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On the fish fauna of Red Sea sand bottoms

Zur Sandfischfauna des Roten Meeres

C. Dieter Zander

Institut für Zoologie der Universität Hamburg, D-20146 Hamburg-Rotherbaum, Germany,
cedezet@uni-hamburg.de

Summary: The fish faunas of sand bottoms from two regions of the Red Sea were investigated in the years 2017-2019. The studied habitats presented high species richness, which was combined with high diversity and homogeneity values. With regard to the kind of prey and kind of foraging the dominance of benthos feeders and, within this category, the group of collectors became apparent. Therefore, secondary consumers prevail in food chains. No differences were found in all prey categories between sand bottoms with few reefs and such with frequent reefs. Genuine sand bottom fishes were present in low numbers, therefore, the most sand bottom fish species colonize these habitats from the nearby reefs. The fish assemblages vary in different geographical regions of the Red Sea. Finally, the question arose, whether the sand bottoms in tropic areas are more productive than in temperate climates, where the values are low. The presented results may confirm this assumption and, therefore, contradict the current dogmas.

Key words: Red Sea, sand bottoms, fish assemblage, food chain, kind of foraging.

Zusammenfassung: In den Jahren 2017-2019 wurde die Fisch-Fauna der Sandböden aus zwei Regionen des Roten Meeres untersucht. An allen Untersuchungsstellen wurde ein großer Artenreichtum bei gleichzeitig hoher Abundanz und Homogenität festgestellt. Die Zusammensetzung der Fischgemeinschaft in Hinsicht auf Ernährung und Nahrungserwerb ergab eine Dominanz der Benthos-Fresser unter denen die Sammler am häufigsten auftraten. In der Nahrungskette traten am meisten Karnivoren der 2. Stufe auf. Zwischen Sandböden mit wenigen oder keinen Riffen und solchen mit häufigen Riffen gab es keine Unterschiede. Echte Sandboden-Fische sind in der Minderheit; daher werden diese hauptsächlich von Rifffischen besiedelt. Wahrscheinlich variieren die Sandfisch-Faunen in verschiedenen geografischen Regionen des Roten Meeres. Abschließend wird die Frage diskutiert, ob die Sandböden in tropischen Regionen höhere Produktion aufweisen als solche aus gemäßigtem Klima, in denen die Werte relativ niedrig sind. Die erzielten Resultate könnten diese Annahme bestätigen, was der vorherrschenden Lehrmeinung widersprechen würde.

Schlüsselwörter: Rotes Meer, Sandböden, Fischgemeinschaft, Nahrungskette, Nahrungserwerb.

1. Introduction

Marine sand bottoms (psammal) are of lesser importance than hard bottoms or plant associations if biomass and production are regarded (Ott 1996). This should be valid for temperate as well as tropical regions. Whereas the mesopsammon has been extensively investigated (e.g. Gerlach 1971, Giere 2007, Gray 1981), studies on endo- and epifauna of sand bottoms are rare. Just the organisms of these categories offer the prey for the existence of the epibenthic macrofauna including fish.

After investigations of fish communities of tropical reefs off Galapagos (Zander 2006), the Caribbean and the eastern Atlantic (Zander 2011), and pseudocaves in the Red Sea (Zander 2018), the present study was directed at fish faunas of tropical sand bottoms. It was performed in the years 2017-2019 in two localities of the Red Sea. The aim was to gain data and results of species richness and diversity, of the abundance in the respective locality, of the frequency in regard to single habitats, and of the role in the respective community. Finally, the results are compared with those of former investigations.

2. Material and Methods

The investigations were performed at two localities in the Red Sea, Dahab, Gulf of Aqaba, northern Egypt (October 2017 and 2019) and Marsa Alam in middle Egypt (October 2018). Beside genuine sand bottoms also bottoms which are mixed with few or many coral reefs were visited. Therefore, two kinds of bottoms were studied 2019 in Dahab, i.e. environments

Fig. 1: Representatives of sand bottom dwelling fish from the Red Sea. **a** *Taeniura lymna* can camouflage by digging into the sand. **b** *Callechelys marmorata* retires in its narrow hole in the sand bottom if endangered. **c** *Scorpaenopsis oxycephalus* rest at rocks but also on the sand bottom. **d** *Pterois volitans* leave rocks or reefs at dust and is to find then also on sand bottoms. **e** *Corythoichthys flavofasciatus* live predominantly between algae or sea grass but make excursion on sand bottoms. **f** *Plotosus lineatus* appear in huge swarms on sand bottoms, they possess venomous fin rays.

