FEEDING HABITS OF *OPHICHTHUS RUFUS* (ANGUILLIFORMES, OPHICHTHIDAE) IN THE WESTERN MEDITERRANEAN

by

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ABSTRACT. - *Ophichthus rufus* (Rafinesque, 1810) is a Mediterranean benthic fish with nocturnal habits. It lives in sand or mud bottoms at depths between 50 and 150 m. Until now, nothing about its feeding habits was known. Stomach contents of 689 individuals, collected between 1985 and 1987, were analyzed. The diet is basically composed of benthic organisms, among which the decapods *Processa canaliculata* and *Alpheus glaber* and the teleost fish *Callionymus maculatus* are prominent. Young of both sexes and adult males have an euryphagic carnivorous diet, whereas adult females are closer to a stenophagic piscivorous diet.

RÉSUMÉ. - *Ophichthus rufus* (Rafinesque, 1810) est un poisson benthique méditerranéen, aux habitudes nocturnes, qui fréquente les fonds sablo-vaseux à une profondeur comprise entre 50 et 150 mètres. Son régime alimentaire n'avait pas encore été étudié. Les contenus stomacaux de 689 exemplaires, capturés entre 1985 et 1987, ont été examinés. Le régime alimentaire est principalement composé d'animaux benthiques, parmi lesquels les Décapodes *Processa canaliculata* et *Alpheus glaber*, et le Téléostéen *Callionymus maculatus*, sont les proies principales. Les jeunes des deux sexes et les mâles adultes sont des poissons carnivores euryphages, tandis que les femelles adultes sont essentiellement sténophages ichthyophages.

Key-words. - Ophichthidae, *Ophichthus rufus*, MED, Feeding habits.

Ophichthus rufus (Rafinesque, 1810), the Rufus snake eel, is a benthic species exclusively distributed in the Mediterranean. Along the north-eastern coast of Spain it is usually found in sand or mud bottoms at depths of between 50 and 150 m (Matallanas, *in* Sostoa, 1990). It has an almost cylindrical snake-like body which is of similar thickness from head to tail. The body is scaleless and has long dorsal and anal fins, which do not reach to the tip of the tail. There is no caudal fin. The relatively small mouth extends behind the eye, which is small and covered by the skin. The species has nocturnal habits. During the day it buries itself, using its tail, in the mud, and emerges to feed only during the night (Tortonese, 1970).

Very few studies have been carried out on the genus *Ophichthus* (McCosker, 1977), and even fewer on the species *O. rufus*. Some references concern only its size and distribution (Tortonese, 1960; Fischer *et al.*, 1987) and breeding period (Spartà, 1937), but nothing is known about its feeding habits.

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MATERIALS AND METHODS

Samples were obtained, always during daylight and from between 90 and 120 m depth, by professional trawling in a region of sandy-mud bottom called "Els Capets", located near Blanes (Costa Brava, Catalan Sea), with a total area of approximately 24 km^2. A total of 689 individuals, collected between 1985 and 1987, were analysed. Data were grouped into months regardless of year, in order to increase sample size, except for June when no individuals were available.

Fish were fixed on board ship in 10% formalin and stored in 4% formalin. The total length (TL) of each specimen was recorded. Stomachs were removed from measured and sexed fish, then opened, and their contents were stored in 70% alcohol for sorting and identification. Prey was identified to the lowest possible taxon and specimens per taxon were counted and weighed. Wet mass was used, thereby implying higher experimental error, but correlation between wet and dry mass is very high (Glenn and War, 1968). Because of differential prey digestion rates, the weight of prey fractions found was recorded even if they were considerably digested.

