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Journal of Experimental Marine Biology and Ecology 333 (2006) 115–128

Journal of EXPERIMENTAL MARINE BIOLOGY AND ECOLOGY

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A comparison of video and point intercept transect methods for monitoring subtropical coral communities

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Received 16 September 2005; received in revised form 5 December 2005; accepted 11 December 2005

Abstract

This study evaluated the use of video transects obtained from SCUBA divers or remote operated vehicle (ROV) and point intercept transect (PIT) method from divers for monitoring subtropical coral communities. Comparisons were made between the datasets obtained by the ROV and SCUBA diver video transect ('Diver') and the PIT method on three nearby coral sites with different hydrographies, scleractinian coral composition, dominant species and percentage cover. There was no significant difference between the ROV and 'Diver' datasets whereas the PIT method tended to over-estimate percentage cover at sites where corals are not extensive. Power analysis showed that the minimum detectable change in coral percentage cover, δ, had low mean values between 0.39% and 1.65% for the ROV dataset, 0.66% for the "Diver" dataset, and 12.11% for the PIT dataset. This implied that the ROV and SCUBA survey methods can produce higher precision in terms of detecting temporal changes in coral communities and are thus more suitable for scientific research and management purposes than the PIT method. Other advantages of using video transects by SCUBA divers or ROV include provision of permanent records for subsequent studies and public information, less field time incurred and wider survey areas.

Keywords: Point intercept transect; ROV; Subtropical coral community; Video transect

1. Introduction

Globally, coral reefs are under serious threats resulting from a variety of natural and human disturbances (Hodgson, 1999; Wilkinson, 2000; Hodgson and Liebeler, 2002). Assessment of the conditions of key organisms in tropical and subtropical coral communities has become a high research priority. The traditional methods for reef monitoring are SCUBA-based, using either photography or video taping for visual documentation (Thompson and Cope, 1982; Carleton and Done, 1995; Harriott et al., 1999; Miller and Müller, 1999; Tratalos and Austin, 2001; Rogers and Miller, 2001; Ninio and Meekan, 2002). These diver-based methods, however, have limitations in terms

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doi:10.1016/j.jembe.2005.12.009

of diving time, weather conditions, water temperature and range (both depth and horizontally) that can be covered. Inexperienced divers can also cause damage to the reef habitats. Instead of SUCBA-based techniques, remote operated vehicles (ROVs) have also been deployed in field surveys, especially in deeper waters on continental shelves (Auster and Tusting, 1997; Auster et al., 1995, 1997, 1998, 2003) and deep seas (Lauerman, 1998; Fijikura et al., 1999; Scoltwedel and Vopel, 2001), where diver-access is impossible. These instruments have also been used for environmental monitoring in shallow water habitats (Greene and Alevizon, 1989; Kasprzak and Wilson, 1994; Cook and Krumm, 1996; Culbertson and Peter, 1998; Cruz et al., 1999), and for coral reef surveys (Williams et al., 1999; Williams and Mahon, 2004).

Field transects are the most widely used survey method because it is easy to use. One of these transect methods is point intercept transects (PIT) which measure the points of interest at specific interval either below the line or below and adjacent to the transect tape (Wilkinson, 2000). This is the survey method currently adopted by Reef Check to assess percent cover of shallow coral communities. It is a simple technique which only requires a transect tape and record sheets for coral species and substrate types. Video transect is a belt transect using video for recording. It has the merits of providing relatively high precision in estimating percentage coral cover since experienced divers can collect data through video taping whereas marine biologists work on the video records for data analysis. Video transect methods also provide permanent records for coral surveys and greatly reduce field expense and time as compared to visual methods. The only drawback is that equipment used in video transects, i.e., underwater video camera or ROV with camera, are expensive to buy and maintain.

Unlike tropical seas, subtropical corals grow in patches instead of in extensive reef formation. This may pose a concern in estimation of coral cover using the PIT method adopted by Reef Check (Hodgson, 2000) as compared to using similar method for coral reef monitoring. In this study, comparisons were made between the use of PIT and video survey methods, so as to identify the best approach to document ecological changes in subtropical coral communities.

2. Materials and methods

2.1. Study sites

Coral beds, comprising over 30 scleractinian species, occur in subtropical shallow waters of the Hoi Ha Wan Marine Park in Hong Kong (22°20′N; 114°10′E). Because of the complexity of the shoreline and various wave exposures, coral communities in this bay are fragmented with different dominant species and percentage covers (Cope, 1984). All previous coral studies in Hoi Ha Wan were SCUBA diver-based, using photo-quadrat transects for visual documentation (Cope, 1984; Cope and Morton, 1988; Collinson, 1997; McCorry, 2002). Annual monitoring of coral cover in Hoi Ha Wan has also been undertaken by Reef Check since 2000 (Hodgson, 2000). Three coral areas within the marine park, namely Coral Beach, Marine Life Centre Bay and Pier Area (Fig. 1), were selected based on topographic variability for the present investigation. These sites are separated by ~300 to 1000 m and range ~−3 to −8 m below Chart Datum. Previous surveys on Coral Beach and Pier Area have shown that coral cover and dominant scleractinian species of these sites are different (Thompson and Cope, 1982; Cope, 1984; Collinson, 1997). Coral Beach is more wave-exposed than the other two sites. Marine Life Centre Bay and Pier Area are affected by an adjacent stream which flows on rainy days and a larger stream with constant flow at the back of Hoi Ha Wan, respectively. Coral Beach and Pier Area are surrounded by buoys and designated as diving and snorkeling spots within the marine park. Marine Life Centre Bay is fished by local villagers using sampans equipped with fish cages and gill nets.

2.2. Hydrographic study

Five physico-chemical parameters: temperature, dissolved oxygen, salinity, pressure and light intensity of waters at the height of the coral heads, i.e., ~0.3 m above the seabed, were monitored using a SEACAT *C–T* Recorder (Model SBE 16plus) equipped with additional dissolved oxygen, pressure and light intensity sensors. This standalone instrument recorded and logged measurements continuously in situ every 15 min, and was deployed at each site for 3–4 days in November 2004. Pressure values in bars were transformed into tidal height in metres.

