Comparison between complex and simple reef survey techniques using volunteers: is the effort justified?

S. Harding[1], C. Lowery[1] and S. Oakley[2]

ABSTRACT

A comparison was made between volunteers' estimates of benthic cover and reef fish abundance and diversity using two common monitoring methods, Reef Check, and a sub-set of the methods adopted by the Global Coral Reef Monitoring Network (GCRMN). Greenforce volunteers with no prior reef surveying experience were taught to dive, then trained in reef organism identification and the two monitoring techniques. After training, volunteers performed surveys using the two techniques, and three weeks later, resurveyed the same transect lines. Transects were also surveyed by the Greenforce scientific staff. Most Reef Check categories were recorded correctly at all levels of experience. Useful information could also be collected by volunteers using the more detailed GCRMN benthic codes. Reef fish families and most target species were identified correctly. Greenforce staff recorded a few additional species, but there was no significant difference in target species abundance recorded by the two groups after three weeks. This study confirms previous work that given proper training and supervision, data collected by volunteers can be validated and relied upon to assess the diversity and status of coral reefs at a low to medium level of taxonomic complexity for fish, hard corals and selected macro-invertebrates.

Keywords Volunteers, Validation, Coral reef monitoring techniques, Benthic cover, Fish censuses

Introduction

The use of volunteers to collect biological data is now well established in marine environments (see Wells 1995 for a review). In the early 1970s Earthwatch pioneered the use of volunteers in marine science projects. While the projects often lasted many years, the volunteers were brought in, trained and then put to work collecting data for a relatively short period – usually a few weeks to months. Since then, many new programmes have started. Some were designed simply as educational tools while others have had dual goals of education and the collection of valid scientific data.

In volunteer based projects that aim to collect valid scientific data the key question is whether the information obtained is reliable. Reliability is a function of training. To survey a complex coral reef system, training is needed in the measurement techniques (transects, quadrats etc.) as well as in taxonomy.

In the tropical marine context, research programmes usually involve the use of SCUBA diving to carry out surveys of coral reefs, mangroves and seagrass beds. There have been a few publications concerning the validity of volunteer data collected on coral reefs.

Thorough validation exercises have been conducted in the Caribbean by Coral Cay Conservation for benthic organism cover and abundance (Mumby et al. 1995), in East Africa by Frontier for the visual censusing and length estimation of reef fish populations (Darwall and Dulvy 1996) and, more recently, for Reef Check categories (Roxburgh 2000).

Brown (1999) has analysed volunteer data collected during the long-term monitoring of reefs in Hawaii whilst the effectiveness of volunteer divers in documenting artificial aquatic habitats has been assessed by Halusky et al. (1994). Experienced volunteer divers have also been used to collect data on reef fish in the Florida Keys (Schmitt and Sullivan 1996).

A study of the quality of data collected by volunteer programmes is useful to determine the limits of validity and can be helpful in the design of training schedules for field scientists (Mackney and Spring 2001). This paper reports on a validation exercise undertaken at Pulau Banggi, East Malaysia by Greenforce volunteers and scientific staff.

Pulau Banggi is the largest island off the coast of Sabah at the northern tip of Borneo (Fig. 1a). The Banggi region has a combination of shallow fringing reefs, deeper patch and bank reefs and coral cover on the rocky slopes of high islands. Fringing reefs generally reach a depth of 10-15 m whilst other reef types can have corals extending to 25 m.

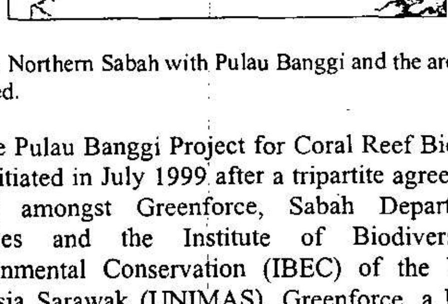

Fig. 1a. Northern Sabah with Pulau Banggi and the area of study indicated.

