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Biological monitoring of coral communities in Tung Ping Chau Marine Park, Hong Kong SAR, China: changes before and after marine park designation

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Abstract A biological monitoring program was carried out in Tung Ping Chau Marine Park (TPCMP) from September 2002 to October 2003 and data collected were compared with historical data obtained in 1999 to evaluate any changes in coral cover and species diversity since the designation of Tung Ping Chau as a marine park in November 2001. Permanent transects and quadrats were set up within the core areas in AMW and AYW since 1996. These transects and quadrats were resurveyed in this present study. Generally, there was no significant change in the coral community structure in A Ye Wan (AYW) and A Ma Wan (AMW) during the last four years from 1999 to 2003. However, percentage cover of corals appears to be increasing faster, at 9% in AMW from 37.5% in 1999 to 46.15% in 2003 than in AYW (at 2%) from 15.5 % in 1999 to 17.14% in 2003. There were changes in the ranking in dominance of some coral species from 1999 to 2003 but the most dominant species remained the same. These are *Platygyra acuta*, *Pavona decussata*, *Porites lutea*, *Leptastrea purpurea* and *Goniopora lobata* in AMW and *Platygyra acuta*, *Platygyra carnosus*, *Leptastrea purpurea* and *Favites flexuosa* in AYW. A total of 61 coral species have been reported from TPCMP and 44 of these are located within the permanent transects. No major environmental disturbances (e.g. typhoon, high water temperature) appear to have seriously affected the overall coral community structure in Tung Ping Chau in the last four years so the coral communities were stable and healthy. However, recent increase in the number of visitors, especially skin and SCUBA divers, to the marine park could impose some pressure on these coral communities so monitoring for changes in coral abundance and diversity must continue to be carried out in the future.

Keywords corals, Tung Ping Chau Marine Park, Hong Kong, marine protected areas monitoring

Introduction

Tung Ping Chau Marine Park (TPCMP) is located in the northeastern corner of Hong Kong SAR, China (Fig. 1). Because of the presence of large coral communities and extensive algal bed around the island, it has recently (November, 2001) been declared as the 4th Hong Kong marine park (Ang et al. 2000). This new marine park has two management features which are not found in the other three existing marine parks. These include the designation of two core areas and two recreational fishing areas within the boundary of the marine park. The two core areas represent the areas with highest conservation value, i.e., the highest live cover of hard corals. These areas, one in A Ma Wan (AMW) and one in A Ye Wan (AYW) (Fig. 1), enjoy a higher degree of protection than the rest of the marine park and only limited human activities are allowed within the core areas. The two recreational fishing areas are located at the two ends of the island (Fig. 1) and are areas with low coral cover. Hook and line recreational fishing is allowed in these designated areas and it is deemed that fishing within these areas will not cause undue damage to the overall marine flora and fauna of the marine park.

The designation of the core areas within the marine park is welcomed by different sectors of the public. With much publicity about the beauty of TPCMP both by the government department and by the public media, however, the number of visitors to TPCMP has sky rocketed. It is therefore of importance to monitor the conditions of the marine park after its designation to find out the potential impact of the influx of visitors as well as whether there is any change in the coral communities within the core areas after being accorded greater protection.

Tung Ping Chau has been the research base of this study team even before its designation as a marine park. Pre-designation data on its coral diversity and distribution are therefore available. This allows a comparison to be made to assess coral distribution, coverage, composition and species richness within TPCMP before and after its designation as a marine park.

Materials and Methods

Field Monitoring and Image Analysis of Photoquadrat Data

Permanent transect lines in the core areas have already been set up by this research team way back in 1996–97 (Tam 1998). Yearly monitoring of these transects has since been carried out. These permanent transect lines (nine in AMW and five in AYW) (Fig. 1) are laid perpendicular to the shore for a length of 40 m. A quadrat of 0.25 sq. m is laid at each 5 m interval and all the coral species within the quadrat are video taped using an underwater camera. There is no significant difference in the information obtained whether a transect intercept method (Loya 1978) is used or the quadrat method is used (Tam 1998).

To continue to monitor the coral cover and diversity in the core areas, the same transect lines and quadrat transect method were employed to enable a better comparison between the survey data and the historical data. Underwater survey was conducted in winter (dry season, December 2002 to February 2003) and spring (wet seasons, March to April 2003). All video images were captured in a computer and analyzed using an image

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analyzer. (Image Pro Plus version 5). Species diversity and coral cover were then calculated.