2.3. Video transect and data collection by ROV

A ROV (Model *Commando II*: Inter Mares Limited, Hong Kong) equipped with a modified wide angle lens and auto-focus camera, an on-land LCD monitor (Philips), and a DVD player–writer (Pioneer DVR-720H-S) was employed as part of the video transect surveys. The ROV comprised the main body, a power pack and a control console. The main body contained

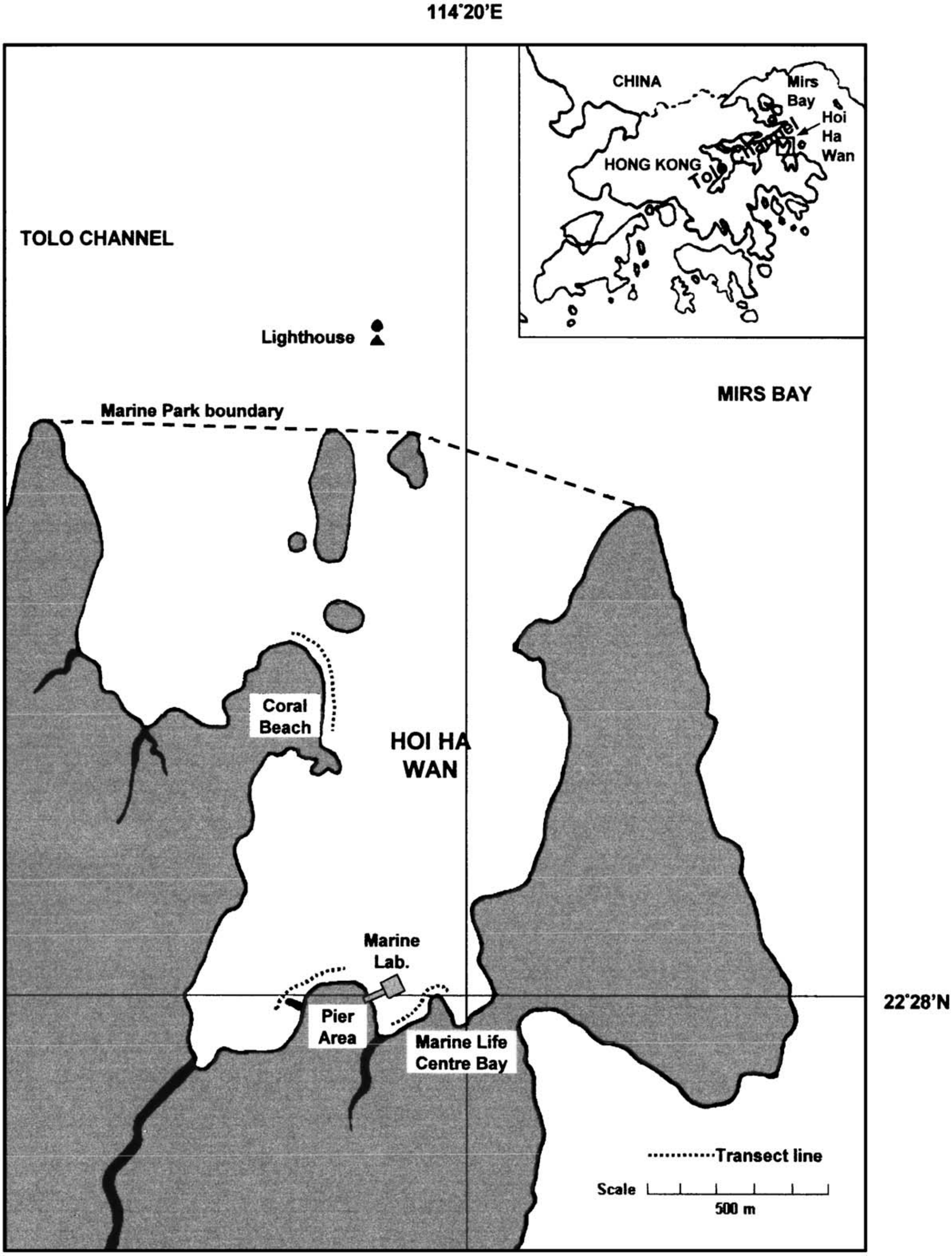

Fig. 1. A map of Hoi Ha Wan showing the study sites, Coral Beach, Marine Life Centre Bay and Pier Area and the respective transect locations.

the control, power and motor drive electronics, electric motors, high-resolution video board camera with tilt mechanisms and depth, heading overlay control, with the camera dome being made of clear, high compact acrylic. The vehicle was connected to a power pack through an umbilical cable that also served for data communication and video transmission. The whole set up was further connected to the control console. There were three propellers at the back, side and bottom of the ROV to give forward, side-way and downward movements, respectively, when in operation. The anodized aluminium buoyancy tube system on the top of the ROV and the lead weight held at the base of the stainless steel crash frame allowed adjustment in waters of different densities. At each survey site, the ROV was manoeuvred through the control console using a joystick and, by viewing the real-time images and depth and heading direction information shown on the LCD monitor, it was possible to search for a desirable depth and coral area for video sampling.

The layout of the study transects was similar to the Manta Tow Survey method by Miller and Müller (1999). Five 50 m transect videos were obtained by running the ROV haphazardly and parallel to the shore at each coral area. Distances between each transect varied between 5–10 m. Transects of a 50 cm wide swathe of the substratum were sampled and recorded by running the ROV at a speed of 10 m per minute and at 0.4 m above the substratum. Real-time images were observed on the monitor and recorded by the DVD writer. Each frame shown on the monitor was equivalent to an area of 0.6×0.44 m, i.e., ~ 0.26 m^2 on the seabed. Video clips of five 50 m transects of each three sites were obtained, i.e., a total of 15 video transects were investigated and recorded.

Percentage cover and benthic categories at the survey sites were estimated using the frame and point count method modified from Miller (1999). Fifty non-overlapping frames were chosen randomly along each 50 m transect video on which 100 random points were observed, i.e., 5000 points were observed for each transect. Benthic categories followed those used by the Reef Check Survey Manual, i.e., hard corals, soft corals, recently killed corals, fleshy algae, sponge, rock, rubble, sand, silt/clay and others (Hodgson et al., 2003). The category under hard corals was further subdivided to the genus and species level, wherever morphological distinction between species within a genus was possible. Identification of scleractinian species followed that of Veron (2000). As the number of points in each category is directly proportional to the planar area covered by that particular attribute, percentage cover was 100× the proportion of the total number of sampling points, i.e., 100, on each frame (Carleton and Done, 1995). Five transects comprising 50×0.26 m^2 frames resulted in a total study area of 65 m^2 at each site.

