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Feeding of Pelagic Fish in Waters of Mauritania: 2. Representatives of Families Carangidae, Scombridae, Pomatomidae, and Trichiuridae[1]

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Abstract—Feeding peculiarities of mass pelagic ichtyophagous fish from the Canary upwelling waters and frontal zones of Mauritania have been investigated: vadigo *Campogramma glaycos*, false scad *Caranx rhonchus*, bluefish *Pomatomus saltatrix*, Atlantic bonito *Sarda sarda*, West African Spanish mackerel *Scomberomorus tritor*, large-eyed hairtail *Trichiurus lepturus* and pompano *Trachinotus ovatus*. These species feed on epipelagic fish living or forming temporary agglomerations at the depths up to 200–250 m from the surface.

Keywords: *Campogramma glaycos*, *Caranx rhonchus*, *Pomatomus saltatrix*, *Sarda sarda*, *Scomberomorus tritor*, *Trichiurus lepturus*, *Trachinotus ovatus*, feeding, Atlantic Ocean, Canary upwelling, Mauritania

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INTRODUCTION

Materials on the feeding of mass pelagic fish in the economic zone of Mauritania, which is one of the most productive fishery regions in the World Ocean, have been collected under the aegis of the program on the estimation of the conditions for pelagic fish stock[2]. The previous publication (Gushchin and Corten, 2015) described feeding peculiarities of planktonphagous fish. This work presents the results of study the feeding for seven ichtyophagous fish species: vadigo *Campogramma glaycos*, false scad *Caranx rhonchus*, bluefish *Pomatomus saltatrix*, Atlantic bonito *Sarda sarda*, West-African Spanish mackerel *Scomberomorus tritor*, large-eyed hairtail *Trichiurus lepturus* and pompano *Trachinotus ovatus*.

The purpose of this study is to determine food composition and reveal seasonal peculiarities of food spectrum for pelagic ichtyophagans in the zone of increased productivity of the Canary upwelling and adjacent local frontal zones of Mauritania.

MATERIALS AND METHODS

The materials on pelagic fish feeding were collected in 2003 in the economic zone of Mauritania between 17°30′ and 20°40′ N (figure) during three missions of the Mauritanian SRV *Al-Awam* and four trips of Dutch fishery ships (*Maartje Theadora* and *Willem v.d. Zwan*). Control trawls on SRV *Al-Awam* were carried out for half an hour at daytime on the horizons of fish agglomerations. The trawls on the fishery vessels were carried out day-and-night on fish agglomerations horizons. Trawling time was unlimited and reached several hours. As the trawl sack was filled the catch was hooved with the fish pump and the samples were taken. Food bolus from fish stomachs was used for study of the feeding. Thus, time interval between the catches and sample fixing was not more than one hour, although probability exists that previously caught but not hooved specimens might have been included in the sample. The volume of the investigated material is given in Table 1.

Total length (*TL*), mass and degree of internal organs adiposity (according to 5-point scale) were determined. Fish stomachs were fixed with 5–6% neutral solution of formalin. The processing and study of stomach contents were carried out in the laboratory using standard methods (*Metodicheskoe posobie*..., 1974). All organisms found in the stomachs were determined up to possible taxon. The mass of stomach contents and separate components were weighed up to an approximation of 10 mg. The number of organisms was calculated. The total indices of stomach fullness (ISF) were determined as the ratio of total food mass to total fish mass (in ‰). The share of different com-

