Diet of *Torpedo torpedo* and *Torpedo marmorata* in a coastal area of Central Western Italy (Mediterranean Sea)

Régime alimentaire de *Torpedo torpedo* et *Torpedo marmorata* dans le secteur central des côtes occidentales italiennes (mer Méditerranée)

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Résumé

Romanelli M., I. Consalvo, M. Vacchi, M.G. Finoia – [Régime alimentaire de *Torpedo torpedo* et *Torpedo marmorata* dans le secteur central des côtes occidentales italiennes (mer Méditerranée)]. *Mar. Life*, 16 (1-2) : 21-30.

Afin d'étudier le régime alimentaire de *Torpedo torpedo* et de *T. marmorata*, nous avons prélevé régulièrement, pendant une année, des lots des deux espèces lors du débarquement de chalutiers au port de Fiumicino, aux environs de l'embouchure du fleuve Tevere (mer Tyrrhénienne). Pendant 67 inspections journalières nous avons enregistré environ 1700 exemplaires de torpilles, et nous avons vu que les quantités débarquées de chaque espèce ne sont pas corrélées. Les quantités de torpille commune sont élevées en automne – hiver, durant cette période nous avons enregistré plus de 85% des exemplaires prelevés pendant tout le cycle d'échantillonnage. En laboratoire nous avons mesuré, pesé et examiné le contenu stomacal de 534 exemplaires de *Torpedo torpedo* et de 367 exemplaires de *Torpedo marmorata*. Les proies retrouvées dans les estomacs de 240 torpilles communes et de 92 torpilles marbrées montrent que les deux espèces sont piscivores, mais il y a peu de superposition des deux régimes parce qu'elles mangent différents poissons. On a noté, en particulier, que les torpilles communes mangent surtout des juvéniles de *Solea solea* pendant l'hiver et d'autres poissons littoraux durant les mois les plus chauds, tandis que les torpilles marbrées se nourrissent de téléostéens vivant dans des zones un peu plus profondes comme des gobies, des sparidés et des clupéidés ; ces données confirment que les deux espèces vivent dans des secteurs bathymétriques différents. Nos données ont mis en évidence que les torpilles communes les plus jeunes mangent des proies plus petites, mais ce phénomène ne se vérifie pas avec les torpilles marbrées.

MOTS CLÉS :
torpille, nourriture, mer Tyrrhénienne, Sélaciens, Italie.

Abstract

Romanelli M., I. Consalvo, M. Vacchi, M.G. Finoia – Diet of *Torpedo torpedo* and *Torpedo marmorata* in a coastal area of Central western Italy (Mediterranean Sea). *Mar. Life*, 16 (1-2): 21-30.

In order to study the diet of *Torpedo torpedo* and *T. marmorata* samples were regularly taken for one year from the landings of some commercial trawlers based at Fiumicino, near the River Tiber's outflow (Tyrrhenian Sea). A total of approximately 1,700 torpedoes were recorded during 67 daily inspections, and we found that landings of two species were uncorrelated. Landings of common torpedoes were high in Autumn-Winter, with more than 85% of total individuals recorded at this time.
In the laboratory, 534 *T. torpedo* and 367 *T. marmorata* individuals were measured, weighed, sexed and examined for their stomach content. Prey obtained from 240 common and 92 marbled torpedoes showed that both species are piscivorous, but there is little overlap in their diets since they target different fishes. In Autumn-Winter common torpedoes mainly fed on *Solea solea* juveniles and on several other littoral fishes during warmer months, whilst marbled torpedoes always focused on prey from somewhat deeper areas of the continental shelf, such as gobies as well as sparids and clupeids; thus our data confirmed that the two examined species live at different depths.
Our data showed that larger common torpedoes had eaten heavier prey but a partly different pattern was seen among *T. marmorata* specimens.

KEY-WORDS:
diet, torpedoes, Italian, Tyrrhenian, Selachians.

Introduction

Although data on the populations of Mediterranean Selachians are still scarce, several studies performed in recent years show that the abundance of most species has sharply decreased over past decades (Bertrand *et al.*, 2000; Hemida *et al.*, 2000; Vacchi, Notarbartolo di Sciara, 2000; Soldo, 2003). This being so, monitoring of catches from commercial and/or recreational fisheries and studies on sensitive facets of the biology of local populations (e.g.: growth and fecundity at age) are useful to enable us to understand which populations are more severely depleted, when more complete demographic data are not available. Similarly, information on diets may help to single out species whose feeding habits are presumably more affected by the biomass losses and alterations of interspecific relationships induced by fisheries (Greenstreet, Rogers, 2000) as well as other human activities.

The diets of the common torpedo, *Torpedo torpedo* (Lianneus, 1758), and the marbled torpedo, *Torpedo marmorata* Risso 1810, were mainly studied along the southern coast of the Mediterranean Sea (Capapé, 1979; Abdel-Aziz, 1994; Froese, Pauly, 2004), showing that both species feed on fish as well as, to some extent, large crustaceans and other invertebrates.

As analogous data are still lacking for populations of both species from the northern side of the basin (apart from those briefly reported by Minervini and Rambaldi, 1985, for the common torpedo) our report makes good this lack and also identifies distinct seasonal patterns in the diet of both fishes.

Materials and methods

In order to study the diet of the electric rays living in the Central Tyrrhenian Sea *T. torpedo* and *T. marmorata* samples were collected monthly for one year from November 2000, from the daily landings of the professional otter trawlers based in Fiumicino, near the River Tiber's outflow (Latium, Italy, **Figure 1**).