The Pulau Banggi Project for Coral Reef Biodiversity was initiated in July 1999 after a tripartite agreement was signed amongst Greenforce, Sabah Department of Fisheries and the Institute of Biodiversity and Environmental Conservation (IBEC) of the Universiti Malaysia Sarawak (UNIMAS). Greenforce, a UK-based non-profit organization, utilizes volunteers to conduct

[1] Greenforce, 11-15 Betterton Street, London, WC2H 9BP, UK. Email for correspondence: simonharding@yahoo.com
[2] Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Kuching, Sarawak, Malaysia.

baseline surveys of terrestrial and marine habitats. The information collected is supplied to interested parties in the host countries to create sustainable management plans for the regions studied.

Initially, the principal aim of the project was to collect information on the marine biodiversity of the Banggi region. Special emphasis is also placed on assessing both commercial and non-commercial reef fish populations and the current slams of the coral reefs in the area. The project is designed to run for 5-7 years with the primary aim gradually altering over time so that environmental education and the provision of alternative livelihoods are prioritised once the surveying programme is running. It is expected that the information generated will be used to support a proposal for the designation and management of the region as a Marine Protected Area within the time frame of the project.

The growing need to assess the global condition of coral reefs in the early 1990's led to the call for the establishment of the Global Coral Reef Monitoring Network (GCRMN) at the 7"' ICRS (1992) and the formation of the International Coral Reef Initiative (ICRI) in 1994. Reef Check monitoring was launched in 1997 to coincide with International Year of the Reef and is now administered by the Reef Check Foundation. GCRMN has chosen Reef Check methods to serve the Network's community-based monitoring needs under the ICRI umbrella (Hodgson 1999a, Hodgson 19996).

There are a number of basic differences in the design and implementation of GCRMN and Reef Check programmes and methods. GCRMN was set up to link groups interested in monitoring coral reefs (volunteers, government technical teams and academic scientists) for diverse reasons and using all monitoring methods. GCRMN has however, recommended that a subset of the coral reef methods included in English et al., be used. These methods were designed for use in Australia and the Western Pacific by teams of scientists (not volunteers). The methods are generic and do not recommend what level of taxonomy to use or what phyla or species should be included. GCRMN methods were designed to measure reef fish, hard corals and other categories of benthic algae and invertebrates. For hard corals, a set of growth forms is recommended as a method of gathering data on coral types without the need for detailed taxonomy.

In contrast, the Reef Check methods were specifically designed to be used by non-biologist volunteer divers who are trained and supervised by experienced marine scientists. The goal of Reef Check monitoring is to provide the minimum training needed to extract the maximum information about coral reef health in the shortest possible time (Hodgson 2000). To do this, reef health was defined based on a set of indicator organisms.

Reef Check therefore differs from GCRMN in that fewer indicator species or benthic categories are selected for assessment. For example, Reef Check combines all hard corals into one category whilst GCRMN splits them into 15 life-forms. It has been suggested that some of the more detailed GCRMN techniques such as the hard coral life-form categories may be too detailed for non-specialist volunteers (Erdmann et al. 1997, 10C/UNEP/SPREP, 1994).

This study tests this suggestion in relation to the potential use of volunteers to undertake long-term monitoring studies for Reef Check/GCRMN community-based reef management projects.

Methods

Validation design

The primary aim of this study is to assess the validity of data collected by volunteers in comparison to a standard, i.e. reference data collected by the scientific staff. In addition, we also examined whether the information produced by volunteers had improved in quality over time as the surveyors become more 'experienced'. To accomplish these tasks a study site was surveyed (reef fish censuses and benthic cover) just after the completion of the scientific training by all the volunteers and by scientific staff (Week 1). Repeat surveys were carried out by staff to increase the number of replicates available for statistical analyses. The site was then visited three weeks later (Week 4) to re-survey the same transect lines. Comparisons between volunteers and staff within the surveys (Week 1 and Week 4) and between censuses (Week I vs. Week 4) were then made.

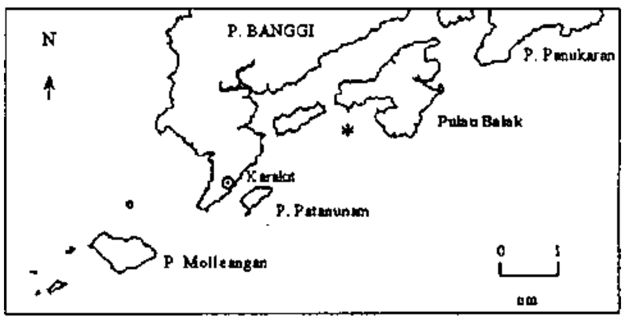

Fig. lb. Map of south-west Banggi indicating the position of the study site (•).

