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Feeding ecology of little tunny *Euthynnus alletteratus* in the central Mediterranean Sea

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The feeding habits of *Euthynnus alletteratus* and its variations compared to predator size in the central Mediterranean Sea were investigated. The stomach contents of 187 specimens were analysed, ranging from 26.8 to 50.3 cm total length, caught by authorized experimental drift-nets. The difference in food items found in the stomachs was evaluated by occurrence of prey frequency, prey weight, and prey abundance; these criteria were used to calculate an index of relative importance. Fish were the dominant food detected according to all numerical indicators examined and were mainly represented by *Maurolicus muelleri* and larval stages of teleosts. Hyperiid amphipods, dominated by *Anchylomera blossevillei* and *Phrosina semilunata*, were well represented in terms of frequency of occurrence. Variations in the diet composition compared to fish size were observed. Comparative analysis performed on prey abundance highlighted a trend of increasing predator size-classes among prey items. The specimens of the smallest sizes ate mainly adult clupeiforms and larvae or other juvenile teleosts. As fish grew, there were increased amounts of adult teleosts, crustaceans (hyperiids and isopods) and cephalopods. *Maurolicus muelleri* was the most important prey for the largest specimens analysed. Significant differences among size-classes, both in prey abundance and in prey weight, were confirmed by non-parametric multivariate analysis of variance (NP-MANOVA).

INTRODUCTION

Little tunny *Euthynnus alletteratus* (Rafinesque, 1810) is a widely spread scombrid fish: it is found in the tropical and subtropical waters of the western and eastern Atlantic Ocean, in the Mediterranean, in the Sea of Marmara and occurs sporadically in the Black Sea (Demir, 1961, 1963 in Yoshida, 1979). Little tunny belongs to a highly migratory species (FAO, 1994), with an inclination to aggregate in large schools, often with other scombrid species like *Auxis* spp. and *Sarda sarda* of the same size (Marchal, 1963; Collette & Nauen, 1983). *Euthynnus alletteratus* has been investigated on a worldwide scale with regard to the different aspects of its biology, taxonomy and behaviour (De Sylva & Rathyen, 1961; Marchal, 1963; Matsuura & Sato, 1981; Collette & Nauen, 1983), while information on its feeding habits mainly derives from studies carried out along the western Atlantic Ocean (Etchevers, 1976 in Collette & Nauen, 1983; Menezes & Aragao, 1977; Manooch et al., 1985; Ramirez-Arredondo, 1994). In this area, little tunny is considered an opportunist and very voracious predator, primarily feeding on teleost fish with local preference for clupeoids, although its diet also includes crustaceans, algae and cephalopods. Despite the economic importance of this species in some parts of the Mediterranean Sea (Falautano et al., 2002; Kaharaman, 2005) and its ecological role as a predator in the pelagic domain, scanty information is available on its feeding habits in this area. Little tunnies from the Straits of Sicily are reported to be mainly piscivorous, with a marginal addition of crustaceans, cephalopods and vegetal remains in their diet (Campagnuolo et al., 1998). Such considerations, however, are based on the examination of a very limited number of stomach contents. Similar results, confirming the dominance of fish preys and the occasional occurrence of crustaceans in the diet of little tunny, were obtained after analysing the stomach content of specimens from the Aegean and Ionian Seas (Zaboukas et al., 2001).

In this paper, we aim at describing the feeding habits of *E. alletteratus* in the southern Tyrrhenian Sea, which is an area of unique importance for the commercial fishing activity of the pelagic fish species (Mostarda et al., 2004). There, little tunny were caught seasonally from late summer to early spring by local fishermen as a casual catch during fishing activities focused on other tuna species, like *Auxis rochei* and *Sarda sarda* (Andaloro et al., 1998). Since the implementation of the ban on tuna drift-nets (EU regulation no. 1239/98), the biomass of *E. alletteratus*, as well as that of *A. rochei* and *S. sarda*, has been expected to increase as a consequence of decreased fish mortality, although we cannot exclude that poaching occurs. The increase of the pelagic domain biomass resulting from a diminished fishing effort would most certainly have an impact on the preys. Therefore, the knowledge of feeding behaviour of the pelagic species in this area is a precious tool for understanding the trophic dynamics and developing proper fishing management strategies in an ecosystem-oriented approach framework.

