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Cephalopod Species in Mozambican Waters Caught in the "Mozambique 0307" Survey: Distribution, Abundance and Assemblages

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Abstract—The present paper reports for the first time for Mozambique waters the distribution, abundance and species assemblages of cephalopods in the outer shelf and upper/middle slope (100 – 700 m depth) from data collected in spring of 2007 during the "Mozambique 0307" bottom-trawl survey. A total of 129 hauls were performed following a random stratified sampling scheme in the different sectors and bathymetric strata. The biomass estimates were computed by the swept area method. Cephalopod species accounted for 8.4% of the total biomass captured, with a total of 50 species belonging to 13 families. The most important families in terms of species richness were Octopodidae and Sepiidae with 10 representatives each. The most abundant species was the omastrephid *Nototodarus hawaiiensis*, present in all sectors. The second most abundant species in terms of biomass was *Sepia acuminata*, followed by the *Veladona togata* (Octopodidae) mainly between 400 and 600 m depth. The highest biomass estimates were recorded in the sectors named Bazaruto B and Boa Paz, between 200 and 400 m depth. Species assemblages were analysed with the Bray-Curtis similarity index and the group average clustering method was applied, revealing three cephalopod assemblages : the shelf community (100-200m), a wide transitional zone between shelf edge-upper slope (200-600 m) and the middle slope (600-700 m), mainly characterised by *Sepia* species, *Nototodarus hawaiiensis*, and *Histioteuthis* species, respectively. The diversity indices showed a higher diversity in Sofala, in the north of the study area, and in the shelf community in all sectors.

INTRODUCTION

The coast of Mozambique extends for 2,740 km and supports numerous fisheries that are very valuable, and mainly target crustaceans distributed over the continental shelf. Despite the importance of fisheries, the associated marine fauna are poorly known.

The first attempt to estimate the fish resources of Mozambique was made by Shomura *et al*. (1967) and Gulland, (1970). Later, Burczynski (1976) and Birkett (1978) presented some abundance estimates based on the swept-area method from fishery investigations along the coast of Mozambique on the *R/V Professor Mesyatsev*. The Soviet trawler *Aelita* and the German Democratic Republic trawler *Kattegat* also carried out fishery investigations in Mozambican waters (Budnichenko, 1977;

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Anonymous, 1978). Finally, as a part of NORAD's long-term support of fisheries research and development in Mozambique, seven surveys with the *R/V Dr. Fridtjof Nansen* were mounted over a period of about 14 years (Sætersdal *et al*., 1999). However, there is little information available about cephalopods from these surveys, and only related to some commercial species, and in some of these investigations sampled areas and gear differed.

More recently (March-April 1999), the Portuguese research vessel *Capricornio* carried out a trawl survey in Mozambique (Días *et al*., 1999) but cephalopods were not target species.

During March and April 2007 a research cruise ("Mozambique 0307") was conducted onboard the Spanish R/V *Vizconde de Eza* in order to assess the demersal resources as well as demersal species composition and distribution in the region down to 700 m depth. Data collected on these species allowed i) determination of the qualitative and quantitative composition of assemblages, ii) an analysis of their spatial distribution and iii) estimates of abundance of the most important species. The present work can be considered as the first major step towards increasing the knowledge of the cephalopods in Mozambique waters.

MATERIAL AND METHODS

The "Mozambique 0307" survey took place between 10th March and 11th April 2007. The study area extended from 26º50'S to 17ºS, covering the depth range between 100 and 700 m and a total area of 53,428 km^2. The research vessel was the *R/V Vizconde de Eza*, a stern trawler of 53 m length and 1,400 GRT, equipped with a standard Baka bottom-trawl, with a 52 m headline and 32 m footrope. The trawl had a stretched mesh of 46 mm in the codend and was covered internally with a 25 mm mesh liner. Gear performance and geometry during the fishing operations were monitored by a Simrad ITI sensors system. Mean headline height and mean wing spread were 1.9 and 20.0 m, respectively.

For sampling purposes the area was divided into five geographical sectors, namely: 1 (Sofala), 2 (Bazaruto A), 3 (Bazaruto B), 4 (Boa Paz) and 5 (Inhaca). Five bathymetric strata were also considered within each of the sectors: A (100-200 m depth) , B (200-400 m), C (400-500 m), D (500-600 m) and E (600-700 m) (see Figure 1). The geographical position of the fishing stations was selected according to a stratified random sampling scheme taking into account the above stratification. The number of hauls per geographic sector and depth strata was made proportional to the trawlable surface adjusted to the ship time available at sea, with coverage of around 2.44 hauls for every 1,000 km^2. The duration of each haul was 30 minutes and were carried out during daylight at a mean towing speed of 3.0 knots. Catch values were standardized to number of individuals and biomass per 30 minutes of trawling by sectors and strata, for subsequent statistical analysis as described by Cochran (1971). The total biomass and the biomass by strata and sector were calculated using the swept area method (Sparre and Venema, 1997).

The identification of cephalopod assemblages was performed by calculating the transformed (double square root) Bray-Curtis similarity coefficient from the mean yields in weight of the hauls performed in each of the resulting sector-stratum combinations (i.e. 1A, 1B, 5D, 5E) and the subsequent classification by cluster analyses applying the UPGMA linkage algorithm. The data matrix used comprised the sector-stratum combinations as cases (25 rows) and cephalopods species as variables (50 columns). The PRIMER software (Clarke & Warwick, 1994) was used to calculate contribution of species to the similarity between groups. Diversity was assessed by estimation of the species richness (d) and the Shannon-Wiener (H) indices (Magurran, 1989).

