Beitr. Paläont., **20**:89–97, Wien 1995

Long-term fluctuations of coral communities at Aqaba and on Sanganeb-Atoll (northern and central Red Sea) over more than a decade

Langzeituntersuchungen über mehr als eine Dekade an Korallenvergesellschaftungen bei Aqaba und am Sanganeb-Atoll (nördliches und zentrales Rotes Meer)

by

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SCHUHMACHER, H., KROLL, D.K. & REINICKE, G.B., 1995. Long-term fluctuations of coral communities at Aqaba and on Sanganeb-Atoll (northern and central Red Sea) over more than a decade. — Beitr. Paläont., **20**:89–97, 7 Figures, 2 Tables, 1 Appendix, Wien.

Abstract

Quantitative analyses of coral communities had been carried out on test squares in a fore reef area of a fringing reef near Aqaba (northern Red Sea) and on inner and outer reef slopes on Sanganeb-Atoll (central Red Sea) in 1976 (MERGNER & SCHUHMACHER, 1981) and 1980 respectively (MERGNER & SCHUHMACHER, 1985a). Further investigations at Aqaba in 1989 and on Sanganeb in 1991 yielded information on the growth and mortality of individual colonies as well as data on long-term fluctuations of community parameters. Near Aqaba, data of the test square U–7 (5 x 5 m in size) at a depth of some 10 m showed that significant changes occurred in the composition of the coral reef community between 1976 and 1989: xeniid soft coral colonies completely disappeared during this time. In total, 112 species of Cnidaria including 88 Scleractinia were found in the test square in 1976 and 1989. The diversity (H' = 3.23 in 1989– H' = 3.42 in 1976, based on Cnidaria-coverage) compared to the highest in the world. On Sanganeb-Atoll coral communities of four test squares (TQ–IV) of 5 x 5 m were analyzed. The data of 1991 for four TQs comprised a total of 3034 colonies of 130 species of stony corals, soft corals and hydrocorals, among them 86 species of Scleractinia. A mean diversity of H' = 2.80 in 1991 and H' = 2.58 in 1980 (based on Cnidaria-coverage) was recorded. The comparison of the qualitative analyses of the Sanganeb TQs in 1980 and 1991 proved the constancy of the coral communities. The analysis of the TQs near Aqaba and on Sanganeb-Atoll, however, showed significant differences when compared latitudinally. On Sanganeb-Atoll the data suggest that the stable abiotic conditions support a relative constancy of the coral communities in the reef areas studied, whereas near Aqaba considerable alterations become evident over a decade. Higher fluctuations of abiotic conditions (light, temperature) near the boundary of the geographical reef belt as well as grazing by sea urchins may account for retarded regeneration after occasional disturbances.

Zusammenfassung

Quantitative Analysen von Korallengemeinschaften sind in Testquadraten im Vorriff eines Saumriffes bei Aqaba (nördliches Rotes Meer) und an inneren und äußeren Riffhängen des Sanganeb-Atolls (mittleres Rotes Meer) im Jahr 1976 (MERGNER & SCHUHMACHER, 1981) bzw. 1980 (MERGNER & SCHUHMACHER, 1985a) durchgeführt worden. Erneute Untersuchungen bei Aqaba im Jahre 1989 bzw. am Sanganeb-Atoll im Jahre 1991 lieferten nicht nur Informationen bezüglich Zuwachs und Lebenserwartung von individuellen Kolonien, sondern auch bezüglich Langzeit-Schwankungen abstrakter Kenngrößen dieser Besiedler-Gemeinschaften. In Aqaba zeigen die Daten des Testquadrates U–7 (5 x 5 m; in 10 m Tiefe) bedeutende Veränderungen in der Zusammensetzung der Korallengemeinschaft zwischen den Jahren 1976 und 1989. Kolonien der Xeniidae-Weichkorallen verschwanden vollständig in diesem Zeitraum. Insgesamt wurden 112 Arten von Cnidaria bzw. 88 Scleractinia-Arten im Testquadrat während der Untersuchungsdaten gefunden. Die Diversität (H' = 3.23 in 1989 bzw. H' = 3.42 in 1976, basierend auf der Cnidaria-Bedeckung) gehört zu den höchsten Werten weltweit. Die Korallengemeinschaften des Sanganeb-Atolls wurden in vier Testquadraten (5 x 5 m Größe; ca. 10 m Tiefe) analysiert. Die Daten von 1991 betreffen 3034 Kolonien von 130 Arten Steinkorallen, Weichkorallen und Hydrokorallen, unter ihnen 86 Arten von Scleractinia, bezogen auf alle vier TQs. Die Diversität liegt im Mittel bei H' = 2.80 in 1991 bzw. H' = 2.58 in 1980, basierend auf der Cnidaria-Bedeckung. Der Vergleich der qualitativen Analysen der Sanganeb TQs in den Jahren 1980 und 1991 belegt eine

