) for proposed operations and developments in the marine environment. Proponents of development projects are required to monitor reef communities at regular intervals and take action to protect them if coral mortality exceeds a defined trigger value. Consequently, Dampier's reefs are probably amongst the most comprehensively-monitored in Western Australia, with records extending back 20 years in the case of Woodside Offshore Petroleum's monitoring program (LDM 1994b).

Within the coral communities of the Dampier Harbour, monitoring programs have captured the ongoing processes of natural background mortality, recruitment and growth, and have also documented instances of coral mortality following short-term natural and anthropogenic impacts including cyclones (LSC 1990), coral bleaching (LDM 1994a, b; 1999) and dredging (LSC 1988). The typical pattern

Figure 1. Location of sites in the 2003/4 coral health monitoring program.



revealed by monitoring is one of constant or gradually increasing coral cover for several years, interrupted by occasional events that significantly reduce live coral cover.

Of the events recorded as producing substantive mortality of Dampier Harbour corals, cyclones have had the most impact, with corals of the fast-growing and relatively fragile genus *Acropora* generally being the hardest hit (Marsh 1978; LSC 1990). Cyclones Ilona and Orson in particular (December 1988 and March 1989 respectively) caused major damage to reefs along the eastern shore of Mermaid Sound, breaking up and killing many coral colonies, and reducing live coral cover at most sites by 50% to 100% (LSC 1990).

Coral mortality attributed to bleaching (loss of symbiotic algae) has been relatively minor in comparison to cyclone impact. Widespread but sparse bleaching, affecting a range of genera but less than 1% of colonies, was reported throughout Mermaid Sound in March 1994 (LDM 1994a). Several recently-dead *Acropora* colonies, and bleached but live colonies of many other genera, were recorded at two eastern Mermaid Sound sites in May 1998 (LDM 2000). Most of the non-Acroporid colonies had recovered and regained colour before the next survey in May 1999 (LDM 2000). Both the 1994 and 1998 bleaching incidents were correlated with surface water temperatures above 30°C (LDM 1996b, 1999; ECS 1998).

Predation by the Crown-of-Thorns Starfish *Acanthaster planci* (Johnson & Stoddart 1988; Simpson & Grey 1989; LSC 1990) and the snail *Drupella cornus* (LDM 1996, 2000) has also been recorded as a source of mortality on offshore Dampier reefs. These corallivores do not appear to be abundant in the Archipelago however, and have never been recorded at densities comparable to the outbreaks of *A. planci* in the Great Barrier Reef (Johnson & Stoddart 1988; Benzie & Stoddart 1992) or *D. cornus* at Ningaloo (Turner 1994). It is not clear whether these species have the potential to attain outbreak-level populations in the Archipelago or Dampier Harbour. Either the structure of coral communities of the Harbour (Blakeway & Radford, this volume) may not be favourable to supporting dense aggregations of predators, or other environmental conditions promoting outbreaks have not been met.

Grazing of corals by fish is common within the Harbour. During the 12 months of coral monitoring associated with dredging (Stoddart et al., this volume) divers noted widespread occurrence of grazing scars on *Porites* and removal of branch tips of *Acropora* species. Mortality of whole colonies was not observed.

Relatively little is known about natural background coral mortality from competition, parasitism and disease in Dampier reefs. These are all potentially significant agents of mortality, and the lack of information about them represents a significant gap in our understanding of natural coral community dynamics in the region.

The most significant acute cause of coral mortality noted in past monitoring reports is dredging. Coral mortality resulting from dredge-generated sedimentation has generally been described as localised and relatively limited in these reports. Mortality attributed to dredging by Woodside Offshore Petroleum over the 1986/87 summer was confined to two sites within 1.3 km from the dredged channel, which lost less than 10% coral cover (LSC 1988). A follow-up maintenance dredging program in 1989 had no detectable effect on coral cover (LSC 1990), nor did another dredging program in the same area in 1994, although divers did note tissue mortality due to sediment accumulation on a few Porites, Lobophyllia and faviid colonies (LDM 1994a).

In some cases, the spoil disposal component of dredging programs has been closer to coral communities than the uplift of spoil. In 1998, a substantial spoil disposal program by Hamersley Iron Pty Limited was undertaken using the East Lewis spoil grounds, the western limits of which come within 250 m of rich coral communities off the eastern shore of East Lewis Island. Quantitative monitoring of coral transects at various depths before and after the disposal program failed to detect any decline in coral cover from what was a clear increase in turbidity and sedimentation (ECS 1998).

Figure 2. Abundance and diversity of corals at monitoring sites along the eastern shore of Mermaid Sound during the baseline survey.

