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An evaluation of resource partitioning between two billfish, *Tetrapturus belone* and *Xiphias gladius*, in the central Mediterranean Sea

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The present study attempts to give information on the resource partitioning between the Mediterranean spearfish (Tetrapturus belone) *and the swordfish* (Xiphias gladius). *The contents of 53* T. belone *and 95* X. gladius *non-empty stomachs were analysed from specimens caught in the central Mediterranean Sea (Strait of Messina), from 2004 to 2006, by the harpoon fishery. Daily catches (expressed as number of fish) showed the contemporary occurrence of both species in the studied area then allowing direct comparison of diets. Epipelagic fish were the dominant prey (%IRI = 99.1) of* T. belone. *Eight families were identified among them, with the dominance of Belonidae and Clupeidae, which represented 40.9% and 36.8%, respectively, of the total preyed items in terms of %IRI and were mostly composed of* Sardinella aurita *and* Belone belone.

Xiphias gladius *preyed mainly on teleosts and cephalopods, which represented 59% and 39.1%, respectively, of the total preyed items in terms of %IRI. Eleven teleost and five cephalopod families were recognized among them with the dominance of Trichiuridae (IRI% = 30.5) and Ommastrephidae (IRI% = 27.6). The first was represented only by* Lepidopus caudatus *(IRI% = 30.5), while the latter by the squid* Todarodes sagittatus *(IRI% = 21.1) and* Illex coindettii *(IRI% = 6.5). Results of a multivariate statistical analysis demonstrated that the dietary compositions differed significantly between swordfish and spearfish. Diet overlap analysed with the Schoener and Horn indices showed low values (0.23 and 0.21 for the two indices) underlining a food partitioning that prevents competitive exclusion. Our results highlight a feeding strategy that is more related to the habitat of the species than to the food availability. In fact, migration patterns of the two predators are quite different. Swordfish show vertical migrations from 0 to 800 m while spearfish are characterized by limited migrations, ranging between 0 and 200 m depths. The observation of specific prey items in the stomach content of both billfish confirmed the bathymetric range of their migrations.*

Keywords: resource partitioning, billfish, *Tetrapturus belone*, *Xiphias gladius*, central Mediterranean Sea

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INTRODUCTION

Billfish, Mediterranean spearfish (Istiophoridae: *Tetrapturus belone*, Rafinesque, 1810) and swordfish (Xiphiidae: *Xiphias gladius*, Linnaeus 1758), are highly migratory and top predator marine fish (Palko *et al.*, 1981; Nakamura, 1985) of high commercial value. Mediterranean spearfish have a distribution limited to the Mediterranean Sea, although some specimens have been recorded from the Atlantic side of the Strait of Gibraltar (Di Natale *et al.*, 2005b). Moreover, this species is considerably abundant around Italy (Nakamura, 1985), particularly in the Tyrrhenian Sea, where it is caught as by-catch of large pelagic fisheries and in the Strait of Messina (Di Natale *et al.*, 2005b). Swordfish is found in the open waters of tropical, subtropical and temperate oceans of the world, including the Mediterranean Sea (Palko *et al.*, 1981; Di Natale *et al.*, 2005b). After the crisis in swordfish fishery in recent years, worsened by the European ban on driftnets since 2002 (UE Regulation No. 1239/98), harpoon and long lines are the only fishing gear permitted for the catch of both pelagic species, although, in the Strait of Messina, spearfish and swordfish are caught only by harpoon, using traditional boats called 'feluche' or 'passerelle', from the late spring to summer. These boats, once used mainly to catch swordfish and bluefin tuna (*Thunnus thynnus*), are now adapted to fishing activity in relation to resource availability and behaviour, also selecting spearfish as a target species (Sisci, 1984, Cavallaro & Lo Duca, 1996; Di Natale *et al.*, 1996, 2005b; Potoschi, 2000; Romeo *et al.*, 2001, 2003). Information on harpoon catch data of *T. belone* from the Strait of Messina are reported by Di Natale *et al.* (2003, 2005a,b), Potoschi (2000) and Romeo *et al.* (2001), although scanty information on its biology (Potoschi, 2000) and feeding ecology is available (Spartà, 1961; Nakamura, 1985; Castriota *et al.*, 2008).

Regarding *X. gladius*, several aspects of fishery, biology, genetics and stock structure have been studied in the Mediterranean Sea (De Metrio *et al.*, 1989; Cavallaro &

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Lo Duca, 1996; Di Natale & Mangano, 1995; Tserpes & Tsmenides, 1995; Di Natale *et al.*, 1996; Romeo *et al.*, 2001, 2003). However, the feeding ecology of this billfish has been not investigated in this area; studies took place in other Mediterranean areas such as the Aegean Sea (Salman, 2004; Peristeraki *et al.*, 2005), the Adriatic Sea (Bello, 1991) and the Ligurian Sea (Orsi-Relini *et al.*, 1996).