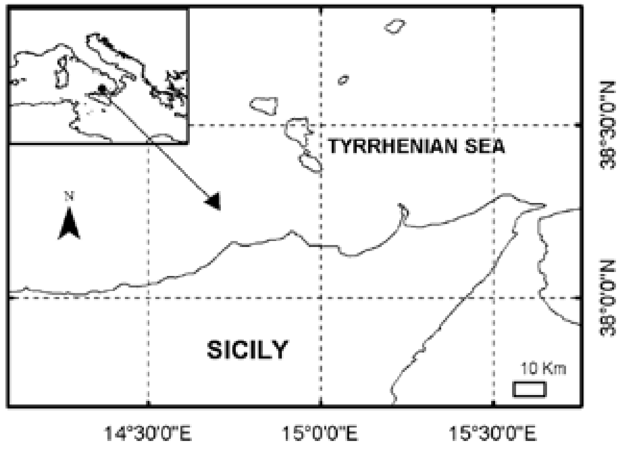

Figure 1. Map of the sampling area.

Table 1. *Prey considered for NP-MANOVA.*

Cephalopods
Pelagic gastropods
Hyperiids
Isopods
Crustacean larvae
Other crustaceans
Juvenile teleosts
Juvenile clupeiforms
Adult clupeiforms
Maurolicus muelleri
Other adult teleosts
Teleost larvae
Vegetal remains

MATERIALS AND METHODS

The study area is located in north-eastern Sicily off the coast of Capo d'Orlando and S. Agata di Militello (Figure 1). Between August 2002 and April 2004, we caught 187 little tunnies using authorized experimental drift-nets (of the type 'ferrettara') made up of three nets with different mesh sizes (86 mm, 72 mm and 68 mm) for the catch of different sizes of fish. Monthly catches were carried out during the night between the hours of 2200 and 0100 hours.

All fish were measured to the nearest 1 mm total length, weighed to the nearest 0.1 g and then eviscerated. The stomachs were immediately preserved in 70% ethanol for later analysis. In the laboratory, stomachs were dissected for content analysis. After sorting, prey items were identified to the lowest possible taxon, counted and weighed to the nearest 0.1 mg, after removing excess water with blotting paper. The count of fragmented preys was based on the number of traceable anatomical parts to single specimens (number of eyes, mouth parts, spinal columns, tails, etc). Whenever possible, adult stages were counted separately from early stages. Larval and juvenile stages of teleosts were identified according to Lo Bianco (1937) and to Costa (1999) methods. The number of empty stomachs was recorded and used to calculate the vacuity coefficient (Cv%=number of empty stomach/total number of analysed stomachs×100). The importance of the different prey types was evaluated using the following dietary indexes:

- frequency of occurrence percentage F% (= number of stomachs containing prey items *i*/total number of non-empty stomachs×100).
- abundance percentage N% (= number of individuals of prey items *i*/total number of all prey items×100).
- weight percentage W% (= weight of prey items *i*/total weight of all prey items×100).
- index of relative importance (IRI), using weight instead of volume: IRI=(N%+W%)×(F%) (Hyslop, 1980; Hacunda, 1981).
- index of relative importance percentage IRI% (=IRI/∑IRI×100).

Prey items were then grouped into 13 prey categories (Table 1), following ecological criteria (different life styles for adults and early stages, different ecological roles). Furthermore, prey items with F% >20 (e.g. *Maurolicus muelleri*) were considered as separate categories.

In order to describe diet variation among size-classes of 2.5 cm total length (TL), a correspondence analysis (CA) was applied, namely a technique that reduces a species per sample matrix to a limited number of varying sizes whereby basic variations are explained (Davis, 1986). This technique was performed on prey abundance.

On the basis of CA results, non-parametric multivariate analysis of variances (NP-MANOVA) (Anderson, 2000, 2001; McArdle & Anderson, 2001) and post-hoc multiple comparisons were carried out to detect differences in fish diet according to size, both in prey abundance and prey weight. This analysis was performed on five homogeneous size-classes of 5 cm TL, each composed of 20 samples: I (<30 cm), II (30–35 cm), III (35–40 cm), IV (40–45 cm), V (>45 cm). Data were transformed to ln(x+1); this analysis was based on the Gower distance, using 4999 permutations.

Once significant differences were discovered, multivariate dispersions among groups were tested with PERMDISP (Anderson, 2004).

The IRI% of prey categories for the above mentioned five size-classes was also calculated in order to highlight the differences in prey importance among them.

