DIPLOMARBEIT

Titel der Diplomarbeit

Molluscan association on coral reefs at Dahab (Gulf of Aqaba, Egypt)

Band 1 von 1 Band

Verfasserin

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angestrebter akademischer Grad

Magistra der Naturwissenschaften (Mag.rer.nat.)

Wien, 2012

Studienkennzahl lt. Studienblatt:	A 444
Studienrichtung lt. Studienblatt:	Diplomstudium Ökologie
Betreuerin / Betreuer:	Univ.-Prof. Mag. Dr. Martin Zuschin

Personal introduction

My fascination with the sea started when I was ten. I wondered how it would be to explore the reefs and sand flats from underwater. Stubborn as always, I kept that dream and two years later I learned to SCUBA dive. Proud as a peacock I showed around my little certificate and for my birthday my mother presented me with a week of diving in the Red Sea. It was love of the first sight, when I met my first shark with 12 years and since then the sea spellbound me. Thus, at the age of 18, after working 6 months in national parks in Costa Rica, the decision to study marine biology was the next logical step. In my studies in the University of Vienna and in the abroad semester at the University of Western Australia my focus was on marine ecology with environmental protection in the background. During this time I got introduced to molluscs by Prof. Martin Zuschin and Dr. Jane Prince. The topic stuck and especially its potential for environmental protection assessments has fascinated me ever since.

In remembrance of Johanna.

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Abstract

The Red Sea has a rich biodiversity with many endemic species and the combination of flora and fauna from the Indo-Pacific and the Mediterranean Sea. The molluscs are one part of this rich biodiversity and their distribution and abundance in the coral reef around Dahab (Egypt) is the goal of this study. 35 transects with a total of 350 m^2 resulted in 3253 molluscs including 35 gastropod and 32 bivalve taxa. Depths between 2 and 30 m at six sampling sites were covered and three reef types were distinguished: fringing reef, patch reef and coral carpet. 2326 living and 911 dead individuals were found. *Chama* sp., Ostreidae and *Pedum spondyloideum* showed the highest abundance. One third of the taxa was encountered only once and 70 % had less than ten individuals. Molluscan biodiversity is highly dependent on the coral habitat. Most molluscs were found between two and five m and the patch reef had more individuals than the other types. Fringing reefs and coral carpets mark different depth zones and differ in abundance and taxonomic composition of rare molluscs, while the patch reef stretches between them. This is reflected in species composition and abundance. Clear distinction between the dead and the living assemblage was shown due to the overgrown bivalves after death, transport of shells into cracks of the reef and occupied by hermit crabs.

This study is a first assessment of coral associated molluscs in Dahab and provides the base for further research. A comparison with other regions of the Red Sea already shows a similar change in molluscan composition that led to an increase of *Coralliophila*, though numbers of *Drupella cornus* seem to have decreased since 2010.

In the face of climate change, longterm monitoring around the northern Red Sea, especially in Dahab, might show if changes of species composition can be seen and may present the base for longterm protection of tropical reefs.

Zusammenfassung

Das Rote Meer ist reich an endemischen Arten und bildet die Verbindung von Flora und Fauna aus dem Indo-Pazifik und dem Mittelmeer. Die Biodiversität der Mollusken stellt eine dieser Faunen dar und die Feststellung der Abundanz und Verteilung im Korallenriff um Dahab, Golf von Aqaba, ist das Ziel dieser Arbeit. 35 Transekte zu 350 m^2 ergaben 3253 Mollusken von 35 Gastropoden und 32 Bivlaven Taxa. Tiefen zwischen 2 und 30 m wurden an sechs Stationen beprobt und drei Hauptrifftypen wurde unterschieden: Saumriff, Riffblöcke und ebene Korallenteppiche. 2326 lebende Individuen und 911 tote wurden bestimmt, wobei *Chama* sp., Ostreidae und *Pedum spondyloideum* die höchste Abundanz zeigten. Ein Drittel aller Taxa kam nur einmal vor und 70 % hatten weniger als zehn Individuen. Die Mollusken Diversität hängt sehr stark von den Korallenhabitaten ab. Die meisten Mollusken wurden in zwei bis fünf m Tiefe gefunden und die Riffblöcke stachen mit einer höheren Anzahl an Individuen als die anderen zwei Rifftypen hervor. Die untersuchten Saumriffe und Korallenteppiche erstrecken sich in verschiedenen Tiefenzonen und unterscheiden sich in der Abundanz und Verteilung der seltenen Mollusken. Die Riffblöcke erstrecken sich zwischen diesen zwei Habitaten, was sich auch in der Faunenzusammensetzung wiederspiegelt. Eine klare Abgrenzung lässt sich zwischen den lebenden und den toten Molluskensammlungen machen. Durch das Überwachsen von inkrustierenden Muscheln von den Korallen, den Verlust von Schalen in Riffspalten und teilweise Überrepresentation durch die Besetzung mit Einsiedlerkrebsen kommt.

Der Vergleich mit Aqaba und anderen Regionen im Roten Meer zeigt bereits Veränderungen in der Zusammensetzung der Mollusken im vorigen Studien. Die Anzahl von *Coralliophila* ist angestiegen im Vergleich zu anderen Studien während bei der Zahl von *Drupella cornus* scheinbar ein Rückgang beobachtet wurde. Diese Studie bildet die Basis für weitere Forschungsarbeiten. Vor allem im Angesicht des Klimawandels ist ein Langzeitmonitoring in Dahab wichtig, um weitere Veränderungen in der Artenzusammensetzung zu dokumentieren und um die Basis für Langzeitschutz tropischer Riffe zu gewährleisten.

1

Introduction

The Red Sea has a rich biodiversity with many endemic species and the combination of flora and fauna from the Indo-Pacific and the Mediterranean Sea. Intensive Research on the littoral benthos has been done since the 1950ies (Fishelson 1971). Works on molluscs, has been done by several authors, including Mastaller (1978), Taylor and Reid (1984), and Zuschin and Oliver (2005). Here, the Gulf of Aqaba, is the main focus of the research.

The Gulf of Aqaba is a smaller version of the Red Sea. The shallow sill at Nabq mainly prevents deep water mixing with Red Sea water. Hypersaline, oligotrophe waters characterise the Gulf and its narrow shelf, which reaches only 0.25–2 km from shore (Friedman 1968). This narrow shelf is due to the tectonic valley, which is deeper than 1000 m, and the general confined width of 10–26 km of the gulf (Medio et al. 2000). The waves and currents are strongly influenced by the north and northeast wind (Medio et al. 2000).

The fringing reefs and contour reefs, that grow on the narrow shelves, often reach only 10 to 50 m from shore due to the steep slopes (Medio et al. 2000). In these coral reefs, a divers molluscan fauna can be found, which differs between the reef flat and the reef slope. Many of the molluscs are associated with living corals, depending on them for food or substrate (Hadfield 1976). Therefore changes in coral assemblage and coverage are reflected in the molluscan population.

A first assessment of species numbers and abundance of coral reef-associated molluscs around Dahab (Egypt), is the goal of this study. Consequently, the aim is 1) to analyse the differences of molluscan assemblage at different sites and depths around Dahab 2) to identify differences between the assemblage of dead and living individuals found and 3) to compare the study area with other regions in the Red Sea, in order to gain information about regional differences.

2

Material and Methods

Field work was performed between 28 October and 2 December 2011 in the area of Dahab, northern Red Sea. More than 40 SCUBA dives were done in order to collect data from 35 transects (350 m^2), ranging from 30 m to 2 m water depth (Table 2.1). The Dahab Marine Research Center (DMRC, GPS: N 28.480871, E 34.512186) in the Laguna Hotel was the basis for the study.

2.1 Sampling sites

The six sampling sites were located in the Gulf of Aqaba around Dahab (Egypt) (Fig. 2.1). Two in the south are part of the Nabq National Park. Golden Blocks (GPS: N 28.43844, E 34.462457) and Moray House (GPS: N 28.437601, E 34.458852) are about seven km from the DMRC (Fig. 2.1). Two sampling sites are about ten km north of the DMRC Rick's Reef (GPS: N 28.557013, E 34.523393) and Ana el Gamina (GPS: N 28.567383, E 34.53272) (Fig. 2.1). Two sites are at the house reef of the DMRC, Islands (GPS: N 28.4775, E 34.511897) and Suleiman's Reef (GPS: N 28.479872, E 34.512996) (Fig. 2.1).

The Sites were chosen by accessibility and coral reef coverage between 2 and 30 m depth. Every transect was then categorised into one of the following reef typs: fringing reef, patch reef (coral dominated), coral patches (sand dominated), coral carpets and

Table 2.1: Site information.

Nr	Site name	GPS	Transects	Depths
1	Golden Blocks	28.43844,34.462457	1–6	5,10,15,20,25,30
2	Ricks Reef	28.557013,34.523393	7–13	2,5,10,15,20,25,30
3	Suleiman's Reef	28.479872,34.512996	14–17	2,5,10,15
4	Islands	28.4775,34.511897	18–21	2,5,10,15
5	Ana el Gamela	28.567383,34.53272	22–28	2,5,10,15,20,25,30
6	Moray House	28.437601,34.458852	29–35	2,5,10,15,20,25,30

Fig. 2.1: Close-up of sampling sites (red) and Dahab (yellow) in the Gulf of Aqaba, Egypt. Going from north to south: Ana el Gamina, Rick's Reef, Suleiman's Reef, Islands, Golden Blocks and Moray House. Map source: Google TM Earth

rock bottom (Table 2.2).

Fringing reefs develop close to shore on hard substrate in shallow waters depending on favourable oxygen and light conditions (Ladd 1977). It was further distinguished by the dominant coral: fringing reef with massive corals, *Millepora-Acropora* or only *Millepora*. The fringing reef stretches between two and five m depth and makes up the smallest group. A patch reefs was defined as loosely grouped, rising, and block-like reef close to sandy areas (Ladd 1977), which can rise to the water surface. Patch reefs can be seen as transition zone, partially overlapping with the other types. The depth ranges from 5 to 20 m and species living in sand can also be encountered here. Coral patches often surround these bigger patches. Coral patches were coralline-sand-dominated areas with coral patches being smaller than a diameter of three m and reaching a height of two to three m. Coral carpets spread from 20 to 30 m depth, follow the natural slope of the hard substrate and are dominated by several corals: *Acropora*, *Stylophora*, *Favites* and *Favia*. The coral colonies have a smaller diameter and lower coverage of the hard substrate. This type makes up the main part of the transects. Rock bottoms showed a low living coral coverage (< 20 %) and was mainly found in the deeper extensions of coral carpets (Riegl and Piller 1999).