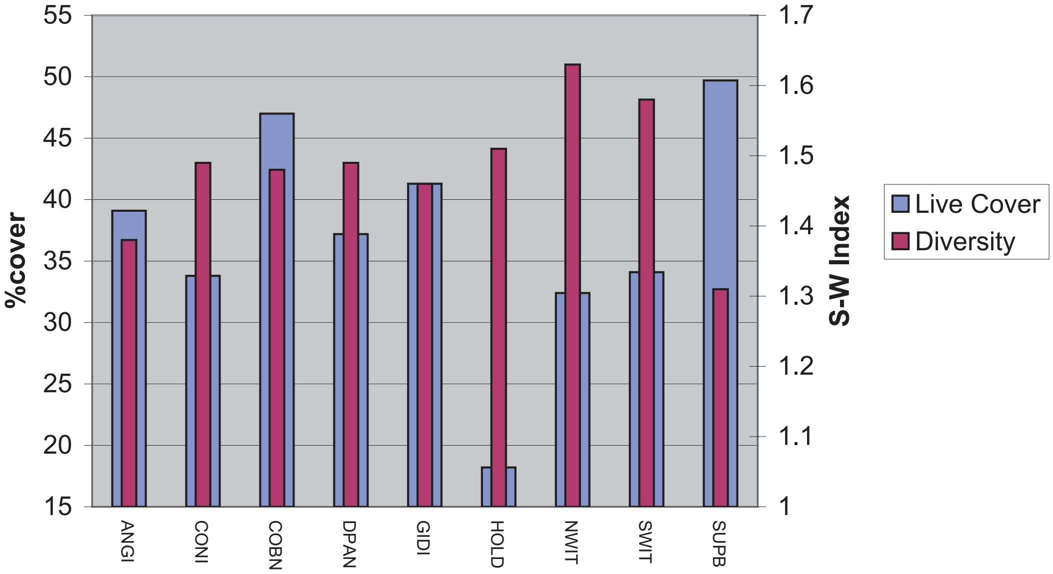
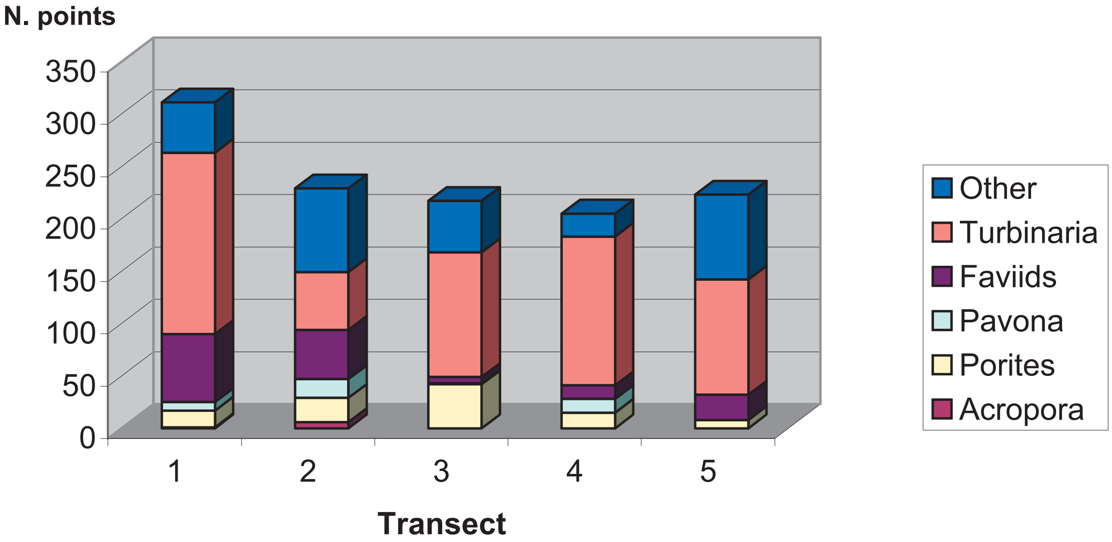


Figure 3. Distribution of major taxa groupings at SUPB during the baseline survey



A variety of additional anthropogenic sources of mortality—including anchor damage, fishing line damage, boat impacts and collection of aquarium coral—occur around various sites within the Dampier Harbour, but have never been specifically measured.

2004 mortality events

During January to October 2004, the Dampier Port Authority (DPA) and Hamersley Iron Pty Limited undertook sequential capital dredging programs within the south-east of Mermaid Sound in Dampier Harbour, involving the removal and disposal of over 6Mm^3 of spoil (Stoddart & Anstee, this volume). A fortnightly coral reef monitoring program was established at several sites around the dredging and disposal locations to allow rapid assessment of, and response to, any developing mortality (Stoddart et al, this volume). A number of reference sites were established outside the immediate area of dredging to provide a context of natural change in coral mortality. Due to concern that these reference sites could themselves become impacted by dredge-generated sediments, an additional set of Far Reference Sites were established several kilometres distant from the dredging and disposal locations.

Two significant mortality events were recorded during the 2004 monitoring program. The first was a dramatic reduction in live coral along the southern shore of West Lewis Island (Fig. 1) related to inundation by freshwater following heavy rain during Cyclone Monty in early March (Stoddart and Anstee, this volume; Stoddart et al, this volume). One of the Far Reference Sites, WLI2, lost around 95% of live coral cover, with another nearby site, WLI1, losing over 15%. WLI1 was impacted by the same freshwater event that reduced coral cover at WLI2 but was not affected as strongly, probably due to the greater depth at WLI1. Shallow coral communities around the shoreline of several other inshore islands of the Dampier Archipelago were also severely impacted, with coral mortality estimated visually at > 50% (unpublished data).

The second major mortality event recorded in the monitoring program was an 80% reduction of live coral cover at the Supply Base site (SUPB, 500m south of the principal dredge site, see Fig. 1), which was attributed to dredge-generated sedimentation (MScience 2004; Stoddart et al, this volume). While the actual onset of mortality was unable to be observed due to weather conditions of very high turbidity during dredging, the pattern of mortality and physical distribution of sediment were consistent with smothering as the primary cause of mortality.

