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STATUS OF CORAL REEFS IN THE ASEAN REGION

L.M. Chou[1], C.R. Wilkinson[2], W.R.Y. Licuanan[3], P. Aliño[3], A.C. Cheshire[4], M.G.K. Loo[1], S. Tangjaitrong[5], S. Sudara[5], A.R. Ridzwan[6] and Soekarno[7]

[1] Department of Zoology, National University of Singapore, Kent Ridge, Singapore 0511
[2] Australian Institute of Marine Science, Townsville Queensland 4810, Australia
[3] Marine Science Institute, University of the Philippines, Diliman, Quezon City 1101, Philippines
[4] Department of Botany, The University of Adelaide, Adelaide South Australia 5001
[5] Department of Marine Science, Chulalongkorn University, Bangkok 10330, Thailand
[6] Faculty of Fisheries and Marine Science, Universiti Pertanian Malaysia, 43400 Serdang, Selangor, Malaysia
[7] Research and Development Centre for Oceanology, Indonesian Institute of Sciences, Ancol Timur, Indonesia 11048

ABSTRACT

Monitoring of reefs under the ASEAN-Australia Living Coastal Resources Project over a span of nearly ten years showed that many of the reefs surveyed in the ASEAN region were poor in live coral cover. Based on available data archived at the project's Regional Database Centre in Bangkok, less than 20% of the reefs in the five participating ASEAN countries are in excellent condition (>75% live coral cover). Analysis indicated that the region's reefs could be divided into three distinct groups, all reefs from Thailand (including both the Andaman Sea and Gulf of Thailand), all reefs from Indonesia (including both Ujung Kulong-Indian Ocean and Seribu Islands) and a final group that included the reefs of Malaysia, the Philippines and Singapore. No fixed trends were detected in depth or temporal variation in the regional analysis.

INTRODUCTION

Over 30% of the world's coral reefs are located in the ASEAN region, growing in shallow and reasonably clean waters. Coral reefs are found in all six ASEAN countries, with the largest extent occurring in the two archipelagos of Indonesia and the Philippines. All reef types (fringing, patch, atoll, barrier) are represented in the region. The warm climate, constant nutrient source from land masses, and strong currents favour the development of reefs. Coral reefs are unique marine ecosystems supporting high biodiversity (Veron 1986; Grassle *et al.* 1990) through the tight and efficient cycling of nutrients among associated organisms. The massive limestone framework is built through thousands of years by many different species of hard corals.

Coral reefs are self-sustaining and particularly robust to natural impacts such as typhoons or cyclones, and will normally recover in 10 to 20 years to something that closely resembles the original structure. They will also be resistant to the effects of gradual sea-level rise, as they continually build their own base structure upwards as they grow. They have coped with sea-level rise in the past and should do so in the future (Wilkinson & Buddemeier 1994). However, coral reefs are very fragile to persistent stresses by humans, and reefs in the ASEAN region are showing clear signs of devastation and collapse.

Much has been documented about the significant roles of reefs. The dense concentration of marine species makes them potential candidates for bioactive compounds (e.g. sponges as reported by Thompson *et al*, 1985). Reefs also serve as natural breakwaters, buffering sandy beaches against strong surf. Without them, or when the structure of a dying reef begins to break down, beaches in high energy areas get eroded quickly. This situation will be exacerbated by global warming and the accompanying sea level rise (Buddemeier & Smith 1988; Smith & Buddemeier 1992). Small islands in open seas are most vulnerable. At the same time, reefs provide a source of sand to beaches. Reefs have also been mined for sand and rocks (UNEP/IUCN 1988; Brown 1986).

Throughout the ASEAN region, reefs provide significantly to the economic livelihood of coastal populations. Fish is the major protein source and reefs contribute up to 12% of total fish catch (Munro & Williams 1985; Salvat 1992). The major traditional benefit provided by coral reefs has been in sustainable fisheries. Many peoples and cultures have grown up adjacent to reefs and obtained a large part of their animal protein from fishes, clams, beche de mer, etc. For example, approximately 20% of the animal protein intake for the Philippines comes from coral reef fisheries (Alcala *et al.* 1987). Reefs also provide a sustainable source of rock and sand in areas where these commodities are scarce.

Shorelines behind coral reefs are protected against oceanic waves. Many tropical coasts would be severely eroded without the reefs and large areas of productive mangrove forests and seagrass beds would be washed away. Beaches and coral reefs are also major attractions in tourism, the largest growing sector of many ASEAN economies.