2.4. Video transect and data collection by SCUBA divers

The method was similar to that of the ROV except a hand-held underwater video camera was used (Osborne and Oxley, 1997; Hill and Wilkinson, 2004). All settings, except swimming speed, were similar to that of the ROV in order to better compare the results obtained by the two video transect survey methods. A digital video camera (Sony DV DCR-PC110E) in an underwater housing was used to obtain video clips of 5×50 m transects at each study site. The camera was held ~ 0.4 m above the seabed and recorded the transect at a speed of ~ 6 m per minute. The video camera was maintained perpendicular to the substratum to minimize parallax error and to keep it in focus. A reference bar attached to the underwater video housing was used to standardize the height at which filming was undertaken.

Each video transect recorded a 0.4 m swathe of the seabed. Approximately 0.15 m^2 on the seabed was filmed on each frame. Similarly, video clips of five 50 m transects of each sits were obtained, i.e., a total of 15 video transects were investigated and recorded. Percentage cover values for each coral species were estimated on 5000 random points using the frame and point count method. Five transects comprising 50×0.15 m^2 frames resulted in a total study area of 37.5 m^2 at each site.

2.5. Data collection by point intercept transect (PIT) method

The PIT method used in this study followed that applied by Reef Check to some 20 coral sites in Hong Kong. Coral Beach and Pier Area are among those sites annually surveyed by Reef Check. Four 20 m transects were laid at a depth of circa −7 m at Coral Beach and −3 to −4.5 m at Marine Life Centre Bay and Pier Area. SCUBA divers swam along the transect lines and recorded the benthic category directly below the transect line at every 0.5 m point. Since 40 points were recorded for each transect, a total of 480 (40×4 transect replicates $\times 3$ sites) points were categorised in ten items as in the ROV survey (Hodgson et al., 2003), except that the category of hard corals was not further refined taxonomically since the methodology of the PIT method adopted by Reef Check groups recorded all scleractinian species as a single category.

In all three survey methods, invertebrates, such as sea urchins and cucumbers, covering the corals or substratum were not counted in the points, but rather the coral/substratum underneath them. Table 1 summarizes the ROV, diver and PIT methodologies used in this study.

2.6. Data analysis

The three coral sites were compared for their hydrographic environments with respect to the five physico-chemical parameters measured. These datasets were further subdivided based on daylight, i.e., data obtained between 0600 and 1759 h, and night time, i.e., data obtained between 1800 and 0559 h. Mean data of the daylight and night time periods were normalized prior to Principal Component Analysis (PCA) using PRIMER v5 (Clark and Gorley, 2001).

Percentage cover of coral species or substratum categories was calculated from datasets obtained by the ROV, SCUBA diver and PIT methods. In addition, number of species, Shannon–Weiner diversity H' (Shannon and Weaver, 1963) and species evenness J (Pielou, 1966) at the three survey sites were calculated from data obtained from the ROV and SCUBA diver methods. Differences in percentage cover, H' and J values from the ROV and SCUBA diver methods and percentage cover from the ROV and PIT methods were analyzed by Student t-test. Percent data were arcsine square root transformed prior to the statistical test (Zar, 1999).

To discern community pattern derived from the ROV and SCUBA diver methods, the percentage cover of coral species was further analyzed using the non-metric multidimensional scaling (MDS) method of PRIMER v5. The percentage cover data, comprising mean values of each scleractinian species for each transect, were standardised to a proportion of the highest value obtained for each species and Bray–Curtis similarity measures (Bray and Curtis, 1957) among the three sites were computed prior to the analysis. Similarly, to compare the ROV video transect and PIT method, the benthic cover data were analyzed using MDS ordination.

The ROV, SCUBA diver and PIT datasets were further subjected to power analysis to gauge the statistical strength of the raw data generated by the three survey methods. The power analysis was achieved by calculating the minimum change, δ, that can be detected using the arcsine transformed dataset (Eq. (7.9), Zar, 1999: 109):

$$\delta = \sqrt{\frac{s^2}{n}}(t_{\alpha(2),v} + t_{\beta(1),v})$$

where s^2 = variance, n = number of frames, $v = n-1$, the power is specified as 90% (β=0.1), at a 5% level of significance (α=0.05). Since transformed data were

Table 1
Comparison of remote operated vehicle (ROV), 'Diver' and Point Intercept Transect (PIT) methods applied in this study

Method	ROV	Diver	PIT
Format of data records	Video images of transect on DVD	Video images of transect on DVcam tape and subsequently transformed into DVD	Spreadsheet
Resolution (pixels on CCD and horizontal TV lines)	1/3 in. CCD with 560,000 pixels, 470 horizontal lines	1/4 in. CCD with 690,000 pixels, 500 lines	–
Observation distance from substratum	0.4 m	0.4 m	0.8–1 m
Camera focal length	28 mm	38 mm	–
Angle of field of view	90°	80°	–
Mean area of coverage for a single field-of-view based on observation distance from substratum and angle (both given above)	0.26 m^2	0.15 m^2	–
Swim speed	10 m min^{-1}	6 m min^{-1}	~4 m min^{-1}
Transect length and number (per site)	5×50 m	5×50 m	4×20 m
Number of points analyzed	50 frames per transect, 100 random points analyzed per frame	50 frames per transect, 100 random points analyzed per frame	40 evenly-distributed points per transect analyzed
Area surveyed (per site)	65 m^2	37.5 m^2	A distance of 80 m
Coral taxa recorded	√	√	×
Benthic categories recorded	√	Recorded on the tape but not analyzed in this study	√

– = not applicable.