RESULTS AND DISCUSSION

A total of 129 valid hauls were made during the cruise. Fish was the most important group with 87% of total estimated biomass. Almost all molluscs caught during the cruise were cephalopods. They were the second most important taxonomic group in the survey, with total catches of 3,615 kg which corresponded to 30,305 individuals. The estimated overall cephalopod biomass in the sampled area (55,680 tonnes) accounted for some 8% of the total biomass of all taxa (about 696,000 tonnes).

Cephalopods were quite ubiquitous and sometimes abundant in the catches. There were 50 species caught, from 13 taxonomic families (see Table 1). The most

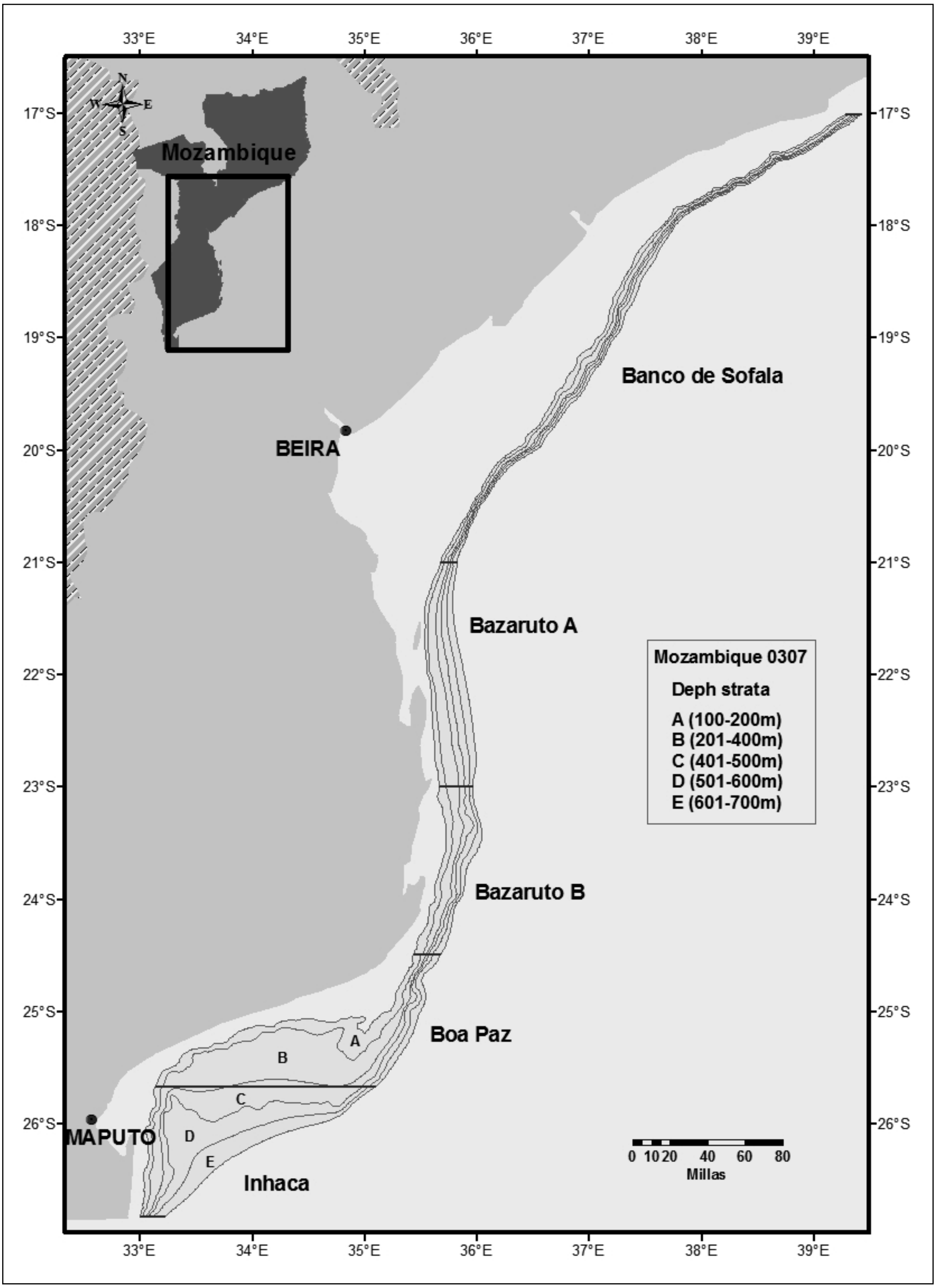

Fig. 1. The "Mozambique 0307" study area, showing the different strata and sectors sampled

Table 1: Cephalopod species occurrence index by bathymetric stratum (A-E) and geographic sector (1-5) from the cruise "Mozambique 0307"

