

**Baseline data analysis as a tool for predicting the Conservation Value of coastal habitats
in East Asia**

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Abstract

Coral Cay Conservation (CCC), a UK based not-for-profit organisation, operates using teams of international volunteers to conduct coral reef and tropical marine resource assessments in order to provide a baseline of data to facilitate marine resource management. This *modus operandi* provides the resources necessary to conduct a detailed study at minimal cost to the host country partners.

This paper introduces a technique of data analysis to define the conservation value of the shallow (< 30 m) coastal environment. All data initially undergoes multivariate analysis to define discrete benthic habitat classes using the methods described by Mumby and Harborne [1]. Subsequent analysis of benthic and reef fish data in terms of biodiversity and reef health indices allows spatial comparison of sites of differing conservation value and the geographic delineation of areas suitable for Marine Protected Area status.

Keywords: biodiversity, conservation value, baseline survey data, coral reefs, conservation management rating, marine protected areas.

Introduction

The intrinsic value of ecosystems to the global environment is immense, with ecosystems providing vital functions for the regulation of the global environment [2-4]. Biodiversity levels have been widely used as indicators of conservation value [5-6]. Moreover, biodiversity is known to influence ecosystem functioning for terrestrial systems [7-9] and is now similarly under investigation for aquatic systems [4].

The economic valuation of an ecosystem's functions and services is also now well established [10-11] and is becoming an increasingly more important tool in the designation of protected areas in both the terrestrial and marine context.

Conservation value is a commonly used term in the field of tropical marine conservation and coastal zone management [12-13]. Coral reef conservation value has been related to fisheries potential [14], the biodiversity of corals, invertebrates and reef fish [15] and the habitat available for rare or endangered species. For coral reef systems the concept of economic valuation has been well documented by Cesar [16] for a range of locations and case studies whilst Cesar et al. [17] concisely put forward the economic case for conserving coral reefs. Other conservation – related values cited for coral reefs include aesthetic value [18], naturalness, uniqueness, accessibility, and representativeness [19].

A number of studies have used estimates of coral reef conservation value to decide both the areas that require protection and the degree of zoning needed [12,13,15]. The latter study emphasised that measures of coral reef conservation should not be taxonomically based at the species level

for, in this case, hard corals, as many managers do not have much if any expertise in taxonomy. This leads to the suggestion that there is a need for clear and simple tools to define conservation value from the baseline data collected on coral reefs. Edinger and Risk [13] based their conservation values on coral morphology. In this paper we present a conservation management rating (CMR) that is based on coral reef flora and fauna biodiversity and abundance but is expressed as a simple scale to highlight areas that are recommended for designation as Marine Protected Areas (MPA's). The CMR is easy to understand and can be combined with GIS data to accurately show the areas earmarked for conservation. A worked example is presented using data collected by CCC volunteers on the Perhentian Islands, Malaysia in 2003 whilst participating in the Malaysia Reefs and Islands Conservation Project [20].

Coral Cay Conservation (CCC), a UK based not-for-profit organisation operates by using teams of international volunteers to conduct tropical marine resource assessments with the primary aim of providing a baseline of data to facilitate coastal management. This approach provides the extensive resources necessary to conduct a detailed study of the shallow coastal environment at minimal cost to the host country organisation, who form a partnership with CCC. Coral reef projects have been conducted throughout South East Asia since 1995 whilst the initial series of CCC projects began in Meso-America in 1986. A full list of current CCC projects and publications can be viewed on the website (www.coralcay.org)

Methodology

Data Collection

On all CCC marine projects the primary aim is to collect baseline data for use in biological resource assessment and subtidal habitat delineation. CCC's standard baseline survey technique utilises a series of plot-less transects, perpendicular to the reef, starting from a maximum depth of 28 metres and terminating at the reef crest or in very shallow water. Benthic and reef fish surveys are focused on life-forms or families respectively along with a pre-selected number of target genera or species that are abundant, easily identifiable and ecologically or commercially important. The technique has been validated in a peer-reviewed publication [21]. Further details of the CCC baseline survey technique are provided in the MRICP report [20]. In addition to marine resource data CCC also collect information on background oceanographic and meteorological conditions, plus both anthropogenic activities and their subsequent impacts on the marine environment.

