Diet composition of the Mediterranean horse mackerel, *Trachurus mediterraneus* (STEINDACHNER, 1868) (Osteichthyes: Carangidae), from the Aegean Sea

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ABSTRACT. Data on feeding habits in aquatic ecosystems are of great importance in determining the role that a certain fish species plays in its habitat and in related ecosystems. In this study, the diet composition of Mediterranean horse mackerel, *Trachurus mediterraneus* was investigated for 728 specimens from the central Aegean Sea to compare our data with those from other regions of the Mediterranean Sea and throughout all four seasons. Catches from five major groups were identified. Crustaceans (particularly copepods) proved to be the most important food item considering the index of relative importance (IRI). At least 58 different copepod species were identified. Abundant copepod species that occur in every season were *Corycaeus* sp., *Oncaea media*, *Oncaea* spp., *Isias clavipes*, *Euterpina acutifrons* and *Oithona nana*. *Isias clavipes* occurred only in spring, with all of them appearing in the diet with a %IRI >10. Although found in a relatively smaller quantity, teleost larvae ranked as the second most important prey in the overall diet, with increasing quantities in fish larger than 18.0 cm.

KEYWORDS: Mediterranean horse mackerel, *Trachurus mediterraneus*, diet composition, prey, food, Aegean Sea

INTRODUCTION

Mediterranean horse mackerel, *Trachurus mediterraneus* (STEINDACHNER, 1868) is a common semipelagic carangid fish distributed across the entire Mediterranean Sea and the eastern Atlantic coasts (SMITH-VANIZ 1986). Despite its abundance and commercial value, few data are available on its feeding habits. BEN-SALEM (1988) conducted a study on the stomach contents of *T. trachurus* and *T. mediterraneus* in the eastern Atlantic and the Mediterranean but only provided frequency of occurrence of food items because of a low number of samples. Quantitative analysis of main prey in *T. mediterraneus* was made by KYRTATOS (1998) based on specimens from the central Aegean Sea between 1979 and 1980. SEVER & BAYHAN (SAHINOGLU) (1999) presented preliminary results from analysing the main food of this species in Izmir Bay. Diet composition and feeding intensity of Mediterranean horse mackerel in the eastern Adriatic were also examined by ŠANTIĆ et al. (2004).

Data of feeding studies in aquatic ecosystems are of great importance in determining the role that a certain species plays in its habitat and related ecosystems. Although food composition of the species has been comprehensively studied in various regions of the Mediterranean Sea, there are no studies in which groups of food items have been compared for different seasons and in relation to the length categories of the target species. It is the purpose of our study to identify the most important food groups of the horse mackerel and their seasonal variation.

We believe that the results of the present study can be applied to stock management of the investigated Mediterranean region for both the target species and other species with which it competes for food in the same habitat.

MATERIAL AND METHODS

Samples were obtained from commercial fishermen, who generally use purse seine and gill nets in Izmir and Candarli Bays, Turkish Aegean Sea, which covered significant fishing grounds in the central part of the sea in 2008. A total of 728 *T. mediterraneus* were collected all year round, with total lengths ranging from 9.7 to 25.3 cm (175 in June and August; 192 in September, October and November; 180 January and February; 181 in March, April and May). Fish were dissected soon after capture and stomachs removed and stored in formalin (4 %) until contents were analysed. Stomach contents were homogenized in petri dishes and then examined using a SZX7 Olympus stereo microscope with 0.8-5.6 x (zoom) and 10 x resolution. Except for Copepoda, for which identification was made at the species or generic level, prey items were identified to the lowest possible taxonomic level. Once counted, the individuals of the same prey species were weighed together (wet weight to the nearest ± 0.0001 g), after excess moisture was removed by blotting prey items on tissue paper.

