FISH FAUNA OF MANGROVE CREEKS, SEAGRASS MEADOWS AND SAND FLATS IN GAZI BAY: A STUDY WITH NETS AND STABLE ISOTOPES

Participants:

G. van der Velde (Catholic Univ. Nijmegen)
P.H. van Avesaath (Catholic Univ. Njmegen)
M.J. Ntiba (Univ. Nairobi)
G.K. Mwatha (KMFRI)
S. Marguiller (Free Univ. Brussels)
A.F. Woitchik (Free Univ. Brussels)

Introduction

Shallow bays with mangroves and seagrass meadows are known to be nursery grounds or feeding areas for many fish species. Some species occur both as juveniles and as adults in these biotopes, but others move to other biotopes as adults such as depth zones on the coral reef and vice versa. Although seagrass meadows and mangroves often coexist in close proximity, their fish faunas have usually been studied separately. Very few studies have studied fishes of coral reefs, seagrass beds and mangroves together. This has been partly due to methodological problems. In this progress report the study of the relation between the fish assemblages of the biotopes in Gazi Bay (Fig. 1) is described. The combined measurement of $\delta^{13}C$ and $\delta^{15}N$ of the tissue of fish and the natural abundance of these isotopes provides a tool to determine the sources of nutrition for the fish and indicates trophic relationship among the fish and other organisms. Isotope enrichment occurs between animals and their foods. ^{13}C enrichment is estimated at about 1‰ per trophic level for carbon ^{15}N enrichment at 3-4 ‰ for nitrogen (Fry & Sherr, 1984, Minagawa & Wada, 1984). This information can provide insight into the role in the food web of the fish species selected.

This progress report describes the results of analyses that were carried out in the framework of the STD-3 project on interlinkages between Eastern African coastal ecosystems. The fish samples used for these analyses were part of the collection gathered during the Netherlands Indian Ocean Expedition, which was funded by the Netherlands Organization of Scientific Research (NWO).

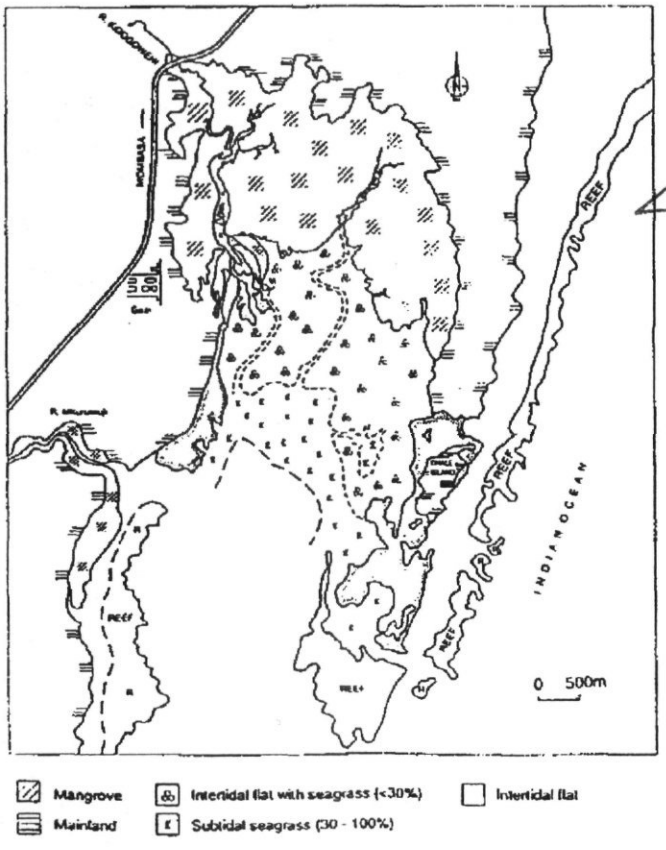

Fig. 1 Map of Gazi Bay with the main biotopes.

Materials and Methods

Several locations in Gazi Bay were sampled (Fig. 2). Various fishing techniques were used to describe the community structure of the fish assemblages of the different sites. Of the passive fishing gear, the fike nets (stretched mesh size 20 mm, length 1.6 m) were the most successful. They were used to catch fish at several sites in the eastern creek of the mangrove area. Due to the relatively poor visibility in the water, the visual census count technique could only be used in or near the mangrove area and the inner slope of the coral reef. Of the active fishing gear, the beam trawl (stretched mesh size 20 mm, width 1.5 m) appeared to be the most successful. Using this technique, several habitats were sampled, creating a transect from the mangroves towards the coral reef. The hauls of the beam trawl were standardized to allow a comparison of the relative abundance of the fish caught at the various locations. At each site 3 hauls of about 500 m length were made during daytime. These hauls were regarded as replicate samples. The trawl was towed by two inflatables with 25 Hp outboard engines at low speed. The fish caught during a haul were put in marked plastic bags which were subsequently stored in styrofoam boxes filled with ice for transport. The fishes were stored in a freezer the same day and identified, measured (total length) and weighed the next day. After formaline (4%) had been injected into the intestines via the anus, the fishes of each sample were put together in plastic bags with pores in which a waterproof label was introduced. The fish were kept in formaline (4%) for one day. The next day, the formaline was replaced by ethanol (70 %). To allow optimum preservation, the bags with the samples were put in plastic barrels containing 70 % alcohol after 2-3 days and stored in a deep freezer for transport to the Netherlands on board the RV Tyro. The intention was to use the preserved fish for a study of the stomach content. Part of the collection was transported to the University of Nairobi.