There has been considerable damage to reefs in ASEAN in the last 50 years and the rate of damage is apparently increasing, particularly in the past 10 years. It is probable that about 10% of ASEAN reefs have been severely damaged and it is almost impossible to reverse this declining status. The reefs around Singapore have been extensively reclaimed; reefs in Jakarta Bay have disappeared because of mining or pollution and the reefs of Thailand and the Philippines have largely disappeared under sediment and sewage (Wilkinson 1993). However, most could recover with proper management. Unless urgent measures are undertaken to manage these resources, they will be lost and with them, the enormous potential to generate sustainable income.

Senior marine scientists in the ASEAN countries recognized the severe degradation of their coral reefs. It was thus essential that the coral reefs be examined. A team of experienced ASEAN workers in coral reef research and monitoring formulated the first set of methods for reef assessment as part of the ASEAN-Australia Living Coastal Resources Project (LCR) which was funded by the Australian Agency for International Development (Wilkinson *et al.* 1993).

METHODS OF ANALYSIS

The line intercept transect (LIT) data at the Regional Database Centre in Bangkok consisted of 205,272 records from 942 transects surveyed at 49 locations across the five participating countries (Table 1). The initial summary was to obtain the extent of live coral cover across the ASEAN countries. The live coral cover (i.e. using only the standard LCR lifeform categories for both *Acropora* and non-*Acropora* corals) was calculated as a percentage of the total transect length. The total transect length was calculated as a total of all lifeform lengths excluding WA (water) and DDD (missing data) codes. The extent of live coral cover was then expressed as a percentage of the total number of transects carried out in each country (Table 2).

The data were next summarized according to location, depth and phase (the project had two phases), resulting in 99 location-depth-phase samples. The raw data for the summaries were: cover measurements of the standard LCR lifeform categories expressed as a percentage of the total transect length where the total transect length was computed as described above. Thus, if several reefs were sampled within a given locality, an average lifeform cover was computed for the locality on the condition that if two depths were sampled in each reef, separate averages for 'shallow' (approximately 3m depth) and 'deep' (approximately 10m) transect lines were computed. The depths were approximate because there were some variations used by the different survey teams. For example, the Singapore LITs were done at 3m and 10m depths measured from the crest, but the Philippines/Thailand/Indonesia data were not from the crest because the reefs did not have distinct crest. Separate averages were also computed for resurveyed sites, ie. those before June 1989, which was the end of LCR Phase I, and those after (Phase II). Thus, for a given locality, for example the Singapore Southern Islands, up to four sets of lifeform percentage cover data were included in the analysis:

1. Southern Islands 'shallow' transects surveyed during LCR Phase I;
2. Southern Islands 'deep' transects surveyed during LCR Phase I;

3-4. The equivalent sets in LCR Phase II.

Data on the status of reefs were analysed using Detrended Canonical Correspondence Analysis (Ter Braak 1988). Several authors have diagnosed shortcomings in the LCR-LIT data collection, storage, and analysis. These included inconsistency in the coding of lifeforms and taxonomic identifications (Licuanan 1989; Licuanan & Montebon 1991), and variability due to small changes in the position of the transect line (Mundy 1991). These should be kept in mind when interpreting the results of any analysis.

Table 1. List of the 49 reef locations surveyed in the five participating ASEAN countries.

Country	Location	Country	Location
Indonesia	Seribu Island A	Malaysia	Langkawi
	Seribu Island B		Port Dickson
	Seribu Island C		Pulau Perhentian
	Seribu Island D		Pulau Sembilan
	Seribu Island E		Redang Islands
	Ujung Kulon A		Sabah
	Ujung Kulon B		Sarawak
			Tioman Island
Philippines	Bacuit Bay, Palawan	Thailand	Ang Thong Islands
	Bais, Negros Oriental		Chang Islands
	Batanes		Chumporn
	Bolinao, Pangasinan		Krabi
	Cagayan		Mak Islands
	Calatagan, Batangas		Pattaya
	Cebu		Phang-Nga
	Polillo, Quezon		Pha-Ngan Islands
	Puerto Galera, Mindoro		Phuket
	San Juan, Batangas		Ranong
	Siargao Island, Surigao		Samaesan Island
	Sigangkai		Samet Island
	Turtle Island		Samui Islands
	Ulugan Bay, Palawan		Sattahip
			Satul
Singapore	Southern Islands		Surin
			Tan Islands
			Tao Islands
			Trang

