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ASPECTS OF THE BIOLOGY AND FEEDING ECOLOGY OF THE ORBICULATE CARDINAL FISH *SPHAERAMIA ORBICULARIS* (CUVIER, 1828) (TELEOSTEI : APOGONIDAE) IN A KENYAN MANGROVE FOREST

by

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SUMMARY. — The orbiculate cardinal fish *Sphaeramia orbicularis* is the most abundant teleost among the root system of the extensive mangrove forests bordering Gazi bay, Kenya. The species was never recorded from the bay proper and it can thus be considered to be a true mangrove resident. The sampled population clearly consisted of two cohorts : the modes were approximately 65 mm and 80 mm. Most individuals with standard lengths > 40 mm had mature gonads ; the number of eggs ranged from 4 700 to 10 000. *S. orbicularis* are carnivores, mainly feeding on small epi- and hyperbenthic crustaceans. Numerically, gammaridean amphipods and tanaids were the dominant prey categories in the stomachs of both size classes. Individuals belonging to the smaller cohort mainly supplemented their diet with harpacticoid copepods, while larger fishes also fed on postlarval brachyuran crabs and caridean shrimp. The latter two taxa were important prey items in gravimetrical terms. A preliminary analysis of the otoliths revealed 21 stress marks and 20 striations. An attempt to validate these growth rings indicated that the average age of fishes in the samples ranged from 11 (smaller cohort) to 15 (larger cohort) months.

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Introduction

The orbiculate or chubby cardinal fish *Sphaeramia orbicularis* (Cuvier, 1828) is widespread in the tropical and subtropical areas from Pacific and Indian Ocean regions. It typically forms small aggregations in very shallow water (0.1 to 1 m) among mangroves, rocks, debris, or piers of shallow sheltered shorelines (FishBase, 1998) and also occurs in the undercut caves and crevices of submerged coral and lime stone reefs (Allen, 1975 ; Kuiter, 1992). Along the East African coast it has been reported to occur south to Maputo, Mozambique (Smith & Heemstra, 1986). It is distributed north to the Ryukyu Islands (southern Japan), south to Vanuatu and New Caledonia and east to the Caroline, Gilbert and Mariana Islands in Micronesia. The species has further been recorded from the Andaman Islands (India), Singapore, Indonesia, Papua New Guinea, the Philippines, Hong Kong and Taiwan (Allen, 1975 ; FishBase, 1998).

Sphaeramia orbicularis (Actinopterygii, Perciformes, Apogonidae, Apogoninae) has a short, compressed body covered with ctenoid scales. It is characterised by two separate dorsal fins, a large oblique mouth, a well-developed membrane between the last ventral fin ray and the abdomen, an emarginate caudal fin, an anal fin with 2 spines and 9 soft rays, and pectoral fins with 12 soft rays. There are 26 scales along the lateral line. The first gill arch has 24-27 gill rakers. The colour is greenish-grey with a dark vertical (diagonally oriented) bar whose width is about half the eye diameter ; it starts from the origin of the 1st dorsal fin to just in front of the vent (Fig. 1). The maximum size is 10 cm standard length (Allen, 1975 ; Smith & Heemstra, 1986).

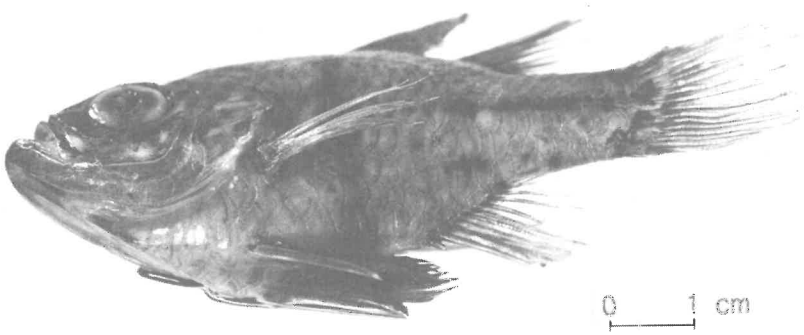


Fig. 1. — *Sphaeramia orbicularis*, 85 mm standard length (male).