Studies on trophic ecology of fish are useful and fundamental in understanding the functional role of different fish within aquatic ecosystems (Wootton, 1998; Blaber, 2000; Cruz-Escalona *et al.*, 2000; Linke *et al.*, 2001; Hajisamae *et al.*, 2004). Pelagic top predators may be considered as potential competitors for food, although it is possible that they adopt different strategies for exploiting the same environment (Dagorn *et al.*, 2000). The analysis of feeding habits and trophic relationships of these fish will be crucial for the successful management and conservation practices (Gerking, 1994). Then, our main goals are to describe the dietary habits of these two predators and to explore the ways in which food resources are partitioned among them, in order to identify interactions between the two billfish.

MATERIALS AND METHODS

The catch data of Mediterranean spearfish and swordfish were collected daily in the Strait of Messina (central Mediterranean Sea) from 2004 to 2006, using fishermen's logbooks and interviews with the crews from all the harpoon fishery boats. A sample boat was selected for the daily boarding of a scientific observer. The number of caught fish was recorded for every fishing day.

The study focused on diet was carried out on the stomach content of 53 spearfish and 95 swordfish. Fish were measured to the nearest centimetre from the tip of the bill to the posterior margin of the middle caudal rays (lower jaw fork length (LJFL)).

The stomachs were removed and stored in a 70% alcohol solution for content analysis. In the laboratory, all prey items were identified to the lowest possible taxonomic level, then counted and weighed to the nearest 0.1 g. All stomach contents were preserved in 70% ethanol, while cephalopod beaks were preserved in a glycerol solution and 70% ethanol.

The degree of prey digestion was determined according to the following scale (Vaske *et al.*, 2004): ND, non digested prey; ID, initial digestion, with loss of parts of skin and fish scales, and of carapaces for crustaceans; AD, advanced digestion, with loss of fins and muscular parts; and CD, complete digestion, only the remains of muscle, bones, carapaces and cephalopods beaks. Preys classified in the ND and ID stages were measured to the nearest millimetre (total length for fish, mantle length for cephalopods, carapace length for crustaceans).

As hard parts resistant to digestion (i.e. cephalopod beaks, fish otoliths and eyes) cumulate in the stomachs over more meals, leading to overestimation of the importance of prey they belong to, only prey bearing fleshy remains were considered for the analyses, as they were supposed to have been recently eaten by the predator (see Santos *et al.*, 2001 for details on this matter). Cephalopod beak lengths—the lower rostral length and the lower hood length in decapods and octopods respectively (Clarke, 1986)—were used to estimate mantle length of digested cephalopods and to reconstitute their weights, using relationships either in the literature (Clarke, 1986; Bello, 1991), or from measurements on specimens in our reference collection (ICRAM collection).

Data analysis

Vacuity index (V) for empty stomachs was calculated as a percentage of the total number of stomachs.

The PRIMER software was utilized to compute prey species accumulation plots as an average of 999 curves based on varying random orders of the stomach. In order to assess whether the curve reached an asymptote, the logistic and linear regressions were calculated and their integrity of fit coefficient R^2 were compared: the sample size was considered sufficient if the R^2 for the logistic curve resulted higher than the R^2 for the linear relation (Castriota *et al.*, 2005).

The importance of the different prey items was evaluated by calculating the frequency of occurrence $F\% = (n_i/N)^*100$, abundance $N\% = (n_i/n_t)^*100$ and weight $W\% = (w_i/W_t)^*100$. These values were used to calculate the index of relative importance (IRI%) for each taxonomic category using mass: $IRI\% = (N\% + W\%)^*(F\%)$ (Pinkas *et al.*, 1971; Hyslop, 1980; Hacunda, 1981).

Diet breadth was calculated by Levin's standardized index (Krebs, 1989; Labropoulou & Papadopoulou-Smith, 1999) for biomass:

$$B_i = \frac{1}{n-1}\left(\frac{1}{\Sigma_j p_{ij}^2} - 1\right)$$

This index ranges from 0 to 1; low values indicate a diet dominated by few prey items (specialist predators), while high values indicate generalist diets (Gibson & Ezzi, 1987; Krebs, 1989).

The degree of dietary overlap between *X. gladius* and *T. belone* was calculated using the Schoener index (1970), as follows:

$$T = 1 - 0.5 \sum |px_{fi} - py_{fi}|$$

where px_{fi} and py_{fi} are the proportions by weight in stomachs of the resource 'fi' (prey category) for species x and y, corresponding to spearfish and swordfish, respectively. This overlap index varies from 0, when the two species use a totally different resource, to 1, when they use the same prey category in the same proportions.