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weitgehende Konstanz der Korallengemeinschaften. Im latitudinalem Vergleich hingegen offenbarte die Analyse der TQs bei Aqaba und am Sanganeb-Atoll deutliche Unterschiede. Die Daten für das Sanganeb-Atoll weisen darauf hin, daß stabile Umweltbedingungen eine relative Konstanz in den untersuchten Riffabschnitten gewährleisten, während bei Aqaba beträchtliche Veränderungen innerhalb einer über zehnjährigen Periode offensichtlich werden. Größere Schwankungen von abiotischen Bedingungen (Licht, Temperatur) nahe der Grenze des geographischen Riffgürtels sowie Weidedruck durch Seeigel scheinen für eine verzögerte Regeneration nach gelegentlichen Störungen verantwortlich sein.

1. Introduction

Coral reef communities are dynamic. The space occupied by hermatypic organisms, by ahermatypic organisms and open space are continuously changing. In order to identify the extent of such fluctuations, we recorded quantitatively the benthic composition of fore reef areas at different positions on a latitudinal gradient over a time span of more than ten years.

Three underlying questions are:

1. If species composition does change qualitatively and quantitatively, do higher community characteristics, such as diversity, remain unchanged or vary in the same degree? Is a "trend" visible?
2. Can life history traits be recognized?
3. Do the geographically different community structures reflect a latitudinal gradient?

The 2270 km long basin of the Red Sea stretches from the tropics to the northern outpost of reef development in the Indopacific at the tip of the Gulf of Aqaba. Therefore seasonal differences in illumination and temperature can be expected to be more pronounced in the northern than in the central Red Sea and even reach the subsistence minimum of reef-building corals.

MERGNER & SCHUHMACHER (1981, 1985a) had already provided detailed quantitative analyses of the community composition on the fore reef at Aqaba for the year 1976 and on the outer and inner reef slopes of Sanganeb-Atoll in the central Red Sea for the year 1980; repeat investigations of these areas in 1989 (MERGNER et al., 1992) and 1991 respectively yielded a second "snapshot" of these particular sections of the reef.

The distance between the two localities allows the hypothesis of the "dynamic equilibrium model" (HUSTON, 1979) to be tested. According to that hypothesis, a high diversity is maintained as long as the frequency of disturbance and speed of recovery are in equilibrium. The temperature (five degrees higher at Sanganeb than at Aqaba) and the geographically determined high amount of illumination should favour a more rapid recovery on Sanganeb than at Aqaba resulting in larger colonies and fewer species per area.

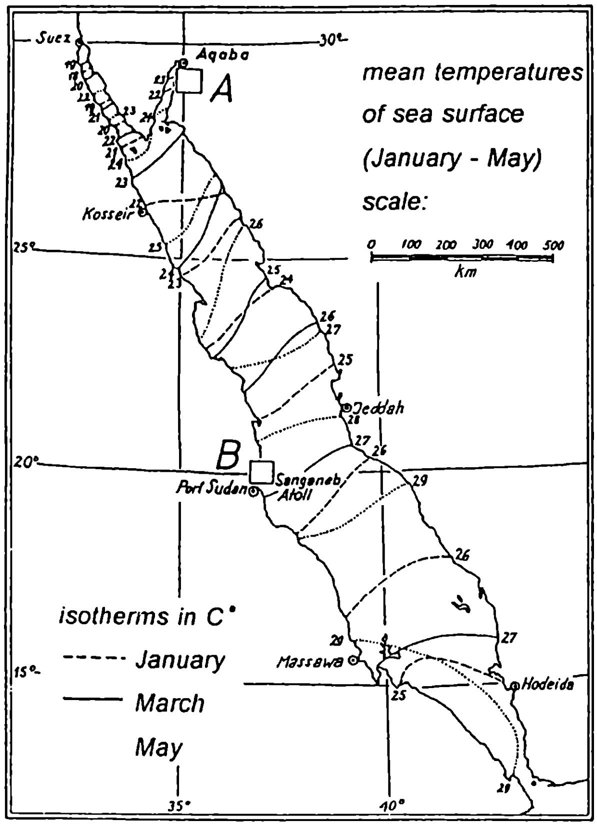

Figure 1: Map of the Red Sea, including isotherms (January – May) and the locations of study sites A = Aqaba and B = Sanganeb-Atoll. After SCHUHMACHER & MERGNER (1985a).

2. Study site and time

The coral reefs of the northern Gulf of Aqaba are among the most northerly ones in the world at a latitude of 29° 30' N. The test area, a square of 5 x 5 m, is on the middle fore reef about 150 m off the Marine Science Station at Aqaba (Figs. 1A and 2), in the coastal fringing reef at a depth of 10 m. The bottom slopes at a gradient of about 20 %. This area is characterized by a regime of moderate illumination and current conditions. Previous studies of the sublittoral biota of the 25 km Jordanian coastline (MERGNER & SCHUHMACHER, 1974) had revealed that this area was a representative section of the fore reef least disturbed by man.