Not much is known about the biology of *Sphaeramia orbicularis*. They are paternal mouth brooders (ALLEN, 1975 ; SHAO & CHEN, 1986 ; KUITER, 1992). Courtship and spawning have been reported to occur fortnightly (shortly before new moons and full moons). The average brood size for 72 to 89 mm standard length incubating males ranges from 6 100 to 11 700 eggs. Hatching takes place after 8 days at temperatures between 27 and 30°C (ALLEN, 1975). The larval phase is pelagic and sexual maturity is attained at 7 cm by the males and 6 cm by the females. The only study reporting on its feeding ecology (ALLEN, 1975) was done on a population living in a rather a-typical, man-made environment : a pool-like enclosure with concrete walls on three sides and the floor of a house as a roof (Palau Archipelago, Western Caroline Islands). The species was shown to be an opportunistic carnivore, feeding at night (early evening and just before daybreak), primarily on insects and a variety of benthic and planktonic crustaceans (ALLEN, 1975). Still, it was obvious that many prey were attracted by the lights in the vicinity of the house. The aim of this study was to investigate the diet of *S. orbicularis* in its natural, most typical habitat, i.e. between the roots of mangrove trees. Further, some basic information about the biology of the species is provided.

MATERIAL AND METHODS

Study area

Gazi Bay (Kenya) is located some 50 km north of the Tanzanian border and 60 km south of Mombasa Island (4°22′ S, 39°30′ E). The bay is between 1.75 and 3.50 km wide and 3.25 km long. Samples were taken in the mangrove forest bordering a side creek of the major creek in the eastern part of the bay. This creek has no freshwater input and is characterised by dense seagrass and macro-algae cover. The dominant mangrove species in the proximal vicinity of the sampling spot was *Rhizophora mucronata*, while *Sonneratia alba* and *Avicennia marina* were also present. The most abundant seagrasses were *Enhalus acoroides, Thalassia hemprichii* and *Thalassodendron ciliatum*, while *Halimeda opuntia, Sargassum binderi* and *Gracilaria crassa* were the dominant seaweeds. Average water depth at the sampling spot was 0.4 m (low tide) to 1.1 m (high tide). In the bay proper, the mean tidal range during the sampling period was between 0.8 m (neap tide) and 2.8 m (spring tide) (cf. Tide tables for Kenya ports and Dar Es Salaam Harbours of 1993).

Sampling

Daytime samples were taken on the 11th, 12th and 13th of August 1993 ; both day and night collections were made on the 18th of the same month. Sampling was always done at low tide. Ten fyke nets with the following specifications were used : mesh sizes of 18 mm stretched in the cod-end and 26 mm near the mouth, mouth opening of 0.86 m^2, wing length of 1.77 m. These were installed at low tide in such a way that they closed off a specific area with mangrove trees. On some occasions a dragnet (mesh size 20 mm stretched, length 5 m) was used. Fish were sometimes chased into the fyke nets from between the network of *Rhizophora mucronata* roots where they took refuge. All fishes were immediately anaesthetised in a benzocaine (ethylamino-4-benzoate) solution in seawater to prevent regurgitation of stomach contents and to avoid unnecessary suffering. The samples were then preserved in a 10% formaldehyde-seawater solution. Half of the daysample of August 18 was preserved in 70% ethanol for otolith analysis. Surface water temperature and salinity were measured with a mercury thermometer and a refractometer, respectively. Temperature was 25-26°C and salinity was 35.