As a rule landings from 8-12 boats (out of the 32 local trawlers) were inspected during each visit to the harbour but samples were combined later and no data were recorded on the fishing areas and effort. Local trawlers are known to operate all year-round within 50 km (mainly within 35 km) of the home harbour and the main shelf areas are at 40-70 m and 90-130 m depth, *i.e.* near the closed coastal zone (EC Regulation No. 1626/94) and the shelf outer margin (La Monica, Raffi, 1996) where some high-valued littoral species and large aggregations of other fishes may be respectively targeted. Offshore grounds are much deeper (220-550 m), the targeted species mainly being epibathyal crustaceans.

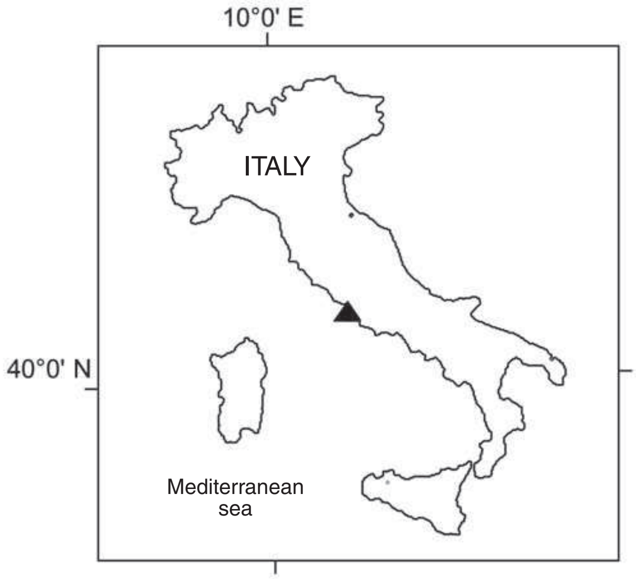

Figure 1
Position of the fishing harbour of Fiumicino on the Italian coastline.
Position du port de Fiumicino sur la côte occidentale de la péninsule italienne.

As preliminary interviews with fishermen had proved difficult and reports were often vague (partly because each boat had usually performed 3-6 hauls, landing operations were fast and involved several trawlers at the same time), we assumed that all landed *T. torpedo* and *T. marmorata* individuals came from 40-130 m grounds, in agreement with the above-mentioned operational pattern of trawlers and previous reports on the distribution of the two species along the Italian coast (Tortonese, 1956; Bini, 1967; Fischer *et al.*, 1987).

A total of 67 distinct inspections of daily landings were performed during the entire study. The presence of *T. torpedo* and *T. marmorata* individuals were respectively recorded in landings from 41 and 55 out of the total daily inspections carried out at Fiumicino harbour.

In the laboratory all torpedoes were thawed, sexed and their total lengths, full and eviscerated weights respectively taken to the nearest millimetre and gram. Both the stomach and its content were weighed, and the latter was stored in 70% ethanol for further analysis.

All prey were fishes and they were identified at family/species level (Tortonese, 1970, 1975; Fischer *et al.*, 1987; Aboussouan, 1994). When otoliths were the only remains of preyed fishes they were coupled and recorded as unidentified teleosts; only in a few cases were otoliths were recognised at family level (Härkönen, 1986). In order to reduce the problem of prey ingested in the fishing net,

Table I

Numbers of *Torpedo marmorata* and *T. torpedo* indidviduals landed and sampled at Fiumicino during the 12-month study.

Nombre d'exemplaires de Torpedo mormorata *et de* Torpedo torpedo *débarqués ou prélevés dans le port de Fiumicino pendant un cycle annuel d'échantillonnage.*

Season	No. of inspections (days)	Percentage days with torpedoes	No. sampled individuals	Overall sex-ratio in samples	Median lenght of sampled males (mm)	Mean range of sampled males (mm)	Length weight of sampled males (mm)	Median length of sampled males (g)	Median length of sampled females (mm)	Mean length of sampled females (mm)	Length range of sampled females (mm)	Median weight of sampled females (g)	No. individuals landed by scrutinized boats
						Torpedo torpedo							
AUTUMN*	17	76.5%	179	0.74	302.5	A 294.8	146-445	429.1	308.5	D,E,F 299.2	96-430	482.2	530
WINTER	19	89.5%	177	0.38	259.5	A,B,C 264.1	124-397	303.0	330.0	D,G,H 325.1	120-454	647.6	640
SPRING	21	28.5%	48	1.67	326.0	B 313.2	215-400	558.4	269.5	E,G 252.6	130-351	372.0	48
SUMMER	10	70.0%	130**	1:28	303.0	C 298.2	145-408	459.4	275.5	F,H 281.6	120-477	394.8	130**
						Torpedo marmorata							
AUTUMN*	17	88.2%	109	1.48	250.0	I 245.5	123-310	304.8	315.5	K,L 314.2	165-473	661.9	109
WINTER	19	68.4%	48	1.00	250.0	J 248.1	183-294	294.1	310.0	M,N 319.0	172-497	649.6	48
SPRING	21	91.5%	110	0.72	236.0	J 238.2	143-364	286.5	264.5	K,M 280.8	180-462	363.5	110
SUMMER	10	80.0%	100	0.82	233.0	I 228.6	131-320	270.2	269.0	L,N 279.6	132-553	425.0	100

*: sampling partitioned between years 2000-2001;
**: 5 torpedoes obtained from boats operating by fixed nets;

A: U=6.528 (p<0.0001); B: U=3.297 (p<0.001); C: U=2.443 (p<0.05); D: U=2.814 (p<0.01); E: U=2.828 (p<0.005); F: U=2.412 (p<0.05); G: U=2.611 (p<0.01); H: U=2.635 (p<0.01); I: U=2.858 (p<0.005); J: U=5.049 (p<0.0001); K: U=2.303 (p<0.05); L: U=2.134 (p<0.05); M: U=2.022 (p<0.05); N: U=4.220 (p<0.0001);

intact fish (on the whole 8 individuals, 6 from stomachs of marbled torpedoes) were discarded from analysis.

