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Some Biological Aspects of Thornback Ray (*Raja clavata* L., 1758) in the Southeastern Black Sea

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Abstract

Feeding, reproduction and growth of thornback ray (*Raja clavata* L., 1758) were studied from the South-eastern Black Sea near the Georgian border. Females made up 56% and males 44% of the individuals. The total length (TL) of females ranged from 34.3 to 88.2 cm (21.5-62.7 cm disc width (DW)), and males from 48.0 to 95.0 cm (35.5-61.0 cm DW)). The total length-weight (TL-W), disc width-weight (DW-W) and total length-disc width (TL-DW) relationships were $W=0.001TL^{3.42}$ ($r^2=0.91$), $W=0.008DW^{3.21}$ ($r^2=0.94$) and $DW=0.65TL+2.47$ ($r^2=0.88$), respectively, for the sexes combined. The total length at 50% maturity (TL_{50}) was about 64.03 cm (44.24 cm DW) for males and about 66.72 cm (47.27 cm DW) for females. Out of 50 stomachs examined, 70% of them were empty. The prey items found in the stomachs were anchovy (*Engraulis encrasicolus*), horse mackerel (*Trachurus trachurus*), whiting (*Merlangus merlangus euxinus*), goby (*Gobius* sp.), shrimps (*Upogobia pusilla*, *Crangon crangon*) and unidentified crab.

Key Words: Thornback ray, *Raja clavata*, Black Sea, food, maturation.

Introduction

The thornback ray (*Raja clavata*) is a shallow water bottom-living elasmobranch found in the Atlantic from Iceland and Norway southwards to South Africa, including the Mediterranean and Black Sea. *R. clavata* inhabit shelf and upper slope waters from the coastal line to about 300 m deep and feed on all kinds of bottom animals, preferably crustaceans (Stehmann and Bürkel, 1984).

Elasmobranchs are among the top predators in marine environment, thus they affect the populations of both fish and invertebrates at lower tropic levels (Ellis *et al.,* 1996). However, feeding studies of elasmobranches in the Black Sea have been limited to the spiny dogfish (*Squalus acanthias*) (Düzgüneş *et al.,* 1999; Erdem *et al.,* 2001; Demirhan, 2004; Mater *et al.,* 2005). The thornback ray is one of the most abundant elasmobranch species landed by the Black Sea fishery as bycatch (2.17%) (Çiloğlu *et al.,* 2002).

Information on the feeding habits of species contributes to a better understanding of the tropic dynamics and food webs, which is essential for appropriate fisheries management (Pauly *et al.,* 2000). The purpose of this study was to examine the feeding habits, growth and maturation of thornback ray caught from the south-eastern Black Sea coasts of Turkey.

Materials and Methods

Thornback rays were captured in the south-eastern Black Sea in 2002-2003 (Figure 1). Most of the fish samples were collected by longline in a depth of 20 m to about 120 m in all the seasons (Demirhan *et al.,* 2005). Line setting began before sunset (approx. 16:00 h) and hauling started on the next day about 16 hours after the setting in all seasons. Additional samples were collected from commercial purse seiners.

Rays were measured for total length (TL) and disc width (DW) to the nearest centimeter and weighed to the nearest 10 g. Sex and maturity were determined by macroscopic examination of gonads and claspers with maturity scales, as proposed by Stehmann (1987).

Males were classified into maturity stages according to the relative size of pelvic fin and claspers, as measured from anterior edge of the cloaca (Hanchet, 1988);

Immature: Claspers length (CL) smaller than pelvic fin length (PFL).

Maturing: CL up to 1.5 cm greater than PFL.

Mature: CL exceeding PFL by 1.5 cm or more.

Females were classified into maturity stages according to structure and ingredients of uteri and egg diameter of ovaria (Stehmann, 1987);

Immature: Uteri threadlike, no obviously developing ova in the ovaries.

Mature: Uteri flaccid and highly vascularized, fertilized eggs present in the uteri, developing ova present in the ovarium (diameter of eggs greater than 0.5 mm)

Relationships were established between TL and the difference between claspers tips and ventral fin tips for determining the length at the beginning of maturation (PFL and CL are equal) and full maturation (CL is 1.5 cm greater than PFL) (Figure 2).

Figure 1. Sampling area.