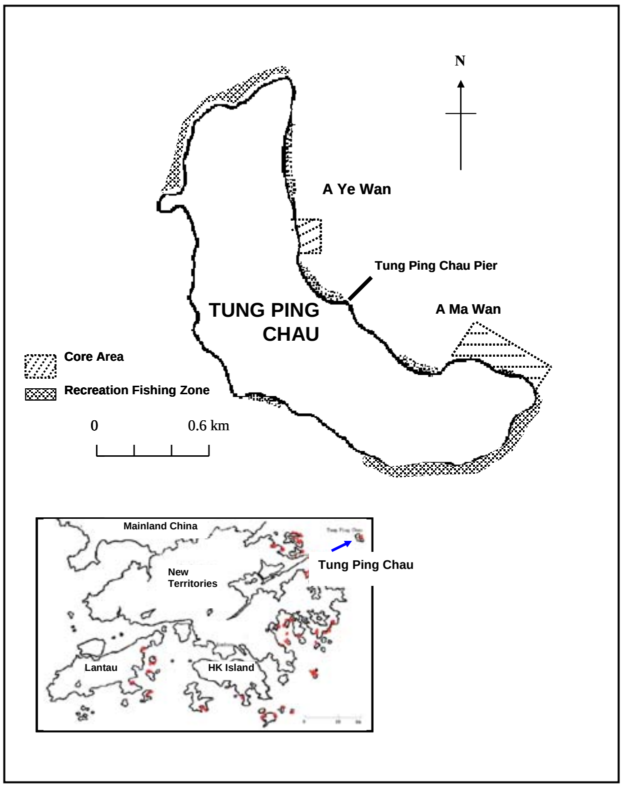

Fig. 1. Map of Tung Ping Chau Marine Park showing the two coral monitoring sites A Ye Wan and A Ma Wan (Core Areas). Insert is the map of Hong Kong showing the location of the marine park.

All the results found in recent surveys were compared with the historical data obtained in September – October 1999 (before marine park establishment) by our research team. Coral coverage and diversity were calculated only from the permanent quadrat data obtained in all three surveys. In some instances when a quadrat could not be relocated hence was missing in any one of these surveys, it would then be omitted from the calculation.

Statistical Analysis

Data on coral community structure in AYW and AMW obtained among seasons were examined. The data were first tested to satisfy the assumptions of the parametric statistics. Non-parametric statistics were used after several attempts at data transformation failed to satisfy the parametric assumptions. Changes in percentage coral cover among different seasons in AYW and AMW were analyzed by Wilcoxon Signed Rank Test. Brillouin's index of diversity was used to measure coral diversity (Brillouin 1956). Brillouin's index *H* was calculated based on the following equation:

$$H = (\log N! - \sum \log n_i!) / N$$

Where N is the total number of species
n_i is the number of individuals in species *i*, which in this case, will be the total area of coral species *i* in the quadrat.

Brilloiun's index is more appropriate for non-random data, such as those collected in the present studies using permanent transects and quadrats (Blower et al., 1990). Two types of Brilloiun's index were calculated: the total Brilloiun's index that considered all the species found in all the quadrats together and the mean Brilloiun's index, which is the average of Brilloiun's indices calculated for each quadrat.

Multidimensional Scaling (MDS) analysis of Bray-Curtis similarity matrices was also used as a multivariate method to analyze the coral community structure. PRIMER 5 was employed for this type of analysis (Clarke and Warwick 2001). The data were plotted in MDS ordinations that were repeated ten times to increase the likelihood of minimizing the stress in a two-dimensional representation. Species cover data for the quantitatively surveyed sites were double square root transformed. Clustering of the transformed data sets was carried out using the dissimilarity coefficient with Euclidean distance and complete linkage to generate site and time groups of similar species composition and community type. SIMPER (SIMilarity PERcentage) analysis was performed to identify species that contributed most to the similarities within groupings and the differences among groupings. Moreover, coral communities were classified into three water depth zones: shallow (< -1m Chart Datum), middle (-1 to -2m CD) and deep zone (>-2m CD) to further investigate if any depth specific changes had occurred over time.

Results

Surveys in 2002-2003

In these surveys, 39 species belonging to 17 genera and 26 species belonging to 11 genera of corals were recorded within the transect quadrats in AMW and AYW respectively (Table 1). Of a total of 61 species of corals identified in TPCMP, 44 species were recorded within the 14 permanent transects in these surveys.

For the live coral coverage, no significant difference (Wilcoxon Signed Ranks Test, $p>0.05$) was found between winter 02 and spring 03 (Fig. 2) in both AYW and AMW. In the final survey, 46.15% (± 9.58 %) of live coral cover was found in AMW and 17.14 % (± 9.81 %) in AYW. No change of live coral coverage was expected as no mass mortality of corals was observed during the study period nor was there any occurrence of significant disturbance like storm during this period (AFCD 2004). Moreover, it is unlikely to observe any increase in coral cover within a few months period because of the slow grow rate of corals in Hong Kong. AMW showed a higher mean coral diversity than in AYW in both seasons although the difference was not statistically significant (Wilcoxon Signed Ranks Test, $p>0.05$). The total and mean Brillouin's diversity indices are 1.09 and 0.84 (± 0.10) for AMW and 1.05 and 0.78 (± 0.11) for AYW in spring 03.

Platygyra acuta was the most dominant coral species in both AYW and AMW with cover of 6.6% and 10.0% respectively (Table 2). *Pavona decussata* was the second most dominant coral in AMW with a cover of 9.2%. This was mainly due to the presence of a large patch of this species intercepted by one of the transects. Other than these two species, *Cyphastrea japonica*, *Cyphastrea serailia*, *Favites abdita*, *Favites pentagona*, *Goniopora lobata*, *Hydnophora exesa*, *Leptastrea purpurea*, *Platygyra carnosus*, *Porites aranetai* and *Porites lutea* were also dominant in TPCMP.

