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USING OBLIGATE SYMBIONT POPULATIONS AS INDICATORS OF NEAR-SHORE CORAL REEF HEALTH

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Abstract

Obligate symbionts from *Acropora* corals were collected from 10 near-shore coral reef sites along the northern coast of Bintan. The data was used in a Special Symbiont Index (SSI) to assess the "health" of the sites. Increased sediment load from construction resulted in a low diversity and abundance of these obligates at some sites, as the corals were unable to support a representative community. Those sites near river mouths also had low index values. Comparison of these sites with data collected from Singapore highlighted the extreme stress experienced by coral reefs in Singapore, which had very low SSI values. This was expected as Singapore's reefs have been subjected to sediment stress from reclamation and development for more than 30 years. The SSI index was formulated for its ease of use, and minimisation of sampling error and experimenter bias, and is a useful index for environmental impact assessment studies.

INTRODUCTION

The occurrence of organisms in association with corals, whether temporary or permanent, has been well documented (Garth 1964, 1973, 1984; Patton 1966, 1976; Castro 1986). These organisms are mainly invertebrates such as copepods, sponges, flatworms, crustaceans and certain species of fish, such as *Gobiodon*. While not as diverse or as well studied as the coral reef communities in which they are found, they are nonetheless quite numerous. All of these organisms are dependent on the coral for food and shelter, but the obligate symbionts are more specialised - specific species can be found only on specific host coral species, and their lives are tied closely to the health of the host. Literature on the taxonomy and biology of many of these obligates is extensive, but almost no work has been done utilising these organisms as indicators of environmental change.

Impact of human-induced pollution on the marine environment is an important aspect of coastal management. The expanding economies and populations of the Asian countries have led to the rapid and widespread degradation of coastlines. Development for industries and housing (including reclamation), destructive resource use and pollution from badly managed port activities and industrial effluent are the major concerns. In many cases, rapid development does not allow long-term monitoring of the environment for assessing the impact of human encroachment. A relatively quick and easy-to-understand index to pin-point areas of high diversity, and therefore worthy of conservation, would be of great value.

Such an index is proposed in this paper. Data collection is easy and efficient, calculations and mathematics are minimal, and the results are indicative of the state of health of the sites surveyed.

METHODOLOGY

Sampling was conducted at 10 sites, approximately 5 km apart, along the northern coastline of Bintan. Randomly selected coral heads of *Acropora* between 25 and 45 cm in diameter were collected from a 50 m transect, laid perpendicular to the high tide point. The collection method is described in Goh et al. (1990), and the selected coral heads were covered in plastic bags and removed at their base. The bags were then sealed to prevent escape of the symbionts. Widest diameter was recorded, and all symbionts (crabs, shrimps, fish) were removed, identified and counted.

Definition of Obligate Symbiont Fauna

Much discussion still revolves around the precise terminology of the associations between corals and their symbionts. Obligate symbionts are dependent on living coral for their life processes (Castro 1986; Garth 1973). However, for ease of reference, the term obligate refers only to the species that are host-specific (at least to the general level), and found only in the living portions (not at the base) of the coral colony. Since the obligate, host-specific fauna are closely linked to the health of their host, a healthy host (and hence a healthy coral reef) is thus able to support a more diverse community of these organisms. As these symbiont species are more sensitive to changes in water quality than corals, observations on the diversity and density of these associates can therefore give a good indication of the health of coral reefs.

The Special Symbiont Index (SSI)

This index was calculated for each site using the following criteria:

$$SSI = N_{spp} \times MSD \times MRI$$

where N_{spp}=number of obligate species observed at each site, MSD=mean obligate species density (ie. the average number of obligate species per unit length, and multiplied by a factor of 10), and MRI=the mean ratio of infestation of obligate fauna, and is equivalent to the average of the ratio between number of obligates per coral head, and the number of obligates found at the site, and multiplied by a factor of 10.

