

FIELD STUDIES IN COASTAL ECOSYSTEMS OF THE SINAI PENINSULA

DAHAB, EGYPT 2006



UNIVERSITY OF VIENNA



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Abstract

This year marks the 12th annual coral reef ecology field course held by the University of Vienna in the Red Sea. The course – which took place between 23 October and 3 November 2006, consisted largely of a marine part, held for the 5th time in Dahab, Egypt, and two days of terrestrial excursions in the surrounding desert and mangrove ecosystems. One focus was on surveying two environmentally similar reefs differing mainly in scuba diving pressure. The goal was to examine the abundance and occurrence of dominant reef-associated fishes – herbivores (Scaridae, Acanthuridae), corallivores (Chaetodontidae) and omnivores (Pomacentridae, selected Labridae) – and to determine whether ecological factors such as habitat-substrate characteristics and structural complexity play a role in structuring the different functional groups.

A second focus was on the corallivorous snail *Drupella cornus*. This study was designed to determine potential correlations between the abundance, biomass and size of *D. cornus* and the infection rates and degree of destruction of coral colonies, specifically of the genus *Acropora*.

For this study, a series of 20 m x 5 m belt transects were laid at two depths (3 and 8 m) in four sites – three at the so-called “Islands” diving site (Sites 1,2,4) and one at “Rick’s Reef” (Site 3, less frequented by scuba divers). Special photographic ID cards were made to help identify the selected fish and coral species. The structural complexity and the substrate composition were recorded using point sampling along the transect lines (every 50 cm using a plumb).

We counted a total of 2645 fish from 5 different families. Pomacentrids were by far the most abundant group. Several fish families showed significant differences between certain reef sites, although the pattern was not consistent over all fish groups. Differences were also recorded between depths: the Acanthuridae and Pomacentridae, for example, were significantly different between zone 1 (3 m) and 2 (8 m). Finally, four coral-associated pomacentrids were most abundant at the more pristine site 3, which also had the highest coral coverage and exhibited the most *Acropora* colonies. In all four study sites, the shallow zone had a higher density of *Acropora* spp. than the deep zone. Study site 3 (Rick’s Reef) showed by far the highest density for both the shallow and the deep zone. A total of 470 *D. cornus* were collected. Most *Drupella* found (321; 68%) were in the smallest size class 1 (10-19mm). Length-weight ratios were calculated for 81 individuals and showed an exponential relationship. The larger size classes apparently preferred different coral species than the smallest size class. The number of *Acropora* colonies invaded by *D. cornus* was low throughout the different *Acropora* species, mostly under 10%. There was a significant correlation between invasion of colonies by *D. cornus* and colony damage.

The northernmost mangroves in the Red Sea north of Dahab in the Nabq protected area revealed a diverse fauna, including juvenile stages of many coral reef fish species along with several bird species. The desert excursion to Wadi Gonai yielded a wide range of plants highly adapted to dry conditions with either their root system and/or their leaf size and shape. Insects (in particular tenebrionid beetles) characterized this environment, although other highly adapted insects and spiders, along with larger faunal elements (geckos, lizards) were recorded and documented.

CORAL REEFS

INTRODUCTION

Coral reefs are mainly restricted to tropical latitudes within 30° of the equator and, compared to other ecosystems, are subject to relatively constant environmental conditions and balanced seasonal cycles. Such relative stability may produce organisms that are poorly adapted to environmental changes and therefore it is often argued that coral reefs ought to be among the least resilient ecosystems on the planet and are good indicators of environmental changes (Glynn 1993, Brown 1997). Despite the sensitivity to disturbances, reefs have also been one of the most persistent ecosystems throughout Earth's history (Veron 1995). However, the number of reef-creating organisms has increased and decreased over time, and, interestingly, the species and even taxonomic orders dominant in the present era are significantly different from those of earlier times (Veron 1995). Consequently, there is an ongoing debate over the issue of reef resilience and stability and whether the geologic past is relevant to the scale and types of contemporary disturbances (Brown 1997, Knowlton 2001, Pandolfi 2002).

What is clear is that, through the combined direct and indirect effects of anthropogenic activities such as overfishing, destructive fishing practices, coastal development, eutrophication, pollution and SCUBA diving, especially the last one hundred years have witnessed direct human pressure on entire functional groups of organisms in oceans and on coral reefs (Jackson et al. 2001). Changes in the absolute and relative abundance of functional groups and of their substrate species, even in high-diversity systems like coral reefs, may extensively affect the ability of local communities within the ecosystem to resist and recover from future disturbances. Therefore, the influence of several substratum variables, particularly structural complexity and live coral coverage, on key coral reef species richness and abundance has been investigated numerous times in the past (Roberts & Ormond 1987, Syms & Jones 2000, Graham et al. 2006).

To study anthropogenic reef impact, our surveys took place in two environmentally similar reefs differing mainly in their touristic diving pressure. This enabled us to point out similarities and differences between almost undived and very popular touristic dive sites.

Moreover, we attempted to determine whether there are major distinctions in the abundance and occurrence of the observed organisms depending on the degree of exposition and on depth.

Although the numerous spatial niches provided by the three-dimensional reef structure, reef structural complexity and habitat type play a central role in determining the composition of reef-associated species, there has been controversial discussion over how closely fish communities are bound to their habitat. On one hand, some studies show a high degree of variability that is independent of habitat change. On the other hand, some data indicate that coral-specialists clearly suffer when coral cover is reduced (Sale et al. 1984, Williams 1986, Doherty & Fowler 1994, Doherty 2002, Syms & Jones 2000, Spalding et al. 2002).

The primary purpose of the present study was to analyze the appearance of dominant reef-associated organisms and functional groups, and to determine whether ecological factors such as habitat-substrate characteristics and structural complexity (e.g. live and dead coral coverage, coverage by algae, coral rock, stone or sand, coral diversity and morphology) play a role in structuring the different reef-associated species-communities. We therefore observed the occurrence of herbivorous (Scaridae, Acanthuridae), corallivorous (Chaetodontidae) and omnivorous (selected Labridae) reef fish as well as habitat specialists (Pomacentridae) and examined the extent to which the structure and abundance of these fish communities are influenced by the above-mentioned factors.

Coral reefs are not only impacted by human activities, but also by natural ones: predation of corals by the coral-eating crown-of-thorns starfish *Acanthaster planci*, damage caused by storms, coral diseases and temperature-related stress are among the most commonly recorded natural impacts on coral reefs. In many cases, disturbances interact to cause ecological change here. For example there is strong evidence that humans, by overfishing keystone predators (Ormond et al. 1988, McClanahan 1995) or elevating nutrients (Birkeland 1982), may increase the frequency, intensity, and geographic extent of population outbreaks of coral predators such as *Acanthaster planci* and corallivorous gastropods (*Drupella* sp.).

The coral-eating snails *Drupella* spp. are documented as coral-erosive invertebrates that cause great damage to corals worldwide. For example in the Pacific and Western Australia, *D. cornus* has been reported to exhibit large population increases or outbreaks that result in the defeat or destruction of their coral prey (McClanahan 1997). A similar incident occurred in Kenya. The abrupt population growth of *D. cornus* was mostly observed in reef areas where heavy fishing and a decrease of durophagous predators occurs. In unfished reefs, large population increases of *D. cornus* are less-known, despite the presence of their preferred coral prey – branching *Acropora*, *Montipora* and *Pocillopora* (McClanahan 1997).

Accordingly, the invasion of *Acropora* by *Drupella cornus* was also investigated in Dahab. One major aim was to determine whether there is a significant correlation between the abundance, biomass and size of *D. cornus* and the infection rates and degree of destruction of coral colonies. For this purpose we also examined the general distribution and the diversity of *Acropora* spp. within the reef.

In conclusion, studies that integrate population and community biology with ecosystem processes will provide a much better understanding of the effects of biodiversity loss on reef function. This approach will also improve our ability to optimally manage these complex systems (Kenneth 1994).

MATERIAL AND METHODS

Study area

The field work was conducted in Dahab, Egypt, which is located in the south of the Sinai Peninsula, in the Gulf of Aqaba, Northern Red Sea, between 27 and 29 October 2006. Four sites were examined (figures 1 and 2). Three of them were located in “The Islands” and the fourth at “Rick's Reef”. These sites were chosen based on their different live coral coverage, which reflects different reef conditions.



Fig.1: Location of the study sites in the “Islands”. Sarah Village hotel complex visible at upper left. Note lighter, trampled stretch used by divers to enter the water. Images from ©GoogleEarth



Fig. 2: Location of the study sites at “Rick’s Reef”. The sites are approx. 30 m north of the standard entrance into the reef. Images from ©Google Earth

Site 1 was located in Pool 3 at the Islands and represents a frequently dived inner reef slope. Here, the reef was least disturbed by physical factors such as waves and currents. Site 2 (T1: 28 28 38,7 / 34 30 50,5 and T2: 28 28 39,0 / 34 30 51,5) represented a reef slope on the outer reef, which is also frequently visited by divers. The outer reef’s complexity reflects the resistance of corals against these physical forces. Site 3 (T1: 28 33 27,6 / 34 31 29,1 und T2: 28 33 27,0 / 34 31 28,4) is less often used for diving, and was located on the left hand of the entrance of the dive site “Rick’s Reef”. It represents a gently falling reef slope on the outer reef. Site 4 (T1: 28 28 36,0 / 34 30 46,3 und T2: 28 28 35,5 / 34 30 46,0), again located at the Islands, is used nearly daily for diving and is positioned on the outer reef slope.

Methods

Two teams of 8 persons each were divided into 3 sub-teams. Each sub-team dealt with a specific aspect, namely:

1. Visual counts of the fish families Scaridae and Acanthuridae as well as the determination of structural complexity and substrate type.
2. Visual counts of the fish families Pomacentridae, Chaetodontidae and selected labrids. This sub-team also laid the transects.

3. Determination, counts and measurements of *Acropora* corals along with the occurrence of the coral-feeding gastropod *Drupella cornus*.

Each team of 8 persons laid two replicate belt transect in two different reef zones (upper and lower reef slope), defined by 3 m (Zone 1) and 8 m depth (Zone 2), respectively. The transects measured 20 x 5 m and were further subdivided into four sections (each 10 x 2.5 m): two longitudinal sections from 0 to 10 m (section 1) and two longitudinal sections from 10 to 20 m (section 2). The transects were laid using 30 m reels, whereby one end was attached to the reef and one diver swam at the desired depth and distance. The band was attached to coral structures along the way to reduce deviations. The width of transects was marked by attaching 5 m lines perpendicularly at the beginning, the middle and the end of the transect line. The deeper transects were laid in the morning (~10 am) and the shallower m transects in the afternoon (~ 3 pm). This yielded a total of four transects per day, the two replicate transects at the same depth being separated by a 10 m gap.

Each transect was worked up successively by the three teams described above. Data were recorded with a pencil on a waterproof data-sheet taped to a writing pad (appendix 1-3). Special photographic ID cards were made (laminated color prints) to help identify the selected fish and coral species (appendix 4-6). The fish species were chosen based on their functional association in their reef habitat (table 3, Khalaf and Kochzius, 2002), and modified according to the species actually observed in training sessions (tab. 1). All corals (Acroporidae) were determined according to C. Wallace (pers. comm.) using specially prepared photographic ID sheets. The dates were taken in a specific sequence as described below.

1.) Scaridae and Acanthuridae were counted 10 min after the transect had been deployed in order to allow the fishes to assume their normal distribution and return to normal behaviour. The team swam slowly, without specified pauses along the transect, one diver on each side of the transect line. Each transect took a minimum of 5 min.

2.) The counting of the Pomacentridae, Chaetodontidae and the labrids (*Thalassoma* spp.) started after the first fish survey team reached the halfway mark of the transect (10m). A minimum of 10 min were required to complete the transect because many of the selected species are coral-associated and often hid in the coral structure, making them more difficult to see, identify and count.

