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Quantitative analysis of five symbiotic relationships of fishes from Dahab (Egypt, Red Sea)

Quantitative Analyse von fünf symbiontischen Beziehungen bei Fischen von Dahab (Ägypten, Rotes Meer)

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Summary: Five symbiotic relationships between fish and between fish and invertebrates were quantitatively investigated off Dahab (Egypt, Sinai). The symbioses comprised *Diadema* urchins and their hosts, *Actiniaria* spp. and their hosts, contacts of cleaner fish (*Labroides dimidiatus* and *Larabicus quadrilineatus*) with their clients, goatfish (*Parupeneus* spp.) and their fish follower, and goldspotted goatfish (*Parupeneus cyclostoma*) and bird wrasse (*Gomphosus caeruleus*) as alternate followers. With means of SCUBA 32 dives of about 60 minutes in reef habitats and 12 in eelgrass/pebble environments were performed in 2012 and 2014. The numbers of symbioses and the number of the participating partners were counted. The observations were quantitatively analyzed with the aim to elaborate differences between the results from the reefs from different depth and between reefs and the eelgrass environment. Anemones and *Diadema* were more abundant in the eelgrass habitat whereas cleanerfish and their clients were abundant in the reefs. Bird wrasses were absent in eelgrass habitats whereas burrowing goatfish were equally abundant in reefs as well as in eelgrass habitats. Comparing the values from the reefs of different depths 70 % of the results were identical but in the case of reefs against eelgrass only 28 % were identical. Species richness and stability of the investigated habitats are especially influenced by the cleaner fish/client and the anemone/host partnership because these reveal the narrowest contacts.

Key words: Red Sea, coral reefs, eelgrass meadows, symbioses, species richness

Zusammenfassung: Im Roten Meer wurden bei Dahab (Ägypten, Sinai) einige Symbiosen zwischen Fischen sowie zwischen Fischen und Wirbellosen quantitativ untersucht. Diese Symbiosen umfassten *Diadema*-Seeigel und ihre Bewohner, Actinaria spp. und ihre Bewohner sowie die Kontakte von Putzerlippfischen (*Labroides dimidiatus* und *Larabicus quadrilineatus*) und ihren Kunden, Meerbarben (*Parupeneus* spp.) und ihren Folgerfischen, sowie Zitronenbarben (*Parupeneus cyclostoma*) und Vogellippfischen (*Gomphosus caeruleus*) als gegenseitige Verfolger. In den Jahren 2012 und 2014 wurden insgesamt 32 Tauchgänge von ca. 60 min in Riffbiotopen und zwölf Tauchgänge in Seegras-/Geröllbiotopen durchgeführt, dabei wurde die Zahl der Symbiosen gezählt, ebenso wie die Anzahl der beteiligten Partner bzw. Kontakte. Diese Beobachtungen wurden quantitativ mit dem Ziel ausgewertet, Unterschiede von Riffhabitaten in verschiedenen Tiefen sowie Riff- und Seegrashabitaten zu ermitteln. Aktinien und *Diadema* waren im Seegras häufiger als am Riff, während Putzer und ihre Kunden im Riff häufiger waren. Kontakte von Vogellippfischen waren im Seegrasbiotop sehr selten. Im Sand wühlende Meerbarben sind etwa gleich häufig in den beiden Biotopen. In den Riffen erwiesen sich 7 von 10 (= 70 %) Daten in den Jahren 2012 und 2014 als identisch. Dagegen waren nur 5 von 18 (= 28 %) Vergleiche von Riff und Seegras/Geröll identisch. Artenreichtum und Stabilität der untersuchten Habitate werden besonders durch die Putzer-Kunden- und die Anemonen-Bewohner-Symbiosen beeinflusst, weil diese besonders enge Verknüpfungen aufweisen.

Schlüsselworte: Rotes Meer, Korallenriff, Seegraswiese, Symbiosen, Artenreichtum

1. Introduction

The numbers and closeness of symbioses can mark the maturation of ecosystems and are, therefore, an important factor in biocenoses. Symbioses comprise advantageous mutualism with positive effects for both partners as well as parasitism with clear negative consequences. A critical discussion revealed that several partnerships between fishes and invertebrates or between fish the partnership can be disadvantageous if additionally the energy balance is regarded (Zander 2013): this means a kind of cryptic parasitism, which is characterized by greater energy demand when living together with a partner than living without one.

Therefore, the question arises for the abundance of symbioses in an ecosystem. Tropical reefs offer the most species rich communities in the marine environment (Hiatt & Strasburg 1960; Roberts & Ormond 1987). They present, therefore, the most numbers of partnership combinations even if fish are considered (Fricke 1975).

The answer may be given by a set of investigation in the Red Sea which is focused on five symbioses in which fish were involved (fig. 1a-b). The importance of such symbioses can be related to their abundance in the respective habitat. Considered were protection partnerships like those of anemones with the Red Sea anemonefish *Amphiprion bicinctus* (fig. 1c-d). The anemone is protected by the very aggressive *A. bicinctus* which dispels potential predators whereas the fish is protected by the nematocysts of its host to which they are able to acclimatize (Chatwick & Arvedlund 2005). This symbiosis is a partnership of mutual advantage. Several fish species hide between the spines of sea urchins where these are protected. Here *Diadema* urchins with its inhabitants (mostly cardinal fish, Apogonidae) were observed. This symbiosis seems to be only of advantage for the fish, it is not clear whether sea urchins can have disadvantage, e.g., that the fish may prey on their tube feet (de Loach 1999) (fig. 1e-f).

The symbiosis of cleaner wrasses *Labroides dimidiatus* and *Larabicus quadrilineatus* (fig. 2a-c) and their clients are advantageous for both partners: the cleaner fish search and preys on copepod and isopod parasites which live on skin and between gills of the client fish. But eventually the cleaner preys also on the mucus and scales of the client and is sometimes a parasite (Grutter & Bschary 2003). This symbiosis is, therefore, characterized by body contacts with other fish which is also valid for the partnership of the labrid *Gomphosus caeruleus* and the mullid *Parupeneus cyclostoma* (fig. 2d-e). Until now this symbiosis was only mentioned by a short notice of *G. caeruleus* following *P. forsskali* (Fricke 1970). The goatfish seems to follow mostly the labrid but the former tries also to contact the mullid. It still cannot be judged about advantage or disadvantage of the partners. This behavior appears as especially strange if the acquisition of prey by *P. cyclostoma* is regarded which search for small fish on the substrate. Finally, a competition partnership is presented by fish species which profit by the sand burrowing activity of goatfish (*Parupeneus* spp.) (figs 1a, 2f). The most goatfish (family Mullidae) are sand bottom dwellers which get their invertebrate prey by burrowing in the sediment. This behavior attracts other fish to follow and to participate on the freed invertebrates (Moosleitner 2008).

Four of the mentioned symbioses are known since longer times (Davenport & Norris 1958; Eibl-Eibesfeldt 1955, 1961; Fricke 1970, 1975; Grutter & Bschary 2003) whereas the *Gomphosus caeruleus-Parupeneus cyclostoma* partnership needs further observations.