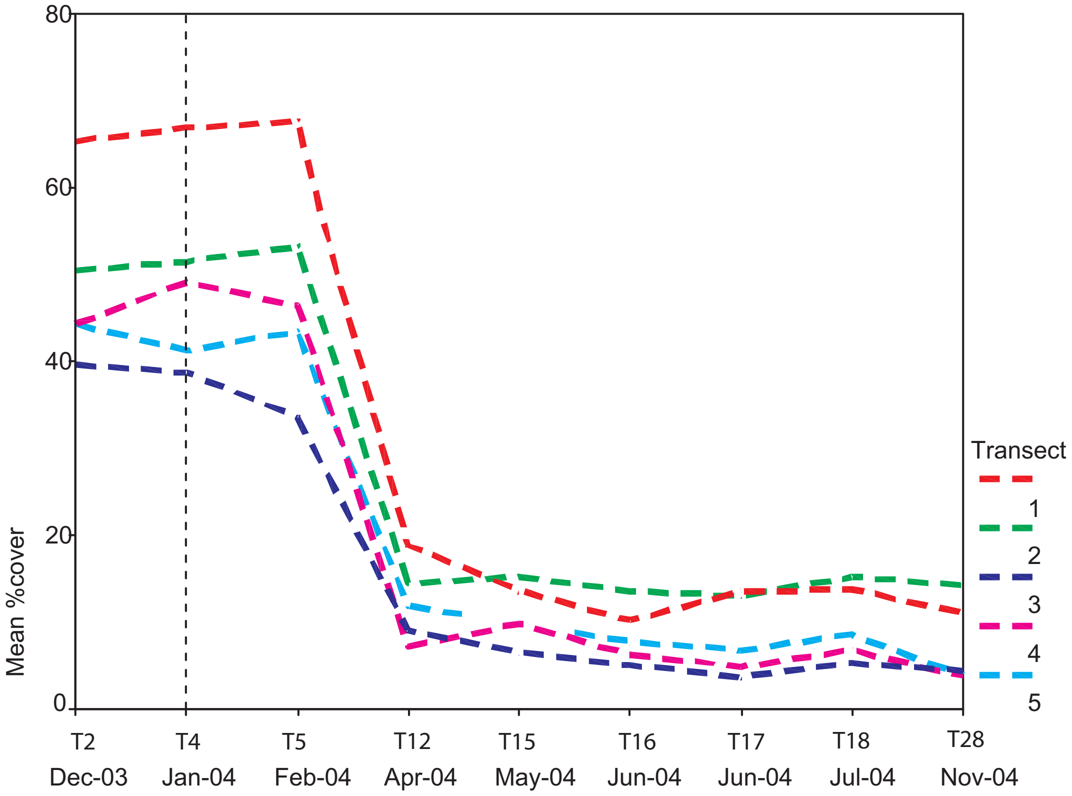
Smaller mortality events were detected at other sites such as GIDI, WINI and TDPL (Fig. 1) Mortality (of 10-20%) at GIDI was caused by coarse sediment and plant material deposited on tabulate *Acropora* colonies by strong swells prior to and during Cyclone Monty. At TDPL and WINI, monitoring recorded an apparent loss of >25% of live coral cover, but this was largely due to overgrowth by the macroalgae *Sargassum* during summer. When the *Sargassum* receded over winter, monitoring showed that actual mortality of corals had been less than 10% (Stoddart et al, this volume).

A detailed analysis of the patterns of mortality in the major events was conducted to assist in assessing what species or populations might be at risk from future challenges. At SUPB a comprehensive taxonomic and size frequency analysis of mortality was undertaken in response to a commitment in the DPA's Interim Environmental Management Plan for further research in the event of significant dredge-related mortality (URS 2004). That analysis (MScience 2004) is summarised below, followed by a summary of mortality at WLI2 and other sites.

Coral mortality at SUPB

Coral abundance (measured as % live cover) at SUPB during baseline surveys in late 2003 was the highest of any of the monitoring sites along the eastern edge of Mermaid Sound, averaging 49% over the five 10m transects surveyed (Fig. 2). Coral diversity (Shannon-Weiner index using the six coral classes identified) was the lowest however (Fig. 2),

Figure 4. Coral cover at SUPB from December 2003 to July 2004 – the vertical dotted line indicates the start of dredging. Points on the x axis are trips (T) and their relevant dates, when SUPB could be sampled.



due to the domination of live coral cover by species of *Turbinaria* (Fig. 3).

The chronology of coral decline at SUPB is difficult to assess, as between late January and mid April 2004 weather conditions or poor visibility precluded successful capture of video or still images for analysis. When dredging was suspended for 5 days in mid April, water quality improved sufficiently to allow a survey to proceed. Analysis of resultant images revealed a decline in coral cover from almost 50% in the pre-dredging period to around 10%. Since then, coral cover appears to have stabilised and is varying within limits of the method of measurement (Fig. 4).

Water quality monitoring (Stoddart & Anstee, this volume) and examination of corals at the SUPB site suggested physical covering of corals by sediment appeared to be the primary cause of mortality. Massive suspension of sediments by propeller wash during a few brief episodes when dredging was within 100-200 m of corals appeared to be the primary cause. Corals at nearby sites were subjected to effectively similar levels of light attenuation and turbidity, but showed no mortality (Stoddart et al., this volume).

Taxonomy of coral loss

There were no clear species-specific mortality effects at SUPB, with the majority of species present being affected to some degree. Statistical assessment of whether dredging-induced mortality affected some species more than others would have been of little use as most species identified from the transect records were represented by only 1-3 individuals. The pattern of coral loss is summarised in Table 1. Table 2 breaks down the loss into species within families, while Table 3 shows impacts on individual species.