BATIMETRIC STRATA					SPECIES	FAMILY	GEOGRAFIC SECTORS				
A	B	C	D	E			1	2	3	4	5
			■	■	*Amphitretus pelagicus*	AMPHITRETIDAE	■				■
		■	■	■	*Liocranchia reinhardti*	CRANCHIIDAE	■				■
		■	■		*Abralia sp*	ENOPLOTEUTHIDAE	■				
		■	■		*Enoploteuthis leptura*	ENOPLOTEUTHIDAE		■			
				■	*Histioteuthis atlantica*	HISTIOTEUTHIDAE					■
	■	■	■	■	*Histioteuthis celetaria pacifica*	HISTIOTEUTHIDAE	■	■	■	■	■
■	■	■	■	■	*Histioteuthis corona*	HISTIOTEUTHIDAE	■	■	■	■	■
		■		■	*Histioteuthis hoylei*	HISTIOTEUTHIDAE	■			■	
				■	*Histioteuthis macrohista*	HISTIOTEUTHIDAE	■				
			■		*Histioteuthis meleagroteuthis*	HISTIOTEUTHIDAE					■
				■	*Histioteuthis sp*	HISTIOTEUTHIDAE			■		■
■					*Loliginidae*	LOLIGINIDAE	■				
	■				*Loligo reynaudi*	LOLIGINIDAE		■			
■	■				*Uroteuthis duvauceli*	LOLIGINIDAE	■	■		■	■
■	■				*Uroteuthis edulis*	LOLIGINIDAE		■	■	■	
		■	■	■	*Bathypolipus valdiviae*	OCTOPODIDAE	■				■
			■	■	*Benthoctopus unicirrhus*	OCTOPODIDAE	■				■
				■	*Benthostopus thielei*	OCTOPODIDAE	■				
	■				*Donoctopus schmidti*	OCTOPODIDAE		■			
■					*Octopus aegina*	OCTOPODIDAE				■	■
■					*Octopus defilippi*	OCTOPODIDAE		■	■		
				■	*Octopus vulgaris*	OCTOPODIDAE		■			■
■	■	■			*Pteroptopus sp.*	OCTOPODIDAE	■	■	■		■
■	■	■	■		*Scaergus unicirrhus*	OCTOPODIDAE	■	■	■	■	■
■	■	■	■	■	*Veladona togata*	OCTOPODIDAE	■	■	■	■	■
■					*Eucleoteuthis luminosa*	OMMASTREPHIDAE				■	
■					*Nototodarus hawaiiensis*	OMMASTREPHIDAE			■	■	
		■	■	■	*Ommastrephes bartramii*	OMMASTREPHIDAE		■	■	■	■
	■	■	■	■	*Ommastrephidae*	OMMASTREPHIDAE	■	■			■
			■	■	*Ornithoteutis volatilis*	OMMASTREPHIDAE					■
				■	*Todarodes angolensis*	OMMASTREPHIDAE					■
■	■	■	■	■	*Todarodes filippovae*	OMMASTREPHIDAE	■	■	■	■	■
	■		■	■	*Moroteuthis aequatorialis*	ONYCHOTEUTHIDAE	■				■
	■	■	■		*Opisthoteuthis extensa*	OPISTHOTEUTHIDAE	■	■			■
		■		■	*Opisthoteuthis medusoides*	OPISTHOTEUTHIDAE	■	■			
		■		■	*Psychroteuthidae*	PSYCHROTEUTHIDAE	■	■			
		■			*Psychroteutis glacialis*	PSYCHROTEUTHIDAE				■	
	■	■			*Sepia acuminata*	SEPIIDAE	■				
■	■	■			*Sepia australis*	SEPIIDAE	■	■	■	■	■
	■	■	■	■	*Sepia confusa*	SEPIIDAE				■	■
■					*Sepia hieronis*	SEPIIDAE	■				
■	■				*Sepia incerta*	SEPIIDAE				■	
■		■			*Sepia joubini*	SEPIIDAE	■	■			■
■					*Sepia prashadi*	SEPIIDAE	■	■	■	■	■
	■				*Sepia simoniana*	SEPIIDAE					■
■					*Sepia sp.*	SEPIIDAE		■	■	■	■
		■		■	*Sepia vermiculata*	SEPIIDAE	■			■	■
	■	■	■	■	*Austrorosia mastigophora*	SEPIOLIDAE	■	■	■	■	■
■	■	■	■	■	*Neorossia carolae*	SEPIOLIDAE	■	■	■	■	■
				■	*Spirula spirula*	SPIRULIDAE				■	

important families in terms of species richness were Octopodidae and Sepiidae with ten representatives each. They were followed by Histioteuthidae and Ommastrephidae both of them represented by seven species, and Loliginidae by four species. The remaining families were represented by one or two species only (Figure 2a).