3.) *Acropora* colonies (10 cm or larger) were identified to species level and counted last, i.e. behind sub-team 2 (Pomacentridae etc.). Data recorded were the largest diameter of each colony,

the amount of partial mortality (PM) in three classes (0: no PM, 1: PM < 50%, 2: PM > 50%), feeding marks (in percentages) and numbers and size of *Drupella cornus* present in these coral colonies. Four size classes of corals were distinguished: 10 – 19 cm, 20 – 29 cm, 30 – 39 cm and 40 – 49 cm. Due to the more time-consuming work, only the first 10 x 5 m of the transects were considered and the data were extrapolated for the second 10 m transect length (section 2). Exceptions include three observations (Site 1, Zone 2, Transect 2, both sides and Site 4, Zone 2, Transect 1, Side 1), where the full transect length was evaluated. In addition, one data sheet was lost and substituted with appropriate data from the corresponding transect (Site 1, Zone 2, Transect 1, Side 1). Parallel to *Acropora* determination, specimens of *Drupella cornus* were collected outside the transects. A sliding calliper and a balance (Lutron GM – 500) were used to measure size and weight; the latter value was taken as the biomass of the species. The field data for *Acropora* and *Drupella cornus* were processed using Microsoft Excel and SPSS. For colony size, an ellipsoid figure with a length:width-ratio of 3:2 was regarded to be the best estimation. Therefore, based on the largest diameter (a) and the shortest diameter (b = 2/3 a), the area of the ellipsoid was calculated. Partial mortality (PM 0 %, < 50 %, > 50 %) was considered together with the former calculations to estimate the surface area of living coral. In order to estimate 'living area', colony size was multiplied with a factor based on PM, 0 % mortality equalling 1, < 50 % equalling 0.75 and > 50 % equalling 0.25. Based on the Log4 of the latter data, different classes were created.

The following abbreviations are used for the 13 *Acropora* (A.) species investigated: acu = *A. acuminata*, dig = *A. digitifera*, eur = *A. eurystoma*, gem = *A. gemmifera*, hum = *A. humilis*, hya = *A. hyacinthus*, lor = *A. loripes*, sam = *A. samoensis*, sec = *A. secale*, sel = *A. selago*, squ = *A. squarrosa*, sub = *A. subulata*, var = *A. variolosa*.

4.) In order to determine the structural complexity and the substrate composition, point sampling was undertaken along the transect line every 50 cm using a plumb. Structural complexity was measured for each transect by summarizing the modulus of height-change between one and its subsequent sampling point.

The identity of the structure hit by the plumb was recorded to obtain point sampling data on the substrate. We distinguished seven categories: Live hard coral (LC), soft coral (SC), recently killed and dead coral (DC), coral rock (RC), coral rubble (RB), sand (SD) and others (OT). Hard corals are defined as living scleractinians, and soft corals as living Alcyonacea. Recently killed corals are dead corals where one can still determine the genus, while coral rock was undeterminable dead structure build up by corals in the past. Coral rubble is defined as broken

coral structures, sand as fine-grained sediment surface area. The category “Others” was used for plants and animals, e.g. algae, bivalves, etc.

In addition to point sampling data, larger-scale substrate cover was also visually estimated over the whole belt transect area. A team of two persons (one for each replicate transect) recorded this substrate cover. Four different substrate categories were chosen (live corals, dead corals, coral rock and sand). By swimming over the transects, the percentage of each of these categories was estimated and recorded on underwater data-sheets. At the same time, photographs (or short videos) were taken to confirm the in situ estimations.

RESULTS

Fish counts

In total we counted 2645 fish of 5 different families (Table 1). In abundance, fish communities were by far dominated by pomacentrids (Fig. 3), but densities were highly variable among sites and zones. We found significant differences between the four study sites in *Acanthurus nigrofuscus* (site 3 vs 4: Chi-square for two samples: $n_1=23$, $n_2=62$, $df=1$, $\chi^2=5.745$, $p=0.01$), *Chromis dimitiata* (site 1 vs 2: Chi-square for two samples: $n_1=71$, $n_2=280$, $df=1$, $\chi^2=4.837$, $p=0.02$), *C. viridis* (site 1 vs 3: Chi-square for two samples: $n_1=2$, $n_2=91$, $df=1$, $\chi^2=13.797$, $p<0.001$), *Pomacentrus sulfureus* (site 2 vs 3: Chi-square for two samples: $n_1=143$, $n_2=131$, $df=1$, $\chi^2=11.195$, $p<0.001$; site 1 vs 3: Chi-square for two samples: $n_1=191$, $n_2=131$, $df=1$, $\chi^2=6.377$, $p=0.01$; site 1 vs 4: Chi-square for two samples: $n_1=191$, $n_2=113$, $df=1$, $\chi^2=11.247$, $p<0.001$) and *Thalassoma rueppellii* (site 1 vs 2: Chi-square for two samples: $n_1=54$, $n_2=80$, $df=1$, $\chi^2=9.398$, $p=0.002$).

Table 1: Number of fish counted in the total area of 1600 m² (16 transects á 100 m²).

Scaridae	52	Acanthuridae	383	Pomacentridae	1943	Labridae	215	Chaetodontidae	52	Total	2645
<i>H. harid</i>	4	<i>A. nigrofuscus</i>	215	<i>D. aruanus</i>	24	<i>T. lunare</i>	0	<i>C. austriacus</i>	48		
<i>S. fuscopurpureus</i>	5	<i>A. sohal</i>	0	<i>C. dimidiata</i>	823	<i>T. rueppellii</i>	215	<i>C. trifascialis</i>	4		
<i>S. niger</i>	10	<i>A. gahhn</i>	2	<i>C. viridis</i>	108						
<i>C. sordidus</i>	13	<i>N. elegans</i>	4	<i>C. weberi</i>	1						
<i>C. bicolor</i>	1	<i>N. unicornis</i>	0	<i>C. embae</i>	1						
undef. Scaridae	12	<i>N. brevirostris</i>	0	<i>A. flavilatus</i>	14						
juvenile Scaridae	7	<i>Z. xanthurum</i>	34	<i>A. leucogaster</i>	199						
		<i>Z. desjardinii</i>	9	<i>A. bicinctus</i>	4						
		<i>C. striatus</i>	119	<i>P. ulfureus</i>	578						
				<i>C. flavaxilla</i>	24						
				<i>N. melas</i>	0						
				<i>P. trilineatus</i>	15						
				<i>D. trimaculatus</i>	0						
				<i>D. marginatus</i>	18						
				<i>P. lacrymatus</i>	134						

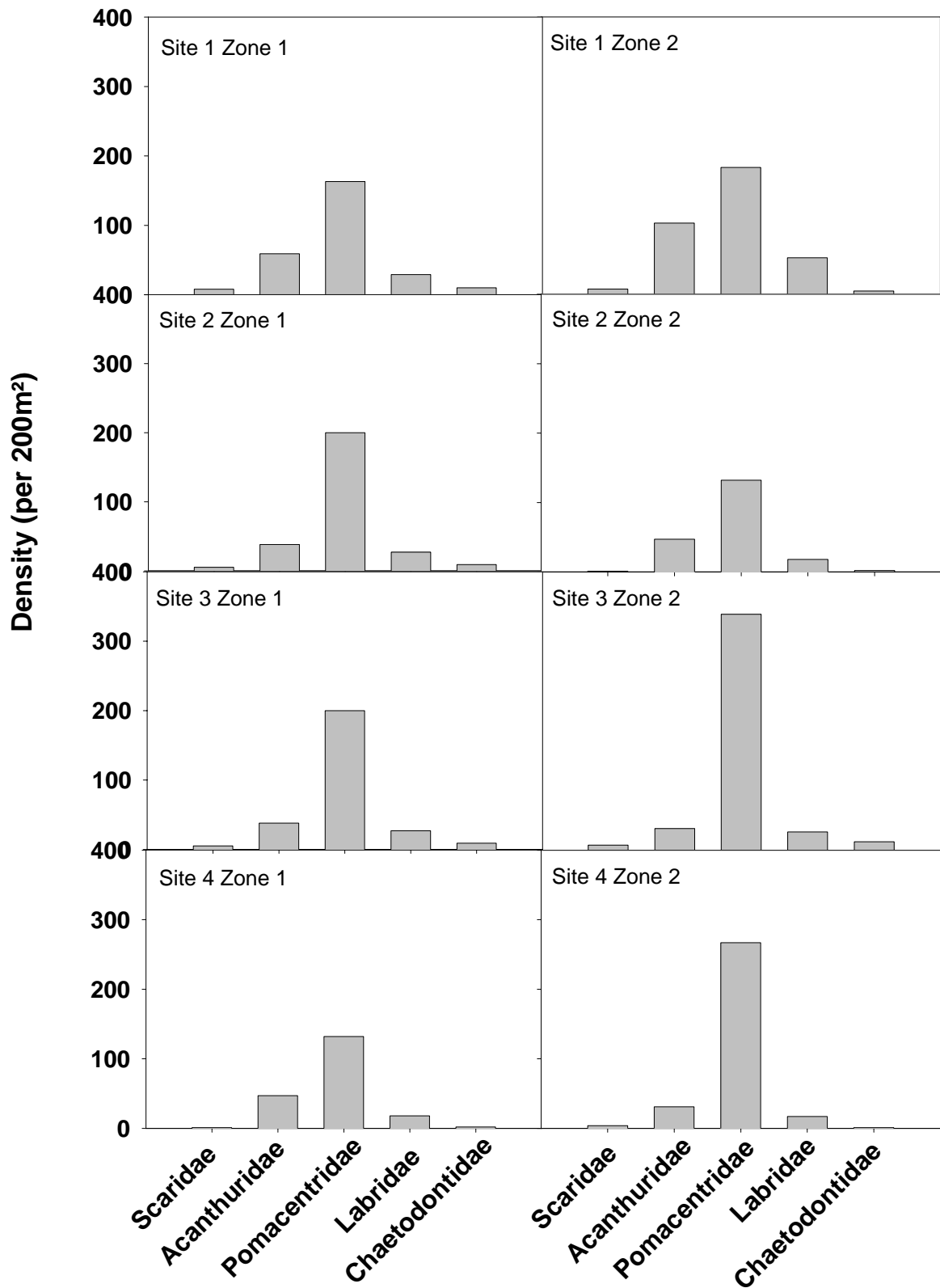


Fig. 3: Fish family densities in different study sites and zones (200 m² observed per zone) at Dahab (Gulf of Aqaba, northern Red Sea).

The abundance of three different Pomacentridae species in the four different study sites is shown in figure 4. The abundance of coral inhabitants and coral feeders (*C. viridis*, *D. aruanus*, *D. marginatus*, *C. austriacus*) and the coral *Acropora* was not statistically different between the four study sites, but study site 3 – where all 4 fish species were most abundant – was also characterized by the most *Acropora* colonies (Fig. 5). Significant differences between zone 1 and 2 were found in Acanthuridae (Wilcoxon: $z=-2.033$, $n=8$, $p=0.042$) and Pomacentridae ($z=-2.38$, $n=8$, $p=0.017$) species (Fig. 6). However, we found no significant differences between the selected fish groups (Scaridae, Acanthuridae, Pomacentridae, Labridae, Chaetodontidae) over different study sites.