Analysis of samples and data analysis

All fish were identified to species level and counted. Both standard length (distance from the tip of the snout to the beginning of the caudal fin) and total length (distance from the tip of the snout to the tip of the caudal fin) of the specimens were measured to the nearest 1 mm. The Bhattacharya method for the detection and separation of cohorts was applied to the length-frequency data. Individuals were pooled into 2 mm size classes prior to analysis. The ashfree dry weight (ADW) of 50 *Sphaeramia orbicularis* was measured to the nearest 1 µg after drying at 60°C for 5 days and burning at 550°C for 2 hours. The sex of fishes was determined after exposing the gonads through slits made along the abdomen. Fecundity was estimated by counting the number of eggs in ripe ovaries extracted from mature females (6 individuals between 62 and 78mm standard length). Otoliths (sagittae) from 16 fishes with known standard length and sex were extracted, fixed on slides, polished with sand paper (numbers 500 and 1000) and cleaned with a piece of soft leather soaked in wet aluminium powder. Stomach content analyses were performed on 60 individuals taken from the modal length classes (see below, 30 individuals were taken from

both day and night samples). All food items in the stomach were identified to a high taxonomic level (Table II). For several small taxa (harpacticoid copepods, ostracods, brachyuran zoeae and megalopae,) assigned dry weight (DW) values, independent of the animal's length, were used. All other animals were measured, and their DW prior to digestion was calculated from length-DW regressions established for animals collected from the same area. SL-DW regressions were established for Gammaridae, Lysianassidae, Corophiidae, Tanaidacea, Aegidae and Caridea. The original size of incomplete prey items was calculated from regressions relating the length of unbroken parts, e.g. head capsule, urosome, pleosome, telson or carapace, to total length. Food composition is expressed as gravimetric percentage (%G) :

$$\%G = \frac{\text{DW prey type i}}{\text{total DW of the ingested food}} \times 100$$

which can be converted into energy units or to g carbon, as numerical percentage (%N) :

$$\%N = \frac{\text{number of items of prey type i}}{\text{total number of prey items ingested}} \times 100$$

and as percentage frequency (%F), i.e. the percentage of stomachs in which a certain prey item occurs.

Results and discussion

The fish fauna of Gazi Bay has been studied intensively between 1991 and 1996. A variety of sampling gear has been deployed in all important habitats of the bay proper and in the major creeks intersecting the mangrove forests (Van der Velde *et al.*, 1994 ; Kimani *et al.*, 1996 ; De Troch *et al.*, 1996, 1998). An up-to-date species list is presented in Wakwabi & Mees (submitted). This is the first study to report on fishes present between the root system of the mangrove trees bordering Gazi Bay. A total of 1351 fishes (22 species belonging to 13 families) were collected from between the mangrove roots, 95.6% of which were *Sphaeramia orbicularis* (Table 1). This species has rarely been caught in the bay proper ; it can thus be considered to be a true mangrove resident.

Table I

List of fish species caught with fyke nets in the mangrove creeks of Gazi Bay.

Family	Species	% Abundance
Apogonidae	*Apogon guamensis*	0.15
	Apogon nigripes	0.07
	Sphaeramia orbicularis	95.86
Acanthuridae	*Acanthurus nigrofuscus*	0.15
Chaetodontidae	*Chaetodon auriga*	0.07
	Chaetodon fulcula	0.07
Gerridae	*Gerres oyena*	0.22
Holocentridae	*Neoniphon sammara*	0.15
Labridae	*Coris aygula*	0.37
	Coris formasa	0.07
Lethrinidae	*Lethrinus harak*	0.07
	Lethrinus lentjan	0.07
Lutjanidae	*Lutjanus argentimaculatus*	0.15
	Lutjanus ehrembergi	1.11
	Lutjanus fulviflamma	0.07
Pomacentridae	*Neopomacentrus fulignosus*	0.15
Scaridae	*Scarus sordidus*	0.15
	Scarus psittacus	0.07
Siganidae	*Siganus stellatus*	0.37
	Siganus sutor	0.07
Sphyraenidae	*Sphyraena putnamiae*	0.15
Theraponidae	*Pelates quadriliniatus*	0.15

Table II

Diet composition of Sphaeramia orbicularis in Gazi Bay.