Qualitatively, it appeared that the Acroporids and the faviids were the taxa impacted most heavily. Of the faviids, *Diploastrea heliopora* seemed most robust and all three recorded individuals survived without loss of tissue. Only one other species, the fungiid *Lithophyllon edwardsi*, survived without tissue loss, but as this species was represented by one individual only, the result may not be general.

Corals of the genus *Turbinaria* appeared reasonably resistant to sedimentation. Although colonies of all 7 *Turbinaria* species at SUPB suffered significant partial

Table 1. Changes in species abundance and cover over the DPA dredging period at SUPB.

	Base	June 04
Percent cover living coral	49%	9%
Number of colonies	168	95
Number of species	37	21
Diversity (S-W) – major groups	1.31	1.19
Diversity (S-W) - species	2.81	2.21
Species lost entirely	16	
Species losing over 75% of cover	11	
Species losing up to 70%	8	
Species unaffected	2	

Table 2. Mortality at SUPB recorded by family.

Family	N. of Species (Base)	N. of Colonies (Base)	N. of Species by average loss per colony			
			100%	70-100%	10-70%	0-10%
Acroporidae	3	4	3			
Agariciidae	2	7		1	1	
Dendrophylliidae	7	87		3	4	
Faviidae	13	30	8	2	2	1
Fungiidae	3	6	1		1	1
Merulinidae	1	1	1			
Mussidae	1	2	1			
Oculinidae	1	2		1		
Pectiniidae	3	11	1	2		
Pocilloporidae	1	1		1		
Poritidae	1	16		1		
Trachyphylliidae	1	1	1			
TOTALS	**37**	**168**	**16**	**11**	**8**	**2**

mortality, most of the individual colonies survived and none of the 7 species were lost from the site. *Turbinaria mesenterina*, the most abundant coral at SUPB, typified this response. A total of 47 *T. mesenterina* colonies were recorded in the baseline survey. Although these colonies suffered an average 57% tissue loss during dredging, the majority of them (39) were still alive in the June survey. The Agariciid coral *Pavona decussata* showed a similar pattern; despite sustaining an average 55% partial mortality, each of the original 6 colonies survived.

Photographs taken in December 2004 indicate that most colonies remained in the same state as the July survey. There appears to have been a minor loss of faviids and a minor gain of *Porites* in the intervening months, but neither was sufficient to register in the analyses.

Based on observations by divers when recording transects at SUPB, colony morphology has a strong influence on susceptibility to sedimentation effects at moderate levels of sedimentation. Colonies with flattened upper surfaces (encrusting corals and plate corals) or branching corals, where branches were sufficiently dense to hold a raft of sediment, were particularly prone to mortality. Colonies with vertical faces (such as *Pavona decussata* and many *Turbinaria* species) shed sediment easily and were resistant

Figure 5. Vase-shaped Turbinaria colony at SUPB infilled with burrowed fine sediment, April 2004.

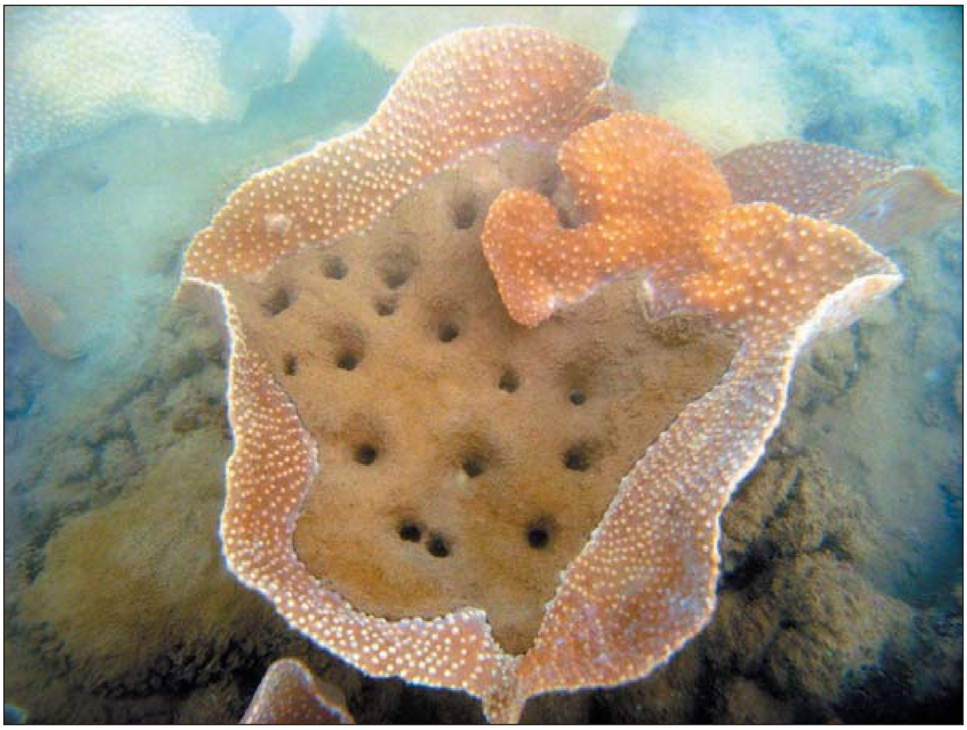


Table 3. Estimates of partial mortality and loss of entire colonies by species at SUPB.