The investigations were performed in reef habitats in different years at different depths and, therefore, are able to compare. Additionally, these are compared with an eelgrass habitat with some pebbles and small boulders. The aim of the projected investigations was to analyze

selben Art und jungen *Dascyllus trimaculatus* an der Anemone *Heteractis* sp. **e** *Diadema*-Seeigelgruppe mit Schutz suchenden Kardinalbarschen der Art *Cheilodipterus quinquelineatus*. **f** Einzelner *Diadema*-Seeigel mit den Kardinalbarschen *C. novemstriatus* und *Apogon cyanea*.

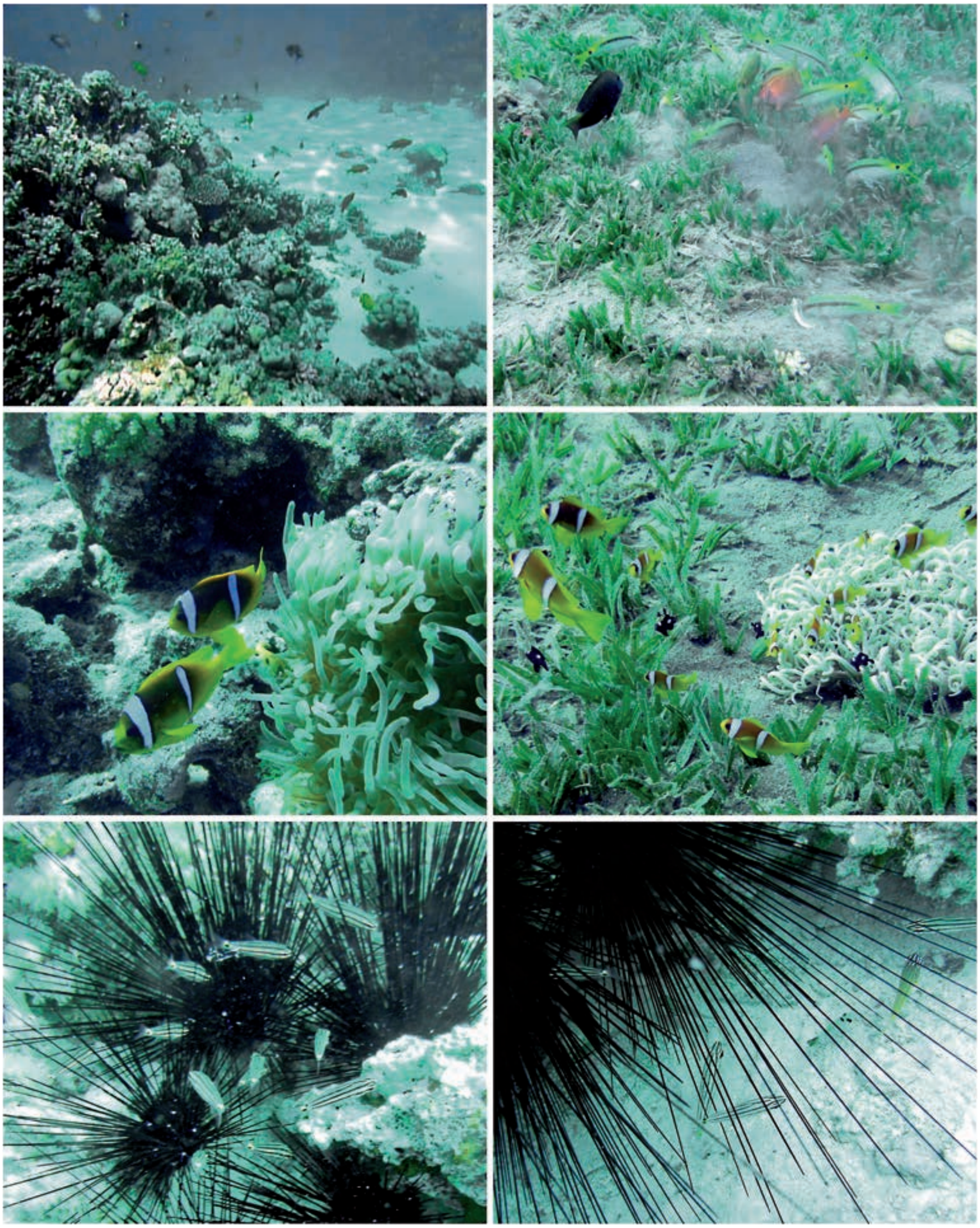

Fig. 1: **a** A characteristic reef habitat in a depth of about 15 m off Dahab (Egypt). **b** A characteristic eelgrass habitat in a depth of 7-8 m off Dahab (Egypt). Several goatfish species (*Parupeneus forsskali*, *P. macronema, P. rubescens*) are burrowing in the substrate, followed by a surgeonfish. **c** A pair of Red Sea anemone fish, *Amphiprion bicinctus*, at their host, the anemone *Entacmaea* sp. **d** A pair of *A. bicinctus*, several young of them and of *Dascyllus trimaculatus* at their anemone, *Heteractis* sp. **e** Group of *Diadema* urchins protect the cardinalfish *Cheilodipterus quinquelineatus*. **f** A single *Diadema* sp. with *C. novemstriatus* and *Apogon cyanea*.

Abb. 1: **a** Ein typisches Riffhabitat in ca. 15 m Tiefe bei Dahab (Ägypten). **b** Ein typisches Seegrashabitat in 7-8 m Tiefe bei Dahab (Ägypten). Mehrere Meerbarbenarten (*Parupeneus forsskali*, *P. macronema, P. rubescens*) wühlen im Substrat, gefolgt von einem Doktorfisch. **c** Ein Paar des Rotmeer-Anemonenfischs (*Amphiprion bicinctus*) vor seinem Wirt, einer *Entacmaea*-Anemone. **d** Ein Paar *A. bicinctus* mit mehreren Jungtieren der