The contribution of each type of food to the diet was expressed as the percentage of frequency of occurrence, OC% (percentage of stomachs with a specific species or taxonomic group, in relation to number of stomachs with food), numerical percentage N% (percentage of specimens of a particular species or taxonomic group, in relation to total number of specimens), weight percentage W% (percentage in weight of all specimens of a particular taxonomic group in relation to total weight of all the prey items), average number percentage per stomach N%m, average weight percentage per stomach W%m, and the index of relative importance IRI = %OC (N% + W%) (Pinkas *et al.*, 1971). The total number of stomachs analyzed NUM ST, the number of empty stomachs EMPT ST, the average number of prey individuals per stomach Nm/ST, the average weight of stomach contents Wm/ST, the vacuity coefficient VAC COEF (or percentage of empty stomachs) (Hureau, 1970), the average index of feeding intensity FEED INT (or percentage of stomach contents weight in relation to the total fish weight) (Aoyama, *in* Yasuda, 1960), and the Shannon diversity index H' (which is a measure of the diet amplitude) (Shannon-Weaver, 1963), were also computed (Table I).

Prey was classified using Hureau's Q nutrition coefficient (Q = N% + W%) (1970) and the Geistdoerfer (1975) terminology. All calculations were made with the "REGIM" program (Moreno-Amich, 1985).

In order to identify changes in the diet of *Ophichthus rufus* with body size, 5 size groups were established as follows: Size 1- TL < 250 mm. Size 2- TL between 250-310 mm. Size 3- TL between 310-400 mm. Size 4- TL between 400-490 mm. Size 5- TL > 490 mm. Table II summarizes the number of specimens examined per month and size class.

RESULTS

General diet composition

The qualitative and quantitative composition of the annual diet of this species is given in table I. Of the 689 stomachs analysed, 496 were empty, indicating a very high vacuity coefficient (71.99%).

The general diet was almost totally dominated by benthic prey, while bathypelagic and benthopelagic species were of secondary importance. The most frequent prey was the

Table I. - Qualitative and quantitative composition of *Ophichthus rufus* diet. Num.st. = total number of stomachs analysed; Empt.st. = number of empty stomachs; Vac.coef. = vacuity coefficient; Feed int. = average index of feeding intensity; H' = Shannon diversity index; Nm/ST = average number of prey individuals per stomach; Wm/ST = average weight of stomach contents; OC% = frequency of occurrence; N% = numerical percentage; N%m = average number percentage per stomach; W% = weight percentage; W%m = average weight percentage per stomach; IRI = index of relative importance.

NUM.ST. 689	EMPT.ST. 496	VAC.COEF. 71.99	FEED INT. 0.5898	H' 1.64	Nm/ST 1.25	Wm/ST 0.2924
	OC%	N%	N%m	W%	W%m	IRI
Arthropoda	40.93	35.27	39.38	13.52	39.57	2201.82
Cl. Crustacea	40.93	35.27	39.38	18.52	39.57	2201.82
O. Euphausiacea	4.66	3.73	4.66	0.76	4.66	20.95
Meganyctiphanes norvegica	3.63	2.90	3.63	0.54	3.63	12.48
O. Isopoda	0.52	0.41	0.52	0.03	0.52	0.23
O. Decapoda	25.39	22.82	23.33	16.41	24.54	996.05
Decapoda Natantia	21.24	19.50	19.69	15.21	20.40	737.51
Alpheus glaber	5.18	4.15	4.15	1.61	4.33	29.86
Processa canaliculata	8.29	8.71	7.77	7.40	8.09	133.57
Processa mediterranea	2.07	1.66	2.07	2.71	2.07	9.06
Processa sp.	5.70	4.56	5.18	2.04	5.38	42.18
Solenocera membranacea	0.52	0.41	0.52	0.66	0.52	0.55
Mollusca	1.55	2.90	0.00	15.63	0.52	28.81
Cl. Cephalopoda	1.04	2.49	0.00	15.63	0.52	13.78
Ommastrephes sagittatus	0.52	2.07	0.00	15.57	0.47	9.14
Cl. Bivalvia	0.52	0.41	0.00	0.00	0.00	0.21
Pisces Teleostei	32.64	27.39	30.57	58.40	31.42	2800.37
Callionymus maculatus	2.07	1.66	2.07	3.05	2.07	9.76
Lesueurigobius friesii	0.52	0.41	0.00	0.52	0.40	0.48
Gadiculus argenteus	0.52	0.41	0.52	0.68	0.52	0.57
Merluccius merluccius	1.04	0.33	0.52	3.29	0.56	4.26
SbO. Stomiatoidei	1.04	0.83	1.04	3.11	1.04	4.08
Engraulis encrasicholus	0.52	0.41	0.52	6.40	0.52	3.53
Argyropelecus hemigymnus	0.52	0.41	0.52	1.33	0.52	1.16
Glossanodon leioglossus	1.04	1.66	0.52	5.14	0.93	7.05
Argentina sphyraena	0.52	0.41	0.52	0.72	0.52	0.59
Deltentosteus quadrimaculatus	1.04	0.83	0.52	1.62	0.63	2.54
Benthic organisms	26.42	24.07	23.32	23.86	24.58	1266.33
Benthopelagic organisms	1.04	2.49	0.52	16.25	0.99	19.42
Pelagic organisms	0.52	0.41	0.52	6.40	0.52	3.53
Bathypelagic organisms	5.70	5.39	5.18	8.23	5.59	77.67
Unidentified	26.42	21.16	26.42	4.20	25.91	670.29