Using Site 3 (Pasir Lagoi) as an example, the calculations would therefore be:

$$SSI_{site\ 3} = 6 \times \frac{(7/36 + 5/36 + 22/35 + 12/30 + 6/25)}{5} \times 10 \times \frac{(3/36 + 4/36 + 4/35 + 4/30 + 3/25)}{5} \times 10 = 22.02$$

Data from Singapore

Data collected from Singapore by Goh (1987) and Goh et al. (1990), using the same method of collection as in Bintan, was subjected to the SSI (Table 1).

Table 1. Abundance, number of species and diameter of Acropora heads collected from Singapore (Goh 1987; Goh et al. 1990).

Site	Pulau Hatu								Cyrene		Pulau Semakau		Pulau Jong			
Species/Sample No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**	**1**	**Total**	**1**	**Total**	**1**	**2**	**3**	**Total**
Tetralia	1	0	2	1	2	1	1	8	2	2	0	0	2	2	1	5
Cymo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
No. of species	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1
Abundance	1	0	2	1	2	1	1	8	2	2	0	0	2	2	1	5
Diameter (cm)	34	22	28	17	29	35	16.5	181.5	42	42	34	34	47	38	12.5	97.5
No. of coral heads sampled								6		1		1				3
SSI								0.15		0.11		0				0.25
Ranking (within Singapore)								4		5						2

Site	Beting Bembang Besar			Raffles Lighthouse						Terumbu Pembang Laut					
Species/Sample No.	**1**	**2**	**Total**	**1**	**2**	**3**	**4**	**5**	**Total**	**1**	**2**	**3**	**4**	**5**	**Total**
Tetralia	1	1	2	1	1	1	1	2	6	1	2	1	2	2	8
Cymo	0	1	1	2	0	0	1	0	3	0	0	0	0	0	0
No. of species	1	2	2	2	1	1	2	2	2	1	1	1	1	1	1
Abundance	1	2	3	3	1	1	2	2	9	1	2	1	2	2	8
Diameter (cm)	45	36.5	81.5	50.5	63	40.5	63	41.5	258.5	134	40	25	41	40.5	280.5
No. of coral heads sampled			2						5						5
SSI			0.3						0.19						0.1
Ranking (within Singapore)			1						3						6

RESULTS

Six genera of symbionts were collected from 8 sites (Table 2), consisting of 5 crustaceans and one fish. Ranking of the SSI shows that sites 3 (Pasir Lagoi), 1 (Pasir Merah) and 10 (Tanjong Berakit) supported the highest diversity and abundance of symbionts. The sites with poor diversity and abundance were sites 5 (Tanjong Bintan), 4 (Tanjong Sading) and 8 (Pulau Satu). No *Acropora* corals were found at sites 6 and 9.

Table 2. Abundance, number of symbiont species and diameter of colonies sampled at eight sites along the north coast of Bintan, Indonesia.

Site	Site 1 (Pasir Merah)					Site 2 (Tanjong Gemal)						Site 3 (Pasir Lagoi)					
Species/Sample No.	1	2	3	4	Total	1	2	3	4	5	Total	1	2	3	4	5	Total
Coralliocaris	0	0	7	0	7	0	0	0	0	0	0	0	0	5	0	0	5
Pontania	0	2	0	0	2	0	0	2	0	0	2	3	2	0	6	0	11
Gobiodon	0	2	8	2	12	0	1	2	2	0	5	2	0	10	3	2	17
Cymo	0	0	0	1	1	1	1	4	0	0	6	0	1	4	1	2	8
Tetralia	0	0	0	0	0	2	0	0	2	0	4	0	1	0	0	0	1
Teraloides	2	2	2	2	8	0	2	2	0	1	5	2	1	3	2	2	10
No. of species	1	3	3	3		2	3	4	2	2		3	4	4	4	3	
Abundance	2	6	17	5	30	3	4	10	4	1	22	7	5	22	12	6	52
Diameter (cm)	30	20	40	20	110	15	20	25	25	26	111	36	35	35	30	25	161
No. of coral heads sampled					4						6						5
SSI					13.3						12.0						22.0
Ranking					2						4						1

