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THE CORAL COMMUNITY STRUCTURE ON THE REEFS VISITED DURING THE SNELLIUS II EXPEDITION IN EASTERN INDONESIA

by

H. MOLL

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The line-transect method was applied to gather data on the species composition and sociology of coral reefs on a large number of localities throughout Eastern Indonesia. Multivariate analyses indicated exposure as the major ecological parameter in governing the species composition of these reefs.

H. Moll, Rijksmuseum van Natuurlijke Historie, Postbus 9517, 2300 RA Leiden, The Netherlands.

INTRODUCTION

The Snellius II Expedition of 1984 and 1985, was set up as a joint Indonesian-Dutch venture, to examine a wide range of scientific topics. Problems relating to geology, oceanography, meteorology, marine biology, and polution were investigated. Theme 4 of this enterprise, concerning the coral reefs, was carried out from August until November 1984. During these months nine different localities were studied. Descriptions of these areas are given by Best et al. (1985). For the location of these areas see fig. 1.

One of the more practical objectives of theme 4 is to assess the condition these reefs are in. Apart from the damage inflicted by natural conditions, disturbances caused by human interference received a lot of attention. Based on a scientific interpretation of the reef surveys, recommendations can be made concerning nature conservation, marine park management, and coastal resources protection and development. Eventually, the scientific data

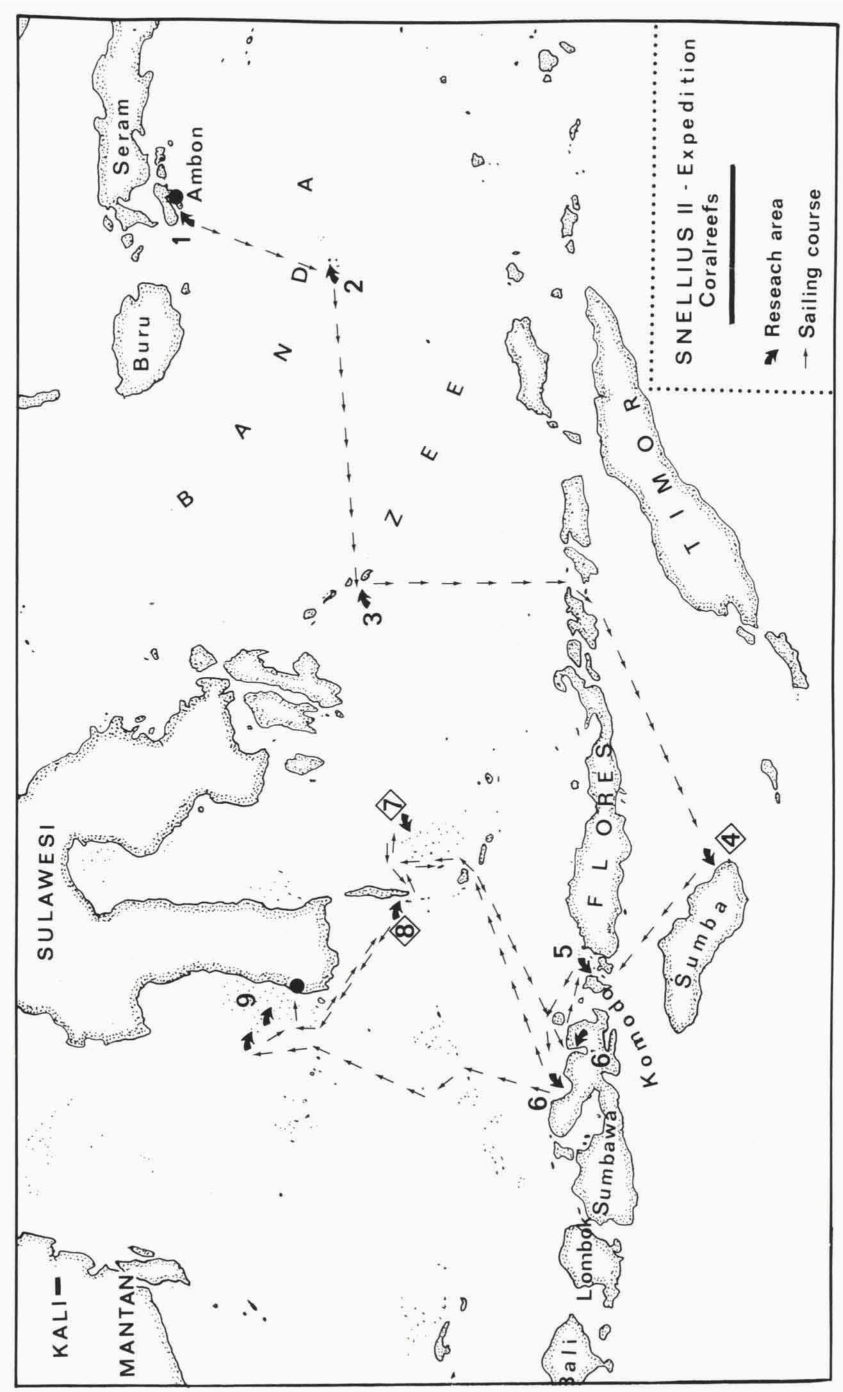

Fig. 1. Eastern Indonesia. The research areas discussed here are marked ◇. For explanation of other numbered areas see Best et al. (1985).

gathered during this expedition will form the reference data set to initialize standard methods for the description and monitoring of the reefs in Indonesia. For regular monitoring purposes these methods need also to be applicable by surveyers with little or no scientific training.

At each locality the coral fauna was studied with various techniques. The line-transect method provided a wealth of systematic and numerical data which form the basis of this work. Most of the recent works on the methods to survey and monitor coral reefs (Stoddart & Johannes, 1978; Dahl, 1982; Rogers c.s., 1983; Anonymous, 1984; Kenchington & Hudson, 1984) refer to this method. The efficiency of the most common techniques has been tested by Weinberg (1981) for an Atlantic reef. His conclusions concerning the line-transect method were discussed by Moll (1983). The simplicity of this technique, its high resolution, its versatility, the nature of this survey, and the availability of comparable data from the same region, led to the choice of the line-transect method.

The choise of analytical techniques depends mainly on the format of the data and should be an a priori consideration when commencing field work. Surveys can be of a more general nature (visual census, manta boards, etc.) to highly specialized (detailed taxonomic identification, individual interactions, juvenile abundancy, etc.). Growth forms, when not specifically recorded, can be deduced from detailed taxonomic records. Identifications are mainly based on skeletal morphology although a wealth of other characteristics are available to the taxonomist (Lang, 1984). Analyses of the present data include: taxonomic inventory; average values of the coral composition for the entire region; correlation analyses on transect totals; cluster analyses on transect totals; analyses on the coral cover by various growth forms; cluster analyses and multivariate analyses on the species composition.

METHODS

As the available time was rather limited, studies could only be carried out at two or three sites at each locality. A major problem in comparing the coral composition at various localities is the inconsistency in reef morphology. Therefore, initial surveys were carried out over a large area between depths of 6 and 10 meters and afterwards sites were chosen at places where coral growth was well developed and representative of a large part of the reef. Additional data on lagoons, reef-flats, steep drop-offs, and other faunistically interesting sites were recorded in field notes.

