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CORAL ASSEMBLAGES OF REEF FLATS AROUND PULAU PARI, THOUSAND ISLANDS, INDONESIA

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Abstract

A spectrum of physical influences, resulting from the reversing monsoons, governs the distribution of corals on reef flats around the Pulau Pari complex of islands in the Java Sea, Indonesia, with greater diversity in the relatively sheltered southern reefs and reduced diversity on the more physically exposed northern reefs. A total of 74 species were recorded on southern reefs as compared with 43 species on the exposed northern reef flats.

The outer reef flats at all sites were dominated by *Acropora* species which showed a distinct zonation pattern. *Acropora pulchra/aspera* species dominated the unconsolidated landward section of the outer reef flat, *Acropora digitifera* occupied the mid-seaward section, while *Acropora hyacinthus* colonised the seaward edge.

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INTRODUCTION

Umbgrove (1929) was the first scientist to study the reefs of the Java Sea in detail. In these early studies Umbgrove recognised the important role of physical factors both in governing the morphology of the islands and the structure of benthic communities or "facies" comprising the reef flats. In 1975 Rosen proposed a similar scheme for reefs in the Indian Ocean, with different coral assemblages reflecting exposure to varying levels of wave energy and light. Other workers have recently shown the importance of exposure to wave energy in controlling reef development (Bradbury & Young 1981, Brown and Dunne 1980, Chappel 1980) and reef diversity (Grigg and Maragos 1974, Dollar, 1982).

Clearly then wave energy may be paramount in determining both reef type and resulting community structure in shallow waters. The present study presents data on the influence of reversing monsoons on the composition and zonation of reef flats in the Java Sea, an area little studied since the extensive work of Umbgrove in the early part of the century.

MATERIAL AND METHODS

a) Study site

The Pulau Pari complex of islands is situated at the southerly end of a chain of more than a hundred islands, commonly known as the Thousand Islands, which extends NNW - SSE across the Java Sea towards the Sunda Straits, Indonesia (Fig. 1).

The island complex is composed of Pulau Burung, Pulau Tikus, Pulau Kongsi and Pulau Tengah, the islands being separated from each other by a system of lagoons (Fig. 1). The islands are surrounded by well developed fringing reefs with prominent shingle banks on the north east and east rim.

The dominant physical influence in the area is the reversing monsoon wind. Umbgrove (1929, 1930) related the monsoons to be geomorphology of coral islands in the Thousand Islands and concluded that the more southerly islands of the group were subject to a strong wind effect from the north west quarter (the westerly monsoon which prevails from December-April) and an even stronger wind from the east (the easterly monsoon which prevails from May-November).

The Thousand Islands are also strongly influenced by the effects of reversing currents - Umbgrove noted that the reefs and islands of the group were aligned in the direction of their long axes and attributed this to the erosive effects of a current which runs along the north coast of Java, eight months westward and four monts eastward. The latter current is described as twice as fast as the westward current and Umbgrove quotes figures of 28 and 17 cm sec^{-1} for currents in the open sea of the region during the west and east monsoons respectively.

The tidal cycle for Jakarta shows a range of approximately one metre between high and low tide levels throughout the year. Salinities in the area vary between 31 - 33%.

b) Reef surveillance

Five areas were chosen for study (Fig. 1) using methods adopted by Loya (1978). After plotting a species/area curve, 10 m long measuring tapes were place at 5 or 10 m intervals across the inner reef flat and the percentage coral cover of individual colonies noted. Measuring tapes were placed at 2 m intervals across the outer reef flat areas. All observations were made by snorkelling.

RESULTS

The reef flats around the islands of Pulau Pari are characterised by an extensive sand flat (up to 500 m in extent), an inner reef flat, a shallow moat, an outer reef flat (varying from 10 - 20 m in width) and on the north east and east rim of Pari Island prominent shingle ramparts.

a) Species composition

A total of 88 coral species from 28 genera were recorded (Table 1) on transects across reef flats at all sites, with southern reef flats showing greater diversity in terms of number of species than northern reefs. A total of 74 species was recorded on southern reef flats, while only 45 species were noted on northern reef flats.

b) Species distribution

Figure 2 illustrates the percentage living and dead cover of all corals and also the distribution of the dominant genera with respect to distance across the reef flat at all sites.