Fig. 2 shows details of the reef south of the various ports of Aqaba and the location of the 25 m^2 square (called U–7) in the fore reef. The Sanganeb-Atoll is located in the central Red Sea at a latitude of 19° 45' N and 37° 26' E (30 km off Port Sudan; Figs. 1B and 3).

The study areas were four 5 x 5 m squares at a depth of 10 m along a SSW–NNE transect across the Sanganeb-Atoll. They were situated along a line bisecting the angle between the surface current generated by the monsoon and the water movement produced by the day and night breeeze. Hence the two squares facing north-east were exposed to the swell of the open sea and the lagoon respectively,

Community parameters	Sanganeb TQ I–IV (mean) 1980	1991	Aqaba test area U–7 1976	1989
Cnidaria:				
number of colonies	666	759	2050	1541
colony size (cm^2)	189	150	52	49
diversity (H')	2.58	2.80	3.42	3.23
evenness (J')	0.64	0.67	0.74	0.73
hermatypic corals, % of TQ	34.8	26.5	21.6	28.0
ahermatypic corals, % of TQ	15.4	18.9	20.6	1.4

Table 1: Comparison of community parameters (number and size of colonies, diversity, evenness) of Cnidaria between the four test areas of Sanganeb-Atoll in 1980 and 1991 (mean) and the test area U–7 near Aqaba in 1976 and 1989.

whereas the other two squares facing south-west were protected from this hydrodynamic impact.
Fig. 3 shows details of the atoll and the locations of the test squares (called TQ I–IV). Data collection at Aqaba took place during spring of 1976 and 1989.
An additional survey in spring 1982 is not considered here. The investigations on Sanganeb-Atoll were carried out during March/April in 1980 and 1991.

3. Methods

The test squares U–7 at Aqaba and the TQ I–IV on Sanganeb-Atoll are each 5 x 5 m in size, they are laid out at a depth of approximately 10 m, marked off by nylon ropes.
The size of the Aqaba square had been determined after a precedent species/area survey as the smallest one representing all species of that reef area. The Sanganeb squares were identically sized for the sake of comparison. The colonization of the area by Cnidaria and other sessile organisms was mapped colony by colony by means of underwater drawings, photographs and video tapes. Specimens which could not be identified in situ were collected directly next to the test area and identified later. Nearly all the original nylon ropes marking the squares were located during repeat investigations. We were therefore able to remap the identical areas.
Further details of the methods used are given by MERGNER & SCHUHMACHER (1981).
Calculations of species diversity (Shannon-Wiener Index) were made using both coverage of colonies (square centimeters) and the number of colonies. These two

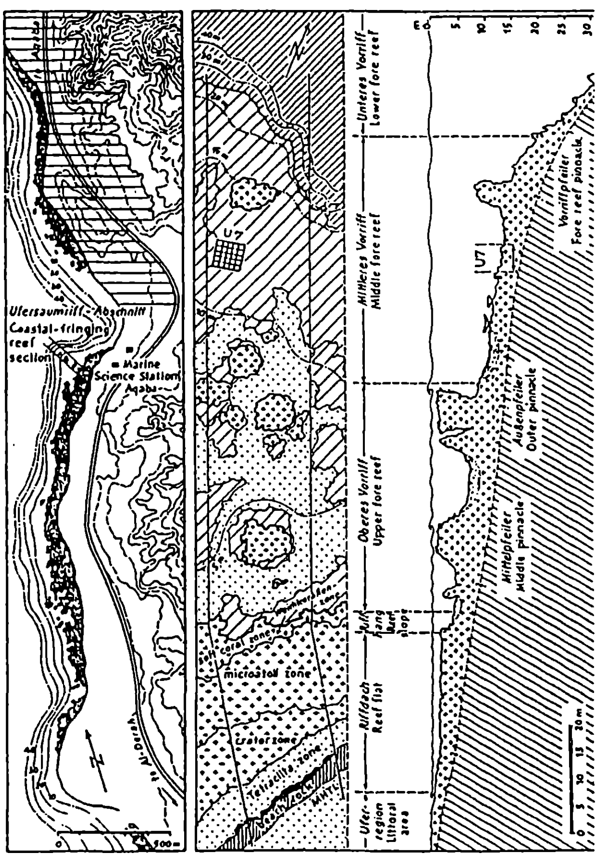

Figure 2: Location of the study site south of the town of Aqaba. Left: shore line with fringing reef near the Marine Science Station (hatched area: harbour facilities built in 1977/78); center and right: top plan view and profile of a transect perpendicular to the shore with test square U–7. After MERGNER & SCHUHMACHER (1981).

