Diet of the grey gurnard, *Eutrigla gurnardus* in the Adriatic Sea, north-eastern Mediterranean

by

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ABSTRACT. - A total of 449 individuals of grey gurnard *Eutrigla gurnardus* (Linnaeus, 1758) were collected between December 2007 and July 2008 by bottom trawl surveys in the Adriatic Sea, north-eastern Mediterranean. Stomach contents were investigated in order to analyse diet composition according to fish size and depth. The most important prey were Crustacea, mostly Mysidacea such as *Lophogaster typicus* and Decapoda such as *Goneplax rhomboides* and *Philocheras bispinosus,* followed by Teleostei, mostly Perciformes as *Gobius niger* and *Callionymus* spp. Dietary differences were found in relation to a critical predator size of 120 mm (TL). Decapoda were more frequently found in the diet of juveniles and Teleostei in that of adults living at a greater depth. Feeding strategy analyses revealed trophic specialization towards reference prey, thus narrowing the trophic niche.

RÉSUMÉ. - Régime alimentaire d'*Eutrigla gurnardus* (Triglidae) en mer Adriatique (nord-est Méditerranée).

Au total, 449 spécimens de grondin gris, *Eutrigla gurnardus* (Linnaeus, 1758), ont été capturés entre décembre 2007 et juillet 2008 dans le cadre de campagnes de pêche à la traîne en mer Adriatique. Les contenus stomacaux ont été étudiés afin d'analyser leur régime alimentaire, en fonction de la taille et de la profondeur. Les proies les plus importantes sont des Crustacea, surtout des Mysidacea tels que *Lophogaster typicus* et des Decapoda tels que *Goneplax rhomboides* et *Philocheras bispinosus,* suivis par des Teleostei, surtout les Perciformes tels que *Gobius niger* et *Callionymus* spp. On a constaté une modification du régime alimentaire à partir de la taille critique de 120 mm (LT) : les Decapoda sont plus fréquents dans le régime alimentaire des jeunes et les Teleostei dans celui des adultes vivant à de plus grandes profondeurs. Les résultats de l'analyse du régime alimentaire ont mis en évidence une spécialisation trophique pour des proies de référence et donc une niche trophique étroite.

Key words. - Triglidae - *Eutrigla gurnardus* - Adriatic Sea - Diet - Feeding habits.

Eutrigla gurnardus (L., 1758) is a widely distributed demersal species that occurs in the Mediterranean and eastern Atlantic. This fish inhabits depths of 20-300 m in muddy and sandy substrata (Relini *et al*., 1999). Its trophic biology in the Mediterranean Sea is poorly known. Current literature only refers to the North Sea (Ursin, 1975; Agger and Ursin, 1976, De Gee and Kikkert, 1993, Floeter *et al*., 2005; Floeter and Temming, 2005; Weinert *et al*., 2010) and the Spanish (Catalan) Mediterranean coast (Moreno-Amich, 1994). As to Italian coastal areas, available data are very limited, dating back several decades (Valiani, 1934).

The present study sets out to analyse stomach contents and dietary changes in relation to abiotic (depth) and biotic (length) variables with a view to better understanding the ecological role of this species in Adriatic demersal marine communities similar to those in the North Sea where the species is considered to be an emerging key predator that feeds on invertebrates as well as on fish (Floeter *et al*., 2005; Weinert *et al*., 2010). Knowledge of the feeding ecology of both commercial and non-commercial fish species is essential for implementing a multispecies approach to fishery management (Gulland, 1997).

MATERIAL AND METHODS

Sampling

A total of 449 samples of *E. gurnardus* were collected seasonally by international bottom trawl surveys in the Mediterranean Sea in winter and summer at depths between 31 and 185 m in the northern-middle Adriatic Sea from the Gulf of Trieste (45°40'N; 13°37'E) to the line joining the Gargano to Dubrovnik (42°08'N; 15°16'E). The bottom trawl surveys were carried out from December 2007 to March 2008 and from June to July 2008 along the Italian coasts (Fig. 1).

