DOI: 10.55268/CM.2024.54.104

ASPECTS REGARDING THE DIET COMPOSITION OF *TRACHURUS MEDITERRANEUS* (STEINDACHNER, 1868) FROM THE ROMANIAN BLACK SEA COAST

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ABSTRACT

Knowing the diet composition of a fish species provides a key to understanding their place in the marine food web. Between May 2021 and September 2022, 120 stomachs of horse mackerel with sizes between 8.0 and 15.5 cm (average length 11.43±1.35 cm), were sampled and analyzed. The identified prey were: fish (*Engraulis encrasicolus* - anchovy), copepods (*Acartia clausi, Calanus euxinus*), molluscs and annelids polychaetes. Regarding the value of the Relative Importance Index (RII), the copepod group dominated. This prey is probably characteristic of small size individuals that dominated the samples. Their diet was similar between years. The analysis of Fullness Index (FI) highlights an increase in the index according to length. There are no significant FI differences between the stations, month and years.

Keywords: fish, feeding seasons, copepod, Relative Importance Index, Fullness Index

INTRODUCTION

Marine fish play crucial roles in marine ecosystems functioning. Understanding their diet composition provides insights into their ecological niche, trophic interactions and position within the food web.

Horse mackerel is a small pelagic fish, with landings taking place off the Romanian Black Sea coast from spring to autumn (Maximov, 1914). Păun *et al*. (2019), highlighted that this species accounts for about 30% of Romania's summer pelagic catches and a significant portion of the Black Sea's total catches, providing both income for fishermen and essential nutrients to the population.

Several authors described the diet of the horse mackerel in the Mediterranean Sea (Lipskaja, 1966; Tortonese, 1975; Šantič *et al*., 2013), in the Atlantic Ocean (Cabral and Murta, 2002) and in the Black Sea (Sirotenko and Istomin, 1978; Yankova *et al*., 2008; Bănaru and Harmelin-Vivien, 2009). The authors showed that horse mackerel in an opportunistic predator feeding on diverse invertebrates and small fish and its diet may change according to size, location and season.

Moreover, Bănaru *et al.* (2010) showed that significant changes occurred in the structure and the functioning of food webs on the Romanian Black Sea coast and were related to various human impacts (overfishing, eutrophication, invasive species). Major changes in the main commercial fish species diets were shown in the period 2004-2006 compared to previous studies (Bănaru and Harmelin-Vivien, 2009).

Despite its important role in commercial fisheries, Romanian catches of the horse mackerel strongly decreased from 2666 tons in 1988 to 54 tons in 2023 (PNCD, 2023). This decrease may be related to overfishing and/or changes in the trophic environment that may potentially affect fish growth and reproduction.

However, there are no recent studies on the diet of horse mackerel on the Romanian Black Sea coast. The hypothesis of our study is that their diet may have changed over time potentially related to available prey fluctuations. Moreover, changes in the mean mass of gastric contents may reflect differences in feeding intensity.

The present study aimed to analyze the diet composition and feeding intensity of the horse mackerel in these waters over the 2021-2022 period, based on stomach content analyses.

EXPERIMENTAL

The study area was located in the northwestern part of the Black Sea (Vadu station) and in the southern part (Eforie South and Mangalia stations), (Fig. 1).

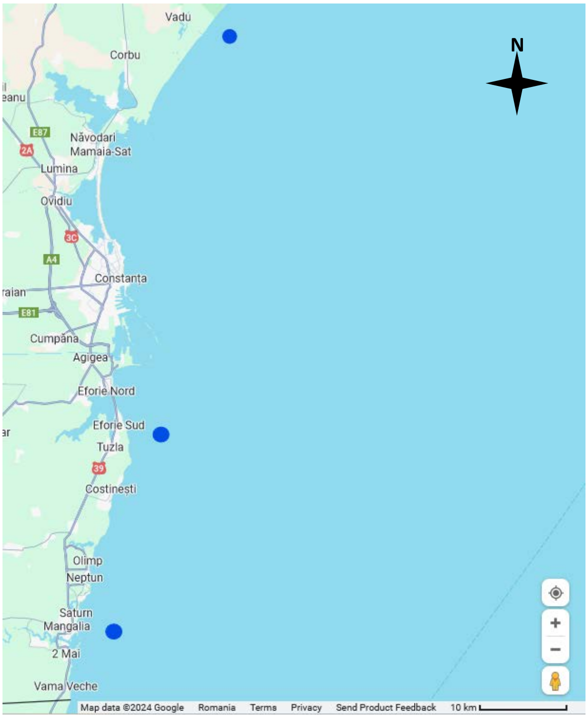

Fig. 1. Sampling stations (*source: Google map capture*)

From May 2021 to September 2022, a number of 120 individuals of horse mackerel were collected in the morning (06:00-07:00) at stationary pound net along the coastal area of the Black Sea in the northern area (Vadu) and the southern area (Eforie South, Mangalia).