Identified and unidentified food items found in the stomachs were both counted (always selecting lowest estimates for unidentified prey), measured and weighed to the nearest mm and 0.1 gram. Since prey were usually not heavily digested (only 4.3% of food items found in the examined *T. torpedo* and none of those from *T. marmorata* specimens were otoliths and/or naked bones) no correction were made on prey lengths and weights to allow for the different digestion state of food items as well as the effect of the conservation liquid on them. However, when comparing by Mann-Whitney test mean sizes/weights of prey obtained from different clusters of torpedoes the most digested food items were not considered.

Percentages of empty stomachs (*i. e.* vacuity index, I_v after Hyslop, 1980) were recorded in distinct clusters of *Torpedo* spp. individuals and discrepancies statistically assessed by Chi-square test (Zar, 1999).

In the analysis of data, males and females of both torpedoes caught in Autumn and Winter were pooled, as well as those from Spring and Summer samples. A further stratification of samples was obtained by splitting torpedoes into distinct clusters of individuals respectively weighing up to and more than 500 grams.

The faunistic composition of stomach contents from distinct *Torpedo* spp. clusters was compared by correspondence analysis while the role of each prey in the diet was assessed by means of the following index:

$Q = W_i(\%) \times N_i(\%)$ (Hureau, 1970);

where:

$W_i(\%)$ = Percentage of prey of the i cluster on the total weight of prey;

$N_i(\%)$ = Percentage of prey of the i cluster on the total number of prey;

In order to assess whether there is any correlation between local landings of the two species a Sparkman rank test (Zar, 1999) was performed on numbers of animals landed each day.

A total of 534 (from 228 males and 306 females) *T. torpedo* and 367 (187 females and 180 males) *T. marmorata* stomachs were respectively examined during our investigation.

Results

A total of about 1,350 common torpedoes and 367 marbled torpedoes were landed by the boats investigated during the entire study **(Table I)**.

Once all daily data, either negative for both torpedoes or showing the presence of only one individual for each species, had been eliminated, the residual 58 records showed that daily landings of the two species were uncorrelated as the parameter "r" was estimated at −0.0640 ± 1.460 (95% confidence limits). *T. torpedo* landings peaked in Autumn-Winter (numerically forming about 85% of those recorded during our study), whilst numbers of *T. marmorata* individuals unloaded by the fishing vessels were low in Winter and comparatively high in Summer (on average 3.69 and 12.50 marbled torpedoes were counted respectively, considering only the days during which these animals were seen).

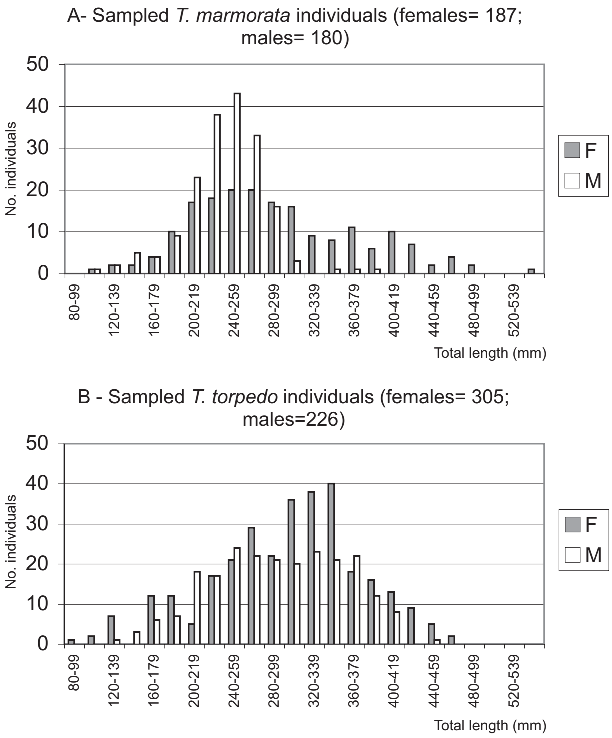

Figure 2

Size composition of the *Torpedo marmorata* and *T. torpedo* samples from the Fiumicino area examined during our study.