The following indices were used to quantify the importance of different prey items in the diets of *T. mediterraneus*: (i) percentage frequency of occurrence (%F) for each prey group computed separetly=number of stomachs in which a food item was found divided by the total number of non-empty stomachs, multipled by 100 (ii) percentage numerical abundance (%Cn)=number of each prey item in all non-empty stomachs, divided by the total number of food items in all stomachs, multipled by 100 and (iii) percentage gravimetric composition (%Cw)=wet weight of each prey item, divided by the total weight of stomach contents, multiplied by 100 (Hyslop 1980). Main food items were identified using the index of relative importance (IRI) by Pinkas et al (1971). This index has been expressed as: IRI=%Fx(%Cn+%Cw) where % Cn and % F are, respectively, numerical abundance and the frequency of occurrence, and % Cw is the volumetric percentage of the prey type. In addition, %IRI was calculated, being the proportion of IRI of each prey type in relation to the total IRI value. %IRI=(IRI/ Σ IRI)x100. The vacuity index (VI) was used for feeding intensity. The percentage of empty stomachs to the total number of examined stomachs was expressed as the vacuity index (VI). Vacuity index (%VI): %VI=100x (number of empty stomachs / number of examined stomachs) (Berg 1979).

RESULTS

Of a total of 728 stomachs of the Mediterranean horse mackerel, 106 were empty (14.56 %). VI was low during autumn (12.77 %) and spring (13.33 %) but somewhat higher values were observed in winter (15.56 %) and summer (16.67 %). Stomach contents of *T. mediterraneus* included prey from five major taxonomical groups (Polychaeta, Crustacea, Mollusca, Chaetognatha, Osteichthyes). Frequency of occurence, numerical abundance, gravimetric composition and index of relative importance of different prey species found in the stomachs are presented in Table 1. Given numerical occurrence, there was a clear dominance of crustaceans comprising 92.65 % of the diet in total. Fish larvae (47.23 %) and crustaceans (46.19 %) were present in similar proportions regarding gravimetric composition, both of which formed the major weight percentage of prey. According to the %IRI, crustaceans were the most important prey group while other taxa, i.e. molluscs and teleost fishes were less important in the diet. Of crustaceans, copepods contributed most importantly to the diet (%IRI=78.38), followed by larvae of decapod crustaceans (%IRI=7.63), and the non-crustacean bivalves (%IRI=5.85) and fish larvae (%IRI=5.75). Copepods were the primary food in all seasons, despite quantities ranging between 55.48 and 88.03 of %IRI (Table 2). The majority of the copepods were identified to species or generic level and at least 58 different prey taxa were determined (Table 3). Abundant

TABLE 1

Diet composition of *Trachurus mediterraneus* (%F: frequency of occurrence, %Cn: percentage numerical composition, %Cw: percentage gravimetric composition, IRI: index of relative importance and %IRI: percentage index of relative importance).

Prey groups	%F	%Cn	%Cw	IRI	%IRI
Polychaeta					
Errantia	0.96	0.06	0.09	0.14	<0.01
Crustacea					
Ostracoda	2.57	0.16	0.24	1.04	0.01
Copepoda	75.24	79.49	27.29	8033.56	78.38
Cladocera	16.08	1.10	0.97	33.19	0.32
Mysidacea	19.94	1.55	2.38	78.39	0.77
Euphausiacea	14.47	0.97	3.18	59.99	0.59
Isopoda	0.96	0.06	0.023	0.07	<0.01
Amphipoda	1.29	0.07	0.28	0.46	<0.01
Natantia	0.96	0.06	0.43	0.47	<0.01
Brachyura	7.40	0.72	1.96	19.82	0.19
Stomatopoda	2.25	0.14	0.29	0.97	0.01
Decapod larvae (unidentified.)	44.69	8.34	9.16	782.03	7.63
Mollusca					
Gastropoda (Mesogastropoda)	19.94	1.75	0.76	49.89	0.49
Bivalvia (Filibranchiata)	61.09	4.32	5.50	599.96	5.85
Cephalopoda	1.93	0.20	0.16	0.60	0.01
Chaetognatha					
Sagitta sp.	0.64	0.05	0.13	0.16	<0.01
Osteichthyes					
Eggs and larvae of teleosts	12.22	0.97	47.23	588.90	5.75

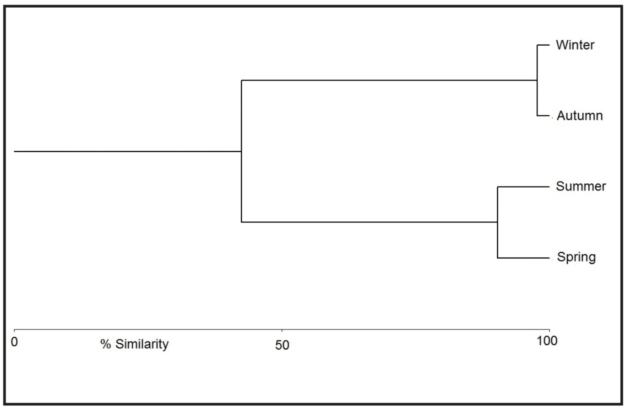

Fig. 1. – Dendrogram of the cluster analysis showing diet similarity (%W) in relation to seasons, using Bray-Curtis index.