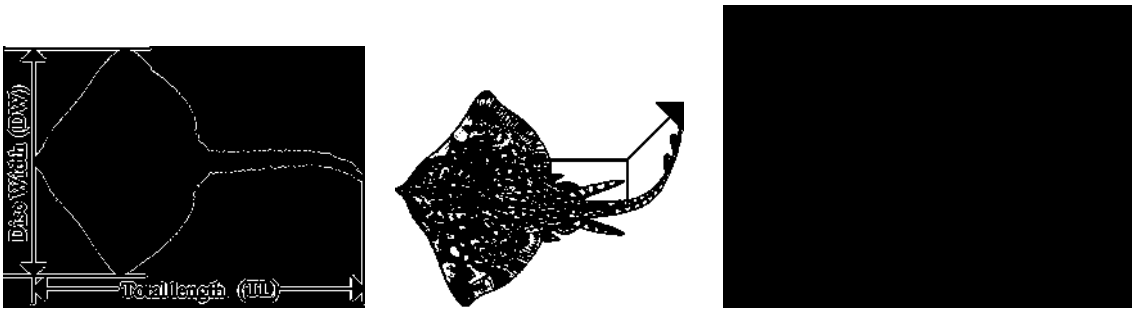

Figure 2. Total Length (TL), Disc Width (DW), Clasper Length (CL), Difference Between Clasper and Ventral Fin Length (DCV) and Ventral Fin Length (VFL).

Stomachs with contents were placed in plastic bags and frozen for subsequent analysis. Whenever possible, fish remains were identified to species. The gross stomach contents were noted. Account was taken of the fullness of the stomach. Prey groups weighed to the nearest 1 g. The method of frequency of occurrence (O%), percentage number (N%), percentage weight (W%) and percentage of relative importance (IRI%) for each prey type were used to explain the importance of prey in the diet of dogfish (Hyslop, 1980). However, the different approaches were applied in order to determine the importance of prey items in the food composition of thornback ray. Firstly, the length or width of prey items were estimated and, secondly prior to weighting the prey items different digestion stages in the stomach were estimated by using their Length-Weight or Carapace Width-Weight relationships from the literature (URL, 2004).

Results

A total of 52 thornback rays were captured. Among them, 96% were captured by longline, and the remaining samples were obtained by commercial purse seiners. The individuals ranged from 34.3 to 95.0 cm in total length and 0.168 to 5.45 kg in weight (Table 1 and Figure 3).

Thornback ray weight increases rapidly with growth which is evident by coefficients governing the TL-W and DW-W relationship curves according to "$W= a*L^b$" (Table 1). However DW-TL relationships were established according to "$DW = a_2\ TL - b_2$". The coefficients calculated from the relationships are given in Table 2.

Figure 3. Length (a) and weight distribution (b) of sample.

Table 1. Characteristics of sample

	Total Length (cm)				Disc Width (cm)				Weight (kg)			
	Min	Mean	Max	SD	Min	Mean	Max	SD	Min	Mean	Max	SD
Female	34.3	76.9	88.2	11.61	21.5	54.5	62.7	7.96	0.17	3.30	5.45	1.25
Male	48.0	73.2	95.0	12.46	35.5	48.9	61.0	7.88	0.62	2.60	5.00	1.22
Both of sex	34.3	75.2	95.0	12.03	21.5	51.9	62.7	8.33	0.17	3.01	5.45	1.28

Table 2. Total Length-Weight (TL-W), Disc Width-Weight (DW-W) and Total Length-Disc Width (TL-DW) relationships of females, males and sexes combined

	Weight -Total Length (r^2)	Disc Width -Weight (r^2)	Disc Width -Total Length (r^2)
Females	$W = 0.0003*TL^{3.7}$ (0.94)	$W = 0.009*DW^{3.19}$ (0.95)	DW=0.72*TL-1.25 (0.94)
Males	$W = 0.005*TL^{3.02}$ (0.96)	$W = 0.004*DW^{3.39}$ (0.92)	DW=0.56*TL-7.59 (0.87)
Both of sex	$W = 0.001*TL^{3.42}$ (0.91)	$W = 0.008*DW^{3.21}$ (0.94)	DW=0.65*TL-2.47 (0.88)

Reproduction

It was found out that TL and DW at which 50% of thornback rays were mature were estimated as 66.72 cm in TL and 47.27 cm in DW for females, while 64.03 cm in TL and 44.24 cm in DW for males (Figure 4 and 5).