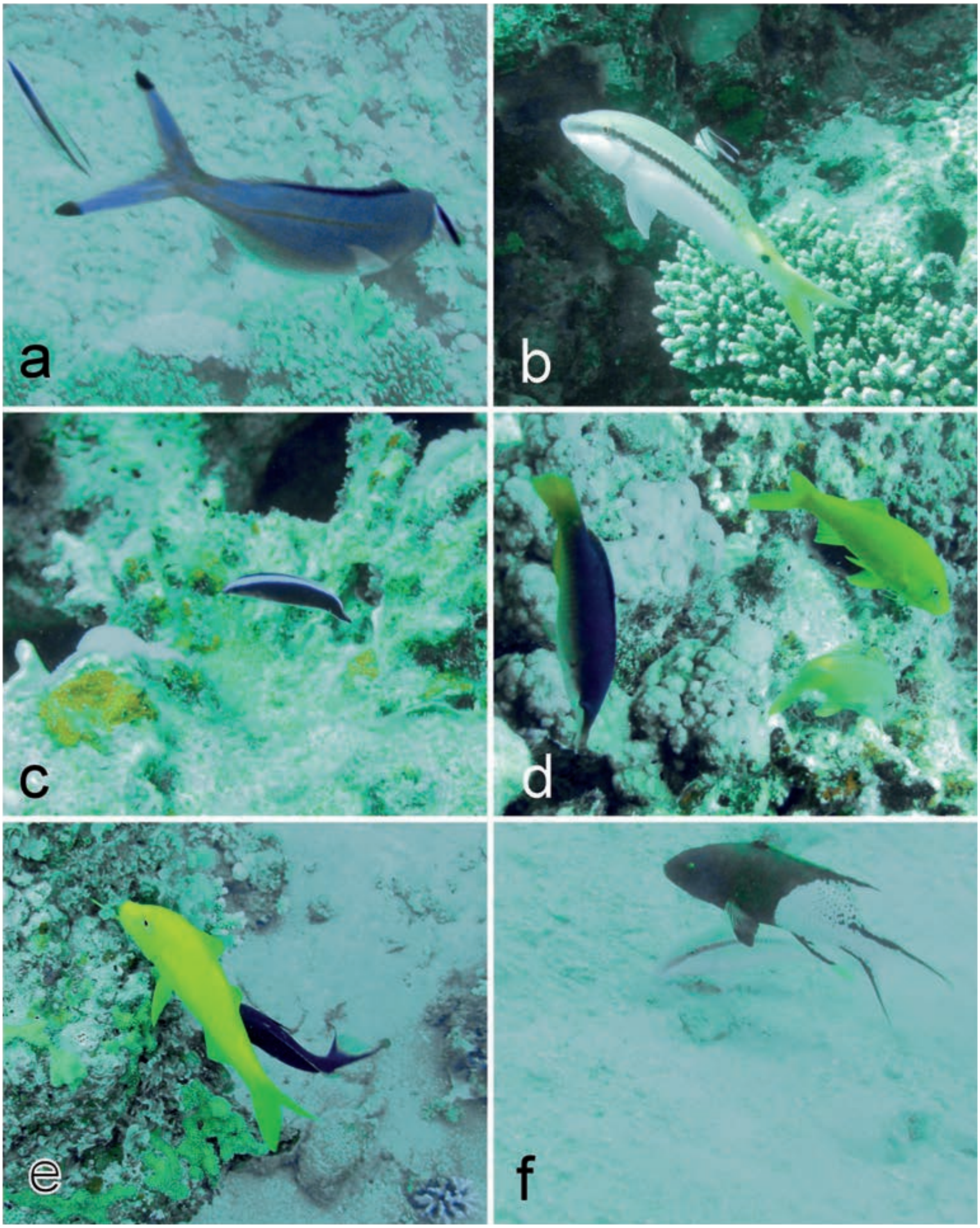

Fig. 2: a Two cleaner wrasses (*Labroides dimidiatus*) swim onto a Suez fusilier (*Caesio suevica*). **b** *L. dimidiatus* cleaning a goatfish (*Parupeneus forsskali*). **c** The cleaner wrasse *Larabicus quadrilineatus* which cleans only as young. **d** A bird wrasse (*Gomphosus caeruleus*) persuades two yellow-spotted goatfish (*Parupeneus cyclostoma*). **e** *G. caeruleus* comes in contact with *P. cyclostoma*. **f** A Red Sea goatfish (*Parupeneus forsskali*) burrows in the sand for prey whereas a lyretail hogfish (*Bodianus anthioides*) waits on freed organisms.

Abb. 2: a Zwei Putzerlippfische (*Labroides dimidiatus*) schwimmen auf einen Rotmeer-Füsilier *(Caesio suevica*) zu. **b** *L. dimidiatus* putzt eine Meerbarbe (*Parupeneus forsskalii*). **c** Der Putzerlippfisch *Larabicus quadrilineatus* putzt nur als Jungfisch. **d** Ein Vogellippfisch (*Gomphosus caeruleus*) verfolgt zwei Zitronenbarben (*Parupeneus cyclostoma*). **e** *G. caeruleus* kommt in Kontakt mit einem *P. cyclostoma*. **f** Eine Rote-Meer-Barbe (*Parupeneus forsskali*) wühlt im Sand, während ein Herzog-Schweinslippfisch (*Bodianus anthioides*) auf freigelegte Organismen wartet.

different conditions for the existence of symbioses which may be a contribution to a better understanding of the ecosystems in tropical marine environments.

2. Methods

The respective observations were performed in Dahab at the Gulf of Aqaba (Sinai, Egypt, Red Sea) in October 2012 and in October 2014. With means of SCUBA 17 reef and six eelgrass habitats were repeatedly investigated in 2012, and 15 reef and six eelgrass habitats in 2014 by the way of quantitative counting under water. The reefs were presented by steep walls or single blocks covered with corals and other aufwuchs (fig. 1a), the eelgrass habitats consisted of sand bottoms sloping weekly down which are covered mostly with *Cymodocea* sp. but also some pebbles or small boulders with mini-reefs were present (fig. 1b). The reef investigations differed in the depths of observation: it was 15-20 m in 2012 and 6-10 m depth in 2014. Therefore, the nomenclature which is used in the following is "Reef20" or "Reef10", respectively. The observation depth in the eelgrass habitat (named "Eelgrass") was in both years not below 10 m. Generally, the sites and times of dives varied.

During an "observation unit" which lasted about one hour and comprised a distance of about 200 m a calculation was possible in order to relate the abundance of the objects to almost quantitative values. The performed investigations were focused on the above mentioned symbioses: anemone spp. – anemonefish (*Amphiprion bicinctus*), *Diadema* urchins – inhabitants, cleaner wrasses (*Labroides dimidiatus* and *Larabicus quadrilineatus*) – clients, bird wrasse (*Gomphosus caeruleus*) – gold spotted goatfish (*Parupeneus cyclostoma*), and goatfish (*Parupeneus* spp.) – followers. The numbers of all symbiont partners were counted and noticed under water on a writing table. All values were related to the above defined observation units, that is the sum of all observed numbers divided by the number of dives, respectively. In order to emphasize differences between results from Reef 20 and 10 and of reefs and Eelgrass these were compared, the relevance is confirmed by the calculation of the mean and the mean error, expressed by their significance p.

3. Results

The above mentioned symbioses can be characterized by functional patterns: 1. Protection partnership, 2. Contact partnerships, and 3. Competition partnerships.

3.1. Protection symbiosis

Anemones were inhabited not only by *Amphiprion bicinctus* but also by four other fish species (figs 3-4). Every anemone proved to be colonized, in the reefs *Stichodactyla* sp. dominated in Reef20, but in Reef10 also *Entacmaea* sp. was abundant. There was a slight dominance of *Cheilodipterus* spp. (*C. quinquelineatus* and *C. novemstriatus*) over *A. bicinctus*. Only four fish species were present in the anemones of the eelgrass habitat where juveniles of *Dascyllus trimaculatus* dominate (fig. 3). The group size of *A. bicinctus* in an anemone was in both habitats mostly a pair, but also single or three, four or five individuals were found (figs 3-4). In Reef10 and in Eelgrass even 12 *A. bicinctus* were present; that means that juveniles, at most ten, lived together with a pair of adult anemone fish. If only a single *A. bicinctus* was found the fish must have lost its partner. The 2-individual-category is in the reefs more abundant than in eelgrass habitats in which the higher categories slightly dominate (figs 3-4).