The individuals were measured and weighed, and their biometric characteristics, station and date of their sampling were noted. Total length of fish examined ranged from 8.0 to 15.5 cm. Each stomach of the horse mackerel was analyzed individually, weighed and their body mass was recorded (Fig. 2). After that, the stomach was placed in formaldehyde (4% solution) to stop digestion. Species abundance and their wet weight, to the nearest 0.001 g after removal of surface water by blotting on tissue paper, were recorded in the laboratory. The organisms present in the stomach were identified under a microscope, after which the Fullness Index (FI) and Relative Importance Index (RII) were calculated. All the analyzed stomachs contained food.

Fig. 2. Analysis of the horse mackerel stomachs (*Source: Original photos*)

A straightforward method of data collection through stomach content analysis is to note the number of stomachs containing one or more individuals from each food category, with this number expressed as a percentage of the total stomachs analyzed (Hyslop, 1980). Sikora *et al.* (1972) calculated the mean dry body mass in predatory species and referred as "biomass units". The variation in the mean mass of stomach contents in relation to fish size is commonly used to determine daily feeding rates (Staples, 1975). Body mass values serve as a measure of food consumption relative to fish size.

The measurement of ingested food weight (FW) is expressed as percentage of total fish weight (W) according to the formula defined by Hureau (1969):

$$FI = FW / W \times 100 \qquad (1)$$

where: FI is the index of fullness (fullness index).

Frequency of occurrence and numerical percentage of food components are generally calculated to characterize stomach contents (Hyslop, 1980). The frequency of occurrence (FO%) is expressed as the percentage of the total number of stomachs in which the respective species occur:

$$FO\% = FOi / FOt \times 100 \qquad (2)$$

where:

FOi = number of stomachs in which species *i* occur;

FOt = total number of stomachs.

A realistic evaluation of the stomach contents is based on the combination of several trophic indices.

A more complex indicator that was used in this study is the "relative importance index" (RII) in the formula of Pinkas *et al*. (1971), Ahlbeck *et al*. (2012):

$$RII = (\%N + \%V) \times \%FO \qquad (3)$$

where: N% = number in percentage of food elements in the intestines;
V = volume of each element;
FO = frequency of occurrence of a food item.

To see the similarity between years regarding the spectrum of food, the Czekanowski Index (Czekanowski, 1909) of presence/absence was used, according to the following formula:

$$I = [2c /(a + b)] \times 100 \qquad (4)$$

where:
a = number of species present in Fig. 3;
b = number of species present in Fig. 4;
c = number of species common to both lists.

Statistical analyzes were performed using STATISTICA 12.7 to determine differences in the FI of individuals between stations, months and years.

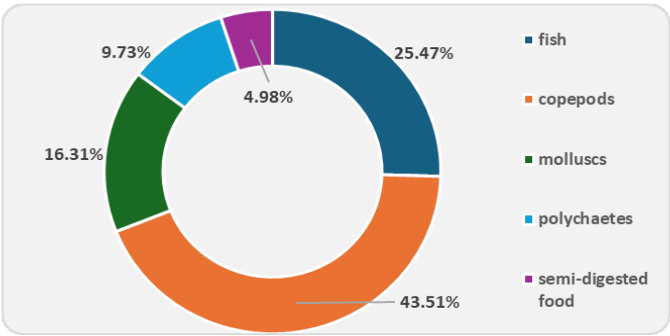

Fig. 3. Relative Importance Index (RII%) of the horse mackerel prey species in 2021