In almost all cases coral cover generally increased across the inner reef flat to reach a maximum in the moat area with dead coral cover reaching a maximum on the landward edge of the outer reef flat. After this point living coral cover rapidly increased up to and beyond the reef front.

Montipora ramosa occupied the inner reef flat at all sites, being particularly conspicuous at site 1, where it accounted for about 80% of the total coral cover. In addition it was abundant in the moat areas of sites 2, 3 and 5. Micro atolls of Heliopora coerulea were also conspicuous in the moat at site 3.

Stands of Porites species (Porites lutea, Porites attenuata, Porites nigrescens, Porites andrewsi and Porites (Synaraea) iwayamaensis) were obvious only on the southern reefs, particularly at site 5 where they accounted for more than 50% of the total cover.

All the outer reef areas were dominated by Acropora species and only at site 1 was Montipora foliosa abundant. At site 2 encrusting and branching Montipora species (Montipora informis, Montipora composita, Montipora levis and Montipora tortuosa) accounted for 35% total midway across the outer reef flat.

Figure 3 illustrates a distinct zonation pattern for Acropora species on the outer reef flat which was particularly marked at sites 1, 2, 3 and 4. At these sites the number of Acropora species recorded varied between 3 - 6, the common dominant species being Acropora aspera/pulchra (these species being included together because of the difficulty in separate identification on the reef flat (Wallace 1978)). Acropora digitifera and Acropora hyacinthus with Acropora formosa occurring abundantly at site 2. The relatively limited number of Acropora species recorded at these sites contrasted markedly with the more diverse outer reef flat at site 5 where 14 Acropora species were identified.

Generally Acropora aspera/pulchra species favoured the unconsolidated landward edge of the outer reef flat where broken coral fragments survived the breaking waves to the exclusion of other species. Acropora digitifera successfully colonised the mid-seaward edge of the outer reef flat while plates of Acropora hyacinthus dominated the reef edge. At site 5 this zonation pattern was not as clear as that described at other sites. The cover of each individual species was low being less than 12% of the total transect, compared with individual covers of between 30-60% for Acropora aspera/pulchra at site 2 and 35% for Acropora hyacinthus at site 1.

DISCUSSION

There is a very clear resemblance between the reefs described in this paper and those described to the south in the Bay of Batavia by Umbgrove (1939). The wind rose described for reefs in the Bay of Batavia, with the greatest "wind effect" on the northern reefs and the least influence on the south western reefs appears to hold in the Pari Island complex. The wind rose actually proposed (Umbgrove 1929) for islands in the southern sector of the Thousand Island group with the greatest "wind effect" on north west and south east reefs and relatively little influence on the north east sector certainly does not fit observations made in the present study. Features noted at Pari Island such as the Montipora ramosa dominated moat, the northerly located shingle ramparts and the abundance of Montipora foliosa on the north west side of the island complex are all characteristics of reefs described by Umbgrove in the Bay of Batavia.

There are however important differences to be noted between the reefs of the Bay of Batavia and the Pari Island complex in the southerly Thousand Islands. Firstly the shingle ramparts of Pari Island are restricted to the north east and eastern sectors of the complex and do not extend along the entire northern border as described for reefs in the Bay of Batavia. Secondly Umbgrove describes the reefs of the south west sector of the islands of the Bay of Batavia as showning an impoverished reef facies because of the strong sedimentation effect in this area. Within the Pulau Pari complex the reefs of the south west sector constitute a much more diverse coral assemblage than any other encountered in the present study. Table 1 and Figure 3 reflect the diversity of corals at site 5 with 57 species recorded here compared with between 20-27 noted for the northern reefs; the outer reef flat at site 5 exhibiting a particularly high diversity of Acropora species.

The relatively high diversity observed at site 5 may be explained by two factors - protection from severe wave action and the greater depth of water (40 cm) covering the reef flat at low water when compared to the depths (5 - 10 cm) recorded at sites 1 - 4 (Sya'rani - unpublished). The southern reefs (sites 4 and 5) appear to be relatively protected from monsoon influences since Porites assemblages, characteristic of sheletered waters (Rosen 1971, 1975) are found at both sites.

