ISSN: 0001-5113
AADRAY

ACTA ADRIAT.,
45 (1): 43-50, 2004

UDC: 597.58:591.13(262.3-191.2)
Original scientific paper

Diet composition and feeding intensity of Mediterranean horse mackerel, *Trachurus mediterraneus* (Osteichthyes: Carangidae), in the central Adriatic Sea

Mate ŠANTIĆ[1], Ivan JARDAS [2] and Armin PALLAORO[2]

[1]Department of Biology, Faculty of Science, University of Split, 21000 Split, Croatia
e-mail: msantic@pmfst.hr

[2] Institute of Oceanography and Fisheries, 21000 Split, Croatia
e-mail: jardas@izor.hr;
e-mail: pallaoro@izor.hr

Diet composition and feeding intensity of the Mediterranean horse mackerel, Trachurus mediterraneus, *collected in the central Adriatic Sea were examined. Stomach contents of 1200 specimens, taken at monthly intervals (January-December, 1996) were analyzed. The stomach contents consisted of six major prey groups: Crustacea (Euphausiacea, Mysidacea, Decapoda), Cephalopoda, Polychaeta and Teleostei. Euphausiacea constituted the most important food resource by weight, number and frequency. Teleosts were the second most important food category, while Mysidacea, Decapoda, Cephalopoda and Polychaeta were occasional foods. Euphausicea were dominant during all seasons, and especially abundant in summer and autumn. Feeding intensity varied throughout the year. The lowest feeding intensity was recorded in winter at lower sea temperatures and during spawning (May, June). Feeding activity increased just prior to (April) and after (July, August) spawning. Feeding intensity also varied during the diurnal cycle. The highest feeding intensity was recorded at night and during early morning hours.*

Key words: *Trachurus mediterraneus*, food composition, feeding intensity, Adriatic Sea

INTRODUCTION

Mediterranean horse mackerel, *Trachurus mediterraneus* (STEINDACHNER, 1868), is distributed throughout the Mediterranean, the Black, and the northeastern Atlantic (SMITH-VANIZ, 1986) seas. In the Adriatic, *T. mediterraneus* is a schooling semi-pelagic species, most commonly found at depths of 20-200 m (JARDAS, 1996). It spawns in late spring and early summer (ARNERI & TANGERINI, 1984; VIETTE *et al*., 1997). There are no reliable statistical data on *T. mediterraneus* landings in the Adriatic Sea but the annual catch can be tentatively estimated at 400 tons. In the Mediterranean, however, it constitutes a large portion of pelagic and demersal fisheries and landings, and fluctuated from 5 120 to 109 560 tons in 1989-98 (FAO, 2000). In the Adriatic, the species has remained abundant compared to economically important and over-fished species (VRGOČ, 2000). Despite its abundance, very little is known about the trophic ecology of this species in the Adriatic. Information on the diet

of *T. mediterraneus* in the Adriatic indicates that its main diet comprises crustaceans and fish (LIPSKAJA, 1966; BINI, 1968; TORTONESE, 1975). BEN-SALEM (1988) and KYRTATOS (1998) presented more detailed information about the diet of this species in the Mediterranean.

The purpose of the present study was to determine diet composition and feeding intensity of Mediterranean horse mackerel during the year and during the day in the eastern Adriatic.

MATERIALS AND METHODS

Samples of Mediterranean horse mackerel were taken from five localities in the eastern Adriatic (Fig. 1): near the islands of Vis and Svetac (A), south of Šolta Island (B), Split Channel (C), Blitvenica fishing area (D) and Jabuka Island (E), at the continental shelf between depths of 60 (locality A) and 175 (locality E) meters.

Samples were taken from commercial bottom-trawl catches carried out with a cod-end net of 22 mm mesh (stretched) at a trawling speed of 2-3 knots. The nets were hauled three times a day: from 04:00 to 10:00, from 11:00 to 16:00, and from 17:00 to 22:00. Monthly samples were collected from January to December 1996 and 1200 specimens (100 specimens per month), ranging 11.6-38.0 cm, were examined. The fish were measured to the nearest 0.1 cm (total length) and 0.1 g. The fish were dissected immediately after capture and the gut was removed and preserved in a 4% formaldehyde solution to prevent further digestion. Evidence of regurgitation was never observed in any of the fish.