RESULTS AND DISCUSSION

Results of the analysis showed that most of the reefs in the ASEAN region were in poor condition. The two largest areas of coral reefs in the region are in Indonesia and the Philippines. However, scientists in the Philippines estimate that less than a third of their reefs (those in remote areas like Palawan and the Sulu Sea) are in good to excellent condition, with the rest in only fair to poor 'health' (Table 2). The situation is similar in Indonesia. There has also been considerable destruction of the reefs of Thailand. Nearshore reefs like those of the once flourishing reefs around Pattaya Bay have been polluted and damaged by fishing and boating activities. Many reefs around the Gulf of Thailand have been damaged by dynamite fishing, pollution from prawn pond developments and sewage wastes. In the Andaman Sea, pollution and over-fishing is damaging the reefs around Phuket. However the offshore reefs still have relatively high coral cover. On the west coast of Peninsular Malaysia, the reefs have been severely impacted by sediments flowing off the land as a result of land clearing and industrialisation (Mohamed *et al.* 1992). The reefs in Singapore although small in area, are also being degraded as a result of extensive land reclamation (Chua & Chou 1992).

Table 2. Extent of live coral cover (as %) on reefs of five ASEAN countries surveyed by scientists in the ASEAN-Australia Living Coastal Resources project (based only on data achived at the Regional Database Centre).

Country	No. of Transects	Excellent	Good	Fair	Poor
Indonesia	190	2.6%	24.2%	31.6%	41.6%
Malaysia	193	11.4%	52.8%	27.5%	8.3%
Philippines	238	1.3%	7.5%	49.2%	42.0%
Singapore	142	2.8%	9.2%	20.4%	67.6%
Thailand	178	16.9%	42.1%	34.8%	6.2%

Note: Live coral cover is determined on transects placed usually at depths of 3 and 10m on reef slope. The percentage refers to percentage of transects with cover >75% (excellent); <75% and >50% (good); <50% and >25% (fair); <25% and 0% (poor).

Results of the Detrended Canonical Correspondence Analysis (DCCA) showed that reefs throughout the region can be divided into three distinct groups (Fig. 1a). These include all reefs from Thailand (including both the Andaman Sea and Gulf of Thailand), reefs from Indonesia (including both Ujung Kulong-Indian Ocean and Seribu Islands) and a final group that included the reefs of Malaysia, the Philippines and Singapore. Whereas there is some overlap between these groups, they are largely unambiguously defined. The reefs of Malaysia and the Philippines formed less clearly defined sub-clusters within an overall grouping. The reefs of Singapore are largely indistinguishable from the overall Malaysia-Philippines group. Separation into groups is supported by the DCCA analyses and has been confirmed using TWINSPAN and UPGMA cluster analyses.

Groupings of locations arise from similarities and differences in the dominant lifeforms found at each location. In general, the reefs of Indonesia are characterised by high cover of the algal lifeforms (turf - TA, coralline - CA, *Halimeda* - HA and macro - MA), the reefs of Thailand are characterised by high cover of massive corals (CM) and recently-dead coral (DC) lifeforms. The sub-cluster for Malaysia is characterised by a higher diversity of coral lifeforms (as are some locations of Thailand); where branching and tabulate *Acropora* (ACB, ACT) and foliose, encrusting and submassive corals (CF, CE and CS) had a relatively high cover. Soft corals (SC) was the most obvious feature of the reefs of the Philippines. Singapore locations have features in common with the Malaysia and the Philippines subclusters, but have relatively higher abiotic material (sand - S, rubble - R) and algae-covered dead coral (DCA) (Fig. 1b).

To check whether the tendency of locations to cluster together by country is due to biases in the coding method used by the different survey teams, the LIT data used above were reduced to seven categories. The use of these categories (*Acropora* corals, non-*Acropora* hard corals including *Millepora* and *Heliopora*, soft corals, algae, recently dead and algae-covered dead corals, abiotic material, and other fauna) should eliminate most mistakes in coding. Results are summarized in Figs. 2a-b. The main effect of the reduction in the number of lifeform categories is the reduction in the distinction of the country clusters described earlier (Fig. 2a; note that the ordination in Fig. 2 is rotated compared to that of Fig. 1 but this has no bearing on the interpretation). However, the results remain essentially the same. Algae remain the main feature of the Indonesia cluster (Fig. 2b). *Acropora* and non-*Acropora* corals are still higher in cover on the reefs of Malaysia, and some locations in Thailand and the Philippines. The Philippines cluster has both higher soft coral and other fauna cover, suggesting that the two categories can be combined further without any effect on the results. Dead corals remain a feature of the Thailand cluster, but note that the Singapore locations have separated from the other locations (relative to Fig. 1a) because of higher DCA cover.