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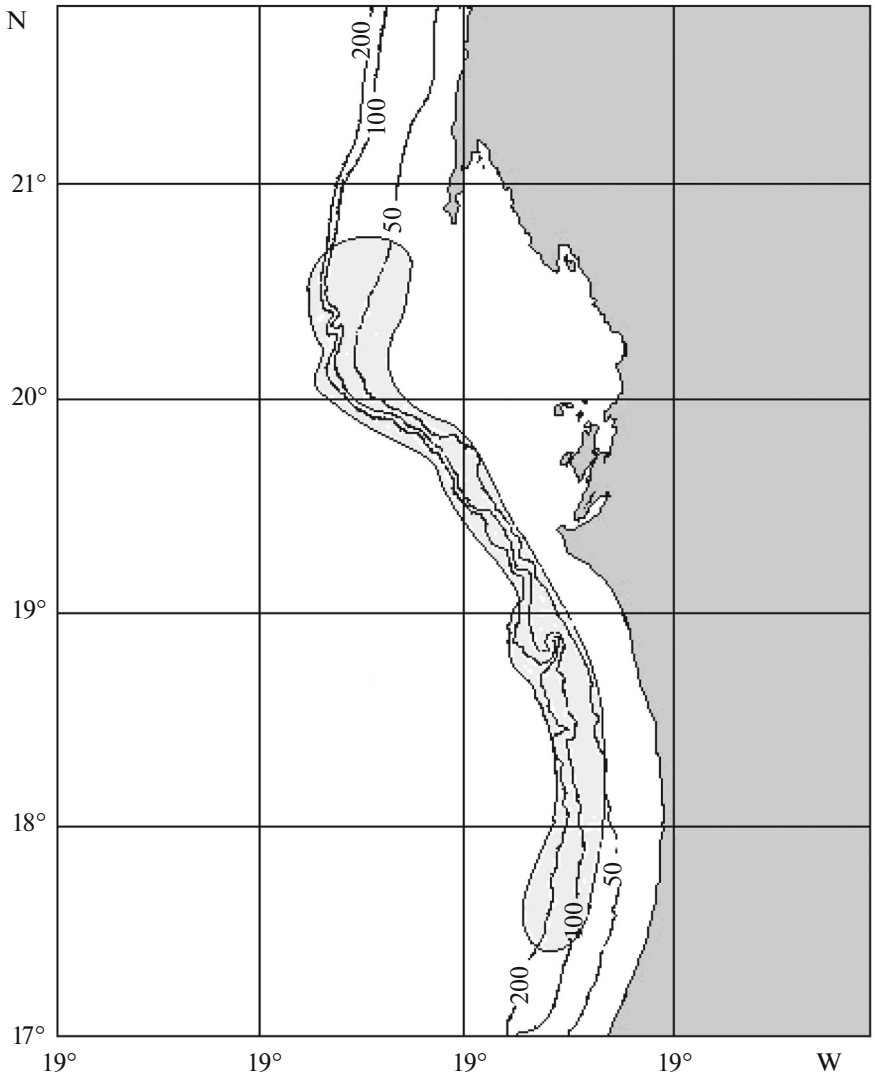

Sampling area (■) for study of ichtyophagous fish feeding; (—) are isobaths.

ponents in fish diet was determined based on fish mass (in %). The frequency of occurrence was determined as the ratio of the sum of food component occurrence to total number of all components findings (in %). All diet characteristics were analyzed without taking into consideration daily rhythmical patterns.

RESULTS AND DISCUSSION

The distribution of pelagic fish in Mauritanian waters is closely related to cumulative effect of the Canary current intensity and the Canary upwelling and the influence of the coastal current (along the longshore current) directed northward which power increases during the warm season. There are two hydrological seasons: the cold season (January–April) and the warm season (August–September). Transitional periods are observed between these seasons. In the warm season the intensity of upwelling is minimal and it is located in the region of the Cape Blanc. Warm waters of the coastal current penetrate farther northward and form local frontal zones with increased productivity in the zone of contact with the Canary current (Domanevskii, 1998). In the cold season waters of the Canary upwelling can be observed farther southward. The coastal longshore current decreases its intensity and reaches only the Cape Timiris. In the cold season European anchovy *Engraulis encrasicolus* and European sardine *Sardina pilchardus* are the basis of the catches while in the warm season these are round *Sardinella aurita* and flat sardine *S. maderensis* (Domanevskii, 1998). Pelagic predatory fish, namely, vadigo, false scad, bluefish, Atlantic bonito, West-African Spanish mackerel, large-eyed hairtail and pompano follow planktophagous fish agglomerations and these fish are connected with the latter as with food objects in their distribution.