Total length (TL, mm) and weight (W, g) of each individual were measured in the laboratory to an accuracy of 0.1 g. Sex was determined on the basis of macroscopic gonads, and specimens were classified as females (F), males (M), juveniles (J, macroscopically unidentifiable sex) or not deter-

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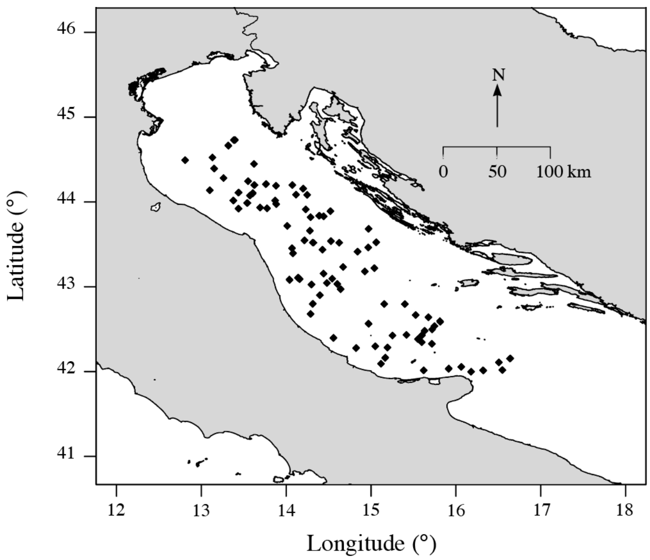

Figure 1. - Sampled sites in the north Adriatic Sea, north-eastern Mediterranean.

mined (ND, individual not examined) (Relini *et al.*, 2008). 156 females, 118 males, 109 juveniles and 66 undetermined were recorded. The stomachs of each of these specimens were removed and preserved in 70% ethanol for subsequent examination in the laboratory.

Diet analyses

Food items were identified to the lowest taxonomic level possible, taking into account each prey type and digestion state. Food items were counted, weighed (nearest 0.001 g) and photographed by means of a NIKON P5100 digital camera connected to a Leica MZ6 stereomicroscope. Inorganic particles and detritus present in the stomachs were also recorded. Data were collected in a database and processed with R software, version 2.10.1.

The relative importance of each item was calculated on the basis of item quantity (number) divided by the total number of overall prey (%N = number of prey i / total number of prey x 100), weight proportion (%W = weight of prey i / total weight of overall prey x 100) and frequency of occurrence (%O = number of stomachs containing prey i / total number of stomachs containing prey i x 100). These values were used to calculate the relative importance index (IRI): IRI = %O (%N + %W) and IRI proportion (%IRI). Stomach content coefficients were determined according to an empirical scale as empty (A) = stomach barely bloated with no and/or with only a few small prey; semi-empty (B) = stomach slightly bloated with only a few and/or with considerably small prey; semi-full (C) = stomach sufficiently bloated with considerable amounts of small prey or with only a few large prey; full (D) = stomach massively bloated with large amounts of small prey or with only a few large prey (Chrisafi *et al.*, 2007). These indexes were used to calculate a fullness index (FI = number of stomachs with the same degree of fullness / total number of stomachs examined x 100) and to determine changes in trophic level according to two main size classes correlated to depth.

Group average hierarchical cluster analysis was carried out using the Bray-Curtis similarity index (Clarke and Warwick, 1994) to assess differences between predator length and number (%N) of ingested food categories, data being transformed by Wisconsin double standardization to mitigate prey item range. This analysis was made to determine ontogenetic changes in fish diet. Specimens were subdivided into 6 size-classes.