Family	Genus	Species	N	avg. % loss per colony	% colonies lost
Species losing all tissue					
Acroporidae	*Acropora*	*verweyi*	1	100	100%
Acroporidae	*Acropora*	*?latistella*	2	100	100%
Acroporidae	*Montipora*	*?turtlensis*	1	100	100%
Faviidae	*Montastrea*	*?curta*	2	100	100%
Faviidae	*Favia*	*pallida*	1	100	100%
Faviidae	*Favites*	*flexuosa*	1	100	100%
Faviidae	*Favites*	*abdita*	3	100	100%
Faviidae	*Favites*	*complanata*	2	100	100%
Faviidae	*Goniastrea*	*indet*	1	100	100%
Faviidae	*Platygyra*	*sinensis*	1	100	100%
Faviidae	*Platygyra*	*pini*	3	100	100%
Merulinidae	*Hydnophora*	*exesa*	1	100	100%
Trachyphyllidae	*Trachyphyllia*	*geoffroyi*	1	100	100%
Fungiidae	*Herpolitha*	*limax*	3	100	100%
Mussidae	*Lobophyllia*	*hemprichi*	2	100	100%
Pectiniidae	*Echinophyllia*	*aspera*	6	100	100%
Species losing most of their tissue					
Dendrophylliidae	*Turbinaria*	*bifrons*	3	98	67%
Pectiniidae	*Mycedium*	*elephantotus*	3	95	67%
Agariciidae	*Pachyseris*	*rugosa*	1	95	0%
Pocilloporidae	*Pocillopora*	*damicornis*	1	95	0%
Pectiniidae	*Pectinia*	*paeonia*	2	92	50%
Dendrophylliidae	*Turbinaria*	*reniformis*	19	88	53%
Faviidae	*Goniastrea*	*australensis*	1	82	0%
Poritidae	*Porites*	*?solida*	16	79	38%
Faviidae	*Caulastrea*	*tumida*	4	75	75%
Oculinidae	*Galaxea*	*fascicularis*	2	75	50%
Dendrophylliidae	*Turbinaria*	*frondens*	12	75	33%
Species losing some tissue					
Faviidae	*Favites*	*indet*	1	70	0%
Faviidae	*Goniastrea*	*pectinata*	7	60	43%
Dendrophylliidae	*Turbinaria*	*mesenterina*	47	57	17%
Agariciidae	*Pavona*	*decussata*	6	55	0%
Fungiidae	*indet*	*indet*	2	50	50%
Dendrophylliidae	*Turbinaria*	*indet*	3	43	33%
Dendrophylliidae	*Turbinaria*	*conspicua*	2	28	0%
Dendrophylliidae	*Turbinaria*	*peltata*	1	20	0%
Unaffected species					
Faviidae	*Diploastrea*	*heliopora*	3	2	0%
Fungiidae	*Lithophyllon*	*edwardsi*	1	0	0%
TOTAL			**168**	**80**	**60%**

N=number of colonies at baseline monitoring

Figure 6. Live colonies of Pavona (top), Porites lutea (middle) and P. australiensis (lower right) at -3 m depth WLI2 post-Cyclone Monty (photo December 2004).