Regarding abundance in weight, Ommastrephidae was the most important family contributing a 78% to the total cephalopod biomass. Sepiidae and Octopodidae accounted for 12% and 6% respectively. Histioteuthidae and Loliginidae contributed 2% each and the remaining 8 families represented less than 1% (Figure 2b). Only seven

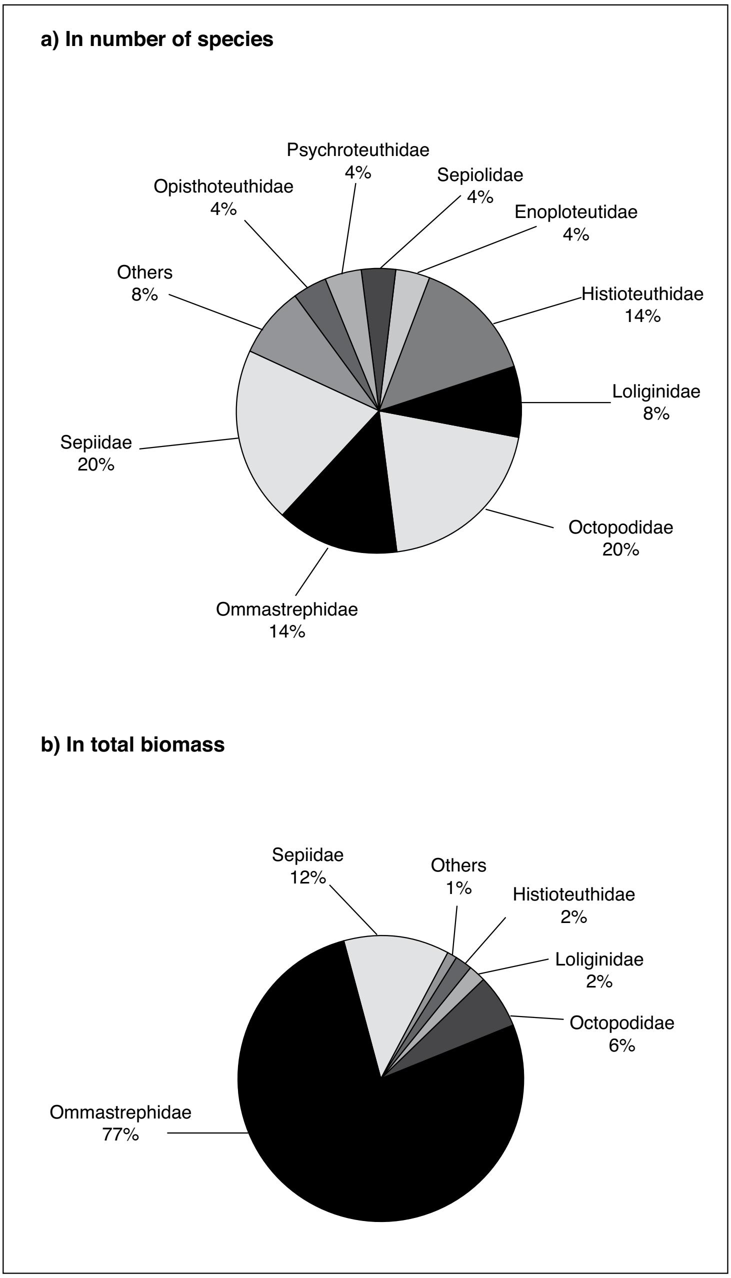

Fig. 2. Relative importance, in species number (a) and total biomass (b) of cephalopod families caught during the cruise "Mozambique 0307"

cephalopod species attained biomass estimates higher than 500 tonnes in the study area. They were: *Nototodarus hawaiiensis* (43,528 t), *Sepia acuminata* (3,590 t), *Veladona togata* (3,294 t), *Sepia confusa* (1,790 t), *Histioteuthis celetaria* (1,134 t), *Uroteuthis duvaceli* (567 t) and *Sepia simoniana* (502 t). Their spatial distribution is represented in Figure 3a-f.

Table 1 also shows the occurrence indices by geographical sector and depth stratum of cephalopod species caught during the cruise. Some of the most common were also the most abundant.