The study site

All surveys for the validation exercise were carried out at a single site to the south-west of Pulau Balak (07° 07.80N 117° 07.34E; Figure lb ·). The site is a small patch reef, roughly conical in shape rising from a sandy bottom (15 m depth) to a reef top (2 in depth). It is isolated from the nearest neighbouring reef, a fringing reef to the north, by -100 metres, suggesting that the fish population is mainly resident here (sensu Sale and Douglas 1981). Preliminary assessment dives by scientific staff indicated that the site possessed sufficient reef fish diversity and benthic variability, particularly in terms of coral life forms, for the validation exercise.

Volunteer training programme

Greenforce operates four 10-week phases a year to the Banggi project, each with a maximum of 16 volunteers.

Participants undergo training for the first three weeks of the phase. British Sub-Aqua Club dive training is followed by an intensive science schedule encompassing coral reef biology and ecology, reef fauna and flora recognition (with identification to species for target organisms) and survey techniques. Volunteers are then tested on their identification skills with the pass mark set at 80%. A written or slide test of potentially 45 fish families and 57 target species is undertaken. Coral life-forms and invertebrate groups are tested 'in situ' by snorkelling and diving respectively.

A pass mark must be achieved before the volunteer can survey a particular subject. At least 2 practice surveys are carried out for each type (fish, benthic substratum) before actual surveying begins. Field identification of reef organisms was based on the following texts: Allen (1997), Eichler and Myers (1997), Leiske and Myers (1994), Myers (1999) and Veron (1986).

Survey techniques

The survey methods generally followed Reef Check techniques (Hodgson 1999b), but consisted of two 20 m transects rather than the standard four 20 m at one depth band. In addition, more detail was incorporated into either the fish censuses or benthic substratum estimations for GCRMN data collection (English et al. 1997). Two 20 m survey lines, with a 5 m gap in between were secured to the study reef between 3 and 5 m below chart datum. Polypropylene line with knots (Brennan bowline) tied every 0.5 m was used. A separate loop of different coloured string was tied at 5 m intervals along the line to delineate the fish census blocks.

Fish censuses

A pair of divers recorded the number of selected reef fish types (families or species) present in a 25 m^2 area (5 m along the line and 2.5 m either side) between the reef and the sea surface for a period of three minutes. The divers then swam slowly to the 5 m mark and repeated the process for the next block until the line was completed. Of each buddy pair, one volunteer recorded Reef Check groups whilst the second surveyor documented target and non-target species. Reef Check fish consisted of all Chaetodontids, Lutjanids, Haemulids, Serranids, large Scarids (>20 cm TL) and three indicator species: *Bolbometopon muricatum*, *Cheilinus undulatus* and *Cromileptes altivelis*. The target list was comprised of 57 species from 19 reef fish families representing the major trophic groups (Harding et al. 2001). The list was compiled from the most common species recorded over the first six months surveying at permanent sites in the region (Harding et al. 2000) and followed the recommendations set out in English et al. (1997). Additionally, the 'fish target' diver recorded the number of non-target species observed along the lines. The absolute number of each Reef Check or target species was recorded unless a particular species became too numerous where abundance categories (20-50, 50-100, >100 individuals) were used. Lastly, a direct comparison census was completed for both Reef Check and GCRMN surveys where a volunteer and staff member recorded the same reef fish on the same dive. All surveyors were not allowed to discuss their results until the data had been transferred to the survey forms.

Benthic cover estimation

The Reef Check line-point technique was used for this study. Substratum type was recorded under each 0.5 m point along two 20 m lines with the first point representing zero and a total of 40 points on each line. Reef Check uses a total of 10 categories for benthic substrata (Hodgson 1999b) whilst GCRMN methods further divide the substrata into 30 different groups (English et al. 1997). All surveyors recorded the substrata using the GCRMN categories and the Reef Check values were later calculated by combining selected GCRMN codes. Categories and codes are listed in the aforesaid texts.