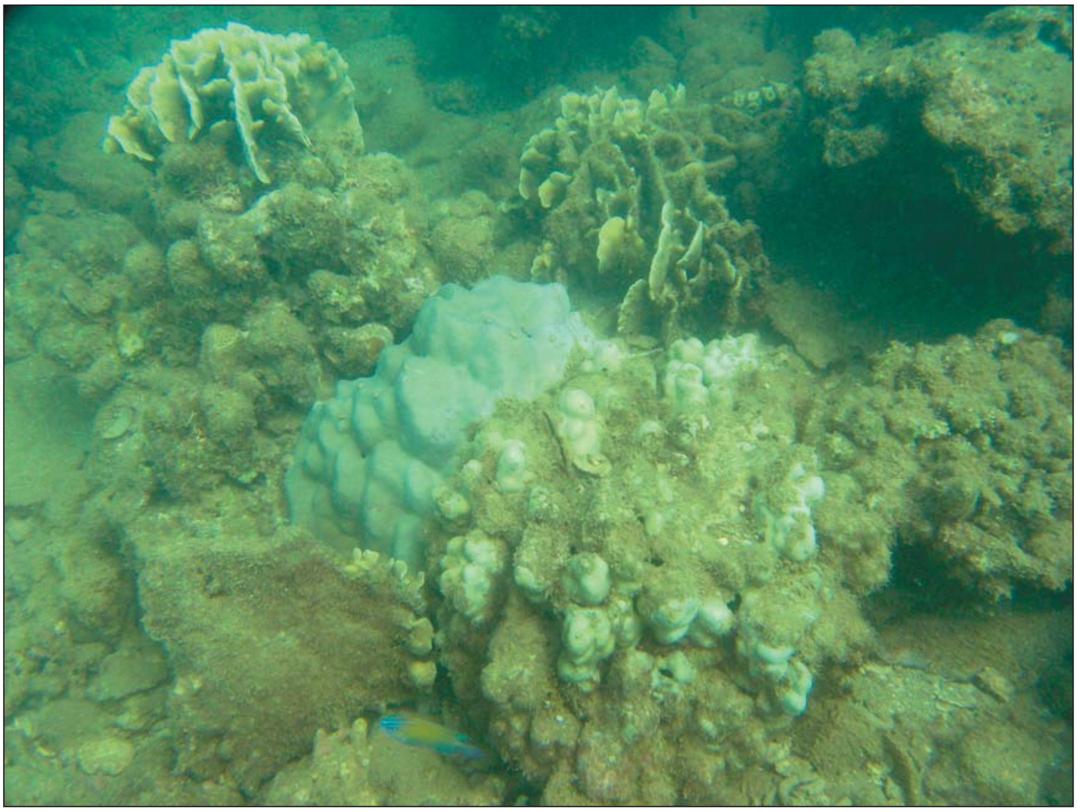
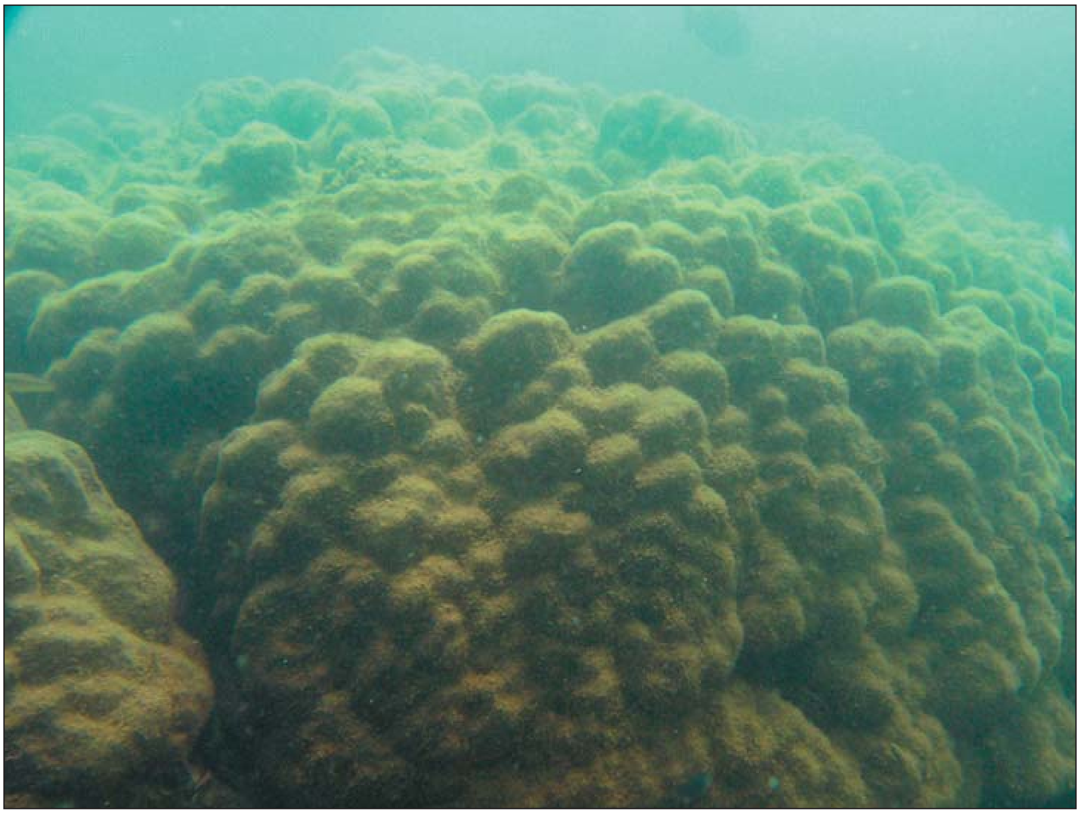


Figure 7. Dead 1.5m diameter Porites colony at WLI2 post-Cyclone Monty (photo March 2004).



to moderate sedimentation. As sedimentation increased to very high levels, even the resistant species were impacted— either by direct burial as sediment rises, or by infilling of structures like the vase-shaped interiors of *Turbinaria* (Fig. 5) or the spaces between the *P. decussata* blades.

Like most of the shallow nearshore reefs of Mermaid Sound, SUPB was dominated by small coral colonies, with over 50% of colonies having a surface area less than 400 cm2 (eg a 20 x 20 cm coral). Estimates of the initial area and final area of coral colonies did not provide any clear patterns. As would be expected, the average size of colonies decreased due to shrinkage of most corals from partial mortality (Fig. 6), but there was no clear association between colony size and survival.

Coral mortality at WLI2

When first surveyed in late 2003, WLI2 had 47% live coral cover, composed predominantly of Porites lutea and P. australiensis, with significant proportions of Pavona decussata, faviids, and several corymbose Acropora colonies. During the passage of Cyclone Monty on the 1st – 3rd of March 2004, Dampier and the hinterland experienced very heavy rainfall and runoff (over 300mm in 24 hrs), much of which was delivered to the coast via the Maitland River, approximately 20 km southwest of West Lewis Island. Surface water salinity in Mermaid Sound dived sharply to approximately 20 mg/L and remained low for several days (Stoddart & Anstee, this volume).

Surveys immediately after the cyclone recorded the total mortality of all corals at WLI2 down to a depth of approximately 3 m below mean lower low water (MLLW). Most of the dead corals and many of the deeper live corals were bleached and several corals were covered in a thin layer of fine terrigenous sediment. Shallow corals at WLI1 were also affected and spot surveys on the southwestern shore of East Lewis Island and the southern shore of Enderby Island showed a similar near-complete mortality of shallow coral communities. In all, it is likely that several hundred hectares of shallow reef were impacted.