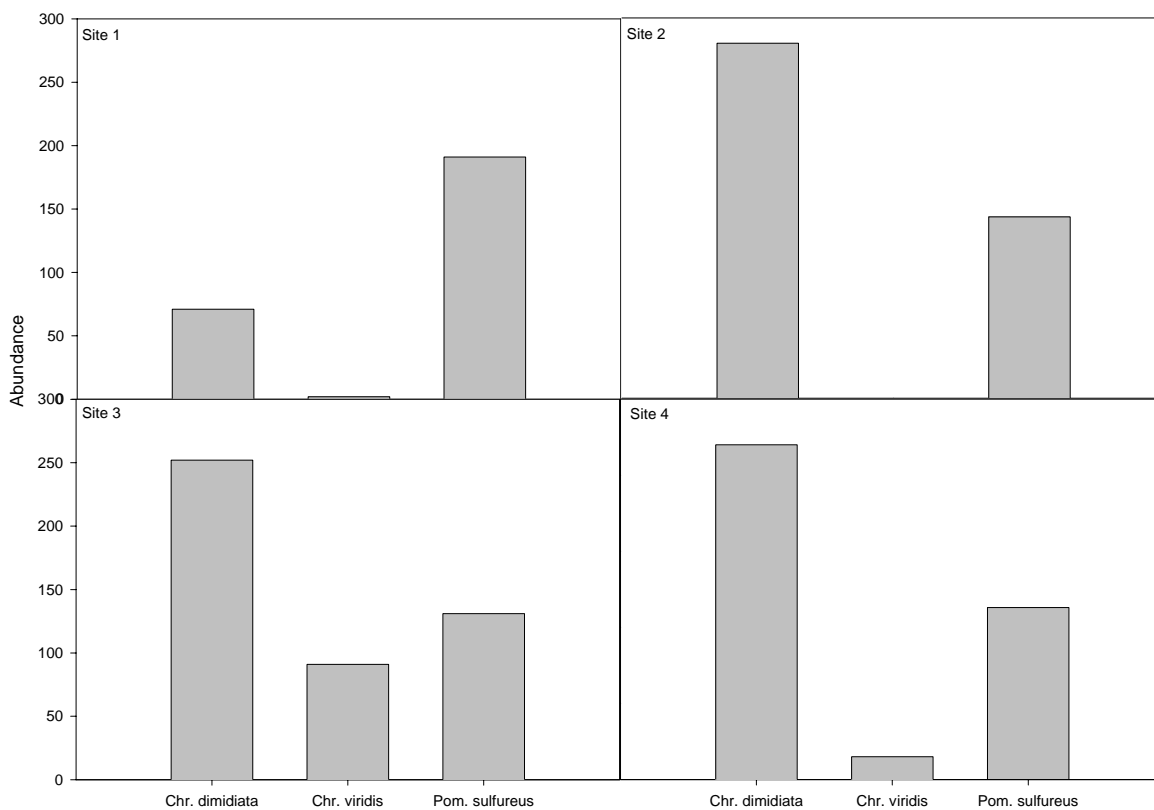


Fig. 4: Abundance of the three most dominant pomacentrid species in the four different study sites in zone 2.

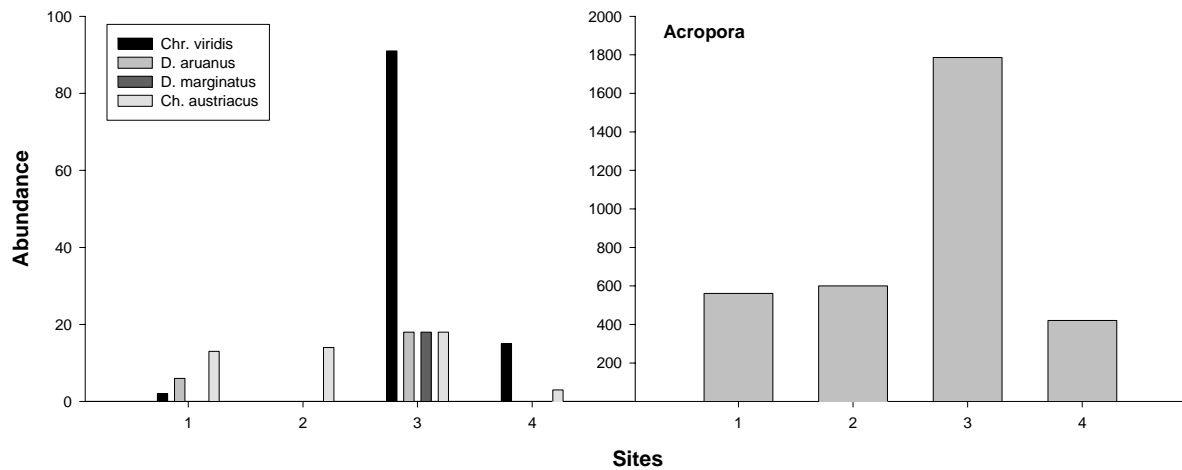


Fig.5: Abundance (number of individuals) of *C. viridis*, *D. aruanus*, *D. marginatus*, *C. austriacus* and *Acropora* (number of colonies) at 4 different study sites.

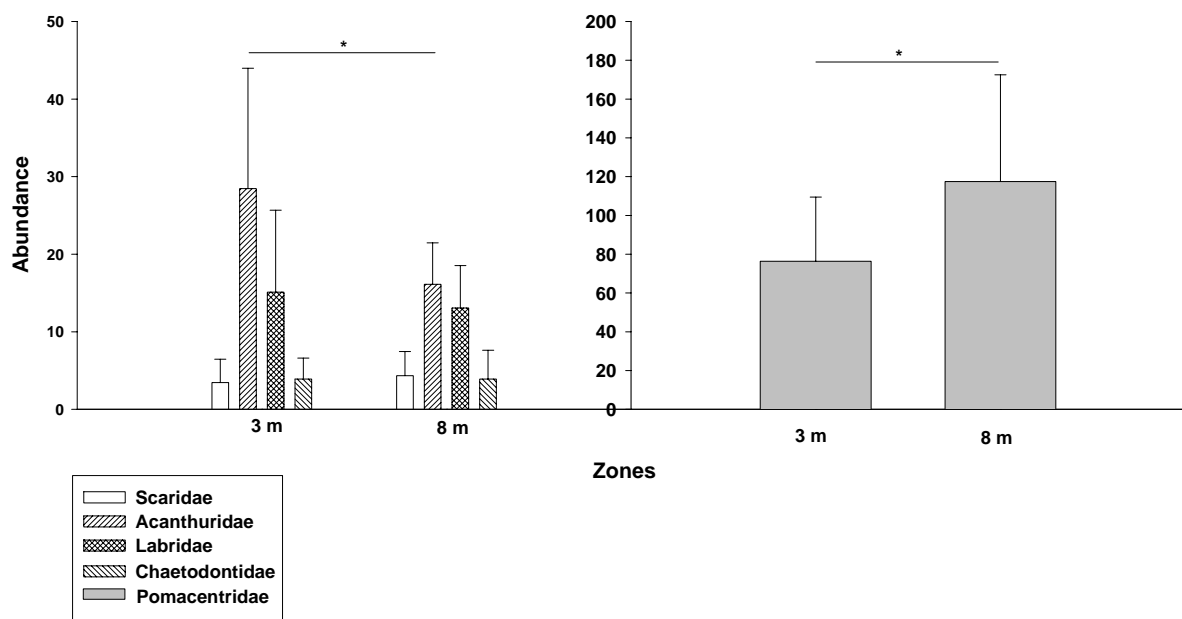


Fig. 6: Numbers of individuals of the five investigated reef fish families in different reef zones (upper (3 m) and lower (8 m) reef slope) at Dahab (Gulf of Aqaba, northern Red Sea).

Substrate sampling

We found significant differences between the four different study sites in hard coral coverage (Kruskal-Wallis: $\chi^2=7.894$; $df=3$; $n=4$; $p<0.05$) and structural complexity (Kruskal-Wallis: $\chi^2=12.199$; $df=3$; $n=4$; $p<0.01$). Post hoc Mann-Whitney-U-tests showed differences in hard coral coverage, where site 3 was significantly higher in coverage than site 2 ($z=-2.178$; $n=4$;

$p < 0.05$) and site 4 ($z = -2.323$; $n = 4$; $p < 0.05$; Fig. 7), and in structural complexity (Fig. 8) between study site 1 and 3 ($z = -2.309$; $n = 4$; $p < 0.05$), 1 and 4 ($z = -2.309$; $n = 4$; $p < 0.05$), 2 and 4 ($z = -2.309$; $n = 4$; $p < 0.05$) and 3 and 4 ($z = -2.309$; $n = 4$; $p < 0.05$). In contrast, no significant differences were observed in dead coral, coral rock, soft coral and sand frequency between the four study sites, although live coral coverage was significantly higher in zone 1 (Wilcoxon: $z = -2.383$, $n = 8$, $p = 0.017$), while there was significantly more sand coverage in zone 2 (Wilcoxon: $z = -2.207$, $n = 8$, $p = 0.027$; Fig. 9).

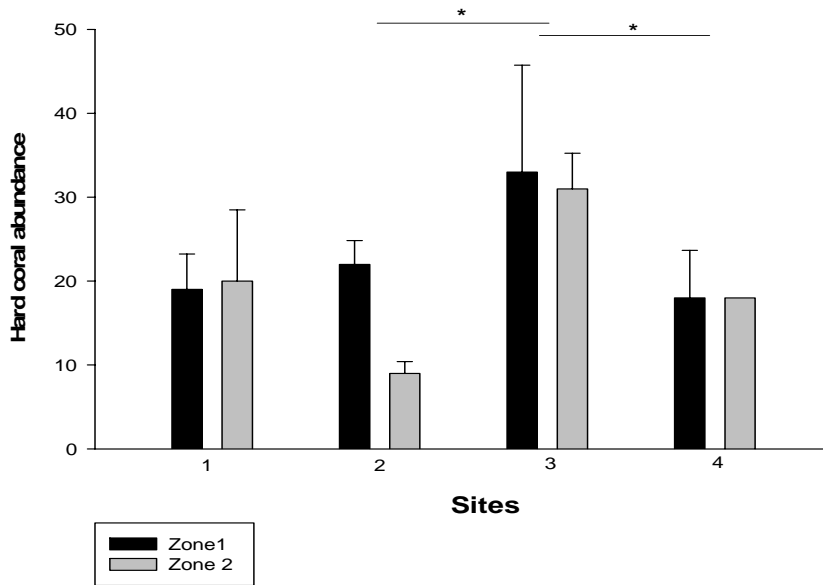


Fig. 7: Hard coral abundance at point intercepts at 4 study sites at Dahab (Gulf of Aqaba, northern Red Sea).

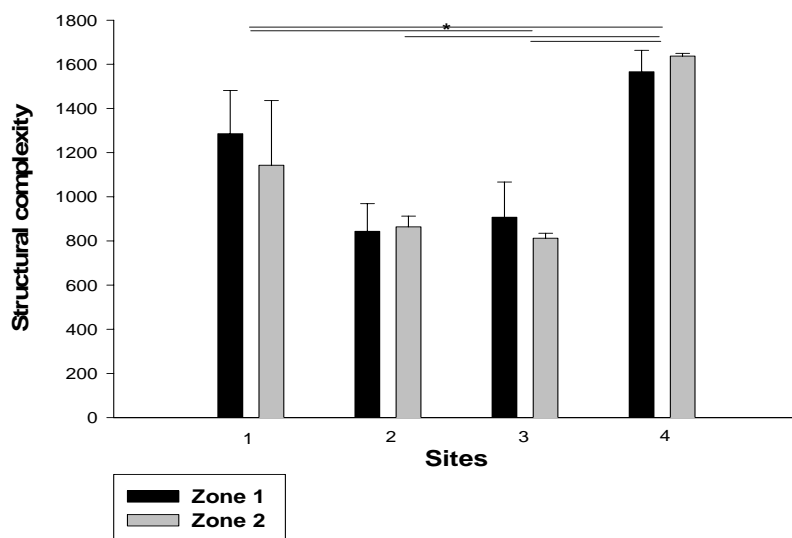


Fig. 8: Differences in structural complexity (sum of variance between subsequent measures of relief at point intercepts in centimeters) among 4 study sites at Dahab.