Table 2
Summary of hydrographic data (mean values) measured at the three survey sites

	Coral Beach (days 1 and 2)	Marine Life Centre Bay (days 1 to 4)	Pier Area (days 1 and 2)
N for day	138	228	228
N for night	141	216	141
Dissolved oxygen (day) (mg L^{-1})	6.88±0.02	6.87±0.03	7.02±0.08
Dissolved oxygen (night) (mg L^{-1})	6.89±0.01	6.87±0.07	7.00±0.05
Light intensity (day) (PAR)	101.50±151.59	180.43±155.64	139.80±142.36
Light intensity (night) (PAR)	0.34±0	0.80±11.11	0.34±0
Tidal height (day) (m)	5.21±0.46	3.08±0.37	5.68±0.49
Tidal height (night) (m)	5.47±0.43	3.96±0.30	6.71±0.86
Salinity (day) (‰)	32.73±0.02	32.68±0.01	32.79±0.06
Salinity (night) (‰)	32.71±0.02	32.67±0.01	32.82±0.03
Temperature (day) (°C)	24.64±0.18	24.83±0.24	23.48±0.70
Temperature (day) (°C)	24.60±0.12	24.73±0.21	23.67±0.45

used, the resultant δs were obtained by conversion to the original scale (Sabetian, 2003).

3. Results

3.1. Hydrographic data

Table 2 shows the mean data of water temperature, salinity, dissolved oxygen, light intensity and tidal height,

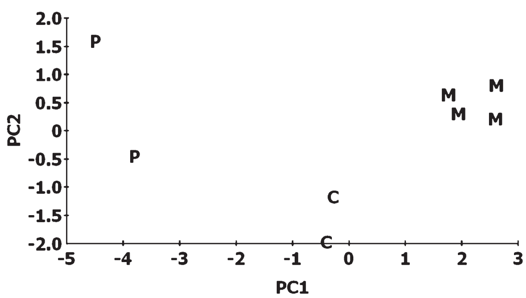

Fig. 2. PCA ordination showing the first two principal component axes, PC1 and PC2, of the normalised hydrography data for C, Coral Beach, M, Marine Life Centre Bay and P, Pier Area.

respectively, according to day light and night time periods at the three coral sites in November 2004. Results of PCA (Fig. 2) showed that the first two principal components (PC1 and PC2) accounted for 92.1% variation within the dataset and the coral sites appeared as three well-separated clusters, indicating their difference in hydrographies. According to eigenvectors generated under PC1 (Table 3), coral site at the Marine Life Centre Bay had higher water temperature and light intensity during day and night time, and larger tidal height during day light; whereas coral site at Pier Area had higher dissolved oxygen and salinity during day and night time, and larger tidal height at night. The hydrographic conditions at the Coral Beach site were in between the above two coral areas. A larger variation in hydrographic measurements was also noted for the Pier Area site, in which the data points were separated along PC2.

Table 3
Results of PCA of the hydrographic parameters measured at the three survey sites

Results of principal component analysis

Eigenvalues

PC	Eigenvalues	Percentage variation	Cumulative percentage variation
1	7.90	79.0	79.0
2	1.31	13.1	92.1
3	0.6	6.0	98.1
4	0.14	1.4	99.6
5	0.04	0.4	100.0

Eigenvectors (coefficients in the linear combinations of variables making up PCs)

Variable	PC1	PC2	PC3	PC4	PC5
Dissolved oxygen (day)	−0.332	0.284	−0.169	−0.233	−0.046
Dissolved oxygen (night)	−0.342	0.227	−0.007	−0.245	−0.048
Light intensity (day)	0.135	0.703	0.568	0.315	0.198
Light intensity (night)	0.254	0.301	−0.755	0.426	0.262
Tidal height (day)	0.323	−0.324	0.133	0.225	0.714
Tidal height (night)	−0.350	−0.137	0.023	0.114	0.284
Salinity (day)	−0.342	−0.145	−0.039	0.522	−0.441
Salinity (night)	−0.348	0.085	0.050	0.437	−0.296
Temperature (day)	0.338	−0.250	0.138	0.177	−0.027
Temperature (day)	0.334	−0.261	0.196	0.216	−0.118