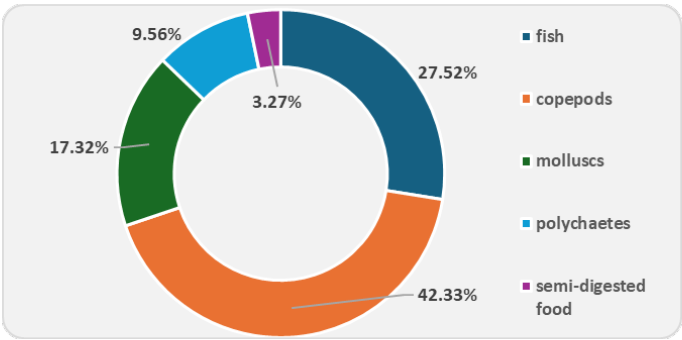

Fig. 4. Relative Importance Index (RII%) of the horse mackerel prey species in 2022

RESULTS AND DISCUSSION

A natural predator can rapidly shift its trophic niche, changing the entire food web configuration to accommodate differences in prey abundance and availability (Garrido and Murta, 2011).

Thus, to create a diet matrix representative for a species, dietary data from different regions and periods should be used.

This study allowed to obtain new data on the diet of *Trachurus mediterraneus*, a highly commercial important species for Romanian fisheries. An objective analysis requires both quantitative and qualitative aspects of their diet and the potential spatial and temporal variations.

Diet

The identified prey in the analysed stomach content were: fish *Engraulis encrasicolus* (anchovy); copepods *Acartia clausi*, *Calanus euxinus*; molluscs and polychaetes. The occurrence, number and volume indices allowed to the estimate the Relative Importance Index (RII) of the horse mackerel preys from their stomach contents presented hereafter. The copepod group was the one that prevailed both in 2021 and 2022 and was classified as their main food source in this area, followed by fish and molluscs and polychaetes (Fig. 3, Fig. 4).

In both 2021 and 2022, the group of copepods dominated the horse mackerel diet (42-43.5%), followed by fish (25.5-27.5%), mollusks (16-17%), polychaetes (9.5-9.7%) and semi-digested food (Fig. 3, Fig. 4). According to the calculated Czekanowski index, the similarity regarding the diet composition is 100% between years.

Bayhan *et al.* (2013) showed that *Trachurus mediterraneus* in the Aegean Sea preyed mainly on copepods. In Portuguese waters, horse mackerel fed primarily on fish, but crustaceans were the main prey (Cabral and Murta, 2002). Tortonese (1975) briefly reports that *Trachurus* species in Italian waters feed on fish and crustaceans. According to Lipskaja (1966), horse mackerel in Albanian waters during summer feed on various developmental stages of fish and crustaceans, including amphipods, mysids, and decapods. The diet of juvenile Mediterranean horse mackerel and horse mackerel in the eastern central Adriatic primarily consisted of copepods, euphausiids, cladocerans, mysids, amphipods and teleost eggs (Šantič *et al*., 2013).

On the Bulgarian coast of the Black Sea, close to our study area two studies described the horse mackerel diet (Yankova *et al.,* 2008; Georgieva *et al*., 2019). Yankova *et al.* (2008) show that the main prey of horse mackerel in the Black Sea in 2007 were fish and zooplankton, while the smaller individuals consumed mysids. The percentages of *Sprattus sprattus* and *Engraulis encrasicolus* increased with size (with a maximum of 55% for the 15 cm size class individuals), while mysids were more consumed by smaller individuals (35% for the 11 cm size class individuals). Georgieva *et al.* (2019) showed that during the analyzed period 2013-2015, the preferred prey groups for horse mackerel were polychaetas, crustaceans and fish. Polychaetes were found in the stomachs of all fish size classes and had the largest contribution of body biomass to their diet. Crustaceans were also present in almost all size classes.

Koç and Erdoğan (2019) state that in the Sea of Marmara on the Turkish coast it was determined that horse mackerel has two major systematic groups in its diet: crustaceans (copepods, cladocerans, mysids, amphipods, decapods) and fish, and the predominant and preferred prey of were crustaceans, similar to the present study.

Kyrtatos (1998) reported that *T. mediterraneus* (up to 20.0 cm in length) from the Aegean Sea primarily feed on mysids and copepods, but as their length increases, they shift to consuming fish larvae and post larvae. Similarly, Lipskaja (1966) noted that the stomachs of the smallest specimens mainly contained copepods, while larger individuals consumed anchovy (*Engraulis encrasicolus*) fish larvae and post larvae.