Abb. 1: Auswahl von Fischen der Sandböden des Roten Meeres. **a** *Taeniura lymna* kann sich durch Eingraben in den Sand tarnen. **b** *Callechelys marmorata* zieht sich bei Gefahr in seine Höhle im Sand zurück. **c** *Scorpaenopsis oxycephalus* ruht an Felsen aber auch auf Sandböden. **d** *Pterois volitans* verlässt Felsen oder Riffe zur Dämmerung und ist dann auch auf Sand zu finden. **e** *Corythoichthys flavofasciatus* lebt vorwiegend zwischen Algen oder Seegras und macht Ausflüge auf freie Sandflächen. **f** *Plotosus lineatus* kommt in riesigen Schwärmen auf Sandböden vor, Strahlen der Flossen sind mit Giftdrüsen versehen.

dominated by reefs but with extended sand islands here called "Reef/Sand", and wide sand bottoms with few reefs called "Sand/Reef" (in short R/S and S/R. Eleven observations were made in Dahab 2017, ten in Marsa Alam 2018. In 2019 eight observations off Dahab regard R/S and 10 regard S/R. The fish fauna was investigated by SCUBA diving of 1 hour, which comprised a distance of ca. 200 m and depths of 10 to 5 m. The fish were discriminated (figs

Fig. 2: Representatives of sand bottom dwelling fish from the Red Sea. **a** *Heteroconger hassi* live hemi-sessile in great colonies in strengthened sand tubes from where they catch plankton. **b** *Parupeneus forsskali* are genuine sand dwellers and burrow in the sediment for prey. **c** *Istigobus decoratus* is a goby species which lives on the sand. **d** *Chaetodon paucifasciatus* are regularly found on sand bottoms and are a herbivorous species. **e** *Pardachirus marmoratus* are well camouflaged on the respective sediment. **f** *Arothron stellatus* are often found resting on the sand bottoms.

Abb. 2: Auswahl von Fischen der Sandböden des Roten Meeres. **a** *Heteroconger hassi* lebt hemi-sessil in großen Kolonien auf reinem Sandboden in Röhren, von denen aus sie Plankton fangen. **b** *Parupeneus forsskali* ist ein echter Sandbodenbewoher, der im Sediment nach Nahrung wühlt. **c** *Istigobus decoratus* ist eine Grundelart die auf dem Substrat lebt. **d** *Chaetodon paucifasciatus* wird regelmäßig auf Sandböden zu finden, ist aber ein Pflanzenfresser **e** *Pardachirus marmoratus* ist farblich gut an das jeweilige Substrat angepasst. **f** *Arothron stellatus* wird oft auf dem Substrat ruhend gefunden.

1, 2) and their abundance summarized on a tablet. The observed species were assorted to six categories, respectively: 1 = single, 2 = few, 3 = moderate, 4 = numerous, 5 = dominant, 6 = swarms. The analysis includes the frequency of occurrence in the single sites. These parameters and also some indices were used: Shannon Index "H_s" for diversity and evenness "J" for homogeneity of the respective fish assemblages. The localities or habitat types were compared by the SØRENSEN index (species identity) and the RENKONEN index (frequency identity).

3. Results and Discussion

In the years 2017 and 2018 different localities, Dahab and Marsa Alam (northern and middle Red Sea), are compared: the number of species

Tab. 1: Frequency values of fish species from diverse sand bottoms of the Red Sea.
Tab. 1: Frequenzwerte von Fischarten aus verschiedenen Sandböden des Roten Meeres.