This index is one of the least objectionable indices available when food availability data are unavailable. The Horn index of resource overlap (Horn, 1966) was also calculated, because it guarantees good results compared to other overlap indices (Cailliet & Barry, 1979) and it is subject to low bias due to variation in sample size and resource categories (Smith & Zaret, 1982).

This index was calculated as follows:

$$CH = \frac{2\left(\sum p_{ij} p_{ik}\right)}{\sum p_{ij}^2 + \sum p_{ik}^2}$$

where p_{ij} and p_{ik} are the percentages of the i^{th} group of n preys found in stomach contents of predators 1 and 2,

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corresponding to *T. belone* and *X. gladius*, respectively. The value of CH ranges from -1 (no overlap) to 1 (perfect overlap).

The definition of overlap rate was modified by Langton (1982): low overlap 0.0–0.29, moderate overlap 0.30–0.59 and high overlap (to be biologically significant) 0.60–1.00. Following Sturdevant *et al.* (2001), diets were considered similar for CH > 0.6. Overlap was first calculated using prey weight and computed at a family level.

To assess the adequacy of the number of samples analysed, the cumulative number of new prey types against the cumulative number of non-empty stomachs were plotted (Ferry & Caillet, 1996).

Prior to the statistical analysis, data were square root transformed. The similarity matrix was constructed to form a multi-dimensional scaling ordination (MDS), i.e. using a PRIMER statistical package version 5 (Clarke & Gorley, 2001).

A one-way similarity analysis (ANOSIM) was performed on the similarity matrices to test whether the dietary samples of both species were different. To assess which dietary items offer the greatest contribution to the similarity, a similarity percentage (SIMPER) was used.

RESULTS

A total of 261 *T. belone* and 518 *X. gladius* were caught over three years by the total number of harpoon fishery boats in the central Mediterranean Sea (Strait of Messina) (Figure 1).

The two species occur each year in the same area and period, mainly in July and August, as shown by the trend on the catch (Figure 2).

Fifty-three stomachs of *T. belone* with a length ranging between 105 and 195 cm (LJFL) and ninety-five stomachs of *X. gladius* with a length ranging between 110 and 210 cm (LJFL) were collected from the sample boat. Data on fish length/frequency are given in Figure 3. The vacuity coefficient analysed for specimen sampled was 2.10% for spearfish and 7.36% for swordfish.

The cumulative prey types curve (Figure 4) computed for *T. belone* and *X. gladius* resulted to be more adequate when using a logistic curve ($R^2 = 0.9742$, $F_{(1,51)} = 5384.51$, $P < 0.0001$ and $R^2 = 0.954$, $F_{(1,93)} = 6987.27$, $P < 0.0001$, in

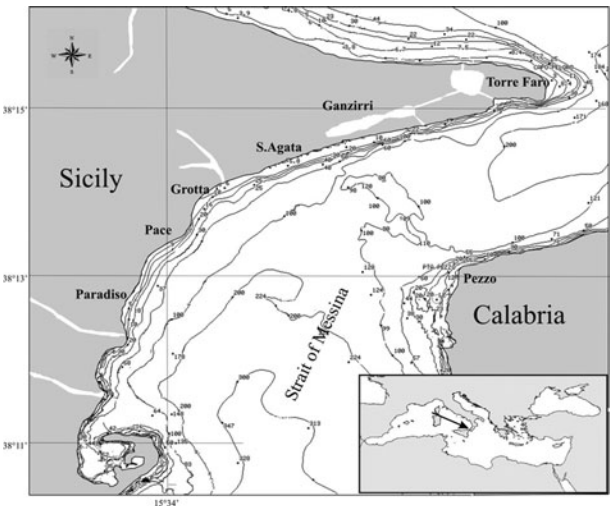

Fig. 1. Study area.