In most of the references mentioned above, small horse mackerel individuals consumed zooplankton (especially copepods) and fish dominate the diet of large horse mackerel individuals. In this study copepods present the highest RII percentage, which is probably explained by the smaller size of the individuals studied (average length = 11.4 ± 1.4 cm) compared to previous studies. Copepods are small planktonic organisms (Gamulin, 1979), which explains their significant presence in the stomach of small pelagic horse mackerel.

Bănaru and Harmelin (2009) found that carnivorous polychaetas were the main prey of horse mackerel on the Romanian Black Sea coast, fish (sprat and anchovy) were the secondary prey and crustaceans (copepods, mysidaceae, shrimps and amphipods) and macrophytes were the rare pray. Small and medium-sized individuals (7-14 cm) mainly consume polychaetas, while sprat dominates the diet of large size-class fish (>14 cm).

In this study the horse mackerel diet was not significantly different between 2021 and 2022 suggesting similar trophic conditions and available prey. Changes in the diet structures can indicate shifts in ecosystem dynamics, prey populations, and environmental conditions. Analyzing the food habits potential stressors or disturbances affecting marine ecosystems could be identified. Bănaru *et al*. (2010), showed that, compared to previous studies carried out on the Romanian coast, most fish species have changed their diet. They adapted their way of feeding to the decreasing diversity of species in the Black Sea communities. Compared to the previous studies, the role of polychaetes and European sprat in fish nutrition, including that of the sturgeon, increased between 2004-2006 (Bănaru *et al*., 2010). It can be explained by the prevalence of polychaetes in benthic biocenoses and European sprat in the pelagic compartment. These two species of prey are among the organisms that feed mostly on particles of organic matter or plankton brought by the Danube. Excess nutrients and invasive species contribute together with fishing to induce a drastic decrease in the complexity of marine food webs (Bănaru *et al.*, 2010).

The Black Sea ecosystems are influenced by the Danube. The significant production of phytoplankton on the Romanian coast is supported by dissolved organic matter and nutrients from the Danube. The inputs of the Danube River have a direct or indirect impact on the trophic networks of pelagic fish and which can be variable depending on the seasons (Bănaru and Harmelin-Vivien, 2009). The diet of fish can be varied in terms of prey abundance and availability. Variations in horse mackerel diet were demonstrated by Bănaru and Harmelin-Vivien (2009), between size classes, areas, and seasons. Moreover, discrepancies were shown by these authors between the instantaneous feed analyzed based on stomach contents and the time-integrated one obtained by studying the stable isotope ratios of fish.

Marine plankton is the main food source for pelagic fish. However, the particular organic matter brought by the Danube and its isotopic ratios have a significant impact on the zooplankton and polychaetas they consume, and which are important sources of food for these fish species. The composition of the benthic communities downstream the Danube (northern area) and the fishing methods used in the southern area (uncovered stationary pound net) may contribute to the unusual high percentage of polychaetas in the horse mackerel diet (Bănaru and Harmelin-Vivien, 2009).

The variation in horse mackerel diet across different areas is largely attributed to differences in prey distribution, abundance, density, availability, and accessibility (Šantič *et al.*, 2004; Bănaru and Harmelin-Vivien, 2009). However, the low individuals number sampled by station did not allow to explore diet spatial variations in this study. More annual samples from contrasted sampling areas are necessary to explore temporal and spatial variations in horse mackerel diet.

Stomach Fullness Index

The values of the stomach fullness index (FI), both in 2021 and in 2022, were increasing between May and September, which indicates a continuous increase of the food availability and feeding intensity (Fig. 5, Fig. 6).

The feeding intensity of Mediterranean horse mackerel may fluctuate throughout the year, likely related to spawning and water temperature (Šantič *et al.*, 2004). The lower feeding intensity observed in May was probably linked to cooler seawater temperatures (in May 2021, the sea surface temperature was comparatively low at 8°C, compared to 25°C in the summer). Feeding intensity increased in August-September, following the spawning period.

Sirotenko and Istomin (1978) also found that feeding intensity for *Trachurus mediterraneus* in the Black Sea increased to 80-90% after spawning. The high seawater temperatures in July-August accelerated metabolism, leading to a greater demand for food (Šantič *et al.*, 2004).

Also, an analysis of the FI (fullness index) values by length classes for horse mackerel highlights an increase depending on the length, both in 2021 and in 2022 (Fig. 7, Fig. 8). Fullness values indicate a slightly more intensive feeding of larger specimens.