General feeding strategy was analysed according to the Costello method (1990) as revised by Amundsen *et al.* (1996). The diagram generated by this method provides a two-dimensional representation in which each prey point is obtained by plotting the frequency of occurrence (%O) against prey-specific abundance (PSA) calculated according to the following formula: $P_i = (\sum S_i / \sum S_{ti}) \times 100$ where S_i is the stomach content (weight) of prey item i and S_{ti} is the total stomach content (weight) of only those predators with prey item i in their stomach. Prey importance and predator feeding strategy were determined on the basis of dot distribution along diagram diagonals and axes.

RESULTS

General diet composition

Five taxa (Tab. I) and namely Arthropoda (represented by Crustacea), Chordata (represented by Teleostei), Mollusca, Nematoda and Echinodermata, and 33 prey items (Tab. II), were identified in this study. The diet of *E. gurnardus* was mostly made up of crustaceans (%N = 94.2; %W = 71.9), and to a lower extent of teleost fishes (%N = 2.6; %W = 27.5) and molluscs (%N = 2.3; %W = 0.3). Other prey were nematodes (%N = 0.5; %W < 0.1) and echinoderms (%N = 0.1; %W < 0.1). Teleost fishes were more important in terms of

Table I. - Prey taxa recorded in the stomach content of *Eutrigla gurnardus* from the Adriatic Sea, all individuals merged. %N = numerical composition; %W = weight proportion; %O = frequency of occurrence; IRI = index of relative importance; %IRI = IRI proportion.

Prey Taxa	%N	%W	%O	IRI	%IRI
Arthropoda	94.15	71.93	94.04	15618.6	97.61
Chordata	2.57	27.49	11.91	358.05	2.24
Mollusca	2.25	0.34	8.46	21.94	0.14
nd	0.51	0.24	2.51	1.9	0.01
Nematoda	0.45	0	1.57	0.71	0
Echinodermata	0.06	0	0.31	0.02	0

Table II. - Diet composition of *Eutrigla gurnardus* from the Adriatic Sea, all individuals merged. %N = numerical composition; %W = weight proportion; %O = frequency of occurrence; IRI = index of relative importance; %IRI = IRI proportion.

Prey species	%N	%W	%O	IRI	%IRI
Mysidacea					
Lophogaster typicus	31.73	24.72	21.94	1238.58	50.49
Acanthomysis longicornis	6.81	0.48	3.76	27.42	1.12
Gastrosaccus sanctus	0.5	0.03	0.63	0.33	0.01
Gastrosaccus sp.	0.17	0.03	0.31	0.06	0
Decapoda: Brachyura					
Goneplax rhomboides	21.59	22.06	20.69	903.19	36.82
Liocarcinus sp.	7.14	2.93	7.21	72.59	2.96
Liocarcinus depurator	2.16	6.81	3.45	30.92	1.26
Decapoda: Macrura-Natantia					
Philocheras bispinosus	10.13	1.7	6.27	74.2	3.02
Alpheus glaber	1.99	6.06	3.45	27.77	1.13
Philocheras sp.	5.15	0.78	3.76	22.29	0.91
Solenocera membranacea	3.99	2.51	3.45	22.39	0.91
Processa spp.	2.66	0.21	1.57	4.49	0.18
Pontophilus sp.	0.17	1.34	0.31	0.47	0.02
Pontophilus spinosus	0.17	0.99	0.31	0.36	0.02
Philocheras echinulatus	0.17	0.12	0.31	0.09	0
Decapoda: Anomura					
Galathea sp.	0.66	0.18	0.63	0.53	0.02
Galathea intermedia	0.66	0.12	0.63	0.49	0.02
Munida spp.	0.33	3.28	0.31	1.13	0.05
Decapoda: Macrura-Reptantia					
Callianassa spp.	0.17	0.24	0.31	0.13	0.01
Jaxea nocturna	0.17	0.21	0.31	0.12	0
Teleostei					
Gobius niger	0.83	10.54	1.57	17.82	0.73
Callionymus sp.	0.5	2.72	0.94	3.02	0.12
Arnoglossus laterna	0.17	9.31	0.31	2.97	0.12
Callionymus maculatus	0.17	2.36	0.31	0.79	0.03
Bivalvia					
Tellina spp.	0.33	0.09	0.63	0.26	0.01
Mactra corallina	0.17	0.03	0.31	0.06	0
Flexopecten glaber proteus	0.17	0	0.31	0.05	0
Hyalopecten similis	0.17	0	0.31	0.05	0
Opisthobranchia					
Turritella communis	0.33	0.06	0.63	0.25	0.01
Odostomia acuta	0.17	0	0.31	0.05	0
Euphausiacea					
Meganyctiphanes norvegica	0.17	0.12	0.31	0.09	0
Amphipoda					
Ampelisca spp.	0.17	0	0.31	0.05	0
Leucothoe spp.	0.17	0	0.31	0.05	0