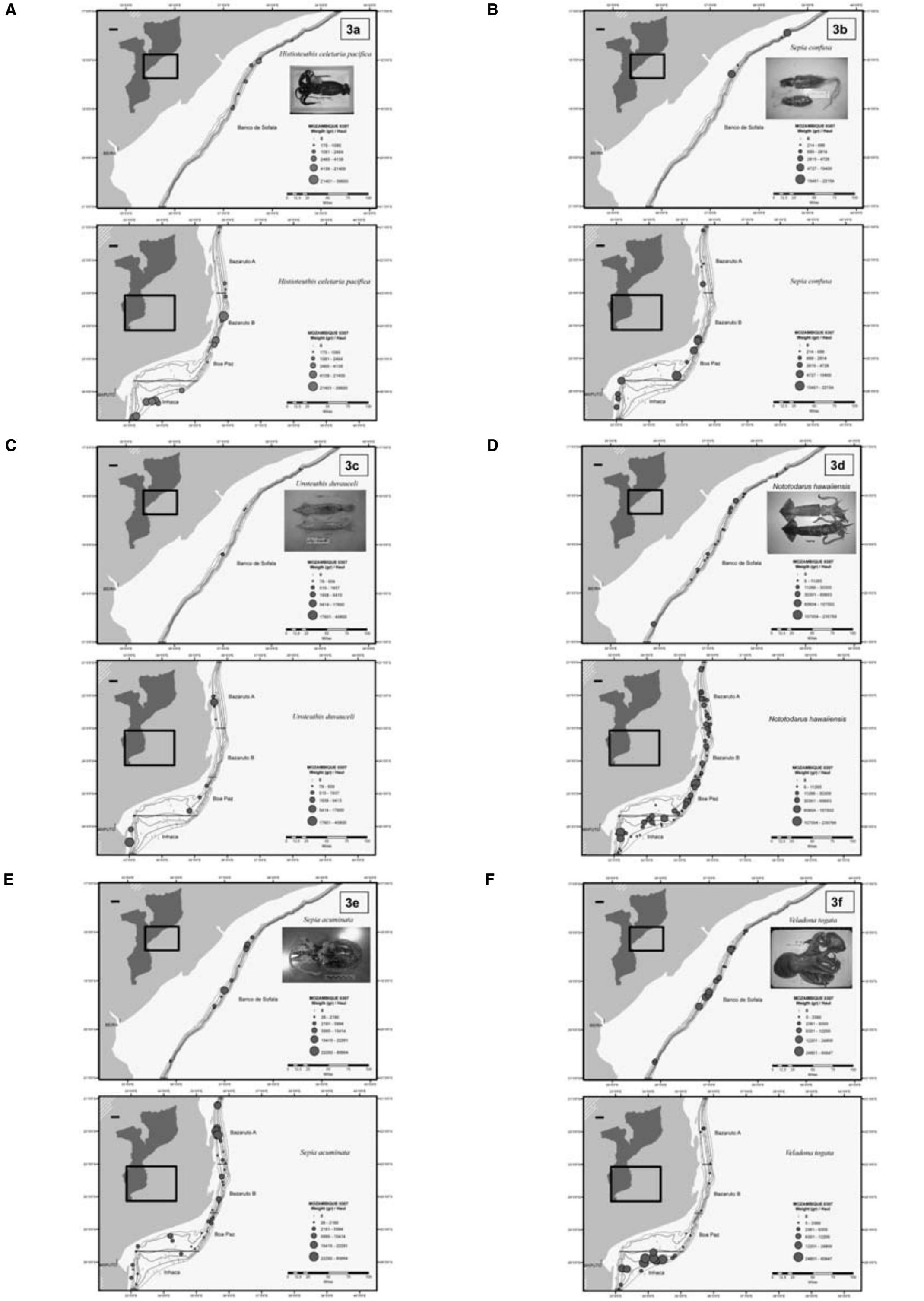

Fig. 3. Spatial distribution of abundance indices (grams/haul) of cephalopod species caught during the cruise "Mozambique 0307": a) *Histiotheutis celetara pacifica;* b) *Sepia confusa,* c) *Uroteuthis duvauceli,* d) *Nototodarus hawaiiensis,* e) *Sepia acuminata* and f) *Veladona togata*

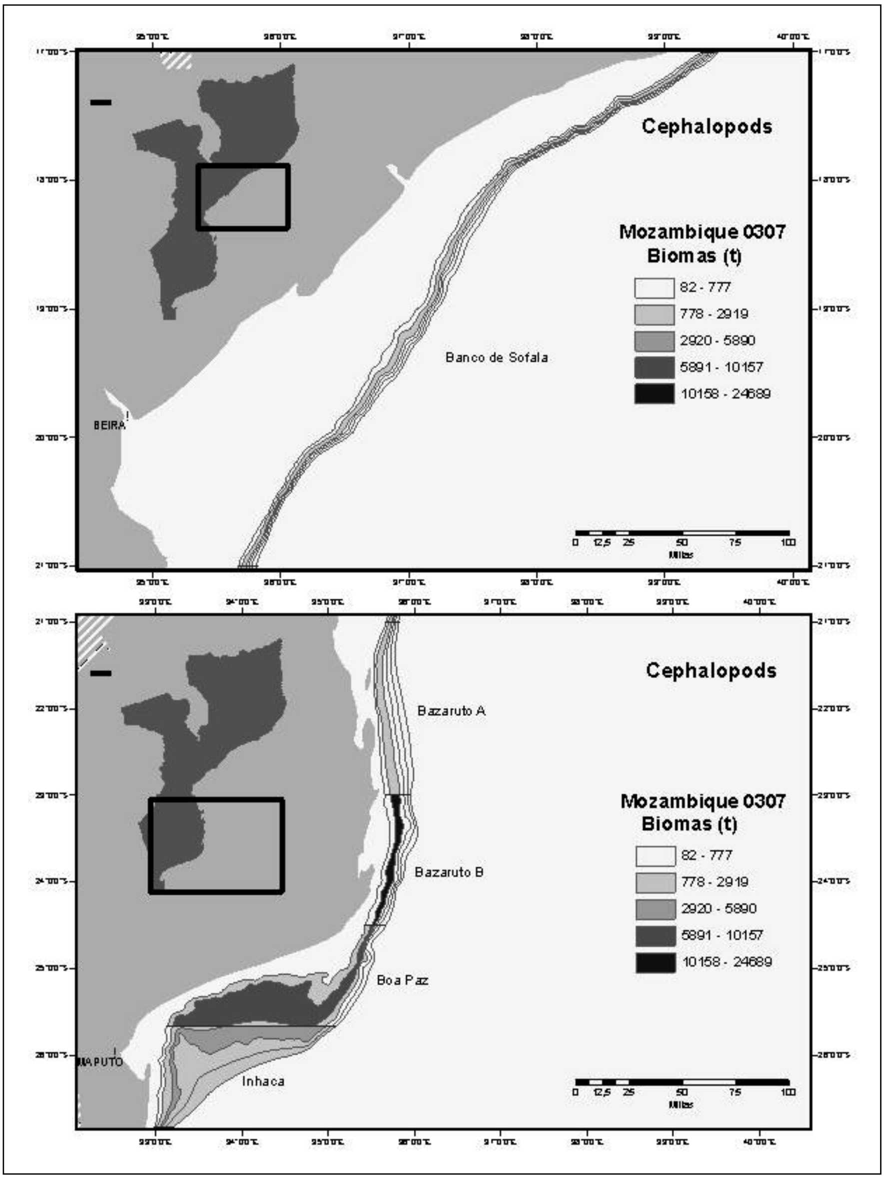

Fig. 4. Distribution by geographic sector and bathymetric stratum, of the total estimated biomass of cephalopods caught during the cruise Mozambique 0307