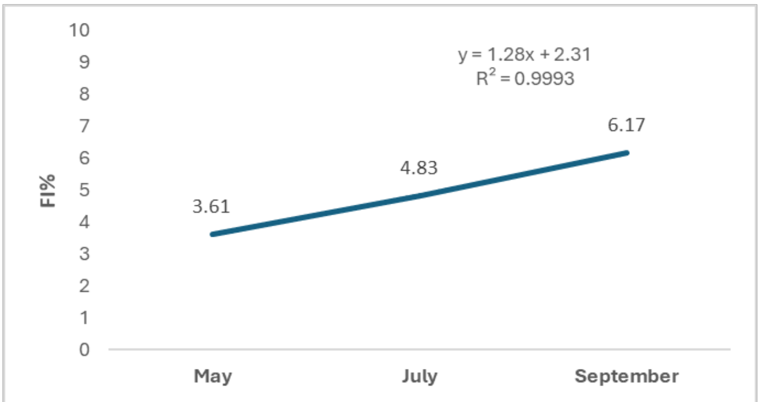

Fig. 5. Stomach fullness index in horse mackerel - monthly average values in 2021

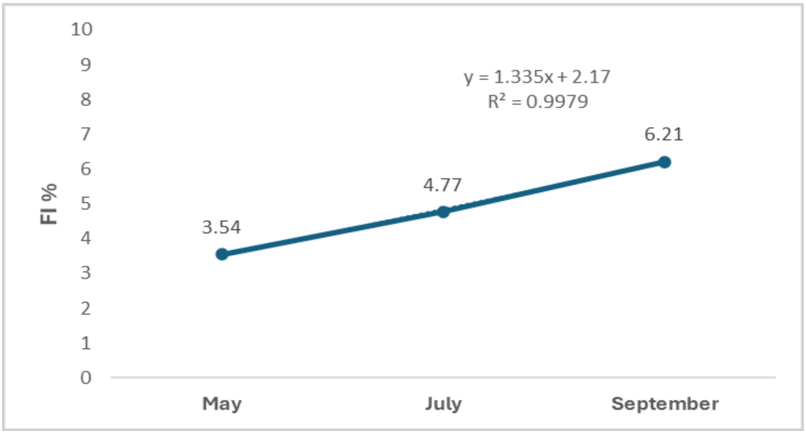

Fig. 6. Stomach fullness index in horse mackerel - monthly average values in 2022