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Table 1. List of Scleractinian corals recorded in the survey transects in 2003 in A Ye Wan (AYW) and A Ma Wan (AMW).

	AYW	AMW
Acroporidae		
Acropora digitifera Dana	x	x
Acropora glauca (Brook)	x	x
Acropora tumida Verrill	x	x
Montipora peltiformis Bernard	x	x
Montipora turgescens Bernard		x
Agariciidae		
Pavona decussata (Dana)		x
Astrocoeniidae		
Stylocoeniella guentheri Bassett-Smith		x
Dendrophylliidae		
Turbinaria peltata (Esper)		x
Faviidae		
Cyphastrea chalcidicum (Forskål)		x
Cyphastrea japonica Yabe and Sugiyama	x	x
Cyphastrea microphthalma (Lamarck)		x
Cyphastrea serailia (Forskål)	x	x
Favia danae Verrill	x	
Favia favus (Forskål)	x	x
Favia helianthoides Wells	x	
Favia lizardensis Veron and Pichon		x
Favia rotumana (Gardiner)	x	x
Favia speciosa Dana	x	x
Favia veroni Moll and Borel-Best	x	x
Favites abdita (Ellis and Solander)	x	x
Favites chinensis (Verrill)	x	x
Favites complanata (Ehrenberg)		x
Favites flexuosa (Dana)	x	x
Favites paraflexuosa Veron	x	
Favites pentagona (Esper)	x	x
Goniastrea aspera Verrill	x	x
Leptastrea purpurea (Dana)	x	x
Leptastrea transversa Klunzinger		x
Oulastrea crispata (Lamarck)	x	x
Platygyra acuta Veron	x	x
Platygyra carnosus Veron	x	x
Plesiastrea versipora (Lamarck)		x
Fungiidae		
Lithophyllon undulatum Rehberg		x
Merulinidae		
Hydnophora exesa (Pallas)		x
Mussidae		
Acanthastrea hemprichii (Ehrenberg)	x	
Pectiniidae		
Echinophyllia aspera (Ellis and Solander)		x
Poritidae		
Goniopora djiboutiensis Vaughan		x
Goniopora lobata Milne Edwards and Haime		x
Goniopora planulata (Ehrenberg)		x
Goniopora sp.		x
Porites aranetai Nemenzo	x	x
Porites lobata Dana		x
Porites lutea Milne Edwards and Haime	x	x
Porites sp.	x	
Total no. of species	**26**	**39**
Total no. of genera	**11**	**17**

Comparison of Coral Community Structures between 1999 and 2003

There was some increase (2%) in the percentage cover of corals in AYW between 1999 and 2003 (Fig. 2) but the increase was not statistically significant (Wilcoxon Signed Ranks Test, p>0.05). There was, however, a 9% increase in the percentage cover of corals in AMW within this same period (Fig. 2) and this

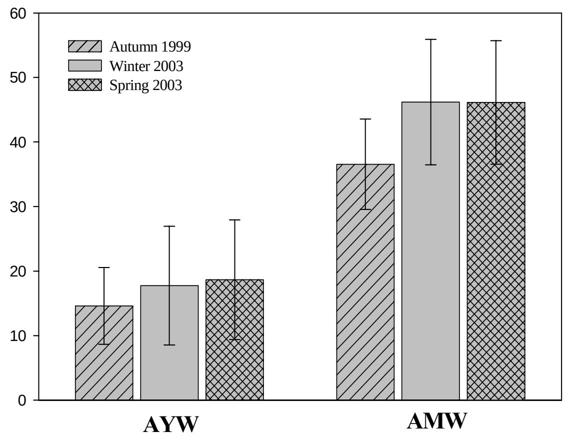

Fig. 2. Mean (± SD) live coral cover (%) in A Ye Wan (AYW) and A Ma Wan (AMW) in winter 2002 and spring 2003 as compared with that assessed in autumn 1999.

Table 2. Changes in percentage cover (relative abundance) of the first ten most dominant coral species found in A Ye Wan (AYW) and A Ma Wan (AMW) between 1999 and 2003. Species with * were not in the top ten list in 1999.