Clearly the degree of physical exposure is critical and it may be that a reversing monsoon influence where certain sites are exposed to strong physical influences for only part of the year provides suitable conditions for coexistence of numerous coral species. Species capable of withstanding heavy wave surge such as Acropora aspera/pulchra with high growth rate (Yap and Gomez 1981 and reproduction by fragmentation (Bothwell 1981 [1982]) colonise the outer reef flat together with more fragile platelike species in a characteristic high energy Acropora assemblage which includes encrusting and branching Montipora, Porites, Pavona and faviid species. In this way high diversity and high cover is maintained in the shallow and well illuminated waters of the outer reef flat.

Although several workers (Grigg and Maragos 1974; Porter 1974) have described observed differences in diversity and cover of reef communities in terms of Sanders stability-time hypothesis, Sanders (1968) himself states that there is no such thing as a "pure" physically controlled or biologically accommodated community. The reefs surrounding the Pulau Pari complex are the result of both physical and biological influences and so represent intermediates on the gradient between these extreme types of community; reefs to the north showing a tendency towards physically controlled systems while the more diverse southern reefs reflect a bias towards more biologically accommodated communities. It is perhaps significant that biological interactions involving Acanthaster attack (Aziz and Sukarno 1977) and agressive overgrowth by diademnid ascidians (Brown unpublished) have been noted only on corals at the most diverse reef (site 5) studied in the present investigation.

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Table 1. Coral species recorded on reef flats at sites 1 - 5.

	Site number				
	1	2	3	4	5
Order: SCLERACTINIA Bourne					
Suborder: ASTROCOENIIDA Vaughan & Wells					
Family: POCILLOPORIDAE Gray					
Genus: STYLOPHORA Schweigger					
S. pistillata Esper	+	+		+	+
Genus: SERIATOPORA Lamarck					
S. hystrix Dana					+
Genus: POCILLOPORA Lamarck					
P. damicornis Linnaeus		+	+		+
P. verrucosa Ellis & Solander	+				
Family: ACROPORIDAE Verrill					
Genus: ACROPORA Oken					
A.robusta (Dana)		+			
A. grandis (Brook)				+	
A. abrotanoides (Lamarck)					+
A. intermedia (Brook)	+				+
A. formosa (Dana)	+	+		+	+
A. splendida Nemenzo		+			
A. vaughani (Wells)					+
A. pulchra/aspera (Brook)/(Dana)?	+	+	+	+	+
A. hyacinthus (Dana)	+		+	+	+
A. cytherea (Dana)					+
A. palifera (Lamarck)		+			+
A. millepora (Ehrenberg)				+	
A. aculeus (Dana)					+
A. delicatula (Brook)		+			+
A. nasuta (Dana)					+

		1	2	3	4	5
	A. cerealis (Dana)	+				+
	A. diversa (Brook)	+	+			+
	A. variablis (Klunzinger)					+
	A. humilis (Dana)					+
	A. digitifera (Dana)	+	+	+	+	+
	A. clathrata (Brook)	+				
	A. divaricata (Dana)					+
	A. subglabra (Brook)	+				
	A. carduus (Dana)					+
	A. microphthalma (Verrill)					+
	A. squarrosa (Ehrenberg)					+
	A. cymbicyathus (Brook)					+
	A. surculosa (Dana)					+
Genus:	ASTREOPORA de Blainville					
	A. myriophthalma (Lamarck)					+
Genus:	MONTIPORA de Blainville					
	M. tortuosa (Dana)	+	+	+	+	+
	M. minuta Bernard					+
	M. informis Bernard		+			
	M. ramosa Bernard	+	+			+
	M. composita Crossland		+			
	M. levis (Quelch)		+			
	M. foliosa (Bernard)	+				+
	Suborder: FUNGIIDAE (Duncan)					
	Superfamily: AGARICIICAE (Gray)					
Family:	AGARICIIDAE Gray					
Genus:	PAVONA Lamarck					
	P. danai (Milne-Edwards & Haime)					+
	P. varians Verrill	+	+	+	+	+
	P. venosa (Ehrenberg)			+		