If the abundance of anemones in the reefs and eelgrass are compared the values proved to be identical (tab. 1). The abundance of anemone inhabitants was higher in Reefs20 than in Reefs10 and consequently not identical (tab. 1). Regarding the abundance of the client *Amphiprion bicinctus* this value was in Reef10 higher than in Reef20 and were, therefore, not identical. The highest value was found in Eelgrass and was, therefore, not identical in comparison with the reefs (tab. 1).

Diadema urchins appeared in groups of one to five in reefs (fig. 5) and of one to 22 in Eelgrass (fig. 6). The most clients were found in single sea-urchins where *Cheilodipterus* spp.

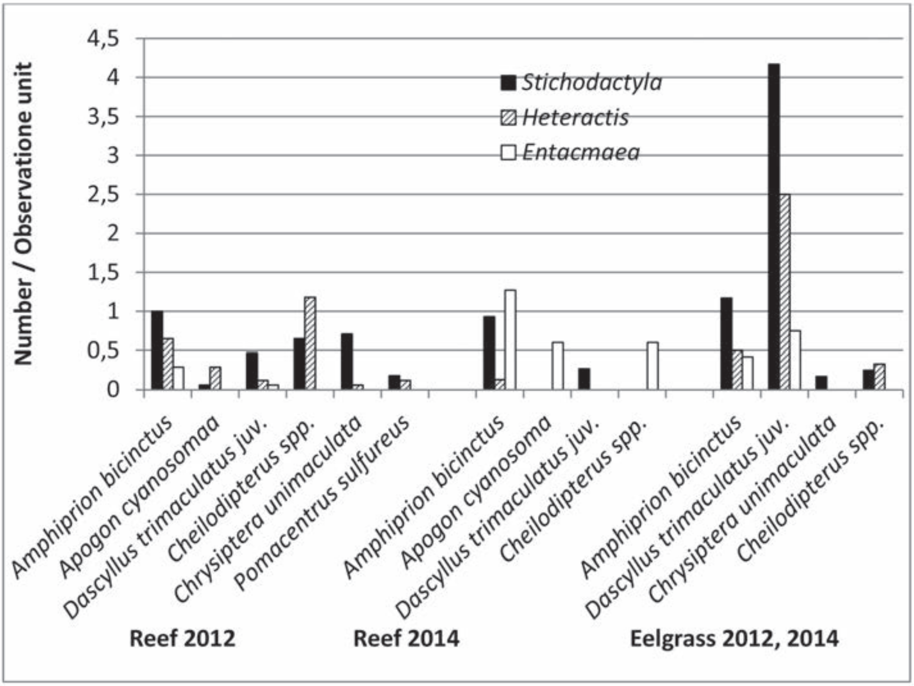

Fig. 3: Species spectrum of symbionts of three anemone genera from three habitats off Dahab, Red Sea. Watch the high abundance of young *Dascyllus trimaculatus* in Eelgrass. *Cheilodipterus* spp. comprise *C. quinquelineatus* and *C. novemstriatus*.

Abb. 3: Artenspektrum der Symbionten dreier Anemonengattungen in drei Habitaten bei Dahab, Rotes Meer. Zu beachten ist die hohe Abundanz von jungen *Dascyllus trimaculatus* im Seegrashabitat. *Cheilodipterus* spp. umfassen *C. quinquelineatus* and *C. novemstriatus*.

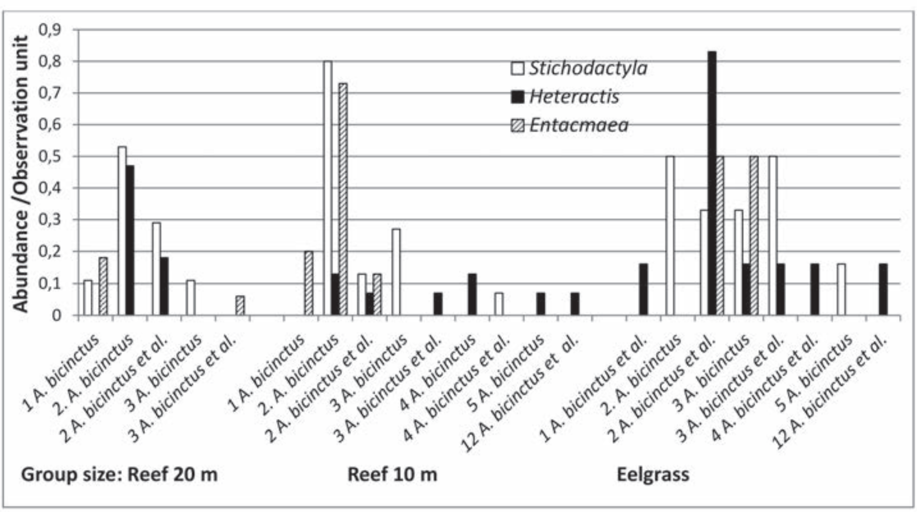

Fig. 4: Abundance of *Amphiprion bicinctus* and other species inhabiting three anemone genera in three habitats. "et al." = other species than *A. bicinctus*.

Abb. 4: Abundanz von *Amphiprion bicinctus* und anderer Bewohner von drei Anemonengattungen in drei Habitaten. "et al." = other species than *A. bicinctus*.

Tab. 1: Comparison of quantitative data of five symbiosis in three different habitats off Dahab (Egypt): reef 20 m, reef 10 m and eelgrass habitat (R20, R10, Eelgrass).
Tab. 1: Vergleich von quantitativen Daten von fünf Symbiosen in drei verschiedenen Habitaten bei Dahab (Ägypten): Riff 20 m, Riff 10 m und Seegras-Habitat (R20, R10, Eelgrass).