Nototodarus Hawaiians with an occurrence index of 75%, *S. acuminata* with 43% and *V. togata* with 36%, were present in all sectors and strata. Other common species such as *S. confusa* (occurrence index of 14%), *H. celetaria* (21%), *U. duvauceli* (12%) and *S. simoniana* (7%) seem to have a more restricted distribution but forming concentrations of higher density.

For *S. confusa*, maximum depth range widens up to 450 m in contrast with the findings of Roeleveld, (1972) and Roper & Jereb (2005) recording this species to a maximum depth of 352 m. Rare species like *Amphitretus pelagicus*, belonging to the only genus of the Amphitretidae family, have been found at depths greater than 500 m, both in Sofala (1) and Inhaca (5) zones (Table 1).

Results from the cruise show that, despite all hauls being conducted from depths deeper than 100 m, a total of ten *Sepia* species were identified. Among them, *Sepia acuminata* was the second most abundant cephalopod species in the depth range between 100 and 500 m (see Table 1), greater than reports by Adams & Rees (1966) and Roper & Jered (2005) who found this species at a maximum depth at 369 m.

These results also increase the geographic range into the Western Indian Ocean of *Todarodes filippovae,* a species described by Adam (1975), that shows a circumpolar distribution in the Southern Ocean up to 35º S (Nesis, 1982; Roper, 1984). The capture of one specimen in the deepest stratum (D, 600-700 m) in the Inhaca zone extends the range of the species northwards (to 26º S) in deep zones of the continental slope, greater even than the maximum depth of 500 m cited by Roper *et al*, (1984).

The genus *Pteroctopus*, with one specimen captured in Boa Paz (4) zone, was not previously recorded from Mozambique waters. *P. tetracirrhus* is a Mediterranean species whose characteristics are close to those of the captured specimen. The possibility of a Lessepsian migration (across the Suez Canal) could be considered, because other cases are reported, as for *Sepiola steenstrupiana* described by Rocha *et al*. (1998) from Somali waters. However, the specimen of *Pterotopus* awaits full analysis in order to confirm identification.

The distribution of total estimated biomass of cephalopods by geographic sector and bathymetric stratum shows that the highest values are found in the sectors Bazaruto B and Boa Paz, between 200 and 400 m depth, the former yielding the greatest abundance with a calculated biomass ranging from 5,871 to 10,157 tonnes (Figure 4). Comparative analyses of cephalopod trends in abundance (individuals/km^2), biomass (kg/km^2) and mean individual weight (kg) in relation to depth indicate that the highest concentrations of this fauna in the

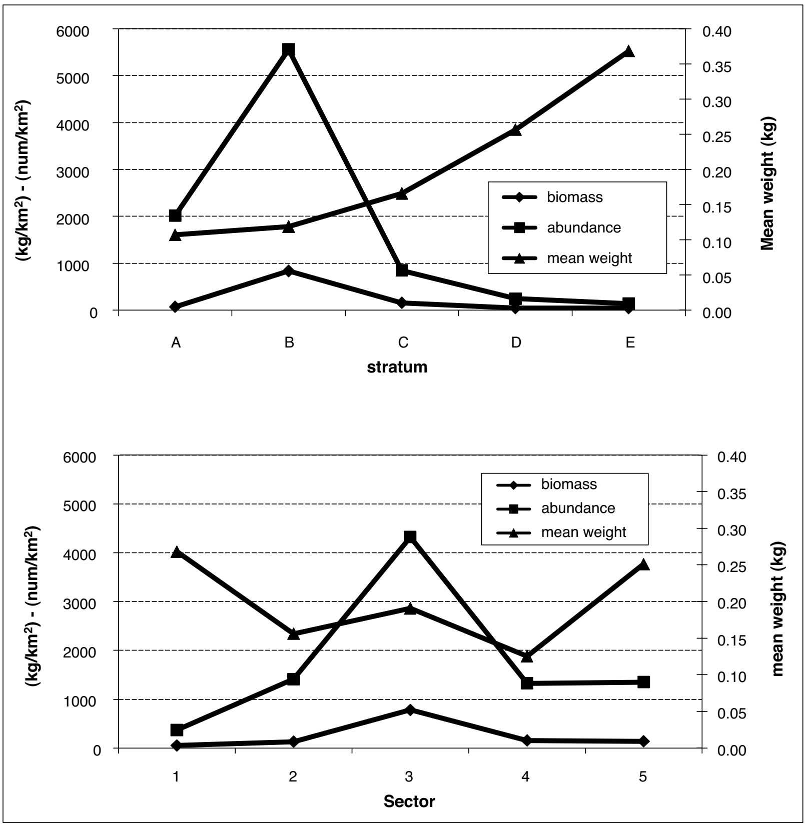

Fig. 5. Trends in abundance (individual numbers/km^2), biomass (kg/km^2) and mean individual weight (kg) in relation to depth and to bathymetric stratum of cephalopod species caught during the cruise "Mozambique 0307". Sectors: 1 – Sofala; 2 – Bazaruto; 3 – Bazaruto B; 4 – Boa Paz; 5 – Inhaca; Strata: A- 100-200m; B – 200-400m; C – 400-500m; D – 500-600m; E – 600-700m