The total of 35 transects ranged from four to seven per sampling site. They covered seven different depth contours and ten m^2 per transect (Table 2.2). At each depth the first quadrat was haphazardly thrown and used as the starting point for the 50 m transect line. The plastic quadrat with a ten cm mesh of strings was used to determine the living coral coverage and the molluscs. The dominant coral genera in the quadrats were noted to see if there is a connection between the abundance of the mollusca and the corals. Every 5 m a count of all bivalves and gastropods larger than one centimetre within one square meter quadrat was taken. Living and dead individuals were distinguished and identified to the species.

Except for *Dendropoma maximum* (Sowerby, 1825) the reef flat was only qualitatively sampled. Transects were placed with different distances from the reef edge on Suleiman's reef. It was distinguished between inner and outer reef flat. Inner reef flat was defined from shore seaward, dominated by sand and algae with a few corals. The outer reef flat reaches from the edge landward and is dominated by hard substrate and corals.

2.2 Abiotic factors

An average salinity of 40.4 ‰ and an average pH of 8.16 was measured at the sites. Water temperature dropped during the period of the field work from 25°C to 22°C, which reflected the normal decrease from summer to winter (28°C to 21°C). Average oxygen concentration in the water was 1.63 ppm. Tide difference was negligible due to the small mean spring range of 0.6 m with a maxima of 1.2 m (Medio et al. 2000).

2.3 Taxonomy

Mollusca were identified to species level where possible either in the field, or through photos. Any material that had to be studied on land was returned to the sea afterwards. Some taxa were only identified to the family and superfamily levels such as Chamoidea, Spondylidae and Ostreidae for example, due to difficulties of infield identification or poor preservation (Zuschin and Stachowitsch 2007). *Tridacna maxima* (Röding, 1798) and *T. squamosa* Lamarck, 1819, were combined to *Tridacna* spp., because their differentiating characteristic can not be seen in life position (Zuschin and Oliver 2003). Individuals smaller than one cm were excluded from the survey. All *Gastrochaena* sp. Spengler, 1783, were counted as living, although a differentiation between living and dead individuals was not possible.

Molluscan identification was based on: Lieske (2009), Rusmore-Villaume (2008), Zuschin and Oliver (2003), Sharabati (1984), Oliver (1992), Bosch et al. (1995), Zuschin et al. (2009), Janssen et al. (2011) and internet sources: www.gastropods.com, www.femorale.com.br and www.marinespecies.org.

Table 2.2: Transects. Reef type after the first assessment, total living and dead individuals per transect and living and dead taxa found.

Nr	Avg Depth	C %	Reef type	Individuals liv	Individuals d	Taxa liv	Taxa d
1	5.2	40	Patch reef	40	34	14	11
2	10.4	40	Patch reef	43	46	10	13
3	15.4	30	Coral patches	30	30	9	6
4	20.3	30	Coral patches	44	28	13	11
5	24.9	30	Coral carpet	55	30	10	7
6	30.2	30	Coral carpet	39	31	12	8
7	2.6	40	Fringing reef with Millepora	73	31	8	11
8	5.6	40	Fringing reef with Millepora	94	56	13	10
9	10.2	30	Fringing reef with Acropora	45	11	9	3
10	15.4	30	Coral patches	65	39	11	9
11	20.1	30	Coral patches	68	29	17	6
12	25.3	40	Coral carpet	59	13	9	4
13	29.9	40	Coral carpet	58	36	11	9
14	2.4	80	Fringing reef	103	12	15	9
15	5.2	70	Fringing reef	106	25	12	7
16	9.8	70	Fringing reef	95	22	11	7
17	15.5	50	Coral carpet	68	12	14	7
18	2.2	80	Patch reef	246	15	15	8
19	5.3	70	Patch reef	94	15	13	5
20	10.3	70	Patch reef	60	28	11	8
21	15.3	60	Patch reef	47	21	10	6
22	2.4	70	Fringing reef with Millepora	45	22	8	8
23	5.4	70	Fringing reef with Millepora	55	25	9	5
24	10.4	70	Coral patches	71	22	9	8
25	15.3	70	Coral patches	33	5	9	3
26	20.6	40	Coral carpet	56	14	11	3
27	25.1	40	Coral carpet	58	22	11	7
28	29.9	65	Coral carpet	37	10	10	8
29	2.2	40	Fringing reef with Millepora	99	42	10	10
30	5.6	30	Fringing reef with Millepora	72	39	13	8
31	9.9	10	Rock bottom	55	29	11	9
32	15.1	20	Rock bottom	64	40	16	10
33	20.0	20	Rock bottom	66	32	15	8
34	24.8	20	Rock bottom	59	21	14	11
35	30.5	20	Rock bottom	36	29	14	7

Depth and average depth in m, coral coverage (C %) in %, Living - Liv, dead - d

2.4 Data analysis

All field data were recorded on waterproof foil and the first analysis of the data was done with Exel. For the further analysis Primer 6.1.6 was used. Non-metric multidimensional scaling (nMDS)and a cluster analysis were done with the data as well as a oneway Similarity analysis (ANOSIM). The samples were standardised by the total and transformed to the square-root. As resemblance measure the Bray Curtis similarity index was used. The 16 nudibranchia of 5 species and the one cephalopod found, were excluded from the data analysis due to small number, but are listed in the appendix.

3

Reef slope assemblage

3253 mollusca from 72 taxa of 35 shelled gastropods and 32 bivalves and 5 nudibranchia were identified from the 35 transects, covering 350 m^2 at six sites. A total of 2326 living (excluding the 16 nudibranchia) and 911 dead individuals were found. The most abundant taxa found were *Chama* sp. Linnaeus, 1758, Ostreidae and *Pedum spondyloideum* (Gmelin, 1791). One third of all taxa was found only once and in 70 % of all taxa less than ten individuals were found (Fig. 3.1).

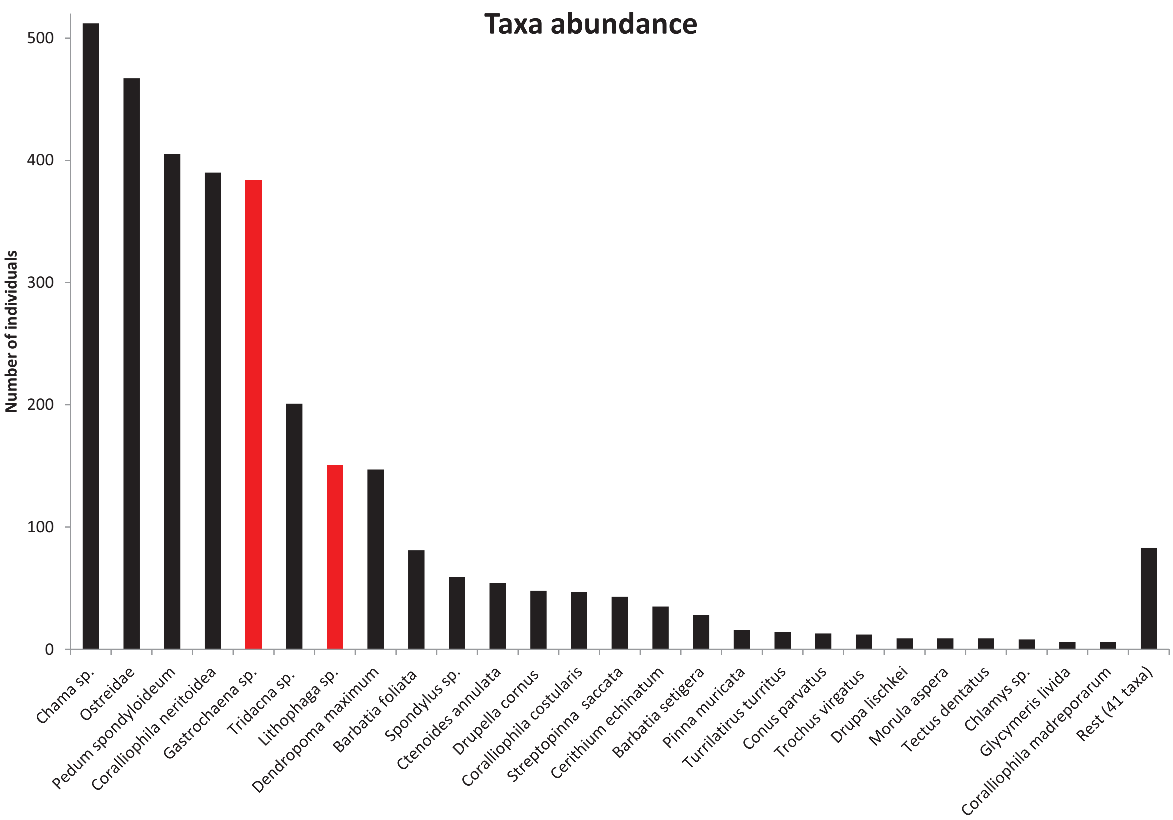

Fig. 3.1: Total molluscs found in 350 m^2 excluding nudibranchia. Boring bivalves are included, though living and dead individuals could not be distinguished (red marked). Rest includes 41 taxa and 83 individuals.

3.1 Living assemblage

The 2326 living individuals belong to 43 taxa, which belong to 24 gastropod and 19 bivialve taxa. Thirteen taxa were only found alive. *Gastrochaena* sp., *Pedum spondyloideum*, *Coralliophila neritoidea* (Lamarck, 1816), and Ostreidae were most abundant (Fig. 3.2). They make up 30 % of all specimens.