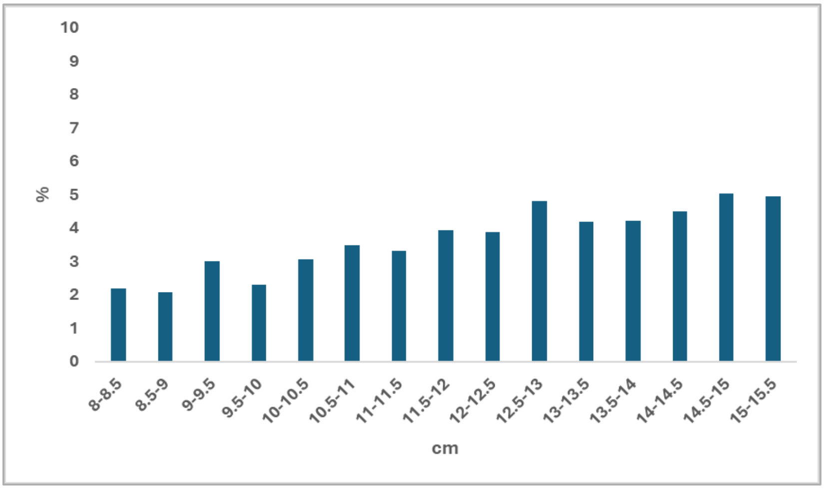

Fig. 7. Values of FI% by length classes in horse mackerel, 2021

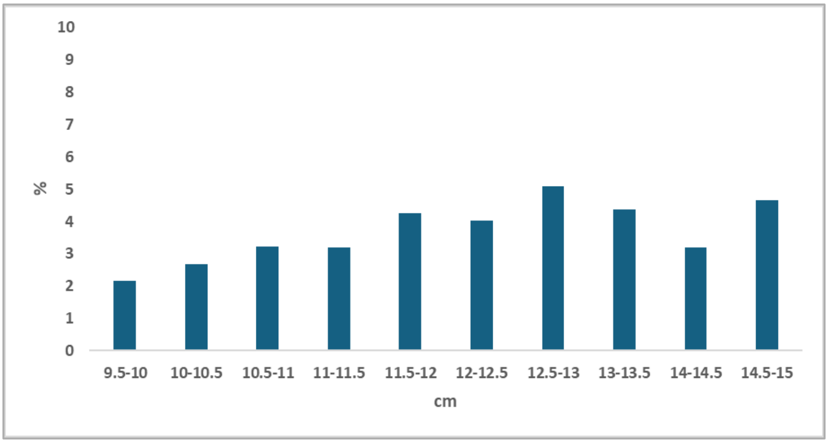

Fig. 8. Values of FI% by length classes in horse mackerel, 2022

The study shows that as horse mackerel grows, their feeding intensity increases. Smaller specimens primarily feed on the abundant copepods. With increasing size, the proportion of fish prey rises while the number of crustaceans decreases. However, smaller prey items, like copepods and mysids, are digested more rapidly than the larger prey found in the diets of large size fish.

The data obtained in the present study on the changes of food content are consistent with those of Yankova *et al.* (2008) on the Bulgarian coast of the Black Sea and according to Šantič *et al.* (2013) at the Adriatic Sea. Georgieva *et al*. (2019), on the Bulgarian coast of the Black Sea, showed that fish prey items had a relatively high percentage of body biomass in small and medium size classes (range 10.5–14 cm TL) and were completely absent in larger horse mackerel individuals. The share of polychaeta biomass tended to increase with horse mackerel body length, while such trends were not found for the other prey groups.

To highlight whether there were significant differences between mean stomach fullness index percentage according to stations and years, the multifactorial ANOVA parametric test was applied. All the p values were > 0.05, resulting in no significant difference between stations, months and years. The smallest FI values were measured in the North in Vadu station and the highest ones in the South in Eforie South (Table 1).

Table 1. The mean stomach fullness index percentage (FI%) values of the horse mackerel by year and by station

Station	Year	N	Mean FI (%)	SD FI (%)	SE FI (%)	Min. FI (%)	Max. FI (%)
Vadu	2021	9	3.69	0.58	0.19	2.96	4.67
Vadu	2021	11	3.53	1.06	0.32	2.04	4.95
Eforie South	2021	9	3.51	1.29	0.43	2.08	6.19
Eforie South	2021	11	3.87	0.91	0.28	2.13	5.15
Mangalia	2021	9	3.72	1.07	0.36	2.24	5.32
Mangalia	2021	11	3.79	1.29	0.39	2.19	6.98
Vadu	2022	7	3.16	0.63	0.24	2.46	4.32
Vadu	2022	13	3.63	0.92	0.25	2.19	5.29
Eforie South	2022	8	4.16	1.54	0.54	2.18	6.81
Eforie South	2022	12	3.24	0.62	0.18	2.11	3.98
Mangalia	2022	10	3.58	1.32	0.42	2.13	6.11
Mangalia	2022	10	3.81	1.20	0.38	2.15	5.78
	Total	120	3.64	1.05	0.10	2.04	6.98

N = number of analysed individuals, SD = standard deviation, SE = standard error, Min. = minimum, Max. = maximum

CONCLUSIONS

In the analyzed period 2021-2022, the group of copepods dominated in the diet of horse mackerel with no differences between years. It is probably due to the fact that copepods are present in the Black Sea area all year round. Their high percentage is probably explained by the smaller size of the studied individuals compared to previous studies. The horse mackerel diet is also composed of polychaetas, crustaceans and fish, similar to other studies.

The increasing values of FI% from May to September indicate a continuous increase of the food availability and feeding intensity related to the trophic environment and needs for reproduction (June to September). The FI values increase also with the individual length suggesting increasing predator capacities.

The present paper is a step ahead to improve the knowledge of the feeding ecology of *Trachurus mediterraneus* from Romanian coast.

Acknowledgement. This research work was part of the PhD thesis of the main author, Păun Cătălin, "Characterization of the horse mackerel population in the Black Sea coastal area", carried out with the support of the National Institute for Marine Research and Development “Grigore Antipa”, Project: Services for the realization and implementation of the National Program for the Collection of Data from the Romanian fishing sector, and by the Faculty of Animal Production, Engineering and Management, University of Agronomic Sciences and Veterinary Medicine of Bucharest.

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