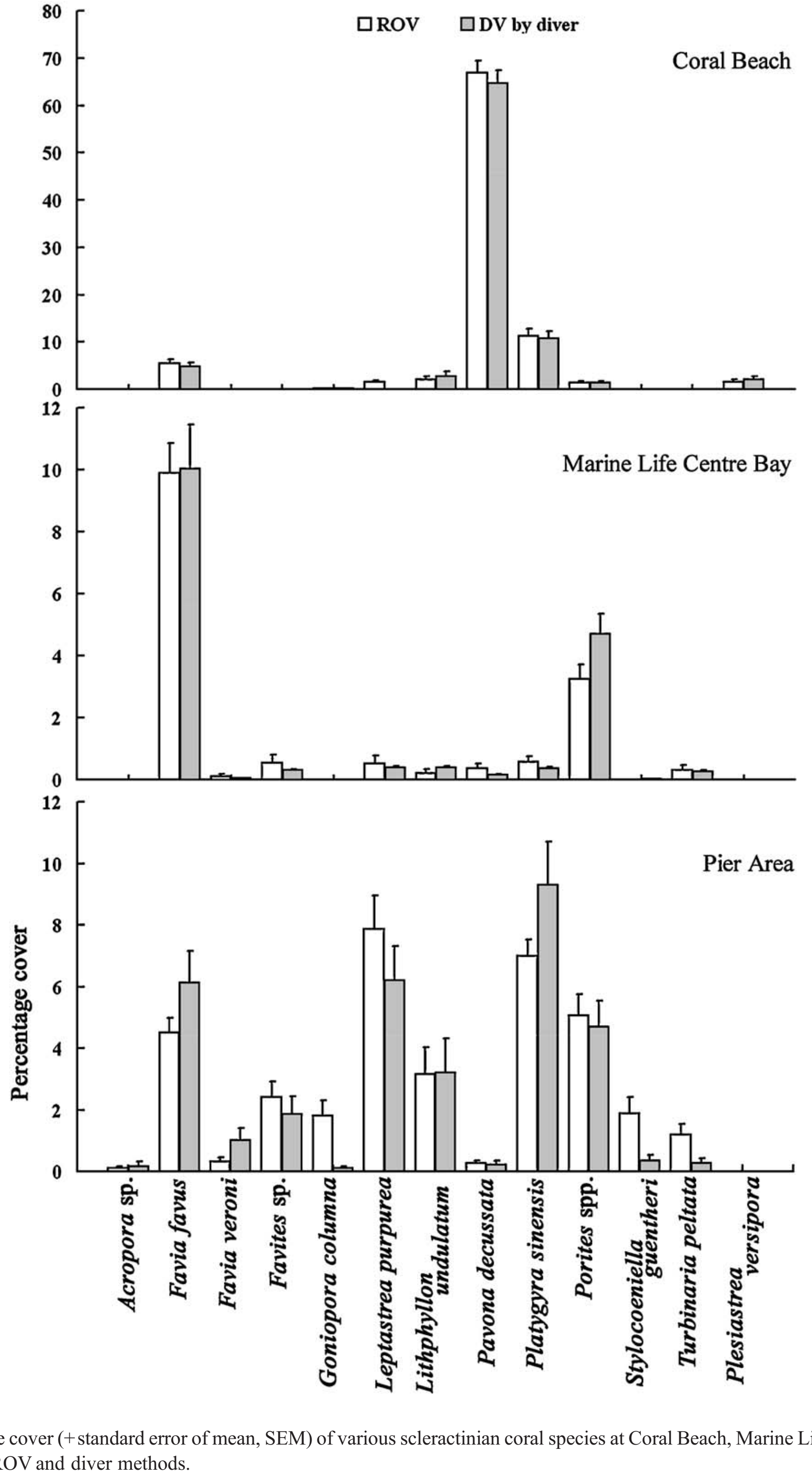

Fig. 3. Mean percentage cover (+standard error of mean, SEM) of various scleractinian coral species at Coral Beach, Marine Life Centre Bay and Pier Area obtained by the ROV and diver methods.

3.2. Comparison between ROV and SCUBA diver methods

Fig. 3 shows the mean percentage cover of 13 scleractinian species at the three coral sites obtained by the ROV and SCUBA methods, including *Acropora* sp. (Acroporiidae), *Favia favus* (Faviidae), *Favia veroni* (Faviidae), *Favites* sp. (Faviidae), *Goniopora columna* (Faviidae), *Leptastrea purpurea* (Faviidae), *Pavona decussata* (Agariciidae), *Lithophyllon undulatum* (Fungiidae), *Platygyra sinensis* (Faviidae), *Porites* spp. (Poritidae), *Stylocoeniella guentheri* (Astrocoeniidae), *Turbinaria peltata* (Dendrophyllidae) and *Plesiastrea versipora* (Faviidae). Fig. 4 shows the mean

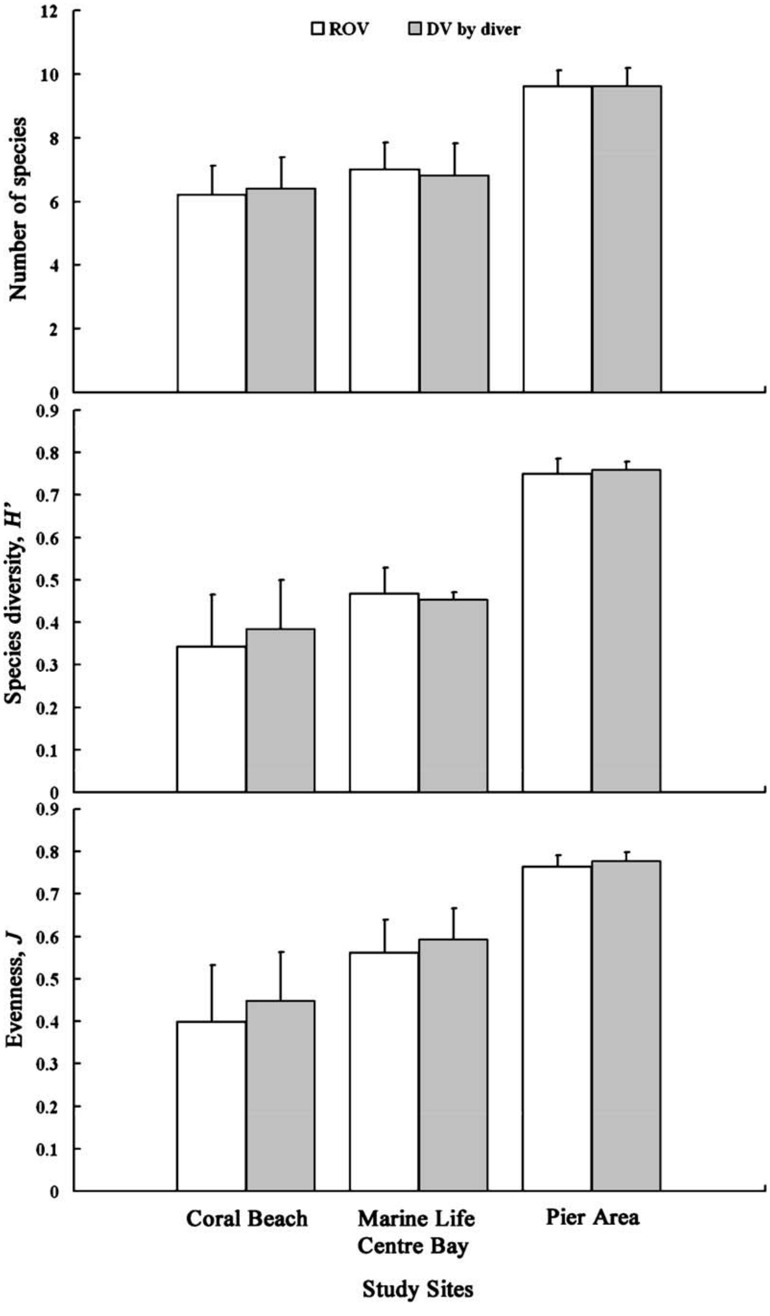

Fig. 4. Mean (+standard error of mean, SEM) number of species, species diversity (H') and evenness (J) estimated for Coral Beach, Marine Life Centre Bay and Pier Area obtained by ROV and diver methods.