Structure de la mesure des échantillons de Torpedo torpedo *et de* Torpedo mormorata *examinés au cours de notre étude et provenant du débarquement des chalutiers de Fiumicino.*

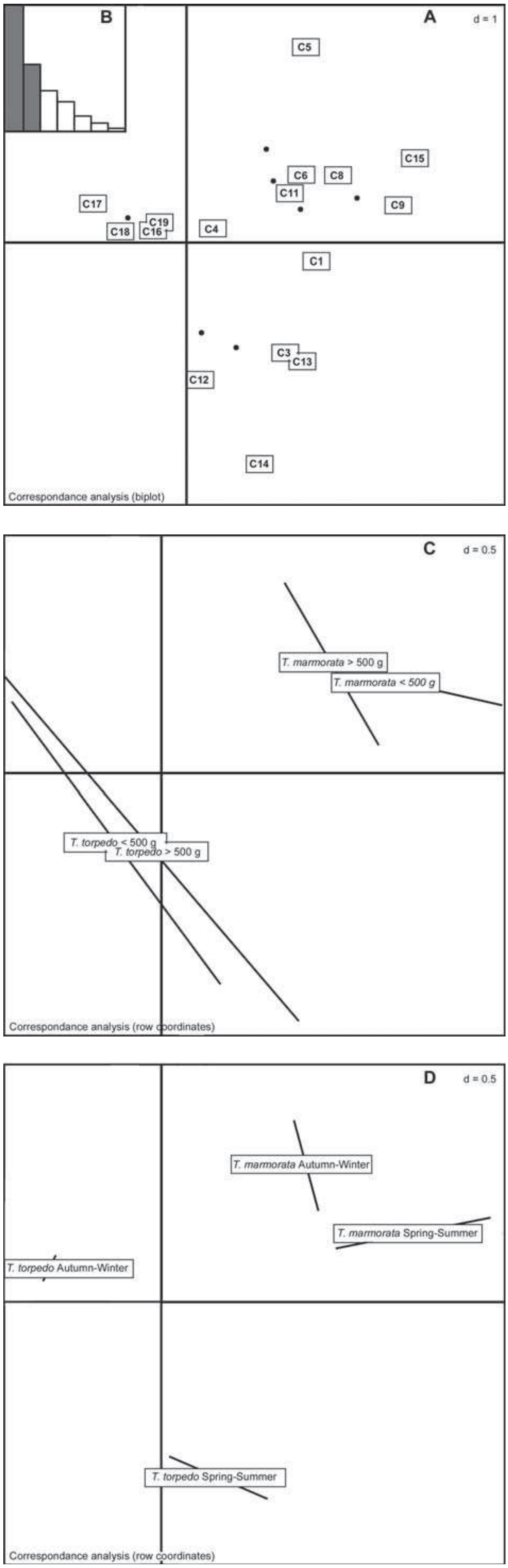

Figure 3

Correspondence analysis based on the composition of prey found in clusters of common and marbled torpedoes weighing either up to 500 g or more, caught in Autumn-Winter and Spring-Summer months respectively (A: plot of CA column coordinates; B: histogram of eigenvalues; C-D: plot of CA row coordinates with confidence ellipsoids). In plot A the zoological taxa and unidentified fishes are labelled C1, C2, C3 and so on, as shown on Tables IIA and IIB; clusters C7 and C15 as well as C2, C10 and C14 are closely clumped and not discernable. Dots show positions of 8 clusters of *Torpedo* spp. stomach samples taken by individuals of different species, sizes and seasons. In plots C-D ellipsoids of confidence are represented as lines due to the availability of only two data sets, i.e. prey either from large and small individuals or from stomach samples obtained during different seasons.

Analyse de correspondances basée sur la composition des proies retrouvées dans les groupes de T. torpedo *et* T. mormorata *de poids inférieur ou supérieur à 500 g capturées durant les périodes automne-hiver ou printemps-été (A: plot of CA column coordinates; B: histogram of eigenvalues; C-D: plot of CA row coordinates with confidence ellipsoids). Dans le graphique A les taxa zoologiques et les poissons non identifiés ont été étiquetés C1, C2, C3 et ainsi de suite, comme dans les tableaux IIA et IIB ; les groupes C7 et C15, ainsi que C2, C10 et C14 sont très proches et il n'est pas possible de les distinguer. Les points montrent les positions de huit groupes de contenus stomacaux de* Torpedo *spp. provenant d'espèces, de taille et de saison différentes. Dans les graphiques C-D, les ellipsoïdes de confiance ont été représentées par des lignes à cause de la disponibilité de seulement deux ensembles de données, par exemple les proies provenant des grands et des petits individus ou provenant des contenus stomacaux de différentes saisons.*

Mean sizes reported in the same **Table I** show that for both species larger females were caught in Autumn-Winter than in Spring-Summer, while for males either seasonal differences were not statistically discernable or were minimal. In spite of such seasonal differences of mean sizes, all samples were combined and the resulting overall size frequencies (except for the lengths of three *T. torpedo* individuals that were not recorded) are shown in **Figure 2**. As a rule animals spread quite smoothly over a large size range but almost all *T. marmorata* males were crowded into the 180-299 mm classes.

In combined samples 240 and 92 stomachs from common and marbled electric rays respectively contained distinct prey and/or discernable amounts of digested food. A total of 416 and 115 distinct animals were respectively counted in the *T. torpedo* and *T. marmorata* stomach samples.

In both species teleosts made up all the prey (beside one *Raja asterias* (Delaroche) individual found in the stomach of a large *T. torpedo* male). **Tables IIA-IIB** provide information on the sizes of torpedoes, vacuity index values, nature and numbers and weights of prey. In the distinct *T. marmorata* clusters vacuity indexes ranged from 67.3% to 82.2% (Nos. of examined individuals: 46 to 164) vs. values of 53.4%-55.4% recorded in the analogous *T. torpedo* pools (Nos. individuals: 74 to 175), and in a few instances such discrepancies were statistically significant.