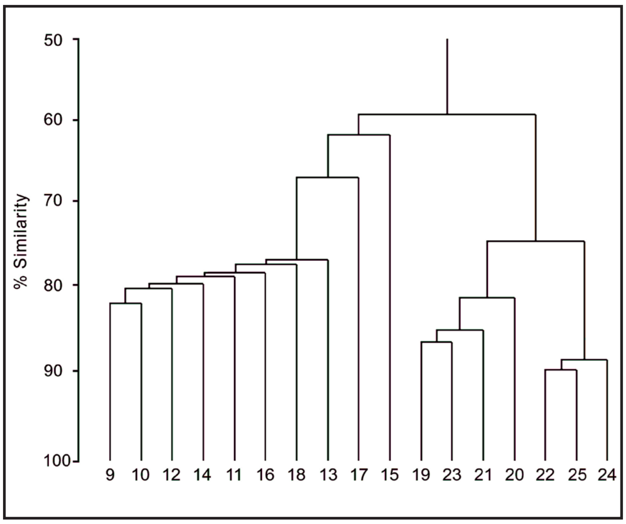

Fig. 2. – Dendrogram of the cluster analysis showing diet similarity (%W) in relation to fish size, using Bray-Curtis index.

TABLE 2

Percentage index of relative importance (%IRI) of species and prey groups by seasons for *T. mediterraneus*.

Prey groups	**January and February**	**March, April and May**	**June and August**	**September, October and November**
N	180	181	175	192
Mean TL (cm)	18.4	17.8	18.6	18.0
Std. Dev.	1.09	1.33	1.49	1.57
Prey groups				
Polychaeta				
Errantia		<0.01	<0.01	<0.01
Crustacea				
Ostracoda	0.01	0.01	0.01	0.02
Copepoda	56.64	55.48	78.79	88.03
Cladocera	0.01	0.05	0.75	0.83
Mysidacea	5.92	0.95	0.52	0.71
Euphausiacea	<0.01	<0.01		<0.01
Isopoda	0.72	0.03	0.04	0.21
Amphipoda	0.01	<0.01	<0.01	0.01
Natantia		0.01	<0.01	0.01
Brachyura	0.15	0.09	0.30	0.17
Stomatopoda			0.02	0.04
Decapod larvae (unident.)	27.75	22.86	0.15	0.15
Mollusca				
Gastropoda (Mesogastropoda)	0.02	5.63	<0.01	0.01
Bivalvia (Filibranchiata)	8.78	6.61	1.20	9.81
Cephalopoda		0.05		<0.01
Chaetognatha				
Sagitta sp.		0.01		
Osteichthyes				
Eggs and larvae of teleosts	<0.01	8.23	18.23	<0.01

copepod species that occurred in every season were *Corycaeus* sp., *Oncaea media*, *Oncaea* spp., *Isias clavipes*, *Euterpina acutifrons* and *Oithona nana*. *Isias clavipes* occurred only in spring, and all of them appeared in the diet with a %IRI>10. A clear peak of decapod crustacean larvae was observed during winter and spring, which sharply decreased to %IRI<1 in all other seasons. Mollusca was the second most important category except in summer. Teleost larvae were present in the diet throughout the year but the most remarkable quantity was in summer. A comparison of seasonal %IRI and %W values of major taxonomical groups based on Bray-Curtis index revealed that winter and autumn were 98.98 % and 97.69 % similar whereas the other seasons had an 88.91 % and 90.26 % diet similarity (Table 2, Fig. 1). Following examination of diet composition in relation to fish size, two groups were formed based on weight percentage of food items (Fig. 2). Gravimetric composition of prey ranged from 0.51 to 1.34 g (mean = 1.06 g) for fish lengths of up to 18.0 cm, which increased to a mean prey weight of 2.53 g (1.81–3.51 g) for fishes larger than 18.0 cm, primarily due to a diet shift to teleost larvae.

TABLE 3

Percentage index of relative importance (%IRI) of copepoda species by seasons for *T. mediterraneus*.