Data analysis and presentation

Benthic substratum data are presented as percentage cover in all figures but was transformed by arcsin prior to statistical analyses (Zar 1984). Comparisons between treatments were performed using two-sample t-tests on transformed data. Fish census information was compared using Czekanowski's proportional similarity index (see Sale 1991, Sale and Douglas 1984) and also by Wilcoxon's test for matched pairs for direct comparison data.

Results

Benthic cover

Comparison between volunteers (V) and staff (S) in Week 1 indicates that some categories differed in percent cover estimation when using the more general Reef Check codes (Fig. 2; data values (means +/- SD) are available from the authors). Values for hard coral (HC), sponges (SP) and reef rock (RC) all differed significantly (two-tailed t-test; $p < 0.05$; Table 1). Volunteers recorded slightly less hard coral cover and more rock than staff in Week 1 (Fig. 2). This trend was also present in Week 4 but to a lesser degree and was not significant ($p > 0.05$) for any Reef Check categories (Table 1). All surveyors recorded a significant increase in macroalgal cover (FS) between Weeks 1 and 4.

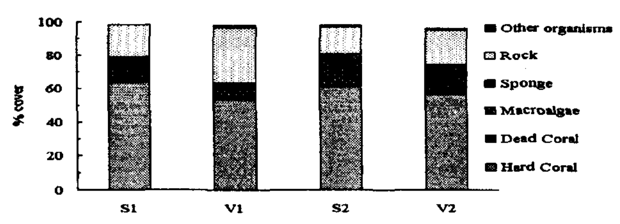

Fig. 2. Reef Check benthic cover estimates by staff and volunteers over a three-Week period (mean values). Where: S1 = staff, Week 1; V1 = volunteers, Week 1; S2 = staff, Week 4; V2 = volunteers, Week 4.

Analysis of the data collected using GCRMN categories also suggests differences between staff and volunteers in Week 1 (Figs. 3a and 3b). However, only two of the twelve coral life forms recorded were significantly different (Table 1; $p < 0.05$): *Acropora* submassive (ACS) and coral encrusting (CE). Both life forms were under-estimated by volunteers, particularly ACS. The total amount of *Acropora* life forms recorded by volunteers also differed significantly from staff.

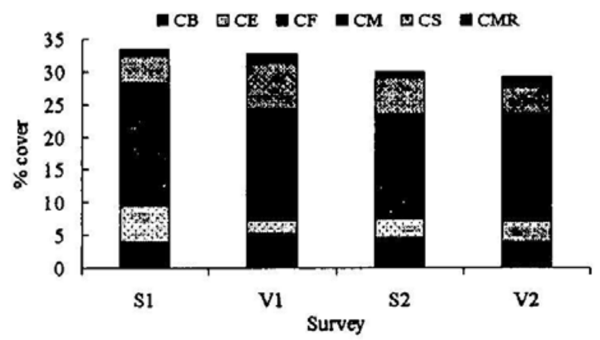

Fig. 3a. GCRMN *Acropora* life-form estimates by staff and volunteers in Weeks 1 and 4 (see Fig. 2 caption for survey details).

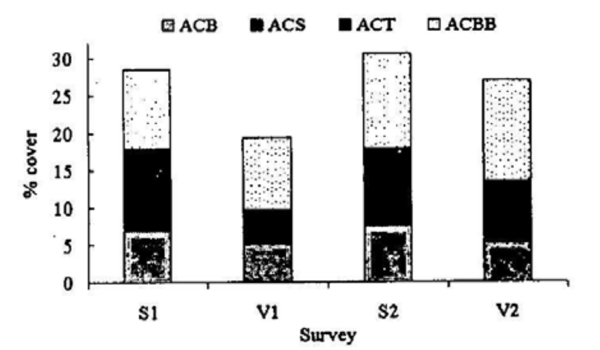

Fig. 3b. GCRMN Non-*Acropora* life-form estimates by staff and volunteers in Weeks 1 and 4 (see Fig. 2 caption for survey details).

By Week 4 the disparity between staff and volunteers was considerably less. Table 1 indicates that no significant differences were found between volunteers and staff for any of the GCRMN substratum categories during the second set of surveys. Again, volunteers recorded a lower mean percentage for total hard coral (Fig. 2) and total *Acropora* life forms (Fig. 3a.) but these were not statistically different from the reference values.