Data Analysis

In order to describe the marine habitats within a project area, benthic and substratum data are analysed using multivariate techniques within PRIMER (Plymouth Routines in Multivariate Ecological Research) software [22]. Full details of the analysis procedure involved are not provided here but can be found in recent CCC final project reports [20, 23]. During PRIMER analysis, agglomerative hierarchical cluster analysis is used to classify field data. The cluster analysis produces a dendrogram grouping site records together based on biological and

substratum similarities. Site records that group together are assumed to constitute a distinct benthic class. Characteristic species or substrata of each class are determined using Similarity Percentage (SIMPER) analysis [24]. Finally, the benthic class of each site record is combined with the geomorphological class assigned during the survey to complete the habitat label. The combining of the geomorphological and benthic classes to produce a habitat label follows the format described by Mumby and Harborne [1].

Conservation Management Rating Determination

The establishment of a Marine Protected Area is based on the needs for environmental stability and the socio-economic demands placed upon the local natural resources. Ideally MPA sites should represent the richest and most ecologically important areas present. The definition of a healthy coral reef community is a complex one and one that relies on a number of variables. In this case study, the relative condition and therefore the relative management potential of each surveyed area is defined using a range of univariate indicators. Each of these indicators is calculated for each benthic class, which is in itself, a geographically defined data set. The factors used for each habitat were;

- Mean hard coral cover,
- Total number of benthic targets recorded
- Shannon-Weiner diversity index of benthic targets
- Total number of reef fish targets recorded
- Shannon-Weiner diversity index of reef fish targets

Hard coral cover has been used as a general indicator of reef condition in South East Asia for a number of years [25-26] but does have some limitations [13]. The Shannon-Weiner index accounts for both species proportionality and equitability and is a widely used technique to measure biodiversity. For coral reef studies see Roberts and Hawkins [27], Reigl and Reigl [28] and Hawkins et al. [29].

Results

Hierarchical cluster analysis revealed thirteen discrete benthic classes or habitats in the Perhentian island group [20]. Mean values of each reef condition indicators were calculated across all benthic classes. Each benthic class was then assessed to determine which of its calculated indicators were greater than the mean value. Each survey record assigned to a benthic class was also given a similar rating. For example a score of five on this rating scale equates to the survey record belonging to a benthic class where all of the five reef indicator variables were greater than the mean. Table 1 briefly summarises the major biological characteristics (reef condition indicators) of each defined habitat (benthic class) and rates each habitat in the final column. Values highlighted in bold text exceed the calculated mean value for the variable in that particular habitat.

Each transect surveyed during the CCC baseline technique is comprised of a composite of more than one survey record, each of which may belong to different benthic classes and therefore have differing degrees of reef condition. By splitting each transect into its constituent parts or habitats, and weighting the composition of each transect according to the length of transect

surveyed, it is possible to construct an overall reef condition value, ranging from 0-5, for that transect. The following equation is used to calculate a management value for each transect:

$$V = (I_a / X_a) + (I_b / X_b) + (I_c / X_c) + \dots$$

Where; V = the overall Conservation Management Rating for the transect.

I_a = the number of univariate variables above average of the first habitat (a) on the transect

X_a = the proportion composition of the transect of the first habitat (a)

To facilitate interpretation of the values, the following scale was used; transects with an overall rating > 4.5 = high conservation potential, from $3.5 - 4.5$ = moderate conservation potential and < 3.5 = low conservation potential. Using this ranking system three habitats (5, 10 and 12) have five reef health indicators that are above the calculated mean across all habitats (Table 1).

Using spatial data on the distribution of each survey transect conducted and the overall rating of reef condition calculated above it is possible to plot the geographic position of each survey transect onto a map to show the relative management potential of the surveyed areas (Figure 1). Next using the survey sectors allocated around Perhentian Besar (Figure 2) we can calculate the relative proportion of each rating within each sector (Figure 3). In this case the ratings indicate that sector B1 has equal amounts of each CMR for the transects surveyed in this sector whilst sectors B4 was dominated by high CMR's with no low rating recorded at all.

Discussion

This paper briefly explains the rationale behind defining conservation management ratings for coral reefs in South East Asia using baseline data collected by Coral Cay Conservation. It should be stressed that the technique is still under development and will be revised and improved accordingly. The inclusion of further univariate indicators of reef condition are worth investigating in order to fine tune the technique. Additional variables could include measures of species richness and evenness, coral mortality index [30] and habitat complexity. The latter is taken into consideration to some degree through the recording of both hard coral life-forms and key target genera or species.

Additionally the CMR data presented graphically here was as single points on a geo-referenced image (Figure 1, 2). Further use of remote sensing tools will enable the production of thematic CMR maps for the study regions and the accurate calculation of reef areas that fall into the three ratings.

It should be noted that the CMR's calculated are specific to the study region and to the range of habitat status found there. Comparison between different reef areas on a national or bioregional scale is not yet possible without considerable further development of the technique and of a habitat classification system for the shallow coastal environment of South East Asia.