A Ye Wan Coral species	Percentage Cover (Relative Abundance, %) 1999	 2003
Platygyra acuta	4.16 (28.20)	5.50 (30.43)
Platygyra carnosus	1.70 (11.52)	2.51 (13.87)
Leptastrea purpurea	1.55 (10.52)	2.20 (12.16)
Favites flexuosa	1.50 (10.15)	1.43 (7.89)
Favites abdita	0.63 (4.25)	1.29 (7.15)
*Porites aranetai**	0.33 (2.26)	0.70 (3.88)
Porites lutea	1.04 (1.07)	0.56 (3.12)
Favia speciosa	0.06 (0.38)	0.50 (2.77)
Cyphastrea serailia	0.33 (2.26)	0.49 (2.70)
Favites paraflexuosa	0.38 (2.55)	0.46 (2.53)
A Ma Wan **Coral species**	**Percentage Cover (Relative Abundance, %)** **1999**	 **2003**
Platygyra acuta	6.31 (17.00)	10.00 (21.27)
Pavona decussata	5.80 (15.64)	9.23 (19.63)
Porites lutea	4.02 (10.85)	5.22 (11.09)
Leptastrea purpurea	4.02 (10.83)	4.87 (10.35)
Goniopora lobata	4.67 (12.58)	4.32 (9.18)
Platygyra carnosus	2.59 (6.98)	3.33 (7.08)
*Hydnophora exesa**	0.46 (1.23)	1.63 (3.46)
Favites pentagona	0.69 (1.87)	1.29 (2.75)
Cyphastrea serailia	0.89 (2.40)	1.01 (2.14)
Favites flexuosa	0.56 (1.52)	0.71 (1.52)

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increase was statistically significant (Wilcoxon Signed Ranks Test, $p<0.05$). No significant difference (pair-t test, $p>0.05$) in the mean Brilloiun's index of coral diversity was detected between 1999 and 2003 in both AYW and AMW.

Eight out of the top ten most dominant species in AYW recorded in 2003 showed an increase in coral cover and relative abundance from 1999 to 2003 (Table 2). *Platygyra acuta*, *Platygyra carnosus*, *Leptastrea purpurea* and *Favites flexuosa* remained the four most dominant corals within this period (Table 2) with the first three species all registering an increase in coral cover and relative abundance but *Favites flexuosa* showing a slight drop in coral cover and relative abundance (Table 2). Some changes in the coral cover and relative abundance of other less dominant species occurred, hence affecting their relative ranking in dominance between 1999 and 2003. *Favia favus*, ranked 7th in 1999, dropped out of the top ten list in 2003 and was replaced by *Porites aranetai*.

The situation was generally the same in AMW. Nine out of the top ten dominant species recorded in 2003 in AMW showed an increase in coral cover from 1999 to 2003 (Table 2). *Platygyra acuta* and *Pavona decussata* remained the top two most dominant species within this period (compare Figs 4 and 6). However, *Goniopora planulata*, ranked 8th in 1999 dropped out of the top ten list in 2003 and was replaced by *Hydnophora exesa*. Moreover, changes in the percentage cover of different species resulted in changes in their ranking order of dominance from 1999 to 2003.

Cluster and MDS analyses on the combined 1999 and 2003 data showed no obvious change in the community composition of corals in both AYW (Fig. 3) and AMW (Fig. 4). The low Kruskal stress values of 0.12 and 0.19 for AYW and AMW respectively imply that the ordination was a good representation of the overall structure of the relationships among the transect quadrats.

For AYW, three out of the five pairs of transects showed more than 80% and one pair showed more than 90% of similarity in coral community within the four year interval between 1999 and 2003 (Fig. 3B). Two main groupings among these transects were identified. Group 1 was comprised of Transect No. 3 alone and the other four pairs of transect (Nos. 1, 2, 4 and 5) were clustered in Group 2 (Fig. 3). SIMPER analysis further showed that *Acropora* species mainly contributed to the dissimilarity between these two groups. *Acropora digitifera* and *Acropora glauca* were the abundant *Acropora* species found in Transect No. 3 while only *Acropora tumida* was found in the other transects. Although there was generally no significant difference (ANOSIM R = -0.056, Sig. Level = 62.7%) in the coral community composition among transects between 1999 and 2003, SIMPER analysis indicated that *Platygyra carnosus*, *Favites abdita* and *Platygyra acuta* were the coral species that contributed most to the dissimilarity within these years as they were the species that increased in their coral cover and relative abundance more significantly from 1999 to 2003.

For AMW, almost all pairs of transect indicated more than 80% of similarity in coral community structure between years (Fig. 4). However, *Platygyra carnosus*, *Porites lutea*, *Hydnophora exesa* and *Cyphastrea serailia* were the four coral species that contributed most to the dissimilarity in the overall coral community structure between 1999 and 2003. Four main groupings among the nine pairs of transect were identified. Group 1 was comprised of Transect Nos. 7 and 9 and was dominated by *Pavona decussata* and *Platygyra acuta*. Group 2 was