Fig. 1c is the same ordination as Fig. 1a except that locations are represented by depths (s for shallow and d for deep) rather than by country identifiers. There were no major trends except in the right side of the ordination where there was an apparent grouping of shallow and deep sites in the Thailand cluster indicating that shallower sites had more massive coral (CM) cover while the deeper sites had more dead coral (DC) cover. Similar groupings could be seen in the Indonesia cluster. This suggests that shallow sites had higher algal cover while the deeper ones had more soft corals and other fauna. Such results should be clearer in more detailed analyses of individual transect data, done at the scale of locations and countries. No trends between LCR Phase I and Phase II could be discerned at this regional level analysis of locations (Fig. 1d). Again, more

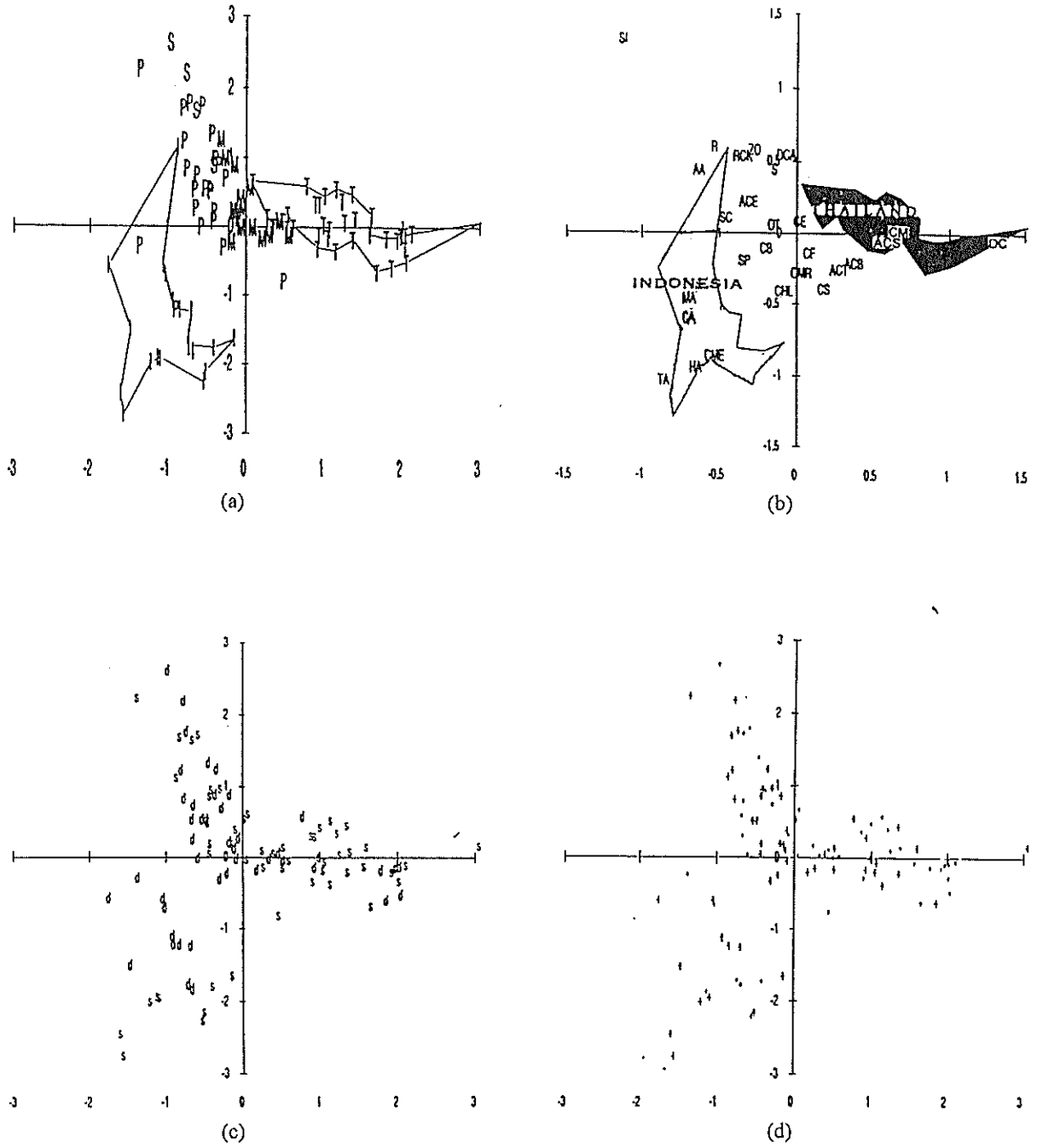

Figure 1. Results of DCCA ordination of LCR line transect data summarised into 99 location-depth-phase samples from the five participating ASEAN countries.