Although a large fraction of prey remained unidentified, the correspondence analysis performed on these data **(Figure 3)** shows that compositions of food samples from torpedoes caught during the two distinct six-month periods are statistically uncorrelated and therefore different. Torpedoes of both species caught at the same time also appear to have fed on prey from different species/families. In contrast, the diets of large and small individuals of the two torpedoes largely overlap during each six-month period.

In Autumn-Winter sole juveniles (identified as *Solea solea* L. on the basis of time/size of presence and the high number of myomeres estimated on several individuals; Padoa, 1956; Piccinetti, Giovanardi, 1984; Paci *et al.*, 1989) and individuals from the mixed "unidentified fishes" cluster were by far the most important food sources of common torpedoes, with Q values of 2122.5 and 1049.8 respectively. In the 292 *T. torpedo* non-empty stomachs caught during this period young sole made up 44.7% and 47.3% of the prey number and weight respectively, whilst the "unidentified fishes" were 38.7% and 27.1% of the same totals. In Spring-Summer common torpedoes fed quite evenly on different prey such as *S. solea*, clupeids, Callionymidae spp. and the "unidentified fishes" which gave Q values between 151.7 and 274.3.

In the marbled torpedoes of Autumn-Winter samples the most important prey were gobies (Q= 685.1) and sparids (Q= 439.6). In detail, gobies and sparids made up 28.3% an 13.0% of the total food items (N= 46) as well as 24.2% and 33.7% of their weight. In Spring-Summer more fishes were consumed, with a major role being played by clupeids (Q= 569.9), sparids (Q= 231.5) and gobies (Q= 185.7) respectively representing 28.1%, 17.7% and 12.8% of the total weight of food items. Only few prey were identified at the species level and they proved to be all fish of shallow and intermediate waters such as *Sardina pilchardus* (Wabaum), *Serranus cabrilla* (L.), *Diplodus annularis* (L.) and *Pagellus erythrinus* (L.), *Spicara maena* (L.) as well as *Gobius niger* (L.) (Bini, 1968a, 1968b; Tortonese, 1970, 1975).

In Autumn-Winter samples the sole found in the stomach of common torpedoes weighing more than 500 grams showed a mean length of 65.7 mm (No. measured preys= 61) respectively while those from lighter individuals were significantly smaller, with a mean of 47.9 mm (No. measured prey = 56; normal approximation of the Mann-Whitney test, $U = 5.645$; $p<0.0001$). In the same stomach samples the weights of the residual prey were significantly higher in the heavier torpedoes than in the smaller ones (Nos. food items = 80 and 73; $U= 5.016$; $p<0.0001$), means being 4.31 and 2.68 g respectively.

Similarly, in Spring-Summer stomach samples prey weighed more when extracted from larger *T. torpedo* specimens, with means of 7.12 and 3.55 g ($U = 7.627$; $p<0.0001$; Nos. food items = 47 and 62) whilst the reverse situation was observed in *T. marmorata* specimens caught at the same time as larger individuals had ingested smaller prey (means = 10.79 vs. 11.48 g; $U = 6.048$; $p<0.0001$; total number of food items = 69) because all females either with large ovaries or developing embryos in the uteri (on the whole, 7 individuals out of 15) had taken poor meals. In Autumn-Winter *T. marmorata* stomachs, no significant differences were found with regard to prey weights because of the few samples available.

Discussion

Our study confirms that both *T. torpedo* and *T. marmorata* are mainly piscivorous species (Bini, 1967; Capapé, 1979; Minervini, Rambaldi, 1985; Abdel-Aziz, 1994) since almost no invertebrate was found in stomach samples.

Table II A, B

Composition of prey found in stomachs of common and marbled torpedoes IIA weight < 500 g, IIB weight > 500 g caught in Autumn-Winter and Spring-Summer months respectively.

Proies retrouvées dans les échantillons de torpilles communes ou de torpilles marbrées prélevés durant les périodes automne-hiver ou printemps-été et de poids inférieur (IIA) ou supérieur à 500 g (IIB).

T. torpedo, autumn-winter samples, males and females ≥ 500g				
	Families or clusters of species	No. sto.	No. preys	Weight (g)
C1	Clupeidae	1	1	22.7
C2	*Engraulis encrasicholus* (L.)	0	0	0.0
C3	Argentinidae	0	0	0.0
C4	Congridae	0	0	0.0
C5	*Trisopterus minutus* (L.)	0	0	0.0
C6	*Cepola macrophthalma* (L.)	1	1	0.4
C7	Serranidae	0	0	0.0
C8	Sparidae	0	0	0.0
C9	Spicara	0	0	0.0
C10	*Mullus* spp.	0	0	0.0
C11	Gobiidae	3	3	25.8
C12	Callionymidae	4	7	2.9
C13	Trachinidae	0	0	0.0
C14	*Ophidion barbatum* L.	0	0	0.0
C15	*Lepidotrigla cavillone* (Lacepède)	0	0	0.0
C16	*Citharus linguatula* (L.)	5	6	11.5
C17	*Bothus podas* (Delaroche)	3	3	13.8
C18	*Solea solea* (L.)	35	59	161.3
C19	Unidentif. fishes	40	56	127.8
	Total		**136**	

No. stomachs with prey = 78 (sex-ratio = 0.86)
Vacuity indexes: (F=53.9%); (M=57.3%); (A M+F=55.4%)