Table 4
Results of Student *t*-test for differences of coral species or substratum category percentage cover and diversity indices values obtained between the ROV and SCUBA diver video transect (Diver), and between ROV and point intercept transect (PIT) methods. Values indicate *p* values

Study site	Coral Beach	Marine Life Centre Bay	Pier Area
ROV vs. Diver (remarks: mean values from each transect were used, *df*=9)			
Coral taxa			
Acropora sp.	–	–	0.72
Favia favus	0.82	0.97	0.39
Favia veroni	–	0.56	0.33
Favites sp.	–	0.29	0.78
Goniopora columna	0.82	–	0.10
Leptastrea purpurea	0.50	0.69	0.51
Lithophyllon undulatum	0.54	0.57	0.24
Pavona decussate	0.85	0.49	0.96
Platygyra sinensis	0.93	0.56	0.76
Porites spp.	1	0.38	0.86
Stylocoeniella guentheri	–	0.35	0.16
Turbinaria peltata	–	0.87	0.15
Plesiastrea versipora	0.73	–	–
Diversity indices			
Species diversity, H'	0.85	0.71	0.74
Evenness, J	0.84	0.71	0.74
ROV vs. PIT (remarks: mean values from each transect were used, *df*=8)			
Substratum category			
Hard corals	0.32	0.004*	0.03*
Soft corals	–	–	–
Sponge	0.06	0.41	0.14
Fleshy algae	–	–	–
Recently killed corals	0.05*	0.19	0.21
Rock	0.09	0.01*	0.01*
Rubble	0.06	0.15	0.12
Sand	0.33	0.47	0.01*
Silt/clay	–	–	0.90
Others	–	–	–

–=no data; *=$p \leq 0.05$.

number of species, H' and J for the three sites obtained by both methods. Results of *t*-test showed no significant difference in number of species, values of H' and J, as well as percentage cover of various coral species obtained by these two methods at the three sites (Table 4). The three sites were characterised by different dominant species: *P. decussata* (65.76%) and *P. sinensis* (10.92%) at Coral Beach, *F. favus* (9.96%) and *Porites* spp. (3.97%) at Marine Life Centre Bay and *L. purpurea* (7.04%), *Porites* spp. (4.87%), *F. favus* (6.31%) and *P. sinensis* (5.73%) at Pier Area. From the MDS plot, coral communities at the three sites were clearly separated, especially at the Coral Beach site (Fig. 5). However, no clear separation between the ROV and diver transect groups could be identified.

3.3. Comparison between ROV and PIT method

Fig. 6 shows the mean percentage cover of various benthic categories obtained by the ROV and the PIT method adopted by Reef Check. Results of *t*-test showed a significant difference in percentage cover values obtained by the ROV and PIT method in terms of hard corals and rock at both Marine Life Centre Bay and Pier Area, and recently killed corals and sand at Pier Area (Table 4). The PIT method recorded significantly higher hard coral but lower rock cover at Marine Life Centre Bay and Pier Area, and lower recently killed corals at Coral Beach and lower proportion of sand at Pier Area than the ROV (Fig. 6). Data from both of the ROV and PIT datasets showed the three sites to be characterised by different dominant benthic substrata and composition of benthic substratum cover. Coral Beach was dominated by hard corals (90.36%), Marine Life Centre Bay by sand (59.27%), hard corals (18.78%) and rock (16.39%) and Pier Area by sand (48.42%) and hard corals (33.50%). The MDS plot for transect data obtained by the ROV and PIT methods grouped the points according to sites rather than to survey methods (Fig. 7). Coral Beach had a distinctive benthic substratum composition when compared to Marine Life Centre Bay and Pier Area. No clear separation was identified between the transect data groups from Marine Life Centre Bay and Pier Area, showing the two sites had similar benthic substrata.

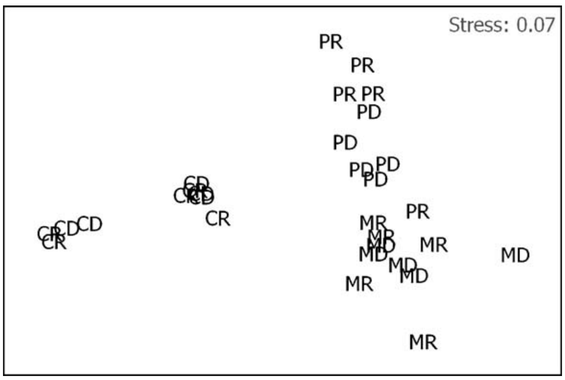

Fig. 5. Non-metric MDS ordination of percentage cover data from ROV and diver methods. CR, MR and PR=ROV data from Coral Beach, Marine Life Centre Bay and Pier Area, respectively. CD, MD and PD=SCUBA diver data from Coral Beach, Marine Life Centre Bay and Pier Area, respectively.