(a) Plot of sample scores from the first two axes of a DCCA analysis with sample points represented by country initials I: Indonesia, M: Malaysia, P: Philippines, S: Singapore, T: Thailand.

(b) The lifeforms most abundant in a given cluster can be identified by matching the position in ordination space occupied by a cluster with corresponding lifeform codes in the same area.

(c) Plot of DCCA sample scores as used in Fig. 1a except that locations are represented by depth (s for shallow sites and d for deep sites).

(d) Same as (c) except points are represented by LCR Phases (+ for Phase I surveys, before June 1989, * for Phase II surveys, after June 1989).

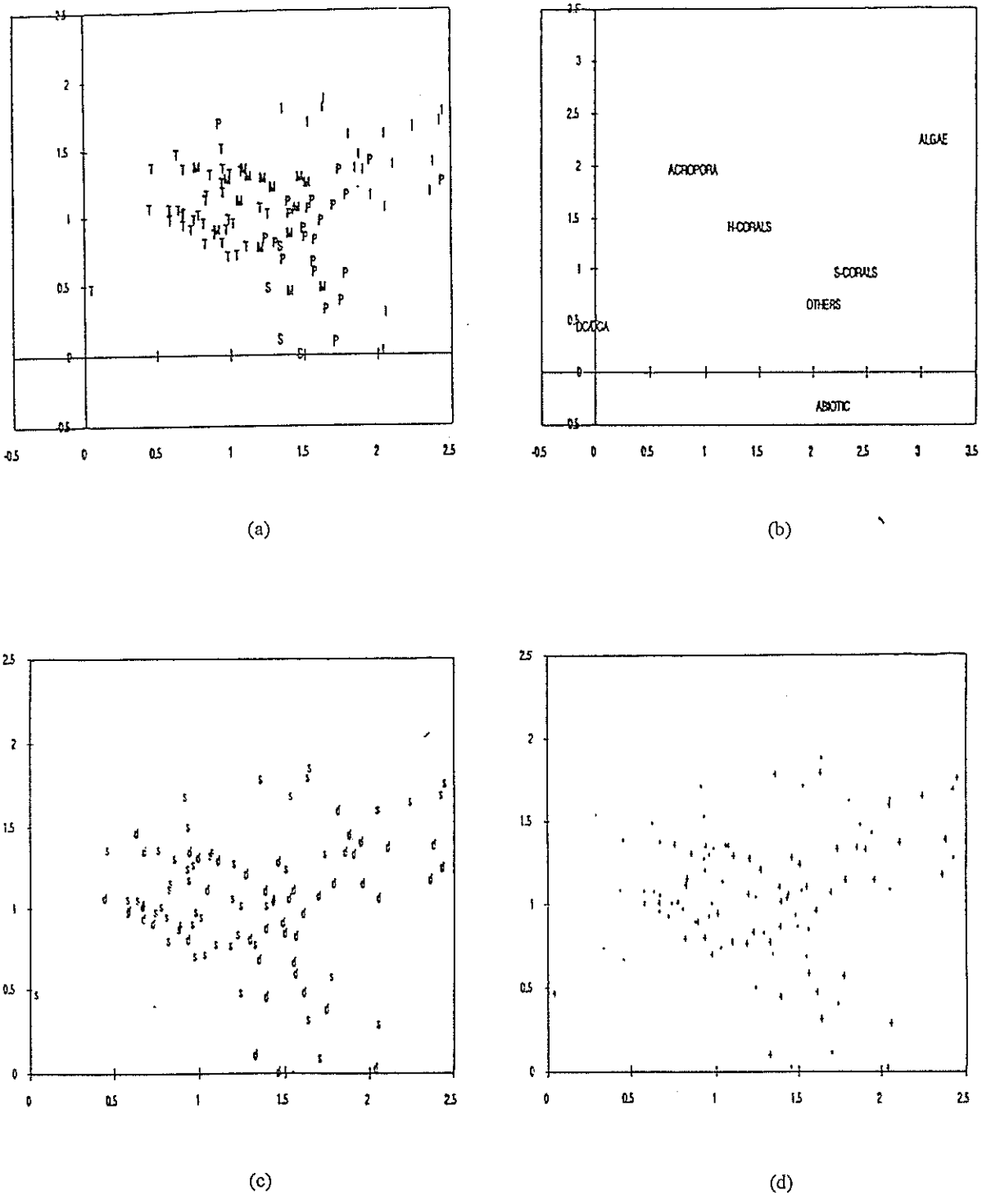