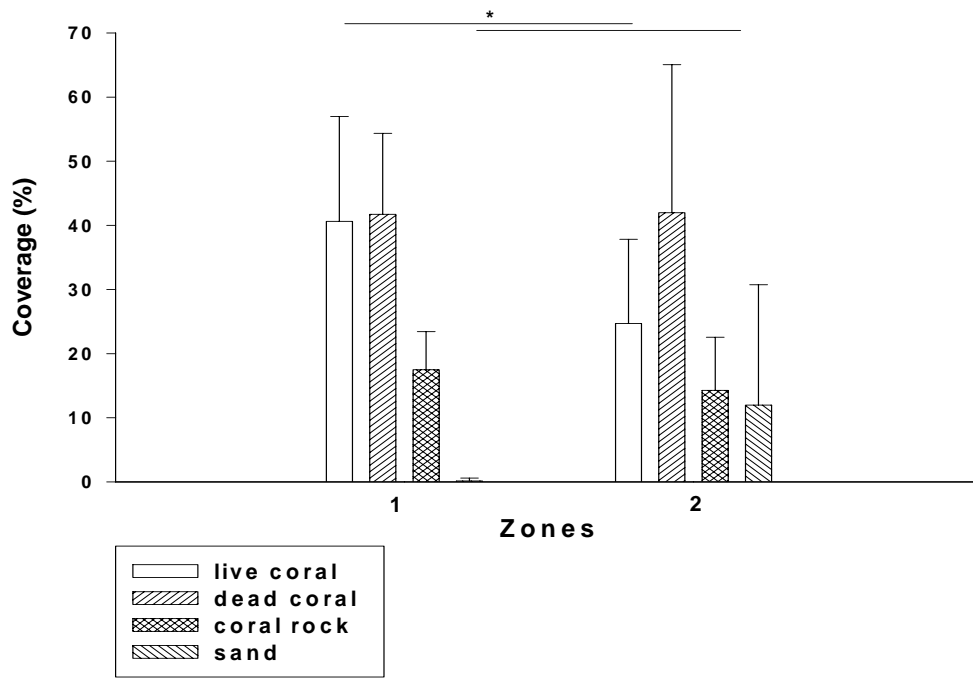


Fig. 9: Substrate coverage between two different zones at Dahab.

Acropora abundance

Both the number and the diversity of *Acropora* species were higher in the shallow zones of all study sites (Fig. 10). Furthermore the shallow zones, especially at site 3, had a much more even distribution of *Acropora* species. In contrast, the deep zones showed a low diversity, with one or two species being considerably more dominant than the others. The most dominant *Acropora* species for the deep zones of all study sites was *A. loripes* (only in site 1 was *A. variolosa* equally dominant).

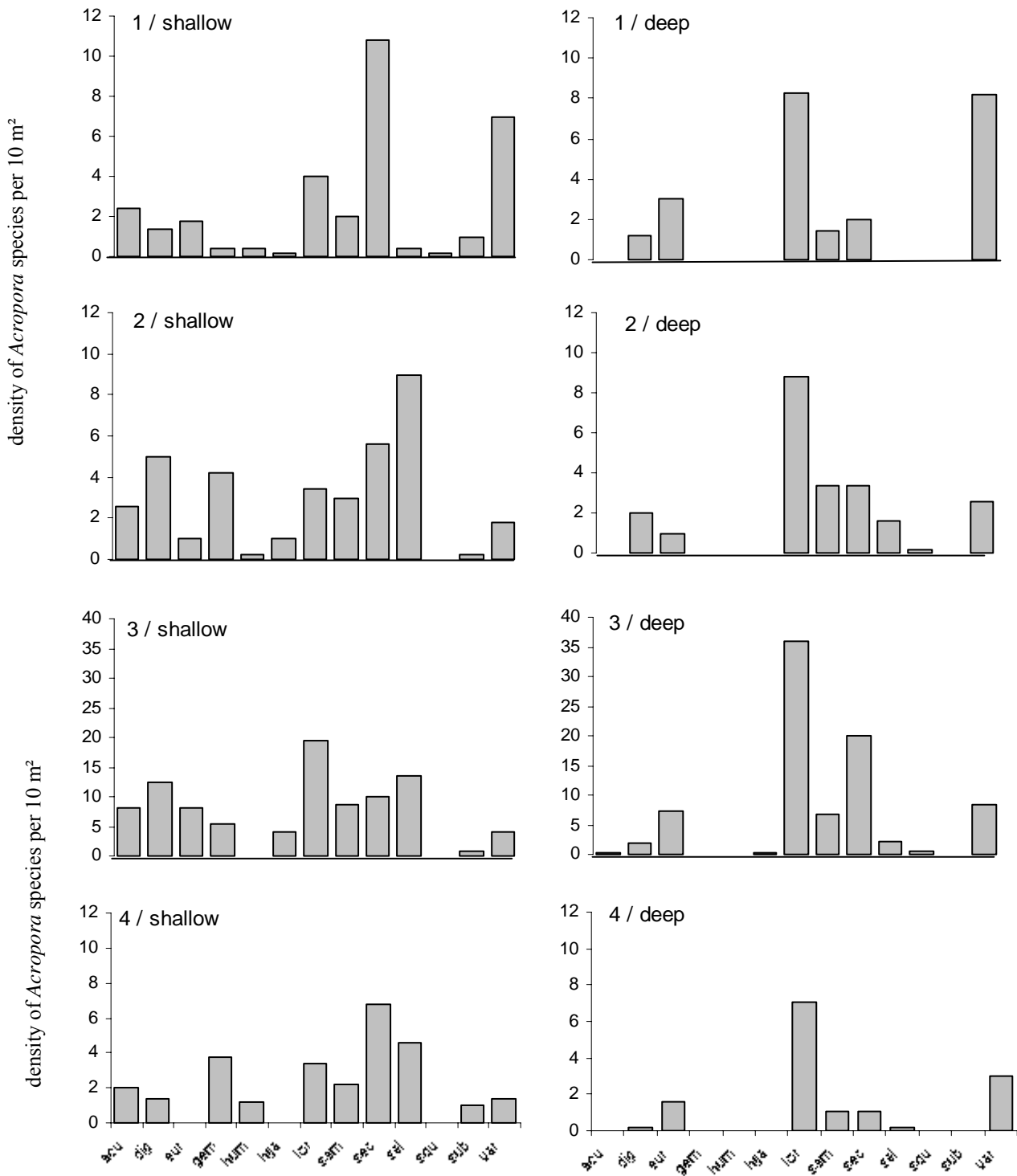


Fig. 10. Density (per 10 m²) of the *Acropora* spp. at each zone (shallow and deep) of the four study sites. Note different scale in site 3.

The overall *Acropora* density differed among the shallow and the deep zones of the study sites. In all four study sites, the shallow zone had a higher density of *Acropora* spp. than the deep zone. Study site 3 showed by far the highest density for both the shallow and the deep zone (Fig. 11).

The live coral cover of *Acropora* spp. in the shallow zones of all sites was higher than in the deep zones. This corresponds with the overall higher *Acropora* density in the shallow zones (Fig. 11). Note that site 3, though having by far the highest *Acropora* density (Fig. 11), had a lower live coral cover than the shallow zone of site 1 (Fig. 12), which has a proportionally low *Acropora* density (Fig. 11).

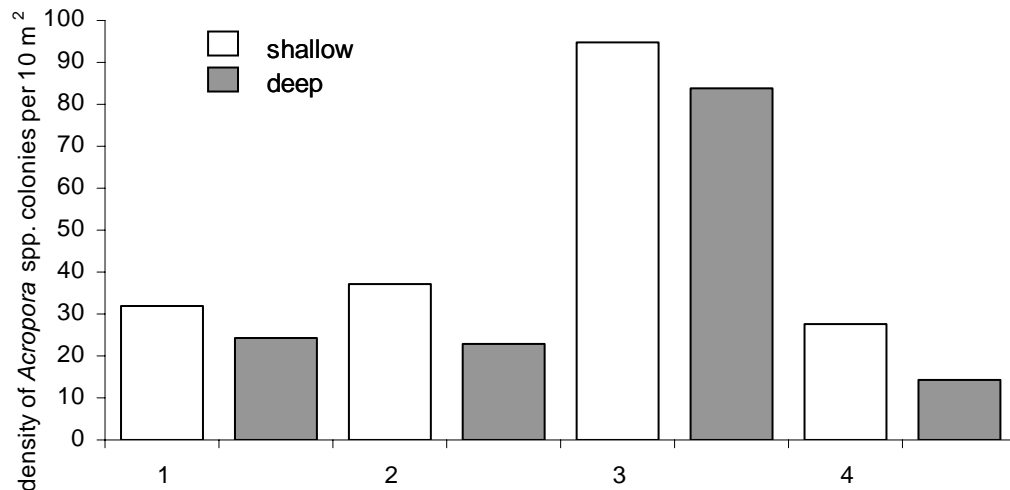


Fig. 11: Density of *Acropora* spp colonies per 10 m² for each zone.

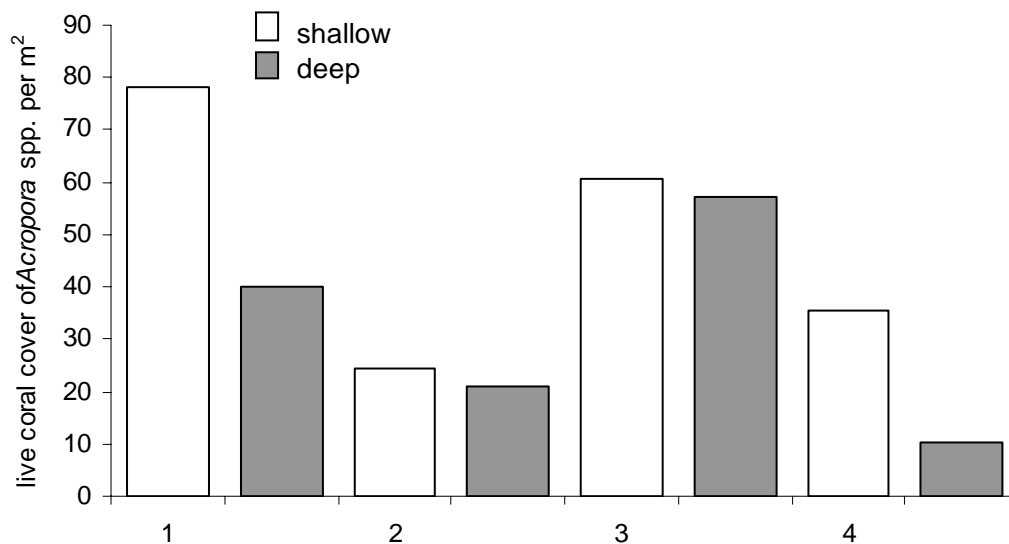


Fig. 12: Live coral cover of *Acropora* spp. measured in m² for each zone of the four study sites separately. The area studied was 100 m² for each zone (maximum potential live *Acropora* coverage). The live coral cover is the total coral area minus the area of partial mortality (see also Fig. 10).

Partial mortality of *Acropora* spp. and impact of *Drupella cornus* on *Acropora* spp.

The partial mortality (PM) in all *Acropora* species monitored varied from moderate (<50 %) to high (>50 %). *A. loripes*, the most abundant species, had the lowest PM (10 %) of all. The highest PM was found for *A. subulata* (60 %) (note that this percentage – due to the few colonies monitored – is probably not representative). However, the high PM for *A. variolosa* (56 %), *A. gemmifera* (49 %) and *A. acuminata* (46 %) is a sound estimate because of a proportionally sufficient number of colonies. For all other species (except *A. loripes* 10 % and *A. digitifera* 11 %) the PM varied at a moderate level of about 20 to 30 % (Fig. 13).