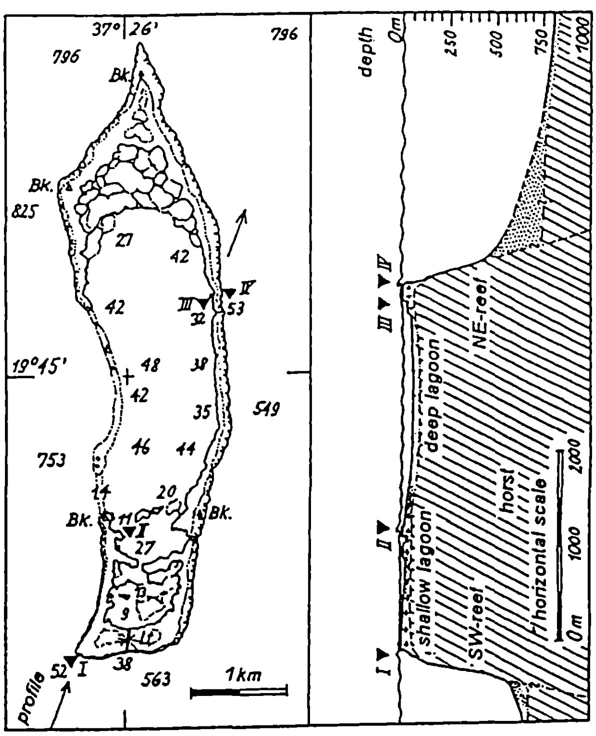

Figure 3: Map (left) and profile (right) of Sanganeb-Atoll near Port Sudan with location of test areas TQ I–IV After SCHUHMACHER & MERGNER (1985a).

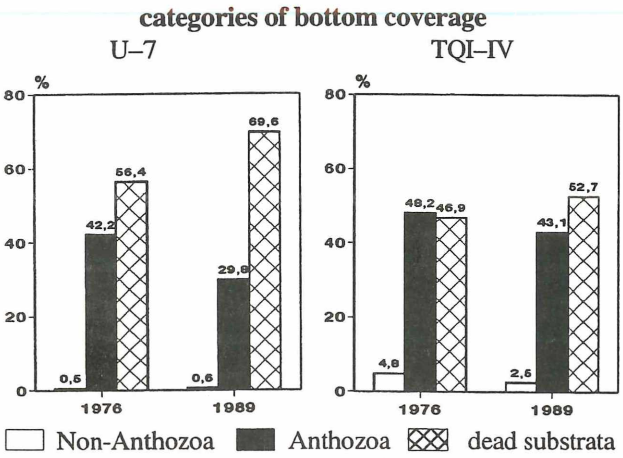

Figure 4: Percentage of coverage of Anthozoans, Non-Anthozoans and dead substrates in the TQ U–7 near Aqaba, 1976 and 1989 (left) and in the TQs I–IV on Sanganeb-Atoll, 1980 and 1991 (right).

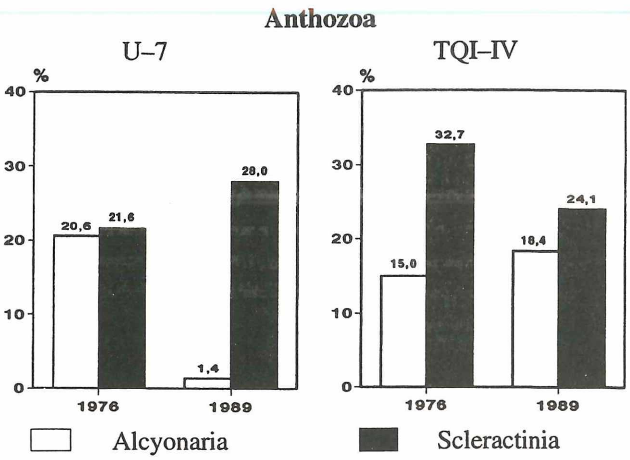

Figure 5: Percentage of anthozoan coverage (Alcyonaria, Scleractinia) in the TQ U–7 near Aqaba, 1976 and 1989 (left) and in the TQs I–IV on Sanganeb-Atoll, 1980 and 1991 (right).

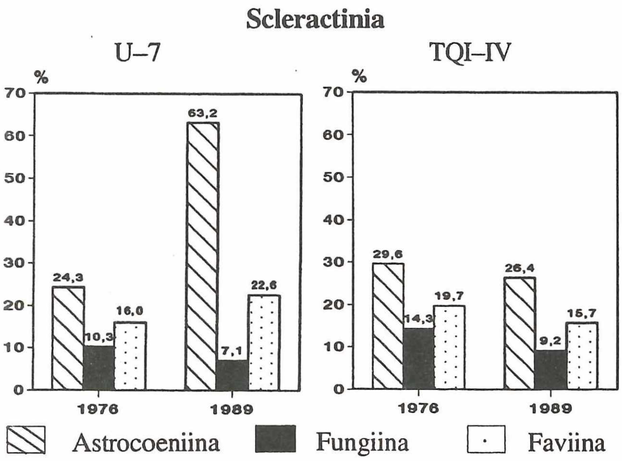

Figure 6: Percentage of scleractinian suborders in the TQ U–7 near Aqaba, 1976 and 1989 (left) and in the TQs I–IV on Sanganeb-Atoll, 1980 and 1991 (right).