	1	2	3	4	5
P. decussata (Dana)					+
Genus: COELOCERIS Vaughan					
C. mayeri Vaughan			+	+	+
Superfamily: FUNGIICAE (Dana)					
Family: FUNGIIDAE (Dana)					
Genus: FUNGIA Lamarck					
Subgenus: FUNGIA Lamarck					
F. (Fungia) fungites (Linnaeus)					+
Subgenus: CTENACTIS Verrill					
F. (Ctenactis) echinata (Pallas)					+
Superfamily: PORITICAE (Gray)					
Family: PORITIDAE (Gray)					
Genus: GONIOPORA de Blainville					
G. stokesi Milne-Edwards & Haime				+	+
Genus: PORITES Link					
P. lutea Milne-Edwards & Haime		+	+		+
P. matthaii Wells				+	
P. attenuata Nemenzo	+			+	+
P. mayeri Vaughan				+	
P. nigrescens .Dana				+	+
P. andrewsi Vaughan		+		+	+
Subgenus: SYNAREA Verrill					
P. (Synarea) iwayamaensis Eguchi				+	+
Suborder: FAVIINA Vaughan & Wells					
Superfamily: FAVIICAE Gregory					
Family: FAVIIDAE Gregory					
Subfamily: FAVIINAE Gregory					
Genus: FAVIA Oken					
F. pallida (Dana)		+	+	+	
F. favus (Forskaal)				+	+

		1	2	3	4	5
	<u>F. lizardensis</u> Veron, Pichon & Wijsman-Best				+	
	<u>F. matthai</u> Vaughan			+	+	
Genus:	FAVITES Link					
	<u>F. chinensis</u> (Verrill)	+	+	+	+	
	<u>F. abdita</u> (Ellis & Solander)		+		+	
	<u>F. halicora</u> (Ehrenberg)	+		+		
Genus:	OULOPHYLLIA Milne-Edwards & Haime					
	<u>Oulophyllia</u> sp.					+
Genus:	CAULASTREA Dana					
	<u>C. tumida</u> Matthai				+	+
Genus:	GONIASTREA Milne-Edwards & Haime					
	<u>G. retiformis</u> (Lamarck)		+	+	+	
	<u>G. edwardsi</u> Chevalier				+	+
	<u>G. aspera</u> (Verrill)				+	
	<u>G. favulus</u> (Dana)		+		+	
	<u>G. pectinata</u> (Ehrenberg)				+	
Genus:	PLATYGYRA Ehrenberg					
	<u>P. pini</u> Chevalier	+		+	+	+
	<u>P. sinensis</u> Milne-Edwards & Haime	+		+		
	<u>P. daedalea</u> (Ellis & Solander)		+		+	+
	<u>P. verweyi</u> Wijsman-Best			+	+	+
Genus:	HYDNOPHORA Fischer de Waldheim					
	<u>H. exesa</u> (Pallas)	+				
Genus:	MONTASTREA de Blainville					
	<u>M. magnistellata</u> Chevalier					+
	<u>M. valenciennesi</u> (Edwards & Haime)					+
Genus:	LEPTASTREA Milne-Edwards & Haime					
	<u>L. pruinosa</u> Crossland		+			

	1	2	3	4	5
Genus: CYPHASTREA Milne-Edwards & Haime					
C. microphthalma (Lamarck)				+	
C. serialia (Forskal)				+	
Genus: ECHINOPORA Lamarck					
E. horrida Dana					+
Family: OCULINIDAE Gray					
Subfamily: GALAXEINAE (Vaughan & Wells)					
Genus: GALAXEA Oken					
G. fascicularis (Linnaeus)		+		+	+
Family: MERULINIDAE Verrill					
Genus: MERULINA Ehrenberg					
M. ampliata (Ellis & Solander)					+
Genus: SYMPHYLLIA Milne-Edwards & Haime					
S. nobilis (Dana)					+
Suborder: CARYOPHYLLINA Vaughan & Wells					
Superfamily: CARYOPHYLLIICAE Gray					
Family: CARYOPHYLLIIDAE Gray					
Subfamily: EUSMILIINAE Milne-Edwards & Haime					
Genus: EUPHYLLIA Dana					
E. glabrescens (Chamisso & Eysenhardt)					+
Order: COENOTHECALIA Bourne					
Family: HELIOPORIDAE Moseley					
Genus: HELIOPORA de Blainville					
H. coerulea (Pallas)		+	+	+	+
Class: HYDROZOA Huxley					
Order: MILLEPORINA Hickson					