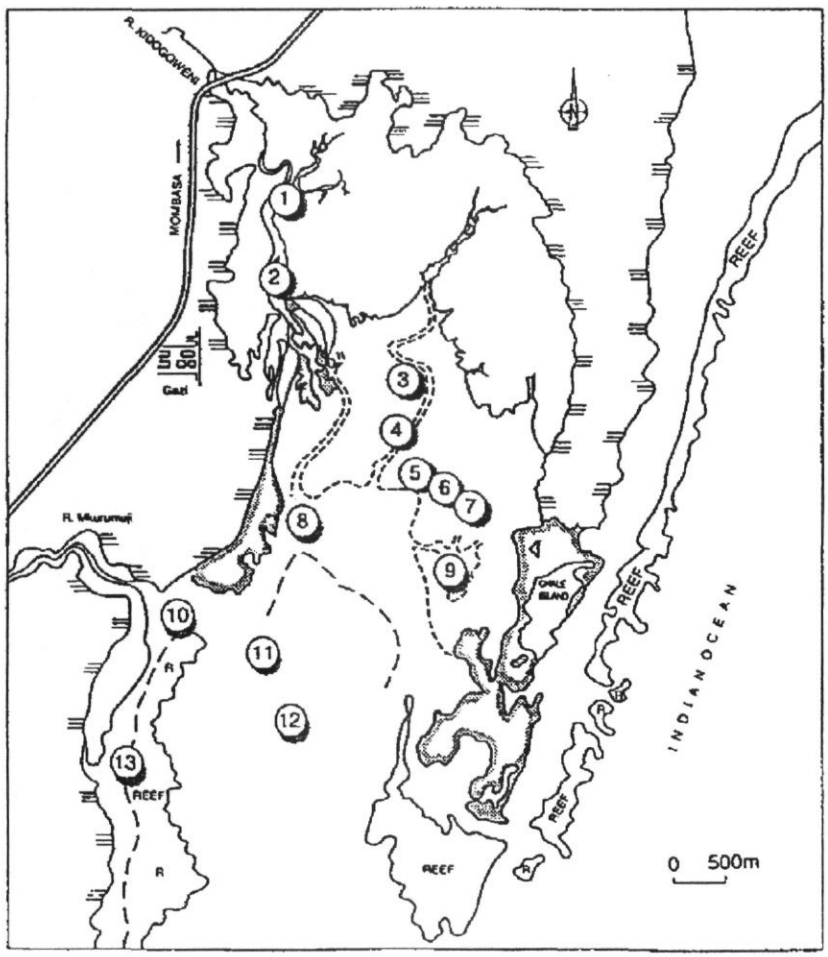

Fig. 2 Location of beam trawl sampling sites

Tissue samples were taken from a selection of fish species for a combined $\delta^{13}C$ and $\delta^{15}N$ analysis. The samples were stored in a freezer. The Laboratory for Analytical Chemistry of the Free University of Brussels carried out this analysis. Dry muscle tissue was lyophilized and ground to a fine powder. This powder was directly used for nitrogen and carbon analyses. The analyses were performed using mass spectrometric measurements (Delta E, Finnigan Mat Isotope ratio mass spectrometer). Stable carbon isotope abundances are expressed relative to the PDB (Pee Dee Belemnite) standard:

$$\delta^{13}C = \left[\left(\frac{^{13}C/^{12}C_{sample}}{^{13}C/^{12}C_{PDBstandard}}\right) - 1\right] \times 1000$$

$\delta^{15}N$ values are reported relative to nitrogen in air. High-purity tank nitrogen gas was used as working standard during sample analysis. This working standard was calibrated against N1 and N2 ammonium sulphate (IAEA, ref. 100 and 106) for $\delta^{15}N$ (Minagawa et al., 1984; Nevins et al., 1985). $\delta^{15}N$ was calculated as:

$$\delta^{15}N = \left[\left(\frac{^{15}N/^{14}N_{sample}}{^{15}N/^{14}N_{standard}}\right) - 1\right] \times 1000$$

The data of the fish catches were processed using (SAS (Statistical Analyzing System). Computer programs (TWINSPAN, FLEXCLUS) were used for the clustering of the data.