The relationships found between TL and length of difference between claspers tips and ventral fin tips are given in Figure 6. It was found out from the relationships that the males began to mature from 57.0 cm and all of the males were mature at 60.05 cm in TL.

Feeding

Out of 50 stomachs examined, 35 (70%) were empty, and 15 (30%) contained prey. The prey items found in the stomachs were anchovy (*Engraulis encrasicolus*), horse mackerel (*Trachurus trachurus*), whiting (*Merlangus merlangus euxinus*), goby (*Gobius* sp.), shrimps (*Upogobia pusilla*, *Crangon crangon*) and unidentified crabs (Figure 7).

The main diet components of thornback rays were crustaceans (O%=52) and demersal fish (O%=35). Crustacea was the main prey group by number of frequency (N%=38) while the second prey group was pelagic fish (N%=33). On the other hand, demersal fish species was the main prey group (W=42%) in the stomachs by percentage of weight (Figure 8).

The stomach fullness of 19 female thornback rays was examined according to uteri ingredients. Fullness of stomach was 22.2% in 9 specimens with egg capsules in their uteri and 70.0% in 10 specimens with no egg capsules in their uteri.

Discussion

Maximum total length observed in this study for males (95.0 cm) and females (88.2 cm) was similar to that reported by Düzgüneş *et al*., (1999). Mean lengths stated in our study (76.9 cm for females and 73.2 cm for males) were slightly greater than those found in other studies carried out in the same region (Erkoyuncu and Samsun, 1986; Düzgüneş *et al*., 1999; Erdem *et al*., 2001). The reason of that could be attributed to sampling method. In the other studies,

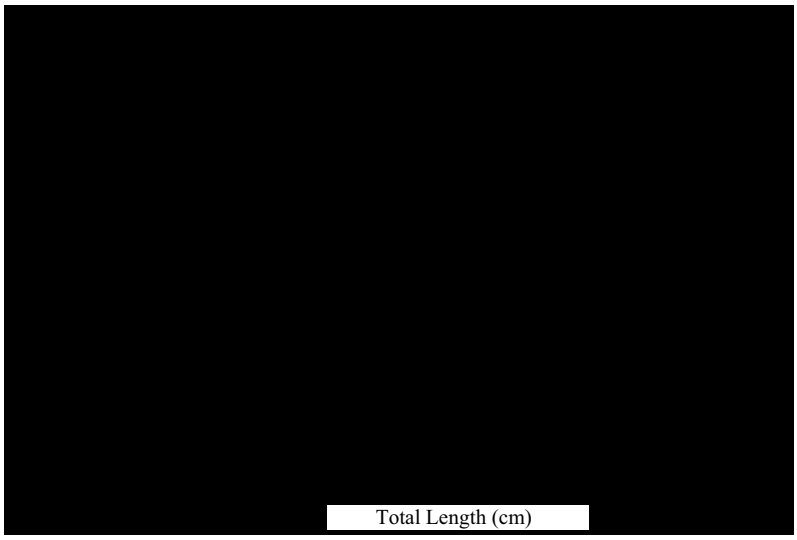

Figure 4. The length (TL) at which 50% of thornback rays are mature.

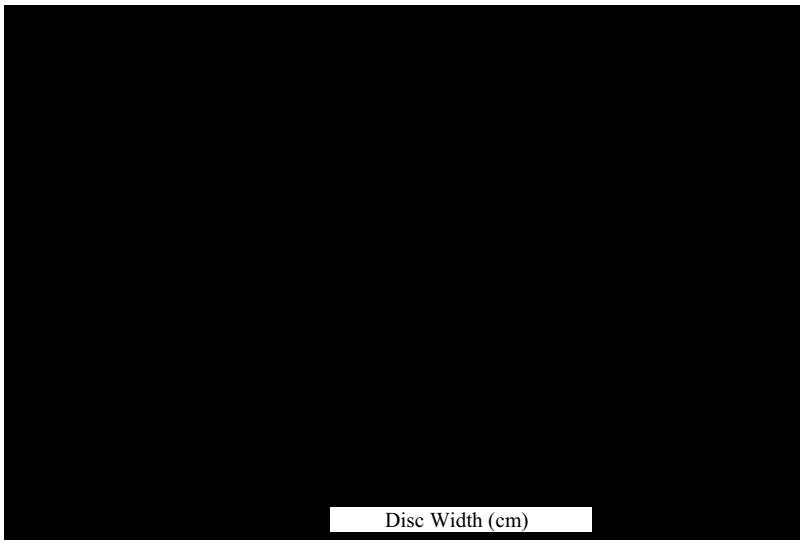

Figure 5. The disc width at which 50% of thornback rays are mature.