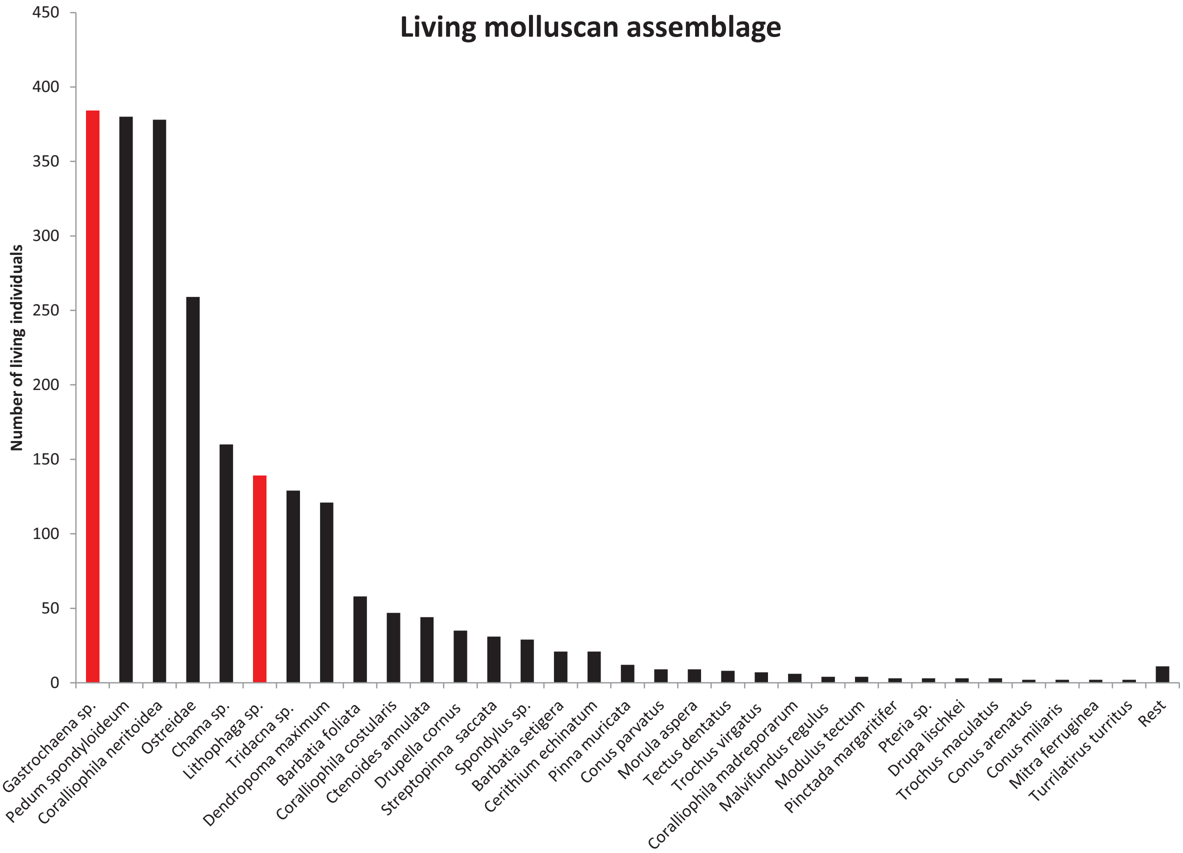

Fig. 3.2: Total living molluscs found in 350 m^2 excluding nudibranchia. Boring bivalves are included (red). Rest includes 11 taxa and 11 individuals.

An average of 11.7 taxa and 66 living individuals per transect and depth were collected, differing insignificantly between sites. Most individuals were found in 2 m water depth and numbers decrease slowly with depth. Between 10 and 25 m depth the mean of the abundances vary only slightly.

The patch reef has the highest individual density with *Coralliophila neritoidea* dominating significantly over the rest (Fig. 3.3). The Islands is the most important site for this reef type with its massive *Porites* sp. colonies. The fringing reef and coral carpets are dominated by encrusting and cementing bivalves, such as *Pedum spondyloideum* and Ostreidae (Fig. 3.3). *Gastrochaena* sp. reached the highest numbers in the coral carpets, while *Dendropoma maximum* defined the fringing reef (Fig. 3.3).

Combining nMDS and cluster analysis, the similarity between the three main reef types, fringing reef, patch reef (including coral patches and patch reefs), and coral carpets (including rock bottoms), is displayed (Fig. 3.4). All three groups overlap.

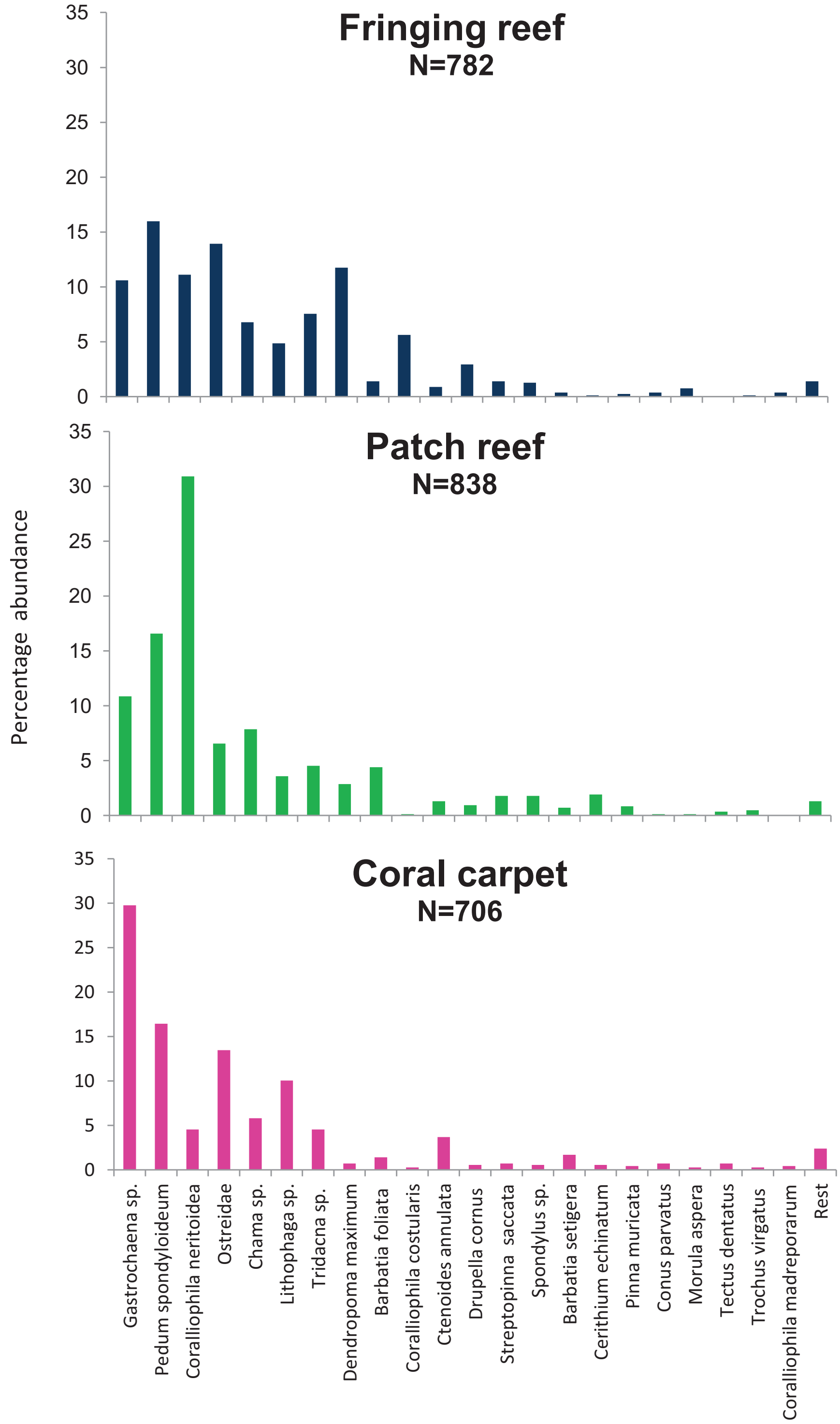

*Fig. 3.3***:** Living mollusc abundance. Divided in three main reef types: fringing reef (blue), patch reef (green) and coral carpet (red). Rest represents 21 taxa and 119 individuals.

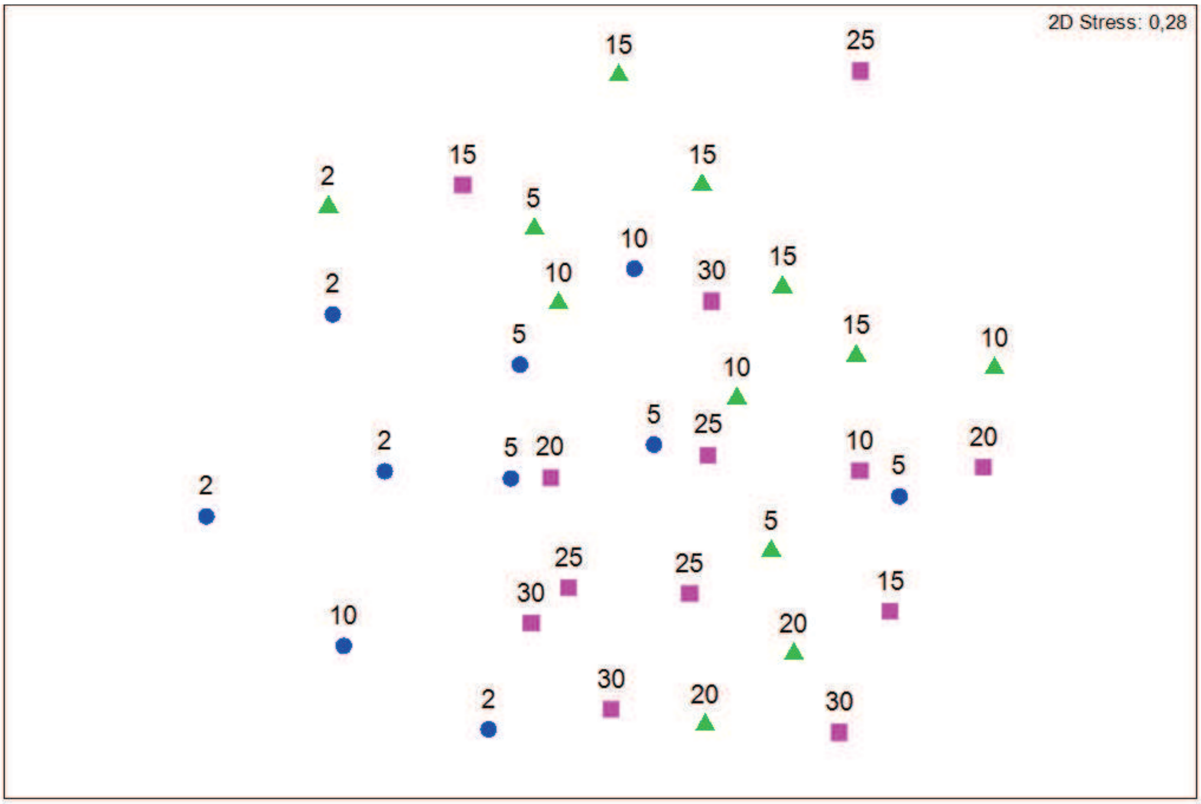

Fig. 3.4: nMDS of the living molluscan assemblage excluding boring molluscs. Fringing reef (blue circles), patch reef (green triangles) and coral carpet (red squares). Numbers represent the transects.

3.2 Death assemblage

The 911 dead individuals belong to 27 gastropod species and 27 bivalve species (Fig. 3.5). Twenty-four taxa were only found dead and the bivalves *Chama* sp., Ostreidae, *Tridacna* sp. were most abundant (Fig. 3.5). These three are the only ones reaching numbers higher than 50 individuals. Four more taxa range between 23 and 30 specimens (Fig. 3.5). The rest had less than 15 individuals, mostly less than five (Fig. 3.5).

The dead specimens are spread evenly over the different depths per site. The sites Moray House, Golden Blocks and Rick's Reef have more specimens than the others (Table 2.2 in the methods).

The nMDS of dead molluscs and cluster analysis showed a similar pattern as the living assemblage (Fig. 3.6), but show even more overlap. The three most abundant taxa are the same in all reef types. However, in the patch reef *Chama* sp. reaches almost 50 % of the individuals and Ostreidae show the lowest percentage compared to the other two types (Fig. 3.7).