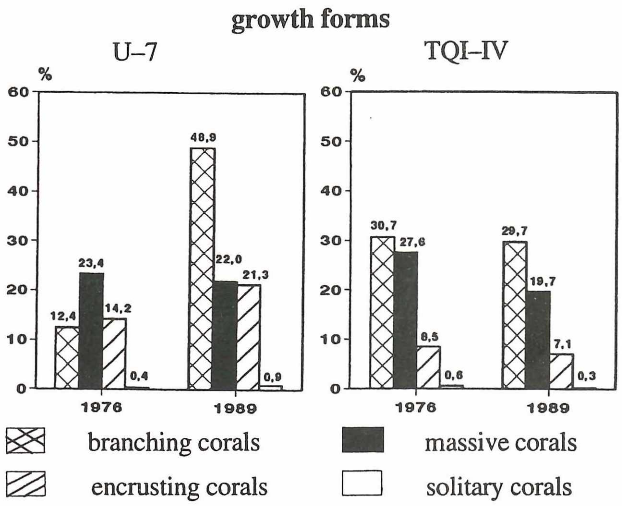

Figure 7: Percentage of scleractinian growth forms in the TQ U–7 near Aqaba, 1976 and 1989 (left) and in the TQs I–IV on Sanganeb-Atoll, 1980 and 1991 (right).

measures are correlated, but, as corals are sessile organisms, both their size and their numerical presence are of ecological significance.

4. Results

This report presents the data of the species concerned, number and size of colonies, living coverage, abundance, growth forms, and species diversity.

The abundance of the species recorded on each monitoring date is given in the Table 2 and in Appendix 1.

Fig. 4 shows that significant changes occurred in the composition of the coral reef community at Aqaba between 1976 and 1989: xeniid soft coral colonies completely disappeared during this time. Thus the share of the Alcyonaria in the total area decreased from 20.6 to 1.4%, whereas that of the Scleractinia increased from 21.6 to 28.0% (Fig. 5). The number of cnidarian colonies dropped from 2050 in 1976 to 1541 in 1989, while the mean colony size (approx. 50 cm^2) remained almost constant (Tab. 1). In total, 112 species of Cnidaria including 88 Scleractinia were found in the test square on the monitoring dates in 1976 and 1989 (Appendix 1).

Within the Scleractinia the suborder Astrocoeniina occupied a major part of the total area, especially in 1989 (63.2 % of anthozoan coverage). The corresponding figures for Faviina and Fungiina were much smaller and were subject to different changes (Fig. 6).

Fig. 7 shows that scleractinian growth forms (related to the share of Cnidaria) are dominated by branching corals (48.9%). Due to the disappearance of xeniids the total anthozoan coverage dropped from 42.2 to 29.8% (Fig. 4).

In spite of the major shifts in the composition of the sessile community the species diversity is still largely maintained ($H' = 3.23$, compared to $H' = 3.42$ in 1976, based on Cnidaria-coverage).

species	mean 1976:1980				mean 1989:1991			
	colony size U–7:I–IV		colony number U-7:I–IV		colony size U-7:I–IV		colony number U-7:I–IV	
Parerythropodium fulvum (7 ; 5)	1	1.29	3.87	1	1.29	1	1	1.69
Sarcophyton ehrenbergi (8 ; 6)	2.47	1	2.66	1	1	1.10	4.00	1
Stylophora pistillata (36 ; 25)	1	1.19	11.39	1	1	1.82	29.29	1
Seriatopora hystrix (38 ; 24)	1	1.29	1	2.75	1	4.25	1	14.00
Acropora hemprichi (45 ; 29)	1	14.19	1	2.08	1	4.81	2.27	1
Acropora variabilis (51 ; 33)	1	3.14	6.74	1	1	1.32	38.57	1
Montipora meandrina (56 ; 39)	1	2.19	31.00	1	1.49	1	37.45	1
Montipora venosa (60 ; 42)	1.68	1	2.67	1	1	4.47	2.00	1
Pavona varians (67 ; 49)	1	1.38	3.22	1	1	2.27	4.00	1
Favia laxa (86 ; 71)	1	1.85	5.60	1	1	7.23	1.60	1
Favia stelligera (90 ; 73)	1	3.43	2.40	1	1	2.44	4.86	1
Goniastrea pectinata (97 ; 79)	1	3.03	9.82	1	1	1.23	8.51	1
Goniastrea retiformis (98 ; 80)	1	2.38	6.35	1	1	2.77	2.49	1
Leptastrea bottae (103 ; 83)	1	3.11	38.67	1	1.83	1	9.33	1
Leptastrea transversa (105 ; 85)	1.21	1	11.00	1	1.64	1	20.00	1
Cyphastrea chalcidicum (106 ; 62)	1	2.33	1.88	1	1	1.05	4.00	1
Cyphastrea microphthalma (107 ; 63)	1	1.13	27.00	1	1	2.95	11.69	1
Echinopora gemmacea (109 ; 66)	1	6.32	1.71	1	1	6.70	2.20	1
E. gemmacea var. *fruticulosa* (110 ; 67)	1	3.46	6.40	1	1	13.71	10.67	1
Galaxea fascicularis (113 ; 88)	1	4.47	1	1.17	1.16	1	1	1.69
Lobophyllia corymbosa (115 ; 91)	1	5.91	1	10.75	1	1.73	1	8.50