However on a local scale the current CMR technique can be used as a useful tool to quickly and clearly indicate to decision makers and managers where the priority areas for protection are located in terms of biodiversity conservation value. Remediation and protection efforts should focus on reefs in better condition where these efforts are more likely to succeed [31].

Conversely a high proportion of low conservation management ratings can indicate that a particular part of the reef system is subjected to one or more anthropogenic impacts. Combining this information with both above surface and underwater observations by survey divers of

impacts such as physical damage, coral disease or bleaching and sedimentation can also lead to mitigation measures to minimise or completely prevent these impacts occurring in the future. Mechanically damaged reefs may be able to recover if protected and not subject to other major impacts such as pollution [32]. However it must be stressed that determined and continual management is necessary to follow recommendations through and have a lasting effect on the local environment. The use of local communities to manage their coral reef resources through enforcement practise has been successful in south East Asia in some cases [33-35].

Conclusion

A new and simple technique for calculating a conservation value for coral reefs from baseline data has been introduced and discussed. The Conservation Management Rating is based on a combination of biodiversity and organism abundance and highlights reef areas that are the priority for protection. Mitigation measures can also be introduced into reef areas scoring lower ratings. The technique is still very much in development and a number of further variables to incorporate into the CMR calculation are suggested.

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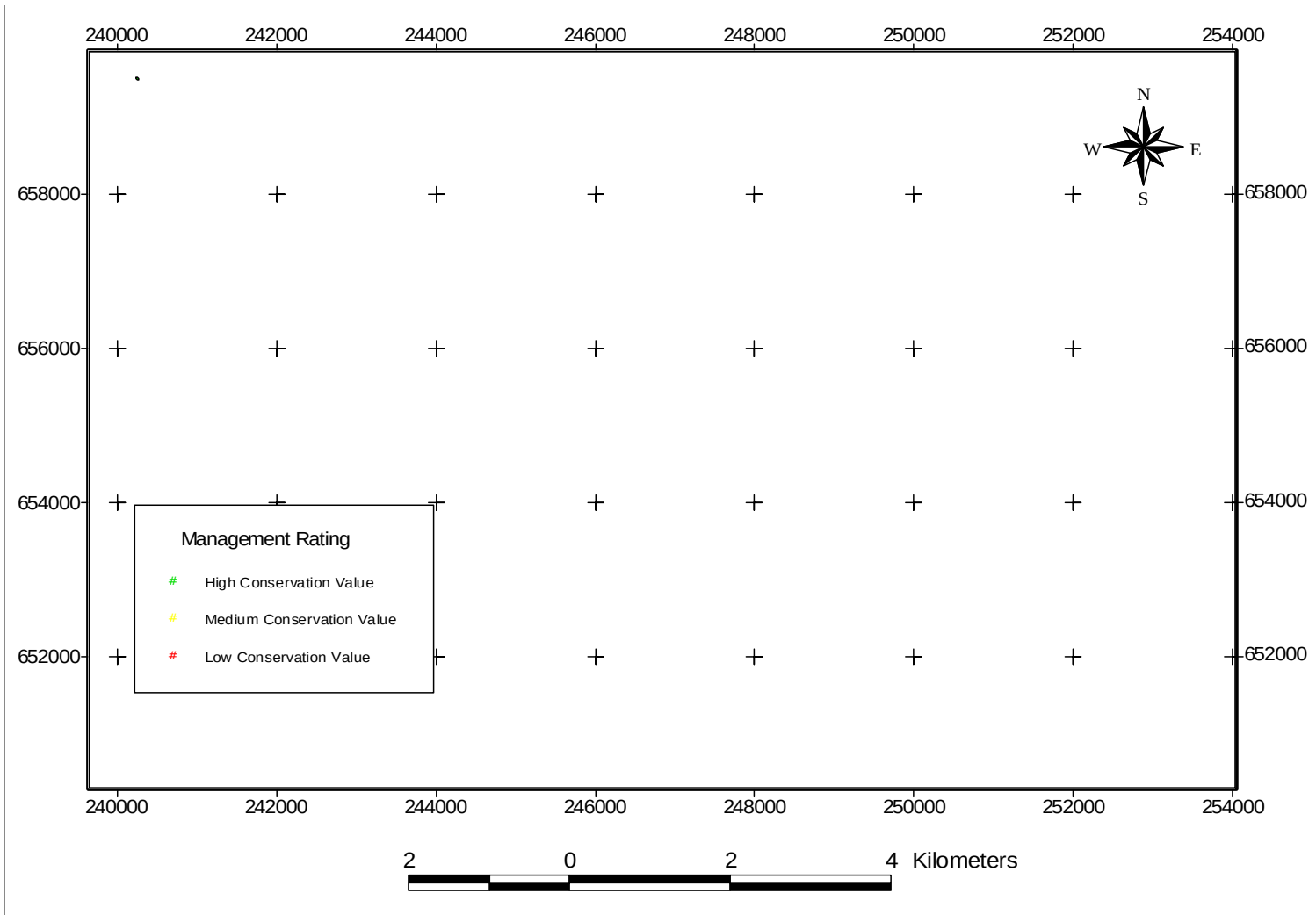