Table 1. Number of investigated stomachs according to fish species and time of sampling (2003)

Species	Month						Total
	March	June	July	September	October	December	
Campogramma glaycos	–	–	5	–	–	13	18
Caranx rhonchus	7	–	14	–	–	10	31
Pomatomus saltatrix	4	–	–	4	–	–	8
Sarda sarda	7	17	48	6	5	–	83
Scomberomorus tritor	–	8	–	–	–	2	10
Trichiurus lepturus	12	–	–	–	–	–	12
Trachinotus ovatus	–	–	–	5	–	–	5
Total	30	25	67	15	5	25	167

Table 2. Food composition of vadigo *Campogramma glaycos* in the waters of Mauritania in July and December 2003

Food component and other indicators	Month			
	July		December	
	W, %	FO, %	W, %	FO, %
Euphausiidae (*Meganyctiphanes norvegica*)	0.5	16.7		
Myctophidae	20.2	16.7		
Engraulis encrasicolus	36.2	16.7	75.0	63.6
Sardinella aurita			6.7	9.1
Sardinella maderensis			0.7	9.1
Trachurus sp.			4.9	9.1
Trachurus trecae	15.2	16.7	12.7	9.1
Undetermined fish	27.9	33.2		
Stomach number:				
– total	5		13	
– with food	4		8	
Length (*TL*), mm	$\frac{462.0 \pm 7.8}{15.6}$		$\frac{376.3 \pm 14.9}{53.6}$	
Mass, g	$\frac{1030.0 \pm 16.8}{33.7}$		$\frac{514.2 \pm 48.0}{173.1}$	
ISF, ‰	$\frac{192.2 \pm 68.7}{137.4}$		$\frac{272.0 \pm 82.8}{298.6}$	
Food digestion degree, points	2.5		1.7	

Here and in Tables 3–8 M is the share of mass, FO is the frequency of occurrence; the average value and its error is above the line and the standard deviation is below the line

Vadigo occurred in the catches as separate specimens throughout the whole year. For study of feeding peculiarities two specimens were sampled in July (*TL* 440–480 mm) and December (*TL* 290–425 mm), food was found in the most stomachs (Table 2). In waters of Mauritania the basis of vadigo diet was generally presented with respect to mass and frequency of occurrence by small-sized fish and their juveniles, mainly European anchovy and Myctophidae. Round sardinella was marked in larger individuals. Similar food spectrum is characteristic for vadigo in other regions (Smith-Vaniz, 1986). Differences have been revealed in vadigo feeding in different seasons. At the beginning of the warm season vadigo fed on anchovy and Myctophidae as well as euphausiids (Euphausiidae). This is apparently due to the fact that anchovy agglomerations (the main food for vadigo) are shifted northwards in this period and leave waters of Mauritania thus becoming less accessible. To compensate food losses vadigo supplements its diet with Myctophidae and euphausiids. In December at the beginning of the cold season anchovy agglomerations enter waters of

Table 3. Food composition of false scad *Caranx rhonchus* in Mauritanian waters in March, July and December 2003

Food component and other indicators	Month					
	March		July		December	
	M, %	FO, %	M, %	FO, %	M, %	FO, %
Polychaeta (*Sabelia* sp.)	7.7	44.3				
Bivalvia (*Tellina* sp.)	53.8	45.4				
Copepoda	7.7	1.6				
Mysidacea (larvae)	30.8	8.7				
Engraulis encrasicolus			56.8	79.0	95.5	71.4
Sardinella sp.					4.5	28.6
Trachurus trecae			30.7	14.0		
Undetermined fish			12.5	7.0		
Stomach number:						
– total	7		14		10	
– with food	7		13		6	
Length (*TL*), mm	$\frac{207.1 \pm 8.1}{21.4}$		$\frac{327.5 \pm 9.4}{35.2}$		$\frac{240.0 \pm 9.5}{29.3}$	
Mass, g	$\frac{147.1 \pm 14.9}{39.6}$		$\frac{357.1 \pm 27.0}{100.9}$		$\frac{142.5 \pm 13.5}{42.8}$	
Degree of internal organs adiposity, points	1.8		0.3		0	
ISF, ‰	$\frac{68.8 \pm 18.5}{48.9}$		$\frac{459.6 \pm 60.9}{228.0}$		$\frac{270.2 \pm 148.0}{468.0}$	
Food digestion degree, points	2.6		1.6		1.2	