Preliminary results

The various fishing techniques yielded a total of about 2000 specimens of fish, belonging to 95 fish species (Table 1). A spectacular fish caught was that of a specimen of the Slender guitarfish (*Rhinobatos holcorhynchus*) in shallow water in the mouth of the bay. This rare fish species is normally caught at depths of 75-183 m and considered to be endemic for the coast from Port Shepstone to kwaZulu (Smith & Heemstra, 1986; Compagno et al., 1989). Its occurrence can the result of upwelling during the monsoon period. Another species observed indicating that is the Blackspotted electric ray (*Torpedo fuscomaculata*) of which a decaying specimen was found at the shore, where fishermen do their landings. It was not collected because of the bad state of the specimen. This species is recorded from deep water but also from estuaries. It was not known from Kenya (Smith & Heemstra, 1986; Compagno et al., 1989). *Fowleria aurita*, *Siganus sutor*, *Leptoscarus vaigiensis* and *Apogon thermalis* were caught in the highest numbers. *Siganus sutor* and *Leptoscarus vaigiensis* were caught most frequently, being present in 70 % of the beam trawl catches. *A. thermalis* and *F. aurita* were caught in high numbers locally. Of the fish species that were caught in lower numbers, *Parascorpaena mossambica* was caught most frequently: like *S. sutor* and *L. vaigiensis*, it was found in 70 % of the beam trawl catches. Demersal fish species such as *Fistularia commersonii* and *Sphyraena barracuda* were caught in small numbers.

As the beam trawl appeared to be the most successful fishing gear, most fish were caught using this technique. A total of 13 sites were sampled (Fig. 2) with the beam trawl by which a transect was made from the mangrove area (western creek) towards the coral reef. The substrates of the sites consisted mainly of sand, with or without a vegetation of seagrass. The substrate of sites 10 and 12 did not have any vegetation. The vegetation of site 1 and 12 was sparse, consisting mainly of *Thalassia hemprichii*. The vegetation of the other sites consisted mainly of dense *Thalassodendron ciliatum* beds at depths ranging from 1 to 2 m at low tide. *Enhalus acoroides* was found locally only at site 3.

The highest numbers of fish were caught in the *Thalassodendron ciliatum* beds near the eastern mangrove creek (sites 3 and 5, Fig. 3). Due to the presence of coral blocks in the eastern creek, it was not possible

Table 1. Gazi Bay. Preliminary list of fish species with numbers of caught specimens. Nomenclature according to Smith & Heemstra (1986).

Fowleria aurita	234	Cheilinus trilobatus	6
Siganus sutor	214	Epibulus insidiator	6
Leptoscarus vaigiensis	185	Calotomus spinidens	6
Apogon thermalis	166	Canthigaster solandri	6
Plotosus lineatus	93	Gerres oyena	5
Archamia fucata	83	Cheilinus chlorourus	5
Scarus ghobban	80	Dascyllus aruanus	4
Lethrinus ramak	76	Synodus binotatus	3
Gerres minuta	75	Histrio histrio	3
Parascorpaena mossambica	70	Aeoliscus punctulatus	3
Paramonacanthus barnardi	65	Pterois miles	3
Archamia mozambiquensis	45	Apogon fraenatus	3
Lethrinus harak	43	Cheilodipterus quinquelineatus	3
Foa brachygramma	38	Abudefduf vaigiensis	3
Sphaeramia orbicularis	35	Valamugil seheli	3
Petroscirtes mitratus	31	Sphyraena barracuda	3
Apogon cookii	28	Lactoria cornuta	3
Plotosus nkunga	24	Arothron immaculatus	3
Syngnathoides biaculeatus	20	Taeniura lymma	2
Plectorhinchus gaterinus	20	Hippocampus histrix	2
Stethojulis strigiventer	20	Epinephelus sp.	2
Bothus pantherinus	20	Terapon jarbua	2
Apogon savayensis	19	Parupeneus indicus	2
Arothron hispidus	19	Amblygobius albimaculatus	2
Apogon guamensis	17	Torpedo fuscomaculata	1
Pelates quadrilineatus	16	Rhinobatos holcorhynchus	1
Plectroglyphidodon lacrymatus	15	Anguilla bicolor bicolor	1
Apogon nigripes	13	Myrichthys maculosus	1
Lutjanus cf. fulviflamma	13	Myrichthys colubrinus	1
Siganus stellatus	13	Pisodonophis cancrivorus	1
Canthigaster valentini	13	Chirocentrus dorab	1
Papilloculiceps longiceps	12	Synodus variegatus	1
Siphamia mossambica	12	Antennarius pictus	1
Pardachirus marmoratus	11	Sargocentron diadema	1
Diodon holocanthus	11	Myripristis kuntee	1
Chrysiptera annulata	10	Fistularia commersonii	1
Petroscirtes breviceps	10	Neoniphon sammara	1
Lactoria fornasini	10	Hippichthys spicifer	1
Lethrinus variegatus	9	Solenostomus cyanopterus	1
Priolepis inhaca	9	Dactyloptena sp.	1
Gymnothorax sp.	8	Upeneus tragula	1
Pomacentrus trilineatus	8	Cheilio inermis	1
Cyclichthys spilostylus	6	Pseudojuloides argyreogaster	1
Novaculichthys macrolepidotus	7	Synchiropus marmoratus	1
Pteragogus flagellifer	7	Amblygobius sphynx	1
Conger cinereus cinereus	6	Acanthurus sp.	1
Saurida gracilis	6	Naso brevirostris	1
Cheilinus bimaculatus	6	Cynoglossus sp.	1

caught by fishermen (not collected)
13 fishes were identified to the family level only and are not included in this list.