Table 2: Comparison of size and number of colonies between the test area U–7 near Aqaba (1976 and 1989) and the average of the four Sanganeb areas TQ I–IV (1980 and 1991)

In 1991, the data of the coral communities in the four test squares on Sanganeb-Atoll comprised a total of 3034 colonies of 130 species of stony corals, soft corals and hydrocorals, among them 86 species of Scleractinia in all four TQs (Appendix 1). The respective figures for 1980 are given in Figs. 4–7. The cnidarian cover of the four test squares ranged from 39.4 to 57.5% with a mean diversity of $H' = 2.80$. Each TQ contained 41–49 scleractinian species with 226 to 424 colonies. With respect to scleractinian growth forms, branching species had a mean share of 29.7%, massive corals 19.7%, encrusting corals 7.1% and solitary corals 0.3% of the total living coverage (Fig. 7). The share of Alcyonaria ranged between 2.7 and 28.9%.

The comparison of the qualitative analyses of the Sanganeb-TQs in 1980 and 1991 proved the constancy of the coral communities. However, although the mean number of colonies increased from 666 to 759, the decrease in mean colony size from 189 to 150 cm^2 (Tab. 1) resulted in a reduction of mean anthozoan coverage from 48.2 to 43.1% (Fig. 4). Furthermore, the share of Scleractinia decreased significantly from 32.7 to 24.1%, whereas the share of Alcyonaria sligthly increased from 15.0 to 18.4% (Fig. 5). Fig. 6 shows that all suborders of Scleractinia had lost between 3 and 5% in 1991.

The decline of Scleractinia affected all growth forms: the share of branching corals fell from 30.7 to 29.7%; massive corals from 27.6 to 19.7% and encrusting corals from 8.5 to 7.1% of total Cnidaria cover (Fig. 7).

Tab. 2 compares the Aqaba and Sanganeb squares with respect to colony size and numbers of 21 alcyonarian and scleractinian species. The ratios of the 1976–1980 comparison have been recalculated, since the data given by MERGNER & SCHUHMACHER (1985b) unfortunately include some errors. With few exceptions, the colonies of Sanganeb are larger than the Aqaba colonies which, however, are more numerous.

Furthermore, it is apparent from the data that different species of corals have undergone different types of changes in the time between the surveys. The specific life histories, however, cannot be discussed in this paper.

5. Discussion

The results call for discussion of two aspects a) the reasons for and extent of changes on the spot over time and b) comparison between the two study areas. A detailed discussion of the community dynamics at Aqaba and on Sanganeb-Atoll will be provided separately. Here, the main features of development at the two sites are put side by side and compared.

The most striking feature at Aqaba is the complete disappearance of xeniid soft corals. In March 1982, SCHUHMACHER found that all xeniids had been wiped out along the Jordanian coast. Reinvasion took place only slowly: in 1989 several xeniid species could again be recognized in the reefs at Aqaba but no colony had yet colonized the test square. The space left by xeniids was partly taken over by scleractinian corals particularly by new settlement of pioneer species such as *Stylophora pistillata*, *Acropora variabilis*, *Acropora squarrosa* and by the growth and enlargement of colonies still persisting. Nevertheless nearly 70 % of the bottom area was free in 1989 (compared to some 57 % in 1976) – most probably due to the grazing activity of a high number of *Diadema* sea urchins (7 animals per m^2 – KROLL pers. com.).

The squares on Sanganeb-Atoll each of which is characterized by a specific community (–"physiographische Leitarten" – MERGNER & SCHUHMACHER, 1985a) preserved these site specific characteristics, although a storm obviously had passed the atoll one or two years before the second inspection date. With no grazing sea urchins present, scleractinian corals are recolonizing the empty space but have not yet reached the same coverage as before. This can be detected from the high number of colonies, the high percentage of branching forms (including mainly pioneer types), the low mean colony size and the total scleractinian coverage in comparison with the respective data from 1980.