Mauritania and this species begins to dominate in vadigo diet. Vadigo starts intensive feeding, the indices of stomach fullness increase (272 vs. 192‰ in July). In this period, comparing the warm season, food spectrum of vadigo is expanded with round and flat sardinella juvenile fish which leave the seashore for nourishing and enter the open pelagic zone (Gushchin, 2013) and horse mackerel *Trachurus trecae*.

The sizes of the preys varied from 28 to 120 mm. The sizes of the preys increase with the growth of vadigo. In the size group of 300–400 mm the average prey size is 69.6 mm and it increases to 96.2 mm in the group with the size of 400–500 mm. For vadigo the dependence of the prey size (TL_{Food}) on the predator length (TL_{pred}) is described by the equation $TL_{food} = 32.591 + 0.148TL_{pred}$ ($r = 0.81$, $p < 0.05$).

False scad occurs in waters of Mauritania in different quantities throughout the year. In March the sample was represented with small-sized individuals. All stomachs contained food, but they had low fullness (69‰) (Table 3). Feeding habit was expressed in the combination of typical bottom (benthic) and pelagic food with the dominance of bottom food with respect to frequency of occurrence and weight. Bottom food was represented by *Sabelia* sp. polychaetes and *Tellina* sp. bivalve mollusks. Polychaetes with the length of approximately 5 mm were found in the single stomach (40 specimens). Bivalve mollusk juveniles (with the shell length of 4–5 mm) were recorded in all stomachs in different quantities. Pelagic food included crustaceans: Mysidacea (juveniles with the length of 1.2–1.5 mm and imago with the length of 11 mm) and Copepoda (with the length about 0.8 mm that was recorded in the single stomach).

In July false scad occurred in the catches in the areas of European anchovy agglomerations. Almost all investigated individuals fed on fish and had high index of stomach fullness (460‰). Food was generally represented by European anchovies and false scad with the length of 93–107 and 82–104 mm, respectively. Anchovies were prevalent with respect to frequency of occurrence and weight. In December false scad fed on juvenile of European anchovies and sardinellas with the size of 25–45 mm. About half of fish in the sample ate and had nutritional state of 270‰. So, false scad had the most intensive diet in July at the beginning of the warm season. One can assume that the main factor for diet changes was the presence of a certain type of accessible food in which agglomerations fish had occurred at that moment.

In the Mediterranean Sea false scad feeds on squids (Teuthida) and plankton crustaceans (Costa, 1991). In

Table 4. Food composition of bluefish *Pomatomus saltatrix* in Mauritanian waters in March and September 2003

Food component and other indicators	Month			
	March		September	
	M, %	FO, %	M, %	FO, %
Sardina pilchardus	69.8	66.7		
Sardinella aurita			70.2	25.0
Trichiurus lepturus			27.7	25.0
Trachurus trecae	30.2	33.3		
Searsidae g. sp.			1.3	25.0
Undetermined fish			0.8	25.0
Number of stomachs:				
– total	4		4	
– with food	3		4	
Length (*TL*), mm	$\frac{397.0 \pm 2.4}{4.8}$		$\frac{540.0 \pm 20.4}{40.8}$	
Mass, g	$\frac{817.2 \pm 11.8}{23.7}$		$\frac{1225.0 \pm 120.6}{241.3}$	
ISF, ‰	$\frac{124.2 \pm 71.1}{142.2}$		$\frac{235.3 \pm 115.9}{231.9}$	
Food digestion degree, points	3.0		2.5	

waters of Senegal bottom food is recorded in false scad diet, specifically the prawn *Penaeus notalis* (Caverivière and Andriamirado, 1997). According to our data in Mauritanian waters the bulk of the diet for false scad is represented by fish (European anchovies, Cunene horse mackerels and sardinella juveniles). Food spectrum of relatively small individuals also includes plankton crustaceans (Copepoda and Mysidacea larvae) and benthic animals (Polychaeta and Bivalvia) which do not occur in the stomachs of large fish feeding solely on fish. The relationship of the size of the preys with the length of the predator for false scad is described by the equation: $TL_{food} = -98.58 + 0.567 TL_{pred}$ ($r = 0.88$, $p < 0.05$).