A report on the application of the transect method at set intervals from the

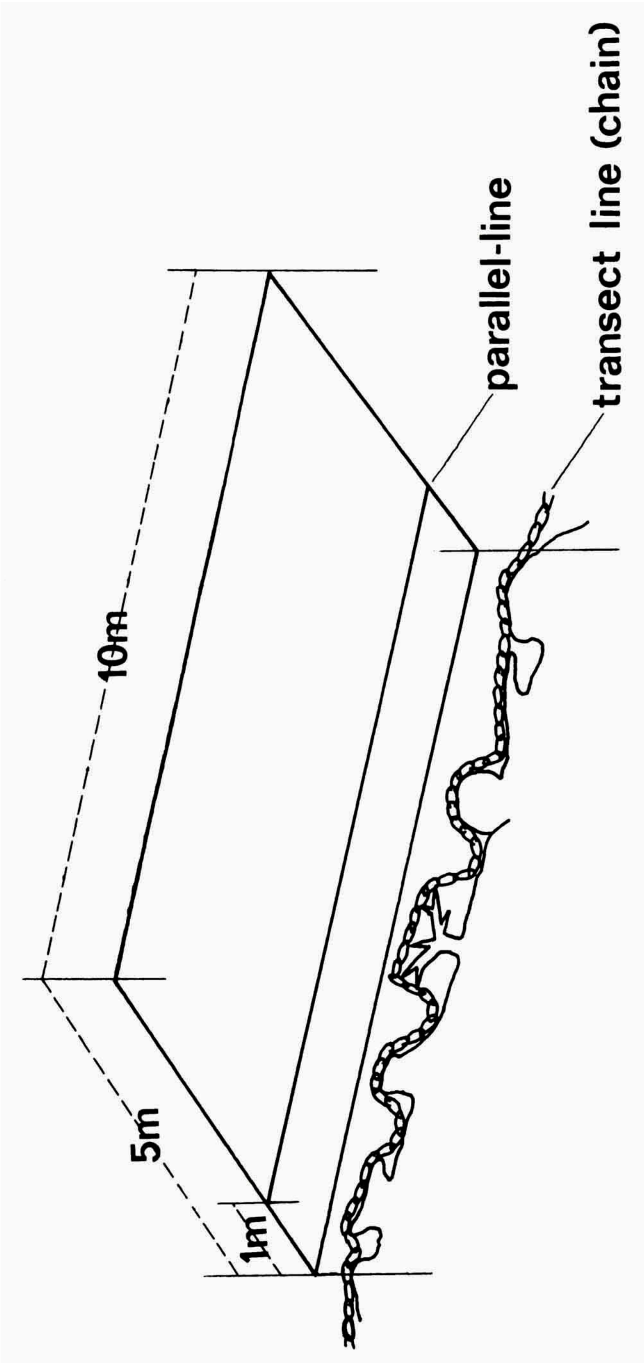

Fig. 2. Field work methodology.

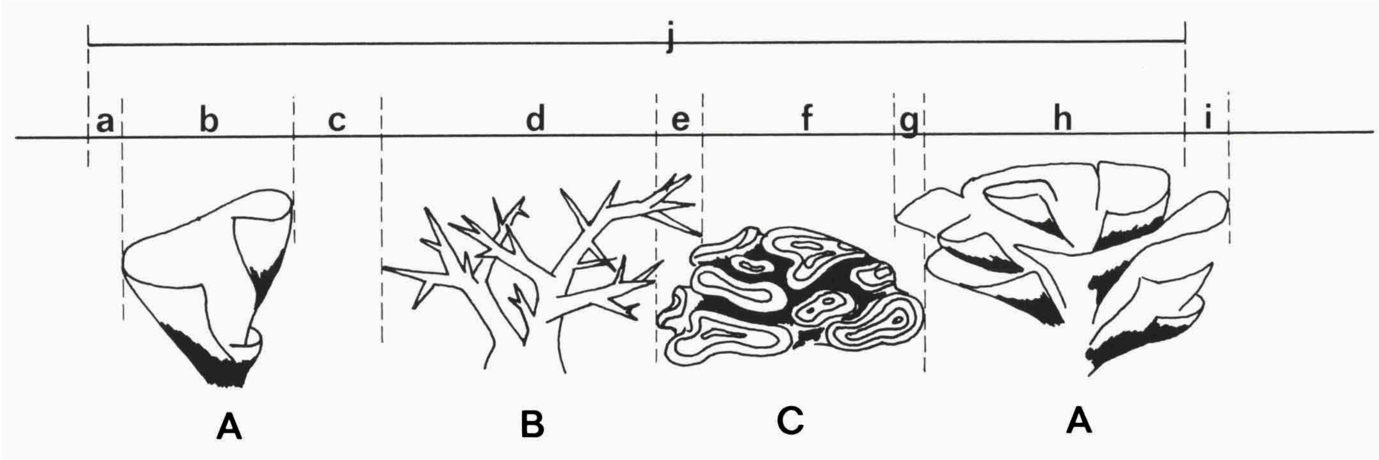

Fig. 3. The method of recording during field work. Transect length: j; cover of species A: b + g + h; cover of species B: d + e; cover of species C: e + f + g; overlap: e + g; total coral cover: b + d + e + f + g + h = cov. A + cov. B + cov. C − overlap.

shore down to 30 meters is available for some Indonesian reefs (Moll, 1983) but this technique is more time-consuming and hence less suitable for an expedition. For a detailed description of the line-tansect method see Loya (1972).

Each study site consisted of a rectangular area of 10 by 5 meters (fig. 2). The transect line (in this case a chain) was laid down along one of the longer sides. The method of recording is futher clarified in fig. 3. The cover values were recorded in numbers of chain-links and are listed as such (59 links/m).

Colonies of uncertain taxonomic status were labelled with numbered aluminium platelets in such a way that they could be recognised in a top view of the area. After completion of the line-transect measurements, an underwater video camera was passed over the area, recording a strip of 1 × 10 m bordered on one side by the transect chain and on the opposite side by the 1 m marker line (fig. 2). After completion of the video runs, but before removing the chain and marker line, each aluminium label together with a fragment of the colony it marked, was collected in a separate plastic bag. In this way, the exact position in the transect and the identification can still be linked. The video recordings of the strips will be reproduced on photographs and will allow for a comparison between the various sampling methods and more detailed studies based on two-dimensional surveying techniques.

For a discussion on various analytical techniques for transect data, see Moll (1983).

RESULTS

In total 42 transects (Tr) were described, but of these only 40 provided a full set of data. Total values and averages are listed in table 1. In two transects (27 and 35) coral cover seems to be more than 100% (595 and 592 respectively). However, in Tr27 there was a total of 66 links overlap, and 34 links in Tr35, meaning that actual cover is 89.6% and 94.6% respectively.

Analyses of these data revealed a highly significant relation between cover and overlap. Furthermore, the number of species is significantly related to the number of colonies. This last variable is itself significantly related to both cover and overlap. However, when examining these results with a partial-correlation analysis (Rohlf, 1977), the relation between number of colonies and overlap appeared to be a fictive one, due only to the strong correlation of both these variables to cover.