Figure 2. Same as Fig. 1 except that lifeform data used were reduced further by aggregating lifeforms into seven major categories: 1: *Acropora* corals, 2: non-*Acropora* hard corals including *Millepora* and *Heliopora*, 3: soft corals, 4: algae, 5: recently dead and algae-covered dead corals, 6: abiotic material, and 7: other fauna.

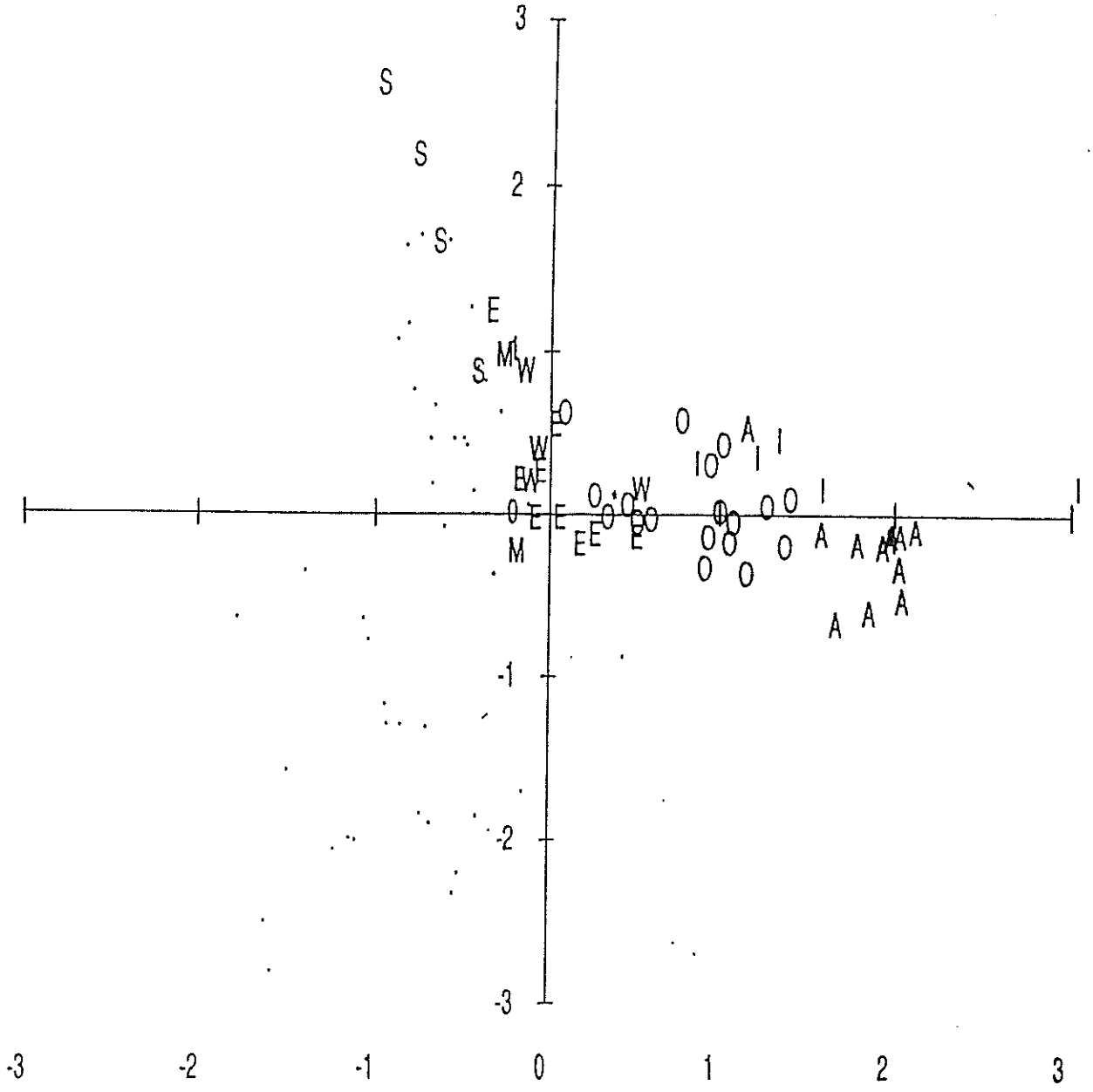

Figure 3. Plots of DCCA sample scores as used in Fig. 1a. Only subregions of Malaysia (W: West coast of peninsular Malaysia, E: East coast of peninsular Malaysia, M: Sabah) and Thailand (I: Inner Gulf of Thailand, O: Outer Gulf of Thailand, A: Andaman Sea) and Singapore (S) are included. Indonesian and Philippine locations are represented by dots.