	1	2	3	4	5
Family: MILLEPORIDAE Blainville					
Genus: MILLEPORA Linnaeus					
M. exaesa Forskal		+	+		+
M. platyphylla Hemprich & Ehrenberg			+		
M. dichotoma Forskal					+
TOTAL NUMBER OF CORAL SPECIES:	21	28	20	38	57

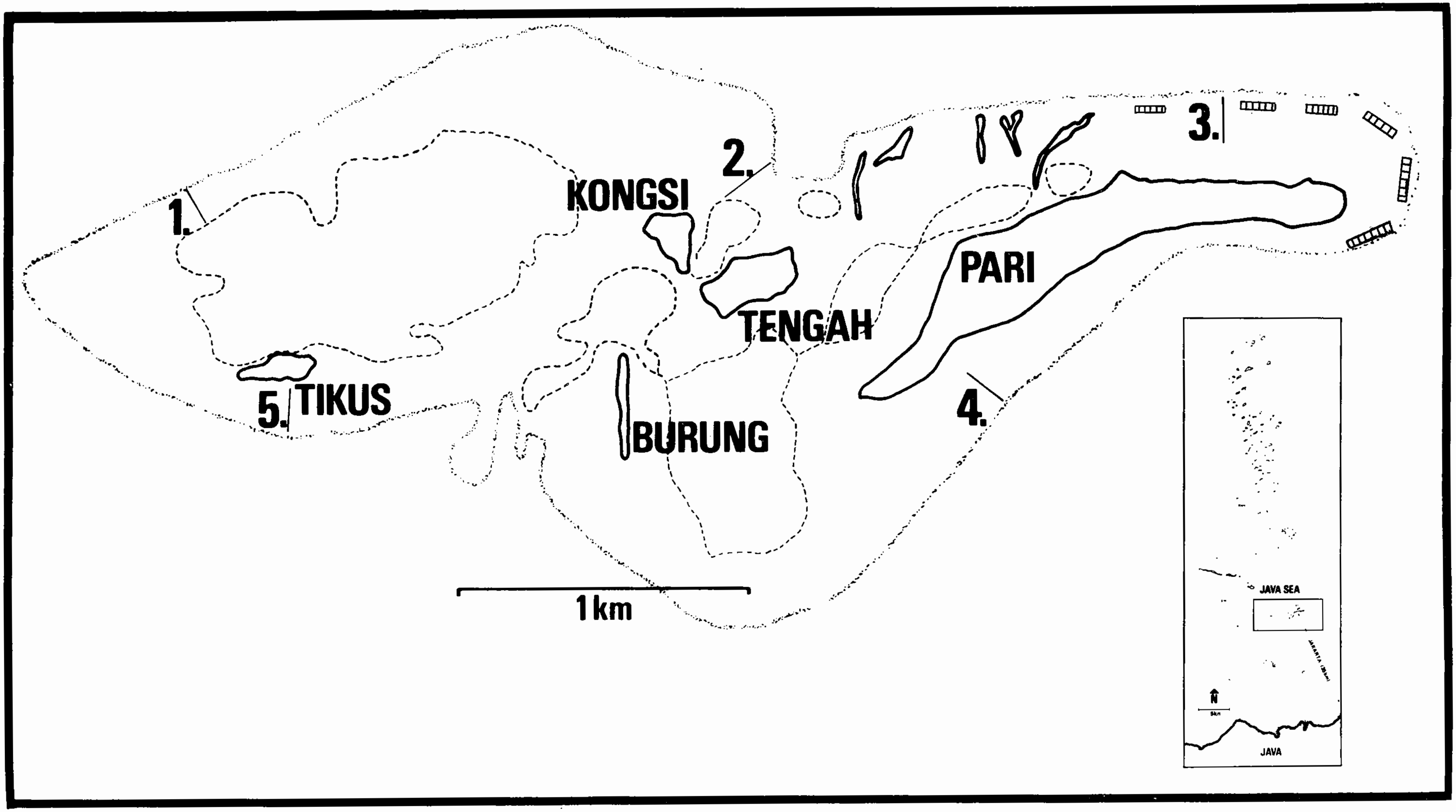

Figure 1. Pari Island Complex showing study sites and position of shingle ramparts (▯▯▯▯) and its location within the Java Sea (inset).