T. torpedo, spring-summer samples, males and females ≥ 500g				
	Families or clusters of species	No. sto.	No. preys	Weight (g)
C1	Clupeidae	3	3	35.9
C2	*Engraulis encrasicholus* (L.)	0	0	0.0
C3	Argentinidae	3	4	5.5
C4	Congridae	1	1	5.7
C5	*Trisopterus minutus* (L.)	0	0	0.0
C6	*Cepola macrophthalma* (L.)	0	0	0.0
C7	Serranidae	0	0	0.0
C8	Sparidae	1	1	1.9
C9	Spicara	0	0	0.0
C10	*Mullus* spp.	0	0	0.0
C11	Gobiidae	3	5	42.3
C12	Callionymidae	14	19	23.7
C13	Trachinidae	3	3	29.1
C14	*Ophidion barbatum* L.	0	0	0.0
C15	*Lepidotrigla cavillone* (Lacepède)	0	0	0.0
C16	*Citharus linguatula* (L.)	3	4	6.5
C17	*Bothus podas* (Delaroche)	0	0	0.0
C18	*Solea solea* (L.)	12	13	48.2
C19	Unidentif. fishes	9	11	24.4
	Total		**64**	

No. stomachs with prey = 46 (sex-ratio = 0.59)
Vacuity indexes: (F=38.8%); (M=67.2%); (B M+F=53.5%)

T. marmorata, autumn-winter samples, males and females ≥ 500g				
	Families or clusters of species	No. sto.	No. preys	Weight (g)
C1	Clupeidae	2	2	42.1
C2	*Engraulis encrasicholus* (L.)	0	0	0.0
C3	Argentinidae	1	1	0.8
C4	Congridae	0	0	0.0
C5	*Trisopterus minutus* (L.)	0	0	0.0
C6	*Cepola macrophthalma* (L.)	3	4	26.0
C7	Serranidae	0	0	0.0
C8	Sparidae	1	1	8.6
C9	Spicara	0	0	0.0
C10	*Mullus* spp.	0	0	0.0
C11	Gobiidae	7	8	65.8
C12	Callionymidae	0	0	0.0
C13	Trachinidae	0	0	0.0
C14	*Ophidion barbatum* L.	0	0	0.0
C15	*Lepidotrigla cavillone* (Lacepède)	0	0	0.0
C16	*Citharus linguatula* (L.)	0	0	0.0
C17	*Bothus podas* (Delaroche)	0	0	0.0
C18	*Solea solea* (L.)	1	1	14.5
C19	Unidentif. fishes	6	8	32.0
	Total		**25**	

No. stomachs with prey: 19 (sex-ratio = 2.80)
Vacuity indexes: (F=78.3%); (M=83.3%); (A M+F=82.2%)

T. marmorata, spring-summer samples, males and females ≥ 500g				
	Families or clusters of species	No. sto.	No. preys	Weight (g)
C1	Clupeidae	9	9	146.3
C2	*Engraulis encrasicholus* (L.)	0	0	0.0
C3	Argentinidae	2	2	17.9
C4	Congridae	0	0	0.0
C5	*Trisopterus minutus* (L.)	0	0	0.0
C6	*Cepola macrophthalma* (L.)	4	4	58.3
C7	Serranidae	2	2	37.2
C8	Sparidae	6	6	72.5
C9	Spicara	4	4	63.4
C10	*Mullus* spp.	0	0	0
C11	Gobiidae	9	10	99.7
C12	Callionymidae	0	0	0.0
C13	Trachinidae	3	3	9.1
C14	*Ophidion barbatum* L.	0	0	0.0
C15	*Lepidotrigla cavillone* (Lacepède)	2	2	20.4
C16	*Citharus linguatula* (L.)	1	1	3.1
C17	*Bothus podas* (Delaroche)	0	0	0.0
C18	*Solea solea* (L.)	1	1	4.7
C19	Unidentif. fishes	5	5	29.7
-	**Total**		**49**	

No. stomachs with prey: 42 (sex-ratio = 0.91)
Vacuity indexes: (F=82.1%) ; (M=66.5%) ; (B M+F=70.1%)

A, B : significantly different vacuity indexes (Chi-square > 6.758; p< 0.001, 1 d. f.)

Correspondence analysis of data depicting the faunistic composition of food samples shows significant differences when examining torpedoes caught in Autumn-Winter or in Spring-Summer. At any time little competition presumably exists between the two species since the composition of their stomach samples differed remarkably.

Our data on the pattern of daily landings as well as the species composition of prey agree with the widespread notion that *T. torpedo* individuals mainly live in strictly littoral waters (in the Mediterranean Sea within the 50-60 m depth contour, usually being fished on 5-25 m grounds; Tortonese, 1956; Quignard, Capapé, 1974) and those of *T. marmorata* in somewhat deeper areas.

Table II B

***T. torpedo*, autumn-winter samples, males and females ≥ 500g**

	Families or clusters of species	No. sto.	No. preys	Weight (g)
C1	Clupeidae	2	2	72.4
C2	*Engraulis encrasicholus* (L.)	0	0	0.0
C3	Argentinidae	0	0	0.0
C4	Congridae	2	2	22.8
C5	*Trisopterus minutus* (L.)	0	0	0.0
C6	*Cepola macrophthalma* (L.)	2	2	16.3
C7	Serranidae	0	0	0.0
C8	Sparidae	1	1	16.4
C9	Spicara	0	0	0.0
C10	*Mullus* spp.	0	0	0.0
C11	Gobiidae	3	4	23.5
C12	Callionymidae	3	4	2.1
C13	Trachinidae	0	0	0.0
C14	*Ophidion barbatum* L.	0	0	0.0
C15	*Lepidotrigla cavillone* (Lacepède)	0	0	0.0
C16	*Citharus linguatula* (L.)	7	9	25.9
C17	*Bothus podas* (Delaroche)	2	2	12.9
C18	*Solea solea* (L.)	42	72	337.3
C19	Unidentif. fishes	36	57	158.1
	Total		**157**	