The three reef types differ in some of the species present (Fig. 3.7). The species *Turbo radiatus* Gmelin, 1791, *T. petholatus* Linnaeus, 1758, *Cypraea* sp. Linnaeus,

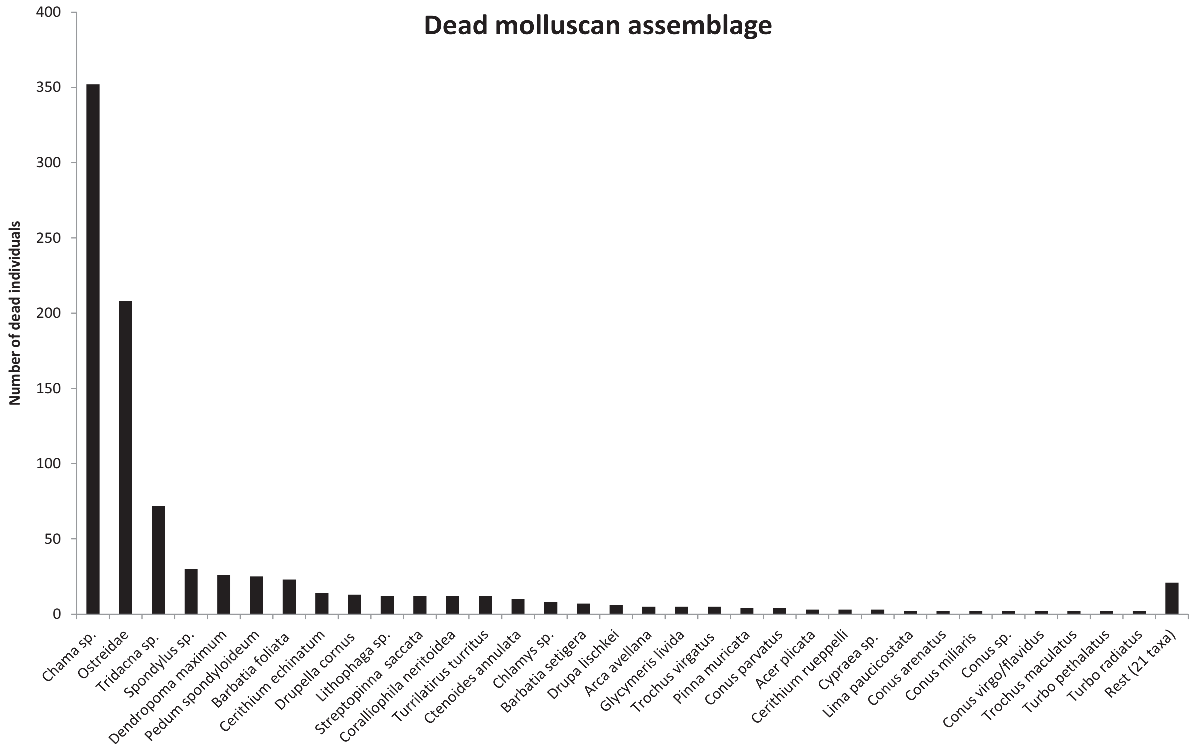

Fig. 3.5: Total dead molluscs found at the six sampling sites. Boring Gastropods are included. Rest includes 21 taxa and 21 individuals.

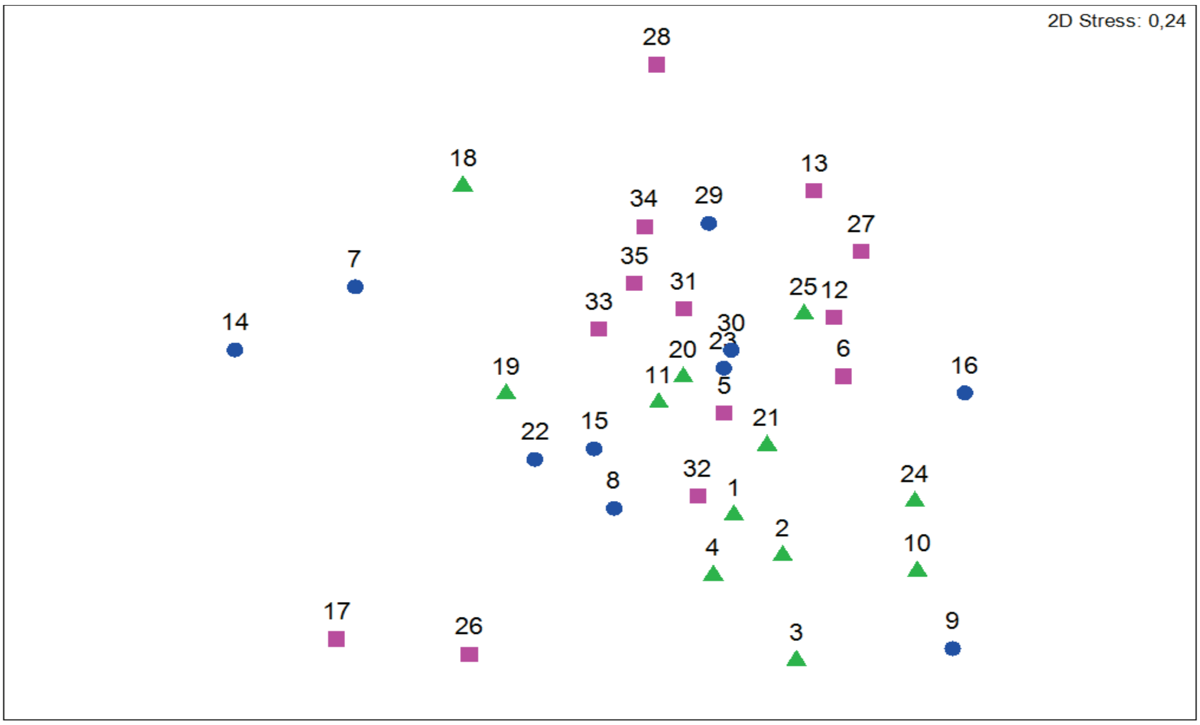

Fig. 3.6: nMDS of the dead molluscan assemblage (stress=0.24). Fringing reef (blue circle), patch reef (green triangle) and coral carpet (red square). Numbers represent the transects.

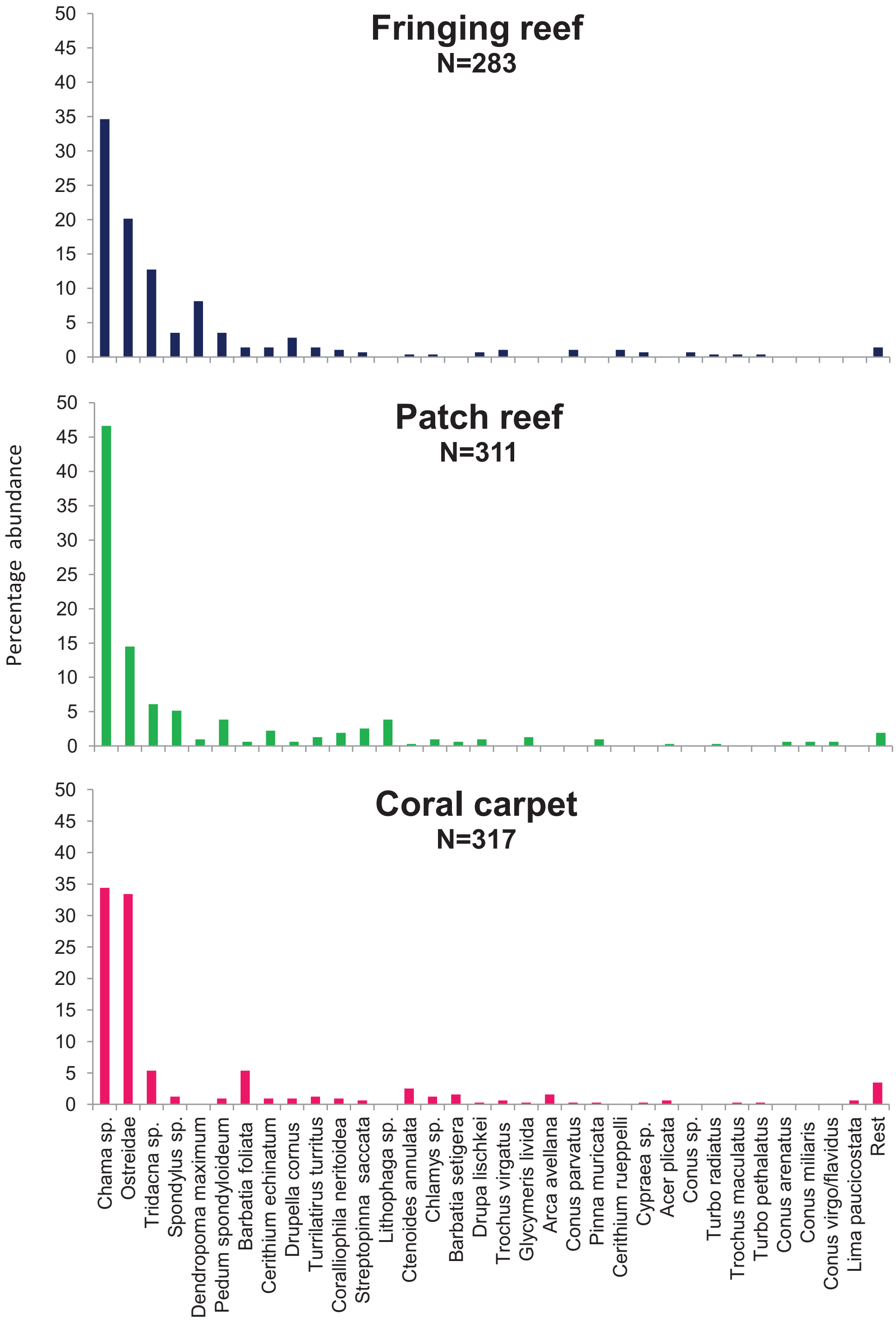

Fig. 3.7: Dead mollusc abundance. Divided in three main reef types: fringing reef (blue), patch reef (green) and coral carpet (red); rest represents 21 taxa and 62 individuals.

1758, and *Cerithium rueppelli* Philippi, 1848 were only found in the fringing reef (Fig. 3.7). In contrast, *Pinna muricata* Linnaeus, 1758, and *Lithophaga* sp. Röding, 1798, were only found in the patch reef (Fig. 3.7). In the coral carpet *Lima paucicostata* Sowerby, 1843, was unique (Fig. 3.7).

3.3 Comparison of living and dead individuals

Living and death assemblages in the nMDS show a clear separation (Fig. 3.8). The death assemblage is more heterogeneous (Fig. 3.8).