Anemone/*Amphiprion*	**Number of dives**	**Frequency**		**Abundance**			**Abundance**		**Symbiont/Host**	**p (significance host)**	**p (significance symbiont)**
		Dives with hosts	%	Host	per dive	Symbiont	per dive	Species numbers		R20/ R10/Eelgrass	R20/ R10/Eelgrass
Reef20	17	15	82.3 %	40	2.3 + 0.2	154	8.2 + 0.7	6	3.85	0/ > 0.5/ > 0.5	0/ < 0.1/ < 0.1
Reef10	15	14	93.0 %	35	2.3 + 0.01	72	4.8 + 0.1	5	2.06	> 0.5/ 0/ >0.5	< 0.1/ 0/ <0.1
Eelgrass	12	10	83.0 %	33	2.7 + 0.05	132	11.0 + 0.2	4	4.40	> 0.5/ >0.5/ 0	> 0.5/ > 0.5/ 0
***Diadema*/Commensals**	**TG**	**Frequency**		**Abundance**			**Abundance**		**Symbiont/Host**	**p (significance host)**	**p (significance symbiont)**
		Dives with hosts	%	Host	per dive	Symbiont	per dive	Species numbers		R20/ R10/Eelgrass	R20/ R10/Eelgrass
Reef20	17	4	23.5%	23	1.4 + 0.2	11	0.7 + 0.4	4	0.48	0 / > 0.5 / < 0.1	0/ < 0.1 / < 0.1
Reef10	15	11	73.3%	27	1.8 + 0.1	54	3.6 + 0.2	4	2.00	> 0.5 / 0 / < 0.1	< 0.1 / 0 / < 0.1
Eelgrass	12	12	100.0 %	135	11.2 + 0.6	280	23.3 + 1.0	10	2.07	> 0.5/ > 0.5/ 0	> 0.5/ > 0.5/ 0
Cleaner/Hosts	**TG**	**Frequency**		**Abundance**			**Abundance**		**Cleaner/Client**	**p (significance host)**	**p (significance symbiont)**
		Dives with cleaner	%	Cleaner	per dive	Clients	per dive	Species numbers		R20/ R10/Eelgrass	R20/ R10/Eelgrass
Reef20	17	14	82.4%	33	1.9 + 0.4	68	4.0 + 0.4	12	0.48	0 / > 0.5 / > 0.5	0 / > 0.5 / < 0.1
Reef10	15	15	100,0%	50	3.3 + 0.2	54	3.6 + 0.2	17	0.90	> 0.5 / 0 / < 0.1	> 0.5 / 0 / < 0.1
Eelgrass	12	7	8.0 %	17	1.4 + 0.1	11	1.5 + 0.2	7	1.45	> 0.5 /< 0.1 / 0	< 0.1 / < 0.1 / 0
***Gomphosus*/Goatfish**	**TG**	**Frequency**		**Abundance**			**Abundance**		**Goatfish/Wrasse**	**p (significance host)**	**p (significance symbiont)**
		Dives with Gomphosus	%	*Gomphosus*	per dive	*P. cyclostoma*	per dive	Species numbers		R20/ R10/Eelgrass	R20/ R10/Eelgrass
Reef20	17	12	76.5%	27	1.6 + 0.2	28	1.6 + 0.2	3	1.04	0 / > 0.5 / < 0.1	0 / > 0.5 / 0
Reef10	15	3	20,0%	24	0.8 + 0.1	18	1.2 + 0.3	3	0.75	> 0.5 / 0 / < 0.1	0
Eelgrass	12	1	8.0 %	1	0.1 + 0	0	0	0	0	< 0.1 / < 0.1 / 0	0
Goatfish/Followers	**TG**	**Frequency**		**Abundance**			**Abundance**		**Symbiont/Host**	**p (significance host)**	**p (significance symbiont)**
		Dives with hosts	%	Goatfish	per dive	Follower	per dive	Species numbers		R20/ R10/Eelgrass	R20/ R10/Eelgrass
Reef20	17	12	70.6%	89	5.2+0.3	35	2.1+0.4	10	0.39	0 / < 0.1 / < 0.1	0 / > 0.5 / > 0.5
Reef10	15	15	100.0 %	119	8.0+0.1	52	3.5 +0.1	13	0.44	< 0.1 / 0 / < 0.1	> 0.5 / 0 / > 0.5
Eelgrass	12	9	75.0 %	134	15.0+0.2	25	3.5 + 0.1	10	0.19	0 / < 0.1 / < 0.1	> 0.5 / > 0.5 / 0

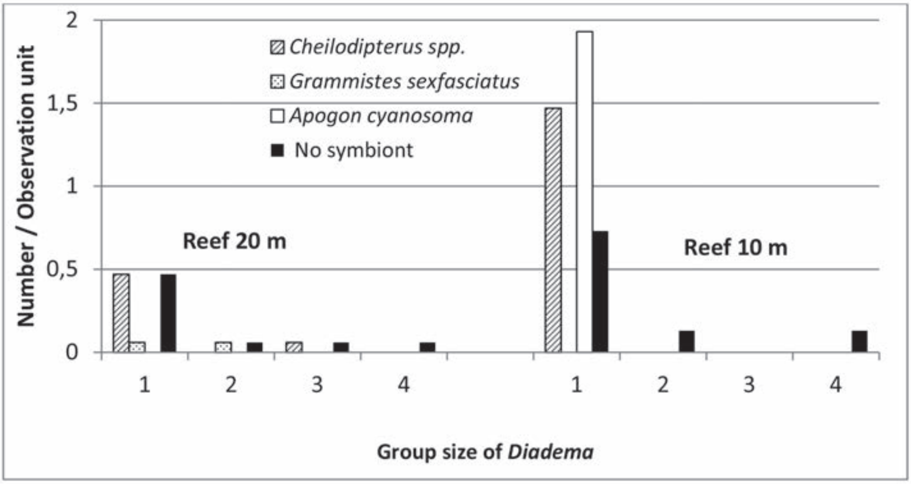

Fig. 5: Group size of *Diadema* sp. assemblages and abundance of symbiotic fish species in two reef habitats. *Cheilodipterus* spp. comprise *C. quinquelineatus* and *C. novemstriatus*.
Abb. 5: Gruppengröße von *Diadema* sp.-Ansammlungen mit den Abundanzen symbiotischer Fischarten in zwei Riffhabitaten. *Cheilodipterus* spp. umfassen *C. quinquelineatus* and *C. novemstriatus*.

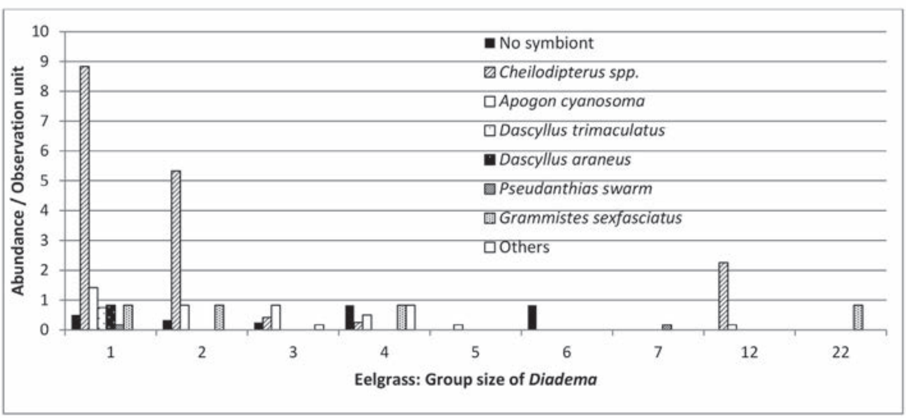

Fig. 6: Group size of *Diadema* sp. assemblages and abundance of symbiotic species in the eelgrass habitat. *Cheilodipterus* spp. comprise *C. quinquelineatus* and *C. novemstriatus*.
Abb. 6: Gruppengröße von *Diadema* sp.-Ansammlungen mit den Abundanzen symbiotischer Fischarten im Seegrashabitat. *Cheilodipterus* spp. umfassen *C. quinquelineatus* and *C. novemstriatus*.