Monitoring over the following months showed that many of the bleached corals at WLI1 regained their zooxanthellae. This was seen predominantly in corals in the depth zone between shallow permanently impacted areas and deeper unaffected areas.

Impacts on other sessile fauna were equally severe. Oysters were the only benthic invertebrates observed to survive in the reef shallows, presumably being able to avoid the freshwater impact by closing tightly for several days. Tridacna clams, in contrast, were unable to survive and many small dead individuals were noted.

Small reef fishes including Pomacentrids, Acanthurids and Labrids remained relatively abundant after the flood. Presumably they had migrated to the deeper reef during the flood and returned to the shallow habitat when water quality returned to normal.

Taxonomy of coral loss

No coral species were able to survive on the shallow reefs impacted by the freshwater inundation. The shallowest living coral colonies, at approximately 3 m below MLLW, were Pavona decussata and Porites lutea, most of which suffered significant partial mortality (Fig. 6). All the Acropora, Lobophyllia and faviid colonies observed at this depth were dead, suggesting that these taxa may be more susceptible to freshwater stress than P. decussata and Porites. The number and diversity of live corals increased significantly below 3m, and corals deeper than approximately 5m below MLLW appeared unaffected.

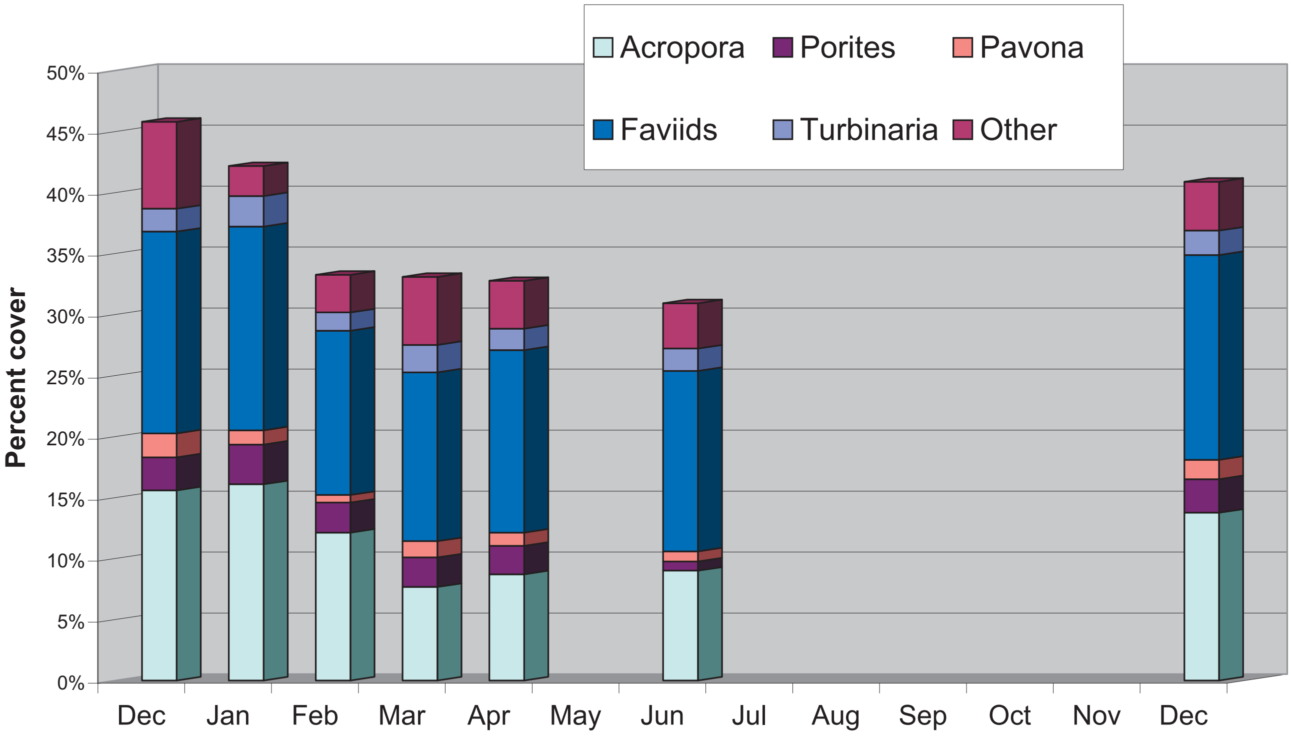
Several of the shallow coral colonies that died were relatively large, including numerous Porites lutea colonies from 1 to 2.5m in diameter (Fig. 7). Based on the average extension rate of Porites measured on the Great Barrier Reef of approximately 13mm per year (Lough and Barnes 2000), the larger colonies were probably around one hundred years old. Thus the flood conditions that killed them can be considered approximately a once-in-one-hundred year event.

Coral mortality at other sites

GIDI – The coral community at the GIDI site occurs on a shelf and drop-off facing west-northwest off Gidley Island. Being towards the outer part of Mermaid Sound, it is exposed to the predominant summer westerly swells (Pearce et al. 2003). During late Summer 2003-4, divers visiting the site noted that many corals, in particular tabulate *Acropora* species, were partially covered with small amounts of coarse sediment and macroalgal drift material. Subsequent quantitative assessment of change in cover saw a drop of almost 20% by April with a subsequent rise for the latter part of the year (Stoddart et al., this volume). When the contribution of the various coral taxa to live cover is examined, it is clear that this drop was principally due to the susceptibility of *Acropora* species to physical damage (Fig. 8), and subsequent recovery, presumably through growth of existing colonies.