Table II. - Number of specimens of *Ophichthus rufus* examined per month and size class (mm).

	< 250	251-310	311-400	401-490	> 490	Total
January	0	7	18	40	11	76
February	0	15	31	45	8	99
March	1	6	97	102	20	226
April	0	9	17	28	2	56
May	0	8	10	9	0	27
June	-	-	-	-	-	-
July	1	0	4	25	6	36
August	1	3	10	18	6	38
September	0	0	3	15	4	22
October	0	0	4	25	12	41
November	0	1	5	5	2	13
December	1	2	5	5	1	14

Crustacea Decapoda *Processa*, mainly *P. canaliculata*, with %OC 8.29, followed by the other Decapoda species *Alpheus glaber* with %OC 5.18. Lowest frequencies were showed by euphausids (*Meganyctiphanes norvegica*) with %OC 3.63. The most frequent prey species among the Teleostei was *Callionymus maculatus* with %OC 2.07. As for the index of relative importance (IRI), *Processa canaliculata* (and *Processa sp.*) was the most important prey, followed by *Alpheus glaber*, *Meganyctiphanes norvegica*, *Callionymus maculatus*, *Processa mediterranea* and another Teleostei species, *Glossanodon leioglossus*.

In relation to the average weight percentage per stomach, prey importance followed the same order, and in feeding coefficient (Q) *Processa canaliculata* (Q= 64.38) was much higher than other species, which had a Q value below 20.

In terms of frequency of occurrence and numerical percentage, Crustacea (%OC 40.93, N% 35.27, respectively) constituted the most important prey group, closely followed by Teleostei (%OC 32.64, N% 27.38, respectively). By weight, however, Teleostei were more important, with a weight 3 times higher than that of Crustacea. According to the index of relative importance (IRI), the most important prey group was Teleostei (though a large number of teleosts were not identifiable because of a high degree of digestion) followed closely by Crustacea, whereas Annellida and Cephalopoda were of secondary importance.

Monthly variations in diet

H' diversity index maintained high values from January to August, exhibiting maxima in April and August. Extremely low values were found from September to December, probably coinciding with the species' winter rest after breeding (Fig. 1b). In comparison, feeding intensity was low from January to May, but reached a sudden maximum in July, when the species gets ready for breeding, and returned progressively to low values after this month.

The vacuity coefficient showed highly significant differences throughout the year ($\chi^2 = 39.7$, d.f. = 10, $p < 0.0001$). Two maxima occurred, one between January and March and another in May, i.e., winter and spring. The vacuity coefficient began to decrease in summer and remained low until December (see Fig. 1a).