Copepoda Species	Winter	Spring	Summer	Autumn
Acartia clausi	4.012	3.925	-	3.533
Acartia latisetosa	-	-	-	0.064
Acartia sp.	0.014	0.011	-	-
Calanus sp.	0.123	-	0.014	-
Calocalanus pavo	0.014	0.011	0.014	-
Candacia aethiopica	0.014	-	-	-
Candacia armata	0.874	0.045	-	-
Candacia simplex	0.055	-	0.014	
Candacia sp.	4.955	0.045	0.014	0.016
Centropages kröyeri	-	-	0.397	0.398
Centropages typicus	0.218	8.721	1.133	0.143
Centropages sp.	-	-		0.016
Clausocalanus arcuicornis	0.123	0.011	-	-
Clausocalanus furcatus	0.014	0.119	0.057	-
Clausocalanus sp.	0.218	1.187	-	0.085
Copepod nauplius	-	-	-	0.021
Euchaeta marina	0.014	-	-	-
Euterpina acutifrons	1.147	11.031	8.867	26.202
Ischnocalanus plumulosus	-	-	0.057	
Isias clavipes	0.014	15.263	0.605	0.064
Labidocera wollastoni	-	2.786	-	-
Nannocalanus minor	3.494	0.204	0.510	-
Paracalanus nanus	-	0.119	-	-
Paracalanus parvus	0.014	0.119	-	0.551
Paracalanus sp.	0.055	-	-	
Pleuromamma abdominalis	-	-	-	0.016
Pleuromamma sp.	0.014	-	-	-
Temora stylifera	9.419	8.338	5.301	1.766
Calanoida (unident.)	9.724	9.079	8.265	7.524

Copepoda Species	Winter	Spring	Summer	Autumn
Copilia sp.	0.014	0.311	-	-
Corycaeus flaccus	0.123	-	-	-
Corycaeus limbatus	0.014	-	1.166	-
Corycaeus typicus	9.419	3.102	1.020	0.467
Corycaeus brehmi	0.014	0.644	0.170	-
Corycaeus giesbrechti	0.341	0.102	-	-
Corycaeus ovalis	0.014	-	-	-
Corycaeus clausi	1.582	-	0.028	
Corycaeus sp.	16.041	1.265	2.823	0.467
Corycaeus latus	-	-	0.170	-
Corycella rostrata	9.219	6.301	1.813	0.170
Lubbockia squillimana	0.014	-	-	-
Oncaea media	15.084	15.408	27.588	28.502
Oncaea mediterranea	4.618	0.311	4.836	0.398
Oncaea spp.	12.788	8.908	26.280	12.577
Oncaea venusta	0.123	-	0.944	-
Oncaea conifera	-	-	-	0.016
Oithona nana	-	0.102	0.014	14.345
Oithona plumifera	-	0.011	0.057	0.016
Oithona sp.	-	2.374	0.014	-
Sapphirina sp.	-	-	0.170	-
Cyclopoida (unident.)	0.014	0.011	-	-
Clytemnestra scutellata	0.007		-	-
Clytemnestra rostrata	-	-	0.038	
Clytemnestra sp.	-	0.011	-	-
Microsetella norvegica	0.027	0.057	0.113	1.604
Microsetella rosea	0.007	-	-	-
Microsetella sp.	0.014	-	0.057	-
Harpacticoida (unident.)	0.014	0.011	3.498	1.041