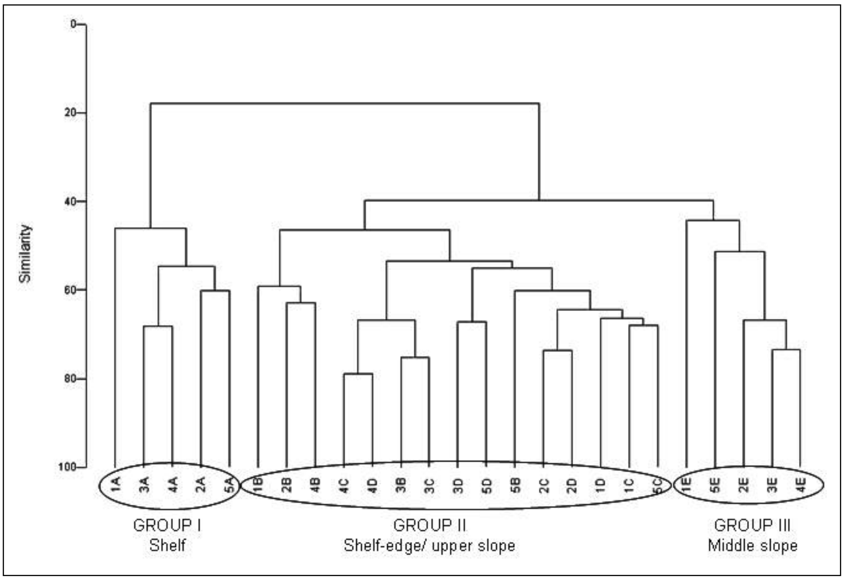

Fig. 6. Dendrogram from cluster analysis showing similarities between average hauls (by sector and strata) based on the composition and abundance of cephalopod species in the "Mozambique 0307" survey

Table 2: Average abundance in grams/haul (Av. Abund.), average similarity (Av Sim.), ratio (Sim/SD), percentage contribution to the grouping and cumulative percentage of each species to each group obtained from the SIMPER analysis of the Mozambique 0308 cruise

Continental shelf group (I), Average similarity: 53.05

Species	Av. Abund	Av. Sim	Sim/SD	Contrib%	Cum. %
Sepia confusa	5487.71	15.53	3.94	29.27	29.27
Se pia simoniana	2691.24	10.91	3.50	20.56	49.84
Uroteuthis duvauceli	4401.57	6.00	1.11	11.31	61.15
Sepia acuminata	1211.80	4.93	1.07	9.30	70.45
Sepia vermiculata	1583.53	4.58	0.96	8.63	79.07
Uroteuthis edulis	479.29	2.61	0.62	4.91	83.99
Nototodarus hawaiiensis	282.20	2.38	0.91	4.48	88.47

Shelf edge -upper slope group (II) Average similarity: 54.03

Species	Av. Abund	Av. Sim	Sim/SD	Contrib%	Cum. %
Nototodaus hawaiiensis	25539.4	23.03	3.22	42.64	42.64
Sepia acuminata	4724.46	8.48	1.55	15.70	58.33
Austrorosia mastigophora	281.31	7.10	2.16	13.14	71.47
Veladona togata	3796.44	5.69	1.01	10.52	82.00
Histioteuthis corona	175.33	2.50	0.66	4.63	86.63
Neorossia carolae	108.77	2.23	0.69	4.13	90.76

Middle slope group (III), Average similarity: 53.75

Species	Av. Abund	Av. Sim	Sim/SD	Contrib%	Cum. %
H. celetaria pacifica	5525.25	14.94	4.96	27.80	27.80
Nototodarus hawaiiensis	5497.62	13.63	2.29	25.35	53.15
Histioteuthis corona	659.59	10.03	8.04	18.66	71.81
Ommastrephidae	206.75	5.06	1.13	9.40	81.21
Neorossia carolae	123.19	3.93	1.13	7.31	88.53
Austrorosia mastigophora	54.56	3.87	1.10	7.19	95.72

area are located between 200 and 400 m (Figure 5) and seem to prove that large individuals tend to distribute in deeper waters. By geographical sector, Bazaruto B shows the highest abundance and mean biomass, with the largest individual weights in Sofala and Inhaca sectors (Figure 5).

The cluster analysis carried out in order to identify cephalopod assemblages indicated three groups, with 46 % of similarity (Figure 6). These ones were: I– "stratum 1 in all sectors", II – "strata 2,3 and 4 in all sectors" and III – "stratum 5 in all sectors". Similarity inside group I is mostly contributed by *S. confusa* (29%) and *S. simoniana* (21%), while in group III species of the genus *Histiotheutis* are the major contributors to group similarity, notably *H. celetaria* and *H. corona* with 27.8% and 18.7%, respectively, and the ommastrephid *Nototodarus hawaiiensis* with 25.3%. And finally, inside group II *Nototodarus hawaiiensis* sustains the similarity inside the group with 42.6%, followed by *S. acuminata* (15.7%), *A. mastigophora* (13.4%) and the octopus *V. togata* (10.5%) (Table 2).