The cubic-clustering-criterion (SAS 1982) from the cluster analysis on data from table 1, has an extreme value at the level of three clusters, indicating three major groups. The first of these contains three transects, all with an extremely high cover. The second combines those transects that have both a high number of species and a high cover. The rest are grouped in the third cluster. This again demonstrates the relation between the above mentioned variables.

Table 2 lists all species that were recorded in the 40 transects studied during the expedition; they total 175 species belonging to 50 genera. Ten of these species were given temporary code-names as their exact taxonomic status is as yet unclear. Apart from collections from underneath the transect line, corals were also collected in the 10 by 5 m quadrant and in the vicinity of the study site. The coral species total for the entire expedition thus rose to 363.

Tr	ns	nc	c	ol	Tr	ns	nc	c	ol
1	19	31	178	6	23	22	31	248	12
4	15	36	296	6	24	23	45	156	
5	12	40	233		25	12	39	155	1
6	11	24	202	2	26	26	36	196	23
7	9	11	69		27	17	45	595	66
8	10	36	250		28	22	40	275	16
9	8	44	240	8	29	12	17	157	
10	19	64	275	23	30	12	17	157	
11	16	22	233	10	31	16	39	377	8
12	17	26	129		32	20	35	287	26
13	8	10	141	2	33	23	51	333	11
14	24	33	381	55	34	12	20	199	7
15	18	24	146	4	35	9	23	592	34
16	11	24	201	5	36	12	36	419	15
17	10	13	179	8	37	23	69	368	48
18	8	10	170		38	29	48	307	34
19	20	42	218	7	39	13	71	251	1
20	16	41	229	6	40	33	53	432	14
21	18	31	245	4	41	10	58	511	67
22	30	34	256	28	42	25	43	260	12

```
        ns   nc     c     ol
total:  683  1426   10564  582
        .    .      .      .
        .    .      .      .
        .    .      .      .overlap
        .    .      .
        .    .      .links; = 179.52 m; coverage percentage = 44.9%
        .    .
        .    . colonies; av.= 35.5 col/transect
        .
        .species; av.= 17 sp/transect
```

Table 1. Totals of each transect with transect number, number of species (ns), number of colonies (nc), number of links (c), and overlap (ol).

Acantastrea echinata	1	2	1	*Acropora accuminata*	2	134	2	*Acropora aculeus*	2	4	1
Acropora brueggemanni	54	399	6	*Acropora carduus*	3	14	2	*Acropora clathrata*	1	11	1
Acropora cf.microphthalma	2	22	1	*Acropora cuneata*	2	8	2	*Acropora cytherea*	7	72	6
Acropora divaricata	9	107	8	*Acropora donei*	1	44	1	*Acropora echinata*	15	63	8
Acropora sp.echiplate	1	5	1	*Acropora elseyi*	1	4	1	*Acropora florida*	5	139	5
Acropora formosa	13	252	6	*Acropora sp.grangrof*	2	19	2	*Acropora granulosa*	10	61	7
Acropora horrida	8	267	4	*Acropora humilis*	4	18	3	*Acropora hyacynthus*	1	8	1
Acropora kirstyae	1	1	1	*Acropora microphthalma*	15	238	1	*Acropora microclados*	3	8	8
Acropora nasuta	3	10	2	*Acropora nobilis*	25	281	5	*Acropora palifera*	25	195	11
Acropora robusta	2	16	1	*Acropora sarmentosa*	3	49	3	*Acropora secale*	2	25	1
Acropora selago	1	8	1	*Acropora subglabra*	1	1	1	*Acropora tenuis*	6	156	5
Acropora valida	1	4	1	*Acropora vaughani*	6	17	2	*Acropora yongei*	6	74	2
Anacropora forbesi	2	3	1	*Anacropora matthai*	6	9	2	*Astreopora myriophthalma*	4	35	4
Clavarina scabricula	2	4	2	*Coeloseris mayeri*	1	4	1	*Ctenactis echinata*	2	6	1
Cyphastrea chalcidicum	2	8	2	*Cyphastrea microphthalma*	3	4	1	*Cyphastrea serailia*	6	20	4
Dendrophyllia fistulla	1	1	1	*Diploastrea heliopora*	1	28	1	*Echinopora aspera*	5	28	4
Echinopora gemmacea	2	7	2	*Echinopora hirsutissima*	2	18	1	*Echinopora horrida*	2	4	1
Echinopora lamellosa	12	145	10	*Euphyllia divisa*	1	63	1	*Favia favus*	1	4	1
Favia matthai	3	9	3	*Favia pallida*	14	69	12	*Favia speciosa*	1	4	1
Favia stelligera	4	46	4	*Favites abdita*	4	19	3	*Favites chinensis*	2	4	2
Favites flexuosa	2	12	2	*Favites halicora*	11	66	9	*Favites pentagone*	3	13	2
Fungia concinna	4	15	2	*Fungia danai*	3	19	3	*Fungia fungites*	10	50	8
Fungia granulosa	3	10	2	*Fungia horrida*	6	20	3	*Fungia lobulata*	1	3	1
Fungia moluccensis	2	2	2	*Fungia paumotensis*	4	8	3	*Fungia repanda*	19	65	11
Fungia scutaria	2	11	2	*Fungia valida*	1	4	1	*Galaxea astreata*	1	7	1
Galaxea fascicularis	16	133	14	*Gardineroseris planulata*	4	20	4	*Goniastrea aspera*	1	9	1
Goniastrea edwardsi	1	1	1	*Goniastrea pectinata*	23	90	11	*Goniastrea retiformis*	1	6	1
Goniopora columna	1	22	1	*Goniopora minor*	2	31	2	*Goniopora lobata*	2	8	2
Goniopora somaliensis	2	5	2	*Goniopora stutchburyi*	1	3	1	*Goniopora tenuidens*	1	15	1
Herpolitha trilinguis	3	25	3	*Hydnophora exesa*	6	64	6	*Hydnophora microconos*	1	12	1
Leptastrea bottae	2	5	2	*Leptastrea pruinosa*	1	3	1	*Leptastrea transversa*	2	6	2
Leptoseris explanata	1	3	1	*Leptoseris scabra*	2	6	2	*Lobophyllia hattai*	2	32	2
Lobophyllia hemprichii	9	99	4	*Merulina ampliata*	10	126	10	*Montastrea magnistellata*	1	1	1
Montastrea valenciennesii	1	4	2	*Montipora aequitberculosa*	42	249	2	*Montipora caliculata*	1	11	1
Montipora corbettensis	1	19	1	*Montipora efflorescens*	8	127	4	*Montipora foliosa*	38	404	8
Montipora hispida	15	118	11	*Montipora hoffmeisteri*	4	31	3	*Montipora millepora*	1	2	1
Montipora monasteriata	18	137	17	*Montipora nodosa*	5	31	8	*Montipora peltiformis*	1	39	1
Montipora sp.costata	8	44	3	*Montipora sp.chim*	1	50	1	*Montipora sp.exdir*	1	6	1