Site	Site 4 (Tanjong Sading)					Site 5 (Tanjong Bintan)						Site 7 (Tanjong Pengudang)					
Species/Sample No.	1	2	3	4	Total	1	2	3	4	5	Total	1	2	3	4	5	Total
Coralliocaris	0	0	0	0	0	0	0	4	0	0	4	0	0	0	0	0	0
Pontania	0	0	0	0	0	2	1	3	0	0	6	0	3	0	2	4	9
Gobiodon	0	0	2	0	2	0	0	0	0	0	0	1	1	2	2	0	6
Cymo	1	2	0	2	5	0	1	1	2	2	6	1	0	0	0	0	1
Tetralia	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	3
Teraloides	0	1	3	2	6	2	2	3	0	0	7	2	2	0	2	3	9
No. of species	1	2	2	2		2	3	4	1	1		3	3	2	3	3	
Abundance	1	2	5	4	12	4	4	11	2	2	23	4	6	4	4	8	26
Diameter (cm)	20	20	22	25	87	19	25	25	25	25	119	30	30	30	25	21	136
No. of coral heads sampled					4						5						5
SSI					3.2						7.2						10.7
Ranking					8						6						5

Site	Site 8 (Pulau Satu)						Site 10 (Tanjong Berakit)												
Species/Sample No.	1	2	3	4	5	Total	1	2	3	4	5	6	7	8	9	10	11	12	Total
Coralliocaris	0	0	5	0	0	5	0	1	0	0	0	0	0	0	0	0	0	0	1
Pontania	2	0	0	0	1	3	0	4	0	2	3	0	0	0	0	0	0	3	12
Gobiodon	0	0	0	1	0	1	0	0	1	1	2	2	0	1	2	2	3	13	27
Cymo	2	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1	1
Tetralia	0	0	4	0	0	4	1	1	0	1	2	0	1	0	0	2	0	2	10
Teraloides	0	0	0	2	0	2	1	0	2	2	0	2	0	2	2	0	2	0	13
No. of species	2	0	3	2	1		2	3	2	4	3	2	1	2	2	2	2	4	
Abundance	4	0	10	3	1	18	2	6	3	6	7	4	1	3	4	4	5	19	64
Diameter (cm)	37	30	30	30	20	147	18	18	20	20	22	25	25	26	30	35	35	35	309
No. of coral heads sampled						5													12
SSI						3.8													12.3
Ranking						7													3

Note: Site 6 (Tanjong Tombak) and 9 (Sungei Sumpat) had no coral reefs near the shoreline.

In a separate study of Bintan reefs, coral cover was recorded at the reefs further from shore, using the line-intercept transect (Dartnall and Jones 1986), but these surveys were not "extensions" of the obligate symbionts study. Whereas the obligate symbiont study was carried out in littoral and sublittoral parts, the transect study was done in much deeper waters. There was no co-ordination between the two groups, which accounts for the inconsistency in results between coral cover and the SSI (Table 3). For example, site 2 (Tanjong Gemal) was ranked fifth using the SSI, but coral cover, recorded at Pulau Rawa was 56.54%, one of the highest for the coastline. Site 1 (Pasir Merah) was ranked highest with the SSI, but the coral cover (at near-by Tanjong Tondang) was very poor. The fact that obligate data for Site 1 (Pasir Merah) was collected from the bay area, while the coral cover data was collected from the fringing reef off Tanjong Tondang, where development of a jetty was in progress, could account for the inconsistent results. On the other hand, this could be an indication of the sensitivity of the obligate fauna to environmental changes. As the corals were subject to increased sediment load, they became less able to support their obligate fauna. Other factors (physical, chemical or geographical), may therefore have caused the (seeming) inconsistency in results from both studies.

Table 3. Comparison between SSI ranking and average coral cover at the nearest site.