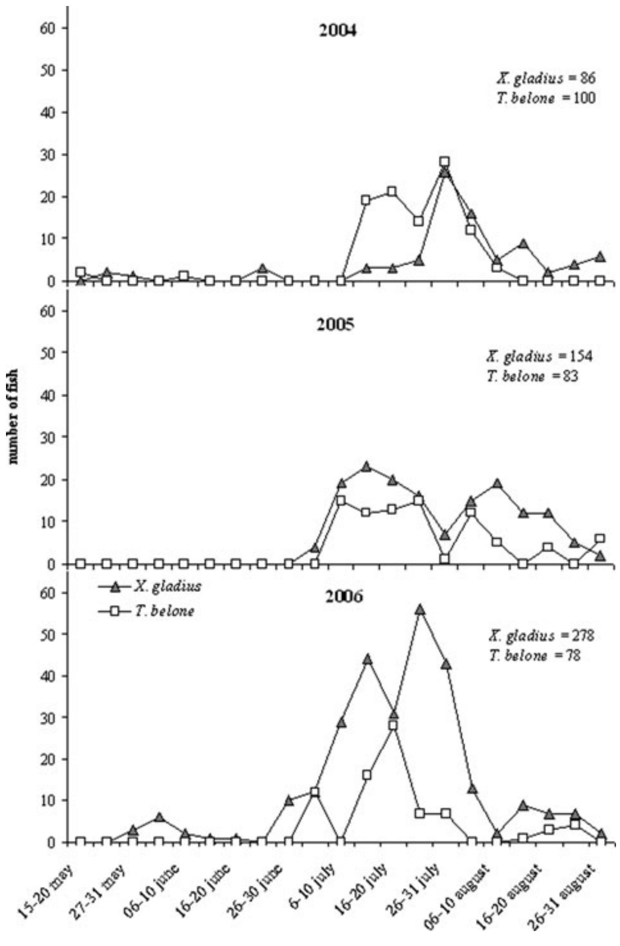

Fig. 2. Number of specimens of *Xiphias gladius* and *Tetrapturus belone* caught during the period 2004–2006 by the total boats of harpoon fishery.

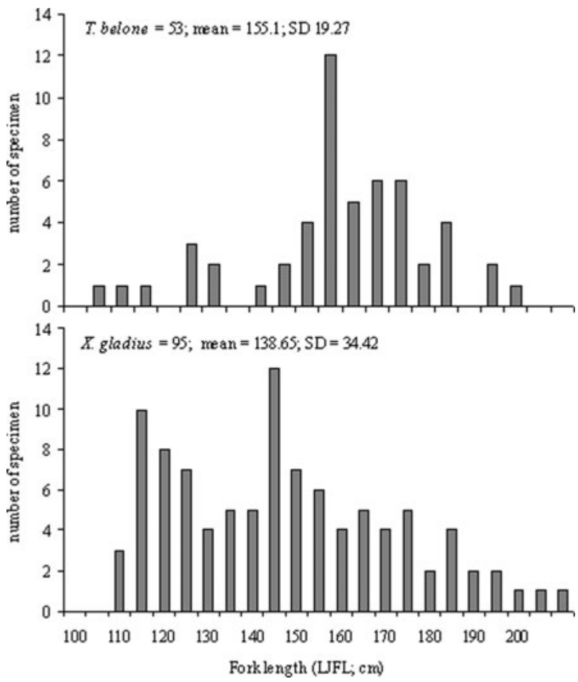

Fig. 3. Length–frequency distributions of *Tetrapturus belone* and *Xiphias gladius* examined for stomach contents during the season 2004 to 2006.

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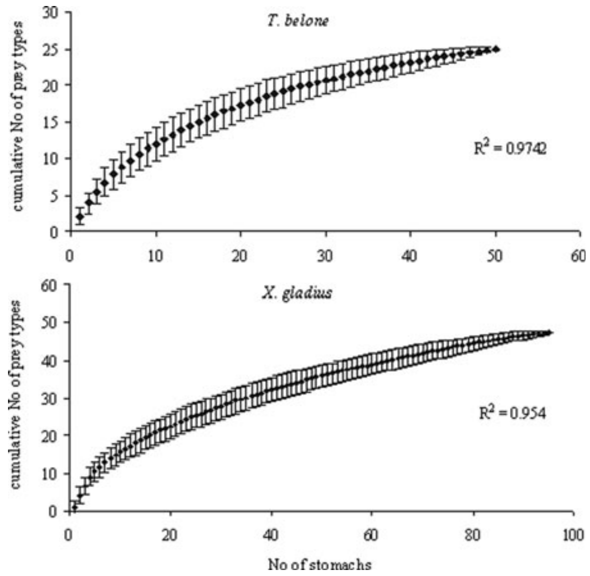

Fig. 4. Prey species accumulation plots as an average of 999 curves based on different random orders of the stomachs extracted. Vertical bars represent standard deviation.

T. belone and *X. gladius*, respectively) than when using a linear relation ($R^2 = 0.9174$, $F_{(1,51)} = 1939.56$, $P < 0.0001$ and $R^2 = 0.9384$, $F_{(1,93)} = 2540.11$ $P < 0.0001$, in *T. belone* and *X. gladius*, respectively). Therefore, the sample sizes were considered sufficient to describe the diet of both species.

Twenty-four taxa and 300 prey individuals were found in the stomachs of spearfish; 46 taxa and 1968 prey individuals in the stomachs of swordfish (Table 1), belonging to six main taxa: Hydrozoa, Crustacea, Cephalopoda, Tunicata, Chondroichthyes and Osteychtes. Only 16 food items were found in both predators.