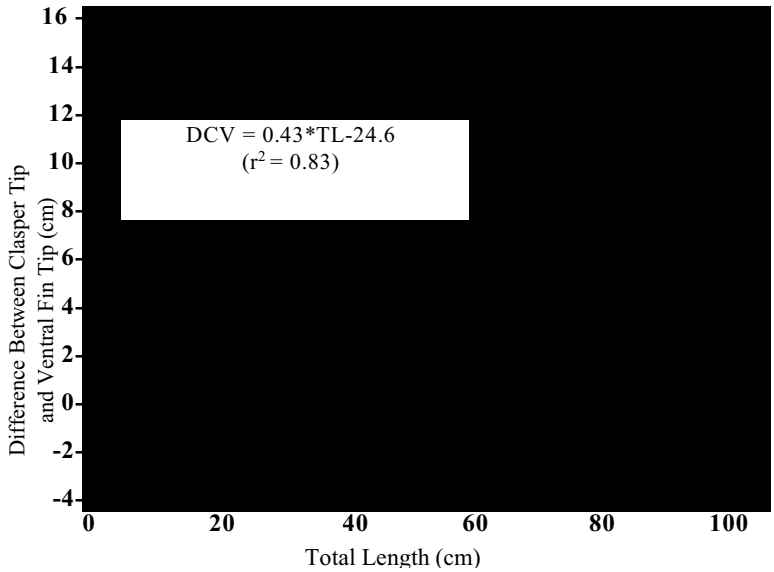

Figure 6. Relationship between total length (TL) and length of difference between clasper tip and ventral fin tip (DCV).

Figure 7. Frequency of occurence (O%) of prey items found in the stomachs.

Figure 8. Frequency of occurence (O%) and number of frequency (N%) of prey groups.

fish were caught by bottom trawls, purse seiners, gillnets or trammel nets. These fishing methods are able to catch every size of thornback rays. On the contrary, longline is a more selective method than those and catch thornback rays over at definite length (Demirhan *et al.,* 2004).

In the length-weight relationship, "a" constant found in our study is smaller than other values reported from the Black Sea for females (Filiz and Mater, 2002) but, greater than all other values from different regions and the Black Sea for males (Filiz and Mater, 2002; Ryland *et al.,* 1984). The "b" constant was greater than all other values for females, and smaller or greater than other values given for males (Filiz and Mater, 2002; Ryland *et al.,* 1984). In addition, the functional regression b-values for males, females and the pooled data were found to be greater than '3'. The confidence interval for the b-values of males, females and the pooled data implies that the body shape displays positive allometric growth characteristics. In the comparison for the values of "b" coefficient, the weights in females increase faster in relation to length than those in males. A similar result is also reported by Ryland *et al.*, (1984). The reason of differences between values given by different authors may be due to the differences in sampling times and methods of the studies reflecting interpopulation variation (Table 3).

Maturity

It is believed that the data was fair enough to construct a knife edge relationship between % maturity against TL and DW. The length at which 50% of thornback rays are mature was estimated to be about 66.72 cm in TL and 47.27 cm in DW for female; 64.03 cm in TL and 44.24 cm in DW for male. Holden (1975) stated that this value for female thornback rays is 72 cm. According to Pawson (1995), females reached maturity at 65-70 cm in DW

and males at 50 cm in DW. It is common among elasmobranchs that females mature at larger sizes than males (Nottage and Perkins, 1983; Mabragan and Cousseau, 2004), as also demonstrated in our study.

Females with egg cases were found almost in all samples during the study carried out from May to December. Pawson (1999) stated that *Raja clavata* females with egg cases were found all year round, but were more abundant during summer in the southern North Sea.

Feeding

Number of prey species found in the recent study was lower than those in other studies carried out in the north-eastern Atlantic, while it is similar to those from the western Black Sea. Main prey group found in this study was different from the studies summarized in Table 4.

Several other authors also reported a dominance of crustaceans and low importance of fish in the diet of the thornback ray (Quiniou and Andriamirado, 1979; Cunha *et al.,* 1986; Ebeling, 1988; Smale and Cowley, 1992; Daan *et al.,* 1993). However, some prey groups except crustacea and pisces were stated as food of thornback ray in different regions. For example; polychaetes (Ebeling, 1988; Daan *et al.,* 1993; Ellis *et al.,* 1996), bivalves (Quiniou and Andriamirado, 1979), holothurians (Ebeling, 1988), and cephalopods (Smale and Cowley, 1992) were considered important prey items.