Montipora sp.venosa	1	5	1	*Montipora stellata*	4	19	1	*Montipora turtlensis*	3	20	2
Montipora undata	7	52	5	*Montipora undulata*	1	2	1	*Montipora venosa*	12	47	5
Montipora verrucosa	2	6	2	*Mycedium elephantotus*	16	212	6	*Mycedium robokaki*	3	28	3
Oulophyllia crispa	1	35	1	*Oxypora lacera*	11	99	8	*Pachyseris rugosa*	6	32	4
Pachyseris sp.	7	117	3	*Pachyseris speciosa*	5	52	5	*Pavona cactus*	3	3	2
Pavona clavus	5	53	4	*Pavona explanulata*	9	36	6	*Pavona varians*	33	102	20
Pavona venosa	3	18	3	*Pectinia alcicornis*	1	2	1	*Pectinia lactuca*	5	33	4
Physogyra lichtensteini	1	6	1	*Platygyra daedalea*	8	64	7	*Platygyra lamellina*	4	25	3
Platygyra pini	5	14	5	*Plerogyra sinuosa*	1	1	1	*Plesiastrea versipora*	1	14	1
Pocillopora damicornis	6	17	6	*Pocillopora eydouxi*	2	34	1	*Pocillopora verrucosa*	8	66	7
Porites australiensis	12	103	9	*Porites sp.bark*	37	162	3	*Porites cf.vaughani*	1	1	1
Porites lichen	152	644	32	*Porites lobata*	24	214	14	*Porites lutea*	70	623	22
Porites mayeri	4	31	3	*Porites murrayen*	2	76	2	*Porites nigrescens*	53	415	18
Porites rus	52	253	8	*Porites solida*	6	87	4	*Porites sp.1*	1	27	1
Porites sp.6	1	9	1	*Porites stephensoni*	3	22	3	*Porites varians*	3	5	1
Porites vaughani	10	61	4	*Psammocora contigua*	1	1	1	*Psammocora nierstraszi*	3	7	3
Psammocora sp.echinop	1	4	1	*Sandalolitha robusta*	2	8	2	*Seriatopora aculeata*	9	43	4
Seriatopora caliendrum	16	105	10	*Seriatopora hystrix*	81	395	16	*Stylocoeniella armata*	2	4	2
Stylophora pistillata	21	105	12	*Symphyllia recta*	2	23	2	*Turbinaria reniformis*	1	2	1
Turbinaria stellulata	1	9	1	*Zoopilus echinatus*	1	17	1				

Table 2. Alphabetically all species found in the transects, together with the total number of colonies, of links, and of transects they were found in.

species	nc	c	nt	species	nc	c	nt	species	nc	c	nt
Porites lichen	152	644	32	*P. lichen*	152	644	32	*P.lichen*	152	655	32
Seriatopora hystrix	81	395	16	*P. lutea*	70	623	22	*P.lutea*	70	623	22
P. lutea	70	623	22	*P. nigrescens*	53	415	18	*Pavona varians*	33	102	20
Acropora brueggemanni	54	399	6	*Montipora foliosa*	38	404	8	*P.nigrescens*	53	415	18
P. nigrescens	53	415	18	*A. brueggemanni*	54	399	6	*M.monasteriata*	18	137	17
P. rus	52	253	8	*Seriatopora hystrix*	81	395	16	*Seriatopora hystrix*	81	395	16
M. aequituberculosa	42	249	2	*A. nobilis*	25	281	5	*Galaxea fascicularis*	16	133	14
M. foliosa	38	404	8	*A. horrida*	8	267	4	*P.lobata*	24	214	14
P. sp.bark	37	162	3	*P. rus*	52	253	8	*Favia pallida*	14	69	12
Pavona varians	33	102	20	*A. formosa*	13	252	6	*S. pistillata*	21	105	12
A. nobilis	25	281	5	*M. aequituberculosa*	42	249	2	*A. palifera*	25	195	11
A. palifera	25	195	11	*A. microphthalma*	15	238	1	*F. repanda*	19	65	11
P. lobata	24	214	14	*P. lobata*	24	214	14	*Goniastrea pectinata*	23	90	11
Goniastrea pectinata	23	90	11	*Mycedium elephantotus*	16	212	6	*M.hispida*	15	118	11
Stylophora pistillata	21	105	12	*A. palifera*	25	195	11	*Echinopora lamellina*	12	145	10
Fungia repanda	19	65	11	*P. sp.bark*	37	162	3	*Merulina ampliata*	10	126	10
M. monasteriata	18	137	17	*A. tenuis*	6	156	5	*S. caliendrum*	16	105	10

Table 3. The most common species in the 40 transects arranged by their number of colonies (nc) at the left, the number of links (c) in the middle column, and finally by number of transects (nt).

The species most commonly found during the expedition are listed in table 3.

The transects were positioned in such a way as to be able to compare communities under different physical conditions. Three localities are analysed here.

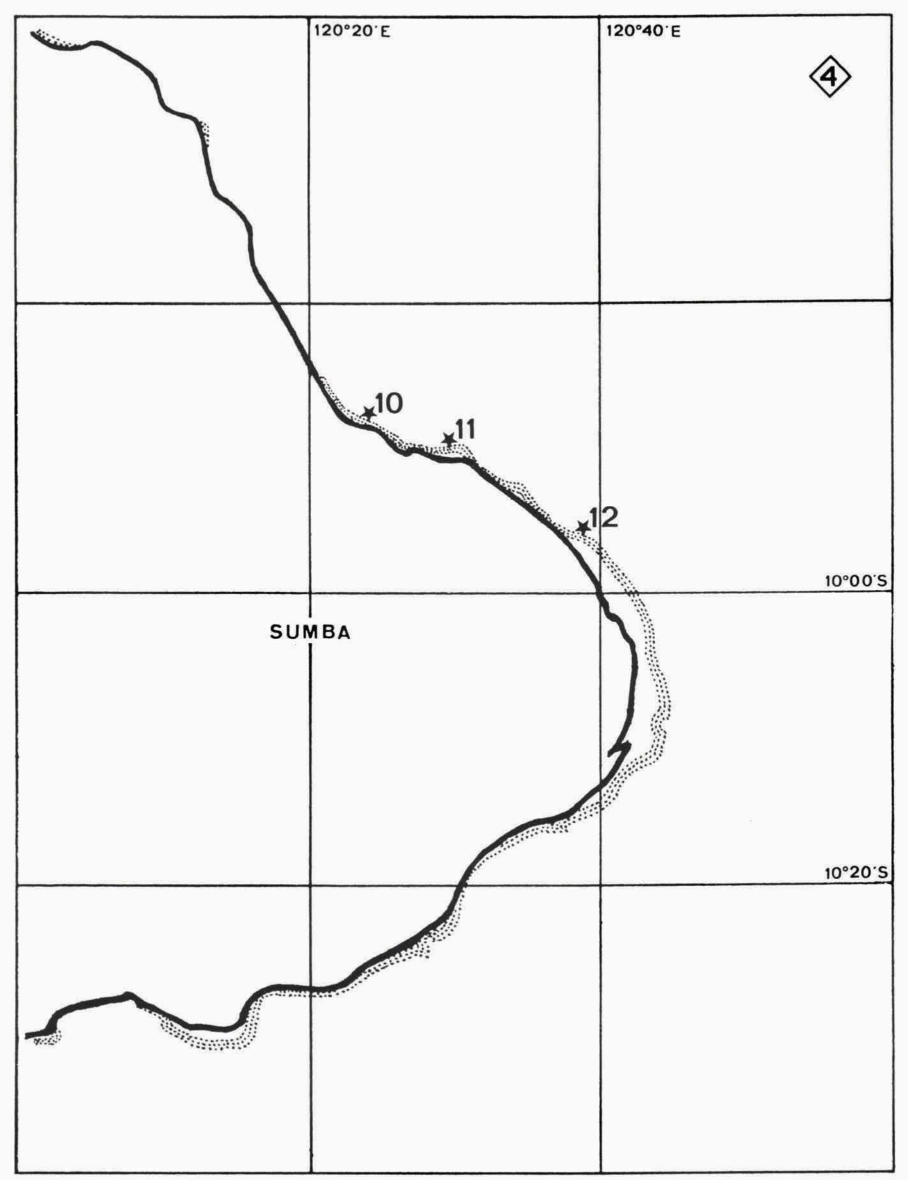

Fig. 4. Position of the transects made at Sumba (④ in fig. 1).