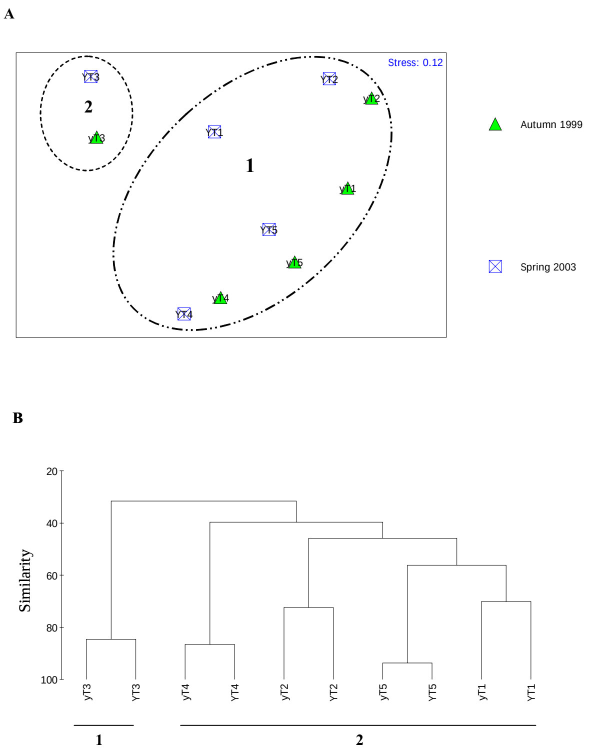

Fig. 3. A. MDS ordination plot based on Bray-Curtis similarities showing the relationship of the 5 pairs of transect in A Ye Wan (AYW) in 1999 and 2003. Kruskal stress = 0.12. Each symbol represents the coral composition in one transect. B. The supporting dendrogram showing the hierarchical clustering of these 10 transects. Community types (1 and 2) identified by the ordination and cluster analyses are shown in A and B.

comprised of Transect nos. 4, 5 and 6 and was represented by high cover of *Porites lutea* and *Platygyra acuta*; Group 3 was comprised of Transect no. 3 alone and showed high cover of *Leptastrea purpurea*, *Platygyra acuta* and *Pavona decussata*. Group 4 was comprised of Transect nos. 1, 2, and 8 and was dominated by *Platygyra acuta* and *Pavona decussata*. *Platygyra* spp. and *Goniopora* spp. appeared to contribute most to the similarity and dissimilarity between groupings.

For spatial analysis, comparison of the coral community structure between AYW and AMW in 1999 and 2003 was also carried out by multivariate analysis. Relatively clear differences (ANOSIM R = 0.426 in 1999 & R = 0.472 in 2003) in coral community structure between sites in both years were found and these are shown in MDS plots (Figs 9 and 10). Cluster analysis also showed that two main groups corresponding to AYW and AMW could be identified in both years (Figs 9B and 10B) except that one of the AMW transects (Transect no. 9) was more similar to the coral community in AYW and two transects in AYW (Transect nos. 2 and 3) were more similar to AMW coral community in 1999 (Fig. 5A). Similar pattern of coral community structures was found in 2003 with two main groups (AYW and AMW) shown in MDS plot (Fig. 6A) supported by cluster analysis (Fig. 6B). *Platygyra acuta* and *Leptastrea purpurea* were the two coral species that contributed most to the similarity of the coral community structure in AYW while this was

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contributed by *Platygyra acuta*, *Leptastrea purpurea* and *Porites lutea* in AMW. *Goniopora lobata* and *Pavona decussata* contributed most to the dissimilarity between AYW and AMW in 1999. However, this became different in 2003 with *Porites lutea* and *Platygyra carnosus* being the dominant contributors to dissimilarity between sites. The average dissimilarity between these two sites was 57.32% and 53.69% in 1999 and 2003 respectively.

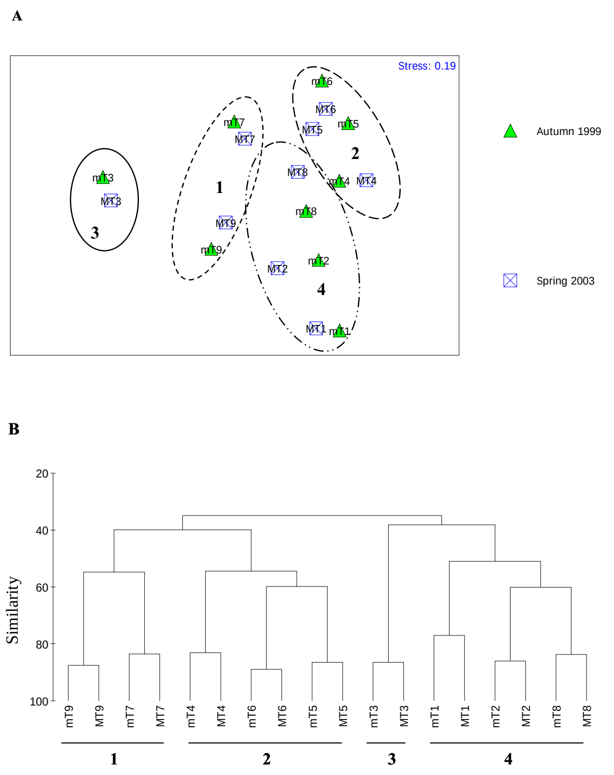

Fig. 4. A. MDS ordination plot based on Bray-Curtis similarities showing the relationship of the 9 pairs of transect in A Ma Wan (AMW) in 1999 and 2003. Kruskal stress = 0.19. Each symbol represents the coral composition in one transect. B. The supporting dendrogram showing the hierarchical clustering of these 18 transects. Community types (1, 2, 3 and 4) identified by the ordination and cluster analyses are shown in A and B.