No. stomachs with prey = 78 (sex-ratio = 0.20)
Vacuity indexes: (F=51.1%); (M=63.9%); (M+F=53.8%)

***T. torpedo*, spring-summer samples, males and females ≥ 500g**

	Families or clusters of species	No. sto.	No. preys	Weight (g)
C1	Clupeidae	7	7	99.6
C2	*Engraulis encrasicholus* (L.)	1	1	3.0
C3	Argentinidae	2	3	7.0
C4	Congridae	1	1	13.6
C5	*Trisopterus minutus* (L.)	0	0	0.0
C6	*Cepola macrophthalma* (L.)	1	1	13.1
C7	Serranidae	0	0	0.0
C8	Sparidae	2	2	46.8
C9	Spicara	1	1	23.8
C10	*Mullus* spp.	2	2	7.7
C11	Gobiidae	1	2	23.7
C12	Callionymidae	7	13	13.8
C13	Trachinidae	4	4	39.7
C14	*Ophidion barbatum* L.	1	1	11.5
C15	*Lepidotrigla cavillone* (Lacepède)	0	0	0.0
C16	*Citharus linguatula* (L.)	0	0	0.0
C17	*Bothus podas* (Delaroche)	0	0	0.0
C18	*Solea solea* (L.)	8	9	50.4
C19	Unidentif. fishes	11	12	66.1
	Total		**59**	

No. stomachs with prey = 34 (sex-ratio = 1.62)
Vacuity indexes: (F=55.2%); (M=53.3%); (M+F=54.1%)

***T. marmorata*, autumn-winter samples, males and females ≥ 500g**

	Families or clusters of species	No. sto.	No. preys	Weight (g)
C1	Clupeidae	0	0	0.0
C2	*Engraulis encrasicholus* (L.)	0	0	0.0
C3	Argentinidae	0	0	0.0
C4	Congridae	2	2	63.1
C5	*Trisopterus minutus* (L.)	1	1	5.0
C6	*Cepola macrophthalma* (L.)	0	0	0.0
C7	Serranidae	0	0	0.0
C8	Sparidae	5	5	157.1
C9	Spicara	0	0	0.0
C10	*Mullus* spp.	0	0	0.0
C11	Gobiidae	5	5	53.4
C12	Callionymidae	0	0	0.0
C13	Trachinidae	0	0	0.0
C14	*Ophidion barbatum* L.	0	0	0.0
C15	*Lepidotrigla cavillone* (Lacepède)	0	0	0.0
C16	*Citharus linguatula* (L.)	1	1	2.0
C17	*Bothus podas* (Delaroche)	0	0	0.0
C18	*Solea solea* (L.)	1	2	4.5
C19	Unidentif. fishes	4	5	21.8
	Total		**21**	

No. stomachs with prey: 16 (sex-ratio = 0.07)
Vacuity indexes: (F=66.7%) ; (M=75.0%) ; (M+F=67.3%)

***T. marmorata*, spring-summer samples, males and females ≥ 500g**

	Families or clusters of species	No. sto.	No. preys	Weight (g)
C1	Clupeidae	3	5	72.1
C2	*Engraulis encrasicholus* (L.)	0	0	0.0
C3	Argentinidae	0	0	0.0
C4	Congridae	0	0	0.0
C5	*Trisopterus minutus* (L.)	0	0	0.0
C6	*Cepola macrophthalma* (L.)	0	0	0.0
C7	Serranidae	1	1	7.0
C8	Sparidae	3	3	65.6
C9	Spicara	1	1	29.2
C10	*Mullus* spp.	0	0	0.0
C11	Gobiidae	0	0	0.0
C12	Callionymidae	1	1	1.4
C13	Trachinidae	0	0	0.0
C14	*Ophidion barbatum* L.	0	0	0.0
C15	*Lepidotrigla cavillone* (Lacepède)	1	1	7.6
C16	*Citharus linguatula* (L.)	1	1	2.1
C17	*Bothus podas* (Delaroche)	0	0	0.0
C18	*Solea solea* (L.)	0	0	0.0
C19	Unidentif. fishes	6	7	30.9
	Total		**20**	

No. stomachs with prey: 15 (sex-ratio = 0.15)
Vacuity indexes, by sex: (F=67.5%) ; (M=66.7%) ; (M+F=67.4%)

S. solea juveniles living in littoral areas covered either with sand or sand/clay (Bini, 1968c; Cabral, 2000) are by far the most important prey of common torpedoes in Autumn-Winter and the presence of other fishes such as some Callionymidae species, gobies and young Clupeids in stomach samples of warmer months seems to confirm that the examined individuals had been fished in nearshore areas (Bini, 1968b; Tortonese, 1970, 1975; Minervini *et al.*, 1985). As marbled torpedoes also appear to feed on coastal fishes, but few specimens found in stomach samples came from strictly littoral species, the dietary shift observed between the two torpedoes under investigation may be due, to some extent, to the different preferred depth ranges, in agreement with the statement by Bini (1967) that along the Italian coast *T. marmorata* specimens are mainly caught at 20-100 m.