Intra-group comparisons between Weeks 1 and 4 generally support the preceding statements regarding volunteer data. Very few significant differences ($p < 0.05$) were found between the two staff data sets, the exceptions were foliose and encrusting coral (CF and CE) and macroalgae (MA). Conversely, a larger number of categories differed significantly for volunteers between the survey weeks but not between staff and volunteers within Week 4 (Table 1). Categories with the highest significance were reef rock (RC), coral massive (CM) and macroalgae (MA).

Table 1. Two-tailed t-test results (p values) for comparisons between benthic data sets collected by staff and volunteers. Where: n.s. = not significant; n/a = not applicable.

Benthic Code	Staff vs. Volunteers		Week 1 vs. Week 4	
	S1 * V1	S2 * V2	S1 * S2	V1 * V2
HC	**0.0043**	(0.083)	n.s.	**0.016**
FS	n.s.	(0.057)	(0.053)	**0.0031**
SP	**0.0122**	n.s.	n.s.	**0.039**
RC	**0.009**	n.s.	n.s.	**<0.0001**
OT	**0.0017**	n.s.	n/a	n.s.
ACB	n.s.	n.s.	n.s.	n.s.
ACS	**<0.0001**	n.s.	n.s.	**0.02**
ACD	n.s.	n.s.	n/a	n/a
ACT	n.s.	n.s.	n.s.	n.s.
ACBB	n.s.	n.s.	n.s.	**0.016**
Σ *Acropora*:	**0.0012**	n.s.	n.s.	**0.0012**
CB	n.s.	n.s.	n.s.	n.s.
CE	**0.013**	n.s.	**0.047**	n.s.
CF	n.s.	n.s.	**0.028**	**0.033**
CM	n.s.	n.s.	n.s.	**<0.001**
CS	(0.059)	n.s.	n.s.	**0.037**
CMR	n.s.	n.s.	n.s.	n.s.
Σ N-*Acropora*:	n.s.	n.s.	n.s.	n.s.
AA	n.s.	(0.072)	n.s.	n.s.
MA	n.s.	n.s.	**0.0023**	**0.0019**

Reef Fish Censuses

Census data was firstly checked for any correlation with the factors of underwater horizontal visibility and dive order. Both variables were not significantly correlated with the total number of target species or the total number of individual fish recorded by surveyors (Spearman's rank correlation; $p > 0.05$). The 10-15 minute interval between diver pairs was deemed sufficient to enable fish to resume 'normal behaviour' (see Fowler 1987).

Fish targets

Volunteers recorded a total of 24 and 26 target species during census 1 and census 2 respectively whilst staff recorded 18 and 20 species. Totals for the mean number of species of target and non-target reef fish recorded by surveyors are presented in Fig. 4. The mean number of target species recorded by the scientific staff was higher than volunteers in both censuses. Means were significantly different in census 1 but not in census 2 (two-tailed t-test on log transformed data; $p < 0.05$). Volunteers recorded over 75% of the number of target species seen by staff on both censuses (Table 2). The mean number of target and non-target species identified was higher in census 2 for both groups of surveyors (Fig. 4). Staff recorded significantly more non-target species than volunteers in both censuses (two-tailed t-test on log transformed data; $p < 0.05$) with very few non-targets being seen by volunteers in Week 1 (Table 2).

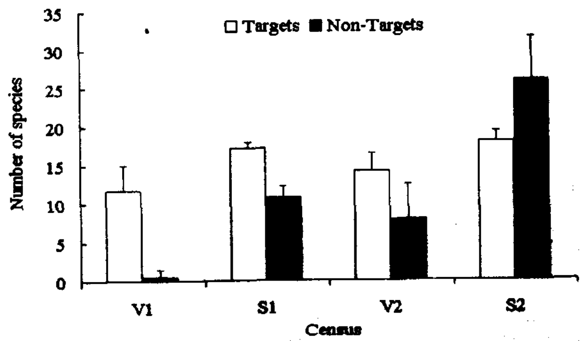

Fig. 4. Number of reef fish species recorded by staff and volunteers (mean values + s.d.). Where: S 1 = staff census 1; V 1 = volunteer census 1; S 2 = staff census 2; V 2 = volunteer census 2. (Staff: n = 2; Volunteers n = 15).

Table 2. Percentage of target and non-target reef fish species recorded by volunteers on censuses compared to staff.