(*C. quinquelineatus and C. novemstriatus*) were the most abundant inhabitants but were surpassed by *Apogon cyanea* in Reef10. In the reefs only five, in Eelgrass at least ten inhabitant species were found. In Eelgrass was the part of urchins without clients relatively low, in the reefs higher, especially in greater groups of the host (figs 5-6).

Abundance of *Diadema* in Reef20 and Reef10 was identical but not in eelgrass where it was clearly higher (tab. 1). Abundance of clients was lowest in Reef20 which value was surpassed by Reef10 and still more by Eelgrass, therefore, the three values are not identical (tab. 1).

3.2. Contact symbioses

Only few cleaner wrasses in the reefs of Dahab had no contact to clients, the most abundant host was

Pseudanthias squamifera. Twelve diverse fish species were observed in Reef20, 17 in Reef10 (figs 7-9). The abundance is higher in reefs than in eelgrass where observations without contact were relatively high and *Parupeneus* spp. dominate as clients (figs 7-9). *Labroides dimidiatus* pairs dominate in reefs where they are more abundant than *Larabicus quadrilineatus*, whereas in eelgrass single *L. dimidiatus* were also conspicuous. *Larabicus quadrilineatus* were in all habitats only as single present.

The statistical analysis can confirm the observations. Reef10 offered indeed higher values than Reef20 but these cannot be confirmed. The values from Eelgrass are, in contrast, still lower than those from Reef10 and significantly different from the reef values (tab. 1).

The abundance of *Gomphosus caeruleus* was remarkably low in the reefs and consequently contacts with *Parupeneus cyclostoma* were very rare (fig. 10). On the other hand, also contacts with *Parupeneus forsskali* could be noticed. Several observations of this partnership revealed that greater part of young *P. cyclostoma* followed the wrasse whereas greater goatfish if yellow colored were pursued by *G. caeruleus*. Apparently, the smaller individual of the respective partner follows the greater one.

The differences of Reef 20 and 10 were not significant (tab. 1). In the eelgrass habitat only one *G. caeruleus* was observed during the whole observation times.

3.3. Competition symbiosis

The abundance of Dahab goatfish (*Parupeneus* spp.) was relatively low in the reefs but slightly higher in the eelgrass habitat (figs 11-12). The number of observations without symbionts was in all habitats high. *P. forsskali* is the most abundant species but three (reef) or five other (eelgrass) species were observed (tab. 1). The group sizes vary between the most abundant groups of one until four or more (figs 11-12). The most goatfish were present in the eelgrass meadows, lower values were found in Reef10 and still lower in Reef20.

The statistical analyses offered significantly different values in regard to goatfish but identical in regard of the follower species (tab. 1).

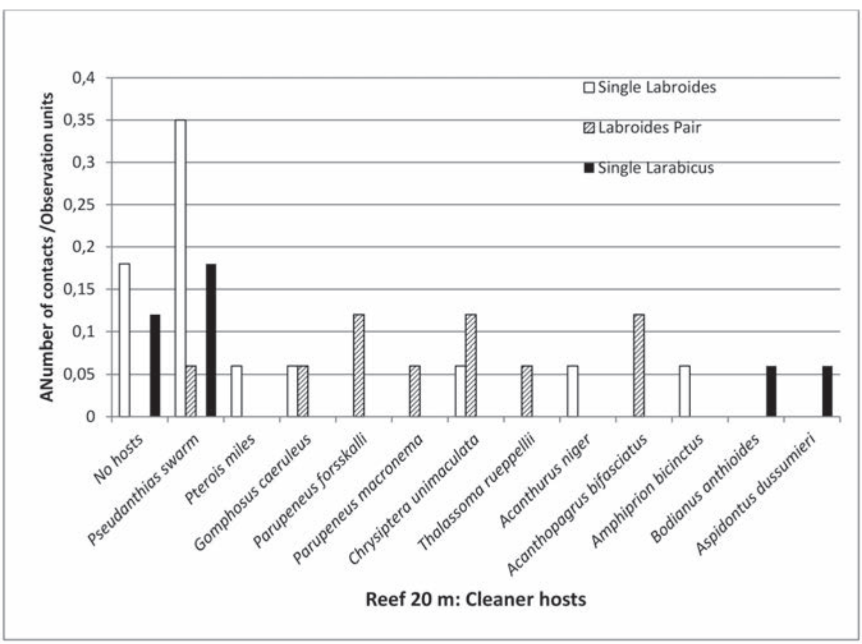

Fig.7: Hosts and abundance of two species of cleaner wrasses in deeper reef habitats off Dahab, Red Sea.
Abb. 7: Wirte und Abundanz von zwei Putzerlippfischarten in tieferen Riffhabitaten .

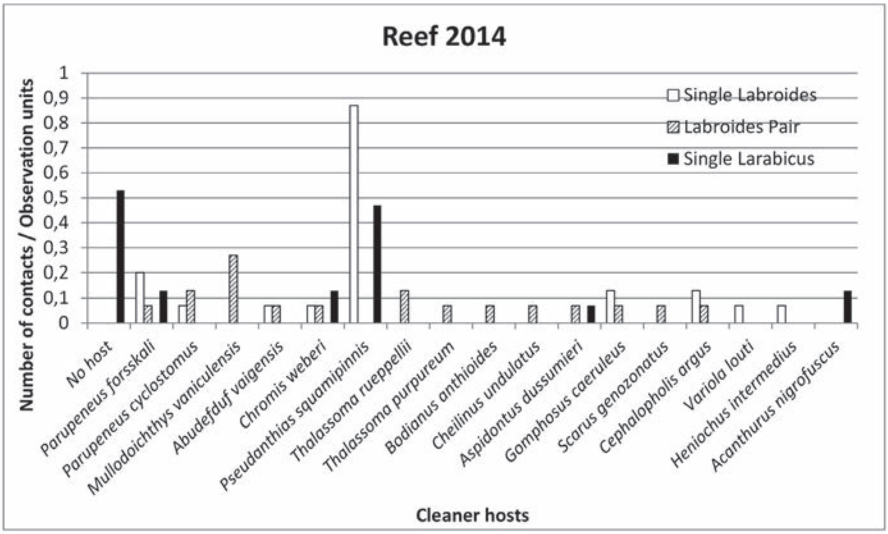

Fig. 8: Hosts and abundance of two species of cleaner wrasses in shallower reef habitats.
Abb. 8: Wirte und Abundanz von zwei Putzerlippfischarten in flacheren Riffhabitaten.