Figure 1

Figure 2

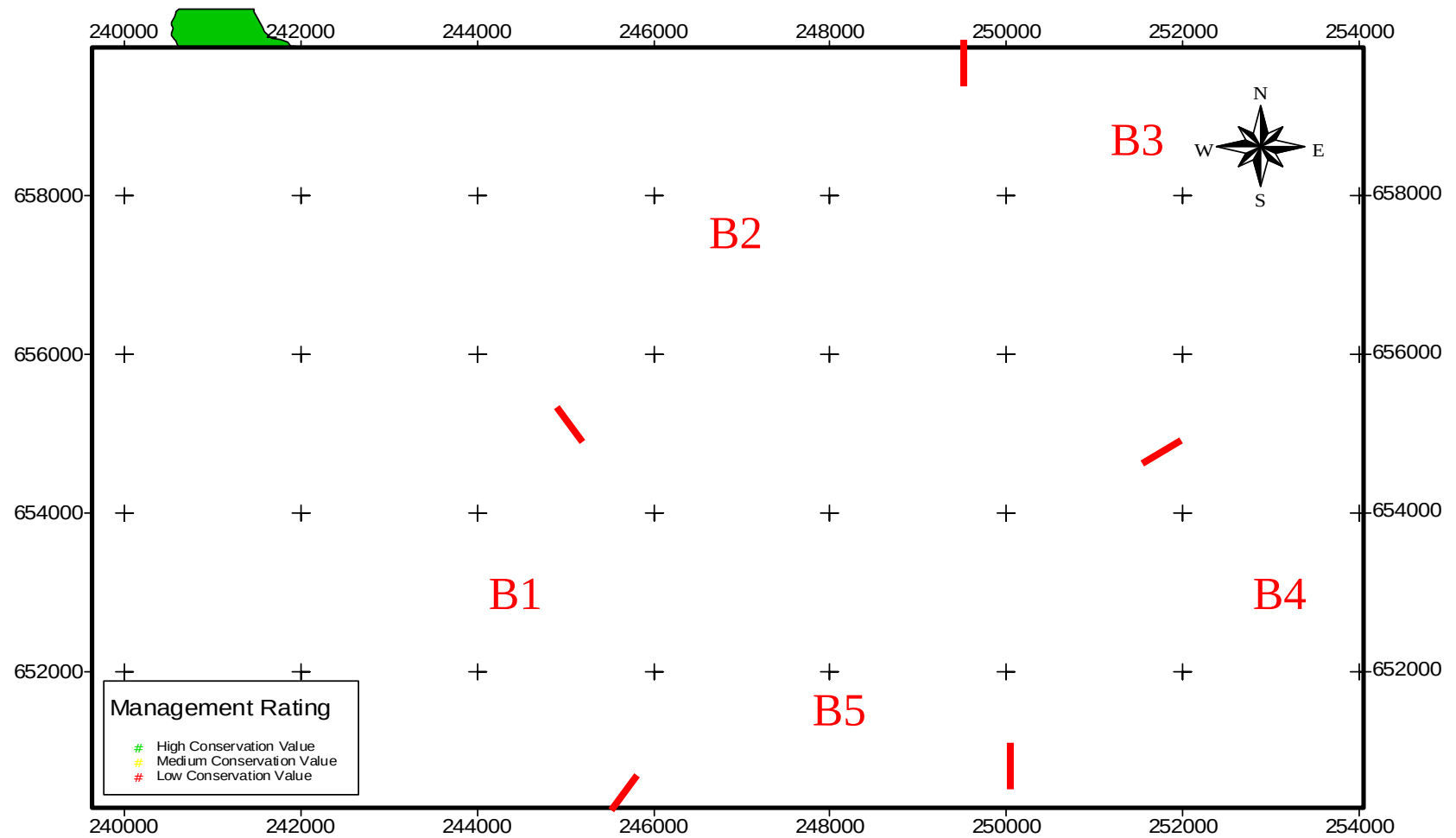


Figure 3

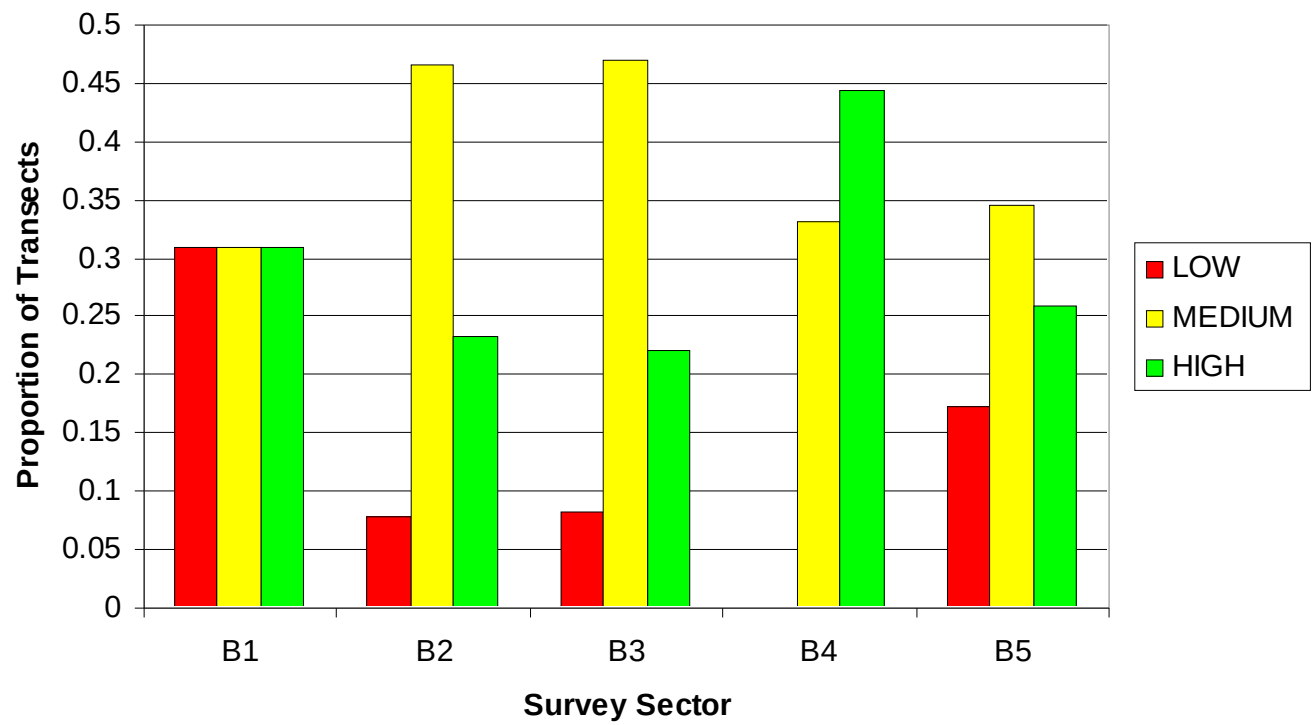


Figure Captions

- Figure 1.** Calculated Conservation Management values for each survey transect completed in the Perhentian Islands, Malaysia during the MRICP
- Figure 2.** Delineation of baseline survey locations and CMR 's around Perhentian Besar into five survey sectors (B1 – B5)
- Figure 3.** Conservation Management Ratings for five survey sectors around Perhentian Besar.

	BENTHIC COVER			ASSOCIATED FISH ASSEMBLAGES		RATING
Benthic Class	No. of species	Log _e Shannon-Weiner Index	Total live hard coral cover	No. of species	Log _e Shannon-Weiner Index	No. of Variables > MEAN
1	5	1.61	0.00	6	1.34	0
2	66	3.19	0.30	44	3.29	1
3	47	3.57	1.19	37	3.28	2
4	47	3.51	1.82	50	3.18	3
5	75	3.70	2.77	61	3.59	5
6	115	4.00	1.01	82	3.83	4
7	41	3.52	1.71	31	2.99	1
8	41	3.38	2.00	23	2.89	1
9	61	3.8	1.71	37	3.23	3
10	112	4.04	1.83	72	3.41	5
11	57	3.68	1.31	42	3.09	1
12	147	4.33	2.06	119	3.85	5
13	67	3.68	1.96	52	3.13	3
MEAN:	67.77	3.54	1.51	50.46	3.16	

Table 1. Calculated values for five reef condition indicators associated with each habitat defined in the Perhentian Islands during the MRICP. Values in **bold** exceed the calculated mean value for the variable in that particular habitat.