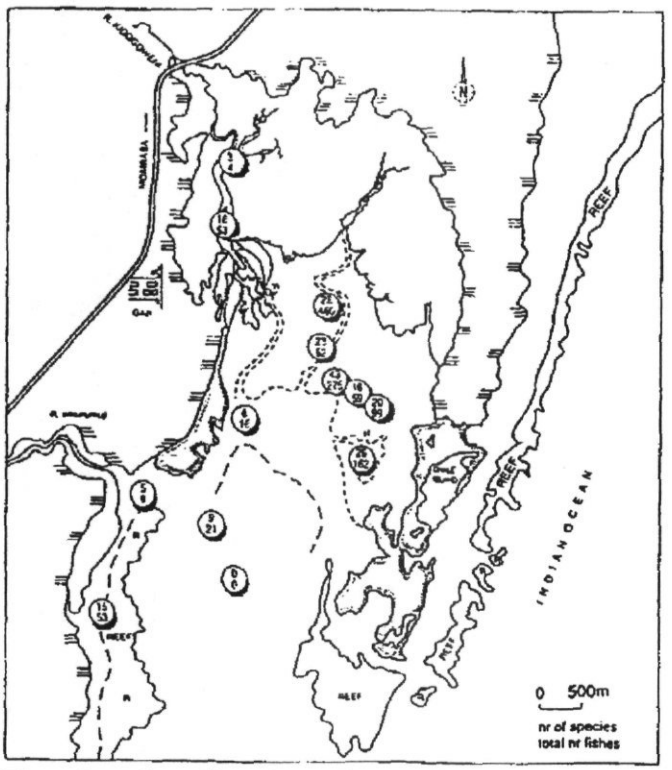

Fig. 3. Distribution of species numbers and total numbers of caught fishes

to trawl in or near the eastern part of the mangrove area. In general, the eastern part of the bay yielded more fish belonging to more species. The trawls in or near the western creek were not very successful. The substrate of these sites (nos. 1, 2 and 8) consisted mainly of bare sand with little or no vegetation. The water current at sampling time at sites 1 and 2 was relatively strong. At site 12 no fish were caught at all. The site was in the middle of a bare sand flat at a depth of approximately 8 m at low tide.

As the distribution patterns of the more frequently caught fish species did not provide a clear insight into the use of the different areas of Gazi bay by the fish, statistical analysis programmes as TWINSPAN and FLEXCLUS were used to group the data (Tables 2, 3, 4 and 5). Only the beam trawl data were used in the analysis.

Table 2. Dendrogram of the hierarchic clustering of the composition of the fish catches of the several locations at the family-level (TWINSPAN).

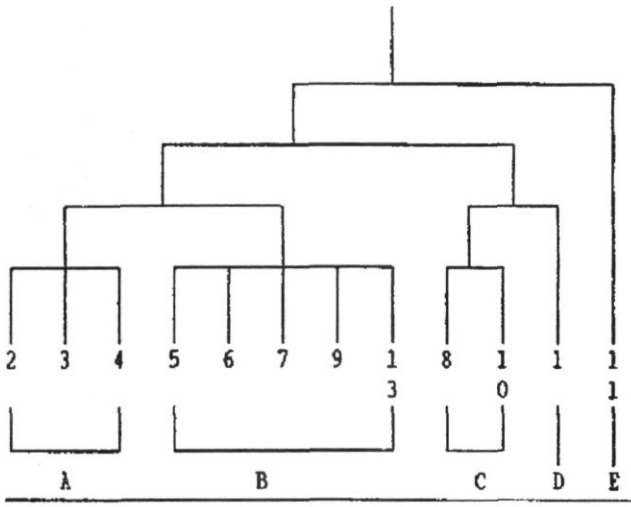

Table 3. Resemblance of the samples of the clusters of the composition of the fish catches of the several locations at family level (FLEXCLUS).

CLUSTER	SIZE	AVERAGE RESEMBLANCE	MOST SIMILAR TO	RESEMBLANCE	ISOLATION
E	1	1.0000	F	0.0345	29.0000
A	3	0.1065	B	0.6496	0.1639
B	5	0.5052	A	0.6496	0.7776
C	2	0.2169	B	0.1554	1.3956
F	1	1.0000	B	0.0397	25.1761

Clustering the compositions of the fish catches at the family level yielded 3 distinguishable groups. Two samples (fish catches at sites 1 and 11, Tables 3, 4) showed no similarity with other samples. The sample at site 11 was separated at the first level, while the sample at site 1 was separated at the third level. The first group of samples (cluster A, Table 2) represents fish catches near the mangrove area. The second group of samples (cluster B, Table 2) consists of samples from sites in seagrass meadows in the bay. The third group (cluster C, Table 2) consists of two samples taken at sites with little or no vegetation. The sample of site 12 was not taken into account in the analysis, because no fish were caught at this site. The average similarity between the groups created with TWINSPAN is relatively

Table 4. Dendrogram of the hierarchic clustering of the composition of the fish catches of the several locations at the species-level (TWINSPAN).