Census	Target species	Non-target species
Week 1	75.27	8.89
Week 4	78.52	30.26

To compare the similarity of counts of targets species Czekanowski's proportional similarity index (SI) was calculated for all pair-wise combinations of volunteers within a census. Data for Caesionids were not included in the comparisons as the family is difficult to census and schools may be moving between the study site and the fringing reefs of the nearby island (Cabanban pers. comm.). Consistency within volunteers was then compared to SI values calculated by pairing volunteer counts with surveys completed by staff during the same census. Fig. 5 indicates that consistency both within volunteers (VV) and between volunteers and staff (VS) increased over the study period. For the latter, mean values increased from 0.651 in census 1 to 0.754 in census 2 representing a 10.3% increase in consistency over three weeks of surveying.

Direct Comparisons

Two direct comparisons between staff and volunteers were completed during each census. A single comparison was also completed by the two scientific staff just prior to the start of census 2 as a control. Analysis of the counts revealed no significant differences between staff and volunteers on all four dives (Wilcoxon matched pairs; $p > 0.05$). However, one survey in census 1 was close ($p < 0.1$) and was marginally significant when tested parametrically (paired t-test on log (x+1) transformed data: $p = 0.048$).

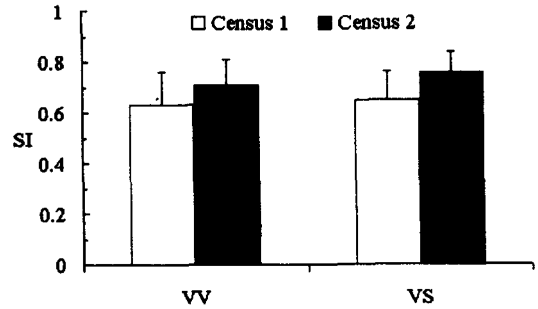

Fig. 5. Similarity Indices (SI) for comparisons of target fish censuses by volunteers and scientific staff (mean values + S.D.). Where VV = volunteer consistency; VS = volunteer vs. staff consistency.

Comparison of fish counts using Czekanowski's proportional similarity index (SI) revealed that the similarity between volunteers and staff on the same survey dive increased markedly from 0.626 in census 1 to 0.795 in census 2, an increase in consistency of 16.9%. Direct comparison for staff produced an SI of 0.858.

Reef Check fish censuses

Of the reef fish selected by Reef Check, divers recorded only Chaetodontids, Serranids and Scarids. Comparison of the number of counts for these families and for selected species within them revealed no significant difference between staff and volunteers (two-tailed t-test on log (x+1) transformed data; $p > 0.05$). Direct comparisons for Reef Check species produced high similarity indices for both pairs on each census suggesting that Reef Check fish are accurately recorded from the first week of surveying. Mean SI values were 0.901 in census 1 and 0.899 in census 2.

Discussion

The results presented here represent the first published validation assessment of volunteers undertaking GCRMN and Reef Check survey techniques in South-East Asia. Previous validation studies for volunteer based surveying programmes have been undertaken in the Caribbean region (Mumby et al. 1995) and East Africa (Darwall and Dulvy 1996, Roxburgh 2000) for benthic cover and fish censuses.

Benthic Cover

Benthic cover estimates by volunteers differed from the reference (staff) estimates in Week 1. Volunteers significantly over-estimated reef rock at the expense of encrusting corals and sponges. By Week 4 the trend was still present but not significant. After intensive training and the completion of practise surveys the volunteers estimates differed by some 10 % for the two main cover categories found on coral reefs. Data collected during the first week of surveying should be either be discarded or subject to a correction factor if the deviation is constant.

Repetition of the line point validation should indicate whether this phenomenon is common to all teams of volunteers during the first week.

When using the more detailed GCRMN categories, volunteers identified most coral life-forms correctly in Week 1. However, one category; *Acropora* submassive (ACS), was mistaken for a submassive coral (CS) because this *Acropora* species does not follow the common pattern of having obvious terminal and radial polyps. A feedback session with the volunteers after the surveys in Week.l corrected this error. Subsequent comparison of estimates in Week 4 showed that the identification of coral life-forms and other' GCRMN' categories ,had -improved. significantly:

Some temporal changes in benthic Giver 'were also apparent. Estimates for macroalgae significantly increased - over the study period, which in turn, could influence the cover of other life forms such as encrusting or massive corals or sponges. Loosely attached clumps of *Padina* spp. were observed between corals in Week 4, which were not noted in the first survey.