Taxon	Number of items recorded		Percentage frequency	
	Day	Night	Day	Night
Amphipoda, Gammaridea	61	261	70	100
Tanaidacea	99	5	23	14
Copepoda, Harpacticoida	16	52	27	43
Caridea	25	17	47	50
Isopoda	9	38	20	54
Brachyura, megalopae	3	19	10	39
Ostracoda	2	13	7	29
Brachyura, zoeae	10	1	7	3.5
Gastropoda	2	8	7	14
Cumacea	—	7	—	14
Amphipoda, Caprellidea	4	1	7	3.5
Mysidacea	3	1	7	3.5
Brachyura, postlarvae	1	2	3	7
Fish larvae	2	1	7	3.5
Polychaeta	—	2	—	3.5
Leptostraca	—	2	—	3.5
Stomatopoda	—	2	—	7
Pycnogonida	1	—	3	—

Sphaeramia orbicularis : some basic data

During sampling time the fishes were aggregated and resting among the rhizophores. Both during daytime and at night, they were relatively inactive, performing few movements over very short distances (0.5 - 2 m). The fish were observed to be more active during the late afternoon and the early morning (dusk and dawn), moving out of their hiding places into the open areas of the creek and around seaweed and seagrass beds. Local density was estimated at 11 individuals per m^2. A sex ratio of 1 :1 was observed. Size ranged from 34 to 91 mm standard length (the factor to convert standard length to total length is 1.35). Length-frequency distributions of both males and females were bimodal (Fig. 2). The modes were approximately 65 mm for the smaller cohort and 80 mm for the larger cohort. The length-ashfree dry weight regression was found to be $ADW = 0.0002 + 4.526SL$ ($p < 0.001$, $N = 49$). Note that this regression has limited applicability as it is derived from fish taken from a narrow size range (42-80 mm SL). Most of the fishes of both cohorts had mature or almost mature gonads. All individuals of > 40 mm SL were mature. This is considerably smaller than the length at maturity of 60-70 mm SL reported by ALLEN (1975). The number of eggs per egg mass for mature ovaries ($N = 6$, 62-78 mm SL) ranged from 4,712 to 10,031. This is comparable to the numbers reported by ALLEN (1975). The average diameter of a ripe egg was 0.4 mm. Two types of growth rings were observed on the otoliths. About 21 widely spaced (44 µm) stress marks separated by some 20 closely packed (2 µm) striations were observed (Fig. 3). The standard length of a newly hatched *Sphaeramia orbicularis* is 3.3 mm, and the smallest postlarvae measure around 10 mm (ALLEN, 1975). The average growth rate of 12 mm long postlarval fish is around 4.5 mm per month and juveniles ranging from 12 to 20 mm SL grow at a rate of 4.81 mm per month (ALLEN, 1975). The time taken by a fish to enter the postlarval phase equals approximately 45 days and the age of a 55 mm individual can be estimated to be 10.9 months. The number of stress marks observed in the sagitta of a 55 mm individual (21) approximates the number of neap and spring tides for an 11 month period. Individuals belonging to the smaller and larger cohort may thus be approximately 11 and 15 months old, respectively. The validation of the small striations between the stress marks is more complicated. They probably are daily growth rings, but this leaves eight days per lunar month during which no growth increment is recorded in the otolith. This is not necessarily due to counting errors but can