Bluefish occurs in waters of Mauritania throughout the year. However, it is hardly accessible for trawling due to high swimming speed. In March it rarely occurred in the catches in European sardine agglomerations in the north of the region. The diet of investigated bluefish individuals with *TL* 390–400 mm included European sardine that was dominant with respect to mass and frequency of occurrence and Cunene horse mackerel (Table 4). The prey sizes were 80–150 mm. In September bluefish with *TL* 480–560 mm that had been caught in round sardine agglomerations fed generally on the above species, but also consumed large-eyed hairtail and the representatives of the Searsiidae family. The prey sizes varied from 50 to 230 mm.

According to the literature data, food spectrum of bluefish is more various in other regions. In addition to fish it includes bottom and plankton crustaceans, polychaetes (Creaser and Perkins, 1994), squids and crabs (Buckel et al., 1999) off the coast of the United States, plankton and bottom crustaceans (da Silva Monteiro and Marques, 1998) off the coast of Africa.

Atlantic bonito occurs in the catches throughout the year. In March all individuals with *TL* 440–530 mm were caught in the central part of the region in the agglomeration of European anchovy that was the basic object of their diet along with a low share of Cunene horse mackerel (Table 5). The prey sizes were 90–118 mm. In June the representatives of genus *Trachurus* with the length of 60–90 mm were the objects of Atlantic bonito diet. In July Atlantic bonito with *TL* 343–805 mm occurred in round sardinella agglomeration and fed on it as well as Cunene horse mackerel, European anchovy and Myctophidae. The prey sizes varied in wide ranges from 46 to 220 mm. In September Atlantic bonito with *TL* 485–600 mm occurred in the agglomerations of horse mackerel, Cunene horse mackerel made the basis of its diet. In October Atlantic bonito with *TL* 502–526 mm fed on juveniles of pelagic fish

Table 5. Food composition of Atlantic bonito *Sarda sarda* in Mauritanian waters in March-June, September and October 2003

Food component and other indicators	Month									
	March		June		July		September		October	
	M, %	FO, %	M, %	FO, %	M, %	FO, %	M, %	FO, %	M, %	FO, %
Engraulis encrasicolus	88.4	75.0			16.9	16.3	11.6	16.7		
Ceratoscopelus maderensis					0.2	4.7				
Myctophidae gen. sp.					0.1	2.3				
Sardinella aurita					34.5	9.3				
Sardinella sp.					14.2	18.6				
Trachurus trecae	11.6	25.0			17.6	25.5	27.3	16.7	26.2	40.0
Trachurus trachurus							27.3	16.7		
Trachurus sp.			54.3	40.0	9.7	14.0	18.7	16.7		
Scomber colias									10.3	20.0
Caranx rhonchus									63.5	40.0
Undetermined fish			45.7	60.0	6.8	9.3	15.1	33.2		
Number of stomachs:										
– total	7		17		48		6		5	
– with food	7		5		46		5		5	
Length (*TL*), mm	$\frac{481.4 \pm 13.7}{36.2}$		$\frac{462.9 \pm 21.2}{82.3}$		$\frac{609.0 \pm 18.4}{127.7}$		$\frac{541.7 \pm 19.4}{47.6}$		$\frac{517.0 \pm 4.5}{10.1}$	
Mass, g	$\frac{1635.0 \pm 105.7}{279.8}$		$\frac{1002.6 \pm 141.7}{548.8}$		$\frac{2396.8 \pm 178.1}{1233.9}$		$\frac{1776.7 \pm 10.4}{25.4}$		$\frac{1532.0 \pm 80.5}{180.0}$	
ISF, ‰	$\frac{307.6 \pm 51.9}{137.4}$		$\frac{10.0 \pm 4.9}{18.9}$		$\frac{172.7 \pm 24.3}{168.1}$		$\frac{21.2 \pm 10.4}{25.4}$		$\frac{2234.8 \pm 877.3}{1961.6}$	
Food digestion degree, points	2.4		2.8		2.0		2.0		2.0	

(false scad, Cunene horse mackerel and Atlantic Chub mackerel) with the size of 80–145 mm.