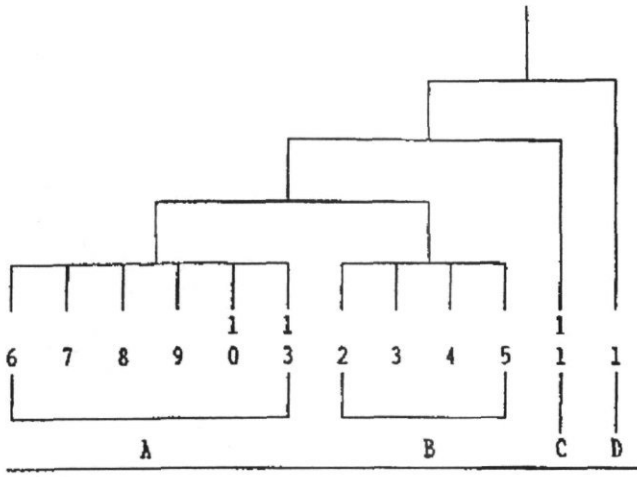

Table 5. Resemblance of the samples of the clusters of the composition of the fish catches of the several locations at species level (FLEXCLUS).

CLUSTER	SIZE	AVERAGE RESEMBLANCE	MOST SIMILAR TO	RESEMBLANCE	ISOLATION
D	1	1.0000	C	0.0123	81.0000
B	4	0.3000	A	0.2173	1.3808
A	6	0.3191	B	0.2173	1.4686
C	1	1.0000	A	0.0193	51.6878

low (Table 3). The isolation (the average similarity of the samples within the groups divided by the average similarity between the groups, Table 3) of clusters A and B is low, implying a high similarity between the clusters. Despite this fact, the distinction between the clusters was maintained because of the occurrence of specific families in the clusters. Muraenidae, Teraponidae, Haemulidae, Blenniidae and Gobiidae were specific for cluster A, while Synodontidae and Lutjanidae were only present in cluster B. Monacanthidae and Ostraciidae were only found at the sites of cluster C, while Labridae and Diodontidae were found here with high frequencies. Syngnathidae and Platycephalidae only showed up with high frequencies in the samples of clusters B and C. Plotosidae were only frequent in cluster D.

The clustering of the data at the species level showed a similar pattern. At the third level of the hierarchic clustering programme TWINSPAN two groups were distinguished (Table 4). Sites 1 and 11 were separated just as in the clustering at family level. In contrast with the clustering at family level, the samples taken at sites 8 and 10 did not constitute a separate group. Furthermore, the sample of site 5 was joined with the samples of sites 2, 3 and 4 (cluster A of the clustering at family level). These samples were grouped together because *Apogon thermalis, Foa brachygramma, Plectorhinchus gaterinus, Lethrinus harak, Petroscirtus mitratus, Siganus stellatus, Bothus pantherinus* and *Arothron immaculatus* were only present in this cluster. *Apogon nigripes* was found only in cluster A of the clustering at species level. In general, the distinction between the samples from sites in seagrass meadows near the mangrove area and those from sites in seagrass beds in the bay remained intact.

In order to describe the use of the seagrass beds by the fish assemblage, the stable isotope content of muscle tissue of a selection of fish species were determined. The fish were caught near the mangroves. The $\delta^{13}C$ values ranged from -13.3 to -21.2 $^{o}/_{oo}$ and $\delta^{15}N$ values ranged from +3.5 to +12.2 $^{o}/_{oo}$ (Fig. 4).
A first distinction in the data was made using cluster analysis (FLEXCLUS) (Fig. 4). Two groups were distinguishable. The programme clustered a group