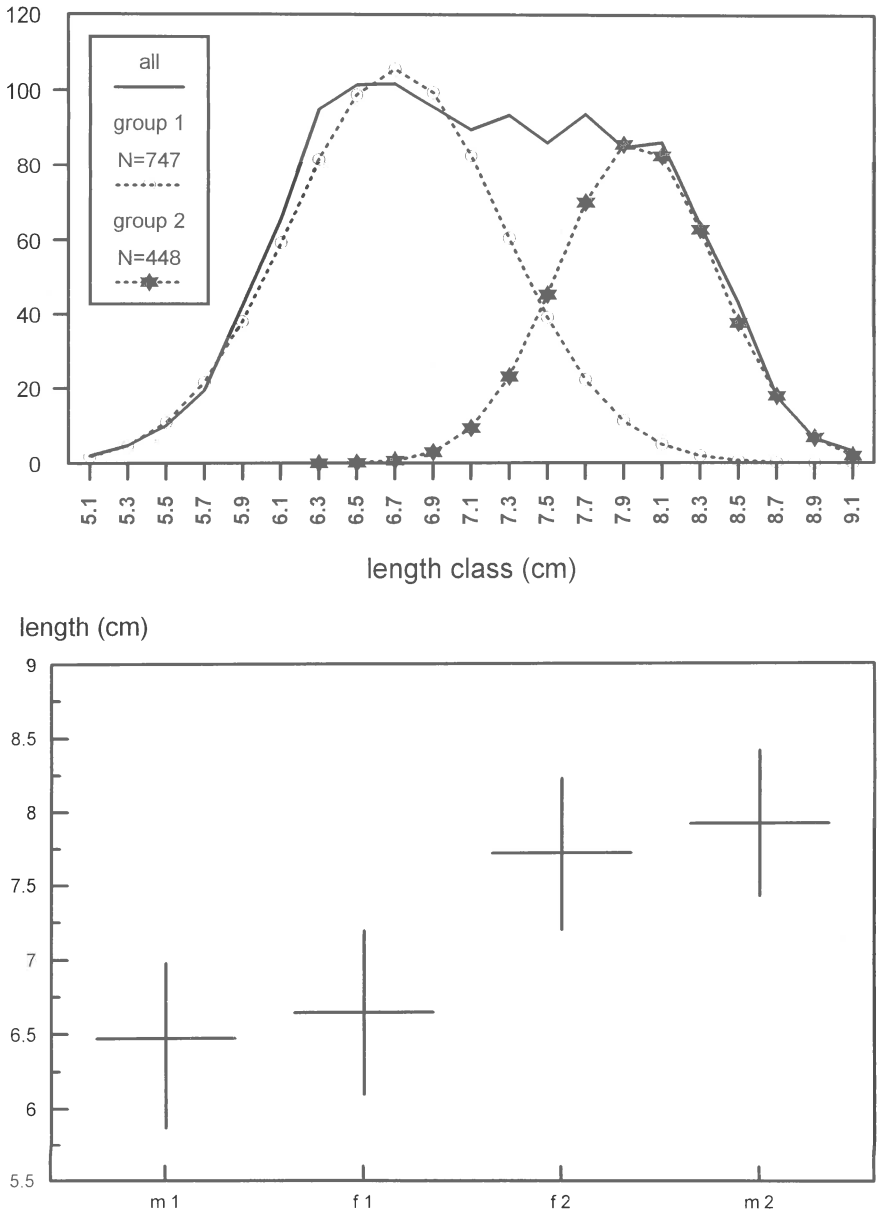
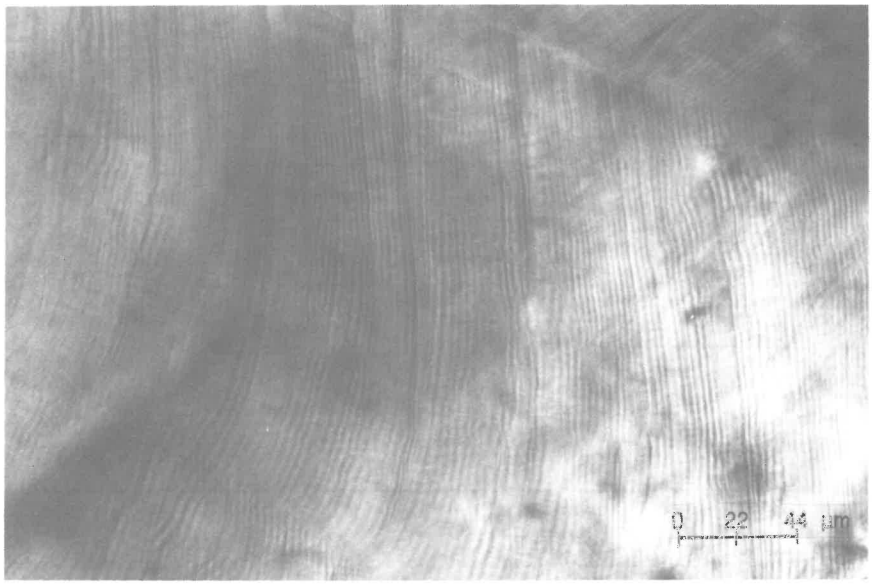


FIG. 2. — Length-frequency distribution of *Sphaeramia orbicularis*. Top : normal distributions fitted to the composite distribution with the Bhattacharya method. Bottom : mean length and standard errors of males (m) and females (f) of the smaller (1) and larger (2) cohorts.

a



b

FIG. 3. — Sagitta of a female *Sphaeramia orbicularis* of 55 mm SL : (a) entire sagitta, (b) detail of the growth rings.

be due to poor feeding conditions or increased predation pressure related to the neap-spring tidal cycle.