RESULTS

Of the 187 stomachs of little tunny caught, ranging from 26.8 to 50.3 cm total length, 40 were empty (Cv%=21.4). The analysis of stomach contents led to the identification of 3772 prey individuals, for a total weight of 1185.1 g. 59 prey taxa were identified, mainly belonging to fish, crustaceans and molluscs, listed in Table 2 along with respective dietary value indexes.

Teleosts, detected in 90.5 % of the stomachs, were the most important preys, thus totalling the highest value of all dietary indexes. Among the identified fish, *Maurolicus muelleri* was the most represented in terms of frequency of occurrence, mass and IRI%, while fish larvae were the most abundant preys. The clupeid *Sardina pilchardus* was also important in terms of weight. Among juvenile fish, clupeiforms were the most represented in terms of weight, abundance and IRI%.

Table 2. *Frequency of occurrence percentage (F%), total abundance percentage (N%), total weight percentage (W%), index of relative importance (IRI) and index of relative importance percentage (IRI%) for prey items of* Euthynnus alletteratus.

		F%	W%	N%	IRI	IRI%
MOLLUSCA						
Cephalopoda						
	Heteroteuthis dispar	2.72	2.50	2.03	12.31	0.32
	Neorossia caroli	0.68	0.12	0.02	0.10	<0.01
	Sepiolidae	1.36	0.12	0.05	0.22	0.01
	Todarodes sagittatus	0.68	1.05	0.02	0.73	0.02
	Ommastrephidae	1.36	0.33	0.05	0.52	0.01
	Teuthoidea	1.36	0.29	0.05	0.46	0.01
	Cephalopoda unidentified	4.08	0.19	0.55	3.03	0.08
	Cephalopoda Total	**12.24**	**2.76**	**5.36**	**99.38**	**0.59**
Gastropoda pelagic						
	Atlanta sp.	0.68	<0.01	0.02	0.02	<0.01
	Diacria sp.	0.68	<0.01	0.02	0.02	<0.01
	Janthina sp.	0.68	<0.01	0.02	0.02	<0.01
	Oxygirus sp.	0.68	0.01	0.05	0.04	<0.01
	Pteropoda	0.68	<0.01	0.02	0.02	<0.01
	Gastropoda unidentfied	1.36	<0,01	0.05	0.04	<0.01
	Total MOLLUSCA	**14.97**	**5.37**	**2.98**	**124.94**	**0.74**
ARTHROPODA						
Hypereidea						
	Anchylomera blossevillei	12.24	0.63	2.85	42.57	1.12
	Brachyscelus crusculum	4.76	0.25	0.60	4.08	0.11
	Phrosina semilunata	10.20	0.65	1.06	17.51	0.46
	Primno macropa	3.40	0.43	0.58	3.45	0.09
	Streetsia sp.	0.68	<0.01	0.02	0.02	<0.01
	Vibilia sp.	0.68	<0.01	0.02	0.02	<0.01
	Hyperiidea	8.84	0.42	2.05	21.89	0.58
Crustacea larve						
	Brachiura Megalopa	3.40	0.02	0.68	2.36	0.06
	Decapoda larvae	1.36	<0.01	0.05	0.07	<0.01
	Stomatopoda (larvae)	3.40	<0.01	0.12	0.42	0.01
	Crustacea (larvae)	2.04	0.01	0.05	0.13	<0.01
Other Crustacea						
	Idotea metallica	0.68	0.02	0.02	0.03	<0.01
	Nerocila sp.	3.40	0.01	0.19	0.69	0.02
	Cymothoidae	9.52	0.83	1.21	19.40	0.51
	Copepoda	0.68	<0.01	0.02	0.02	<0.01
	Stylocheiron maximum	0.68	<0.01	0.02	0.02	<0.01
	Pasiphaea multidentata	0.68	0.09	0.02	0.08	<0.01
	Palaemoninae	0.68	<0.01	0.02	0.02	<0.01
	Decapoda Natantia	1.36	0.01	0.07	0.12	<0.01
	Callianassidae	0.68	<0.01	0.02	0.02	<0.01
	Leucosidae	0.68	<0.01	0.02	0.02	<0.01
	Pseudosquillidae	0.68	0.02	0.02	0.03	<0.01
	Stomatopoda	1.36	0.01	0.05	0.07	<0.01
	Crustacea unidentified	2.72	0.02	0.22	0.63	0.02
	Total CRUSTACEA	**38.09**	**2.61**	**9.75**	**470.94**	**2.87**
VERTEBRATA						
Teleostei juveniles						
	Helycolenus dactylopterus juv.	0.68	0.01	0.02	0.02	<0.01
	Serranus scriba juv.	0.68	0.01	0.02	0.02	<0.01
	Anguilliformes juv.	3.40	0.36	0.10	1.56	0.04
	Callionimidae juv.	0.68	0.06	0.07	0.09	<0.01
	Teleostei juv.	6.80	1.94	1.95	26.49	0.70
Clupeiformes juveniles						
	Engraulis encrasicolus juv.	1.36	1.15	3.52	6.36	0.17
	Clupeiformes juv.	3.40	5.62	9.96	53.01	1.39
	Teleostei juv. total	**14.28**	**9.10**	**13.57**	**323.73**	**1.92**