Species	Dahab 17	Marsa Alam	Dahab 19 R/S	Dahab 19 S/R
Taeniura lymna		0.4		
Pterois volitans	0.3	0,3		0.1
Scorpaenopsis oxyurus	0.2	0.2	0.5	
Synanceja verrucosa		0.3		0.1
Papilloculiceps longiceps	0.2	0.2		
Eurypegasus draconis			0.1	
Echidna nebulosa	0.1			
Sidera griseus	0.1		0.1	
Heteroconger hassi	0.1		0.1	
Callechelys marmorata		0.4		
Synodus dermatogenys	0.1			
Doryrhamphus dactyliophorus		0.1		
Corythoichthys flavofasciatus		0.1		0.3
C. schultzi	0.1			
Trachyrhamphus bioarctatus	0.1			
Plotosus coralloides (large swarm)				0.1
Carangoides bajad		0.1		
Echeneis naucrates (on turtles)		0.3		
Cephalopholis argus	0.1	0.1		
Epinephelus fasciatus	0.1			0.4
E. macrospilos				0.1
Aelothoperca rugoa				0.1
Variola luthi	0.3			
Grammistes sexlineatus	0.1		0.3	0.4
Priacanthus hamrur			0.1	0.3
Parupeneus forsskali	0.7	0.7	1.0	1.0
P. macronema		0.1	0.4	0.3
P. barberinus	0.1			0.2
P. heptocanthus				0.2
P. cyclostoma		0.2	0.4	0.4
P. indicus	0.1			0.1
P. rubescens				0.2
Mullodoichichthys flavolineatus	0.2	0.1	0.4	0.5
M. vanicolensis	0.3	0.6		
Dascyllus trimaculatus			0.4	0.6
Pomacentrus trichrourus			0.1	0.3
Abudefduf vaiigensis			0.5	0.2
Chaetodon auriga	0.3	0.1	0.3	0.2
Ch. paucifasciatus	0.2	0.1	0.4	0.8
Ch. fasciatus	0.1		0.1	0.3
Ch. austriacus	0.1		0.1	0.1
Ch. semilarvatus		0.3		

Tab. 1: Continued.
Tab. 1: Fortsetzung.

Species	Dahab 17	Marsa Alam	Dahab 19 R/S	Dahab 19 S/R
Ch. semilarvatus		0.3		
Ch. lineatus		0.2		
Heniochus intermedius			0.4	0.6
H. diphreutes				0.1
Centropyge flavicaudata				0.1
Fistularia commersoni			0.5	0.8
Scolopsis ghanam		0.2		
Monotaxis grandoculus		0.1		
Kyphosus cinerescens		0.2		
Cheilinus abudjubbe	0.4		0.3	0.7
C. fasciatus	0.4		0.4	0.3
C. lunulatus	0.2		0.6	0.4
C. trilobatus				0.1
Oxycheilinus mentalis				0.1
Cheilio inermis	0.2			0.2
Thalassoma rueppelli	0.2		0.5	0.3
Bodianus anthioides	0.1	0.7	0.6	0.2
Gomphosus caeruleus			0.4	0.2
Cymolutes torquatus		0.1		
Hologymnosus annulatus	0.1			
Halichoeres hortulanus	0.1		0.3	0.3
Labroides dimidiatus			0.1	
Naviculichthys taeniurus			0.1	
Scarus niger			0.2	0.3
S. frenatus	0.2		0.1	0.3
S sordidus			0.1	0.1
Leptoscarus vaigensis			0.1	0.1
Paracirrhites forsteri			0.1	
Naso unicornis			0.4	
Siganus rivulatus		0.2	0.5	0.6
S. argenteus				0.1
Parapercis hexophthalmus		0.3	0.1	0.3
Aspidontus dussumieri			0.1	0.1
Amblygobius albomaculatus		0.3		
Istigobius decoratus		0.1	0.3	
Bothus mancas		0.1	0.1	0.2
Pardachirus marmoratus		0.5		0.1
Zebrasoma desjardini	0.1	0.3	0.5	
Naso unicornis	0.2		0.4	0.1
Acanthurus nigrofuscus	0.1		0.3	0.2
A. gahhm				0.2
A. sohal		0.2		
Ctenochaetus strigatus	0.1			
Sufflamen albicaudatus	0.2		0.5	
Melichthys niger	0.1		0.1	
Arothron stellatus		0.2	0.1	0.4
A. hispidus			0.1	
A. diadematus		0.4	0.1	0.1
Canthigaster coronatus			0.1	0.1
Chelmodon patoca				0.1
Ostracion cyanurus	0.1			0.2
Lactoria cornuta				0.2
Diodon hystrix				0.1
Sum species	**38**	**35**	**48**	**58**
Sum of species from all sites			**94**	

Tab. 2: Values and indices of sand fish faunas from the Red Sea.
Tab. 2: Zahlen und Indices von Sand-Fisch Faunen aus dem Roten Meer.