1. Sumba (locality 4 in fig. 1; transects 10, 11, 12, fig. 4)

In the Sumba area, winds are mostly from the south-west (Weber, 1922). The southern shore is furthermore subjected to oceanic swell throughout the year. Some of this wave action is noticeable along the north-eastern coast where three transects were described. However, the biotope along this coast can be considered quite sheltered, being disturbed by action of wind and waves only occasionally. Adding to this instability are the sporadic cyclones that are reported for this area. Their track often runs from the Aru Islands along Timor towards Sumba (Braak, 1929).

The transect sites all appeared quite disturbed with large overturned *Acropora* tables (not recently so, though) and many loose foliaceous fronds. Cover is somewhat below average (36%) but the numbers of species and colonies are similar to the average of all 40 transects.

Individual values of these three transects show a good deal of variance (see table 1). In tables 4 and 5 the values are split up for the various growth forms.

The growth form branching (br) is subdivided into branching-large (brlg), and branching-small (brsm), forms that are also recognised in the concurrent ecological surveys (Bak, in prep.). Species like *Anacropora, Porites lichen, P. nigrescens, P.rus, Seriatopora* spp., and *Stylophora pistillata* are termed "brsm". Taller arboresecent corals like *Acropora formosa, A. microphthalma,* and *A. nobilis* are grouped in the category "brlg". Field observations indicated the separate occurrence of these groups, especially under exposed conditions. The other categories are: foliaceous (fol), massive (mas), solitary (sol), and tabulate (tab).

Going from Tr10 to Tr12 the cover of branching species decreases (175,

	Tr10			Tr11			Tr12		
	ns	nc	c	ns	nc	c	ns	nc	c
brlg	3	6	33	3	3	98			
brsm	4	40	142	4	8	44	3	4	12
br	7	46	175	7	11	142	3	4	12
fol	2	4	53	2	2	6	2	2	44
mas	5	5	17	3	4	8	11	17	65
sol	5	9	30	2	3	12			
tab				2	2	65	1	3	8
tot	19	64	275	16	22	233	17	26	129

Table 4. Number of species, of colonies, and of links for various growth forms. For abbreviations see table 3.

142, 12). Especially the smaller arborescent species seem to fade out, while massives increase (17, 8, 65). This indicates a deminishing exposure when going from Tr12 to the north. This notion is strengthened by the fact that the solitary Fungids occur mainly in Tr10, sarcely in Tr11 and not at all in Tr12. Foliaceous corals are not of major importance; where their cover is relatively low, tabular *Acropora* species attain their maximum cover.

2. Bahuluang, Salayar (locality 8 in fig. 1; transects 22, 25, 26, 27, fig. 5)

From November until April the north-west monsoon has a marked impact on South Sulawesi. Near Salayar, these winds take a more east/west route and

	Tr10	Tr11	Tr12
		cover	
brlg	25	75	
brsm	72	22	6
br	53	43	4
fol	51	6	43
mas	19	9	72
sol	71	29	
tab		89	11

Table 5. Cover in percentage of the three transects (see table 4).

actual values

Tr	br			fol			mas			sol		
	ns	nc	c	ns	nc	c	ns	nc	c	ns	nc	c
22	11	12	136	4	5	27	15	17	93	-------		
25	5	27	81	-------			5	10	69	2	2	4
26	11	18	105	2	2	13	12	15	72	1	1	6
27	9	23	344	5	19	227	1	1	14	2	2	8

values as % of the total per transect

Tr	br			fol			mas			sol		
	ns	nc	c	ns	nc	c	ns	nc	c	ns	nc	c
22	37	35	53	13	15	11	50	50	26	-------		
25	42	69	52	--------			42	26	45	17	5	3
26	42	50	54	8	6	7	46	42	37	4	3	3
27	53	51	58	29	42	38	6	2	2	12	4	1

Table 6. Actual values and percentages of number of species, number of colonies, and cover for different growth forms in transects 22, 25, 26, and 27. For abbreviations see previous tables.