Table 2 *(Continued.)*

Teleostei adults						
	Engraulis encrasicolus	4.76	1.57	0.87	11.63	0.31
	Sardina pilchardus	7.48	12.82	1.81	109.44	2.88
	Sardinella aurita	2.72	2.26	0.17	6.62	0.17
	Maurolicus muelleri	20.41	36.33	23.11	1213.21	31.90
	Myctophum punctatum	0.68	0.05	0.02	0.05	<0.01
	Capros aper	0.68	0.02	0.02	0.03	<0.01
	Macrorhamphosus scolopax	2.04	0.77	1.33	4.27	0.11
	Paralepididae	0.68	0.05	0.02	0.05	<0.01
	Teleostei unidentified	54.42	22.59	11.77	1869.96	49.17
	Teleostei adults total	**77.55**	**76.60**	**41.93**	**9192.00**	**54.76**
Teleostei larvae						
	Synodus saurus larvae	0.68	0.04	0.02	0.04	<0.01
	Clupeidae larvae	0.68	0.63	3.86	3.05	0.08
	Ophichtydae larvae	0.68	0.03	0.02	0.03	<0.01
	Teleostei larvae	10.88	5.59	27.91	364.69	9.59
	Teleostei larvae Total	**10.88**	**6.29**	**31.69**	**413.22**	**2.46**
	Total TELEOSTEI	**90.48**	**92.01**	**86.91**	**16187.72**	**96.44**
VEGETALIA	Vegetal remains	1.36	<0.01	0.07	0.10	<0.01
OTHERS	Anthropogenic materials	3.4	0.05	0.33	1.34	0.04

Other teleosts, such as *Macrorhamphosus scolopax* and juvenile anguilliforms, were occasionally recorded.

Crustaceans were found in 38.1% of the stomachs and their contribution was more important in terms of abundance (N%=10.0) than in terms of weight (W%=2.6). Among them, hyperiidean amphipods were the most frequent, especially *Anchylomera blossevillei* and *Phrosina semilunata*. Cymothoid isopods, as well as larval stages of brachyuran crabs and stomatopods, were also frequently found.

Molluscs were mainly represented by cephalopods, while gastropods were occasional.

Vegetal remains were occasionally found and their values of weight, abundance and IRI% were negligible.

Anthropogenic materials such as plastics were sporadically recorded.

Figure 2 summarizes F%, N% and W% for the principal taxonomic categories.

Variation by size

After carrying out a comparative analysis, 27.7% of variances were explained for the first two size-classes. A trend of increased predator sizes among prey items from upper right to lower left was evidenced (Figure 3). Teleost larvae, teleost juveniles and adult clupeiforms were concentrated in small-sized little tunnies, while other prey categories, mainly *Maurolicus muelleri* and isopods, were distributed among larger sized specimens. Juvenile clupeiforms were not specifically preyed upon by one or the other size-class.

Results of NP-MANOVA indicated highly significant differences in prey abundance among size-classes ($F_{4,95}$=2.8299; *P*=0.0002). Post-comparisons highlighted significant differences between the I and III (*P*=0.0180), III and V (*P*=0.0108), IV and V (*P*=0.0448) size-classes, and highly significant differences between the I and II (*P*=0.0048), I and IV (*P*=0.0030), I and V (*P*=0.0002) size-classes.

Highly significant differences were also found in prey weight ($F_{4,95}$=2.7109; *P*=0.0012). Post-comparisons showed significant differences between the I and II (*P*=0.0178), I and III (*P*=0.0500), I and IV (*P*=0.0352), IV and V (*P*=0.0450) size-classes, and highly significant differences between the I and V (*P*=0.0006), II and V (*P*=0.0008), III and V (*P*=0.0054) size-classes.