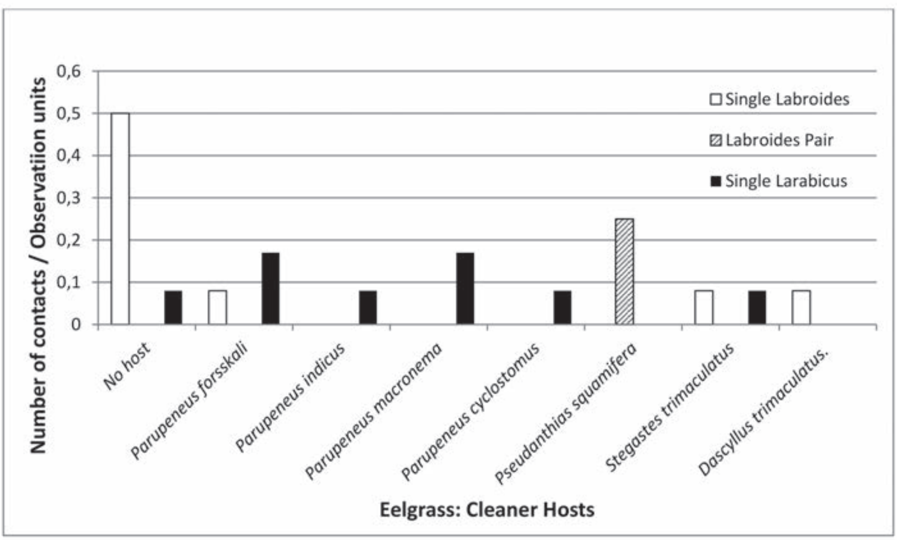

Fig. 9: Hosts and abundance of two species of cleaner wrasses in eelgrass habitats.
Abb. 9: Wirte und Abundanz von zwei Putzerlippfischarten in Seegrashabitaten.

3.4. Analyses of significances

The identity tests revealed that 70 % values from comparisons between the reef habitats were similar whereas in the comparison of both reef habitats with the eelgrass habitat this group attained only 28 % (tab. 1). All other comparisons were significantly not similar. The relation of host and symbionts were only in the case of anemones and *A. bicinctus* generally more than 1, colonists of *Diadema* as well as cleanerfish surpass only in some habitats, especially Eelgrass, this value (tab. 1).

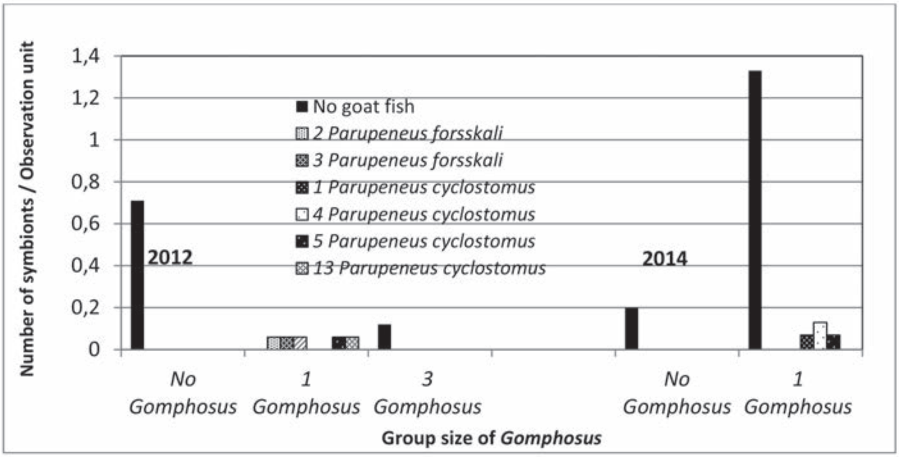

Fig. 10: Abundance of *Parupeneus* spp. and their symbionts *Gomphosus caeruleus* in two reef habitats.
Abb. 10: Abundanzen von *Parupeneus* spp. und ihres Symbionten *Gomphosus caeruleus* in zwei Riffhabitaten.

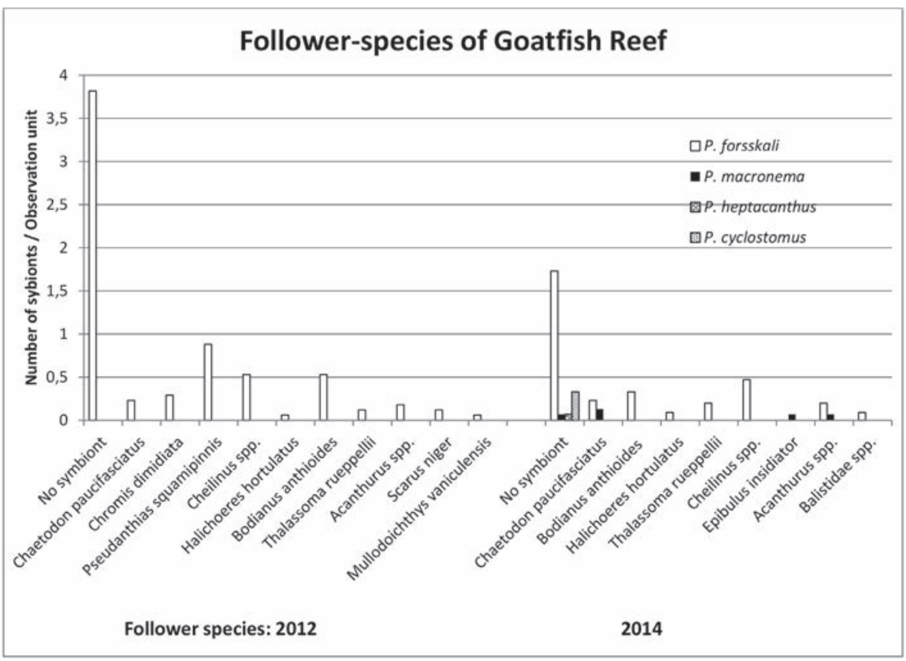

Fig. 11: Follower species of *Parupeneus forsskali* and other *Parupeneus* species in two reef habitats.
Abb.11: Folgerarten von *Parupeneus forsskali* und anderen *Parupeneus*-Arten in zwei Riffhabitaten.

4. Discussion

It was to expect that the abundance of symbioses in Reef20 and Reef10 were very similar. The high rate of not identical comparisons (72 %) between the reefs and eelgrass habitats can stress these findings. The possible reasons for the obtained results are analyzed below. A further point is the question for the role of the investigated partnerships in the reef and eelgrass ecosystems.

Abundance of goatfish in Reef10 is significantly higher than in Reef20. This may

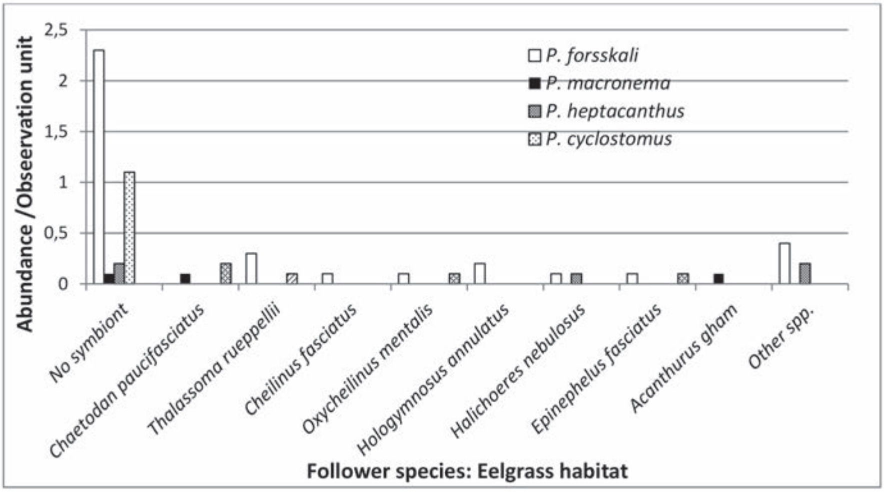

Fig. 12: Follower species of *Parupeneus forsskali* and other *Parupeneus* species in eelgrass habitats off Dahab, Red Sea.
Abb. 12: Folgerarten von *Parupeneus forsskali* und anderen *Parupeneus*-Arten in Seegrashabitaten bei Dahab, Rotes Meer.