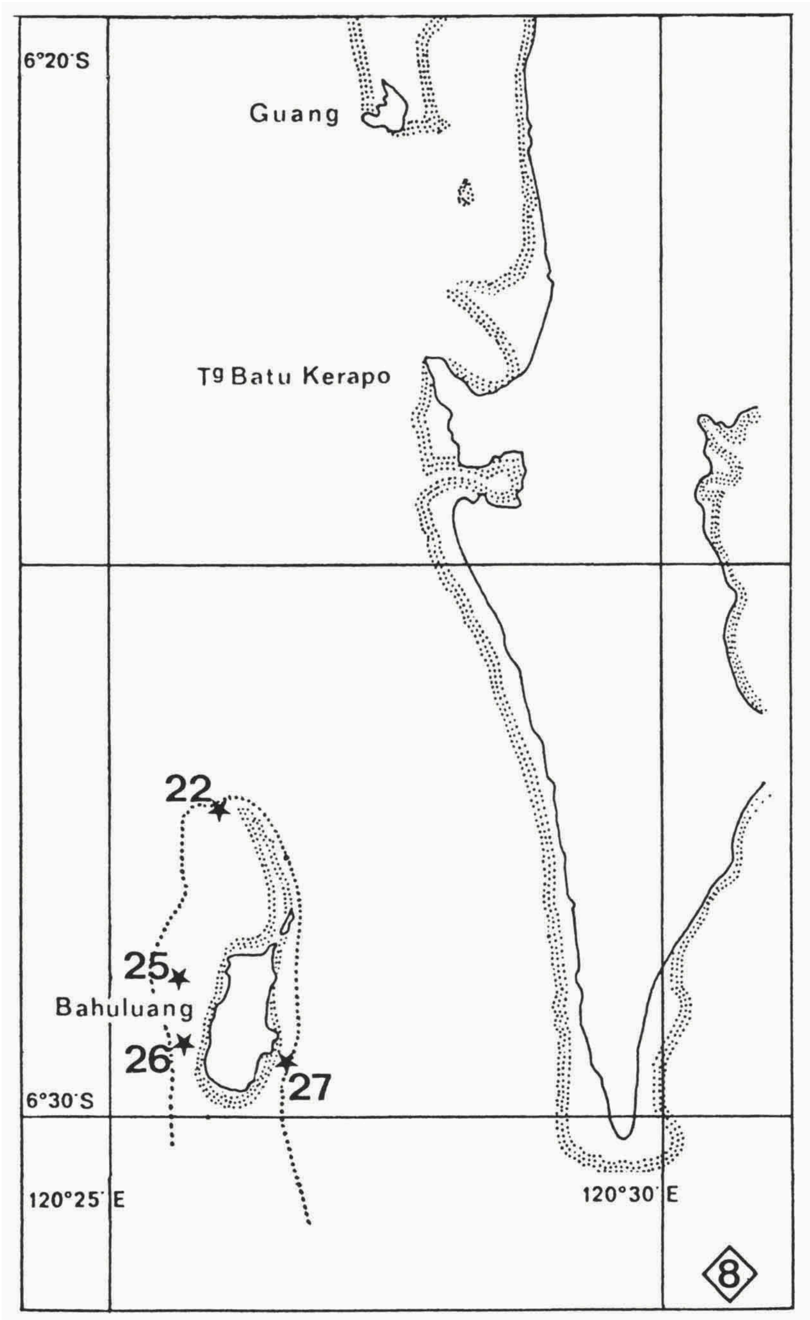

Fig. 5. Position of the transects made at Salayar, Bahuluang (⟨8⟩ in fig. 1).

come in almost perpendicularly to the eastern and western shore (Weber, 1922). The west side of Bahuluang is thus subjected to western winds during these months. During the rest of the year the eastern shore is protected from severe wave exposure by Salayar. This dramatic difference in exposure is expressed in the coral composition (see table 6).

In the east, foliaceous corals contribute about 40% to the cover and the same percentage to the total number of colonies. On the other hand, massive corals are very scarse. The reefs in the west harbour little or no foliaceous colonies, whereas massive species are very numerous and make up 40 to 50% of coral cover. Massive and foliaceous forms seem to have replaced each other at these sites.

Branching corals are well represented at both sides of Bahuluang. They contribute between 40 and 50% to the coral cover in the east as well as in the west. However, apart from *Porites lichen* and *P. nigrescens*, being two of the most common species in Indonesia, remarkable differences are found in the species composition of these arborescent corals.

Only one *Acropora* is found on both sides of the island: *Acropora echinata*. The smaller arborescent corals *(Seriatopora, Stylophora, Anacropora)* are only found in the east and not in the west. There, larger branching species *(Acropora brueggemanni, A. horrida, A. nobilis, A. vaughani)* dominate. Together with the foliaceous *Montipora* species *(M. aequituberculosa, M. foliosa, M. undata)* they form more than 75% of coral cover.

Along the eastern reefs there are large monospecific stands *(Montipora foliosa, Acropora nobilis, A. brueggemanni, A. formosa, A. microphthalma)* resulting in a high coral cover but low species diversity. The large arborescent and mostly fragile growth form of many of these species clearly reflects the more sheltered conditions at this side of the island. This observation is further corroborated by the record (the first for Sulawesi) of the extremely fragile *Zoopilus echinatus* from this reef.

A. brueggemanni is also a very distinctive species at sheltered sites around the island Tinanja (see below). It clearly prefers sheltered conditions with a good water circulation and is indicative of such a biotope.

3. Tinanja, Taka Bone Rate (locality 7 in fig. 1; transects 28, 29, 30, 31, 32, fig. 6)

Taka Bone Rate is the largest semi-atoll in Indonesia and one of the major reef complexes in the world. The island Tinanja itself, is a mere sand bar with an extensive reef-flat.

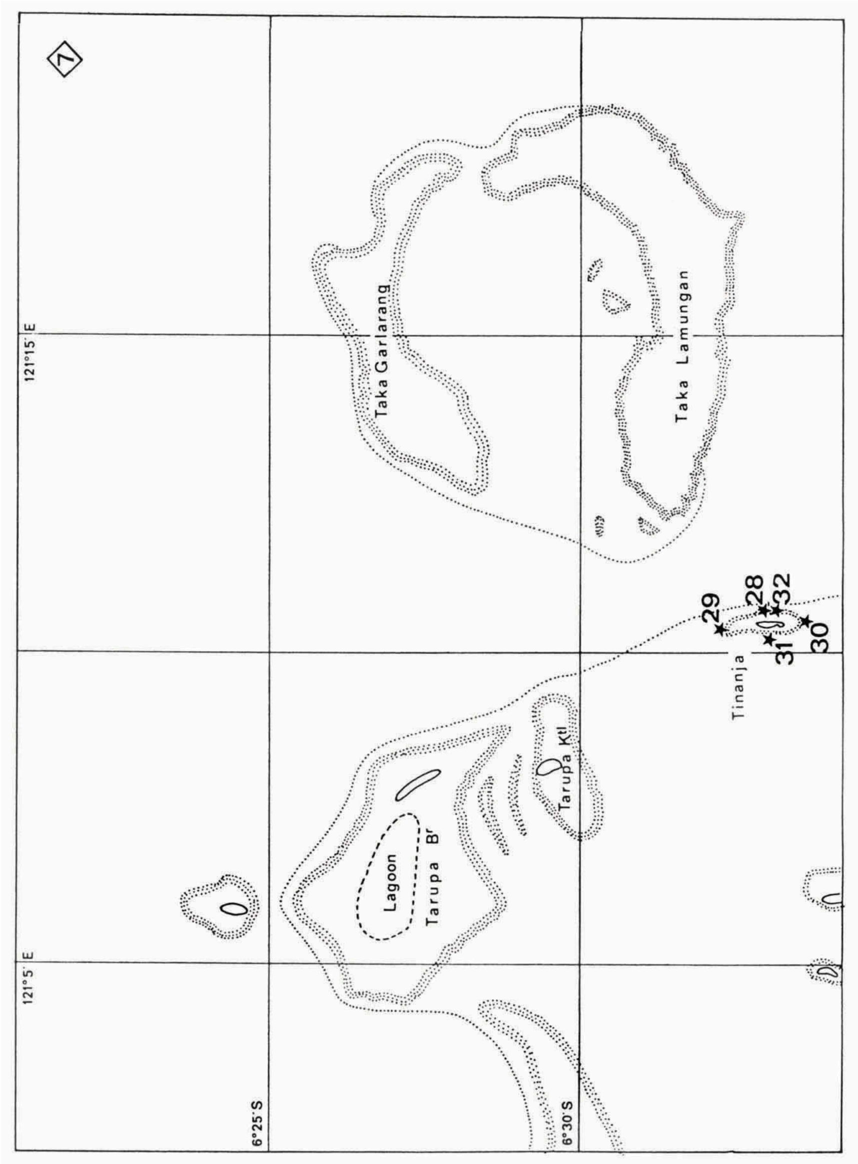

Fig. 6. Position of the transects made at Taka Bone Rate, Tinanja (◇7 in fig. 1).

In table 7, a number of variables are listed for transect 28 to 32 using the same abbreviations as before.

When comparing cover values it appears that the south tip shows a maximum; they are somewhat lower at the eastern side of the island and much lower at the north and west.

Two factors are likely to cause the above results: (1) maximum exposure in the north-east; (2) optimum conditions of food supply and oxygenation near the open sea.