PERMDISP resulted not significant both for prey weight ($F_{4,95}$=0.1919; *P*=0.9394) and for prey number ($F_{4,95}$=0.6009; *P*=0.6686).

The analysis of IRI% in the five size-classes considered (Figure 4) showed that clupeiforms were important only in the I class (IRI%=82.7); their value suddenly decreased to irrelevant in the V class (IRI%=0.8). In the specimens of II and III classes, the most important prey categories were teleosts (IRI%=83.0 and 43.8, respectively). Fish larvae were important in the III class (IRI%=36.5). The diet of specimens in the IV class was represented mostly by teleosts (IRI%=45.5) and *M. muelleri* (IRI%=22.9), although

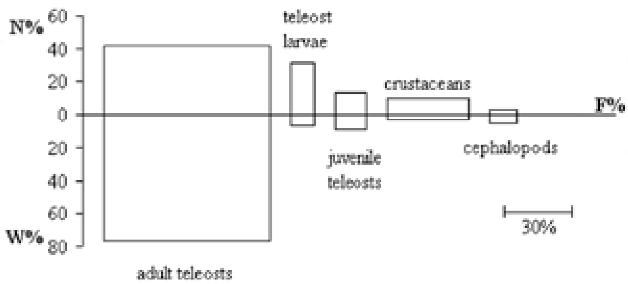

Figure 2. Frequency of occurrence percentage (F%), abundance percentage (N%), weight percentage (W%) for the most frequent prey groups in the diet of *Euthynnus alletteratus* from the southern Tyrrhenian Sea.

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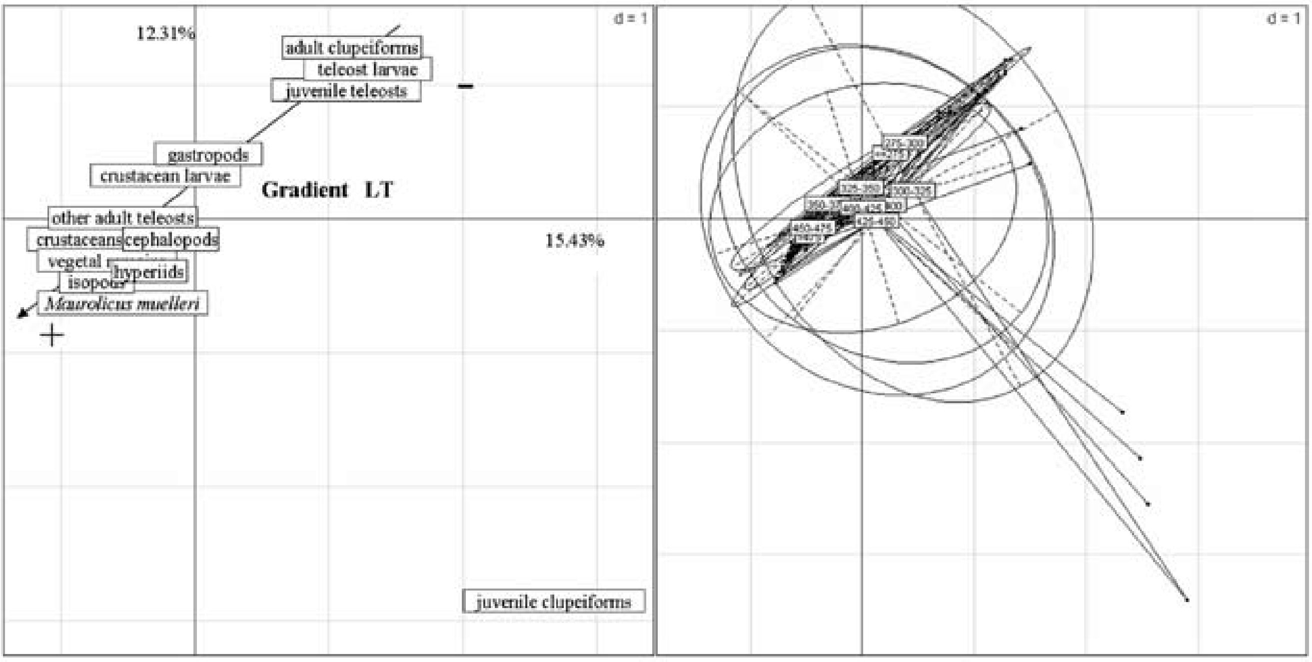

Figure 3. Correspondence analysis of stomach contents (performed on prey abundance) of *Euthynnus alletteratus*, grouped into 2.5 cm TL size-classes.