In order to further investigate the effect of water depth on coral community structure within site, individual quadrats belonging to different transects were also analyzed by multivariate analysis. MDS ordinations for the coral cover showed that the coral community structure in shallow zone (< -1m CD) was significantly different from that of deepest zone (> -2m CD) in AYW in 1999 and 2003 (Fig. 7 and Table 3). Less significant difference was also found between shallow and middle (-1m to -2m CD) zones (Table 3) but no significant difference in the coral community structure was found between middle and deeper zones. Results of SIMPER analysis further indicated that *Favia favus*, *Platygyra acuta*, *Favites flexuosa* and *Leptastrea purpurea* contributed most to the dissimilarity (97.13% in 1999 & 96.69% in 2003) in coral community structure between shallow and deep water zones. For coral community structure between middle and deeper zones, *Oulastrea crispata*, *Favia favus*, *Porites lutea* and *Favites flexuosa* were the coral species that contributed most to the dissimilarity (90.42%) in 1999 while this was contributed by *Favia favus*, *Cyphastrea japonica*, *Porites lutea* and *Favia speciosa* in 2003 (89.79%). However, similar to the results of the comparison made based on Transects, no significant difference (ANOSIM, R = 0.192, significant level = 0.1%) in coral community structures between 1999 and 2003 was detected when quadrat data were used as units of analysis.

Table 3. Results of the ANOSIM test for differences in coral community structure among different water depth zones in A Ye Wan (AYW) and A Ma Wan (AMW) in 1999 and 2003. Shallow: <-1m CD. Middle: -1m to -2m CD, Deep: >-2m CD.

Period Studied		Shallow – Middle Zone		Shallow – Deep Zone	
		Statistic Value (R)	% Sig. Level	Statistic Value (R)	% Sig. Level
AYW	1999	0.242	1.3	0.474	1.3
	2003	0.313	0.3	0.520	5.6
AMW	1999	0.157	0.3	0.207	0.8
	2003	0.073	3.2	0.150	2.2

Table 4. Summary of mean coral cover (%) and coral diversity (Brillouin's Index) in A Ye Wan (AYW) and A Ma Wan (AMW) in 1999 and 2003.

	AYW		AMW	
	1999	2003	1999	2003
Coral Cover (%) ± SE	14.59 ± 3.45	17.14 ± 5.66	36.55 ± 4.04	46.15 ± 5.53
Coral Diversity ± SE (Brillouin's Index)	0.87 ± 0.05	0.78 ± 0.04	0.88 ± 0.03	0.84 ± 0.03

Such differences in coral community structure between water depths were less clear in AMW (Fig. 8 and Table 3). Percentage dissimilarity of coral community structures among water depth zones appeared to be decreasing from 1999 (88.5%) to 2003 (81.77%). Results of SIMPER analysis showed that the dominant coral species that contributed to the dissimilarity of coral community structure among water depth zones were the same in both 1999 and 2003. Among these species, *Platygyra acuta*, *Pavona decussata*, *Leptastrea purpurea* and *Platygyra carnosus* were the most important. However, the contribution of *Goniopora lobata* to the differences in coral community structure especially in deeper water zones in 2003 increased, when compared with that in 1999. Its percentage contribution to dissimilarity between shallow and deep water zones changed from 7.94% in 1999 to 12.84% in 2003. This may be because there was a reduction in the coral cover and relative abundance of this species from 1999 to 2003 (see Table 2).

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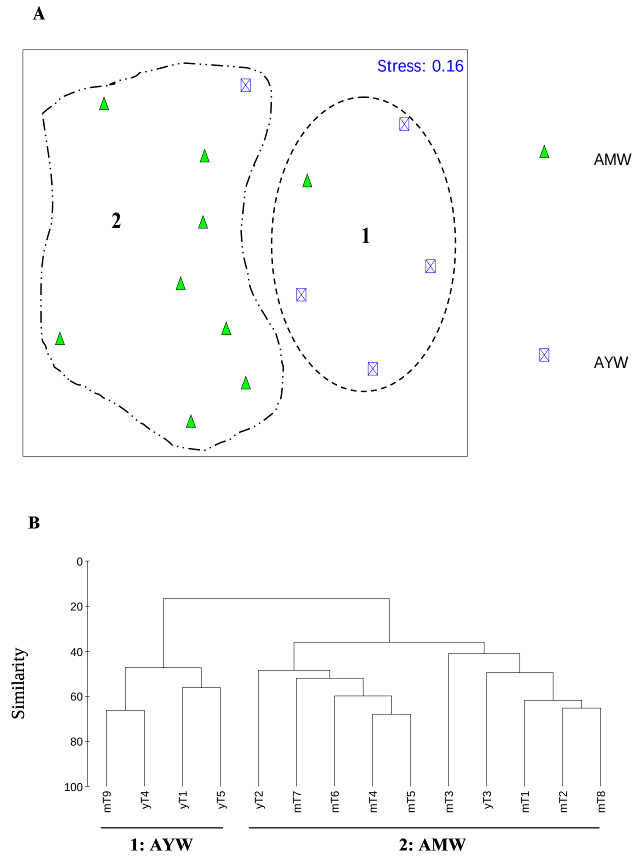

Fig. 5. A. MDS ordination plot based on Bray-Curtis similarities showing the relationship of the 14 transect in A Ye Wan (AYW) and A Ma Wan (AMW) in 1999. Kruskal stress = 0.16. Each symbol represents the coral composition in one transect. B. The supporting dendrogram showing the hierarchical clustering of transects between AYW and AMW. Communities 1: AYW and 2: AMW identified by the ordination and cluster analyses are shown in A and B.