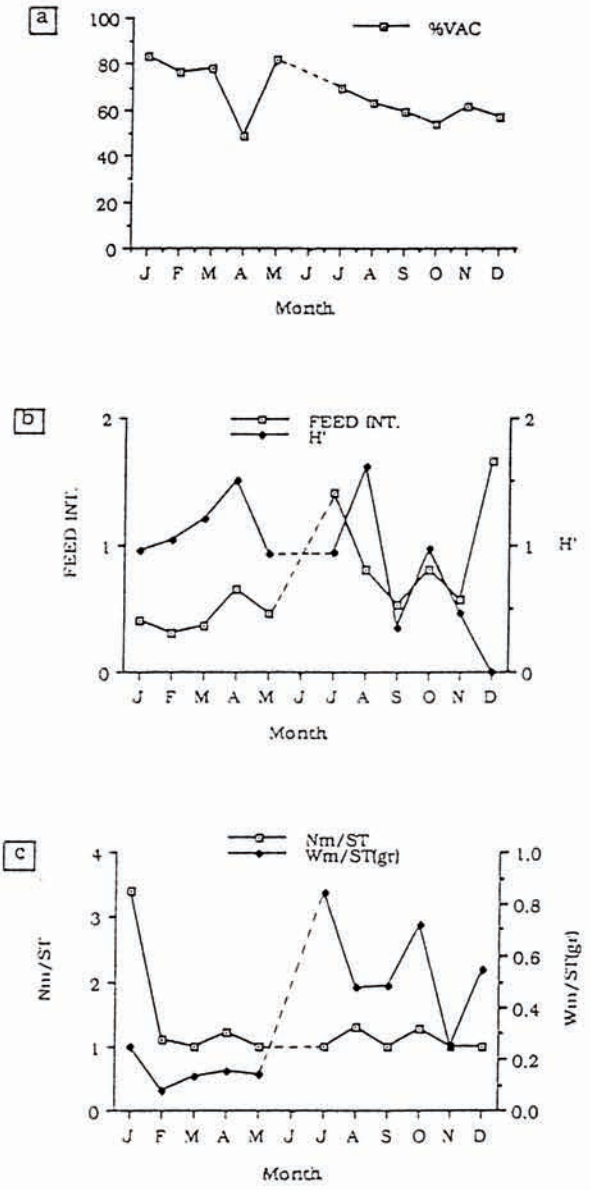

Fig. 1. - Monthly variations in the diet of *Ophichtus rufus* (except June): a- vacuity coefficient; b- feeding intensity and Shannon's diversity index (H'); c- average number of prey individuals for stomach (Nm/ST) and average weight of stomach contents (Wm/ST). Number of specimens analysed per month are indicated on table II.

Average prey number per stomach was extremely constant throughout the year (Fig. 1c), apart from the maximum in January. The average prey weight, on the other hand, was low during January-May, increased sharply in June and remained high until December. From January to May-June, Crustacea predominated (in %OC), whereas from July the situation was reversed and Teleostei began to dominate. This fact may account for the sudden change in the average prey weight per stomach, since Teleostei are the largest prey.

Benthic species clearly predominated during the whole year, but the diet was complemented by pelagic prey from January to September and occasionally by some bentho-pelagic species in January and October-November. *Alpheus glaber* was the predominant crustacean between January and March, and *Processa canaliculata* from April to July. The only fish species which appeared regularly during the year was *Callionymus maculatus*. The remaining fish species appeared occasionally, with pelagic species predominating in August, September and October.

Diet variations according to size

The total length of specimens ranged from 23 to 60.5 cm. Only females of this species, however, reach maximum length; the largest males reach 36 cm. Size 1 corresponded to young individuals, mainly males. Size 2 contained the largest proportion of adult males (68%) and a small proportion of adult females (2%). The largest adult males (19%) and the first large groups of adult females (49%) were found in size 3. Sizes 4 and 5 included only adult females (Table II). As the days become longer the fishing-time increases and the greater catching effort is reflected by an increase in the total number of specimens obtained from January to March. The opposite situation is observed from October to December.

The average number of species prey (N%m) increased progressively to size 3, where there was a clear maximum, but decreased in size 4 before a further increase in size 5 (Fig. 2c). At the same time, feeding diversity (H') reached a maximum in size 3 (Fig. 2b), suggesting that this size, between 31-40 cm, is a specially active period in the life of this species in which maximum effort is expended on seeking food. This size group includes the first large group of mature adult females and the group of largest males. Bearing in mind that, in the following size group, where males practically disappear, both feeding intensity and average prey number per stomach decreased considerably, the maximum found in size 3 may have been due to adult males and therefore new maxima found in size 5 would correspond exclusively to adult females.