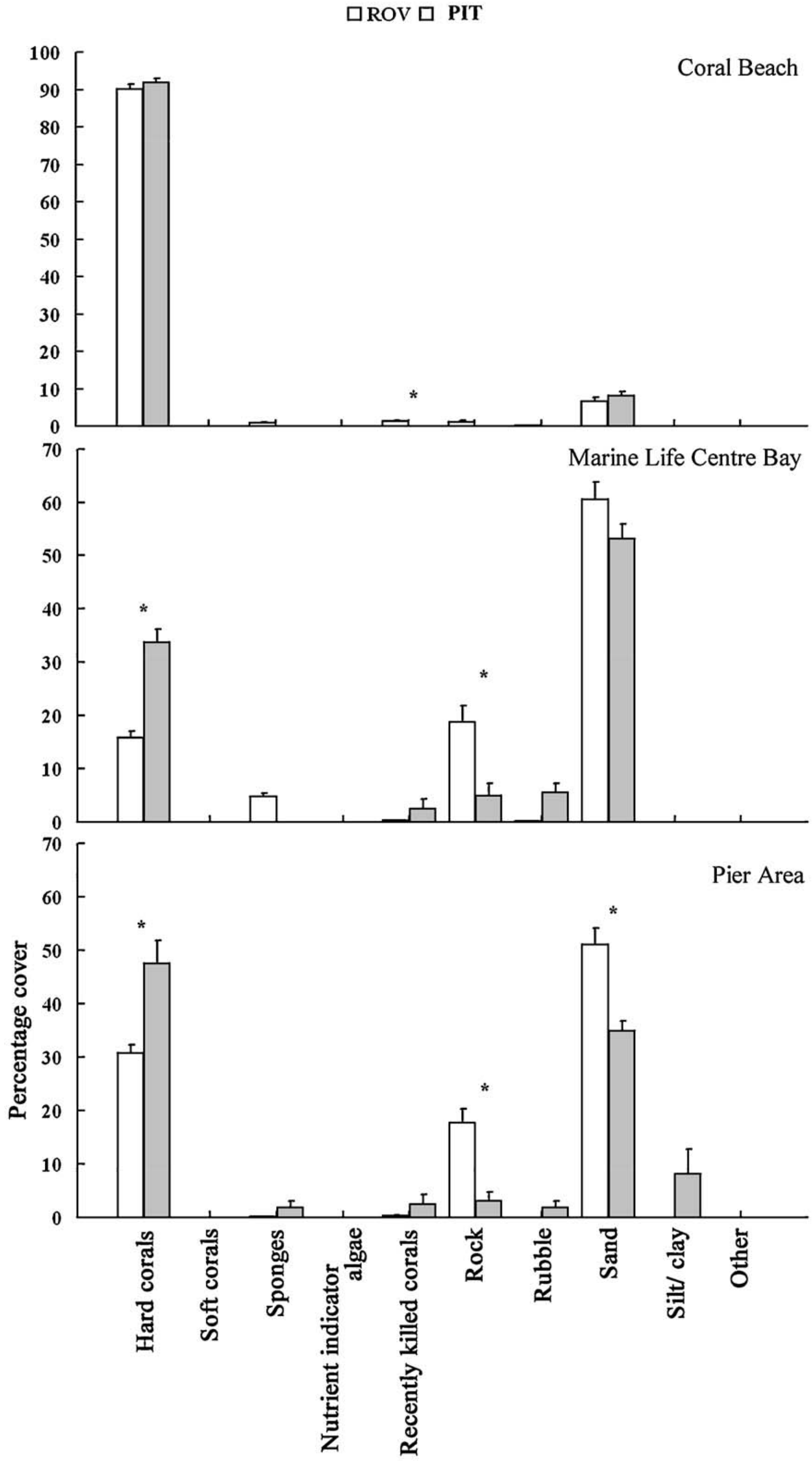

Fig. 6. Mean percentage cover (+standard error of mean, SEM) of various benthic categories at Coral Beach, Marine Life Centre Bay and Pier Area obtained by the ROV and PIT methods. $* = p \leq 0.05$.

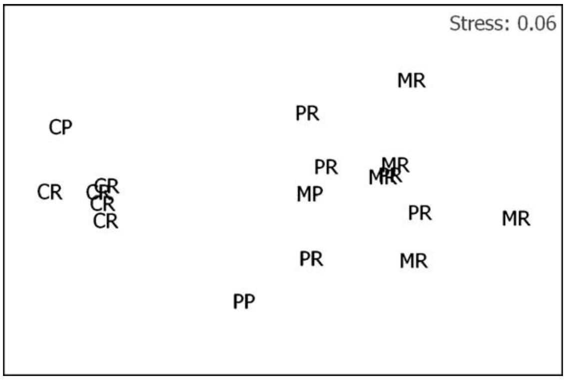

Fig. 7. Non-metric MDS ordination of percentage cover data for ROV and PIT methods. CR, MR and PR = ROV data from Coral Beach, Marine Life Centre Bay and Pier Area, respectively. CP, MP and PP = PIT data from Coral Beach, Marine Life Centre Bay and Pier Area, respectively.

3.4. Power analysis

Table 5 shows how much the percentage cover would have to change before it could be detected by the ROV, diver and PIT survey methods. The mean δs between ROV and diver datasets (0.39% and 0.66%, respectively) were similar (t-test, $p=0.316$), whereas the mean δ of PIT method was 12.11% which was significantly higher than that obtained from the ROV method (1.65%) (t-test, $p<0.001$).

4. Discussion

The δ values obtained for the ROV and SCUBA survey methods were comparatively similar, whereas that for the PIT method was significantly higher than the ROV method. This could be explained by the difference in the number of points analyzed in the survey datasets. For both ROV and SCUBA methods, a total of 5000 points were examined per transect while for the PIT method, only 40 points were analyzed owing to the limitation in data recording during field surveys (Table 1). Hence, the discriminating power for detecting changes in coral cover using the PIT method was low. In addition to the differences in δ values, the PIT method recorded significantly higher hard coral and lower rock cover at Marine Life Centre Bay and Pier Area than the ROV (Fig. 6). Both sites had either medium (~30% at Marine Life Centre Bay) or low (~15% at Pier Area) coral cover as compared to Coral Beach (~90% cover). It thus appeared that the PIT method tended to over-estimate percentage cover at sites where corals are not extensive.

In their review of ecological monitoring methods for coral communities, Hill and Wilkinson (2004) suggested that the video transect method can produce survey results that are suitable for scientific research, whereas data collected by the PIT method are only useful for monitoring the general state of a coral community and for habitat management purposes. This study shows, however, low δ values obtained for the video transect method and significantly higher δ values for the PIT method. Management on coral reef should adopt a method that has the ability to detect even small changes in the community structure. If a method that can only detect large changes is used, then it is often too late to undertake remedial actions to safeguard the coral communities. There are also other advantages of the former method over the latter. A major advantage of the video transect method is that it provides a permanent visual record of a coral community which allows opportunity to return to the images for more information. For example, it is extremely useful to show footages of reefs that have been damaged to marine park managers or judges. Quality control of consistent substratum or species identification from images is also facilitated because images can be archived and viewed again to ensure accurate identifications (Rogers and Miller, 2001). Video records of surveys are also useful for subsequent studies of corals such as early detection of diseases and investigation of species interactions along a time frame. Imagery is also useful for developing outreach products for public information. Unlike the PIT method, video transect can be implemented by experienced divers without expertise in the identification of marine life (Hill and Wilkinson, 2004). The video method also requires much less time in the field than the PIT method (~30 min per five transects per site vs. 1.5 h of diving per site in this study) and is therefore useful for sampling a large area or a number of sites. It requires, however, much more laboratory time spent in image analysis. Since the video method records a swathe of the sea bottom, rare species are more likely to be detected than the PIT method where only points along a transect line are observed. For example, rare benthic categories such as sponge, recently killed corals, rock and rubble at Coral Beach were not detected by PIT but were by the ROV method. Information on coral colony size, which is a useful indicator of coral community stability, can also be obtained by the video method. The statistical power of the transects can be increased in the laboratory by increasing the number of points or frames analyzed, with the latter more effective than the former (Hill and Wilkinson, 2004). Increasing the number of points analyzed decreases the minimum difference in percentage cover values among frames and thus reduces the variance (s^2) for calculating minimum