TDPL and WINI – Both sites are located towards the southern margins of Mermaid Sound, but are quite different in aspect and coral community composition (Blakeway & Radford, this volume). During the fortnightly coral health monitoring, both showed a strong decline in living coral cover (WINI >50% and TDPL around 20%) between December 2003 and April 2004. Over the summer period, strong growth of *Sargassum* (probably at least 2 species Huisman & Borowitzka 2003) overtopped much of the lower coral colonies. Following almost total loss of the *Sargassum* cover over the winter period (May – July), coral cover at TDPL recovered to around the December 2003 level, but a residual mortality of close to 10% was evident at WINI. It is not certain that this mortality related to the *Sargassum* effect, as freshwater inundation and micro-algal blooms also occurred at that site in the period.

Figure 8. Composition of GIDI corals by taxon during the year.



Discussion

Cyclone mortality

In terms of extent and severity of impact, cyclones appear to be the major source of coral mortality at Dampier over the timescales covered by this and previous monitoring programs. Cyclone-related coral mortality occurs by several mechanisms, including mechanical damage by wave impact, smothering by sediment deposition and osmotic stress caused by freshwater influx. Coral taxa vary significantly in their susceptibility to cyclone impacts. *Acropora* species appear highly susceptible to all three mechanisms described above, and are usually the first to succumb to cyclones. However, *Acropora* can also recruit and grow rapidly allowing populations to recover relatively quickly between cyclones. For example, tabulate *Acropora* are now abundant at Angel and Gidley Islands, despite being heavily damaged by Cyclone Ilona in December 1988 (LSC 1990).

The genera *Porites* and *Pavona* appear more resistant to cyclones and are more likely to survive them, albeit with significant partial mortality. The fact that *Porites* and *Pavona* were the most abundant corals at WLI2 even before Cyclone Monty may indicate that the community at that site has been shaped to some extent by similar cyclonic floods in the past. Further analysis would be required to evaluate this possibility. What does seem clear is that both *Porites* and *Pavona* are robust genera, able to cope with all but the most severe natural environmental stresses that occur in Dampier's marine environment.

Sedimentation mortality

Sedimentation at SUPB during the DPA dredging program was both heavier and more protracted than any natural event to which these coral communities would be routinely exposed. As at WLI2, *Pavona* and *Porites* withstood this extreme stress better than many other coral genera. Overall however, *Turbinaria* stood out as the best survivor to sedimentation. Again *Turbinaria* was the most abundant genus at this site before the mortality event. Indeed *Turbinaria* were far more abundant at this site than at any other surveyed site (Blakeway and Radford, this volume) suggesting that the coral community structure there may have been modified by a high frequency of natural sedimentation events.

The pattern of mortality at SUPB gives some indication of which coral species may be most at risk from dredge-generated sedimentation. However, because this site has been subject to high natural turbidity, even the pre-dredging species list represents a reasonably sediment-tolerant community that would not contain highly sediment-sensitive species. Extrapolation of these results to other sites would need careful consideration of the past environmental history of corals at each site.

The three small *Acropora* colonies recorded in the baseline survey at SUPB were among the first corals to die. However, Dampier's inshore habitat appears to be marginal for *Acropora*, judging by the low numbers and small size of inshore *Acropora* colonies. Even in the absence of anthropogenic impacts, they are likely to be ephemeral in this habitat and unlikely to persist for many years.

The heavy loss of faviid species is more concerning. Several reasonably large (~1000cm2) *Favites* and *Favia* colonies suffered complete mortality shortly after the commencement of dredging. These species are widespread and abundant in Dampier's inshore habitat, implying a tolerance to sedimentation. It is likely that mortality resulted when the extremely high sediment load from dredge propeller wash exceeded a threshold of sedimentation tolerance, resulting in complete mortality rather than the gradual partial mortality exhibited by many other genera.

The preceding assessment of dredging-related mortality must be qualified with the outcomes of water quality monitoring which showed that the sedimentation event most likely to cause mortality was probably one or two periods of massive sedimentation caused by propeller wash from a large dredge working within a few hundred metres of corals in calm conditions (Stoddart & Anstee, this volume). Outside of a radius of 1 km, mortality was no different to that of sites in the Reference or Far Reference categories. The actual distance over which sedimentation caused adverse effects on corals may have been less, as there were no monitoring sites in the band 500m - 1km distant from dredging.

Recovery

Both SUPB and WLI2 are likely to gradually regain their coral cover. Partial mortality was far more common than loss of the whole colony at SUPB which should be advantageous to the recovery of this site. As judged by the stability of the 9% cover since May 2004, the remnant colonies should persist and provide a focus for regrowth without the need for recruitment of new corals. Recovery is therefore likely to produce an even greater predominance of *Turbinaria* than that recorded in the baseline survey. With the sea floor in this area now dominated by soft sediments, recruitment of larval corals could be depressed for several years, which could impede the return of species that were lost from the site. Next summer's cyclones could enhance recovery in this respect, as they may sweep fine sediment from the coral skeletons to provide more recruitment space.

The reef top at WLI2 is now essentially a blank slate, which can only be colonised by recruitment. The dead coral skeletons are a good substrate for recruitment and should be colonised relatively quickly if the supply of larval corals and other invertebrates is adequate. How the community will subsequently develop is an open question. Future surveys of the WLI2 transects should provide a good picture of the process.

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