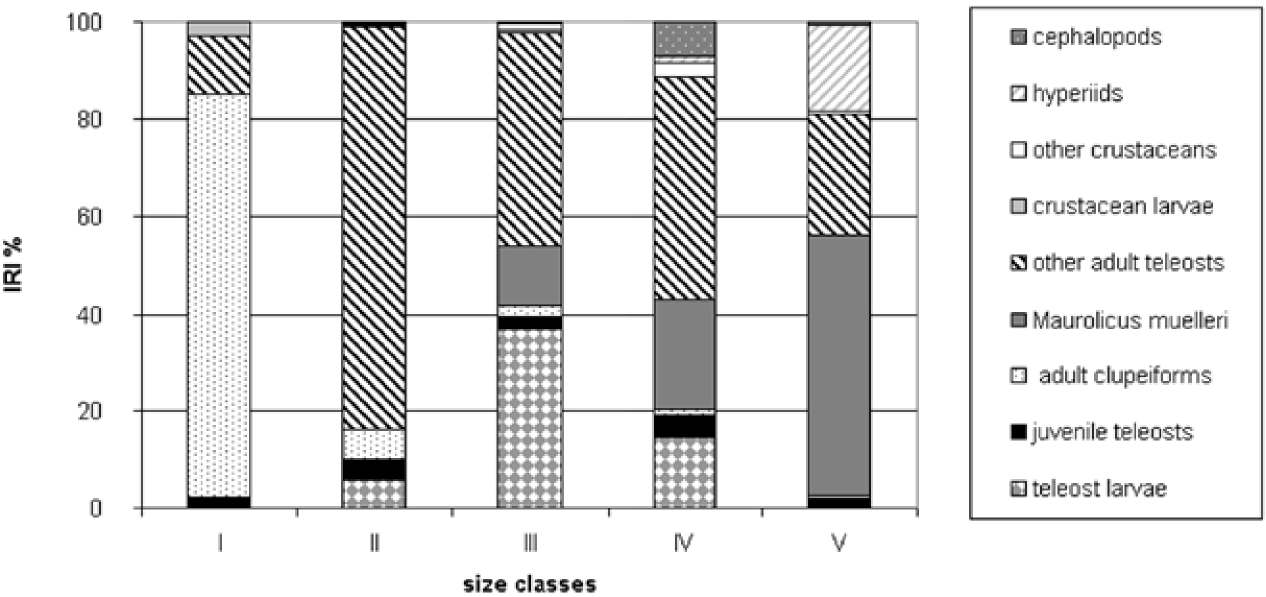

Figure 4. Index of relative importance percentage (IRI%) for the main prey categories in the diet of the five size-classes of *Euthynnus alletteratus* from the southern Tyrrhenian Sea: I (<30 cm), II (30–35 cm), III (35–40 cm), IV (40–45 cm), V (>45 cm).

cephalopods assumed more importance than in the smaller size-classes (IRI%=7.1). In the V class, the *M. muelleri* was the most important prey (IRI%=53.6), followed by adult teleosts and hyperiid amphipods (IRI%=24.6 and 17.6, respectively), the latter being negligible in the other size-classes.

DISCUSSION

Euthynnus alletteratus has been commonly described in the literature as an opportunist predator, feeding on whatever is available at any particular place and time (Yoshida, 1979; Collette & Nauen, 1983). In the Mediterranean Sea, the feeding ecology of *E. alletteratus* was scarcely studied: Whitehead et al. (1986) and Fisher et al. (1987) reported that the diet of this species is based on small pelagic fish integrated with squid, crustaceans and fish larvae. Our results confirmed that *E. alletteratus* is an essentially fish-eating species, as previously reported by Campagnuolo et al. (1998) in Sicilian seas, but also highlighted the importance of crustaceans, which recorded a high rate of frequency of occurrence.