DISCUSSION

Results from our study clearly reveal that *T. mediterraneus* is a zooplanktophagous species, concurring with earlier findings (FISCHER et al 1987, DEUDERO 2001, ŠANTIĆ et al 2004). A wide range of prey items was found in stomachs but several of them were rarely consumed. Crustaceans clearly dominate the diet in terms of numerical occurrence (92.65 %) but they shared the great portion of the diet together with teleost larvae, as far as gravimetric occurrence is concerned. The difference observed between %Cn and %Cw is due to the fact that Mediterranean horse mackerel frequently fed on planktonic crustaceans, whose total weights were low in comparison with the less frequently ingested teleost larvae. Similar results were obtained in the Adriatic Sea (ŠANTIĆ et al 2004) for *T. mediterraneus*, as well as for the other species of the genus, *T. trachurus* (JARDAS et al 2004). Of the crustaceans, copepods were the most important prey group (78.38) followed by decapod larvae (7.63), while others (Amphipoda, Euphausiacea, Mysidacea etc.) had %IRI < 1. It is striking to note that BEN-SALEM (1988) did not record any copepod species in stomachs of Mediterranean horse mackerel from the Aegean Sea. However, in view of the low number of full stomachs (n=43) found by BEN-SALEM (1988), relevant evidence does not seem comparable. Copepods are known to be abundant all year round in the Aegean Sea (MORAITOU-APOSTOLOPOULOU 1972, STERGIOU et al 1997), and they are also of great importance in the diet of several pelagic and semi-pelagic fishes such as *Sardina pilchardus* (SEVER et al. 2005) and *Scomber japonicus* (SEVER et al. 2006). No copepods were observed in the diet of Adriatic Sea specimens of *T. mediterraneus* either, while euphausids consisted of more than 50 % of the total IRI (ŠANTIĆ et al. 2004). This prey shift between different localities could be a good indication for the ability of *T. mediterraneus* to modify its diet in response to available food items. A sudden change in the feeding habits of the Mediterranean horse mackerel was also reported along the southern Spanish coast due to the availability of new and abundant food items (FERNANDEZ-JOVER et al. 2007).

In general, the percentage of empty stomachs of *T. mediterraneus* was relatively low when compared to results of previous studies. The VI ranged between 12.77 % and 16.67 % according to season, which is much lower than the overall ratio of 50.50 % observed by Šantić *et al.* (2004) in the Adriatic Sea. Percentage of empty stomachs was also high in the Gulf of Lyon (32.50 %) while percentages closer to our study were observed at the Tunisian coast (16.46 %) and Aegean Sea (14.50 %) (BEN-SALEM 1988). This difference may be attributed to the favorable environmental conditions in the Aegean Sea supporting feeding intensity of *T. mediterraneus* throughout the year probably with abundant food supplies. There was no prominent variation in seasonal diet in our study. Crustaceans were the primary prey all year round, with lowest %IRI in spring (79.48) and highest in winter (91.20). Molluscs, especially Bivalvia ranked as the second most important category, excluding the summer season when the dominant copepod prey were followed by teleost larvae. In contrast, KYRTATOS (1998) indicated differences in the seasonal feeding habits of the horse mackerel, with a clear decrease of teleost larvae from spring to winter and an increase of copepods, mysids and other crustaceans during the corresponding interval. Little diet variation was observed in Adriatic Sea specimens of *T. mediterraneus* among seasons (ŠANTIĆ et al. 2004). Mean prey weight in stomachs increased with fish size as expected. Food preferences and quantity change with growth and the ability of large mackerels to capture larger prey increases (ŠANTIĆ et al. 2005). In our study, teleost larvae became importance in the diet of Mediterranean horse mackerel with lengths greater than 18 cm, although this prey shift was not very strong even in fish of the maximum length examined in the study. Also other researchers found that larvae and postlarvae of teleosts are important for the diet of *Trachurus* spp. especially for individuals larger than 20 cm (ŠANTIĆ et al. 2004, FERNANDEZ-JOVER et al. 2007). Although total lengths of up to 60 cm have been reported for the horse mackerel in other studies (for example, FISCHER et al. 1987), it appears unlikely to observe *T. mediterraneus* specimens larger than 40 cm in the Adriatic Sea (ŠANTIĆ et al. 2005).

Nowadays, trophic levels are used for the development of ecosystem-origin fishery management strategies. Depending on the trophic controls that are formed upwards from the bottom of the food chain and downwards from the top of the food chain, the long-term changes of fish stocks through the years and intervals between the low and high stock regimes could be defined (DASKALOV 2002, DASKALOV et al. 2007). As a consequence, the findings obtained from this research will contribute to the ecosystem-origin fishery management that will be conducted in the Aegean Sea.

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REFERENCES

BEN-SALEM M (1988). Régime alimentaire de *Trachurus trachurus* (Linnaeus, 1758) et de *T. mediterraneus* (Steindachner, 1868) (poissons, téléostéens, Carangidae) de la province atlantico-méditerranéenne. Cybium 12(3): 247-253.

BERG J (1979). Discussion of methods of investigating the food of fishes, with reference to a preliminary study of the food of *Gobiusculus flavescens* (Gobiidae). Marine Biology 50: 263-273.