weight proportion than of occurrence frequency and proportion (Fig. 2).

Decapod crustaceans were the most important prey items of this population of *E. gurnardus*. Amongst Decapoda, the dominant species in order of importance were: *Goneplax rhomboides*, *Philocheras bispinosus*, *Liocarcinus* spp., *Solenocera membranacea*, *Alpheus glaber*. *Lophogaster typicus* (Mysidacea) appeared to be the most abundant food in the stomachs examined. Amongst teleost fishes, the most preyed species were *Gobius niger* and *Callionymus* spp.

Fullness index

E. gurnardus fullness index varied significantly for the two size classes calculated as the smaller and the larger than the median, the latter being 120 mm ($chi^2 = 12.7752$, df = 3, $p < 0.05$) (Fig. 3). Stomach fullness was greater in adults living at depths greater than the juveniles ($chi^2 = 26.0871$, df = 6, $p < 0.001$). Adults were found to feed on larger prey (teleost fish and decapods such as crabs) with a greater leathery content, related to increased energy requirements (Fig. 4). Sex-wise, greater fullness was recorded for females than for males ($chi^2 = 12.9224$, df = 3, $p < 0.05$).

Diet variation with fish size

The diet similarity dendrogram (Fig. 5) reveals a first dichotomy marking out two distinct main groups depending on total length (TL) being greater or less 120 mm. Other dichotomies were found, marking out a further six groups according to total fish length, and namely class I containing fish of up to 80 mm; class II from 81 to 100 mm; class III from 101 to 120 mm; class IV from 121 to 140 mm; class V from 141 to 160 mm, and class VI longer than 160 mm. Juveniles (class I; class II) were active predators since their first life stages. Their predation was directed at smaller crustaceans such as *Philocheras bispinosus* and *Processa* spp. Specimens in class III were found to start to feed on some molluscs but the most significant change in feeding behaviour was observed for speci-

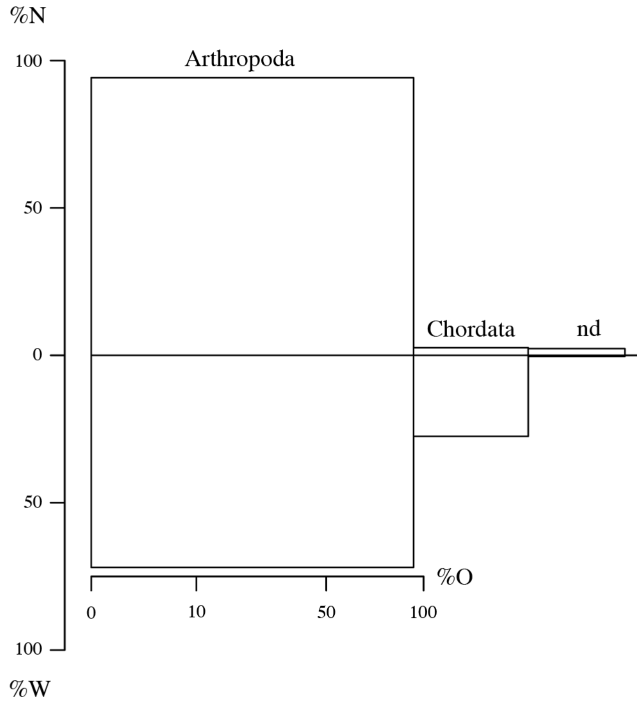

Figure 2. - Proportion of main prey taxa in the stomachs of *E. gurnardus,* all individuals merged. %N = numerical composition; %W = weight proportion; %O = frequency of occurrence; nd = not determined.