In *T. belone*, fish were the dominant group according to all numerical indicators (F% = 92.5; N% = 93.5; W% = 96.7; IRI% = 99.1), as shown in Figure 5. Eight families were identified among them, dominated by Belonidae and Clupeidae, which represented 40.9% and 36.8%, respectively, of the total preyed items in terms of IRI% and were mostly composed of *Belone belone* (IRI% = 39.6) and *Sardinella aurita* (IRI% = 36.6), followed by other fish species such as *Engraulis encrasicolus*, *Coryphaena hippurus* and *Scomberesox saurus*. Identified cephalopods were mainly in complete digestion degree (only beak), with the exception of *Ancistrocheirus lesueri* and *Tremoctopus violaceus* that were in initial digestion degree.

The diet of *X. gladius* was typified by teleosts and cephalopods, which represented 59% and 39.1%, respectively of the total preyed items in terms of IRI% (Figure 5). Eleven teleost and five cephalopod families were recognized among them, dominated by Trichiuridae (IRI% = 30.5) and Ommastrephidae (IRI% = 27.6). The former was represented only by the presence of *Lepidopus caudatus* (IRI% = 30.5), followed by *S. aurita* (IRI% = 5.2), while the latter was represented by *Todarodes sagittatus* (IRI% = 21.1) and *Illex coindetii* (IRI% = 6.5).

Other fish species, belonging to Paralepididae, Carangidae, Scombridae and Sphyraenidae families, were occasionally recorded. *Tremoctopus violaceus*, *Thysanoteuthis rhombus*, *Octopoteuthis* cfr. *sicula*, *Eledone cirrhosa* and *Histiotheuthis bonnellii* were found only in advanced or complete digestion degree and recognized by beaks. Swordfish also preyed on crustaceans that were mainly represented by Euphasidae (IRI% = 0.5).

When the volumetric dietary data recorded for each one of the two species were grouped into families and subjected to MDS ordination, the points of the dietary samples of *T. belone* and *X. gladius* formed two groups that were practically distinct from one another. Although the stress level for the ordination (Figure 6) is quite high, i.e. 0.1, it is relevant that one-way ANOSIM demonstrates that the dietary compositions differed significantly between the two species ($P <$ 0.05%) and produced a global R statistic of 0.201. Results from a similarity percentage analysis (SIMPER) showed that the diet of *T. belone* was mainly represented by teleosts belonging to the Clupeidae and Belonidae families.

In contrast, the diet of *X. gladius* was typified by fish species belonging to the Trichiurudae family and cephalopods belonging to the Ommastrephidae family.

SIMPER showed that the diet of *X. gladius* was distinct from that of *T. belone* because of the presence of relatively greater amounts of Ommastrephidae and Trichiurudae and by a relatively lower volume of Clupeidae and Belonidae (Table 2).

Tetrapturus belone total prey length ranged between 110 and 560 mm, with a mean length of 207 mm (Figure 7). All measured prey items were fish, while all cephalopods analysed in the stomach contents were in advanced or complete digestion degree. The prey items that contributed to a greater extent to the mean lengths observed were *S. aurita* and *B. belone*. Swordfish prey total length measured on a range between 60 and 1060 mm, with a mean length of 249 mm. Most prey items ranged between 160 and 210 mm in body length and they were represented by the cephalopods Ommastrephidae *T. sagittatus* and *I. coindettii*. Prey items with a length > 210 mm were exclusively fish and mostly represented by *L. caudatus*.

The feeding rhythm was determined according to prey digestion degree and stomach fullness. For the two specimens, non-digested prey items were recorded in stomachs containing from 1 to 7 prey items (Figure 8). In the stomachs containing up to 16 prey items, only advanced and complete digested prey items were observed. Nine stomachs contained only cephalopod beaks, ranging from 18 to 41 completely digested beak units.

As regards the diet breadth, Levin's standardized index was 0.15 in spearfish and 0.18 in swordfish. Regarding the diet overlap between the two species in the central Mediterranean Sea, Schoener and Horn indices showed low values (0.23 and 0.21 for the two indices, respectively).

DISCUSSION

This study represents the first evaluation of food partitioning between swordfish and Mediterranean spearfish. Analysis of catch data showed the contemporary presence of both billfish in the Strait of Messina, for the three fishing seasons investigated. Then, swordfish and spearfish live in the same area during the same period, thanks to the considerable upwelling that brings food and nutrients to the upper layers of the Strait (Guglielmo *et al.*, 1995; Zagami *et al.*, 1996).

Table 1. Per cent frequency of occurrence (%F), per cent abundance (%N), percentage by weight (%W) and index of relative importance (IRI) for prey types of *Xiphias gladius* and *Tetrapturus belone*.