Discussion

The highest concentrations of scleractinian hard corals in TPCMP are in the two cores areas located in AYW and AMW. Generally, there was no significant change in the coral community structure in AYW and AMW during the last four years from 1999 to 2003. However, percentage cover of corals appears to be increasing faster, at 9% in AMW than in AYW at 2% (Table 4). AMW has a greater coral cover than AYW to start with, so a greater increase in coral growth in AMW than in AYW may be expected. However, AYW is generally subjected to greater pressure from divers and swimmers than AMW. Whether this has any effect on the slower growth of corals in AYW remains to be verified. There were some changes in the ranking of dominance of some coral species from 1999 to 2003. This is likely a result of differential growth rates among these species. However, the most dominant species in both core areas and the coral species diversity remain unchanged.

Environmental disturbances (e.g. typhoon, high water temperature) are known to cause deaths or partial mortality of individual coral colonies. There were however, no major disturbances of abnormal proportion that occurred in Hong Kong in the last four years (1999-2003). Low seawater temperature (14°C) in winter of 2000, and high seawater temperature (30.6°C or 1.8°C higher than average) in summer of 2001, coupled with heavy rainfall, had caused bleaching of some coral colonies (Choi 2003, Woo 2005) and may have also induced an increase in predation on corals by corallivorous gastropods (Choi 2002). These did not appear to have seriously affected the overall coral community structure in TPCMP. Therefore, the coral communities in TPCMP remained stable and healthy.

It would however be premature to conclude that the establishment of Tung Ping Chau as a marine park in 2001 is already showing beneficial effects on the corals as the time is still too short for this to show clearly. Nevertheless, continuous monitoring of the coral community is necessary if substantial evidence of the results of coral conservation effort in Tung Ping Chau is to be detected.

The increase in the number of visitors to Tung Ping Chau since its designation as a marine park is posing a potential threat to the marine park itself although there is no systematic effort to assess this impact at the moment. Within the last two years, the boat traffic to TPCMP has increased tremendously during weekends from one boat

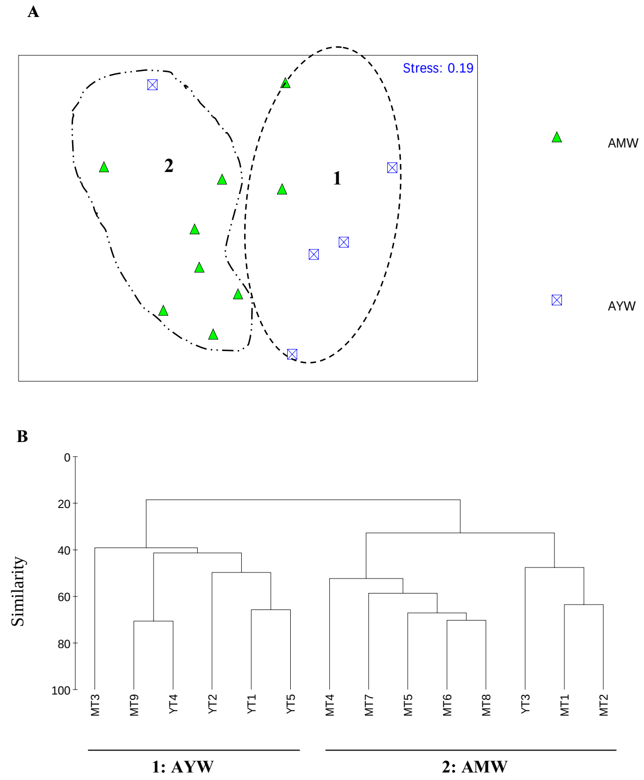

Fig. 6. A. MDS ordination plot based on Bray-Curtis similarities showing the relationship of the 14 transects in A Ye Wan (AYW) and A Ma Wan (AMW) in 2003. Kruskal stress = 0.19. Each symbol represents the coral composition in one transect. B. The supporting dendrogram showing the hierarchical clustering of transects between AYW and AMW. Communities 1: AYW and 2: AMW identified by the ordination and cluster analyses are shown in A and B.