It is known that Atlantic bonito consumes zooplankton (euphausiids), squids and fish including its own juveniles and benthic organisms (Yoshida, 1980). In the region of the Cape Blanc it feeds on schooling pelagic fish and squids (Domanevskii, 1998).

The list of food objects for Atlantic bonito in Mauritanian waters includes mass epipelagic species (European anchovy, round sardinella, Cunene horse mackerel and Atlantic Chub mackerel) as well as mesopelagic fish species (Myctophidae including *Ceratoscopelus maderensis*). The value of the latter in the diet of Atlantic bonito is insignificant, but it permits to presume that Atlantic bonito can start feeding on mesopelagic species when there is the lack of traditional pelagic preys.

Food spectrum of Atlantic bonito varies throughout the year according to seasonal distribution of pelagic fishes. In the cold period Atlantic bonito feeds on European anchovy. In the transitional and the warm hydrological periods the number of consumed species is increased by thermophilic species: round sardinella, horse mackerels and Atlantic Chub mackerel. Atlantic bonito has the most intensive feeding at the end of the warm season (in October) that is apparently due to preparation for spawning. Atlantic bonito is characterized by low selectivity choosing the size of the preys. The prey sizes for individuals with *TL* 300–800 mm vary from 46 to 220 mm. Therefore, the dependence of the prey-predator sizes is poorly pronounced: $TL_{food} = 96.013 + 0.0514 TL_{pred}$ ($r = 0.15$, $p < 0.05$).

West-African Spanish mackerel with *TL* 713–895 mm fed in June on Cunene horse mackerel, round sardinella and mullet *Mugil* sp. (Table 6). Two specimens

Table 6. Food composition of West-African Spanish mackerel *Scomberomorus tritor* in Mauritanian waters in June and December 2003

Food component and other indicators	Month			
	June		December	
	M, %	FO, %	M, %	FO, %
Merluccius sp.			100.0	100.0
Mugil sp.	9.1	12.5		
Sardinella aurita	5.3	12.5		
Sardinella sp.	44.6	12.5		
Trachurus trecae	41.0	62.5		
Number of stomachs:				
– total	8		2	
– with food	7		1	
Length (*TL*), mm	$\frac{790.6 \pm 33.6}{95.1}$		$\frac{545.0}{}$	
Mass, g	$\frac{3471.2 \pm 441.0}{1247.3}$		$\frac{2195.0}{}$	
Degree of internal organs adiposity, points	0.1		0	
ISF, ‰	$\frac{123.2 \pm 47.6}{134.5}$		$\frac{0.6}{}$	
Food digestion degree, points	1.4		1.0	

were caught in December. The stomach of one of them contained food represented by hake *Merluccius* sp. with *TL* 40 mm.

According to the literature data, West-African Spanish mackerel feeds on fish including round and flat sardinella and bonga shad *Ethmalosa fimbriata* (Collette and Nauen, 1983; Cayré et al., 1993). That was confirmed in waters of Mauritania where West-African Spanish mackerel fed on fish of epipelagic complex: Cunene horse mackerel, round sardinella, mullet, and hake. The dependence of the prey size on the length of West-African Spanish mackerel is described by the equation $TL_{food} = -60.76 + 0.262TL_{pred}$ ($r = 0.57$, $p < 0.05$).

Large-eyed hairtail occurred in the catches almost throughout the year, but the major portion of its individuals had empty stomachs. Only in March feeding specimens of large-eyed hairtail with *TL* 660–780 mm were found in the catches of European sardine. Large-eyed hairtail fed on European sardine, European anchovy, Cunene horse mackerel and false scad (Table 7). The prey sizes varied from 30 to 120 mm.