Identification of the prey was carried out in the laboratory, to the species level whenever possible. We registered their number and the wet weight of the food items to the nearest 0.001 g, after removing surface water by blotting on tissue paper. Gonads of all specimens were dissected and weighed to the nearest 0.001 g to calculate the gonadosomatic index (GSI = weight of gonads/fish weight × 100).

Numerous indices quantitatively express the relative importance of different prey in fish diets (BERG, 1979; HYSLOP, 1980). Those used in the present study included: (a) frequency of occurrence (%F), based on the number of stomachs in which a food item was found, expressed as the percentage of the total number of non-empty stomachs, (b) numerical abundance (%Cn), the

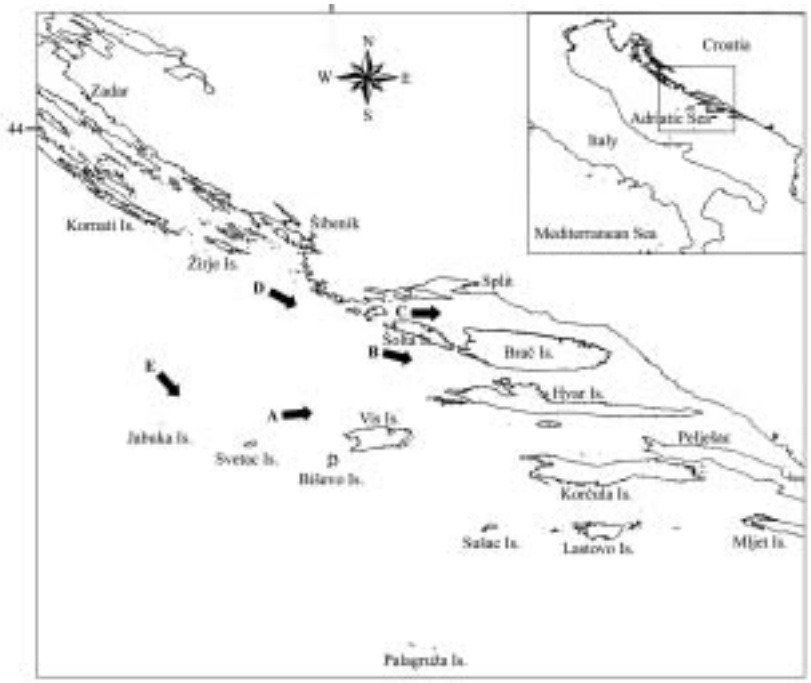

Fig. 1. Study area and sampling localities of Mediterranean horse mackerel (Trachurus mediterraneus) *in the eastern Adriatic: A - near Vis and Svetac islands, B - south of Šolta Island, C - Split Channel, D - Blitvenica fishing area, E - Jabuka Island*

number of each kind of prey, expressed as the percent of the total number of food items in all non-empty stomachs in the sample, and (c) gravimetric composition (%Cw), the wet weight of each kind of prey, expressed as the percent of the total weight of the stomach contents in the sample.

The main food items were identified using the index of relative importance (IRI) of PINKAS *et al*. (1971), modified by HACUNDA (1981):

$$IRI = \%F \times (\%Cn + \%Cw)$$

A vacuity index (%VI = empty stomachs/ total number of stomachs ×100) and a fullness index (%Jr = weight of digested prey/fish weight ×100; HUREAU, 1970) were used to determine feeding intensity.

The variations in vacuity index during the seasonal and diurnal cycles were tested by chi-square test (SOKAL & ROHLF, 1981).

RESULTS

Of the 1200 examined stomachs, 606 were empty (50.5%). Table 1 shows the %F, %Cn, %Cw and IRI of the prey groups and species found in the non-empty stomachs.