The first results in a coral cover minimum in the north (for a large part made up by *Turbinaria* spp.) and a maximum in the south. It further causes

	actual values			in % of the highest values		
Tr	ns	nc	c	ns	nc	c
28	22	40	275	88	100	73
29	12	17	157	48	43	42
30	16	39	377	64	98	100
31	25	31	175	100	78	46
32	20	35	287	80	88	76

	species				colonies				cover			
Tr	%b	%f	%m	%s	%b	%f	%m	%s	%b	%f	%m	%s
28	9	22	64	5	20	13	63	5	11	11	74	4
29	25	17	58	0	18	12	71	0	12	19	69	0
30	44	19	31	6	77	8	13	3	73	11	16	0
31	28	20	36	16	32	19	36	13	25	29	36	9
32	15	15	65	5	34	11	51	3	24	14	61	0

	brch			fol			mas			sol		
Tr	ns	nc	c	ns	nc	c	ns	nc	c	ns	nc	c
28	2	8	29	5	5	29	14	25	204	1	2	12
29	3	3	19	2	2	30	7	12	108			
30	7	30	274	3	3	43	5	5	59	1	1	1
31	7	10	44	5	6	50	9	11	63	4	4	18
32	3	12	69	3	4	41	13	18	176	1	1	1

Table 7. Actual values and percentages of numbers of species (ns), numbers of colonies (nc), and cover (c) for transects 28-32. Values of these variables are also regarded according to the growth forms: branching, foliaceous, massive, and solitary.

the increasing importance of arborescent species along the same gradient. The second factor enhances cover along the eastern side of the island. Under these conditions coral growth flourishes especially when arborescent species are not excluded by harsh exposure.

In the south and south-east corals grow under sheltered conditions but still with a lot of water exhange with the open sea. Here, *A. brueggemanni* and *A. yongei* flourish at the expense of other corals, mainly the massive ones. The remaining massive *Porites (P. lutea* and *P. murrayensis)* are some of the largest colonies. The total number of species is thus smaller than in the east and west (table 8).

At the western side of the island, conditions tend less to favour the large arborescent species and more small massive forms like *Pavona varians, Platygyra daedalea, Porites australiensis* and *Porites lobata* are found here. Although the number of massive colonies is larger, average massive colony size in the west is half of that in the south. Average arborescent colony size is also smaller in the west, but so is the number of colonies, thus signifying a decreasing contribution to cover by this growth form.

The solitary fungids are of minor importance on these reefs. They are best represented at the western side of the island, the most sheltered.

4. Overall analysis

In the localities discussed above, 12 transects were described. These registered 102 species, 48 of which occurred only in one transect. Of the other

		exposed			
species	nt	c	species	nt	c
Cyphastrea serailia	4	18	*Stylophora pistillata*	4	21
Astreopora myriophth.	3	30	*Coeloseris mayeri*	3	14
Montipora nodosa	3	16	*Pocillopora verrucosa*	3	43
Acropora palifera	2	27	*Acropora sarmentosa*	2	29
Acropora tenuis	2	24	*Favites abdita*	2	16
Lobophyllia hattai	2	32	*Montipora hoffmeisteri*	2	15
		sheltered			
species	nt	c	species	nt	c
Fungia repanda	4	13	*Acropora brueggemanni*	3	214
Echinopora lamellosa	2	52	*Fungia horrida*	2	18
Montipora foliosa	2	102	*Pachyseris speciosa*	2	45
Porites rus	2	35			

Table 8. Species that were found only on exposed sites (lower part of fig. 7) or in sheltered sites (upper part of fig. 7). The number of transects in which they were found is stated (nt), as well as their total cover (c) in these transects.

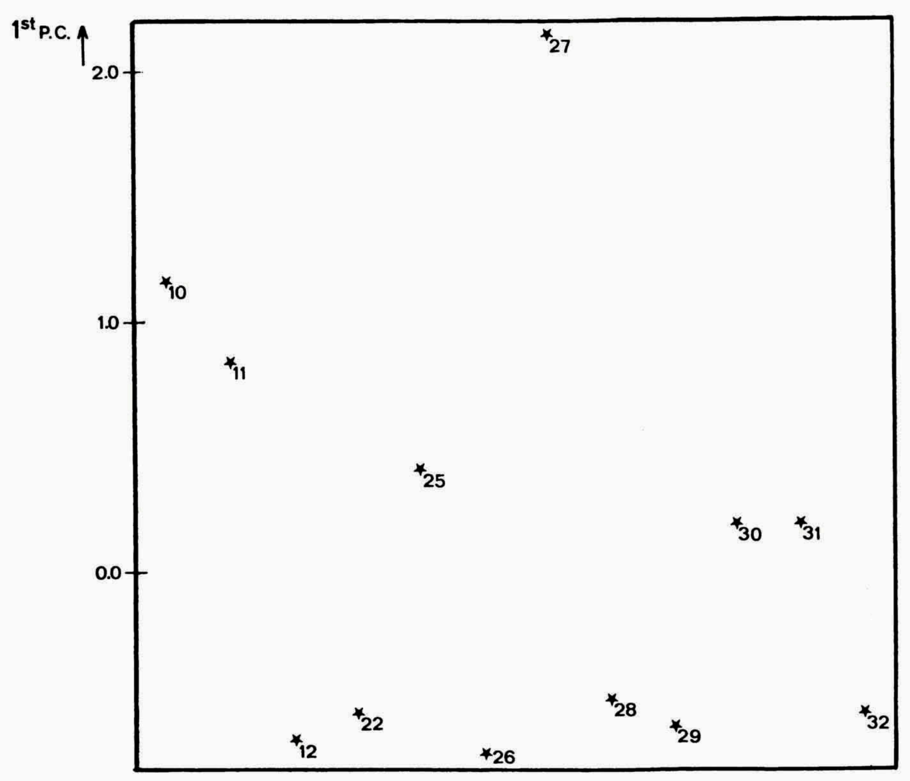

Fig. 7. Results from the multivariate analyses on the twelve transects discussed in this paper. Their scores on the first principal component are represented here.

		exposed			
species	nt	c	species	nt	c
Porites lutea	9	275	*Favia pallida*	5	26
Favites halicora	5	32	*Goniastrea pectinata*	5	29
Galax fascicularis	4	10	*Merulina ampliata*	4	62
Porites australiensis	4	59	*Seriatopora caliendrum*	4	38
		sheltered			
species	nt	c	species	nt	c
Montipora hispida	3	53	*Acropora florida*	2	47
Acropora nobilis	2	172	*Montipora undata*	2	32

Table 9. Species that attribute the major part of their cover either in exposed or sheltered sites. For explanations see also table 8.

54, 9 were registered at only one of the three localities. The remaining 45 species were analyzed for similarities between the 12 transects.

A cluster analysis on this 12 by 45 matrix furnished two major groups. The difference between these groups was based mainly on the total number of species per transect as presence/absence data was used. In a reciprocal averaging analysis the first principal component clearly separated the exposed sites from the sheltered ones (see fig. 7). The factor exposure thus appears to be the major component on which the species composition of these transects can be segregated.

After having arrived at the above mentioned conclusion, the sites were categorized as either exposed or sheltered, and their species composition was compared. There now appeared to be a number of species that demonstrate a clear preference for either the sheltered or the exposed sites that were investigated in the three regions discussed above. Species occurring exclusively in sheltered or in more exposed biotopes are listed in table 8.