DASKALOV GM (2002). Overfishing drives a trophic cascade in the Black Sea. Marine Ecology Progress Series, 225: 53-63.

DASKALOV GM, GRISHIN AN, RODIONOV S & MIHNEVA V (2007). Trophic cascades triggered by overfishing reveal possible mechanisms of ecosystem regime shifts. Proceedings of the National Academy of Sciences of the United States of America, 104(25): 10518-10523.

DEUDERO S (2001). Interspecific trophic relationships among pelagic fish species underneath FADs. Journal of Fish Biology, 58(1): 53-67.

FERNANDEZ-JOVER D, JIMENEZB JAL, SANCHEZ-JEREZ P, BAYLE-SEMPERE J, CASALDUERO FG, LOPEZ FJM & DEMPSTER T (2007). Changes in body condition and fatty acid composition of wild Mediterranean horse mackerel (*Trachurus mediterraneus* Steindachner, 1868) associated to sea cage fish farms. Marine Environmental Research 63: 1-18.

FISHER W, BAUCHOT ML & SCHNEIDER M (1987). Fiches FAO d'identification pour les besoins de la pêche, révision 1. Mediterranée et Mer Noire. Zone de Pêche 37, Vol.2, Vertebres, p. 761-1530. FAO, Rome.

HYSLOP EJ (1980). Stomach contents analysis – a review of methods and their application. Journal of Fish Biology 17: 411-429.

JARDAS I, ŠANTIĆ M & PALLAORO A (2004). Diet composition and feeding intensity of horse mackerel, *Trachurus trachurus* (Osteichthyes: Carangidae) in the eastern Adriatic. Marine Biology 144: 1051-1056.

KYRTATOS NA (1998). Contribution de la nourriture de *Trachurus mediterraneus* (Steind.) et de son influence sur les chaines alimentaires de la mer Egée centrale. Rapp. Comm. Int. Mer Médit. 35: 452-453.

MORAITOU-APOSTOLOPOULOU M (1972). Occurrence and fluctuation of the pelagic copepods of the Aegean Sea with some notes on their ecology. Hellenic Oceanology and Limnology, 11: 325-402.

PINKAS LM, OLIPHANT S & IVERSON ILK (1971). Food habits of albacore, bluefin tuna and bonito in Californian waters. California Department of Fish & Game, Fish Bulletin 152: 1–105.

ŠANTIĆ M, JARDAS I & PALLAORO A (2004). Diet composition and feeding intensity of Mediterranean horse mackerel, *Trachurus mediterraneus* (Osteichthyes: Carangidae), in the central Adriatic Sea. Acta Adriatica (45): 43-50.

ŠANTIĆ M, JARDAS I & PALLAORO A (2005). Feeding habits of horse mackerel, *Trachurus trachurus* (Linneaus, 1758), from the central Adriatic Sea. Journal of Applied Ichthyology (21): 125–130.

SEVER T & BAYHAN (SAHINOĞLU) B (1999). Preliminary study on the feeding regime of the Mediterranean horse mackerel (*Trachurus mediterraneus* Steind., 1868) distributed in the bay of Izmir. Journal of Fisheries and Aquatic Sciences (16): 107-116.

SEVER TM, BAYHAN B & TASKAVAK E (2005). A preliminary study on the feeding regime of European Pilchard (*Sardina pilchardus* Walbaum, 1792) in Izmir Bay Turkey, Eastern Aegean Sea. NAGA, WorldFish Center Quarterly 28(3-4): 41-48.

SEVER TM, BAYHAN B, BILECENOGLU M & MAVILI (2006). Diet composition of the juvenile chub mackerel (*Scomber japonicus*) in The Aegean Sea (Izmir Bay, Turkey). Journal of Applied Ichthyology 22: 145-148.

SMITH-VANIZ WF (1986). Carangidae. In: WHITEHEAD PJP, BAUCHOT ML, HUREAU JC, NIELSEN J & TORTONESE E (eds). Fishes of the North-eastern Atlantic and Mediterranean. UNESCO, Paris, 2: 815-844.

STERGIOU KI, CHRISTOU ED, GEORGOPOULOS D, ZENETOS A & SOUVERMEZOGLOU C (1997). Hellenic waters: physics chemistry, biology and fisheries. Oceanography and Marine Biology, An Annual Review 35: 415–538.

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