Taxa	Species prey	*X. gladius*				*T. belone*			
		%F	%N	%W	%IRI	%F	%N	%W	%IRI
Cephalopoda									
Onychoteuthidae	*Ancistrotheuthis lichtensteini*	2.11	0.46	0.04	0.04				
	Ancistrotheuthis lichtensteini (beak)	6.32	1.07						
Ancistrocheiridae	*Ancistrocheirus lesueri*	1.05	0.05	0.00	0.00	5.66	1.33	0.01	0.16
Und. Cephalopods (beaks)		31.58	6.86			3.77	1.00		
Und. Cephalopods		28.42	5.54	4.60	11.39	1.89	0.33	0.01	0.01
Und. Cephalopods (eyes)		34.74	17.28						
Chiroteuthidae	*Chiroteuthis veranyi*	2.11	0.10	0.31	0.03				
	Chiroteuthis veranyi (beak)	7.37	0.91						
Octopodidae	*Eledone cirrhosa* (beak)	1.05	0.05						
Histioteuthidae	Histioteuthidae	4.21	0.56	0.35	0.15				
	Histioteuthidae (beak)	15.79	3.40			1.89	0.33		
	Histioteuthis bonnellii (beak)	10.53	1.27			5.66	2.00		
Ommastrephidae	*Illex coindettii*	17.89	1.17	7.97	6.46	5.66	1.67	3.12	0.58
	Illex coindettii (beak)	20.00	3.00			9.43	3.67		
	Ommastrephes bartramii (beak)	2.11	0.36						
	Todarodes sagittatus	24.21	2.29	19.75	21.08				
	Todarodes sagittatus (beak)	30.53	8.79			3.77	1.00		
Und. Ommastrephidae		1.05	0.10	1.34	0.06				
Octopoteuthidae	*Octopoteuthis* cfr. *sicula* (beak)	1.05	0.05						
Onychoteuthidae	*Onychoteuthis banksi*	3.16	0.56	0.00	0.07				
Und. Teuthoidea		3.16	0.15	1.04	0.15				
Und. Teuthoidea (beak)		2.11	1.47						
Thysanotheutidae	*Thysanoteuthis rhombus* (beak)	1.05	0.15			1.89	0.33		
Tremoctopodidae	*Tremoctopus violaceus*					1.89	0.33	0.16	0.02
	Tremoctopus violaceus (beak)	3.16	0.20			7.55	4.33		
Chondroichthyes									
Selachoidei		1.05	0.05	0.67	0.03				
Crustacea									
Und. Amphipoda		1.05	0.05	0.00	0.00				
Und. Aristeidae		1.05	0.05	0.10	0.01				
Und. Calanoida		1.05	0.20	0.00	0.01				
Und. Crustacea		3.16	1.58	0.00	0.20				
Und. Euphausiidae		2.11	6.40	0.08	0.54				
Und. Hyperiidea		1.05	0.20	0.00	0.01				
Und. Isopoda		2.11	0.10	0.00	0.01				
Hydrozoa									
Diphyidae		3.16	2.95	0.01	0.37	1.89	1.67	0.00	0.07
Osteichthyes									
Belonidae	*Belone belone*	3.16	0.15	1.27	0.18	33.96	23.00	31.40	39.60
	Belone svetovidovi					1.89	0.33	0.14	0.02
	Belone spp.					7.55	5.33	2.26	1.23
Carangidae	*Seriola dumerili*					1.89	0.33	0.36	0.03
	Trachinotus ovatus	1.05	0.15	3.05	0.13				
	Trachurus trachurus	1.05	0.05	0.01	0.00				
	Trachurus spp.	4.21	0.25	5.17	0.90	3.77	1.00	0.56	0.13
Caproidae	*Capros aper*	1.05	0.05	0.54	0.02				
Centracanthidae	*Spicara smaris*	1.05	0.10	0.12	0.01				
	Spicara spp.	1.05	0.05	0.02	0.00				
Clupeidae	*Alosa* spp.					3.77	1.67	1.43	0.25
	Sardina pilchardus	3.16	0.51	1.14	0.21	1.89	0.33	0.01	0.01
	Sardinella aurita	13.68	1.88	7.79	5.23	32.08	15.67	37.49	36.55
Coriphaenidae	*Coryphaena hippurus*					5.66	1.33	8.29	1.17
Engraulidae	*Engraulis encrasicolus*					11.32	11.00	5.89	4.10
Gonostomatidae	*Gonostoma denudatum*	2.11	0.10	0.19	0.02				
Und. Myctophidae		2.11	0.20	0.13	0.03				
Und. Paralepididae		4.21	0.66	0.71	0.23				
	Paralepis coregonoides	1.05	0.05	0.05	0.00				
	Paralepis speciosa	1.05	0.51	0.20	0.03				
	Sudis hyalina	3.16	0.30	0.75	0.13				
Scombridae	*Scomber japonicus*	1.05	0.05	1.56	0.07	3.77	0.67	1.48	0.17