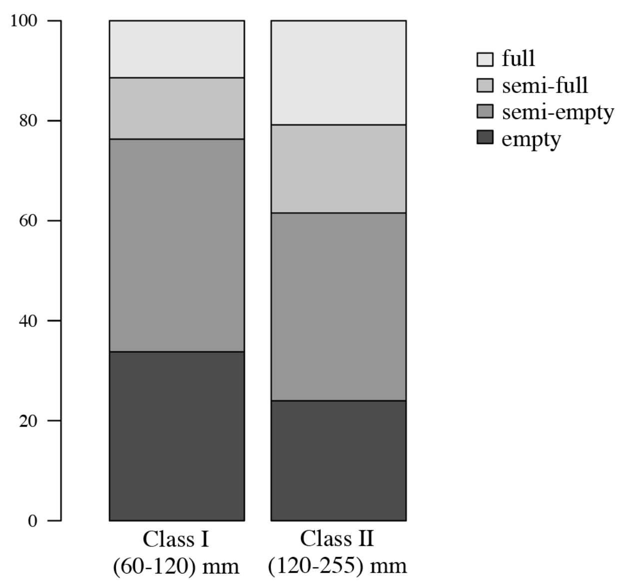

Figure 3. - Variations in stomach fullness of *E. gurnardus* in relation to two size classes. Class I (60-120 mm); Class II (120-255 mm).

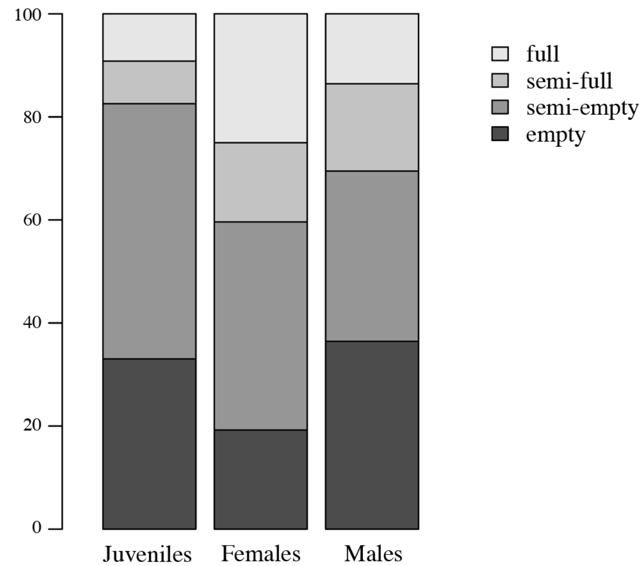

Figure 4. - Variations in stomach fullness of *E. gurnardus* in relation to sex. Juveniles and adults (females and males).

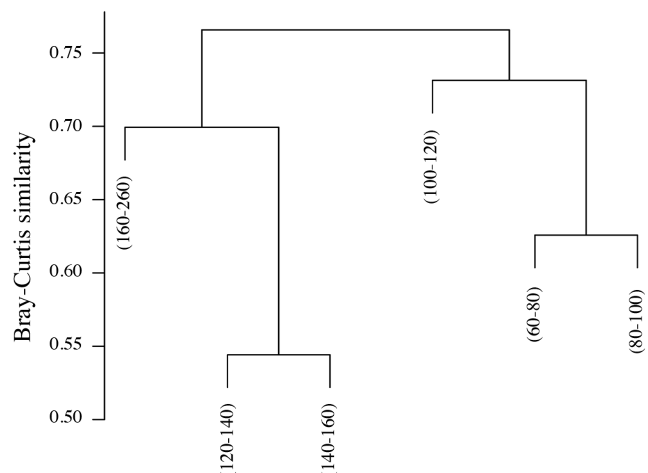

Figure 5. - Dendogram showing feeding similarities among six *E. gurnardus* size classes from the Adriatic Sea. Class I (60-80 mm); Class II (80-100 mm); Class III (100-120 mm); Class VI (120-140 mm); Class II (140-160 mm); Class III (160-260 mm). Species diversity Bray-Curtis similarity index (cluster method: average).