Table 5
Minimum detectable change in coral cover, δ (%), of benthic substratum at the three survey sites by the ROV, SCUBA diver video transect (Diver) and point intercept transect (PIT) methods

Method	Remote operated vehicle (ROV)			SCUBA diver video transect (Diver)			Point intercept transect (PIT)		
Study site	Coral Beach	Marine Life Centre Bay	Pier Area	Coral Beach	Marine Life Centre Bay	Pier Area	Coral Beach	Marine Life Centre Bay	Pier Area
Coral taxa									
Acropora sp.	–	–	0.03	–	–	0.21			
Favia favus	1.19	1.42	0.21	1.22	1.60	1.50			
Favia veroni	–	0.11	0.08	–	0.08	0.58			
Favites sp.	–	0.38	0.12	–	0.25	0.88			
Goniopora columna	0.07	–	0.01	0.11	–	0.08			
Leptastrea purpurea	0.54	0.36	0.23	0.84	0.31	1.60			
Pavona decussata	0.92	0.19	0.23	1.33	0.20	1.61			
Lithophyllon undulatum	3.65	0.20	0.03	3.99	0.12	0.19			
Platygyra sinensis	2.17	0.30	0.29	2.34	0.26	2.03			
Porites spp.	0.53	0.69	0.18	0.45	0.81	1.26			
Stylocoeniella guentheri	–	–	0.04	–	0.03	0.29			
Turbinaria peltata	–	0.22	0.03	–	0.19	0.24			
Plesiastrea versipora	0.83	–	–	1.05	–	–			
Mean δ		0.39			0.66				
Substratum category									
Hard corals	2.01	1.79	2.42				5.77	11.54	20.87
Soft corals	–	–	–				–	–	–
Sponge	0.36	0.98	0.07				–	–	5.76
Fleshy algae	–	–	–				–	–	–
Recently killed corals	0.39	0.18	0.23				–	8.52	8.52
Rock	0.45	4.43	3.72				–	11.00	7.58
Rubble	0.13	0.08	–				–	7.58	5.76
Sand	1.71	4.72	4.36				5.77	13.36	8.52
Silt/clay	–	–	–				–	–	22.74
Others	–	–	–				–	–	–
Mean δ		1.65						12.11	

–=no data.

detectable change (δ). Increasing the number of frames analyzed (n) decreases δ in two ways. Since δ is inversely proportional to the square root of n, increasing n also decreases exponentially both power statistics, $t_{\alpha(2),\nu}$ and $t_{\beta(1),\nu}$, resulting in a further reduction in δ. Detection of temporal change is the major aim of monitoring programmes. Thus, a method with a higher chance to detect such changes, i.e., producing a low δ from the two datasets obtained at subsequent different times, is preferred. The video transect method is superior to the PIT method in this aspect.

The conditions of the site during investigation, however, such as the current patterns, surface conditions and weather all interact to determine whether SCUBA or ROV is the most efficient in obtaining video transects. The main advantage of using ROV over SCUBA is that there is no time limit for how long the vehicle can stay submerged. Thus, a ROV has a wider horizontal range (and also vertical range down to >40 m in depth) than SCUBA-based surveys. A ROV is also useful in unfavourable diving conditions such as limited visibility, adverse weather, and unpredictable, rapid water currents dangerous for divers. The use of SCUBA divers to obtain video transects, however, is sometimes more preferable in constant high current areas because SCUBA divers can attain better balance in water to stabilize the video image and film along the required transect lines. Divers are also useful for deeper dives when operation is close to the shore so as to keep the vessel from running aground.

Some coral scientists are concerned whether the resolution of video transects is high enough for the accurate identification of bottom substrata (Hill and Wilkinson, 2004). With advances in video technology, however, this is not a major problem as demonstrated in the present study. Initially, the video from the ROV was recorded onto VHS tape, with a resolution of 210 lines. This proved inadequate for the project, especially when the SCUBA diver was using a Hi8 videocam with a resolution of around 400 lines. It was therefore decided to change the recording medium to DVD, as this would allow interpretation of individual frames recorded at 25 fps (PAL). At the same time the SCUBA camera was upgraded to DVcam. The resolution of the video obtained by ROV was limited by the 470 line camera and, although recorded onto DVD in 'Fine' mode, at a resolution of 576 lines (PAL), was not as good a resolution as the DVcam used by the SCUBA diver, which was 500 lines, and also transferred to DVD at 576 lines resolution. The ROV has now been upgraded with a 570 line camera, which will make full use of the DVD resolution, and consequently should provide higher resolution than the DVcam in future. Further improvements are also planned for replacement of the umbilical by a fibre optic based system, to capture HD video and provide a 1080 line resolution. The SCUBA diver's hand-held DVcam was of sufficiently high enough resolution to identify most Hong Kong common corals to species level based on colony growth form, colour, polyp size and colony shape. Stills from these DVD footages, for either publication or presentation purposes, however, result in lower resolution pictures as these are restricted by the power of most commercially DVD player's software. It is not yet to capture high resolution pictures from ROV videos close to that of still photography.

Acknowledgements

We thank David D.W. Ying for assistance in the field and laboratory work. We are also grateful to Brian Morton for his comments on the first draft of the manuscript. This study was fully supported by Strategic Research Grants (No. 7001418 and 7001541) and an Applied R and D Project Grant (No. 9660001) from the City University of Hong Kong. We also thank two reviewers whose comments substantially improved the manuscript. **[SS]**

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