Living individuals are 2.5 times more abundant than dead individuals (Table 3.1). Comparing depths, the ratio between dead and living individuals is 0.39 per transect, comparing the sites the ratio lowers slightly to 0.36 (Table 3.1). The ratio of average taxa of life and death assemblage is for both, depth and sites, around 0.66 (Table 3.1).

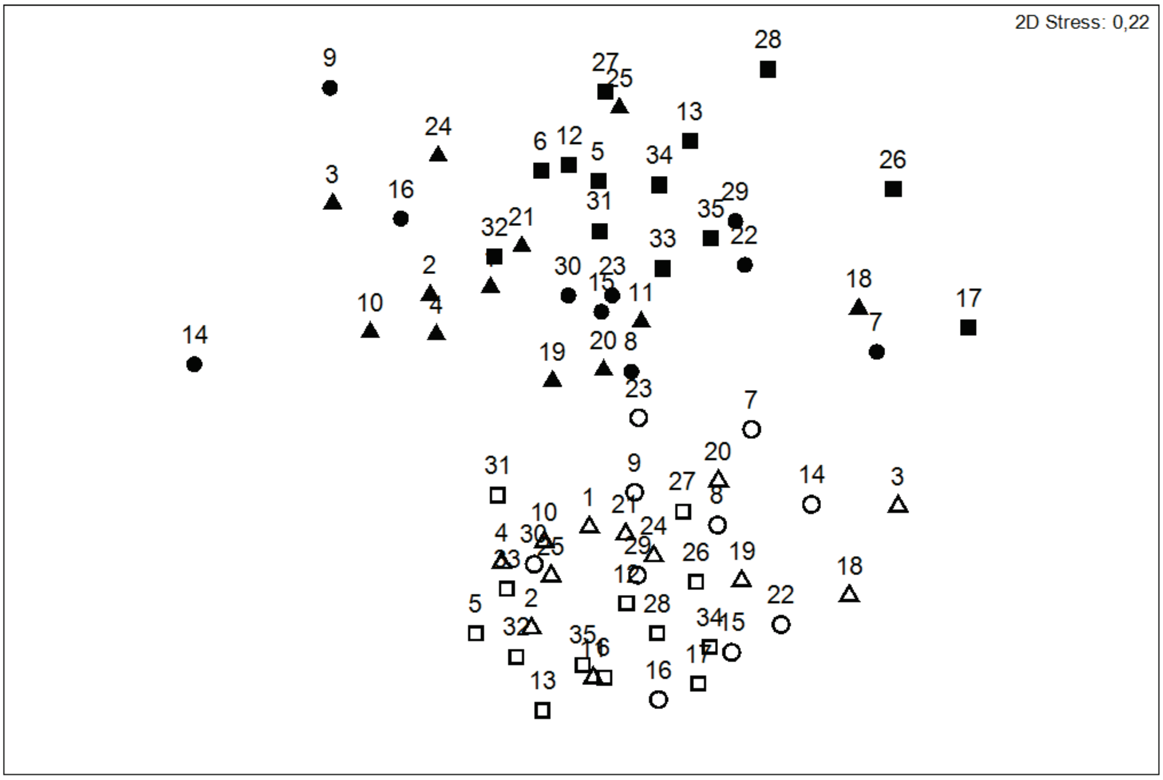

Fig. 3.8: nMDS of the dead (black) and living (white) molluscan assemblage. The two assemblages separate clearly from each other, showing a significant difference in composition. Symbols represents the three main reef types (fringing reef (circle), patch reef (triangle) and coral carpet (square)). Numbers represents the transects.

The most abundant taxa can be found among the first third of both assemblages with few exceptions (Fig. 3.2 and 3.5). *Coralliophila neritoidea* and *C. costularis* (Lamarck, 1816) showed relatively low numbers of dead individuals (Fig. 3.2 and 3.5). A strong difference is also evident for *Dendropoma maximum* and *Pedum spondy-*

loideum (Fig. 3.2 and 3.5). *Chama* sp. has two times more dead than living individuals. Twenty percent more living Ostreidae are found.

Table 3.1: Comparison of living and death assemblage.

	Per depth avg. ind	avg. taxa	Per site avg. ind	avg. taxa
living	66.0	11.7	70.9	11.5
dead	25.9	7.7	25.3	7.7

The ANOSIM of the living assemblage suggests a significant difference between the two m patch reef and the deeper coral carpet ($R > 0.8$, table 4.2, 4.1). The shallow fringing reef and the coral carpet between ten to fifteen m as well as the patch reef show also strong differences ($R > 0.5$, table 4.2, 4.1). On the other hand, the death assemblage shows a stronger differentiation between the upper two examples ($R > 0.9, R > 0.5$) and a higher distinction of the 25–30 m coral carpet from the rest ($R > 0.7$, table 4.2, 4.1).

3.4 Hermit crab occupation

Fifty-five hermit crabs were found in 12 gastropod taxa. The species often occupied by hermit crabs were *Drupella cornus* (Röding, 1798), *Coralliophila neritoidea*, *Cerithium echinatum* Lamarck, 1822, *Turrilatirus turritus* (Gmelin, 1791), and *Drupa lischkei* (Hidalgo, 1904) (Fig. 3.9). Half of the species found with hermit crabs were always occupied when encountered, a prominent example being *Coralliophila neritoidea*. *Dendropoma maximum*, most of *Conus* sp. Linnaeus, 1758, *Trochus virgatus* Gmelin, 1791, *Cypraea* sp., *Turbo* sp. and eight other taxa were not occupied by hermit crabs.

Thus, hermits occupy only one third of all gastropods taxa and 45 $\%$ of all empty gastropod shells. Most hermit crabs were found in shallow depths (2 and 5 m) and near to sandy areas (10 and 30 m) (Fig. 3.10). In two m depth also most dead shells were found. The shallower Islands and Suleiman's Reef show a higher number of hermit crabs than all other sites (Fig. 3.11).

3.5 Comparison to the reef flat

The qualitative analysis of the reef flat resulted in 26 gastropod and 12 bivalve species for the inner reef flat and 25 gastropod and 9 bivalve genera for the outer reef flat (Table 5.5). Compared to the reef slope the reef flat contained 31 species uniquely found there. Forty four species were only found on the reef slope and 17 in both areas (Table 5.5).

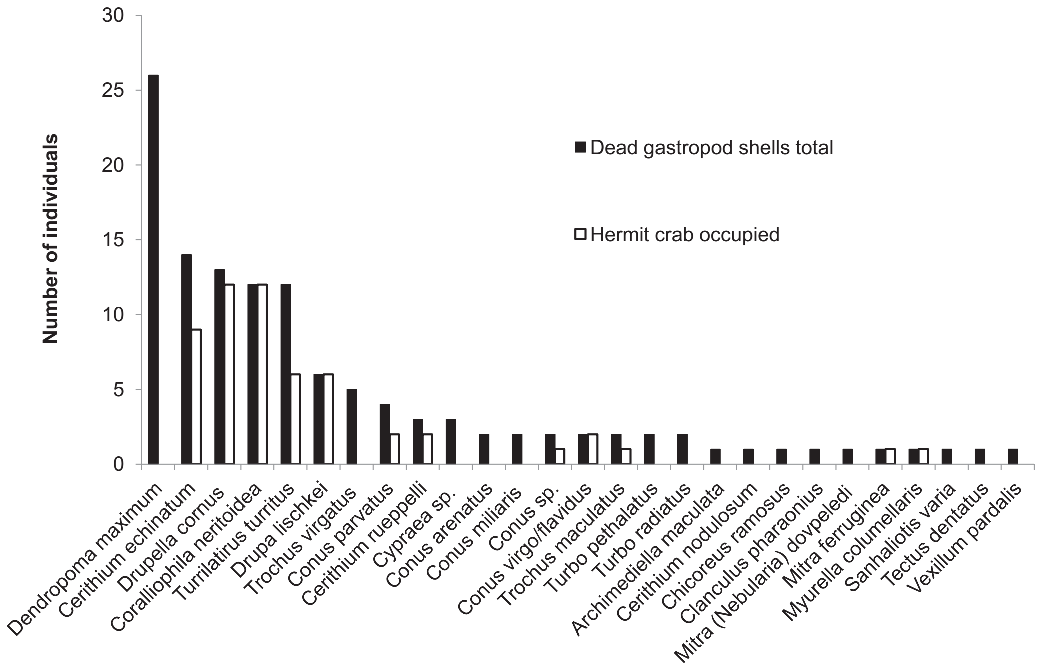

Fig. 3.9: Gastropod taxa occupied by hermit crabs.

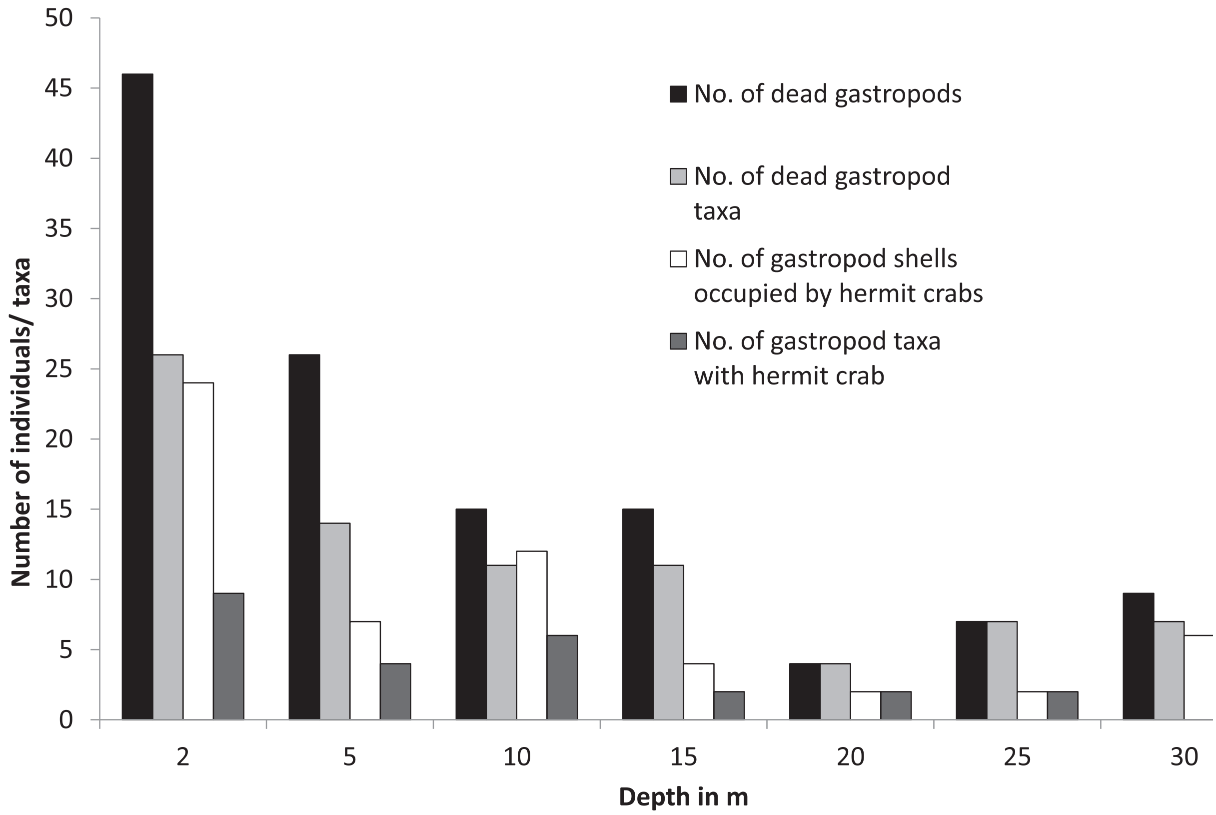

Fig. 3.10: Gastropods occupied by hermit crabs per depth.