	Dahab 2017	Marsa Alam 2018	Dahab 2019 "Reef"	Dahab 2019 "Sand"
Number of species	38	35	48	58
Common species	13		35	
% common species	34	27	73	60
Shannon-Index	3.15	3.48	3.05	3.48
Evenness	0.96	0.98	0.79	0.86
Soerensen-Index	0.36		0.65	
Renkonen-index	0.30		0.56	

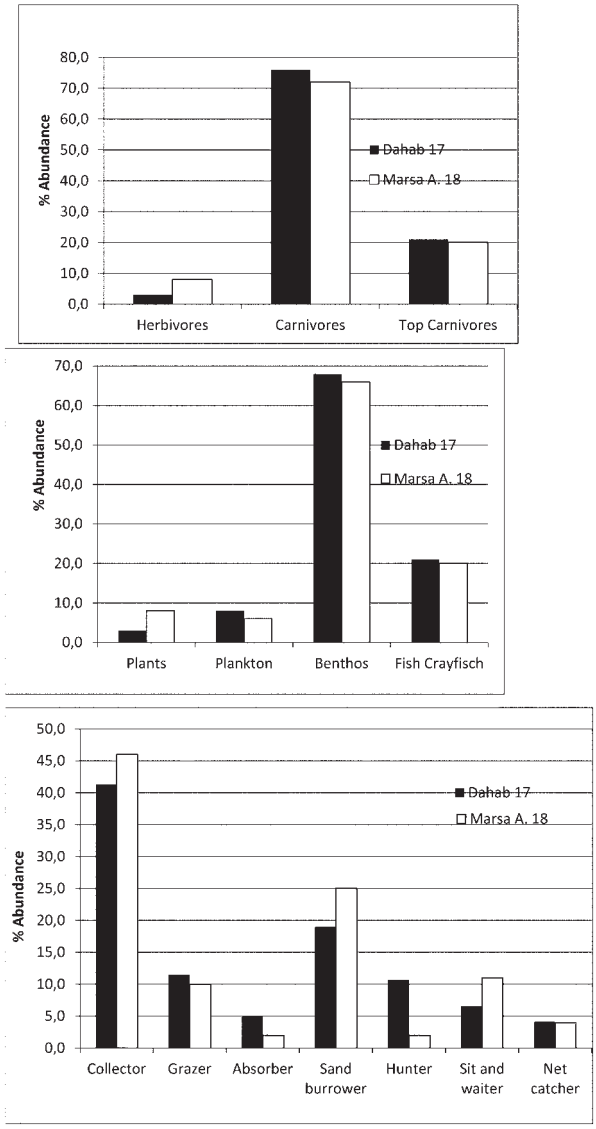

Fig. 3: Comparison of sand-fish assemblages off Dahab 2017 and Marsa Alam 2018. Above: status in the food chain; middle: kind of prey; below: mode of foraging.
Abb. 3: Vergleich von Sand bewohnenden Fische in Dahab 2017 und Marsa Alam 2018. Oben: Stellung in der Nahrungskette; mitte: Art der Nahrung; unten: Art und Weise des Nahrungserwerbs.

proved to be similar (38 or 35, respectively) but the number of common species was low (34 or 27 %, respectively) (tab. 1). On the other side, homogeneity and evenness attained very high values in both localities; these values indicate that the fish assemblage is not dominated by few species. The most dominant fish were *Parupeneus forsskali*, *Mullodoichthys vaniculensis* and *Bodianus anthioides*, whereas the most other species attained only low frequency values. These are also mirrored by the respective abundance values. SØRENSEN index (species identity) by 0.36 and RENKONEN index (abundance identity) by 0.30 were low (tab. 2) as was to expect according to