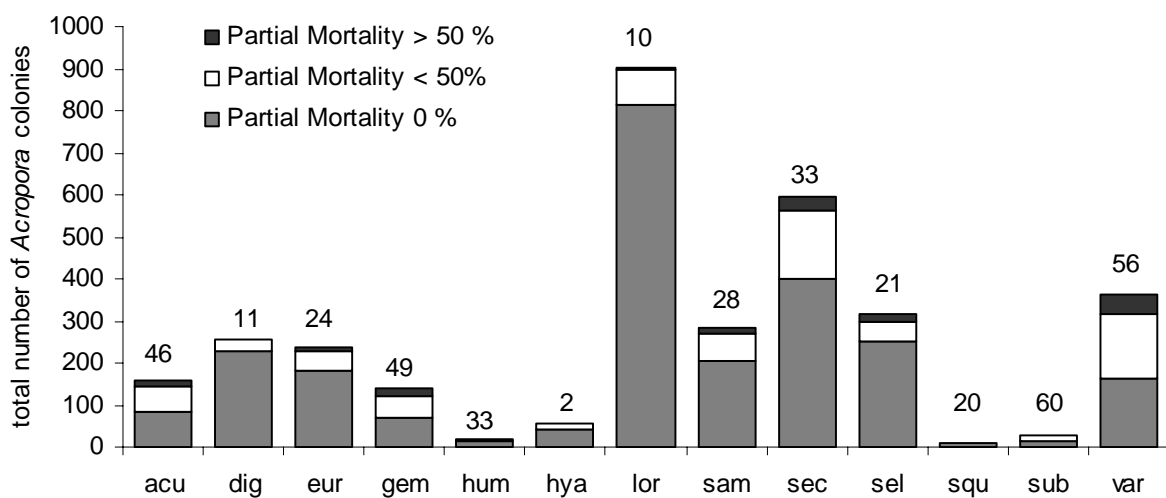


Fig. 13: Partial mortality (PM) for the total number of *Acropora* colonies studied on all four study sites. The PM is compared among the respective *Acropora* species. Three categories of partial mortality were applied: PM > 50 %, PM < 50 %, PM = 0 %. The numbers on top of the bars give the percentage of both partial mortality categories for the respective species. For list of abbreviations see material and methods.

The number of *Acropora* colonies invaded by *D. cornus* was low throughout the different *Acropora* species (Fig. 14). The highest *Drupella* presence occurred in *A. squarrosa* (20 %), although this percentage may not be representative because the total number of colonies was only 10 (i.e. 2 colonies invaded by *D. cornus*). For all other species (except *A. hyacinthus* 14 %, *A. subulata* 13 % and *A. humilis* 11 %) the *Drupella* presence was below 10 %. *A. loripes*, which was both the most dominant species (Fig. 10) and had the lowest PM percentage (Fig. 13), was also least frequently invaded by *D. cornus* (only 2 %).

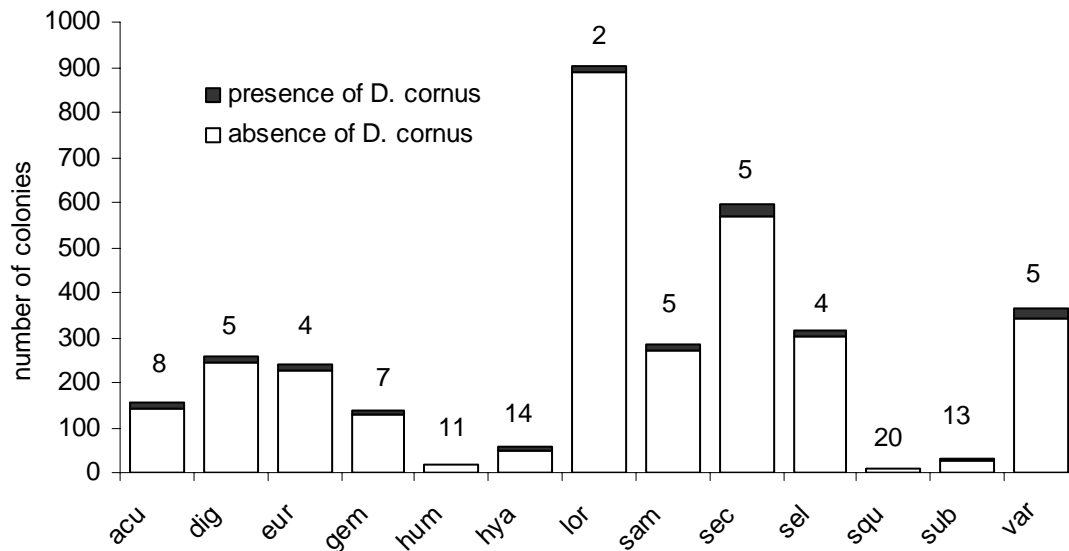


Fig. 14: Presence or absence of *Drupella cornus* for all *Acropora* colonies of 13 species examined at all four study sites. The numbers above the bars give the percentage of colonies invaded by *D. cornus* for each *Acropora* species. For species abbreviations see material and methods.

There was a significant correlation ($r^2=0.38$, $p<0.05$) between invasion of colonies by *D. cornus* (Fig. 14) and colony damage (Fig. 15). In accordance with a high *Drupella* presence (Fig. 14), *A. squarrosa* has also the highest mean percentage (33.3 %) of colonies damaged. High rates of damage were also observed in *A. acuminata* (31.1 %), *A. subulata* (26.3 %) and *A. hyacinthus* (17.9 %), all of which were also frequently occupied by *Drupella*. An exception was e.g. *A. humilis* which showed no damage although *Drupella* was frequently present.

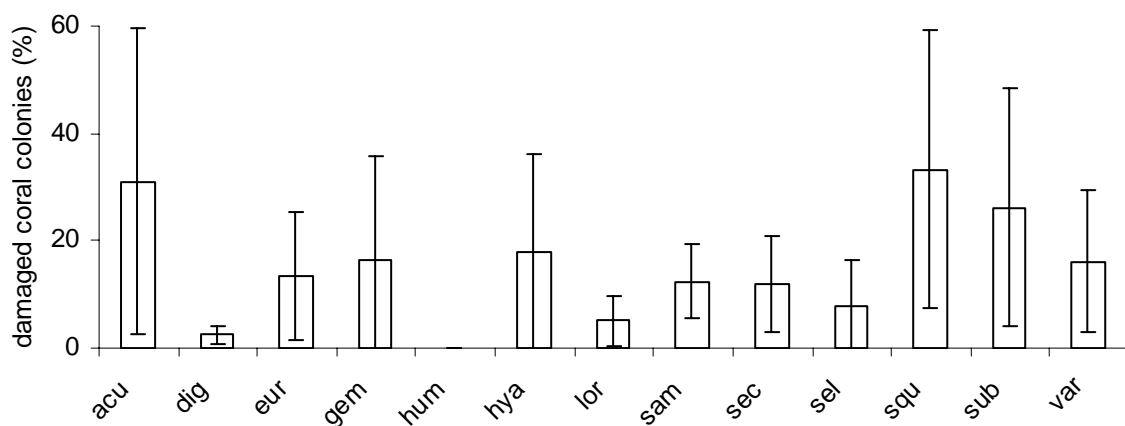


Fig. 15: Mean percentages (\pm standard error) of *Acropora* species damaged by *Drupella cornus* at four different reef sites in the Gulf of Aqaba, northern Red Sea. For total numbers of coral colonies compare with Fig. 11. For species abbreviations see material and methods.

A total of 470 *D. cornus* were collected. Most *Drupella* found (321; 68 %) were in the smallest size class 1 (10-19mm), significantly fewer (94) belonged to size class 2 (20-29mm); size class 3 (30-39mm) accounted for 53 individuals, and only two were bigger than 40mm (Fig. 16).

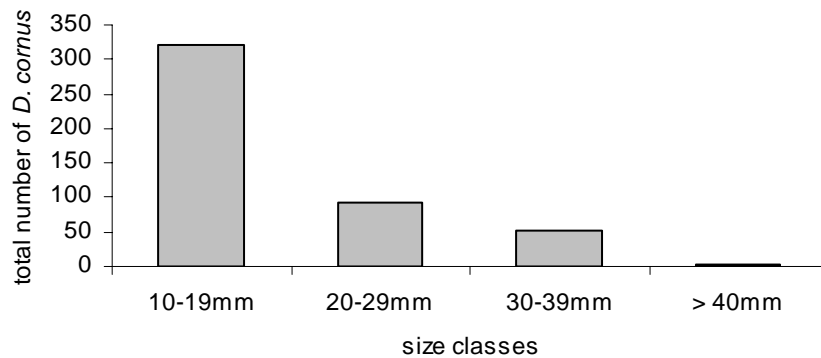


Fig. 16: The overall number of *D. cornus* collected, divided into 4 size classes: size class 1 (10-19mm), size class 2 (20-29mm), size class 3 (30-39mm), size class 4 (> 40mm).

Length-weight relationship and biomass of *Drupella cornus*

The data pairs for biomass and size of 81 collected individuals of *D. cornus* showed an exponential relation. It can be described by the function $y = 0.0003 x^{2.8674}$ ($R^2 = 0.9569$): the larger a snail gets, the higher its biomass (Fig. 17 a). For the largest *D. cornus*, the trend line fits less well, as the mass no longer grows exponentially with size. When the logarithmic biomass is aligned on the y-axis and the size on the x-axis, then the relation described is linear. The resulting function is $y = 0.0556 x - 0.9718$ ($R^2 = 0.9366$) (Fig. 17 b).

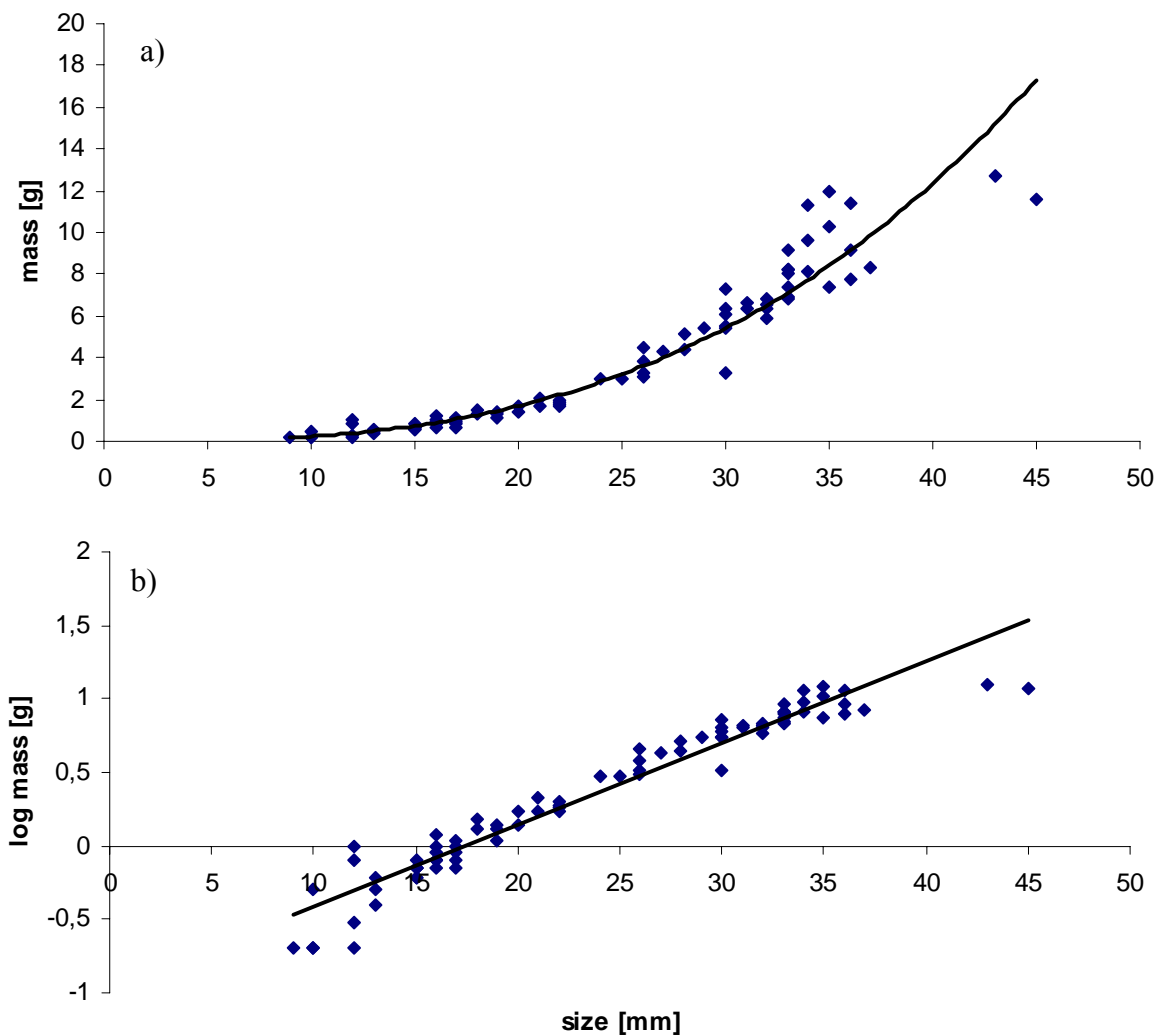


Fig. 17: Exponential (a) and linear (b) relation between mass and size of individuals of *Drupella cornus* [size class 1 (10-19mm), size class 2 (20-29mm), size class 3 (30-39mm), size class 4 (> 40mm)]