These three cephalopod species assemblages correspond to the bathymetric zones, being continental shelf (I), shelf edge-upper slope (II) and middle slope (III) communities. Unlike depth, latitude does not seem to have influence on the spatial distribution of the species, a feature reported by Quetglas *et al*. (2000) and González & Sánchez, (2002) for the Mediterranean. Smale *et al*. (1993), analyzing the fishes and cephalopods communities

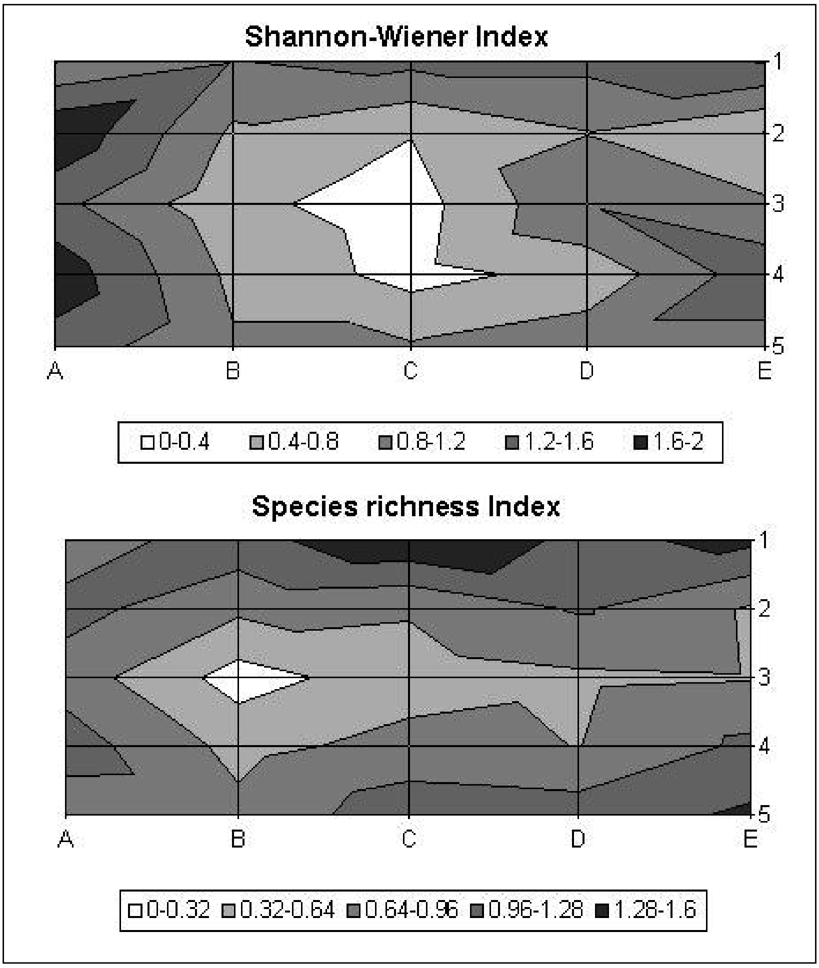

Fig. 7. Representation of the Shannon-Wiener (H) and the species richness (d) diversity indices estimates by sectors and strata

in a near zone (Agulhas Bank, South Africa), concluded that apart from depth, temperature and oxygen concentration have an influence on the distribution of species, though in their study cephalopods were poorly represented.

The diversity indexes (Shannon-Wiener (H) and species richness (d)) show different values in relation to the geographic zones (1-5) and depth strata (A-E), as seen in Figure 7. The highest diversity was found in Sofala (1) followed by Inhaca (5). With respect to bathymetric strata, the highest diversity value was obtained for the inshore stratum (100-200 m), followed by the deepest stratum. The lowest diversity occurs in the middle slope (C stratum) and in the central zone of the surveyed area (Bazaruto B) which shows, on the other hand, the highest abundance (Figure 7). This area is dominated by few species but of very high abundance in some cases, like *Nototodarus hawaiiensis* with a maximum yields in this stratum and zone. Regarding the geographical distribution of this species, Nesis (1984) firstly suggested the possibility of the occurrence in the western Indian Ocean either of a new subspecies of *N. sloani*.or even a new species of this genus. Later, this same author (Nesis, 1986) and Dunning and Förch (1996) confirmed the presence the *N. hawaiiensis* in this area of the Indian Ocean. Probably, those squids recorded in southern African (Agulhas Bank) by Smale *et al*. (1993) as *Nototodarus* sp. could also belong to *N. hawaiiensis*. This species has not been recorded in the Atlantic coast of southern Africa (Sánchez, 1998; Villanueva and Sánchez, 1993).

This first study on Mozambican cephalopods revealed a high diversity among this faunistic group in this zone of the Indian Ocean. Results suggest further research is needed to increase our knowledge and understanding of this group, especially in view of their role in the ecosystem's food chain, their fishery potential, and the abundance estimates for some of the species found.

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