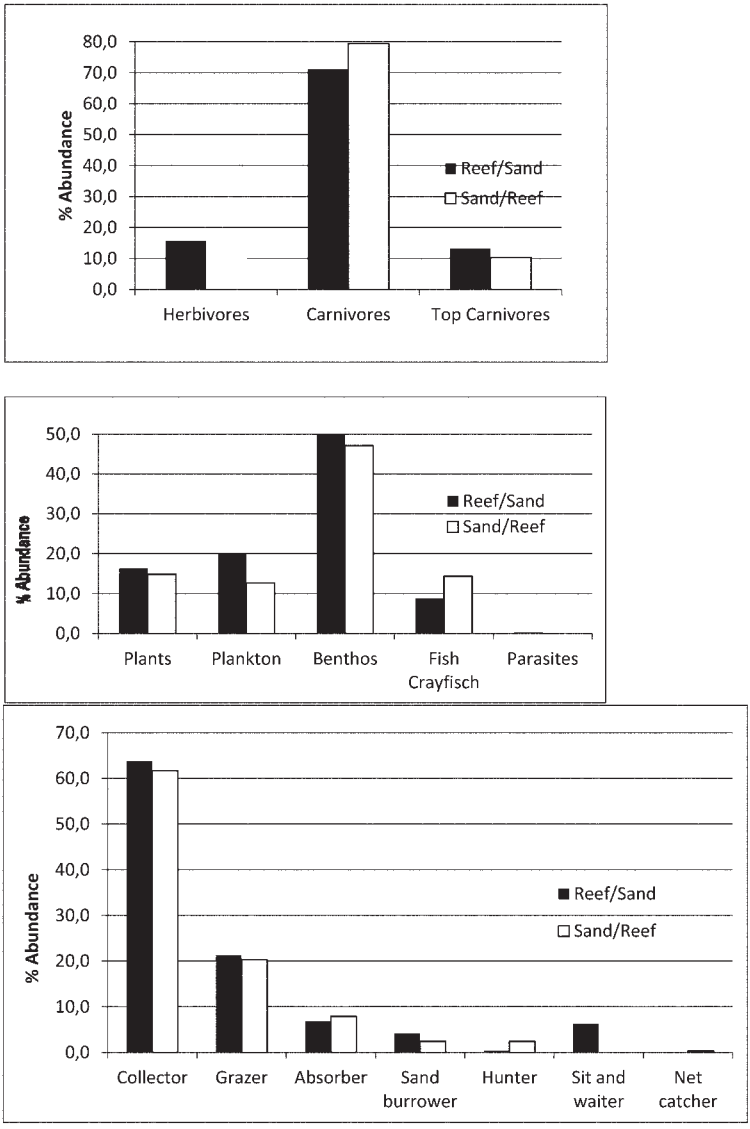

Fig. 4: Comparison of sand-fish assemblages off Dahab 2019 (Reef/Sand and Sand/Reef). Above: status in the food chain; middle: kind of prey; below: mode of foraging.
Abb. 4: Vergleich von Sand bewohnenden Fische in Dahab 2019 (Riff/Sand und Sand/Riff). Oben: Stellung in der Nahrungskette; mitte: Art der Nahrung; unten: Art und Weise des Nahrungserwerbs.

the number of common species. Therefore, it is assumed that the composition of the fish fauna deviates in different regions of the Red Sea.

Prey and prey foraging of the fish assemblages were dominated by carnivores (2. level of food chain), benthos feeders (kind of prey) and collectors (kind of foraging) (fig. 3). If the sand borrowers are added to the collectors these attain together 60 or 71 % of all fish species. This means that the benthos habitat offers obviously sufficient prey for the existence of an accumulation of macrobenthos consumer.

Only slight differences are found between the differently structured sand bottoms off Dahab in 2019. The number of species (tabs 1, 2) is higher in the S/R than in the R/S-habitat, the number of common species is lower in R/S (60 %) than in S/R (73 %). These numbers are higher than in Dahab 2017 and Marsa Alam (2018). The most frequent species were *Parupeneus forsskali*, *Bodianus anthioides* and *Dascylus trimaculatus*. Also *Fistularia commersoni* and *Plotosus coralloides* are remarkable because these species appeared in large swarms – but only in low frequency. Very low values are presented by two other exceptional kinds of foraging: the net catcher presented by *Pterois volitans* and the parasite presented by *Aspidontus dussumieri*. Homogeneity attained similar values as in the years before; evenness values of about 0.8 were slightly lower as in the investigations of 2017 and 2018 (tab. 2). However, the indices of species identity (0.65) and abundance identity (0.56) attained almost the value of 0.6 or surpass it (Zaret & Rand 1971).