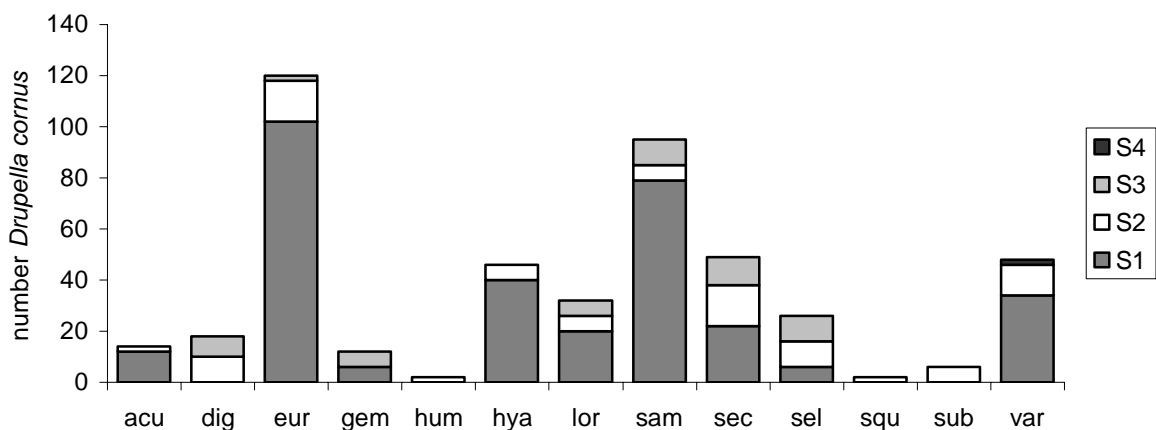


Fig. 18: Number of *Drupella cornus* per size class on *Acropora* colonies [size class 1 (10-19mm), size class 2 (20-29mm), size class 3 (30-39mm), size class 4 (> 40mm)].

The majority of *Drupella* individuals (102) of size class 1 (10-19mm) were found on colonies of *A. eurystoma*, followed by *A. samoensis* (Fig. 18). Most *Drupella* individuals sized between 20 and 29 mm (size class 2) preferred colonies of *A. eurystoma* and *A. secale*, whereas *Drupella* individuals of size class 3 (30-39mm) were mainly found on *A. samoensis* and *A. selago*. Both individuals of size class 4 (>40 mm) invaded colonies of *A. variolosa*.

DISCUSSION

Many studies have been carried out on the influences of diving and snorkelling on reef corals and the associated fauna (Zakai & Chadwick-Furman, 2002, Roupheal & Inglis, 1997, 2001). This study focused on the occurrence of herbivorous, corallivorous and omnivorous reef fish as well as habitat specialists, and their relation to their hard coral habitats. The distribution of these feeding types in different reefs provides one indication of the health and status of the respective reef ecosystems.

The significant differences in the coral coverage between the reef zones investigated in the Gulf of Aqaba, northern Red Sea, are due to a higher abundance of living corals in shallower water. Dead corals and coral rock display nearly the same value in both zones. Directly beneath the ocean surface, light is not a limiting factor and the whole spectrum of light is available. In deeper water less light penetrates and it becomes a limiting factor. Because of mechanical and biological erosion and sediment deposition in low-energy areas, we find more sandy areas in the deeper transects.

Our investigations on the large herbivorous fish revealed no clear relation between the density of Scaridae and Acanthuridae and reef structural complexity. This contradicts the pattern found by Risk (1972), who reported fish diversity to be significantly correlated with structural complexity. The amount of live coral coverage was found to have no influence on the fish density in the two different zones. This is in contrast to Bell & Galzin (1984), who found a close correlation between the percentage of live scleractinian corals and total species richness. Several studies have suggested that the abundance of Chaetodontidae is related to the abundance of live corals (Reese 1977, 1981, Bouchon-Navaro et al. 1985).

Focusing on the species number and general abundance, there were far more Acanthuridae (total number 383) than Scaridae (52) in all sites and zones. Interestingly, in site 1 (the "Islands") the number of counted Acanthuridae is higher in zone 2 although structural complexity is less there. This was also unexpected because, in more shallow depths, light enables more algae to grow, which is the main food of Acanthuridae. During our studies, we observed larger surgeonfish shoals which swam by and increased the number of counted Acanthuridae: this may have biased

our counts. Also Bell and Galzin (1984) found varying abundance for Acanthuridae between different sites. In site 2, which is a highly visited snorkelling area, both the structural complexity and the number of fish showed no differences between the depth zones.

We also investigated corallivorous fish such as butterflyfish and coral-associated fish like pomacentrids. The latter are very often shoaling and thus we generally encountered them in larger groups. The greatest differences in abundance in the different sites were found for *Chromis viridis*, *Dascyllus aruanus* and *Dascyllus marginatus*. These species, especially their juveniles, like to hide from predators in the *Acropora* corals. The highest number of these species was therefore counted at site 3 (Rick's Reef), which also had the highest *Acropora* abundance. The abundance of certain pomacentrids (*Chromis dimidiata* and *C. viridis*) was higher in more sheltered habitats (site 3). In zone 2 we counted more pomacentrids than in zone 1. *Pomacentrus sulfureus* was rather "ubiquitous": it was present regardless of whether the site was exposed or sheltered, affected by diving tourism or undisturbed by it.

Chaetodon austriacus, as a member of the coral-feeding Chaetodontidae family, also had the highest abundance at site 3. The density of *Acropora* species per m² differed in the four investigated sites. Also, the community composition varied in the different zones. Thus, *A. acuminata*, *A. gemmifera*, *A. humilis*, *A. hyacinthus*, *A. squarrosa* and *A. subulata* are absent in the deep zone of almost all sites. Other *Acropora* species such as *A. loripes* which prefer low-exposed areas are more abundant in the shallow (upper reef slopes) regions.

Based on comparisons of the abundance of *Acropora* spp. colonies per 10 m² and its live coverage, it is evident that some sites are dominated by larger *Acropora* colonies. In the deep zones of all sites the density of *Acropora* spp. is lower; the highest values – both in the shallow and deep zone – were found in site 3. The highest live coral cover of *Acropora* spp. was found in site 1, in particular the shallow zone. This is due to the large stands of *A. variolosa*, which had a value of 45.5 m² in the shallow zone of site 1 (only 4.6 m² in the shallow zone of site 3), and *A. subulata* in site 1 (more than 16 m² compared to only 0.4 m² in site 3). Site 1 is less exposed and thus larger, more fragile stands of *Acropora* are supported in the shallow region, while the three remaining sites represent exposed reefs. *Acropora* species which build large stands by mainly asexual reproduction (e.g. *A. variolosa*; Wallace, 1999) seem to be more vulnerable in general as they had higher partial mortalities than other species (Fig. 6). This might be counterbalanced by their ability to proliferate faster due to asexual reproduction.

However, there was no general relation between the partial mortality of *Acropora* spp. and the occurrence of the corallivorous gastropod *Drupella cornus* observed. In *A. subulata*, which had the highest partial mortality (60%) and the third highest rate of *Drupella* presence (13% of all colonies affected), such a relation might exist, but more data (higher number of colonies) would

be necessary to obtain significant results. In contrast, *A. variolosa* had the second highest partial mortality (56%) but only 5% of all colonies were affected by *D. cornus*. However, as calculated over the entire dataset, it was shown that there was a significant correlation between occupation of *Drupella* and signs of damage. *D. cornus* is known to be attracted by mechanically damaged or stressed corals (Morton et al. 2002). Therefore, reefs with a high abundance of damaged or stressed corals might promote *D. cornus* occurrence. This is supported by the present results that the distribution of *Drupella* is more aggregated than regular over reefs and some sites were clearly more infected than others.

The high percentage of affected colonies of *A. hyacinthus*, *A. humilis* and *A. subulata* might be explained by the snail's preference for fine-branching coral species, mainly of the families Acroporidae and Pocilloporidae (Turner 1994b). Interestingly, *A. loripes*, which also has fine-branching colonies, was least affected. As this species dominates deeper reef zones, this situation might reflect different depth preferences for the coral and/or *D. cornus*. Another opportunity might be that *A. loripes* is more resistant against or less preferred by *Drupella*. This results in a community shift towards a dominance of *A. loripes* in heavily damaged reefs.

Nearly 70% of all *D. cornus* individuals found were juvenile (< 20 mm shell length, Turner 1994a). Juvenile individuals are probably overrepresented because study sites were located in rather shallower (3 to 8 metres) sections of the reefs where branching *Acropora* species dominate and because only *Acropora* species were examined. There is evidence that juvenile *D. cornus* individuals prefer fine-branching coral species to be protected from predators; once they grow beyond a size that is susceptible to predation, they may move onto less protective prey such as massive or encrusting corals (McClanahan 1997). Also, fine-branching corals may provide too little space for adult *D. cornus* individuals (> 20 mm shell length, Turner 1994a), which measure up to 40 mm. Finally it must be stated that some reefs investigated are in bad condition and high live coral coverage is only maintained through a few, larger growing species. There is indication that *Drupella cornus* damages some *Acropora* species more than others and that invasion into some reef sites may have consequences on the coral health of these sites.

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ECO-TERRESTRIAL EXCURSIONS TO TWO SINAI DESERT SITES

(1 AND 2 NOVEMBER 2006)

General

Sinai's climate is arid and hyper-arid (Ayyad & Ghabbour 1986). Annual precipitation is up to 200 mm (Zahran & Willis 1992) and declines from the West to the East (125 mm to 25 mm). Winter temperature ranges from below 0 °C in the mountains (G. Katherina 2637 m) to 19° C at the sea shore (Sharm-el-Sheik). Summer temperature in the Sinai reaches 50 to 55 °C with ground temperatures of 70 °C. This explains the difficult conditions for the flora and fauna living in this extreme habitat.

There are several definitions describing a desert: First, a desert is a region or landscape form in which precipitation is lower than evaporation. Therefore, water is not available directly. Secondly, vegetation covers only 10% of the ground and there is no fertile soil. In the past, this has forced humans to nomadism. The subtropical and tropical deserts can basically be grouped into:

- tropic deserts,
- rain shadow deserts,
- coastal deserts and
- continental deserts.