detailed analyses could indicate otherwise. Similar plots (Figs. 2c and 2d) for the analysis involving the reduction in the number of lifeform show similar trends as in Figs. 1c and 1d, except for the depth related patterns in the Thailand cluster.

When only subregions of Malaysia, Thailand and Singapore were included in the DCCA analysis, finer scale trends, such as patterns related to the locations of the Malaysian sites, as in the slight separation of the east coast of Peninsular Malaysian (E) from the west coast (W) and Sabah (M) sites, were observed (Fig. 3). The same holds for the Thailand sites in the outer Gulf of Thailand (O), the inner Gulf of Thailand (I) and the Andaman Sea (A) locations. These can be further discussed at national-level analyses, preferably using comparable analytical methods as those used in the present work, as seen in earlier work done on the Philippines data (Licuanan & Gomez 1988; Uychaioco *et al.* 1992).

At least three major factors will influence the structure of reefs on a regional scale: evolutionary biogeography of the region; differences in impacts on the reefs; and differences in the overall management of reef systems. These real differences may be confounded or amplified by apparent differences, which result from inconsistencies in the method of data collection (or interpretation of the methods) across the region.

Biogeographic processes will generally be reflected at the level of species (which is beyond the scope of the analysis conducted here) and are thus not going to be detected in a lifeform analysis unless the differences in species are also reflected at the level of lifeforms; this is unlikely for the ASEAN region. Regional differences in the dominant lifeforms may well result from differences in the impacts and management of reefs.

Analyses over time (i.e. between Phase I and II) showed no apparent patterns suggesting that the locations studied had no correlated responses or change over time. This was not surprising considering that different environmental factors considered vary in importance over the locations analyzed. In the analyses of the Philippines data (Licuanan & Gomez 1988), depth effects were expressed only in the sheltered, high embayment reefs. Environmental gradients thus cannot be expected to have consistent effects on lifeform distributions especially when it interacts with other gradients.

Wheareas the methodology of the LIT is well-defined, it is possible that it has not been uniformly applied throughout the region. A disturbing aspect of the DCCA analyses is that the three major groups not only reflect country groupings but also language groupings. English is commonly spoken in Malaysia, the Philippines and Singapore, but is not so readily used in Indonesia or Thailand. It is possible that the production of these three groups in the DCCA analyses is a reflection of different interpretations of the methodology rather than any real differences in reef structure. Support for this proposal is seen in that the discrimination of these groupings is less apparent as the lifeforms are collapsed into major lifeform categories. Major lifeform categories are less likely to be ambiguously or differently defined at a regional level hence a more homogenous grouping of locations is apparent.

If proficiency with the English language is a major factor influencing the results at a regional scale it suggests that future studies should be supported by publication of 'Methods' manuals' in other languages to facilitate understanding and uniformity among research groups.

There is presently no equivalent scale analyses of reefs in the species-rich Southeast Asian region. Independent confirmation of these preliminary results would depend on the availability of more data collected with equivalent methods. Similar regional analyses at the transect/reef level would also be needed but is not possible at present. Indeed, the main value of this work is that it provides a framework by which more detailed analyses within locations and countries may be compared with those of others.

REFERENCES

Alcala, A.C., Gomez, E.D. & Yap, H.T. 1987. Philippine coral reefs: status and human responses to changes. **Resource Management and Optimization** 4: 297-340.

Brown B.E. 1986. Human induced damage to coral reefs. UNESCO Reports in Marine Science No. 40, 179pp.

Buddemeier, R.W. & Smith, S.V. 1988. Coral reef growth in an era of rapidly rising sea level: predictions and suggestions for long-term research. **Coral Reefs** 7: 51-56.

Chua, C.Y.Y. & Chou, L.M. 1992. Coral reef conservation in Singapore - a case for integrated coastal area management. In: Chou, L M & Wilkinson, C.R. (eds). **Third ASEAN Science and Technology Week Conference Proceedings, Vol 6, Marine Science: Living Coastal Resources,** National University of Singapore and National Science and Technology Board, Singapore. pp. 437-445.