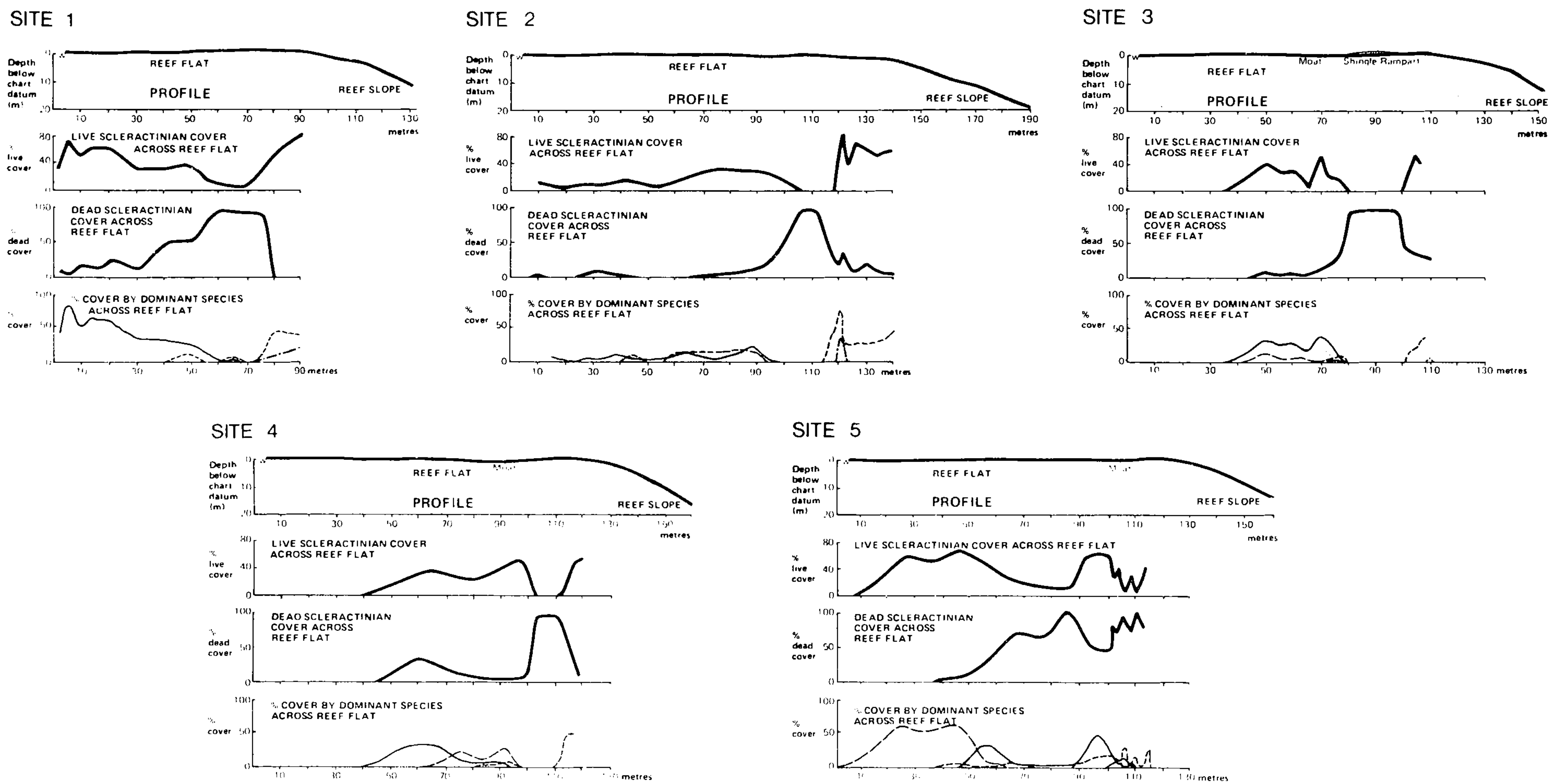

Figure 2. Distribution of living and dead coral across the reef flats at sites 1 - 5.