Tropic deserts

The Sahara belongs to the first-mentioned group and is situated between the tropic of Cancer and the tropic of Capricorn. Warm humid air rises from the equator to the north and south and thereby loses humidity as rain. In the tropopause, a zone of inversion in very high altitudes of the atmosphere, the cold air accumulates under rising air pressure. This induces the cold air, whose temperature continuously rises, to sink again to the ground. During this process it loses any moisture it contains and is returned by the trade winds back to the equator. This explains why tropic deserts are areas of high air pressure, without clouds over long periods of the seasons, and why the humidity is so low (8-10% r. H.).

Rain shadow deserts

Rain shadow deserts form when tall mountain ranges block moisture-laden clouds. As air moves over the mountains, it cools and condenses, causing precipitation on the upwind side. Moisture almost never reaches the downwind side of the mountain, therefore causing a desert there. For example the eastern part of the Atacama Desert between Chile and Peru is separated by high coastal mountains from the Pacific Ocean.

Coastal deserts

Coastal deserts can be found on the west coasts of the continents. Their existence is connected with cold Antarctic upwelling water along the coast, inducing an inversion zone of cold and wet air above the water. Rainfall occurs on the open sea. During the night, onshore winds bring moisture as fog towards the dry coast, which supplies enough humidity for highly specialized communities of desert plants and animals. Typical coastal deserts are the Atacama in SW America or the Namib in SW Africa. Atacama Desert is one of the driest deserts on earth and is virtually sterile because moisture is blocked from both sides by the Andes and by coastal mountains. The average rainfall in Antofagasta - a region in Chile which is part of the Atacama - is just 1 mm per year; there was a period of time where no rain fell there for 40 years. It is so arid that mountains reaching an altitude as high as 6885 m are completely free of glaciers. In the southern part from 25°S to 27°S, such mountains have possibly been glacier-free throughout the Quaternary - though permafrost extends down to an altitude of 4400 m and is continuous above 5600 m (en.wikipedia.org).

Continental deserts

Examples for huge continental desert areas are the central Iranian deserts Lut and Dasht Kavir or the Dakla Makan in China. Their position, surrounded by high mountains or far away from the sea, gives them an extremely dry and continental character.

Excursion to the Nabq protected area

The excursion to Nabq protected area took place on Thursday, 2 November 2006. Nabq was declared as a protected area in 1992 with the status of a Managed Resource Protected Area (MRPA). The National Park Nabq lies 35 km north of Sharm-el-Sheik and links many unique systems such as coral reefs, seagrass beds, mangroves, salt marshes, brackish water oases and dunes (Al-Mufti, 2000). The excursion covered stone deserts, coastal plains and wadis, hypersaline marsh areas, mangroves and different sand dune systems such as the Arak dune system. When driving into the National Park, we were able to observe a pair of Brown-necked raven (*Corvus ruficollis*) or Fan-tailed raven (*Corvus rhipidurus*).

1. Wadi Kharesa

The first site we visited was Wadi Kharesa. Wadi is a term used for dry beds that contain water only after heavy rainfalls.



Acacia raddiana

photo: F. Macherhammer



Acacia raddiana

photo: A. Konz



Acacia raddiana

photo: A. Konz

Acacia raddiana, from the family of Leguminosae, is a solitary, umbrella-shaped tree with long, sharp, silvery-white thorns and feathery, double branching leaves. Its roots contain rhizobium bacteria which convert atmospheric nitrogen into nitrate; this nitrate can then be utilized by the plant. Bedouins respect this tree: tribal laws make it a crime to cut it down. The tree sap is a sticky and thick fluid which is used by Bedouins to promote wound healing. *Zilla spinosa*, family Brassicaceae, has light violet flowers, which bloom after rainfalls. From the family Asteraceae, a taxon of dicotyledonous flowering plants and the second largest family in the Division Magnoliophyta, *Iphiona scabra* and *Pulicaria undulata* were found. *Iphiona scabra* is a shrub with pungent, needle-like leaves, yellow flowers and a characteristic aromatic scent. *Pulicaria undulata* is a much branched, woolly herb with undulated leaves and yellow flowers; it exudes an intensive aromatic scent. *Zygophyllum coccineum* is a member of the Zygophyllaceae,

a family typical for salty desert areas of the Sahara. It is a shrub with cylindrical fleshy leaves and white flowers. *Aerva javanica* from the family Amaranthaceae is an erect, densely stellate-hairy plant which is typical in the East Sahara. Its leaves are flat and elliptic-lanceolate.



Zilla spinosa
photo: A. Konz



Iphiaea scabra
photo: F. Macherhammer



Pulicaria undulate
photo: F. Macherhammer



Aerva javanica
photo: A. Konz



Zygophyllum coccineum
photo: A. Konz

The wadi contained an interesting fauna, including numerous insects and several reptiles: *Tropicolotes steudneri* is a pigmy Sahara species of the family of Gekkonidae living in a variety of habitats throughout the extreme desert. This gecko has slender toes and large imbricate scales, which are smooth on the venter and mostly smooth on the back. Furthermore, it has adhesive lamellae, which enable the gecko to climb smooth vertical surfaces such as rocks. On the other hand, many other species of Gekkonidae lack such lamellae, as they live on sandy grounds. *Eremias guttulata* (Lacertidae) is a very small lizard with a laterally compressed body, a narrow head with pointed snout and a flattened frontal region. It lives in rocky plains with sparse vegetation and in coastal dunes. Surprisingly for the excursion group, Anisoptera (dragonflies) of the family Libellulidae (*Sympetrum* sp.) were sighted in the wadi, which was quite far away from open freshwater. The big odonates obtain sufficient humidity from their prey and are able to fly over large distances. Underneath stones, we found silverfish (Lepismatidae); they feed on

detritus and very often cooperate with ants (Formicidae). One of the ant genera typical for sandy deserts is *Camponotus*, which builds large subterranean nests.

We also documented termites. Termites are significant detritivores that recycle wood and other plant matter. This group is not at all closely related to ants, belonging instead to a group of insects, the Dictyoptera, that also include the mantises and the cockroaches. They live in subterranean tunnels from which only ventilation shafts can be seen on the surface. A typical colony contains nymphs (semi-mature young), workers, soldiers, and reproductive individuals of both sexes. Beyond inhabiting tropical areas, some termite species are also specialized colonizers in deserts. Band-winged grasshoppers of the subfamily Oediponidae are classified under the family Acrididae. *Sphingonotus coerulans* has blue hind wings and blue hind tibiae. It is well camouflaged while resting on the ground. When life conditions are favorable and its population growth rates explode, this species can cause great damage. It then changes its solitary lifestyle and becomes a migratory locust. *Sphingonotus coerulans* is distributed across North Africa and several years ago became a member of the fauna of the semi-desert dry southern Iberian Peninsula.

Quite a few darkling or black beetles (Tenebrionidae) were found not only in the wadi but also in other parts of the National Park. Worldwide, more than 20 000 species are estimated to exist (en.wikipedia.org); about 90% are specialized members of desert habitats. In the Sinai Peninsula, 121 species of Tenebrionidae are registered (Lillig & Pavlicek, 2003). Two species were identified on this excursion: *Adesmia cancellata latreillei* and *Adesmia cothurnata cothurnata*. The structures of the black elytra function as heat distributors. Generally, black beetles are extremely well adapted to live under very hot and dry conditions. The genus *Adesmia* belongs to the type of “fast runners” which can reach speeds of one meter per second. Two other Tenebrionidae were found: *Stenosis* sp. and *Zophosis* sp.. *Zophosis* sp. belongs to the morphotype of “sand swimmers”, which have a streamlined body. *Scanthius aegypticus* was identified, representing the family of Lygaeidae. This species has a striking red, black and white coloration and sucks on different plants.



Tropicolotes steudneri

photo: F. Macherhammer



Sphingonotus coeruleus

photo: F. Macherhammer



Adesmia cothurnata cothurnata

photo: F. Macherhammer

2. *Calotropis procera*

The second site we visited was characterized by a little *Calotropis procera* tree standing solitarily in the middle of the wadi. It belongs to the milkweed family Asclepiadaceae and produces white, purple-tipped flower clusters and smooth green, apple-like fruits. The fruits turn yellow upon ripening, then split open and scatter their seeds, which have a long silky papus. The leaves are up to 20 cm long, oval shaped and fleshy. When damaged they secrete a poisonous milky liquid, causing death by paralysis of the heart when ingested, and blindness when brought in contact with the eyes. Bedouins use the white spongy bark, which reflects the heat, for indigestion and diarrhea. This species acts as indicator for groundwater and can reach heights of 5 or 6 m. It is a member of the Sudanese flora and is distributed from East Africa to the hottest parts of the Eastern Saharo-Arabian sandy desert.



Calotropis procera
photo: F. Macherhammer



Calotropis procera
photo: F. Macherhammer



Calotropis procera
photo: F. Macherhammer

3. Mangroves

The third station was the lagoon near to wreck “Maria Schroeder” with a large community of mangroves. Throughout the world, mangroves are endangered ecosystems and have declined rapidly, leaving many coasts unprotected. In Nabq the mangroves consist of only one species: *Avicennia marina* (Avicenniaceae). This is an evergreen tree up to 6m in height and a natural desalinator. With the help of its aerial roots (pneumatophores) and leaves, it filters the sea water so that enough moisture is available for growth (Al-Mufti, 2000). Mangroves are viviparous plants, producing seeds that germinate before becoming detached from the parent plant. Mangrove stands are an important and sensitive ecosystem, providing an ideal environment for young fish and invertebrates, as well as a nesting and resting site for migratory and resident birds.



Avicennia marina
photo: A. Konz



Avicennia marina
photo: F. Macherhammer

The dark form of *Egretta gularis* (Western Reef Heron) was observed catching fish between the mangroves. Between the roots, hermit crabs, fiddler crabs *Uca* sp. (Ocypodidae) and Thalassinidae were recorded. *Strombus tricornis* (Strombidae) and several open bivalve shells were found between the mangroves.

The fish community between the mangroves is very rich. We were able to record the following species during our short excursion into the stands: *Gerres oyena* (Gerreidae), *Parupeneus forskali* (Mullidae), *Chaetodon auriga* (Chaetodontidae), *Pomacentrus trilineatus* and *Plectroglyphidodon lacrymatus* and *Abudefduf sexfasciatus* (Pomacentridae), *Zebrasoma desjardini* (Acanthuridae), *Acanthopragrus bifasciatus* (Sparidae), *Lutjanus monostigma* (Lutjanidae), *Apogon pharaonis* (Apogonidae), *Cryptocentrus* sp. and *Gnatholepis* (Gobiidae), *Siderea grisea* and *Echidna nebulosa* (Muraenidae). Typical for the muddy bottoms of mangrove habitats is *Cassiopea andromeda*, the upside-down jelly fish (Cassiopeidae).

Birds near the mangroves

The dark grey morph (there is also a white morph) of *Egretta gularis* (Western Reef Heron) was observed catching fish between the mangroves. The typical habitat for this species is coastal wetland, mainly in tropical West Africa, the Red Sea and east to India. We also identified three other waders (so-called shorebirds): *Charadrius dubius* cf. (Little Ringed Plover), *Tringa tetanus* (Redshank) and *Numenius arquata* (Curlew). Their breeding sites are near wetlands or other coastal environments in Europe and Asia. They are migratory and winter in Africa. We also observed *Larus ichthyaetus* (Great Black-headed Gull), *Larus hemprichii* (Sooty Gull) and *Sterna caspia* (Caspian Tern), which were migrating during this period. *Larus ichthyaetus* breeds in colonies in marshes and islands from southern Russia to Mongolia, *Larus hemprichii* breeds on coasts and islands mainly in the southern Red Sea, and *Sterna caspia* has a large, probably global range and can occur along the coasts of the Red Sea during migration. In contrast, the coastal area of the northern Red Sea is a typical winter habitat of *Alcedo atthis* (Common Kingfisher), which we also recorded.