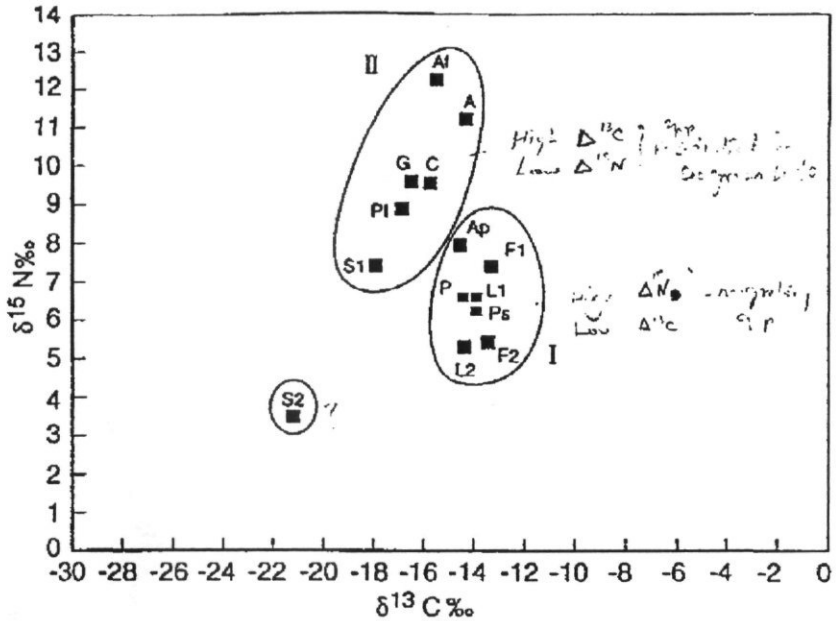

Fig. 4. Stable isotope ratios ($\delta^{13}C$/ $\delta^{15}N$) of fish muscle tissue. Results of cluster analysis (FLEXCLUS). I. Fish species using the seagrass beds as a life time habitat. II. Migrating fish species.
Fish species (total length in cm): A = *Archamia mozambiguensis* (7-8 cm), Af = *Archamia fucata* (7-8), Ap = *Apogon guamensis* (7-9), C = *Conger cinereus cinereus* (55-80), F_1 = *Fowleria aurita* (7-8), F_2 = *Fowleria aurita* (8-9), G = *Gazza minuta* (6-6.5), L_1 = *Leptoscarus vaigiensis* (15-18), L_2 = *Leptoscarus vaigiensis* (12-15), P = *Paramonacanthus barnardi* (8-10), Pl = *Plotosus lineatus* (8-10), Ps = *Parascorpaena mossambica* (7-11), S_1 = *Siganus sutor* (10-15), S_2 = *Siganus sutor* (6-8).

of fish species with relatively high $\delta^{15}N$ and low $\delta^{13}C$ ratios of the muscle tissue. These are fish species that use the seagrass meadows as a life time habitat. A second group was formed of fish species with lower $\delta^{15}N$ and higher $\delta^{13}C$ ratios of the muscle tissue. Based on literature data, these can be considered migrating fish species. The smaller specimens of *Siganus sutor* did not show a similarity with the two distinct groups. An explanation for this effect could not be found. Within a species, bigger fish show a higher $\delta^{15}N$ and $\delta^{13}C$ ratio of the muscle tissue. This indicates that the age or volume of the fish influences either feeding characteristics of the fish or the allocation of the stable isotopes (or both). More research is needed to study this effect. At this moment publication of data of the stable isotopes ratios of fish require specification of length for proper evaluation of the data.

In order to describe the use of the seagrass beds by the different fish assemblages, a rough distinction in the feeding patterns of the fish species was made. Based on literature data (Smith and Heemstra, 1986; Sale, 1991; Randall et al., 1990; Randall, 1992) three groups of feeding categories were distinguished :
-fish species feeding besides on other food items on seagrasses and/or macro-algae in addition to other food items: herbivores
-fish species mainly feeding on zooplankton and benthic animals: planktivores/benthivores.
-fish species feeding mainly on other fish and/or macro-crustacea: piscivores/benthivores.

The data could also be clustered combining the stable radio isotope data with feeding characteristics of the fish species based on literature data

(Fig. 5). A group of fish species showing relatively low $\delta^{15}N$ and $\delta^{13}C$ ratios of the muscle tissue feed on plant material (Group A in Fig. 5).
A group of fish species feeding mainly on zooplankton (Group C), but also feeding on benthic animals, show a higher $\delta^{15}N$ and $\delta^{13}C$ ratio than the herbivorous fish species (Group B). The third group, piscivorous fish species also feeding on benthic animals like macro-crustacea, shows intermediate values in between the group of herbivorous and zooplanktivorous/benthivorous fish species.

An overlap in $\delta^{15}N$ and $\delta^{13}C$ ratios of the various groups exists, indicating that a number of fish species can show different feeding characteristics. It is questionable whether this fact is caused by omnivorous feeding characteristics of the fish species that are not mentioned in literature, changes in $\delta^{15}N$ and $\delta^{13}C$ ratios caused by migrating fish species (Fig. 5.), changes in $\delta^{15}N$ and $\delta^{13}C$ ratios caused by differences in length or the number of data is not sufficient for a proper distinction between the groups. The present data do not allow a further examination of these probable causes at this moment. The valid clustering of the stable radio isotope ratios of the muscle tissue of the fish on bases of feeding characteristics allow the discription of the use of the seagrass beds by the fish assemblages on basis of their feeding characteristics.