The composition of living forms regarding prey and kind of foraging resembles the results

Tab. 3: Genuine and eurytopic sand fish species from two types of habitats off Dahab.
Tab. 3: Echte und euryöke Sandfischarten von zwei Habitatstypen vor Dahab.

Genuine sand fish	**Reef/Sand**	**Sand/Reef**
Parupeneus forsskali	x	x
P. macronema	x	x
P. barberinus		x
P. heptacanthus		x
P. cyclostoma	x	x
P. indicus		x
P. rubescens		x
Mullodoichthys flavilineatus	x	x
Bodianus anthioides	x	x
Siganus rivulatus	x	
S.argenteus		x
Parapercis hexophthalmus	x	x
Istigobius decoratus	x	
Bothus mancus	x	x
Pardachirus marmoratus		x
Sum	**9**	**13**
% of present species	**18**	**22**
Eurytopic sand species		
Chaetodon paucifasciatus	x	x
Heniochus intermedius	x	x
Cheilinus abudjubbe	x	x
Ch. lunulatus	x	x
Acanthurus gahhm		x
Sufflamen albicaudatus	x	
Sum	**5**	**5**
Sum genuine and euryecious spp.	14	18
% of present species	29	31

of the former years (fig. 4). The ratio of top carnivores is lower than in 2017 or 2018, therefore, the other categories are slightly higher. This result may influence also the number of primary consumers which decrease. In contrast, the abundance of sand burrowers increased distinctly. This is caused by the appearance of six or ten mullid species, respectively, whereas before (2017 and 2018) at most only five species of this group were observed. The difference between the categories R/S and S/R proved to be not significant.

Though according to Ott (1996) the production of sand bottoms is relatively low, the abundance of consumer, especially primary consumer, appears to be conspicuous. In the Baltic Sea where only a biomass of 1.3 g/m² was found, their utilization by short living fish was 38 % (Zander & Hagemann 1987). Similar investigations in the Mediterranean Sea resulted in 2.2 g/m² biomass which was utilized by 12 % (Zander & Hagemann 1989; Zander 1995). The respective fish biomass was lower than 1 g/m². Species numbers as well as homogeneity of the fish assemblage attained in the Red Sea high values which indicate an organized community. Beside sediment bound fish species like goatfish there are some eurytopic species which stay for longer times at sand bottoms in order to search for prey. Genuine species attained values of about 20 %, both categories together of about 30 % (tab. 3). These relative low values indicate that 70 % of the observed fish species colonize the sand bottoms from the nearby reefs.

Similar investigations of the Red Sea by other authors are rare. Fishelson (1999) reported 47 fish species from sand bottoms in the northern Gulf of Aqaba of which eight (14 %) species correspond to those of Marsa Alam and 15 (32 %) to those of Dahab 2019. Possibly, Fishelson (l.c.) used other kinds of investigation methods and, therefore, several species may have been overlooked. Another study regards the followers of goatfish in sand bottoms of the Indopacific Ocean (Moosleitner 2008) and compiled 48 species in the Red Sea; 13 (27 %) were identical with the ensemble of Marsa Alam and 24 (50 %) with that of Dahab 2019. The reasons for these discrepancies can lie on geographical differences though Moosleitner comprised localities of the whole Red Sea but regards only the followers of goatfish. The characteristic of the Gulf of Aqaba is that it is the northernmost area of the Red Sea with the least medial temperatures which may result in an impoverishment of the fauna. Also incorrect identifications cannot be excluded to declare discrepancies between this and the former studies.

The present study can only give an overview and the basis for extended ecological investigations of predator prey relationships between macrobenthos and fish community of sand bottoms. Possibly, the tropic sand bottoms will turn out as more productive ones as is assumed until now (Ott 1996). Such a result may to prove true because it is indicated by high homogeneity combined with high abundance in the studied fish community.

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