Average prey weight per stomach (W%m) increased constantly from the smallest individuals to the largest (Fig. 2b). The vacuity coefficient (Fig. 2a) shows no significant differences in the various size groups ($\chi^2 = 6.52$, d.f. = 4, $p = 0.1635$), even though a progressive decrease is observed with size.

DISCUSSION

The high vacuity coefficient (72%) and the high number of unidentifiable prey (26.42%) found in the diet of *Ophichthus rufus*, could be related to its feeding habits; the maximum activity of this species is registered in the early hours of the night and when specimens were caught, in the early morning, part of the stomach content may have been totally or partially digested (no everted stomachs were found).

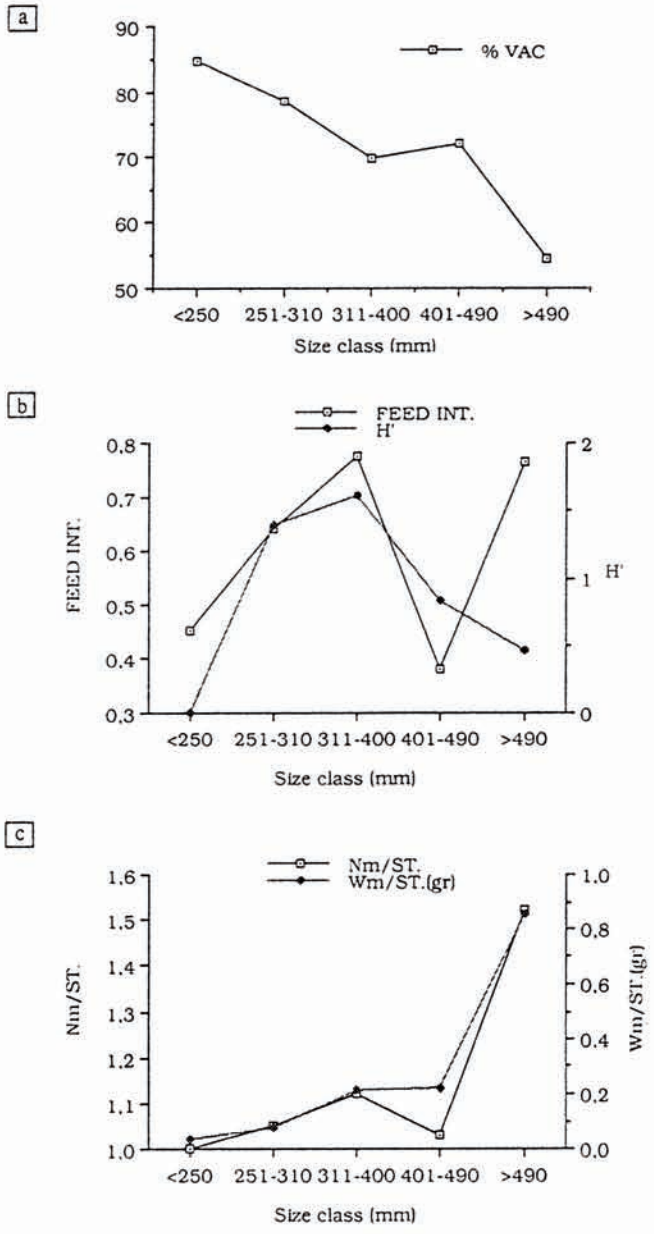

Fig. 2. - Diet variations of *Ophichthus rufus* in relation to size (cm, TL): a- vacuity coefficient; b- feeding intensity and Shannon's diversity index (H'); c- average number of prey individuals for stomach (Nm/ST) and average weight of stomach contents (Wm/ST).

Table III. - Ecological classification of prey found in the stomachs of *Ophichthus rufus*. Depths in metres. System: batP = bathypelagic, B = benthic, P = pelagic, B-P = benthopelagic. Fauna: IN = infauna. Reproduction period: W = winter, Sp = spring, S = summer, A = autumn. * Except for July and September.