Differences recorded for the composition of stomach samples from *T. torpedo* individuals caught in Autumn-Winter or in Spring-Summer reflect a true diet shift, since during the former period the main prey are small *S. solea* juveniles which fast grow out of the targeted size range (Paci *et al.*, 1989; Dinis, Reis, 1995) and/or move to other areas.

In marbled torpedoes evidence of diet change is weaker as few food samples were obtained in Autumn-Winter and these animals live over a greater depth range, thus the dietary differences observed for the spring-summer individuals may be due to seasonal changes in the areas mainly trawled. However, the greater prevalence of pelagic fish such as Clupeidae spp. seem to reflect a more active behaviour pattern of marbled torpedoes during warmer months as well as the inshore migration at this time of *Sardina pilchardus* (Walbaum) (Tortonese, 1970), by far the most abundant species of the family along the Italian coast of the Tyrrhenian Sea (Giovanardi, 1990).

After Hureau's classification (1970), most prey identified at least at the family level were "preferred prey" for the investigated torpedoes as Qs either surpassed or were very close to the threshold value of 200. Our data therefore reflect dietary preferences of *T. torpedo* and *T. marmorata* living in the study area. Our results agree with a previous report that stomachs from 48 *T. torpedo* individuals of unknown size caught, for scientific purposes, in the same area at 12-50 m depths by means of two "rapido" beam trawls in September-October 1982, contained only fishes and numerically the main identified prey were goby and sole (Minervini, Rambaldi, 1985; Minervini *et al.*, 1985).

Although proper statistical comparisons with data summarised in the Capapé (1979) and Abdel-Aziz (1994) reports on the diet of the two torpedoes under investigation are not feasible (as is true for most scientific papers on fish diets, Cortes, 1997), both papers show that prey remarkably differed in some locations of the southern Mediterranean Sea from those found in our stomach samples.

Out of several hundreds of *T. marmorata* stomachs seasonally examined along the northern coast of Tunisia, Gobiidae spp., *Trachurus trachurus* (L.), *Merluccius merluccius* (L.), *Spicara maena* (L.) and *Mugil* sp. numerically made up 13.0% to 4.0% of the 476 counted prey whilst they either were absent or very scarce in our samples. Similarly, Qs calculated from one table of the Abdel-Aziz study on the *T. torpedo* diet off the Egyptian harbour of Alexandria show (assuming that prey volumes appropriately estimate their weights) that main prey were decapod Crustaceans, Soleidae spp., Sparidae spp., Mullidae spp. and Clupeidae. Such discrepancies with our data are presumably due to the deeper distribution of marbled torpedoes along the Tunisian coast (down to 200 m depths, Capapé 1979) as well as different local sediments since sand and sand/clay extend 8-9 kms off Fiumicino (La Monica, Raffi, 1996) whilst rocks and clay prevail in most coastal areas of the Mediterranean Sea.

Vacuity indexes calculated on our *T. marmorata* Autumn-Winter and Spring-Summer samples were 4.0-7.0 fold those recorded by Capapé (1979) and Abdel-Aziz (1994) on a six-month or one-year basis, and such differences were highly significant ($p<0.001$; Chi-square test, un-detailed data). Similarly, in our pooled samples of common torpedoes (534 individuals examined) the vacuity index resulted to be 54.3% vs. the value of 20.1% reported by Abdel-Aziz for 177 stomachs of this species ($p<0.001$; Chi-square test with 1 d. f.).

Such strong discrepancies among samples from different species and distinct geographic areas are presumably not due to water temperature and/or mean size of prey (factors influencing the duration of the digestive process and therefore the vacuity indexes, De Silva and Anderson, 1995) because in Autumn-Winter our common torpedoes always showed lower vacuity indexes than marbled ray, in spite of the smaller fishes preyed upon (Tables IIA, IIB) and the fairly uniform temperature prevailing down to 100 m (Giovanardi, 1990). In our opinion the most likely explanation of the high rate of empty stomachs seen in our samples is that the high-opening trawling nets (estimated height: approx. 2 m.; M. Ferretti c/o CIRSPE, Rome, pers. comm.) deployed in the area mainly catch actively swimming torpedoes which often have not eaten for some time, whilst the traditional flat trawl nets (called "Mediterranean-type" nets, 0.9-1.2 m high) presumably used in previous works seize more individuals staying on the sea floor to digest their prey. This supposition is supported, to some extent, by the observations that marbled ray showed the highest vacuity indexes as they prey on fairly large and motile fishes and that Minervini and Rambaldi (1985) recorded significantly more full *T. torpedo* stomachs (48 out of 72 vs. 156 of 344 in our samples caught during the same period of the year; Chi-square = 9.991, $p<0.005$; Chi-square test with 1 d. f.) operating by two "rapido" beam trawls (height: 0.6 m).

Our data show that larger *T. torpedo* individuals feed on bigger prey, whilst this pattern was not observed for *T. marmorata* because of the fewer stomach samples available as well as the reduction of food intake that ripe and gravid females had experienced, in agreement with Mellinger's report (1971) that females of the species do not gain weight during pregnancy.

The small size of fishes found in the *T. torpedo* stomachs as well as comparison with the few data reported on the abundance and size composition of commercial species (Minervini *et al.*, 1988) and discards (Romanelli *et al.*, 2005) suggest that for both torpedoes there is little competition with local trawlers for prey. Moreover, the above mentioned reports by other authors suggest that both species may feed on a wide range of littoral fishes, and thus the main effect of fisheries is direct mortality induced on torpedoes.

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