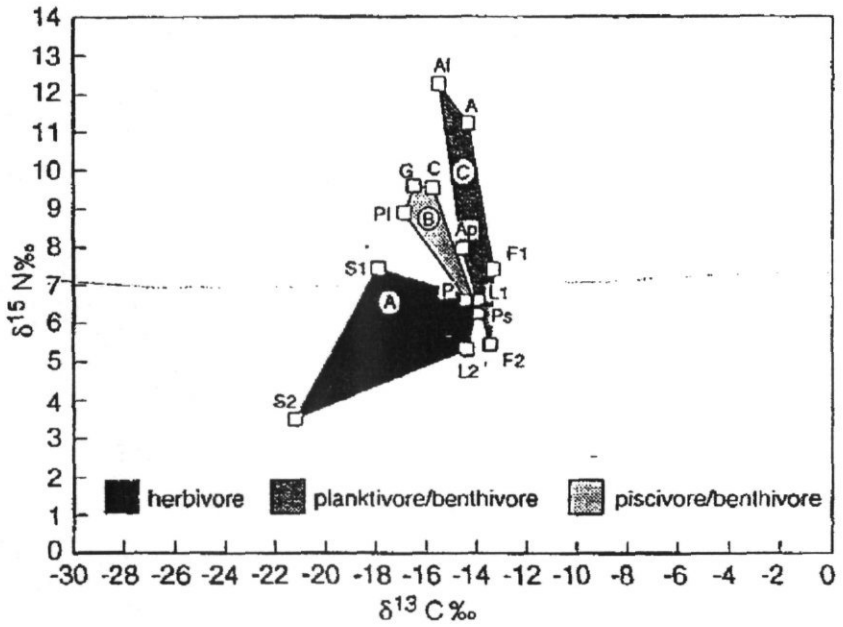

Fig. 5. Stable isotope ratios ($\delta^{13}C$/ $\delta^{15}N$) of fish muscle tissue. Combination of the isotope ratio and feeding characteristics of the fish species (literature data). Fish species (total length in cm): A = *Archamia mozambiquensis* (7-8 cm), Af = *Archamia fucata* (7-8), Ap = *Apogon guamensis* (7-9), C = *Conger cinereus cinereus* (55-80), F_1 = *Fowleria aurita* (7-8), F_2 = *Fowleria aurita* (8-9), G = *Gazza minuta* (6-6.5), L_1 = *Leptoscarus vaigiensis* (15-18), L_2 = *Leptoscarus vaigiensis* (12-15), P = *Paramonacanthus barnardi* (8-10), Pl = *Plotosus lineatus* (8-10), Ps = *Parascorpaena mossambica* (7-11), S_1 = *Siganus sutor* (10-15), S_2 = *Siganus sutor* (6-8).

With regards to the use of the sites as foraging grounds for the fish, it should be stressed that a higher proportion of piscivore/benthivore fish were present in or near channels and creeks. Since sites at a greater distance from a channel showed a somewhat lower relative occurrence of fish

predators, It can be assumed that these fish species did not use the sites as a permanent habitat but only as foraging grounds. In general, about 40 % of the fishes caught were piscivore/benthivore (Fig. 6). A high share of herbivorous fish was demonstrated in the seagrass meadows near the mangroves. There was a gradual change in the shares of the various feeding groups going from the mangroves, via the seagrass beds within the bay, towards the coral reef (Fig. 7).

Preliminary conclusions

- Fish assemblages of seagrass beds are dense and rich compared with unvegetated areas.
- Cluster analysis at species level as well as family level demonstrated that the fish data can be grouped in four to five clusters.
- The results indicate that the distance from the mangrove area influences the fish community of seagrass beds.
- Fish which are totally or partially herbivorous constitute an important component of the fish community within the seagrass beds.
- Stable isotope analysis showed that $\delta^{15}N$ and $\delta^{13}C$ ratio values of muscle tissue of the fishes are consistent with feeding categories as well as habitat use.
- In the vicinity of the mangroves the share of zooplanktivorous fish is relatively high. This share decreases towards the middle of the bay and concurs with an increase in the share of piscivorous fish.
- The share of piscivorous fish is high in the vicinity of the main channels and lower at some distance from the channels.