Furthermore, there are species that, in view of their different cover values under sheltered or exposed circumstances, also exhibit a definite preference for either one of these biotopes. The species listed in table 9 attain a much larger cover under the conditions stated, and only one small colony of each of these species was found in the other type of biotope.

The multivariate analyses also provided correlation matrices of the species involved. They revealed pairs of species and sometimes larger groups of species of which the distribution patterns were highly correlated. The most firmly coinciding groups are listed in table 10.

sheltered

Acropora microphthalma - Montipora hispida ;
Acropora echinata - Fungia fungites ;
Acropora divaricata - Porites rus ;

exposed

Coeloseris mayeri - Montipora nodosa - Montipora verrucosa
Favia pallida - Stylophora pistillata ;
Astreopora myriophthalma - Cyphastrea serailia ;

mostly exposed

Herpolitha trilinguis - Leptastrea transversa -
- Platygyra daedalea - Merulina ampliata .

Table 10. The species that are strongly correlated in their occurrence in either sheltered or exposed sites.

DISCUSSION

When comparing the results presented here to a more detailed transect survey of the Sangkarang Archipelago (Moll, 1983) the following stands out.

Along a much smaller number of transects recorded during the Snellius II Expedition, more species were found than in the 18 months of field work off Sulawesi (363 vs 256). This difference is accounted for by the fact that, apart from transect sites, widely varying biotopes were sampled during the expedition whereas the Sankarang shelf proved to be more uniform.

Species very common in the Sangkarang Archipelago (*Acropora formosa, Porites lutea, P. lichen* and *Seriatopora hystrix)* also scored high during the expedition (considering that Moll (1983) misidentified *Porites lichen* as *P. mayeri). Montipora stellata* (formerly *M. digitata)* being very abundant on reef-flats was not recorded often in the transects during the expedition.

The average cover percentage presented here (see table 1) is a good deal higher than was calculated for the Sangkarang Archipelago. However, at each locality the region of the reef selected during the expedition was very similar in morphology and physical characters to the reef-edge in the Sangkarang Archipelago. Coral cover thus compared, is very similar in both parts of Indonesia.

The differences in cover between north, east, south and west coast in the Sangkarang Archipelago are similar to the results presented here. It should be kept in mind however, that the position of the most exposed biotope differed considerably: north-west in the Sangkarang Archipelago; west at Bahuluang; north-east at Tinanja; and east at Sumba. All analyses indicate that harsh exposure, especially when combined with extensive transportation of sediment (Tinanja) results in a low coral cover. In places with moderate water movement corals flourish, particularly near to open sea. A difference between the most exposed parts of the islands of the Sankarang archipelago and the islands studied during the expedition is that the former are situated on a shelf which protects them from the severe disturbances by water movement from open sea. The north-west coasts of the islands on this shelf therefore better resemble the moderately exposed reefs south off Bahuluang and Tinanja than the very exposed north and south of these two islands respectively.

Many of the cover values in the literature are based on quadrat surveys. Simply comparing those to the percentages furnished by linear survey methods, evokes a number of problems (see Moll, 1986, in prep.) and is not advised. Loya & Slobodkin's (1971) results are based on surveys of 10 m transect lines. They recorded the highest cover (85%) in the deeper *Porites lutea* zone and about 40% in the region comparable to the presently discussed study sites. Pichon & Morrissey (1981) described 30 m transects in the northern Great Barrier Reef and found lower abundancy and cover values for the reef-edge. Average number of species per 30 meter transect was 36 whereas during the Snellius Expedition an average of 17 species per 10 meter transect was registered.

Studies on the reefs of adjacent regions (Papua New Guinea: Weber, 1973; Malaysia: Chuang, 1977; Philippines: Pichon 1977; Northern Great Barrier Reef: Veron, 1978 and Pichon & Morrissey, 1981) all show that exposure to strong water movement and wave action, has a marked influence on the coral composition. Its influence is manifested both in species composition as well as in growth form composition (see also: Barnes e.a., 1971; Porter, 1972a and 1972b; Bak, 1977; Geister, 1977; Jokiel & Maragos, 1978; Wallace & Dale, 1978). In general it is agreed upon that wave action limits the development of coral growth, especially in shallower water. It is also often found to be an important ecological factor in governing the zonation of coral assemblages (Geister, 1977; Rosen, 1971, 1975; Head, 1980; Moll, 1983). The results presented here are somewhat different from the general zonation models provided by these authors. Table 2 demonstrates that the part of the reef sampled during the expedition should be characterised as the "*Porites* zone". Usually this zone is found deeper down the reef-slope and the zone mostly associated with the present study area (in terms of depth and exposure) is the "favid zone". Although average exposure was considered to be lower on the Sangkarang reefs, the exposure-phobic *Porites* zone was found deeper down the reef-slope in this archipelago. This seeming controversy again demonstrates that zonation is governed by a complex of factors of which water movement is only one.

The correlation between cover and overlap is in itself not very surprising. The highly significant nature of this relation further stresses the efficiency of certain growth form strategies. These tactics have been studied within the genus *Acropora* (Vosburgh, 1977). The other growth form strategies such as a tendency for more massive and encrusting morphologies in exposed sites is discussed in Chamberlain & Graus (1975), Graus (1977), and Sheppard (1982).

Cluster analyses have often been used as an aid in studying the coral composition of a reef (Loya, 1972; Maragos, 1974; Done, 1977; Jokiel & Maragos, 1978; Head, 1980; Pichon & Morrissey, 1981; Moll, 1983). In the present study the cluster analysis proved to be less "revealing" with regard to underlying variables than the principal component analyses (PCA). In the PCA (in this case a reciprocal averaging analysis) all species have the same "impact" and the number-of-species is ruled out as major component in the analysis. In the cluster analysis on the species composition, common species have most impact on the outcome whether these species exhibit a preference for a particular biotope or not. As the ecological parameter of exposure does not seem to influence the distribution of some of the most common species, it is clear that this factor is more easily detected when all species are incorporated equally.

The results show that there are large differences in the coral composition within the same area. Most of these differences can be related to the degree of exposure to water movement. Species can be distinguished that are indicators either of sheltered or of more exposed biotopes. Other species, however, seem to flourish under both conditions. These species are only informative of how well the coral fauna is developed in terms of live cover; they are of no use in characterising certain areas of the reef. Species of which the distribution patterns are highly correlated are noted in the present study to characterise certain reef areas. Indicator species of adjacent zones or communites are however known to demonstrate the same high degree of coincidence (Goodwin e.a., 1976) and it is thus imperative to re-examine the individual distribution of each species for cover maxima.

The identification of indicator species and other indices concerning the coral fauna can be valuable tools for the purpose of reef management and protection. The management of a certain reef usually requires extensive surveys to be carried out in the region. Several surveys (or at least two) over a period of time can show where, how, and at what pace, changes are taking place. However with the use of indicator species, growth form ratios, average colony size and number of species values, an initial inventory survey can shed light on processes that were active in the not too distant past up to the date of the survey. This means an enormous reduction in time and cost of investigating the condition of reefs. Especially in a nation as rich in coral reefs as Indonesia, the availability of such data will be of some importance.

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