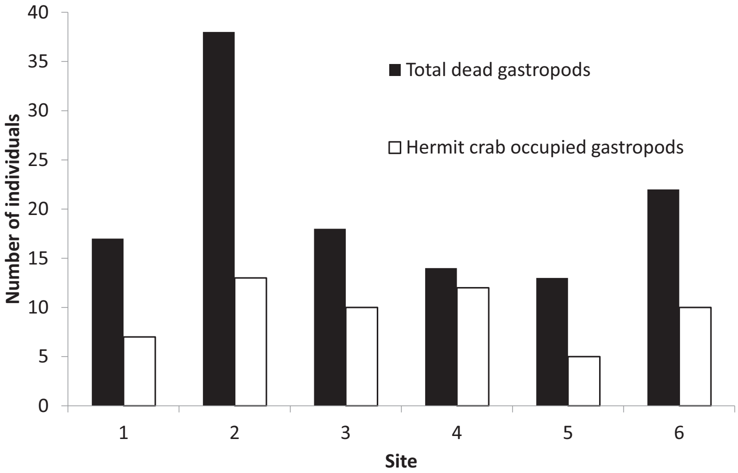

Fig. 3.11: Number of hermit crab occupied gastropod shells per site.

The *Dendropoma maximum* distribution analysis showed a significant decrease from the reef edge to shore and down the reef slope. Most individuals were found at the reef edge and in the agitated waters close to the edge (from 2 m depth to 20 m from shore). On the reef flat and edge *Dendropoma maximum* was found on dead hard substrate and associated with *Millepora* sp., while on the reef slope it was always associated with *Millepora*.

4

Discussion

A high variety of molluscs were encountered. From the 72 taxa 43 were found living and 54 dead, reflecting the rich fauna of the Red Sea. From the 3253 individuals found two thirds were living similar to Zuschin and Stachowitsch (2007), where also a high difference in individuals was found.

Comparison of the living and the death assemblages Comparing the living and the death assemblages shows a clear separation between the two. Both assemblage were better explained by the combination of reef type and depth than by them separately (Table 4.1, 4.2, attached: 5.1, 5.2, 5.3, 5.4). This implies that coral reef associated molluscs depend more on corals, their hard substrate, than on depth (e.g., Hadfield 1976, Morton 1983a b, Zuschin and Stachowitsch 2007). The results of this study also reflect that depth comes in as a side factor for corals in terms of light penetration, water flow and turbidity. Due to this, the fringing reefs and coral carpets investigated mark different zones and differ in the abundance and composition of rare molluscs. While the patch reef is an intermix of both, it still has its specific biodiversity. Taylor and Reid (1984) state the main differences between fringing and patch reef are the terrestrial influences and the resulting habitats. The most common taxa are similar in all reef types and in both assemblages, building the typical taxa for the Gulf of Aqaba (Mastaller 1979, Zuschin and Oliver 2003, Zuschin and Stachowitsch 2007).

Fluctuations in the death assemblage The death assemblage is highly influenced by transportation of the shells after death as well as coral association. The gastropod shell transportation is influenced by predators, hermit crabs and water flow. They also get lost for sampling by falling into cracks in the coral reef. Living coral or coralline algae associated dead molluscs were under represented. After death they are overgrown and no longer assailable through the sampling method (Zuschin et al. 2000). In contrast, encrusting bivalves such as *Chama* sp. and Ostreidae dominate on dead coral surface (Zuschin and Piller 1997). The difference between the two assemblages are important temporal and ecological information (Zuschin and Stachowitsch 2007), especially in areas where fossil reefs are common and thus community changes over thousands of years observable.

Bivalve distribution regional Bivalves have fewer taxa than the gastropods but have higher individual numbers. *Pedum spondyloideum* prefers the association with massive corals, such as *Montipora* spp. in the northern Red Sea (Kleemann 1990), and was very common in the shallow reef. At Lizard Island, Great Barrier Reef Cairns, *P. spondyloideum* was only found in *Porites* (Kleemann 1995). *Gastrochaena* sp. and *Lithophaga* sp. were classified as living, assuming that their holes are quickly over grown by coral when dead.

Tridacna sp. was found mainly around the shallower areas surrounded by coral. *T. maxima* and *T. squamosa* are burrowed partially in the substrate and strongly attached with byssal threats (Kilada et al. 1998). The use of zooxanthella in the folds of its epidermis requires the more photo active reef zones such as the reef flat to five m depth (Kilada et al. 1998). Larvae drift through currents may be another factor for the higher numbers around the reef edge. They get carried along with the currents and the fringing reef provides hard substrate for settlement. Less common *Tridacna* sp. was found in the deeper regions, though bigger individuals were observed similar to Kilada et al. (1998).

Gastropod distribution regional The mobile gastropods were often only found dead due to their nocturnal or cryptic habit. Those only found alive were probably occupied by hermit crabs or too fragile to withstand erosion. *Turbo radiata* seem to be common in earlier studies (Mastaller 1979), however around Dahab numbers are distinctly lower even than in Safaga (Zuschin et al. 2000). Leading to the conclusion that tourist influences may decrease the gastropod due to shell collecting (Zuschin and Stachowitsch 2007). The herbivore *Tectus dentatus* Forskål in Niebuhr, 1775, prefers lower living coral coverage (Mastaller 1979) and was found in the deeper depths of the reef, especially at the site Moray House. This separates it from Aqaba, where *T. dentatus* was evenly distributed (Zuschin and Stachowitsch 2007). *Conus* showed a low number of individuals (27) and appeared more divers in the dead assemblage with more than four species in the dominant taxa. They occurred near sand and reef rock with low living coral cover (Kohn 1983). Also most of them hide during daytime in algae, coral rubble and under reef rock (Kohn 1967), which makes them elusive for sampling.

Corallivorous gastropods *Coralliophila* sp. are strongly associated with the coral they feed from (Al-Moghrabi 1997). Therefore *C. costularis* was more often encountered in deeper waters where *Favia* spp. or *Goniopora* sp. grew, *C. neritoidea* in

Table 4.1: ANOSIM of living assemblage between the combined reef types and depths.

Pairwise Tests Groups	R Statistic	Significance Level %	Possible Perm	Actual Perm	Number ≧ Observed
Patch reef5 vs Patch reef10	-0.5	90	10	10	9
Patch reef5 vs Patch reef15	-0.321	93.3	15	15	14
Patch reef5 vs Patch reef20	-0.25	100	3	3	3
Patch reef5 vs Coral carpet25	-0.214	73.3	15	15	11
Patch reef5 vs Coral carpet30	0.286	26.7	15	15	4
Patch reef5 vs Fringing reef2	0.179	33.3	15	15	5
Patch reef5 vs Fringing reef5	0.071	40	15	15	6
Patch reef5 vs Fringing reef10	-1	100	3	3	3
Patch reef5 vs Coral carpet15	-0.25	66.7	3	3	2
Patch reef5 vs Patch reef2	0	66.7	3	3	2
Patch reef5 vs Coral carpet20	-0.75	100	3	3	3
Patch reef5 vs Coral carpet10	-1	100	3	3	3
Patch reef10 vs Patch reef15	-0.352	91.4	35	35	32
Patch reef10 vs Patch reef20	**0.667**	10	10	10	1
Patch reef10 vs Coral carpet25	-0.204	82.9	35	35	29
Patch reef10 vs Coral carpet30	0.333	11.4	35	35	4
Patch reef10 vs Fringing reef2	**0.5**	2.9	35	35	1
Patch reef10 vs Fringing reef5	-0.074	62.9	35	35	22
Patch reef10 vs Fringing reef10	-0.083	70	10	10	7
Patch reef10 vs Coral carpet15	-0.083	60	10	10	6
Patch reef10 vs Patch reef2	0.333	50	4	4	2
Patch reef10 vs Coral carpet20	-0.167	70	10	10	7
Patch reef10 vs Coral carpet10	0.333	50	4	4	2
Patch reef15 vs Patch reef20	0.214	46.7	15	15	7
Patch reef15 vs Coral carpet25	0.042	37.1	35	35	13
Patch reef15 vs Coral carpet30	0.333	5.7	35	35	2
Patch reef15 vs Fringing reef2	0.365	5.7	35	35	2
Patch reef15 vs Fringing reef5	-0.021	48.6	35	35	17
Patch reef15 vs Fringing reef10	-0.143	73.3	15	15	11
Patch reef15 vs Coral carpet15	0.143	33.3	15	15	5
Patch reef15 vs Patch reef2	**0.583**	20	5	5	1
Patch reef15 vs Coral carpet20	-0.071	60	15	15	9
Patch reef15 vs Coral carpet10	0.083	40	5	5	2
Patch reef20 vs Coral carpet25	0.107	33.3	15	15	5
Patch reef20 vs Coral carpet30	-0.357	93.3	15	15	14
Patch reef20 vs Fringing reef2	**0.5**	13.3	15	15	2
Patch reef20 vs Fringing reef5	0.357	26.7	15	15	4
Patch reef20 vs Fringing reef10	0	66.7	3	3	2
Patch reef20 vs Coral carpet15	0	100	3	3	3
Patch reef20 vs Patch reef2	**1**	33.3	3	3	1
Patch reef20 vs Coral carpet20	-0.5	100	3	3	3
Patch reef20 vs Coral carpet10	0	66.7	3	3	2
Coral carpet25 vs Coral carpet30	-0.219	94.3	35	35	33
Coral carpet25 vs Fringing reef2	0.156	11.4	35	35	4
Coral carpet25 vs Fringing reef5	-0.021	60	35	35	21
Coral carpet25 vs Fringing reef10	-0.25	66.7	15	15	10
Coral carpet25 vs Coral carpet15	0.143	33.3	15	15	5
Coral carpet25 vs Patch reef2	**0.833**	20	5	5	1
Coral carpet25 vs Coral carpet20	-0.571	100	15	15	15
Coral carpet25 vs Coral carpet10	0	60	5	5	3
Coral carpet30 vs Fringing reef2	0.396	11.4	35	35	4
Coral carpet30 vs Fringing reef5	0.104	28.6	35	35	10
Coral carpet30 vs Fringing reef10	0.25	26.7	15	15	4
Coral carpet30 vs Coral carpet15	0.143	40	15	15	6
Coral carpet30 vs Patch reef2	**0.917**	20	5	5	1
Coral carpet30 vs Coral carpet20	-0.357	93.3	15	15	14
Coral carpet30 vs Coral carpet10	0.333	40	5	5	2
Fringing reef2 vs Fringing reef5	0.208	14.3	35	35	5
Fringing reef2 vs Fringing reef10	-0.179	73.3	15	15	11
Fringing reef2 vs Coral carpet15	**0.536**	6.7	15	15	1
Fringing reef2 vs Patch reef2	0.25	40	5	5	2
Fringing reef2 vs Coral carpet20	0.179	26.7	15	15	4
Fringing reef2 vs Coral carpet10	**0.5**	20	5	5	1
Fringing reef5 vs Fringing reef10	0	46.7	15	15	7
Fringing reef5 vs Coral carpet15	0.25	33.3	15	15	5
Fringing reef5 vs Patch reef2	**0.583**	40	5	5	2
Fringing reef5 vs Coral carpet20	-0.107	66.7	15	15	10
Fringing reef5 vs Coral carpet10	-0.083	80	5	5	4
Fringing reef10 vs Coral carpet15	-0.25	100	3	3	3
Fringing reef10 vs Patch reef2	-1	100	3	3	3
Fringing reef10 vs Coral carpet20	-0.75	100	3	3	3
Fringing reef10 vs Coral carpet10	-1	100	3	3	3
Coral carpet15 vs Patch reef2	0	66.7	3	3	2
Coral carpet15 vs Coral carpet20	-0.5	100	3	3	3
Coral carpet15 vs Coral carpet10	-1	100	3	3	3
Patch reef2 vs Coral carpet20	0	66.7	3	3	2
Coral carpet20 vs Coral carpet10	-1	100	3	3	3