Continued

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Table 1. Continued

Taxa	Species prey	*X. gladius*				*T. belone*			
		%F	%N	%W	%IRI	%F	%N	%W	%IRI
	Scomber scombrus	1.05	0.05	2.03	0.09				
Und. Scombridae		1.05	0.05	0.27	0.01	3.77	0.33	2.02	0.19
Scomberesocidae	*Scomberesox saurus*					7.55	1.67	1.84	0.57
Sparidae	*Boops boops*	2.11	0.10	0.05	0.01				
	Oblada melanura					1.89	0.33	0.22	0.02
Sphyraenidae	*Sphyraena sphyraena*	1.05	0.05	0.06	0.00				
Trichiuridae	*Lepidopus caudatus*	23.16	4.67	28.63	30.48				
Und. teleostea		32.63	6.61	9.98	21.38	32.08	18.67	3.30	15.11
Und. teleostea eyes		18.95	10.98						
Und. otoliths		4.21	3.76						
Tunicata									
Salpidae		4.21	1.22	0.04	0.21	1.89	0.33	0.00	0.01

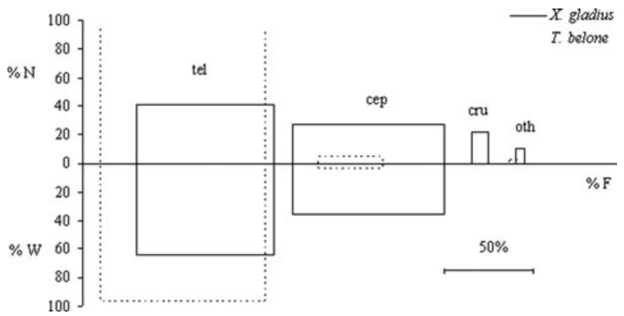

Fig. 5. Per cent frequency (%F), per cent number (%N), per cent weight (%W) for the main food categories in the diet of *Tetrapturus belone* and *Xiphias gladius*.

Table 2. Similarity percentage (SIMPER) analysis showing dietary items mostly contributing to the dissimilarity (mean = 95.07) between *Tetrapturus belone* and *Xiphias gladius*.

Taxa	*T. belone*	*X. gladius*	Cumulative %	Contribution %
	Mean	Mean		
Clupeidae	55.41	16.9	22.84	22.84
Belonidae	48.1	2.41	40.65	17.81
Ommastrephidae	4.44	54.99	57.22	16.56
Trichiuridae	0	54.2	67.53	10.31
Teleostea	4.7	18.88	76.64	9.11
Cephalopoda	0.01	8.71	81.15	4.52
Scomberoidae	4.98	7.31	84.67	3.52
Carangidae	1.3	15.57	87.87	3.2
Coryphaenidae	11.8	0	90.85	2.98

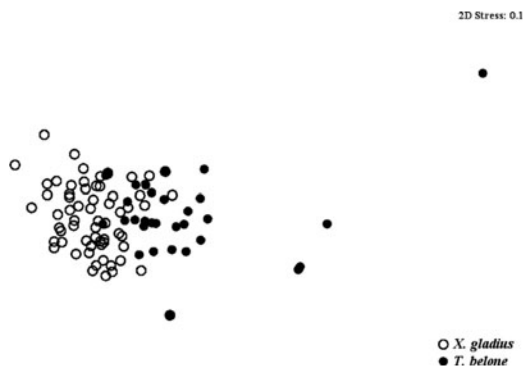

Fig. 6. MDS ordination of the dietary samples of *Tetrapturus belone* and *Xiphias gladius*.

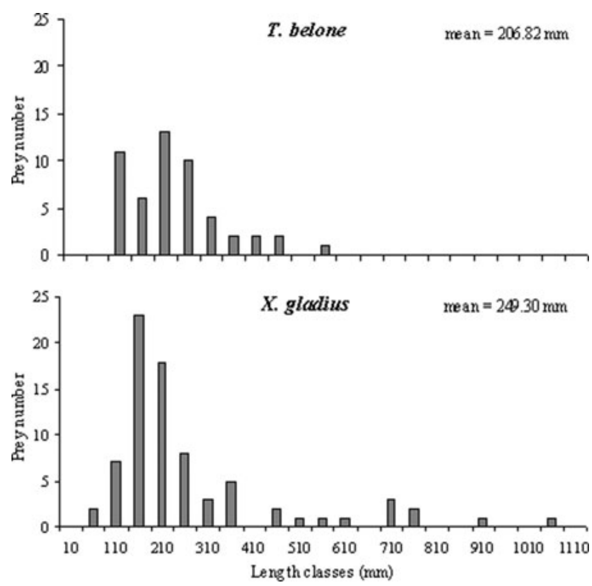

Fig. 7. Length–frequency distributions of preys found in the stomachs of *Tetraturus belone* and *Xiphias gladius*.