Egretta gularis

photo: M. C. Loretto



Tringa totanus & *Numenius arquata*

photo: M. C. Loretto

4. Coastal salt marsh

We found typical coastal salt marsh plants, which are salt- and draught tolerant. *Zygophyllum album*, for example, roots in saline groundwater. It is a low-growing, succulent shrub of silvery-green to blue-green appearance with white flowers. Colonies of *Zygophyllum album* start building small dunes; the species is considered to be a halophytic pioneer form. *Limonium axilare* from the family Plumbaginaceae is one of the most salt-tolerant plants in the drier parts of the coastal salt marsh. It builds and stabilizes small to medium-sized dunes. The roots force their way through the upper, most saline soil layer and develop a horizontal root system at a depth of only 20 to 90 cm. Here, the salt content is much reduced and the substrate remains moist. The blossoms are white to pink.

The dominant plant of the salt-influenced dune systems is *Nitraria retusa* (Nitrariaceae). It grows up to 120 cm in height, covering and stabilizing large and small sand dunes. This perennial shrub has light green, almost silvery succulent leaves and tiny yellowish flowers. During the fruiting season, pea-sized red berries develop. These berries are edible, although quite sour in taste. This shrub is a typical pioneer of deep salty clay layers, but no active roots develop below a depth of 30-40 cm, where there is usually little water and a lot of salt.



Zygophyllum album

photo: A. Konz



Nitraria retusa

photo: W. Waitzbauer

Arak dune system

Site five was the Arak dune system, which ranges from the coastal salt marsh for some distance inland. The dune-building plant here is *Salvadora persica* (Salvadoraceae), which needs a source of freshwater to thrive and therefore grows only further inland. This tree is a very low, creeping form. It stabilizes accumulated sand via extensive root and branch systems and also by trapping old layers of leaves and dry stems. It has a large trunk which is twisted in snake-like manner and split in several sections that rejoin again, following the direction of the wind. The branches grow

vertically (Al-Mufti, 2000) and the fruits are edible, but bitter. The Arak dune system of Nabq contains the greatest accumulation of *Salvadora persica* in the Indo-Pacific region.



Salvadora persica

photo: J. Herler

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Excursion to Wadi Gonai

The first terrestrial excursion led us to Wadi Gonai, which can be described as a dry riverbed filled with water after periods of heavy rain. This region is characterized by strong temperature fluctuations between day and night, dryness and a very specialized flora and fauna which are able to cope with these extreme environmental challenges.

Flora

Acanthaceae

Individuals grow as shrubs or herbs with opposite, decussate leaves without stipules. Most of them are adapted to tropical conditions.

Blepharis edulis: This plant is a thistle-like spiny herb, characterized by blue flowers, which form a dense terminal spike.

Amaranthaceae

Aerva javanica: is a perennial herb with flat, elliptic, lanceolate leaves, densely covered with short, branched hairs, giving the plant a greyish appearance. The flowers are placed in dense woolly spikes, forming a terminal naked panicle.

Areaceae

Many species of this family originated in Africa but are now widely distributed due to their economic importance, for example *Cocos* (coconuts), *Calamus*, known as the Rattan palm for furniture. The distribution of palm plants mostly corresponds to tropical and subtropical climates.

Phoenix dactylifera: The date palm has a simple stem and pinnate leaves with leaflets which are folded upwards. The fruit is fleshy, containing a solitary hard seed with a deeply furrowed ventral side. The trees are dioecious with small white flowers on a richly branched spadix, surrounded by a solitary, large spathe. The calyx is cup-shaped and three-toothed. In the female flowers, the three petals are twice as long as the calyx. The male plant is characterized by six stamens.

Phoenix dactylifera grows naturally on rocky ground but is mostly known as a typical plant in all types of oases (for example marine oases, river oases, desert oases, etc.). This species needs a dry climate but also access to water (“The head in the fire, the foot in the water”). It can cope with a high salinity in the groundwater. It belongs to the monocotyledon plants, meaning the plant simply consists of vascular bundles; it is hardly ever afflicted by parasites.

This plant is known due to the long history of cultivation for over 10,000 years. It is assumed that its origin lies within the Mesopotamian region. Nearly everything of the plant is used

economically, for example the leaves for making ropes and furniture, the fruits as food for both animals and humans, and the wood for piles or posts. After seven to eight years the plant can be harvested for the first time. It takes up to 100 years before the product begins to decrease. At this point the palm tree is cut and for another two years the sap is collected. This sap is further processed into palm wine.

Asclepiadaceae

Most of the genera in this family are characterized by a poisonous milky sap, opposite leaves without stipules, corolla double with a small “corona” inside of various shape, and seed dispersal by air.

Calotropis: This genus appears as a shrub or small tree with broad, ovate, fleshy leaves. The flowers are green outside and pink inside and arranged in terminal and axillary clusters.

Calotropis produces smooth, apple-like, spongy fruits.

Calotropis procera: is a shrub or small tree up to 5 m high with a spongy bark. The long and broad leaves can grow to a length of 20 cm and the fruits can reach up to 15 cm in width. The sap of *Calotropis* is extremely poisonous and can cause death or lengthy injuries.

Solenostemma: The individuals of this genus are characterized by an erect, perennial habit with sweet-smelling white flowers in axillary umbels. The fruits are ovate, smooth, very hard and dark purple in colour.

Solenostemma arghel: This species is a blue-green, velvety-pubescent plant with numerous erect stems. The leaves are elliptical, lanceolate and acute. Other characteristic features are short-peduncled umbels and erect corolla-lobes. The flowers were visited by many insects, especially bees (*Xylocopa* sp.)

Asteraceae

Iphonia: These shrubs have pungent, needle-like leaves. The flowers are yellow, discoid and in rather narrow, few-flowered heads.

Iphonia scabra: The plants are 50 to 70 cm high scabrous, glandular, densely leafy shrubs. Another characteristic feature is the two to four short spines at the base of the needlelike leaves. The short peduncles hardly exceed the length of the leaves.

Brassicaceae

Zilla: This spiny desert shrub characteristically has pink to purple flowers and an indehiscent, globose or square pod with a long subulate, spinescent beak.

Zilla spinosa: This plant is typically 50 to 60 cm high, blue-green and has dichotomously branching and deciduous fleshy leaves.

Capparaceae

Capparis sinaica: This is a clambering shrub, always green with succulent leaves and edible, globose or pear-shaped, fleshy fruits on a long gynophore. The genus is characterized by spectacular white flowers with four sepals and petals and numerous, free stamens.

Fabaceae

Acacia raddiana: These tall, slow-growing trees with round irregular crown and reddish bark are typical of wadis with sufficient groundwater. They produce a rubber-like, milky liquid. Characteristically, there are symbiotic nitrobacter-species of bacteria at the root branches. The legumes are spirally twisted.

Rhamnaceae

Ziziphus: These genera are tree- or shrub-like plants with ovate, three-nerved leaves, bisexual flowers and yellow to brown-red drupes.

Ziziphus spina-christi: Characteristic features of this species are white branches and slightly pubescent leaves. The stipules are transformed into spines in wild forms and unarmed in cultivated forms. Bedouins cultivate it as an important fruit tree, predominantly as a vitamin C source.

Solanaceae

Hyoscyamus: The flowers are funnel-shaped, oblique. The fruits have an unarmed capsule opening by a lid, included in a persistent calyx.

Hyoscyamus boveanus: The flowers are white with purple blotches and stripes, the filaments and anthers are cream-coloured. All parts of the plant are poisonous.

Zygophyllaceae

Fagonia: This genus consists of perennial or annual, pubescent to glabrous shrubs and herbs. The leaves are compound tri- or unifoliolate and the stipules are conspicuous, frequently transformed into spines. The flowers are pink to white and there are 10 stamens without appendages. The fruits are pyramid shaped, 5-carpelled capsules. The seeds are flat, oblong with foveolate-punctate testa.

Fauna

Reptiles

Agamida: This taxon is characterized by a short head with a short snout and nostrils near the tip of the snout. The tongue is broad and not deeply forked.

Pseudotrapelus sinaitus (HEYDEN, 1827) = Sinai-Agame

Their ear openings are large and fully exposed; the third toe is longer than the fourth. Their body is moderately depressed, the limbs are very long and slender; the tibia is longer than the distance between the occiput and the snout. A sexual dichromatism is well-known: dominant males during mating period are bluish, their tail coloration varies from bluish to reddish. General distribution: In southeast Libya, Sudan, Egypt, Sinai, Israel, Jordan, Syria, Saudi Arabia, Yemen, Oman, United Arab Emirates

Uromastyx aegyptia (FORSKAL, 1775) = Ägyptische Dornschwanagame

This huge, robust terrestrial lizard has a thick spiny tail and remarkably strong extremities. The body is robust and dorso-ventrally flattened. The transverse scale rows on the ventral side of the tail are more numerous than those on the dorsal side.

General distribution: Continental Egypt, Sinai, Israel, Jordan, Syria, Iraq, Iran, Saudi Arabia, Oman, and the United Arab Emirates.

Uromastyx ornata (HEYDEN, 1827) = Geschmückte Dornschwanzagame

A robust lizard with a thick and spiny tail, superficially similar to *Uromastyx aegyptia*. The body is robust, dorso-ventrally flattened and with homogeneous scalation. There is one transversal scale row on the ventral side of the tail which corresponds with each row on the dorsal side.

Distribution: Sinai, Israel and Saudi Arabia.

Gekkonidae: The top of the head is covered by small granular or tubercular scales

Ptyodactylus hasselquistii (DONNDORFF, 1798) = Ägyptischer Fächerfingergecko

This is a large and slender gecko with big eyes. The tail is significantly longer than the snout-vent-length (SVL). General distribution: Distributed in North Africa, Egypt and Sudan, Sinai Israel, Jordan, Arabian Peninsula, Iraq and Iran.

Insects

Tenebrionidae: Four-fifths of all tenebrionid species inhabit deserts. Many morphotypes exist, for example globose (surface area minimized in relation to volume), discoidal (“sandswimmers”) or long-legged beetles (“fast runners”).

Adesmia cancellata laetereilei: Arabian Peninsula, Palestine

Adesmia cothurnata cothurnata: long-legged beetle with a pear-shaped body, lives on bedrocks, Arabian Peninsula, Palestine

Trachyderma hispida: Throughout the Sahara desert and east to India, with bristly surface, nocturnal

Trachyderma philistina: Saudi Arabian Peninsula, nocturnal

Mantidae

Sphodromantis viridis: Morphotype similar to *Mantis religiosa*, distribution from the Levante area to North Africa

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Appendix I: photos – Fauna



Xylocopa sp. (photo: R. Gith)



Adesmia cothurnata (photo: S. Kompatscher)



Sympetrum sp. (photo: S. Kompatscher)



Pseudodrapelus sinaita (photo: M.C. Loretto)



Ptyodactylus hasselquisti (photo: W. Waitzbauer)



Uromastyx ornata (photo: W. Waitzbauer)

Appendix II: Photos – Flora



Acacia raddiana (photo: S. Kompatscher)



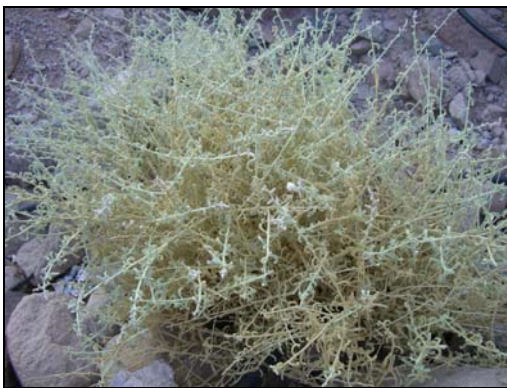
Blepharis edulis (photo: S. Kompatscher)



Solenostemma argel (photo: V. Wiesbauer)



Capparis sinaica (photo: S. Kompatscher)



Aerva javanica (photo: S. Kompatscher)



Hyoscyamus boveanus (photo: V. Wiesbauer)