Permutation (Perm). Bold signature: R-value > 0.5 indicating clearly separated groups

Table 4.2: ANOSIM of death assemblage between the combined reef types and depths.

Pairwise Tests Groups	R Statistic	Significance Level %	Possible Perm	Actual Perm	Number ≧ Observed
Patch reef5 vs Patch reef10	0.083	60	10	10	6
Patch reef5 vs Patch reef15	-0.107	66.7	15	15	10
Patch reef5 vs Patch reef20	-0.5	100	3	3	3
Patch reef5 vs Coral carpet25	**0.714**	6.7	15	15	1
Patch reef5 vs Coral carpet30	0.357	13.3	15	15	2
Patch reef5 vs Fringing reef2	0.143	26.7	15	15	4
Patch reef5 vs Fringing reef5	0.286	33.3	15	15	5
Patch reef5 vs Fringing reef10	0	66.7	3	3	2
Patch reef5 vs Coral carpet15	-0.5	100	3	3	3
Patch reef5 vs Patch reef2	0	66.7	3	3	2
Patch reef5 vs Coral carpet20	**0.5**	33.3	3	3	1
Patch reef5 vs Coral carpet10	-1	100	3	3	3
Patch reef10 vs Patch reef15	-0.278	97.1	35	35	34
Patch reef10 vs Patch reef20	-0.25	70	10	10	7
Patch reef10 vs Coral carpet25	0.444	2.9	35	35	1
Patch reef10 vs Coral carpet30	0.444	5.7	35	35	2
Patch reef10 vs Fringing reef2	0.463	5.7	35	35	2
Patch reef10 vs Fringing reef5	**0.5**	5.7	35	35	2
Patch reef10 vs Fringing reef10	0.417	30	10	10	3
Patch reef10 vs Coral carpet15	0.417	20	10	10	2
Patch reef10 vs Patch reef2	0.333	50	4	4	2
Patch reef10 vs Coral carpet20	**0.667**	10	10	10	1
Patch reef10 vs Coral carpet10	0.111	50	4	4	2
Patch reef15 vs Patch reef20	-0.286	86.7	15	15	13
Patch reef15 vs Coral carpet25	0.208	14.3	35	35	5
Patch reef15 vs Coral carpet30	0.25	14.3	35	35	5
Patch reef15 vs Fringing reef2	0.406	5.7	35	35	2
Patch reef15 vs Fringing reef5	0.281	8.6	35	35	3
Patch reef15 vs Fringing reef10	-0.107	80	15	15	12
Patch reef15 vs Coral carpet15	0.143	26.7	15	15	4
Patch reef15 vs Patch reef2	**0.833**	20	5	5	1
Patch reef15 vs Coral carpet20	0.429	20	15	15	3
Patch reef15 vs Coral carpet10	0.083	80	5	5	4
Patch reef20 vs Coral carpet25	0.25	33.3	15	15	5
Patch reef20 vs Coral carpet30	0.036	46.7	15	15	7
Patch reef20 vs Fringing reef2	0.071	40	15	15	6
Patch reef20 vs Fringing reef5	0.107	33.3	15	15	5
Patch reef20 vs Fringing reef10	**0.75**	33.3	3	3	1
Patch reef20 vs Coral carpet15	-0.25	100	3	3	3
Patch reef20 vs Patch reef2	**1**	33.3	3	3	1
Patch reef20 vs Coral carpet20	0	66.7	3	3	2
Patch reef20 vs Coral carpet10	0	66.7	3	3	2
Coral carpet25 vs Coral carpet30	0.031	42.9	35	35	15
Coral carpet25 vs Fringing reef2	0.396	5.7	35	35	2
Coral carpet25 vs Fringing reef5	**0.677**	2.9	35	35	1
Coral carpet25 vs Fringing reef10	**0.929**	6.7	15	15	1
Coral carpet25 vs Coral carpet15	**0.714**	6.7	15	15	1
Coral carpet25 vs Patch reef2	**1**	20	5	5	1
Coral carpet25 vs Coral carpet20	**0.679**	6.7	15	15	1
Coral carpet25 vs Coral carpet10	0.25	20	5	5	1
Coral carpet30 vs Fringing reef2	0.26	5.7	35	35	2
Coral carpet30 vs Fringing reef5	0.333	2.9	35	35	1
Coral carpet30 vs Fringing reef10	**0.75**	6.7	15	15	1
Coral carpet30 vs Coral carpet15	0.321	20	15	15	3
Coral carpet30 vs Patch reef2	**0.75**	20	5	5	1
Coral carpet30 vs Coral carpet20	0.321	20	15	15	3
Coral carpet30 vs Coral carpet10	-0.333	80	5	5	4
Fringing reef2 vs Fringing reef5	0.26	2.9	35	35	1
Fringing reef2 vs Fringing reef10	**0.75**	6.7	15	15	1
Fringing reef2 vs Coral carpet15	0.179	26.7	15	15	4
Fringing reef2 vs Patch reef2	0.083	40	5	5	2
Fringing reef2 vs Coral carpet20	0.107	33.3	15	15	5
Fringing reef2 vs Coral carpet10	-0.167	60	5	5	3
Fringing reef5 vs Fringing reef10	**0.75**	6.7	15	15	1
Fringing reef5 vs Coral carpet15	**0.536**	13.3	15	15	2
Fringing reef5 vs Patch reef2	**0.917**	20	5	5	1
Fringing reef5 vs Coral carpet20	**0.786**	6.7	15	15	1
Fringing reef5 vs Coral carpet10	0.167	40	5	5	2
Fringing reef10 vs Coral carpet15	0.25	66.7	3	3	2
Fringing reef10 vs Patch reef2	0	66.7	3	3	2
Fringing reef10 vs Coral carpet20	**1**	33.3	3	3	1
Fringing reef10 vs Coral carpet10	**1**	33.3	3	3	1
Coral carpet15 vs Patch reef2	-1	100	3	3	3
Coral carpet15 vs Coral carpet20	-0.25	66.7	3	3	2
Coral carpet15 vs Coral carpet10	0	66.7	3	3	2
Patch reef2 vs Coral carpet20	**1**	33.3	3	3	1
Coral carpet20 vs Coral carpet10	0	66.7	3	3	2

Permutation (Perm). Bold signature: R-value > 0.5 indicating clearly separated groups the shallow patch and fringing reefs with *Porites* sp. and *C. madreporarum* (Sowerby, 1832) on the branching *Pocillopora* sp. and *Seriatopora* sp.. This was also reported by Mastaller (1978) and Schuhmacher (1992). In the earlier studies around the Red Sea numbers of *Coralliophila* sp. were lower, suggesting a change in composition similar to other regions (Schuhmacher 1992). Increase of corallivorous snails is suggested to be caused by overfishing of their predators and physical factors such as water temperature and salinity (Lam et al. 2007).

Drupella cornus numbers suggest similar distribution with highest densities in the shallow reef as in Aqaba (Schuhmacher 1992) and Northeastern Gulf of Aqaba, Jordan (Al-Moghrabi 1997). Between 2 and 5 m a mean density of 0.2 m^{-2} is a lot less than reported from Schöpf (2010). At the Islands no *D. cornus* was found im contrast to the earlier study (Schöpf 2010), either due to different sampling sites or a strong decrease of the snail. Numbers propose the coral reef community is still healthy enough to suppress an "outbreak" of *D. cornus* as reported from various region in the western Australia, central Pacific and Indo-Pacific (Turner 1994, Al-Moghrabi 1997, McClanahan 1997) or a more intensely sampling is needed. McClanahan (1997) suggested high numbers of *Coralliophila* reduces *D. cornus* through competition. *D. cornus* is attracted to weakened coral and further more is common in highly anthropogenic influenced sites. These speculations can only be made in considering the six sites are either in front of hotels or highly frequented dive sites. Closer monitoring of anthropogenic influences (e.g. sewage water, run off, and physical destruction through snorkellers and SCUBA divers) and the population of *D. cornus* and *Coralliophila* in Dahab may lead to a deeper understanding.

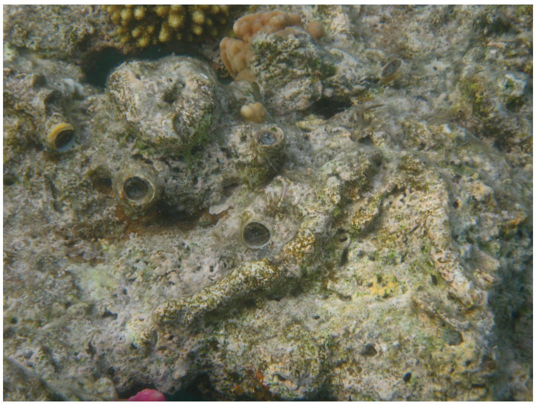

Fig. 4.1: Lose aggregation of *Dendropoma maximum* with community net.
Photo by Nika Pende 2009.