Table 1. Prey groups and species in the diet of Trachurus mediterraneus *(%F = frequency of occurrence; %Cn = numerical composition; %Cw = gravimetric composition according to weight; IRI = index of relative importance)*

Food item	(%F)	(%Cn)	(%Cw)	IRI
TELEOSTEI				
Gadiculus argenteus	6.73	0.46	14.55	101.01
Maurolicus muelleri	6.06	0.69	12.83	81.93
Engraulis encrasicolus	6.56	0.79	5.46	41.00
Helicolenus dactylopterus	1.01	0.05	5.20	5.30
Arnoglossus laterna	1.17	0.08	2.40	2.90
Lesueurigobius friesii	2.35	0.15	2.29	5.73
Aphia minuta	1.01	0.07	0.89	0.96
Other and non-identified Teleostei	13.37	0.35	2.34	35.96
CRUSTACEA				
Euphausiacea:				
Nyctiphanes couchii	29.46	52.94	19.46	2132.9
Euphausia krohni	14.30	25.62	9.53	502.6
Meganyctiphanes norvegica	8.24	4.65	3.36	66.0
Non-identified Euphausiacea	7.07	6.22	1.73	56.2
Mysidacea:				
Lophogaster typicus	1.51	5.75	2.14	11.9
Decapoda:				
Parapenaeus longirostris	2.18	0.13	1.86	4.33
Munida rugosa	1.01	0.04	1.16	1.21
Other and non-identified Decapoda	1.34	0.07	0.71	1.05
Total Decapoda	1.43	0.35	4.67	7.23
CEPHALOPODA				
Sepiola sp.	1.01	0.03	0.96	1.00
Illex illecebrosus	0.67	0.03	2.33	1.58
POLYCHAETA				
Non-identified Polychaeta	0.67	0.12	0.95	0.71

The stomach contents of the Mediterranean horse mackerel consisted of six major systematic groups: Teleostei, Euphausiacea, Mysidacea, Decapoda, Cephalopoda and Polychaeta. According to the IRI, euphausiid crustaceans were the most important prey followed by various developmental stages of fish species. Other taxa found in the stomach contents (Mysidacea, Decapoda, Cephalopoda and Polychaeta) were of lesser importance in the diet. At the species level, two euphausiids *Nyctiphanes couchii* and *Euphausia krohni* were the most important (IRI), followed by three teleosts: *Gadiculus argenteus*, *Maurolicus muelleri* and *Engraulis encrasicolus*. According to the IRI, there was little seasonal variation in the diet (Table 2). Euphausiids were dominant during all seasons, particularly in summer and autumn. Teleosts were present throughout the year, however, were highest during spring. Decapods and cephalopods were present in the diet during all seasons while mysids were absent in autumn and polychaets were found only in autumn and winter.

Figs. 2 and 3 show the feeding intensity during the year. Low values for prey biomass and high values for vacuity index were recorded in May-June, during the spawning of *T. mediterraneus* (Fig. 2). During these two

Table 2. Index of relative importance (IRI) of the major prey groups, by season

Prey group	Winter IRI	Spring IRI	Summer IRI	Autumn IRI
Teleostei	228.38	924.09	240.50	292.54
Euphausiacea	2472.59	2609.52	3620.71	3212.46
Mysidacea	83.67	6.70	2.67	-
Decapoda	6.35	25.17	10.04	4.19
Cephalopoda	3.33	1.75	1.27	8.08
Polychaeta	5.95	-	-	0.99