Another factor that could alter cover estimates is if the survey line has moved slightly between surveys so that the point is over a different type of substratum. Sea state and currents can have an influence by slightly moving the transect line in the swell or water flow. The lines were left - *in situ* between the surveys weeks.

Reef fish censuses

Volunteers had no problem in accurately recording the reef fish specified by Reef. Check. Divers were not looking for many families or species and of these only a: few were recorded on surveys. In contrast, divers recording fish' targets for GCRMN were •potentially counting up to 54 species (Caesionids excluded) although the maximum number of target species seen at the study site was considerably less.

In Week I a number of reef fish were misidentified by volunteers, which could have increased the total number of target species recorded. The latter value increased for both staff and 'volunteers between the -two censuses suggesting that more species were actually recorded in the repeat visit. Sale and Douglas (1981) also recorded an increase in the number of species .on repeat visits to sampling sites.

After three weeks volunteers were, on -average, recording 78% of the targets seen by the scientific staff but far fewer non-target species. The largest improvement was shown by direct comparison surveys between staff and volunteers. Two volunteers consistently saw fewer target species than the rest of the team further justifying the notion of discarding data in some cases. An alternative is to allow volunteers to specialise .in a particular field of surveying but this could lead to a loss of interest and be logistically more difficult (Darwall and Dulvy 1996). .

Precision of the volunteers' data compared.10 staff generally improved over the study period. A previous study in Tanzania (Darwall and Dulvy 1996) measured the- improvement .in precision for individual divers on repeat surveys as 12.8% over a five-week period. For this study, which compared a mean similarity index for all divers (volunteers or staff) between survey periods, the. increase in precision was along similar lines: 10.3% over three weeks.

Observer bias is one factor that should be minimised.. when carrying out visual censuses. Some of the variation in counts may be related to the. surveying 'technique of having a pair of divers in tandem recording the same 5 m wide belt. The position of each diver (inner or outer on the reef slope) may influence the number of species and individuals of reef fish recorded: A positional bias was reported for manta tow surveys (Fernandes et al. 1990).

The use of volunteers in coral reef surveys is a viable option particularly when the level of resources available to complete the task is low and when the goals are designed to meet the abilities of the trainees. Volunteer programmes can generate a large amount of information over a short time period at minimal cost to the host country. However, each monitoring programme should be designed with a specific question or purpose 'in mind. Typically, management decisions are not made based on small changes in the abundance of individual species. If volunteers are to be trained to differentiate coral growth forms (e.g. *Acropora)* there should be a valid ecological or management reason to do so.

This study has shown that recently trained volunteers are able to collect relevant information using both Reef Check and GCRMN survey techniques for benthic cover estimation and fish censuses. Nonetheless, the first few surveys should always be used to remedy potential problems and misidentifications 'whilst allowing volunteers to gain . valuable surveying experience. GCRMN techniques should not come into play until the surveying programme is at least two or three weeks old. Most volunteers can reliably use the more detailed benthic classification of GCRMN after several weeks of training, with, regular monitoring -and feedback sessions. Depending on 'the question of.interest, the 75% level attainable by volunteers attempting GCRMN species level monitoring of target fish may or may. not be useful.

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References

Allen GR (1997) Marine Fishes of Tropical Australia and South-East Asia. Western Australian Museum, Perth: 292 pp.

Brown E (1999) Long-term monitoring of coral reefs on Maui, Hawaii and the applicability of volunteers. In:

Maragos JE, Grober-Dunsmore, R. Proceedings of the Hawaii coral reef monitoring workshop: 131-146.

Darwall WRT, Dulvy NK (1996) An evaluation of the suitability of non-specialist volunteer researchers for coral reef fish surveys. Mafia Island, Tanzania – A case study. Biol Cons 78: 223-231.

Eichler D, Myers RF (1997) Korallenfische Zentraler Indopazifik 1st Ed. Jahr-Verlag GmbH & Co., Hamburg, Germany.

English S, Wilkinson C, Baker V (eds) (1997) Survey manual for tropical marine resources. 3rd Ed. Australian Institute of Marine Science, Townsville, Australia.