Generally, skates and rays are benthic feeders, eating organisms such as small fish, molluscs, crustaceans and worms (Dipper, 1987; Beretovski, 1989). However, Ebeling (1988), Daan *et al*., (1993) and Morato *et al*., (2003) stated that thornback rays are active predators and able to feed semipelagically. According to Parin (1971), the ability of skates to hunt in the water column and even reach the sea surface is well known. Beretovski (1989) concluded that skates could not feed in water column because of their morphology and suggested that pelagic fish traumatized by trawls in the fishing grounds were subsequently preyed upon by skates. In the current

Table 3. Total length-weight, disc width-weight and total length-disc width relationships of females, males and sexes combined from literatures for *Raja clavata*

Study		TL-W relationship	DW-W relationship	L-DW relationship (r^2)
Recent study	female	$W=0.0003*TL^{3.69}$	$W=0.009*DW^{3.19}$	DW=0.72*TL-1.25
	male	$W=0.005*TL^{3.02}$	$W=0.004*DW^{3.19}$	DW=0.56*TL-7.59
	sexes combined	$W=0.001*TL^{3.42}$	$W=0.008*DW^{3.19}$	DW=0.65*TL-2.47
Jones and Geen, 1977	sexes combined	$W=0.0017*TL^{3.47}$		
Ryland *et al*., 1984	female	$W=0.0084*TL^{3.30}$		
	male	$W=0.0019*TL^{3.17}$		
Dorel, 1986	undefined	$W=0.0032*TL^{3.19}$		
	undefined	$W=0.0032*TL^{3.20}$		
Merella *et al*., 1997	sexes combined	$W=0.0024*TL^{3.2}$		
Düzgüneş *et al*., 1999	sexes combined	$W=0.003*TL^{3.18}$	$W=0.019*DW^{3.013}$	
Fernandez *et al*., 2001	sexes combined			DW=0.33*TL-0.94
Filiz and Mater, 2002	female	$W=0.0018*TL^{3.23}$		
	male	$W=0.0006*TL^{3.56}$		
	sexes combined	$W=0.0016*TL^{3.29}$		
Froese and Pauly, 2003	sexes combined	$W=0.004*TL^{3.004}$		
Hessen, 2003	sexes combined	$W=0.0035*TL^{3.17}$		
Filiz and Mater, 2004	sexes combined	$W=0.0016*TL^{3.30}$		

Table 4. Feeding characteristics of *Raja clavata* according to some researchers

References	Number of prey species	Prey groups			
		Crustacea	Pisces		Others
Recent study	7	IRI_e%=45.1	IRI_e%=54.9	IRI_e%=43.4[a] IRI_e%=11.5[b]	-
Ajayi, 1982		W%=83.0	W%=11.6		
Ellis *et al.,* 1996	61	FO%=78.9	FO%=7.33		FO%=10.19[c] FO%=3.47[d]
Erdem *et al.,* 2001	11	FO%=35.29	FO%=62.36	FO%=24.71[a] FO%=37.65[b]	FO%=2.35
Morato *et al.,* 2003	43	IRI%=17.4	IRI%=81.6		-

[a]: demersal species, [b]: pelagic species, [c] : mollusca, [d]: annelidae

study, the pelagic species fished from October to February in the south-eastern Black Sea by commercial purse seiners was one of the important prey groups for thornback rays. Anchovy was not found in the stomachs of the specimens sampled by longlines (4% of longline samples were caught in the anchovy fishing season from October to February). In addition, all the specimens contained anchovy in their stomachs sampled from the purse seiners. Mackerel, another pelagic species was found in the stomach of one specimen sampled by longlines in that season. From our data, it is difficult to say whether *R. clavata* is able to feed pelagically. But it is obvious that pelagic species is one of the main prey groups of thornback rays. However, crustacea and other demersal fish species were found year round in this area as food of thornback ray. It is impossible to consider pelagic fish as a casual component of skate diets because neritic, epipelagic and mesopelagic fish play a rather essential role in feeding of rajid skates in various regions of the world (Ebert *et al.,* 1991; Smale and Cowley, 1992). Consequently, it may, therefore, be concluded that thornback ray does prey upon anchovy, whiting, shrimp and crabs, and is an indiscriminate predator preying upon those species that are most abundant and available in the area and season. Especially in autumn and winter, anchovy is found in the south-eastern Black Sea for feeding migration.