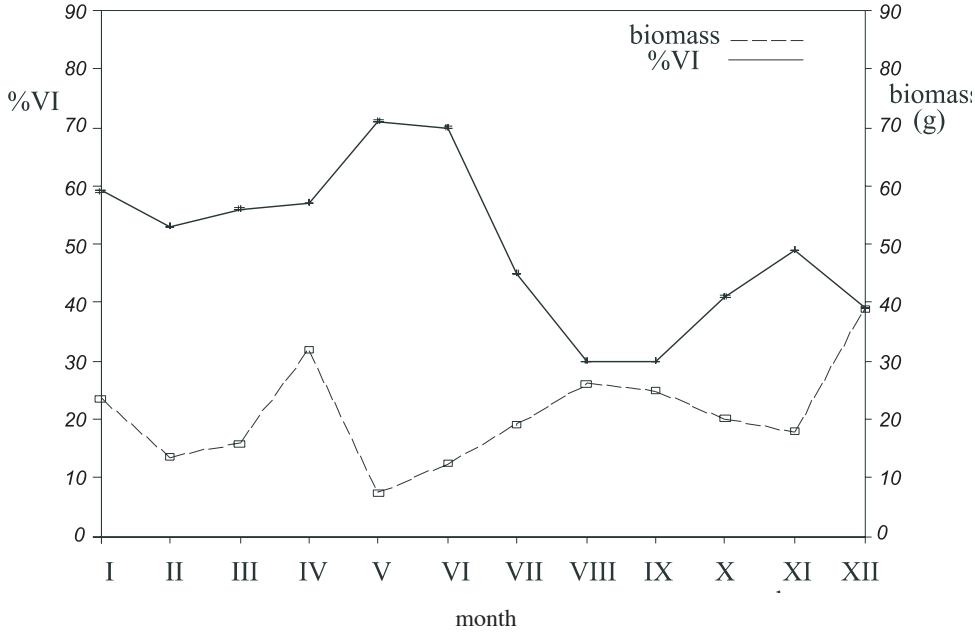

Fig. 2. Biomass of prey (g) and vacuity index (%VI) of Mediterranean horse mackerel (Trachurus mediterraneus) *throughout the year*

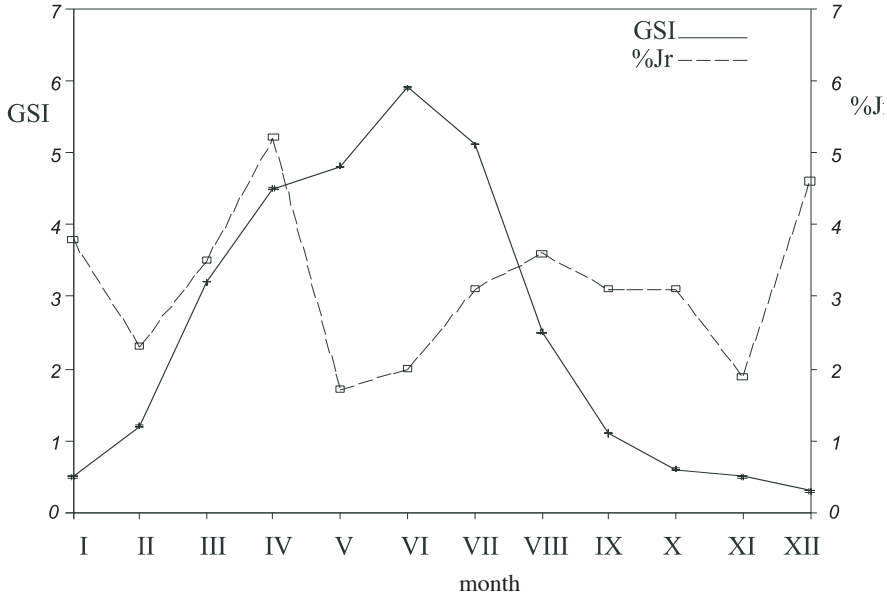

Fig. 3. Gonosomatic index (GSI) and fullness index (%Jr) of Mediterranean horse mackerel (Trachurus mediterraneus) *throughout the year*

months, the gonadosomatic index peaked and the fullness index was very low (Fig. 3).

When spawning terminated in July/August, the fullness index reached its highest value while the vacuity index reached its lowest (Table 3). Feeding intensity decreased in winter (January and February). The vacuity index reached its highest value in April, just prior to spawning and indicates significantly lower feeding intensity in winter and spring ($\chi^2 = 31.3$, $P<0.05$).