Grassle, J.F., Laserre, P., McIntyre, A.D. & Ray, G.C. 1990. Marine biodiversity and ecosystem function. **Biology International 23**, 19pp.

Licuanan, W.Y. & Gomez, E.D. 1988. Coral reefs of the northwestern Philippines: A physiognomic-structural approach. **Proc. 6th Int. Coral Reef Symp.**, Townsville 3: 275-280.

Licuanan, W.Y. 1989. Notes on sampling and analytical strategies for lifeform surveys. In: English, S. (ed) Living Resources of Coastal Areas Newsletter #15. ASEAN-AIMS-AUSAID Living Resources in Coastal Areas Project, Australian Institute of Marine Science, Australia. Pp 5-10.

Licuanan, W.Y. & Montebon, A.R.F. 1991. An evaluation of minimum lifeform transect lengths for classification studies. In : Alcala, A.C. (ed.) **Proceedings of the Regional Symposium on Living Resources in Coastal Areas**. Marine Science Institute, University of the Philippines. pp 75-79.

Mohamed, M.I.H., Azia, H.A. & Ahmad, S.B. 1992. The impact of resort development on the coral reefs o Pulau Redang Marine Park. In: Chou, L.M. & Wilkinson, C.R. (eds.) **Third ASEAN Science and Technology Week Conference Proceedings, Vol 6, Marine Science: Living Coastal Resources.** National University of Singapore and National Science and Technology Board, Singapore. pp 463-470.

Mundy, C. 1991. Determination of sampling strategies for coral reef benthic communities. In : Alcala, A.C. (ed.) **Proceedings of the Regional Symposium on Living Resources in Coastal Areas**. Marine Science Institute, University of the Philippines. pp 81-85.

Munro, J.L. & Williams, D.McB. 1985. Assessment and management of coral reef fisheries: biological, environmental and socio-economic aspects. **Proc. 5th Int. Coral Reef Congr.**, Tahiti 4: 545-578.

Salvat, B. 1992. Coral reefs - a challenging ecosystem for human societies. **Global Environmental Challenge** 2(4) :12-18.

Smith, S.V. & Buddemeier, R.W. 1992. Global change and coral reef ecosystems. **Annual Review of Ecology and Systematics** 23: 89-118.

Ter Braak, C.J.F. 1988. CANOCO-A FORTRAN program for canonical community ordination by [partial] [detrended] [canonical] correspondence analysis, principal component analysis and redundancy analysis (Vers 2.1). Wagenigen, The Netherlands: Agricultural Mathematics Group.

Thompson, J.E., Walker, R.P. & Faulkner, D.J. 1985. Screening and bioassay for biologically-active substances from 40 marine sponge species from San Diego, California, USA. **Marine Biology** 88: 11-21.

UNEP/IUCN 1988. Coral reefs of the world, Volumes 1-3. In: Wells, S.M., Sheppard, D. & Jenkins, M.D. (eds.) **UNEP Regional Seas Directories and Bibliographies**. IUCN Publication Services, Gland and Cambridge. UNEP Nairobi.

Uychiaoco, P.M., Aliño, P.M. & Bermas, N.A. 1993. Some structuring forces and distribution patterns of coral and benthic lifeform communities in the Philippines. **Proc. 7th Int. Coral Reef Symp.,** Guam 1: 575-579.

Veron, J.E.N. 1986. **Corals of Australia and the Indo-Pacific**. Angus and Robertson, North Ryde, 644pp.

Wilkinson, C.R. 1993. Status of coral reefs in Southeast Asia: Threats and Responses. In: Ginsburg, R.N. (ed.) **Proceedings of the Colloquium on Global Aspects of Coral Reefs: Health, Hazards and History**. Rosential School of Marine and Atmospheric Science, University of Miami, Miami. pp. 311-317.

Wilkinson, C.R. & Buddemeier, R.W. 1994. Global Climate Change and Coral Reefs: Implications for People and Reefs. Report of the UNEP-IOC-IUCN Global Task Team on Coral Reefs. IUCN, Gland, Switzerland, pp. 124.

Wilkinson, C.R., Chou, L.M., Gomez, E., Mohammed, I., Soekarno, S. & Sudara, S. 1993. A regional approach to monitoring coral reefs: studies in Southeast Asia by the ASEAN-Australia Living Coastal Resources Project. **Proc. 7th Int. Coral Reef Symp.**, Guam 1:138-143.