Results of a multivariate statistical analysis (ANOSIM and MDS) demonstrated that the dietary compositions differed significantly between swordfish and spearfish. A previous study on diet analysis of *T. belone*, carried out in the same area, but during a different period (1995–2004), reported that cephalopods were the main prey items, followed by teleosts, even if the specific composition showed the same results with the dominance of *S. aurita* as a preferential species (Castriota *et al.*, 2008).

In contrast, the diet of *X. gladius* was typified by fish and cephalopods Ommastrephidae, as already reported by other studies carried out in the Mediterranean Sea (Bello, 1991; Salman, 2004; Peristeraki *et al.*, 2005) and in other areas (Moreira, 1990; Hernández-Garcia, 1995; Vaske & Lessa, 2005). Fish were mainly represented by Trichiurudae

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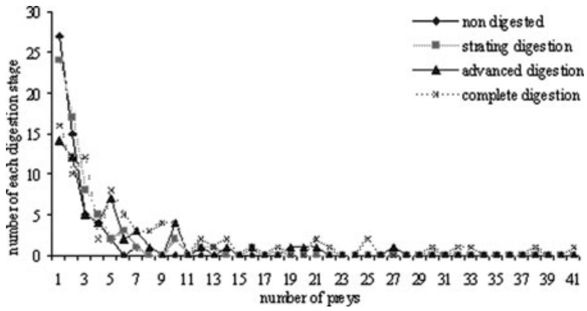

Fig. 8. Number of prey found in the individual stomachs with respective digestion stage which were observed.

Lepidopus caudatus, while cephalopods were represented by squids *Todarodes sagittatus* and *Illex coindetii*. According to other studies (Carey & Robinson, 1981; Takahashi *et al.*, 2003), these Ommastrephidae are generally preyed upon at nighttime, when they migrate to the surface. Moreover, the low values of both Schoener and Horn overlap indices also underlined food partitioning between the two species, which avoid competitive exclusion. It is worth noting that our results highlight a feeding strategy more related to the habitat of the species than to the food availability. In fact, migration patterns of the two predators are quite different. Swordfish show vertical migrations from 0 to 800 m (Carey & Robinson, 1981; Canese *et al.*, 2004), while spearfish are characterized by limited migrations, ranging between 0 and 200 m depths (Roper, 1974). The observation of specific prey items in the stomach content of both billfish confirmed the bathymetric range of their migrations. Actually, mesopelagic fish (Paralepididae) and cephalopods (*O. banksi)* were found exclusively in the stomachs of *X. gladius* and they were totally absent in *T. belone*, where food items were dominated by epipelagic species such as *B. belone* and *S. aurita* (Tortonese, 1975; Roper *et al.*, 1984; Whitehead, 1985). The round sardinella represents the best prey for pelagic fish in the Strait (Spartà, 1961; Campo *et al.*, 2006). In fact, this species is fished every day by pole and line to be used as bait for Scombridae fish, such as the Atlantic bonito, *Sarda sarda*, and the little tunny, *Euthynnus alletteratus* (Andaloro, 2004).

Considering the low values of the Levin index in diet breadth and the occurrence of *S. aurita* in the sampling area (personal comment), we can suppose that *X. gladius* and *T. belone* are specialist feeders, meaning that they selectively feed.

The high number of *Tremoctopus violaceus* in the stomach contents of *T. belone,* also reported in a previous study (Castriota *et al.*, 2008), confirms the preferential epipelagic habitat of the species. In fact, Octopoda most unlikely descends below the thermocline (Voss, 1953; Thomas, 1977; Bello, 1993). The ingestion of epipelagic species, such as *Trachinotus ovatus*, *B. belone, S. aurita*, observed in *X. gladius* stomach contents, is an occasional event that partly explains the occurrence of swordfish on the sea surface also during day-light hours (Romeo *et al.*, 2003).

The prey status shows that feeding behaviour of billfish involve an unusual method of catching the prey, by using the bill. Actually, swordfish stomachs contained whole fish and parts of fish; many ingested *L. caudatus* were found in large portions (3–4); the body of squids *T. sagittatus* and *I. coindetii* were divided in mantle and head, with beak and tentacles, by the whipping action of the bill, as reported also by other studies (Tibbo *et al.*, 1961; Stilwell & Kohler, 1985).

The discovery of beaks of *T. rhombus* and *Octopoteuthis* cfr. *sicula* in swordfish stomachs confirms the role of large predators as effective biological samplers for collecting information on nektonic organisms, as well as on 'rare species', as suggested by Bello (1993).

The data, considering the few studies conducted in the Mediterranean Sea, will be useful in ecological modelling for the better representation of the trophic flows associated with large, medium and small pelagic fish.

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