MERGNER & SCHUHMACHER (1985b) stressed the point that the mean diameter of colonies on Sanganeb is larger than at Aqaba. This feature generally persisted. It may be concluded that favorable conditions (especially light, temperature, lack of grazers) in the central Red Sea result in a growth rate of corals which enables them to recover rapidly after occasional catastrophes. In contrast, the growth rate at Aqaba is scarcely sufficient to overcome the high "colonization resistance" of that site. "Colonization resistance" is understood as "sum" or total effect of abiotic parameters (e.g. illumination, temperature, sedimentation) and biotic conditions (e.g. grazing pressure, fall of larvae) which prevent sessile organisms from settling with subsequent growth at the maximum rate and of the maximum extent.

The two snapshots of the community with an interval of more than a decade permit the preliminary conclusion that general community characteristics such as diversity, mean colony size and growth form, change slowly and remain distinctly different in the central Red Sea and at its northern end. A more detailed comparison of the communities is in preparation.

Acknowledgements

We wish to express our gratitude to the directors and the staff of the Marine Science Station, Aqaba and of the Institute of Oceanography, Port Sudan for providing working space and equipment during our field work. Sincere thanks are due to the late Dr. J. Verseveldt and to L. P. van Ofwegen for identification of the sinulariid soft corals, and to Dr. M. Borel-Best, Dr. B. W. Hoeksema and Dr. G. Scheer for kind assistance with the identification of some of the stony corals. We gratefully acknowledge the financial support provided by Deutsche Forschungsgemeinschaft.

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Appendix 1: Colonization by Cnidaria in the four test areas of Sanganeb-Atoll (1980 and 1991) and the test quadrat U–7 near Aqaba (1976 and 1989)

no I–IV	U–7	order, genus, species
		HYDROZOA
		Hydroidea
		Milleporidae
1		*Millepora dichotoma*
2	1	*Millepora exaesa*
3		*Millepora platyphylla*
		SCYPHOZOA
		Rhizostomeae
		Cassiopeidae
		Cassiopea andromeda
		Stylasteridae
4		*Distichopora violacea*
		ANTHOZOA, Octocorallia
		Stolonifera
		Tubiporidae
5	2	*Tubipora musica*
		Alcyonaria
		Alcyoniidae
	3	*Cladiella pachyclados*
6		*Lobophytum pauciflorum*
	4	*Lobophytum* sp.
7	5	*Parerythropodium fulvum*
8	6	*Sarcophyton ehrenbergi*
9		*Sarcophyton elegans*
10		*Sinularia candidula*
11		*Sinularia dactyloclados*
125		*Sinularia erecta*
12		*Sinularia flabelliclavata*
13		*Sinularia gardineri*
126		*Sinularia heterospiculata*
14	7	*Sinularia leptoclados*
15		*Sinularia minima*
127		*Sinularia muqeblae*
16		*Sinularia notanda*
17		*Sinularia polydactyla*
18		*Sinularia querciformis*
128	8	*Sinularia recurvata*
19		*Sinularia schuhmacheri*
		Nephtheidae
	10	*Nephthea albida*
20		*Nephthea laevis*
21		*Dendronephthya hemprichi*
	9	*Dendronephthya* sp.
22		*Stereonephthya cundabiluensis*
23	11	*Litophyton arboreum*
24		*Paralemnalia eburnea*
25	12	*Paralemnalia thyrsoides*
		Xeniidae
129		*Xenia biseriata*
130		*Xenia blumi*
131		*Xenia crassa*
132		*Xenia garciae*
133		*Xenia impulsatilla*
26	14	*Xenia macrospiculata*
	15	*Xenia membranacea*
134	16	*Xenia obscuronata*
27	18	*Xenia umbellata*
135	17	*Xenia* sp.
28	13	*Heteroxenia fuscescens*
29		*Anthelia fishelsoni*
30		*Anthelia glauca*
31		*Sympodium caeruleum*
		Gorgonaria
		Melithaeidae
136		*Acabaria biserialis*
32		*Clathraria rubrinodis*
		ANTHOZOA, Hexacorallia
		Corallimorpharia
		Actiniaria
		Aliciidae
		Triactis producta
		Stoichactidae
		Entacmaea quadricolor
		Heteractis aurora
		Scleractinia
		Thamnasteriidae
33		*Psammocora haimeana*
34		*Psammocora nierstraszi*
	19	*Psammocora profundacella*
		Astrocoeniidae
35	98	*Stylocoeniella armata*
		Pocilloporidae
36	25	*Stylophora pistillata*
	99	*Stylophora prostrata*
137		*Stylophora subseriata*
37	23	*Seriatopora caliendrum*
38	24	*Seriatopora hystrix*
39	20	*Pocillopora damicornis*
40		*Pocillopora verrucosa*
		Acroporidae
41	35	*Astraeopora myriophthalma*
42		*Acropora capillaris*
43		*Acropora corymbosa*
138		*Acropora digitifera*
139	27	*Acropora eurystoma*
	28	*Acropora forskali*
	26	*Acropora granulosa*
44		*Acropora* cf. *haimei*
45	29	*Acropora hemprichi*
46	30	*Acropora humilis*
47		*Acropora hyacinthus*
48	31	*Acropora pharaonis*