Site No.	Location	Average coral cover (%)	SSI ranking
	Tanjong Tondang (near Pasir Merah)	26.75	
1	Pasir Merah		2
	Pulau Rawa (near Tanjong Gemal)	56.54	
2	Tanjong Gemal		5
	Tg. Said (near Pasir Lagoi)	38.85	
3	Pasir Lagoi		1
	Tanjong Maoi (near Pasir Lagoi)	48.49	
4	Tanjong Sading	35.67	8
6	Tanjong Tombak	2.25	-
5	Tanjong Bintan	35.9	6
7	Tanjong Pengudang	46.01	4
8	Pulau Satu	50.61	7
9	Sungei Sumpat		-
10	Tanjong Berakit	51.29	3

Visual observation of the study sites where the obligates were collected showed better correlation with the SSI. The sites that were ranked low in the SSI were observed to have seagrasses and seaweeds dominating the zone between the beach and the reefal zone, while those that were ranked high had good coral growth nearer the shore. Again, physical and chemical factors may have played a major role in determining the "health" of the area. At Sungei Sumpat (Site 9) and Tanjong Tombak (Site 6), no *Acropora* corals were collected as these areas had a very high out-flow of freshwater, which the corals are intolerant too. These areas were therefore deficient in coral growth, but had an abundance of seagrasses and seaweeds.

The Singapore data indicates a highly stressed reef, with very low SSI values compared to those of the Bintan study sites. Among the "better" sites in Singapore were Beting Bembang Besar, Pulau Jong and Raffles Lighthouse. These sites are typically undisturbed, being visited rarely or not at all by fishermen and scuba divers, with little or no development projects on the islands, with the exception of Raffles.

DISCUSSION

The SSI is a simple, easy to use index that requires little experience to implement. It is mathematically simple, and incorporates the necessary variables of diversity (represented by N_{spp} and MRI), and richness (in terms of density, by MSD). The sampling method is relatively easy, and can be done either at low tide, or using snorkelling gear at higher tides. SCUBA gear may be necessary if the reef occurs in deeper waters. Equipment and manpower requirements are thus minimal.

Complete collection of the obligates was possible, regardless of the experience of the observer, because they would cling to the coral even when the colony was removed from water. Sampling error, which is a major cause for variation in other sampling methods (eg. coral line intercept transects (see Mundy 1991), was thus reduced as the entire community was sampled.

Other, more mobile symbionts were excluded from the analysis as the obligates were the only ones that could be 100% removed with the coral head. *Periclimenes* sp. (a shrimp), for example, is very mobile and can escape if the coral head is disturbed. *Chlamys* sp. (a clam), on the other hand, burrows into the skeleton of the coral, and while there was insufficient supporting data, we speculate that this weakens the coral. In fact, it may be that weakened corals have higher densities of this clam, as they would be less able to resist the burrowers. Yet others, like *Porcellana* sp., are usually found at the base of the coral, which may or may not be dead.

The coral reefs of Singapore have come under great anthropogenic stress, with the large scale development of its coastline over the last 30 years. This has resulted in heavy sediment loads of up to 45 $mg \cdot cm^{-1} \cdot day^{-1}$ on the coral reefs (Lane 1991; Low and Chou in press). Light penetration is reduced, preventing the corals from surviving at the deeper depths (Chou 1987). The necessity of expending energy for the removal of sediment from the coral surface imposes further strain on already limited resources. It is hardly surprising, therefore, that the obligate fauna on *Acropora* in Singapore is at such a low level. However, symbionts on other genera that the obligate fauna on *Acropora* in Singapore is at such a low level. However, symbionts on other genera of corals, especially *Pocillopora* and *Pavona*, seem to be quite diverse. This could be due to the higher tolerance level of these genera to sediment stress (Veron 1986).

Two major disadvantages are immediately apparent in the use of the index: it is destructive, as the coral head has to be broken up to remove the symbionts. As such, only small scale samplings would be possible. Accurate identification of these organisms may be difficult, if corals other than *Acropora* are sampled, as the taxonomy and biology of the symbionts of other corals are less well known. As such, the status of these symbionts as obligate, facultative or parasitic may be in doubt. These two difficulties can be overcome by keeping the sample size small, and limiting the obligate species to those that are well documented, such as *Tetralia* sp. and *Gobiodon* sp.

While it is very important that accurate and extensive data be collected for a proper environmental assessment to be made, in many instances this is not possible, either due to shortage of time or trained personnel. Therefore, even though detailed monitoring of the coral reef community (using methods like the line-intercept-transect) is preferable, and would yield more detailed and accurate data, sampling of the obligate fauna can be used on its own for its rapid results and sensitivity to changes in the marine environment.

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