Table 3. Fullness index (% Jr) and vacuity index (%VI), by season

Season	Fullness index (%Jr)	Vacuity index (%VI)
Winter	0.32	55.3
Spring	0.28	66.0
Summer	0.38	35.3
Autumn	0.36	45.0

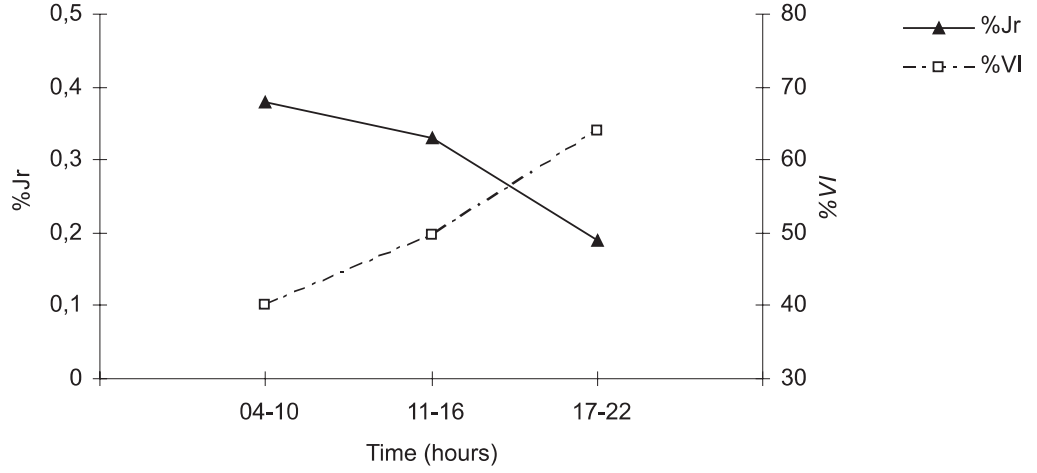

*Fig. 4. Diurnal fullness index (%Jr) and vacuity index (%VI) of Mediterranean horse mackerel (*Trachurus mediterraneus*)*

Feeding intensity was measured after each haul. The vacuity indices showed that feeding intensity was significantly higher during the night and morning and decreased during the course of the day ($\chi^2 = 11.3$, $P<0.05$; Fig. 4). This was confirmed by the fullness index.

DISCUSSION

T. mediterraneus is essentially planktophagous. According to our data, its main prey is euphausiid plankton (*N. couchii, E. krohni* and, less often, *Meganyctiphanes norvegica*). This group represents over 50% of the total IRI and was thus the main food (ROSECCHI & NOUAZE, 1987). *G. argenteus*, *M. muelleri, E. encrasicolus* and other less important teleosts were the secondary food. Other prey, i.e., mysids, decapods, cephalopods and polychaets, were of minor importance and an occasional food.

N. couchii and *E. krohni* are common in the central Adriatic especially in the areas of Vis Island, Jabuka pit and the Blitvenica fishing area, while *M. norvegica* is more frequent in the south Adriatic pit (ŠIPOŠ, 1977; GAMULIN, 1979; NOŽINA, 1979). The different distribution patterns of these zooplankton are probably the reason why *N. couchii* and *E. krohni* were more abundant in the stomachs of central Adriatic *T. mediterraneus* than *M. norvegica*. Since these euphausiid crustaceans are present in the study area year-round (GAMULIN, 1979), they constituted the main food for *T. mediterraneus* year-round.

Data on the food of *T. mediterraneus* in the Adriatic Sea are scant. BINI (1968) and TORTONESE (1975) only mention that fish and small crustaceans are its food. In Albanian waters the species prefers fish (particularly anchovies), amphipods, mysids and decapods in the summer (LIPSKAJA, 1966). In the Aegean Sea, fish larvae and postlarvae (particularly of *Pagellus acarne*, *Diplodus vulgaris* and *Spicara maena*) constitute the dominant biomass in *T. mediterraneus* stomachs, followed by crustacean copepods and mysids (KYRTATOS, 1998). Mysidacea and Copepoda crustaceans constitute a significant proportion of the stomach contents of *T. mediterraneus* in Lyon Bay and Gascone Bay, while in Tunisian waters fish belonging to Gobiidae are the main food items (BEN-SALEM, 1988). The data recorded in this work generally coincide with the above-mentioned references, showing that planktonic crustaceans and fish dominate the diet of Mediterranean horse mackerel. Differences in food habits of *T. mediterraneus* between the Mediterranean and the central Adriatic are mainly due to different distribution, abundance, density, availability and accessibility of prey.