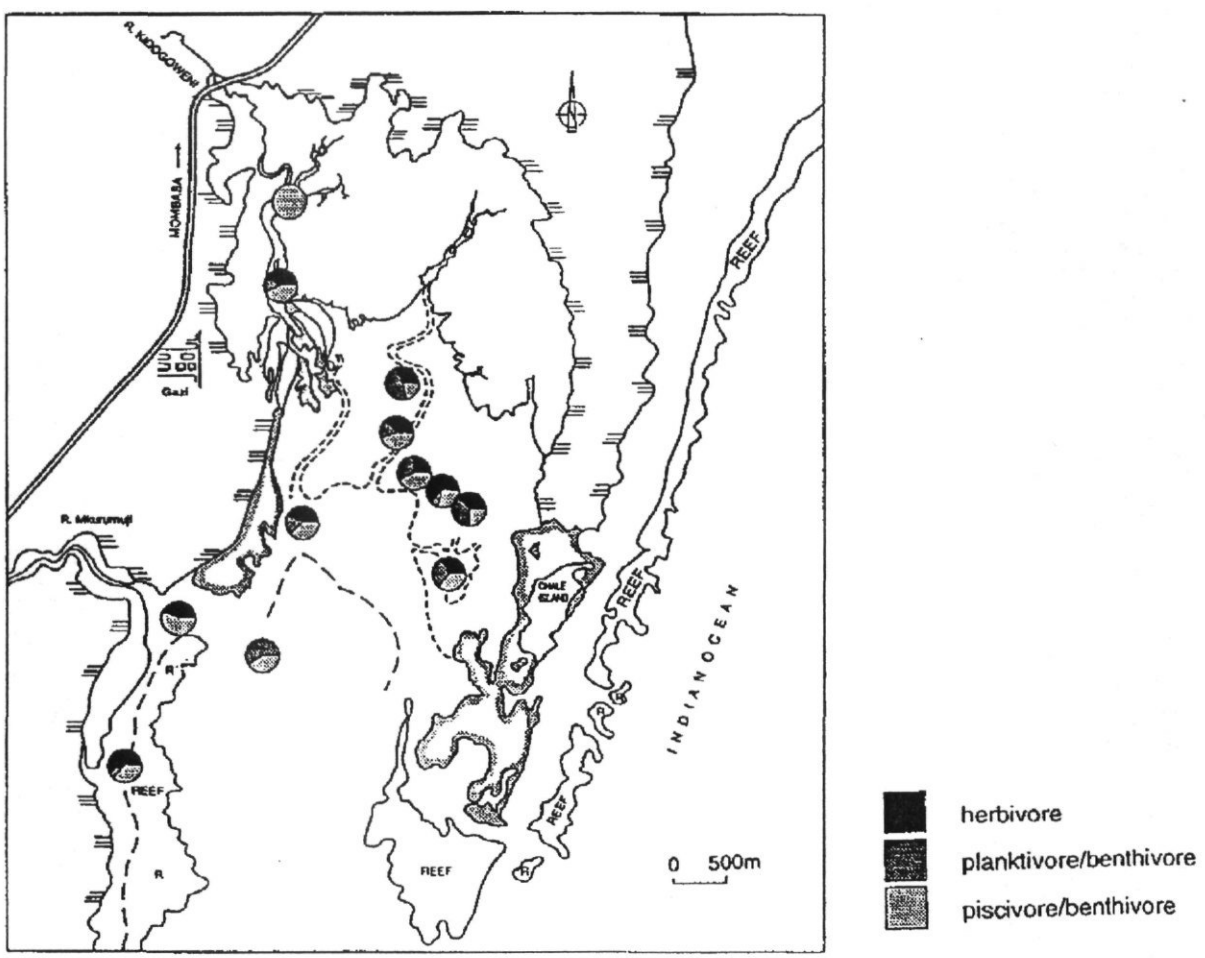

Fig. 6. Shares of dish feeding categories at the sampling sites.

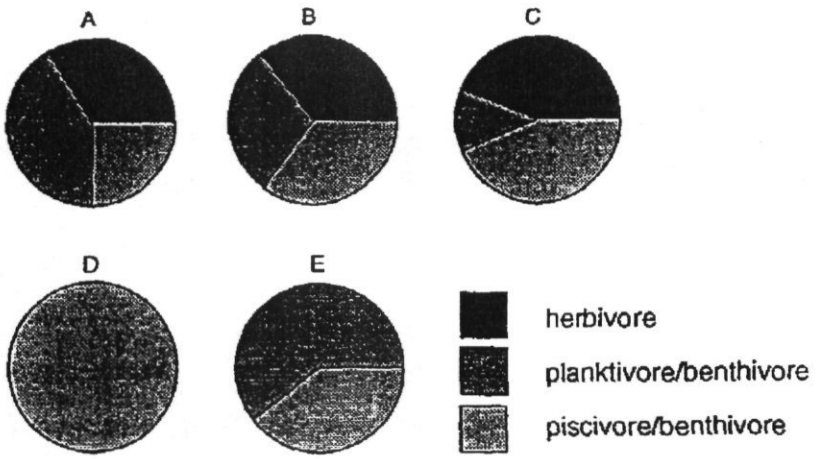

Fig. 7. Share of three feeding categories of fish based on caught numbers arranged according the clusters distinguished at the family level (see table 2).

REFERENCES

-Compagno, L.J.V., D.A. Ebert & M.J. Smale, 1989. Guide to the Sharks and Rays of southern Africa: 1-160. Struik Publishers, Cape Town.
-Fiedler, R. & G. Proksch, 1975. The determination of nitrogen-15 by emission and mass spectrometry in biochemical analysis: a review, Analytica Chimica Acta 78: 1-62.
-Fry, B. & E. Sherr, 1984. $\delta^{13}C$ measurements as indicators of carbon flow in marine and fresh water ecosystems. Contrib. Mar. Sci. 27: 13-47.
-Minagawa, M. & E. Wada, 1984. Stepwise enrichment of ^{15}N along food chains. Further evidence and the relation between $\delta\ ^{15}N$ and animal age. Geochim. Cosmochem. Acta 48: 1135-1140.
-Minagawa, M., D.A. Winter & I.R. Kaplan, 1984. Comparison of Kjeldahl and combustion methods for measurements of nitrogen isotope ratios in organic matter. Anal. Chem. 56: 1859-1861.
-Nevins, J., M.A. Altabet & J.J. McCarthy, 1985. Nitrogen isotope ratio analysis of small samples: sample preparation and calibration. Anal. Chem. 57: 2143-2145.
-Randall, J.E., 1992. Red Sea Reef Fishes: 1-192. Immel Publishing Limited, London.
-Randall, J.E., G.R. Allen & R.C. Steene, 1990. Fishes of the Great Barrier Reef and Coral Sea: i-xx, 1-507. University of Hawaii Press, Honolulu.
-Sale, P.F., 1991. The Ecology of Fishes on Coral Reefs: i-xiv, 1-754.
-Smith, M. & P.C. Heemstra (eds.), 1986. Smiths' Sea Fishes: i-xx, 1-1047. Springer-Verlag, Berlin, Heidelberg, New York, London, Paris, Tokyo.