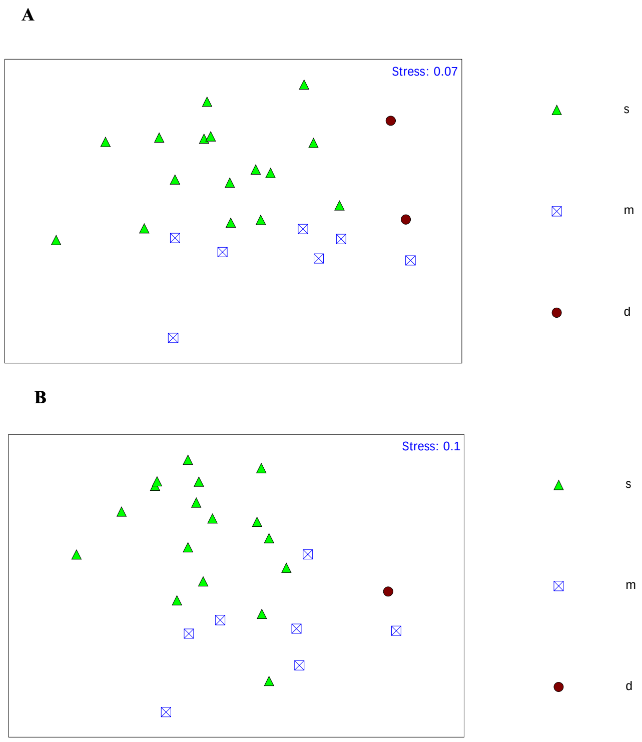

Fig. 7. MDS ordination plot based on Bray-Curtis similarities showing the relationship of the 25 quadrats among three water depth zones in A. 1999 and B. 2003 in A Ye Wan. Kruskal stress = 0.07 for 1999 and 0.1 for 2003. Each symbol represents the coral composition in one quadrat. s = shallow (<-1m CD), m = middle (-1m to -2m CD) and d = deep (> -2m CD).

(capacity around 250 to 300 people) to five to six boats or more. Visitors now also hire their own boat to go to TPCMP even during weekdays. SCUBA and skin diving have become popular. What is even more popular is the eco-tour floaters, so even non-swimmers could now have the chance of getting into the water by wearing floating device (usually life vest) with mask and snorkel. If properly trained or with proper control, diving or floating over the coral areas should not pose too much harm to the environment. What could be potentially destructive is when check out dives are being held or when newly certified divers would practice their skill without very good control of their buoyancy, or when floaters venture into the coral area at low tide (which often occurs at day time in summer). The chance of corals being trampled or kicked and overturned could greatly increase because of these. Many visitors are also not aware of the regulations within a marine park such that they would learn it the hard way after being charged for collecting marine organisms. They often complain of not being informed. The pressure of the visitors on the island itself in terms of domestic waste generated could eventually trickle down to the marine environment.

It is essential that a long term monitoring programme on coral diversity, abundance and community structure in TPCMP be set up. Closer monitoring on the potential impact of eco-tourism, especially on the impact of diving activities on coral communities in the marine park should be carried out. Although the direct impact of these activities on the coral communities in TPCMP is not evident, some breakages observed may be attributable to these activities. A closer monitoring on the potential impact of diving activities on the coral communities in TPCMP is therefore urgently needed.

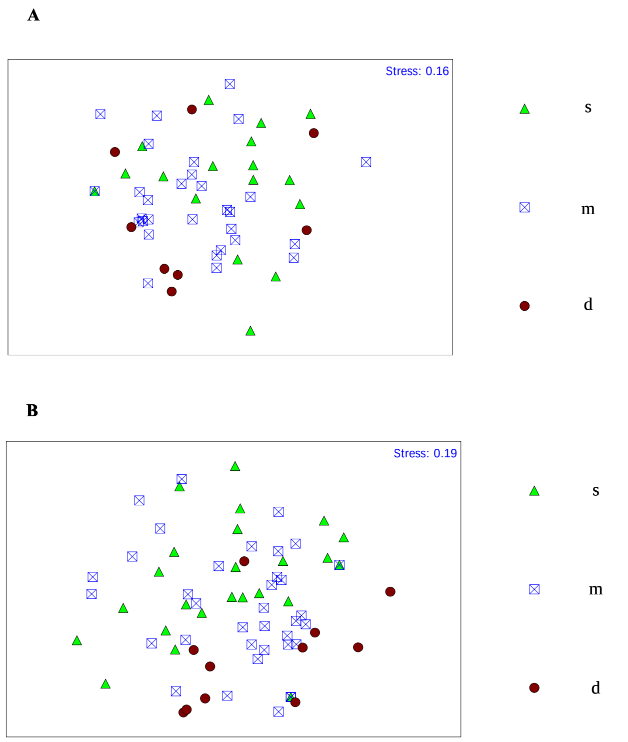

Fig. 8. MDS ordination plot based on Bray-Curtis similarities showing the relationship of quadrats among three water depth zones in A. 1999 (65 quadrats) and B. 2003 (70 quadrats) in A Ma Wan. Kruskal stress = 0.16 for 1999 and 0.19 for 2003. Each symbol represents the coral composition in one quadrat. s = shallow (<-1m CD), m = middle (-1m to -2m CD) and d = deep (> -2m CD).

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