a) Profile of reef
b) Live scleractinian cover
c) Dead scleractinian cover
d) Dominant species cover

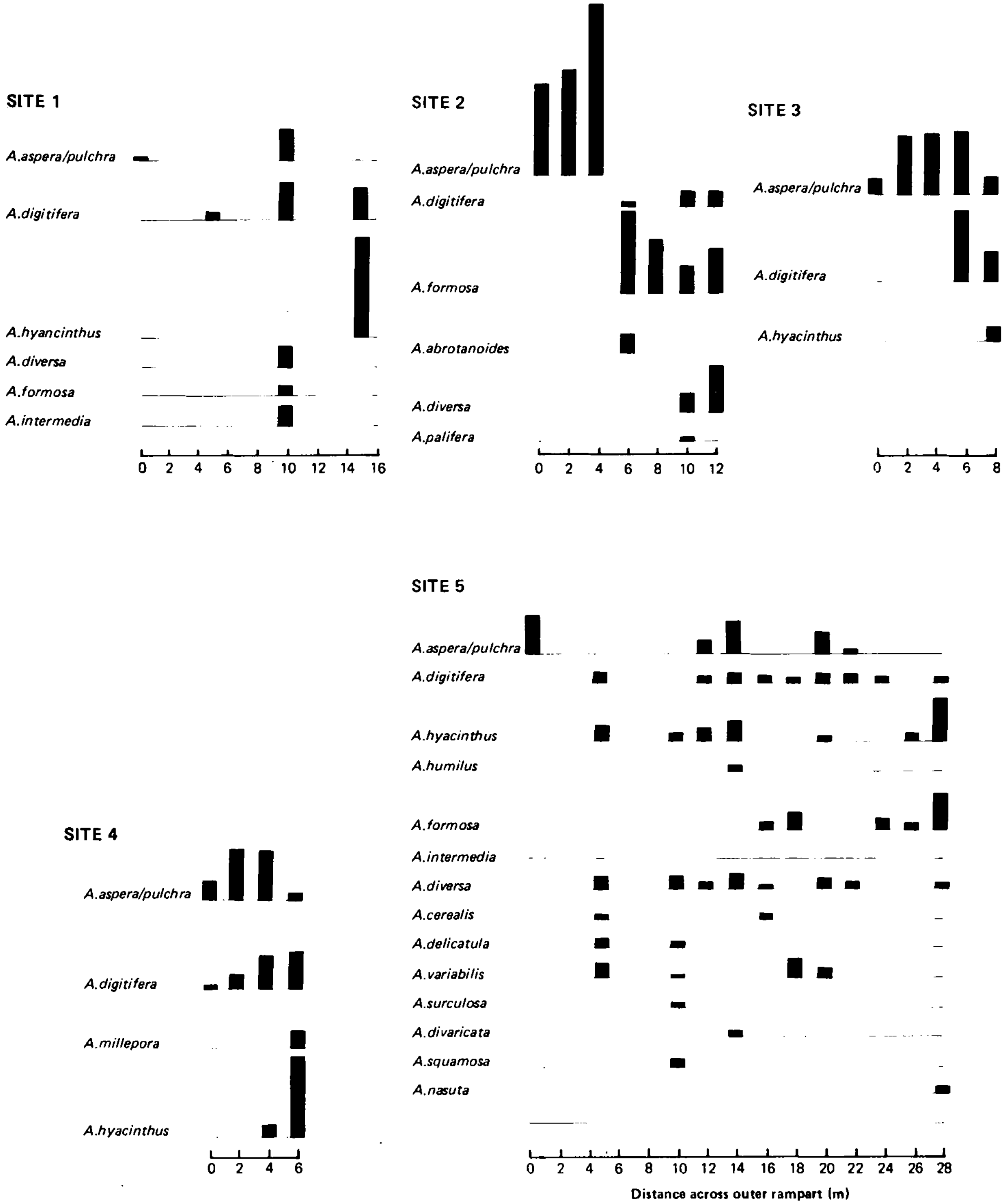

Figure 3. Zonation of Acropora species across the outer reef flats at sites 1 - 5.

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