Erdmann MV, Mehta A, Newman H, Sukarno (1997) Operation Wallacea: Low-Cost Reef Assessment using Volunteer Divers. Proc. 8th Int Coral Reef Symp. 2: 1515-1520.

Fernandes L, Marsh H, Moran PJ, d Sinclair D (1990) Bias in manta tow surveys of *Acanthaster planci.* Coral Reefs 9: 155-160.

Fowler AJ (1987) The development of sampling strategies for population studies of coral reef fishes. A case study. Coral Reefs 6: 49-58.

Halusky JG, Seaman Jr. W and Strawbridge EW (1994) Effectiveness of training volunteer divers in scientific documentation of artificial aquatic habitats. Bull Mar Sci 55(2-3): 939-959.

Harding SP, Lowery CE, Colmer M, Oakley SG (2000) A preliminary species check-list of reef fish for the Banggi Channel, Pulau Banggi, Sabah, Malaysia. Proceedings of the Sixth Biennial Borneo Research Conference, Kuching, Sarawak, Malaysia: 105-125.

Harding SP, Lowery CE, Wesson H, Colmer M, Daw TA (2001) Pulau Banggi Project for Coral Reef Biodiversity: 1st Annual Report (July 1999 – September 2000). Greenforce report to Sabah Fisheries Department: 67 pp.

Hodgson G (1999a) Reef Check Global Survey Program: the first step in community-based management. In: I Dight, R Kenchington, J Baldwin (eds). Proc. Int. Tropical Marine Ecosystems Symposium, Townsville, Australia, November 1999: 321-326.

Hodgson G (1999b) A Global Assessment of Human Effects on Coral Reefs. Mar. Poll. Bull. 38(5): 345-355.

Hodgson G (2000) Coral Reef Monitoring and Management Using Reef Check. Integrated Coastal Zone Management. 1(1): 169-176.

IOC-UNEP-SPREP (1994) Training course on coral reef monitoring and assessment. UNESCO-IOC Training courses reports, Cook Islands.

Lieske E , Myers RF 1994 Coral Reef Fishes: Indo-Pacific & Caribbean. HarperCollins Publishers: 400 pp.

Mackney P, Spring N (2001) The Earthwatch perspective on volunteers and data validity. In: Moore PG (ed) Developing and sharing best-practice in marine-related fieldwork. Occasional publication No. 8. University Marine Biological Station Millport, Isle of Cumbrae. KA28 0EG, Scotland: 37-41

Mumby PJ, Harborne AR, Raines PS , Ridley JM (1995) A Critical Assessment of Data Derived from Coral Cay Conservation Volunteers. Bull Mar Sci 56(3): 737-751.

Myers RF (1999) Micronesian Reef Fishes: A field guide for divers and aquarists, 1st Ed. Coral Graphics, Guam, USA: 298 pp.

Roxburgh T (2000) Checking Reef Check in Tanzania. Reef Encounter 27: 21 pp.

Sale PF (ed) (1991) The ecology of fishes on coral reefs. Academic Press, San Diego, CA.

Sale PF , Douglas WA (1981) Precision and accuracy of visual census technique for fish assemblages on patch reefs. Environ Biol Fishes 6: 333-339.

Sale, PF , Douglas WA (1984) Temporal variability in the community structure of fish on coral patch reefs and the relation of community structure to reef structure. Ecology 65: 409-422.

Schmitt EF, Sullivan KM (1996) Analysis of a volunteer method for collecting fish presence and abundance data in the Florida Keys. Bull Mar Sci 59(2): 404-416.

Veron JEN (1986) Corals of Australia and the Indo-Pacific. University of Hawaii Press, Honolulu: 644 pp.

Wells S (1995) Reef Assessment and monitoring using volunteers and non-professionals. TMRU, University of York, and Coral Cay Conservation. Rosenthial School of Marine and Atmospheric Science, University of Miami, USA: 56 pp.

Wood EW (1979) Ecological Study of Coral Reefs in Sabah. World Wildlife Fund, Project Malaysia Report 15: 166 pp.

Zar JH (1984) Biostatistical analysis. 2nd edition. Prentice-Hall,Englewood Cliffs, New Jersey: 718 pp.