Species	Depths (metres)	System	Fauna	Reproduction period	Vertical migration
Euphausiacea					
Meganyctiphanes norvegica	400-900	batP		April (end W-Sp)	+ till 100m
Decapoda					
Processa canaliculata	30-400	B	IN	February	
Processa mediterranea	50-410	B	IN	W-Sp-S-A *	
Alpheus glaber	30-550	B	IN	March and August	
Solenocera membranacea	100-400	B	IN (gallery)	Sp (W)	+
Cephalopoda					
Ommastrephes sagittatus	50-740	B-P			
Teleostei					
Callionymus maculatus	70-500	B		January-May	
Lesueurigobius friesii	untill 230	B		S-A	
Deltentosteus quadrimaculatus	untill 90	B		Sp	
Gadiculus argenteus	200-1000	B-P		W	
Merluccius merluccius	40-400	B/youngs P		February-March	
Argyropelecus hemigymnus	50-800 (3000)	P-batP		S-A-W	+
Glossanodon leioglossus	150-250 (400)	B-P		November-March	
Argentina sphyraena	400-600	B-P		February-April	
Engraulis encrasicholus		P		April-September	

The preference of *Ophichthus rufus* for benthic prey was confirmed. The most important species in the diet, *Processa canaliculata* and *Alpheus glaber*, spend their lives buried in the substratum. Therefore prey-catching must be active, as the fish has to dig in the bottom in search of food. The most important teleosts in the diet, particularly *Callionymus maculatus*, also have a marked benthic nature. Despite the importance of *P. canaliculata* as a prey species, the use of various feeding coefficients revealed teleosts to be the favourite prey group. The presence of bathypelagic and benthopelagic species in the diet, indicates that *O. rufus* actively catches its prey (probably in the hours of the predator maximum activity), leaving its refuge when necessary. Maximum occurrence of a specific prey species often coincided with the breeding period of that species (Table III). For example, *P. canaliculata* breeds in February and maximum occurrence (34.5%OC) for this species was found in April. Breeding in *A. glaber* occurs in August when its occurrence coefficient increased. *C. maculatus* breeds in January and May when there was a corresponding increase in occurrence. This may indicate that younger and at the same time more numerous prey species are more easily caught by *O. rufus*.

Seasonal variations show that the average prey number reached a maximum in January, coinciding with the highest vacuity coefficient. More sedentary and occasional prey, such as polychaete worms, were also more abundant in January. This may be the result of low food availability, which makes choice more limited. Throughout the month, therefore, food intake is very low, its choice minimum and predatory activity also very low. The observations showed that in winter and spring more benthic-type prey were consumed, whereas bathypelagic or benthopelagic prey was incorporated in summer and autumn, which are therefore periods of high predatory activity. This seasonal changes in *O.rufus* feeding would also explain monthly variations in vacuity coefficient, with certainly two maxima in winter and spring.

Our results indicate that the diet changes with predator size: smaller prey was caught by smaller specimens and, as specimen size increased, prey also became bigger, firstly Decapoda, then Teleostei. A further sexual difference must be noted, in direct relation to size, since larger specimens, basically fish feeders, were females. Therefore young specimens of both sexes and adult males have a different diet (Euphausiacea and Decapoda) than that of adult females (Teleostei and Decapoda).

The digestive structure of *Ophichthus rufus* is a very simple LA type (Mok, 1980). This type occurs in actinopterygians with a long stomach and a straight short intestine having only one loop; no variations in this structure have been observed with growth. According to Mok (1980), a simple intestinal structure is typical of crustacean feeders. Sorbe's classification (1972) of fish according to prey shows that piscivorous stenophagic fish have a high vacuity coefficient and average number of prey groups per stomach close to 1, both of which are generally consistent with our results, especially for females. *O. rufus* is not, however, exclusively piscivorous, but also a crustacean feeder. Following Sorbe's (1972) classification, euryphagic crustacean feeders generally consume a larger amount of Crustacea (in number of individuals and species) than other animal groups. This is true in *Ophichthus* for young specimens of both sexes and for males, but not for large females. Moreover, vacuity coefficient for this type of diet is usually below 50%.

It can therefore be concluded, according to Sorbe's classification (1972), that young specimens of both sexes and adult males have a euryphagic crustacean diet, whereas that of adult females is closer to a piscivorous stenophagic one.

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