In the ocean large-eyed hairtail feeds generally on fish and, to a lesser extent, on cephalopod mollusks, crustaceans and carries out twenty-four hours vertical

Table 7. Food composition of large-eyed hairtail *Trichiurus lepturus* in Mauritanian waters in March 2003

Food component and other indicators	M, %	FO, %
Engraulis encrasicolus	9.8	14.3
Sardina pilchardus	18.2	14.3
Trachurus trecae	3.3	14.3
Caranx rhonchus	14.4	14.3
Undetermined fish	54.3	42.8
Number of stomachs:		
– total	12	
– with food	6	
Length (*TL*), mm	$\frac{731.7 \pm 9.5}{33.0}$	
Mass, g	$\frac{279.6 \pm 15.8}{54.9}$	
Degree of internal organs adiposity	1.6	
ISF, ‰	$\frac{28.0 \pm 9.0}{54.9}$	
Food digestion degree, points	1.3	

Table 8. Food composition of pompano *Trachinotus ovatus* in Mauritanian waters in September 2003

Food component and other indicators	M, %	FO, %
Trichiurus lepturus	76.6	25.0
Undetermined fish	23.4	75.0
Number of stomachs:		
– total	5	
– with food	4	
Length (*TL*), mm	$\frac{449.2 \pm 14.7}{32.8}$	
Mass, g	$\frac{866.0 \pm 79.2}{177.1}$	
Degree of internal organs adiposity, points	0.4	
ISF, ‰	$\frac{84.0 \pm 60.0}{134.1}$	
Food digestion degree, points	2.2	

migrations (Nakamura and Parin, 1993). Ctenophora (Mianzan et al., 1996), bottom organisms, prawns (Caverivière and Andriamirado, 1997), crabs and fish, including its own juveniles, were found in the stomachs of large-eyed hairtail in Argentine shelf region (Portsev, 1980). In waters of Mauritania large-eyed hairtail fed only on fish in cold hydrological season. All fish species found in the stomachs were the most general in the catches and they belong to schooling species of epipelagic complex.

Pompano with *TL* 410–490 mm occurred in the catches in September. Only fish was found in the stomachs, large-eyed hairtail mainly (Table 8). The maximum prey size was 150 mm or 30% of predator body length.

In African waters pompano feeds on bivalve mollusks, prawns, crabs (Diouf, 1996), zooplankton (da Silva Monteiro and Marques, 1998) and fish (Diouf, 1996; da Silva Monteiro and Marques, 1998). In waters of the Gulf Arguin (Mauritania) pompano juveniles feed on zooplankton, Decapoda and Gammaridae larvae. The diet of the smallest individuals includes Copepoda, but they proceed to feed on larger crustaceans with the increase in size (Gushchin, 2013).

CONCLUSIONS

As a result, all investigated fish species (vadigo, false scad, bluefish, Atlantic bonito,West African Spanish mackerel, large-eyed hairtail and pompano) feed mainly on fish including both juveniles and imago. Their preys are represented by epipelagic fish which inhabit or form agglomerations at the depths up to 200–250 m from the surface. This group includes the European anchovy and sardina as well as round and flat sardinella forming large agglomerations on the temperature gradient and feeding on phyto and zooplankton (Gushchin and Corten, 2015) and the young of Cunene horse mackerel, false scad and large-eyed hairtail.

Seasonal dynamics of food objects for ichtyophagous fish is associated with the accessibility of preys forming agglomerations dependent on seasonal changes of hydrological conditions of the water area.

The basic distinguishing feature of food spectrum for the investigated species from the data available in the literature is the absence of cephalopod mollusks in their diet. In particular, Domanevskii (1998) noted earlier that pelagic cephalopod mollusks, mainly squids, are common in the diet of predatory pelagic fish in waters of Mauritania, but they were absent in the samples in 2003. Possible explanation may serve the fact that the entire material on predators feeding was sampled in the areas with large agglomerations of European anchovy, European sardine and other planktophagous fishes that had ousted pelagic cephalopods from the areas of their concentration. Evidently, it is the local peculiarity for the distribution of planktonphagans and pelagic cephalopod mollusks in 2003.

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