mens in classes IV and V. The variety of food items eaten by grey gurnards was seen to increase during life stages corresponding to classes IV and V, when the highest value of niche breadth was attained. Preys include benthic food items such as amphipods, bigger decapods such as Brachyura and *Alpheus glaber*, mysids, and molluscs. Specimens in these classes were also found to begin to prey necto-benthic items such as *Callyonimus maculatus*. Specimens of more than 160 mm (class VI), although preying crustaceans such as *Pontophilus* spp. and *Liocarcinus depurator*, were found to mainly exhibit piscivorous feeding habits. Their prey were seen to include Callyonimidae, *Gobius niger* and Pleuronectiformes such as *Arnoglossus laterna*.

Feeding strategy

Prey-wise, feeding strategy analysis on the basis of stomach contents revealed crustaceans *Lophogaster typicus* and *Goneplax rhomboides* to be the most dominant prey for the predator populations considered (see top right corner of the graph). Such feeding strategy is indicative of an overall predator population with a narrow feeding niche (Fig. 6). Despite their low occurrence, the teleost *Gobius niger* and the crustaceans *Liocarcinus depurator*, *Alpheus glaber* and *Solenocera membranacea* were observed with great specific abundance. These more palatable preys were consumed by only a few individuals displaying high specialization (see upper left corner of the graph). Smaller crustaceans such as *Acanthomysis longicornis*, *Philocheras* spp., *Processa* spp. and teleost fishes *Callionymus* spp. represented rare and less important prey (see lower left corner of the graph).

Graphical feeding strategy analysis shows inter-phenotype contribution to be quite high (high BPC), with a fair number of the majority of prey points being positioned toward the upper left corner of the graph. This points to the fact that a number of individuals of the predator population of *E. gurnardus* considered were specialized in the predation of different resource types, reflecting dietary changes over the lifecycle of this species.

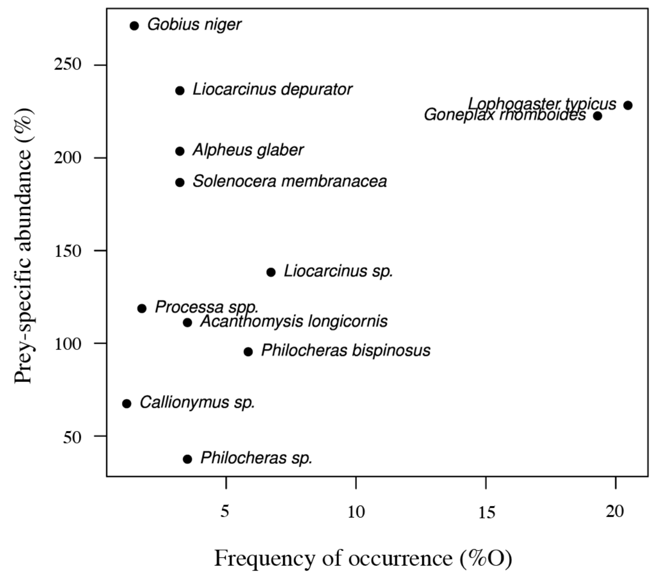

Figure 6. - Prey-specific abundance plotted against frequency of most occurring prey items in the diet of *E. gurnardus* from the Adriatic Sea. %O = frequency of occurrence; PSA (%) = prey-specific abundance.