Feeding

The fish used for stomach content analyses were selected on the basis of the observed bimodal length distributions and the sex ratio : from both day and night samples fifteen males and fifteen females were analysed from each mode (i.e. from the modal length classes of the smaller and larger cohorts). A total of 18 prey categories were recorded from the stomachs of 60 *Sphaeramia orbicularis* (Table II). Only two stomachs of the day time samples contained no food and were excluded from further analyses. Numerical and gravimetrical diet composition is presented for each cohort in Fig. 4 and the frequencies of occurrence of the different prey categories are presented in Table 2. For both size classes, the stomachs contained more food items at night. During the day, fish belonging to the smaller cohort mainly fed on gammaridean amphipods, tanaids, small postlarval carideans and harpacticoid copepods, while fish of the larger cohort preyed almost exclusively on tanaids, supplementing their diet with few gammaridean amphipods and carideans. During the night, smaller individuals mainly took amphipods and harpacticoids (and a few isopods), while larger individuals fed almost exclusively on amphipods. In gravimetrical terms, Amphipoda Gammaridea and Caridea contributed for more than 95% to the diet of both cohorts during daytime and of the smaller cohort at night. Brachyuran crabs were also important (40% gravimetrically) in the diet of the larger cohort at night. *S. orbicularis* is an opportunistic carnivore, exploiting a variety of small epibenthic, hyperbenthic and planktonic prey. They are probably crepuscular feeders. The stomach contents of fishes sampled at night then reflect the feeding activities performed during the previous dusk.

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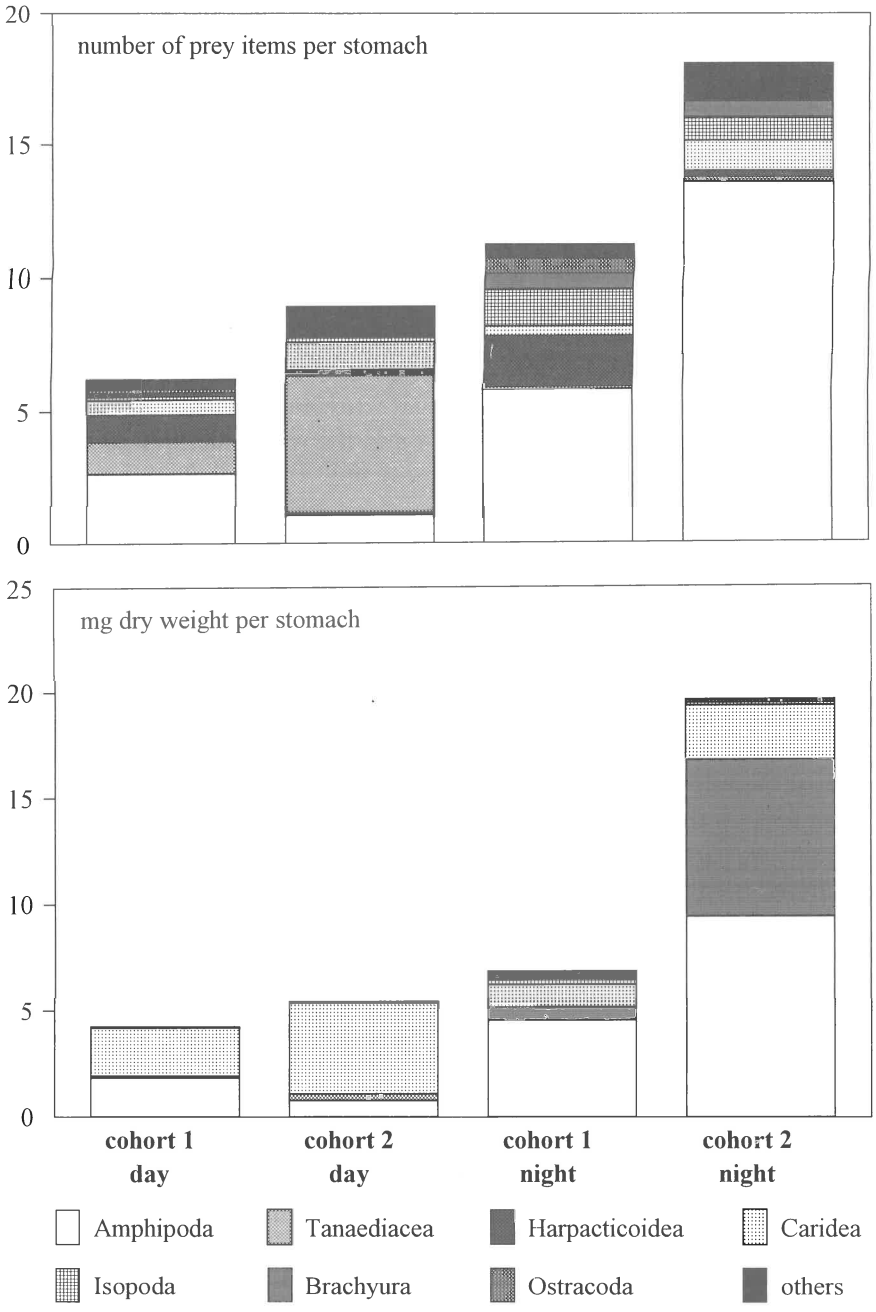