Appendix 1 (continued)

no I–IV	U–7	order, genus, species
49	32	*Acropora squarrosa*
50		*Acropora superba*
51	33	*Acropora variabilis*
52	34	*Acropora* sp.
	100	*Montipora edwardsi*
53	37	*Montipora effusa*
54		*Montipora ehrenbergi*
55		*Montipora granulosa*
56	39	*Montipora meandrina*
57	40	*Montipora monasteriata*
58	41	*Montipora stilosa*
	38	*Montipora stilosa* var. *eilatensis*
59		*Montipora tuberculosa*
60	42	*Montipora venosa*
61		*Montipora verrucosa*
62	43	*Montipora* sp.
		Agariciidae
	47	*Pavona cactus*
63		*Pavona clavus*
140	48	*Pavona decussata*
64		*Pavona divaricata*
65		*Pavona explanulata*
66	103	*Pavona maldivensis*
67	49	*Pavona varians*
68	102	*Leptoseris mycetoseroides*
	45	*Leptoseris* sp.
69	44	*Gardineroseris planulata*
	46	*Pachyseris speciosa*
		Siderastreidae
70	50	*Coscinaraea monile*
		Fungiidae
	51	*Cantharellus doederleini*
	52	*Cycloseris* sp.
71		*Fungia echinata*
72	53	*Fungia fungites*
	54	*Fungia granulosa*
141	104	*Fungia horrida*
73		*Fungia klunzingeri*
74		*Fungia scutaria*
	105	*Ctenactis echinata*
75		*Herpolitha limax*
		Poritidae
76	55	*Alveopora daedalea*
77		*Goniopora minor*
	56	*Goniopora planulata*
78		*Goniopora tenuidens*
	57	*Goniopora* sp.
	58	*Porites* (*Synarea*) *convexa*
79		*Porites echinulata*
80	59	*Porites lutea*
81		*Porites solida*
82		*Porites* (*Synaraea*) *undulata*
83	60	*Porites* sp.

no I–IV	U–7	order, genus, species
		Faviidae
	61	*Caulastrea tumida*
84	69	*Favia amicorum*
85	70	*Favia favus*
86	71	*Favia laxa*
87	72	*Favia pallida*
88		*Favia rotumana*
89		*Favia speciosa*
90	73	*Favia stelligera*
	74	*Favia* sp.
142	75	*Favites abdita*
91	106	*Favites complanata*
92	107	*Favites flexuosa*
93		*Favites halicora*
	76	*Favites peresi*
94		*Favites pentagona*
95		*Favites rotundata*
	77	*Favites* sp.
96	78	*Goniastrea edwardsi*
97	79	*Goniastrea pectinata*
98	80	*Goniastrea retiformis*
	81	*Goniastrea* sp.
99	87	*Platygyra daedalea*
143	108	*Platygyra lamellina*
144		*Platygyra sinensis*
100		*Leptoria phrygia*
101		*Oulophyllia crispa*
	82	*Hydnophora exesa*
102		*Hydnophora microconus*
103	83	*Leptastrea bottae*
104	84	*Leptastrea purpurea*
105	85	*Leptastrea transversa*
106	62	*Cyphastrea chalcidicum*
107	63	*Cyphastrea microphthalma*
108	64	*Cyphastrea serailia*
	65	*Cyphastrea* sp.
109	66	*Echinopora gemmacea*
110	67	*E. gemmacea* var. *fruticulosa*
111	68	*Echinopora lamellosa*
		Oculinidae
112		*Galaxea astreata*
113	88	*Galaxea fascicularis*
		Merulinidae
	89	*Merulina ampliata*
145	109	*Merulina scheeri*
		Mussidae
	110	*Blastomussa merleti*
114		*Scolymia vitiensis*
115	91	*Lobophyllia corymbosa*
116	93	*Lobophyllia hemprichii*
117		*Lobophyllia pachysepta*
118	90	*Acanthastrea echinata*
119		*Symphyllia erythraea*

Appendix 1 (continued)

no I–IV	U–7	order, genus, species	no I–IV	U–7	order, genus, species
		Pectiniidae		96	*Turbinaria mesenterina*
120	95	*Mycedium elephantotus*			**Zoantharia**
121	94	*Echinophyllia aspera*			**Zoanthidae**
122	111	*Oxypora lacera*	123	97	*Palythoa tuberculosa*
		Caryophylliidae			**Antipatharia**
	112	*Gyrosmilia interrupta*			**Antipathidae**
		Dendrophylliidae	124		*Cirripathes* sp.
146		*Tubastraea aurea*			