DISCUSSION

The present study bears out the importance of investigating dietary habits, predator-prey relationships and trophic levels in order to quantify the ecological role of the various components of any marine community. Ideally, priority should be given to studying the trophic biology of scantly known stocks such as, for instance, *E. gurnardus*, especially when it is considered that they may limit or affect the trophic niches of other species of commercial importance.

Very few studies have been carried out on the feeding habits of the Mediterranean grey gurnard particularly in Italian seas (Valiani, 1934). On the basis of stomach content analysis, some authors have reached the conclusion that this predator feeds on crustaceans (mainly Decapoda natantia and Mysidacea) and teleost fishes (Reys, 1960 - Gulf of Lions; Moreno-Amich, 1994 - Catalan coast). Molluscs were also observed to be present in the stomachs, but were deemed to contribute only moderately to the overall diet.

Our findings based on the study of Adriatic Sea populations of the predator are in line with those of these authors. Grey gurnards are epibenthic feeders preying mainly crustaceans. Depending on lifecycle stage, it was observed that *E. gurnardus* increases its predation of fish. Such behaviour probably depends on the predator's changing energetic requirements with growth as well as on its changing predation capacities in relation to fish size (Ursin, 1975; Agger and Ursin, 1976; De Gee and Kikkert, 1993; Moreno-Amich, 1994; Floeter *et al.*, 2005; Floeter and Temming, 2005). Ontogenetic body increase allows growing predators to successfully ingest more elusive, larger prey (Karpouzi and Stergiou, 2003). In addition, adults move faster and are therefore capable of feeding on prey with higher motility (i.e., fish). They become more opportunistic, apparently engaging in a more generalist-oriented foraging behaviour. According to the plotted pattern, smaller crustaceans were seen to be important prey for the smaller sized classes of the predator, while larger crustaceans and fishes were preferred by larger individuals.

The critical size at which *E. gurnardus* in the area examined was found to switch over from feeding mainly on crustaceans to fishes, to predate at greater depths and to start reaching sexual maturity, was observed to be at around 120 mm TL. The differentiation between females and males starts at lengths close to and less than 100 mm TL. 50% of males have been found to attain maturity at around 120 mm TL, while 50% of females at around 150 mm TL (Vallisneri *et al.*, unpublished data). As to size at maturity, our findings are comparable to those reported in the literature, regardless of location (Papaconstantinou, 1982 - Greece; Dorel, 1986 - Gulf of Biscay, France; Muus and Nielsen, 1999 - Denmark). Minor differences as were observed may be attributed to local conditions, especially temperature that stimulates sexual maturation, and to the study methodology adopted by the different authors.

Stomach fullness is greater in females than in males, a fact that may be accounted for by the higher fitness costs (i.e., big eggs and large fecundity) incurred by females and by their access to the best spawning sites.

The analysis of prey-specific abundance against frequency of occurrence shows that *E. gurnardus* has a narrow niche width, *Lophogaster typicus* and *Goneplax rhomboides* being the dominant prey. The most abundant food in their stomachs was found to be represented by the species *Lophogaster typicus* (Mysidacea); this finding is in line with that of the literature relating to the stomach contents of other species of the same Triglidae family in the south Mediterranean (Terrats *et al.*, 2000). It is also in line with the results reported by Colloca *et al.* (2010) for other Mediterranean gurnards (*Aspitrigla cuculus*, *Lepidotrigla cavillone* and *L. dieuzeidei*) that were found to be characterized by a specialist trophic behaviour. A significant negative correlation between prey type similarity and depth distribution similarity was also observed for Mediterranean demersal fish, with gurnards overlapping in both food and depth preferences (Colloca *et al.*, 2010).

In line with the literature (Floeter *et al.*, 2005; Montanini *et al.*, 2008), the Adriatic population studied by us shows that *E. gurnardus* potentially competes as a predator with other fish species. As reported by Floeter and Temming (2005), in the North Sea grey gurnard predation is in fact a very critical process with a significant top-down effect on whiting (*Merlangius merlangus*) and potentially also on cod recruitment.

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