Crabs, another prey groups, found in this study are difficult to feed on because of their carapax. On the other hand, small specimens of this species were found in the stomachs of thornback rays in the recent study. Whiting found in the area in all seasons of the year in different depths (Çiloğlu *et al.,* 2002), is also potential prey item for rays. Thornback rays feed on whiting at all lengths, but crabs under certain lengths (Table 5).

Differences in diet composition of thornback rays stated by several authors may reflect the faunal composition of the region (Smale and Cowley, 1992). On the other hand, such geographic differences should not be so obvious when comparing diets based on higher taxonomic levels (such as fish, crustaceans, and molluscs) (Morato *et al.,* 2003).

The total number of the species of the Black Sea is relatively low (URL, 2005). For this reason, the number of species which might be prey of thornback ray was relatively low.

The percentage of empty stomachs (70%) was found to be higher than those reported in previous studies (Ajayi, 1982; Cunha *et al.,* 1986; Ebert *et al.,* 1991; Smale and Cowley, 1992; Daan *et al.,* 1993; Ellis *et al.,* 1996; Morato *et al.,* 2003). The phenomena of the high percentage of empty stomachs found in this study can be attributed to the use of longlines for sampling (trawls were used mostly in other studies). Longlining is a passive fishing method, which catch fish searching for food. Fish with full stomachs tend not to eat the bait and be caught. Thus, only those fish with empty stomachs or partially full stomachs might have been caught during our study. Vomiting or possibility of higher gastric emptying time can be other reasons of high percentage of empty stomachs found in this study. As longlines remained in the sea bed for 15-18 h at 20-120 m in depths, most of the food items in the stomachs might have been digested completely. There is no sufficient knowledge of gastric emptying time of this species to support this presumption.

The prey items found in the stomachs were in different digestion stages. In some of the stomachs, otoliths, vertebrae or exoskeleton of prey species were recognizable but whole fish or crustaceans could not be weighed. For this reason, weights of digested preys were estimated by several ways; length-weight relationships from the literature used for calculating weight of species having measurable parts (carapax width, vertebrae length or cephalothoraxes length) in the stomachs; mean weight of the species found in the stomachs as a whole used for estimating weight of some species digested. While percentage of anchovy (36%) was higher than whiting (27%) according to measured weights, percentage of whiting (42%) became higher than anchovy (24%) in estimated weights.

Consequently, percentage of relative importance with estimated weight (IRI_e%) is considered to be more suitable method than the other methods to illustrate the importance of prey groups or species (Table 6).

Tablo 5. Sizes of prey items

Prey	Minimum lengths (cm)	Maximum lengths (cm)
Crab (Carapax width)	2.0	3.0
Crangon crangon	0.5	6.5
Upogobia pusilla	3.0	4.0
M. merlangus euxinus	8.0	12.0
Engraulis encrasicolus	7.0	9.0
Gobius sp.	7.0	12.8
Trachurus trachurus	5.0	5.0

Table 6. Different approaches to estimate the importance of prey groups and items

	Frequency of occurence	Frequency of number	Percentage of measured weight	Percentage of estimated weight	Index of relative importance with measured weight	Index of relative importance with estimated weight	Percent index of relative importance with measured weight	Percent index of relative importance with estimated weight
Prey Species	(O%)	(N%)	(W_m%)	(W_e%)	(IRI_m)	(IRI_e)	(IRI_m%)	(IRI_e%)
M. m. euxinus	23	20	27	42	1081	1426	39.7	47.8
Gobius sp.	8	8	15	12	184	160	6.8	5.4
E. Encrasicholus	8	28	36	24	512	416	18.8	13.9
T. trachurus	4	2	1	2	12	16	0.4	0.5
C. crangon	15	18	10	6	420	360	15.4	12.1
U. pusilla	8	4	5	3	72	56	2.6	1.9
Crab	22	14	6	11	440	550	16.2	18.4
Prey groups								
Demersal fish	35	29	42	54	2485	2905	38.4	43.4
Pelagic fish	13	33	37	26	910	767	14.1	11.5
Crustacea	52	38	21	20	3068	3016	47.5	45.1

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