Sessile gastropods *Dendropoma maximum* shows the highest population in turbulent waters. This is due to its feeding from discrete mucus nets, which need a certain amount of particle concentration in the water and water flow to trap them in the net (Kappner et al 2000). In the waters between two m depth and ten m inland from the reef edge loose aggregations of *D. maximum* with community nets can be found (fig. 4.1). The predictable disturbances in this area provide the ideal characteristics for feeding, reproduction and larval settling of the vermetids (Hughes 1978).

Hermit crab distribution The distinct abundance and distribution of hermit crabs in the coral reef is due to their preference for particular shells and the quality of the shells for the crab (Briffa and Mowles 2008). Shell quality is factored by mobility, form, size and fragility of the shell. Thus, in two m the gap between non-occupied and occupied gastropod shell grows, because e.g. *Dendropoma maximum* is not suited for hermit crabs and most Conus sp. found seem to have an aperture which is too narrow. The dead *Drupella cornus*, *Corallophila neritoidea* and *Drupa lischkei* shells are almost always occupied by hermit crabs. These three species seem to satisfy the crabs preferences, as do most of the *Cerithium echinatum* and *Turrilatirus turritus*. In the latter two species, however the quality of the shells seems not always sufficient, probably due to erosion and holes from predators. From the Trochoidea (six species and 13 individuals) only one *Trochus maculatus* Linnaeus, 1758, was occupied by a hermit crab, which needs to be further investigated if this is due to preference of the hermit crabs or if the occupied shells are to well hidden during the day to be sampled.

5

Conclusion

This study showed the reefs around Dahab have a rich molluscan biodiversity with 72 taxa and 3253 individuals found. The ratio between the living and the death assemblage is about 2.5 to 1 individuals, even though the death assemblage has more taxa. The latter is probably due to the influences from different reef flat and sandy areas, through transportation. The composition of the dominant taxa is very similar to Aqaba and Safaga. Between the reef types no clear distinction could be made, suggesting the molluscan distribution depends more on the associated coral. The comparison of the depths indicate the same.

Though the number of *Drupella cornus* is lower and no outbreak can be seen as in other regions around the world. This might indicate the reefs in Dahab are not yet weakened by anthropogenic influences or the relatively high numbers of *Coralliophila* sp. represent a too strong competition for *D. cornus*. *Turbo radiatus* also showed surprisingly low numbers compared to regions in the Red Sea, which speaks for higher anthropogenic activities in the water, such as shell collecting. The low occupation rate of Trochoidea by hermit crabs should be investigated in more detail.

This study is a first assessment of coral associated molluscs in Dahab and provides the base for further research. Longterm monitoring around Dahab should provide information on anthropogenic influences on molluscs and if a change *Drupella cornus* abundance similar to the other regions can be connected to these influences.

In the face of climate change, longterm monitoring around the northern Red Sea, especially in Dahab, might show if changes of species composition can be seen and may present the base for longterm protection of tropical reefs.

Acknowledgements

I give thanks to my mentor Prof. Martin Zuschin for supporting me in the working process and giving help where needed. Further, I want to thank my aunt and my mother, who have supported me financially as well as mentally during the conduction of my diploma thesis, Peter Schueller for technical support and for solving layout problems, DMRC for providing the operating base for the field work, all my research assistants in the field, and my friends for supporting me.

This work was sponsored by the University of Vienna through a scholarship (Förderstipendium).

Attachments

Table 5.1: ANOSIM of living assemblage between depths.

Pairwise Tests Groups	R Statistic	Significance Level %	Possible Perm	Actual Perm	Number ≧ Observed
5 vs 10	-0.147	94.8	462	462	438
5 vs 15	-0.081	72.7	462	462	336
5 vs 20	0.091	25.7	210	210	54
5 vs 25	0.052	33.8	210	210	71
5 vs 30	0.218	10	210	210	21
5 vs 2	0.192	9.3	462	462	43
10 vs 15	-0.137	90.7	462	462	419
10 vs 20	0.147	21	210	210	44
10 vs 25	-0.198	91.9	210	210	193
10 vs 30	0.234	9.5	210	210	20
10 vs 2	0.272	4.3	462	462	20
15 vs 20	-0.044	55.7	210	210	117
15 vs 25	-0.04	62.4	210	210	131
15 vs 30	0.091	30	210	210	63
15 vs 2	0.301	3.9	462	462	18
20 vs 25	-0.125	80	35	35	28
20 vs 30	-0.302	97.1	35	35	34
20 vs 2	0.344	4.8	126	126	6
25 vs 30	-0.219	94.3	35	35	33
25 vs 2	0.194	12.7	126	126	16
30 vs 2	0.381	5.6	126	126	7

Permutation (Perm). Bold signature: R-value > 0.5 indicating clearly separated groups.

Table 5.2: ANOSIM of living assemblage between reef types.

Pairwise Tests Groups	R Statistic	Significance Level %	Possible Perm	Actual Perm	Number ≧ Observed
Patch reef vs Coral carpet	0.118	2.8	5200300	999	27
Patch reef vs Fringing reef	0.096	5.6	646646	999	55
Coral carpet vs Fringing reef	0.132	3.2	1144066	999	31

Permutation (Perm).

Table 5.3: ANOSIM of death assemblage between depths.

Pairwise Tests Groups	R Statistic	Significance Level %	Possible Perm	Actual Perm	Number ≧ Observed
5 vs 10	0.176	6.3	462	462	29
5 vs 15	0.174	4.3	462	462	20
5 vs 20	0.302	2.9	210	210	6
5 vs 25	**0.671**	0.5	210	210	1
5 vs 30	**0.52**	0.5	210	210	1
5 vs 2	0.405	0.4	462	462	2
10 vs 15	-0.093	80.1	462	462	370
10 vs 20	0.25	5.7	210	210	12
10 vs 25	0.167	14.3	210	210	30
10 vs 30	0.325	3.3	210	210	7
10 vs 2	**0.493**	0.2	462	462	1
15 vs 20	-0.048	58.6	210	210	123
15 vs 25	0.091	27.6	210	210	58
15 vs 30	0.143	15.7	210	210	33
15 vs 2	0.328	1.9	462	462	9
20 vs 25	0.344	2.9	35	35	1
20 vs 30	0.229	5.7	35	35	2
20 vs 2	0.263	7.1	126	126	9
25 vs 30	0.031	42.9	35	35	15
25 vs 2	0.363	4.8	126	126	6
30 vs 2	0.269	4.8	126	126	6

Permutation (Perm). Bold signature: R-value > 0.5 indicating clearly separated groups

Table 5.4: ANOSIM of death assemblage between reef types.

Pairwise Tests Groups	R Statistic	Significance Level %	Possible Perm	Actual Perm	Number ≧ Observed
Patch reef vs Coral carpet	0.185	0.1	5200300	999	0
Patch reef vs Fringing reef	0.1	5.7	646646	999	56
Coral carpet vs Fringing reef	0.142	1.9	1144066	999	18

Permutation (Perm).

Table 5.5: Species list with the reef area they were found in.

Species	Reef flat Outer	Reef flat Inner	Reef slope Fringing reef	Reef slope Patch reef	Reef slope Coral carpet
Acer plicata				x	x
Anodontia ovum	x	x			
Arca avellana					x
Arca ventricosa					x
Archimediella maculata				x	
Barbatia foliata			x	x	x
Barbatia setigera			x	x	x
Bursa granularis	x	x			
Canarium mutabilis	x	x			
Cardita variegata	x	x			
Casmaria ponderosa	x	x			
Cerithium adansonii	x	x			
Cerithium echinatum			x	x	x
Cerithium nodulosum					x
Cerithium rueppellii		x	x		
Chama sp.	x	x	x	x	x
Chicoreus ramosus					x
Chlamys sp.			x	x	x
Circe crocea				x	
Clanculus pharaonius		x	x		
Codakia tigerina		x			
Conus arenatus	x	x	x	x	
Conus flavidus	x	x		x	
Conus miliaris			x	x	
Conus parvatus			x	x	x
Conus quasimagnificus		x			
Conus sp.	x	x	x		
Conus taeniatus	x	x			
Conus tessulatus	x	x			
Conus vexillum sumatrensis			x		
Coralliophila costularis			x	x	x
Coralliophila madreporarum			x		x
Coralliophila neritoidea		x	x	x	x
Ctena divergens	x	x			
Ctenoides annulata			x	x	x
Cypraea sp.			x		x
Dendropoma maximum	x	x	x	x	x
Diplodonta sp.					x
Divalinga arabica	x	x			
Drupa ricinus lischkei		x	x	x	x
Drupella cornus	x	x	x	x	x
Electroma alacorvi			x		x
Fragum nivale	x	x			
Fusinus verrucosus	x	x			

Table 5.6: Continuation of species list.

	Reef flat			Reef slope	
Species	Outer	Inner	Fringing reef	Patch reef	Coral carpet
Gastrochaena sp.			x	x	x
Gibberulus gibberulus	x	x			
Glycymeris livida				x	x
Haliotis pustulata	x	x	x		
Haliotis sp.		x			
Isognomon legumen			x		
Lambis truncata sebae	x	x			
Lamellolucina dentifera		x			
Lima paucicostata				x	x
Lioconcha philippinarum				x	
Lithophaga sp.			x	x	x
Longchaeus teres		x			
Malea pomum	x	x			
Malvifundus regulus					x
Mammilla melanostoma		x			
Mauritia grayana		x			
Mitra (Nebularia) dovpeledi					x
Mitra ferruginea					x
Mitra rueppelli					x
Modiolus auriculatus	x	x			
Modulus tectum		x		x	x
Moerella lactea	x	x			
Morula aspera			x	x	x
Morula uva	x	x			
Muricodrupa funiculus	x	x			
Myurella columellaris				x	
Nassarius fenistratus	x	x			
Neritopsis aqabaensis					x
Ostreidae			x	x	x
Otopleura mitralis	x	x			
Pedum spondyloideum			x	x	x
Pinctada margaritifer			x		x
Pinctada radiata					x
Pinna muricata			x	x	x
Priotrochus obscurus	x	x			
Pteria sp.				x	x
Spondylus sp.			x	x	x
Streptopinna saccata			x	x	x
Tapes sp.					x
Tectus dentatus	x	x		x	x
Tridacna sp.	x		x	x	x
Triphoridae sp.	x	x			
Trochus maculatus		x	x		x
Trochus virgatus			x	x	x

Table 5.7: Continuation of species list.

Species	Reef flat Outer	Inner	Fringing reef	Reef slope Patch reef	Coral carpet
Tucetona audouini				x	
Turbo petholatus			x		x
Turbo radiatus	x	x	x	x	
Turrilatirus turritus			x	x	x
Vasticardium marerubrum				x	x
Vasum turbinellus	x	x			x
Ventricolaria toreuma					x
Vexillum pardalis				x	x
Xenoturris cingulifera erythraea					x

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