The feeding intensity of Mediterranean horse mackerel changed during the year, probably related to spawning and water temperature. Feeding intensity increased in March and April (prior to spawning) and reached its lowest during spawning (May-June). It is assumed that during reproduction *T. mediterraneus* reduces the energy spent on catching prey and directs it to gamete production. Expended energy is replaced by intensified feeding after spawning (July-September). This is confirmed by data on *T. mediterraneus ponticus* from the Black Sea, where feeding intensity increased from 80 to 90% after spawning (SIROTENKO & ISTOMIN, 1978). The high sea temperatures in July-September accelerate metabolism, resulting in an increased food demand. WARREN & DAVIS (1967) discussed the profound effects of temperature and seasonality on food consumption rates. More food is consumed in summer than in winter, as demonstrated in an experiment with *Cottus perplexus* (DAVIS & WARREN, 1965). In many fishes, the feeding rate drops as the temperature drops (TYLER, 1971). In the study area, the water temperature reaches a minimum during the winter (February) and beginning of spring (ZORE-ARMANDA *et al*., 1991). Because of the reduced abundance of prey and the lowered metabolism of the fish, predation was probably at a minimum during the winter. ŠIPOŠ (1977) and GAMULIN (1979) showed that in the Adriatic Sea euphausiids were more abundant and denser during the warm part of the year (spring and summer).

Vacuity and fullness indices revealed that the Mediterranean horse mackerel consumed prey during the night and in the early morning. Possibly, feeding activity is higher in low light due to the vertical migration of zooplankton crustaceans (Euphausiacea), the dominant prey. Zooplankton inhabit deeper layers during the day and rise towards the surface during the night to feed (HURE, 1961; VUČETIĆ, 1961).

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Received: 4 December 2002
Accepted: 14 October 2003

Sastav hrane i intenzitet ishrane šnjura pučinara, *Trachurus mediterraneus*, (Osteichthyes: Carangidae) u srednjem Jadranu

[1]Mate ŠANTIĆ, Ivan JARDAS[2] i Armin PALLAORO[2]

[1]Fakultet prirodoslovno-matematičkih znanosti i odgojnih područja, Sveušilište u Splitu, 21000 Split, Hrvatska
e-mail: msantic@pmfst.hr
[2]Institut za oceanografiju i ribarstvo, 21000 Split, Hrvatska
e-mail: jardas@izor.hr; pallaoro@izor.hr

SAŽETAK

Istražen je sastav hrane i intenzitet ishrane šnjura pučinara, *Trachurus mediterraneus* (STEINDACHNER, 1868.) sakupljenog u srednjem Jadranu. Analiziran je sadržaj želuca kod 1200 primjeraka sakupljenih u mjesečnim intervalima od siječnja do prosinca 1996. U hrani je determinirano 6 glavnih skupina plijena: Rakovi (Euphausiacea, Mysidacea i Decapoda), ribe (Teleostei), glavonožci (Cephalopoda) i mnogočetinjaši (Polychaeta). S obzirom na frekvenciju, brojnost i biomasu, eufauzidni račići bili su glavna hrana. Ribe (Teleostei) su predstavljale sekundarnu hranu, dok su ostale skupine plijena bile slučajnja hrana. Eufauzidni račići bili su dominantna hrana tijekom cijele godine, a posebno u ljetno-jesenskom razdoblju. Intenzitet ishrane kolebao je tijekom godine. Niske vrijednosti intenziteta ishrane zabilježene su tijekom zime kada je snižena temperatura mora kao i u razdoblju mrijesta (svibanj i lipanj). Najviši intenzitet hranjenja zabilježen je u razdoblju neposredno prije (travanj) i nakon mrijesta (srpanj, kolovoz i rujan). Intenzitet ishrane šnjura pučinara mijenja se tijekom dnevnog ciklusa. Najveća aktivnost hranjenja zabilježena je tijekom noći i ranih jutarnih sati.

Ključne riječi: *Trachurus mediterraneus*, sastav hrane, intezitet ishrane, Jadransko more