FIG. 4. — Numerical (top) and gravimetrical (botom) composition of the diet of both cohorts of *Sphaeramia orbicularis* sampled during day time and at night.

References

Allen, G.R. (1975). The biology and taxonomy of the cardinalfish, *Sphaeramia orbicularis* (Pisces ; Apogonidae). *J.R. Soc. W. Austr.* **58** : 86-92.

De Troch, M., Mees, J.,. Papadopoulos, I. & Wakwabi, E.O. (1996). Fish communities of Gazi bay (Kenya) : seagrass beds vs. unvegetated areas. *Neth. J. Zool.* **46** : 236-252.

De Troch, M., Mees, J. & Wakwabi, E.O. (1998). Diets of abundant fishes from beach seine catches in seagrass beds of a tropical bay (Gazi Bay, Kenya). *Belg. J. Zool.* **128** : 123-142.

Fishbase, (1998). *FishBase 98 CD-ROM*. ICLARM, Manila.

Kimani, E.N., Mwatha, G.K., Wakwabi, E.O., Ntiba J.M. & Okoth, B. (1996). Fishes of a shallow tropical mangrove estuary, Gazi, Kenya. *Mar. Freshw. Res.* **47** : 857-868.

Kuiter, H. R., (1992). Tropical Reef-Fishes of the Western Pacific : Indonesia and adjacent waters. Penerbit Pt Gramedia Pustaka Utama, Jakarta, Indonesia. 314pp.

Shao, K.-T. & Chen, J.-P. (1986). Ten new records of cardinalfishes from Taiwan, with synopsis of the family Apogonidae. *J. Taiwan Mus.* **39** : 61-104.

Smith, M.M. & Heemstra, P.C. (1986). *Smiths' Sea Fishes*. Springer-Verlag, Berlin. 1047pp.

Van der Velde, G., Van Avesaath, P.H., Ntiba, M.J., Mwatha, G.K., Marguiller, S. & Woitchik, A.F. (1994). Fish fauna of mangrove creeks, seagrass meadows and sand flats in Gazi Bay : a study with nets and stable isotopes. In : *Interlinkages between Eastern-African Coastal Ecosystems*, second semi-annual report on the E.C. STD-3 project, Yerseke, The Netherlands : 28-37.

Wakwabi, E.O. & Mees, J. submitted. The ichthyofauna of a tropical mangrove bay (Gazi Bay, Kenya). *Belg. J. Zool.*