indeed depend on the depth of 10 m whereas abundance decreased in 20 m. The existence of *Parupeneus* spp. depend on sandy bottoms which occur only as small islets on coral slopes between the rocky substrate. These are more frequent in the shallower Reef10. In contrast, in eelgrass meadows sand bottoms prevail so that the high abundance of goatfish was to expect whereas the abundance of follower species even coincided in Reef10, Reef20 and Eelgrass. But also Reef20 with lower values differed not significantly.

A quite other situation exists in the anemone- *Amphiprion*-symbiosis. The abundance of hosts was identical in all three habitats whereas the abundance of fish differed clearly of which abundance in Eelgrass presented the highest values. Therefore, the prior condition for colonization was in fact of same kind in all three habitats. The present dispersion of anemone fish may be caused by the colonization of their larvae living as plankton in upper layers of open water. This situation is increased in Eelgrass where a deep zone was absent. A loss of larvae and young by predation is imaginable but not indicated. Additionally, it may been improved by the island effect (MacArthur and Wilson 1967) by which the young *A. bicinctus* and *Dascyllus trimaculatus* were concentrated on the lowered numbers of suited anemone locations which are rarer than in reefs. The results seem to be in contrast to investigations in Eilat (Israel) where in the lagoon clearly lesser anemones occur than in reefs (Fricke 1975).

The abundance of the host *Diadema* was similar in the reefs but differ clearly from Eelgrass. Inhabitants of *Diadema* were more abundant in the shallower Reef10 than in the deeper zone of Reef20. But these values were by far surpassed by colonists of Eelgrass. This can be explained again by the island effect (MacArthur & Wilson 1967) because sea urchins need hiding places and, therefore, aggregate on the rare hard substrates as do also the inhabitants which profit from safe protection between the spines of urchins.

Abundance of cleaner fish in Reef10 was clearly higher than in Reef20 but these difference was not significant whereas abundance of clients differ only slightly. That means that the relation of cleaner to clients was two times greater in Reef10 than in Reef20. Still higher was this relation in Eelgrass (tab. 1). The abundance values of cleaners from Eelgrass did not differ from Reef20 but from Reef10 which may be due to the slight slope in this habitat whereas the reef presents a steep slope with more advantageous possibilities for dispersion between 10 and 20 m. In Eelgrass was the abundance of cleaner and clients clearly lower than in reefs because hard substrates are rare in this environment where sandy bottoms prevail.

Because *Gomphosus caeruleus* are specialized feeders of organisms which hide between coral branches they cannot exist in greater abundance in the eelgrass meadows. The contact symbiosis with *Parupeneus* spp., especially *P. cyclostoma* which seek on sand bottoms for fish and invertebrates, revealed no difference between the two reef habitats but in Eelgrass *G. caeruleus* was seen only once, but contact to goatfish was not observed.

The importance of symbioses within a community can be judged by the model of May (1972) in which the number of species (S) is proportional but the number of connectance (C) and strength of connectance (i) is reversely proportional to community stability. This means that the more partnerships exist and the narrower these are the more instable is the community against extern disturbances or stress. Numbers of species decrease along the latitudinal gradients, i.e. greatest species richness is found in tropic communities (Fischer 1960; Schall & Pianka 1978), this is also documented by fish faunas (Angel 1993). According to Briand (1983) the number of connectance in marine food webs decreased with increasing species numbers but in other food webs it can increase. Mostly the product of S and C is constant (Yodzis 1980). Also the product of C and i should be constant otherwise it would mean instability (McNaughton 1978). In tropical reefs connectances in the food web prevail before symbioses but are mostly weak with exception in special communities (Paine 1980).

The situation in communities of Reefs and Eelgrass of the present investigations is marked by two partnerships of large strength (*Amphiprion* and anemone, cleaner wrasse and clients), two of low strength (goatfish and followers, *Diadema* and clients) and one (*Gomphosus caeruleus* and *P. cyclostoma*) of unknown meaning. If the partnerships are arranged on a connective scale from 0 (no connectance) to 1 (very strong connectance) an estimation about both partners of the cleaner and of the anemone symbiosis may attain values of 0.8-1.0. The cleaner fish are of great importance for reef communities because the clients are dependant to be freed off parasites: values 0.8-1.0; in absence of cleaners they can change their habitat (Limbaugh 1961). Such an absence of *Labroides dimidiatus* can, therefore, affect the diversity of moving reef fish species whereas the resident species would remain (Grutter et al. 2003).

Anemones can settle on very small hard bottoms which make colonization also on several locations of the eelgrass meadows possible. Because of the rareness of coral blocks in this habitat they can also attract young *Dascyllus trimaculatus* which live in the reef mainly between coral branches. *Diadema* urchins profit only weakly by their clients, but fish which are protected by *Diadema* spines may range between 0.4-0.6 on the connective scale. Cardinalfish species search actively after sea urchins (Fricke 1975) and therefore accumulate in eelgrass habitats where small caves to hide, differently to reefs, are rare. Partially, they seek for anemones where they find also protection. Followers of *Parupeneus* spp. may profit only in low dependence, e.g. by 0.2-0.3, whereas the goatfish undergo rather disadvantage because the follower compete for free burrowed prey. This situation can be characterized as a special kind of parasitism (Zander 2013).

The partnership of *Gomphosus caeruleus* and *Parupeneus cyclostoma* is rather a casual one though the partners remain after meetings also for a longer duration of several minutes. Fricke (1970) reported a close contact of young *P. barberinus* (= *P. forsskali*) with larger conspecifics as well as *G. varius* (= *G. caeruleus*) which Fricke interpreted as protection demand of the goatfish. Another theory explained this behavior as mean for single goatfish to attain swarms of conspecifics which were found mainly at reefs. But, what is the advantage for bird wrasses and if, what advantage? In conclusion, the fish diversity in coral reefs and also eelgrass bottoms will be influenced especially by such partnerships based on cleanerfish and on anemones. In contrast, cardinalfish can also change into small caves or in the near of anemones in order to find protection, followers of *Parupeneus* spp. find prey elsewhere, but it is easier for them to follow goatfish which have the disadvantage that the foraging activity must be increased. In reefs the cleaner fish *Larabicus quadrilineatus* and *Labroides dimidiatus* play the main role for the maintenance of species diversity, in eelgrass habitats with its sand bottoms this role is done by *Parupeneus* spp., only with the difference that the goatfish-follower partnership is not as narrow as the cleaner fish-client partnership is.

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