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Most of the specimens that we have analysed had preys in their stomachs. The resulting value of the vacuity coefficient in our specimens (Cv%=21.4) was rather low when compared with the values recorded in other studies. Campagnuolo et al. (1998) and Zaboukas et al. (2001) reported a vacuity coefficient of 56 and 41.4 respectively, in the analysis of specimens caught by purse seine. The discrepancy between our results and those obtained by other authors could be attributed mainly to the different fishing methods used: as observed by local fishermen and verified by our personal observations onboard and underwater, the fish trapped in purse seine nets regurgitated the ingested food.

The results of our study indicated that *E. alletteratus*, ranging from 26.8 to 50.3 cm total length, in the southern Tyrrhenian Sea, ate mostly teleosts, both adults and at larval or juvenile stage. The occurrence of both pelagic fish, such as clupeiforms and demersal teleosts (e.g. *Macrorhamphosus scolopax*, *Helicolenus dactylopterus*, Paralepididae), in the analysed stomach contents suggested a long vertical distribution of little tunny (Menezes, 1968). Based on our results, this species fed particularly on *Maurolicus muelleri* and clupeiforms (*Sardina pilchardus*, *Sardinella aurita* and *Engraulis encrasicolus*). While the important role of clupeiforms in the diet of *E. alletteratus* had already been reported both in the Atlantic Ocean (Menezes & Aragao, 1977) and in the Mediterranean Sea (Collette & Nauen, 1983; Zaboukas et al., 2001), the role of of *M. muelleri* was unknown. In the stomachs analysed, this species was the most represented prey item in terms of weight (W%=36.3), the most abundant (N%=23.1) and the most important (IRI%=31.9) among adult fish. This marked prevalence of *M. muelleri* in little tunny from the southern Tyrrhenian Sea could be attributed to the widely spread availability of this pelagic fish in this area (Costa, 1999). Its occurrence was also recorded in the stomach of another scombrid fish, *Auxis rochei*, from the same study area (Mostarda, 2006), which strengthened our hypothesis of resource availability.

Crustaceans, represented by small organisms such as hyperiid amphipods, isopods and larvae, were the second major group after fish and were characterized by high N% and low W% percentages. The importance of crustaceans in the diet of *Euthynnus alletteratus* has already been pointed out in other studies carried out in both Atlantic and Mediterranean waters. But, while in these studies crustaceans were mainly represented by stomatopods and decapod larvae (Menezes & Aragao, 1977; Andaloro et al., 1998), in our samples the most frequent and abundant crustacean prey were hyperiids. Similar results were also obtained in the analysis of A. rochei from the same study area (Mostarda, 2006), suggesting that hyperiids are an available resource in this area.

According to previous information (Manooch et al., 1985; Campagnuolo et al., 1998), molluscs, mainly represented by cephalopods, played a minor role in the diet of little tunny. The identified cephalopods found belonged mainly to Sepioidea and Teuthoidea, as also reported by Manooch et al. (1985) and by Dragovich (1969) in the Atlantic Ocean. The contribution of cephalopods in the diet of *E. alletteratus* in the southern Tyrrhenian Sea was very low when compared with that recorded in other scombrids, such as *Thunnus thynnus* and *A. rochei*, in the same area (Sinopoli et al., 2004; Mostarda, 2006).

Vegetal remains were probably consumed incidentally as suspended material, as already suggested by Mannoch et al. (1985) and by Campagnuolo et al. (1998).

The ingestion of anthropogenic materials (plastics) was also considered accidental and related to their presence as suspended objects in the water column.

Variation by size

According to the literature (Chur, 1973; Mannoch et al., 1985; Andaloro et al., 1998), in the size range analysed (26.8–50.3 cm Total Length) we observed a shift in prey items consumed according to the increased size of *E. alletteratus*. The stomach of small size specimens (<35 cm TL) mainly contained clupeiforms, in particular *Sardina pilchardus*, teleost larvae and juveniles. As the fish increased in size, a major importance played by crustaceans (hyperiids and isopods), cephalopods and *M. muelleri* was detected. The latter was absent from the stomach contents of specimens <35 cm TL (corresponding to I and II size-classes), while in the V size-class (TL >45 cm) it was the most important prey, according to all numeric indicators. Concurrently with the increasing importance of *M. muelleri* as predator size, a decrease of other teleosts (such as larvae and clupeiforms) was recorded, thus suggesting a diet shift from epipelagic to mesopelagic preys.

In its first years of life, the feeding ecology of *E. alletteratus* is fragmentary. Our paper brings new data about important aspects of the life cycle of this fishing resource and represents a first step toward an ecosystem-oriented approach to fishing management of this species.

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