



Fish Abundance and Mesozooplankton Resource: a study on *Sprattus sprattus* (Linnaeus, 1758) (Actinopterygii: Clupeidae) in the Romanian Black Sea Waters

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Abstract: Food availability influence the state of fish stocks, with effects on the demographics, composition and productivity of fish populations. In the spring seasons of 2018–2020, expeditions were carried out in order to collect data for *Sprattus sprattus* agglomerations, mesozooplankton community and *S. sprattus* stomach content analysis. Throughout the whole study period, it was shown that the fodder mesozooplankton component recorded high concentrations in the areas where fish had high catch values, promoting the best possible development of fish stocks. The analysis of *S. sprattus* stomach content highlighted the high consumption of copepods and meroplanktonic elements, with copepods being intensively consumed in 2019 and 2020. Fish productivity is directly associated with the presence or absence of mesozooplankton, which can have a cascading effect on fish stocks.

Key words: Fish stock, copepods, meroplankton, sprat, stomach content

Introduction

Mesozooplankton and pelagic fish play a major role in the trophic dynamics of marine pelagic ecosystem (SHANNON et al. 2010). Any aquatic ecosystem depends on zooplankton, large fish stocks being found in areas with high planktonic biomass and abundance. Fisheries success and failure, particularly for pelagic species, are strongly correlated with plankton availability (ABO-TALEB 2019). In some ecosystems, pelagic fish play a prominent trophodynamic role, exercising both top–down control over zooplankton and being an abundant prey

resource for other fish species (PECK et al. 2012). Many fishery species feed on zooplankton (SHI et al. 2020), with copepods being a major component of marine zooplankton and the main source of food for fish larvae (POULET et al. 1991), promoting the survival, growth and development of juvenile fish (HANSEN 2017).

European sprat *Sprattus sprattus* (L., 1758) is one of the fish species with special commercial importance in the Romanian marine area (Țoțoiu et al. 2016). These clupeids form dense schools and feed on a limited number of available prey species in deeper water during the day but disperse in

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the surface layers without feeding activity at night (KÖSTER & SCHNACK 1994, CARDINALE et al.2003). By bridging the lowest trophic levels of the food web (the plankton population) with the higher trophic levels (predatory fish species), *S. sprattus* performs a crucial ecological role in the Black Sea ecosystem, feeding on zooplankton (MÖLLMANN et al. 2005) and having the ability to control its food sources through selective feeding (MÖLLMANN & KÖSTER 1999). Consequently, knowledge of feeding success, diet composition and selectivity in relation to food supply is necessary for understanding the processes affecting the subsequent year-class strength of adult fish (ARRHENIUS 1996). In the past decade, fisheries management efforts have placed increased emphasis on ecosystem-based management, where interactions between a target stock species and the biological environment are considered in addition to the sustainability of the stock itself (LINK 2010).

The availability of suitable food is a key factor in determining the recruitment and growth of fish (BAYHAN & SEVER 2015). Trophic interactions of *S. sprattus* heavily depend on the temporal and spatial overlap of predator and prey, the knowledge and comprehension of the variables influencing the dispersion of fish in space representing the foundation for such processes.

This study aimed to analyse trends in feeding and prey selection of *S. sprattus* in relation to the population dynamics of their mesozooplanktonic prey. In accordance with the study objectives, distribution maps of *S. sprattus* agglomerations and mesozooplankton densities were created. In addition, *S. sprattus* stomach content was analysed in order to determine the consumed mesozooplankton prey items.

Materials and Methods

The collection of mesozooplankton samples was performed by vertically towing the Juday net in the water mass, with a speed of 0.5–1.0 m/s, on standard horizons (10–0 m, 25–10 m, 50–25 m) from stations located in the Romanian Black Sea area (Fig. 1a). According to ALEXANDROV et al. (2014), the mesozooplankton sample was homogenised and quantitative and qualitative processing was performed in the Bogorov chamber, under Olympus SZX10. All plankters were counted in the subsample(s) until each of the three dominant taxonomic groups reached 100 individuals. For the estimation of numbers of large animals, the whole sample was examined in a Petri dish. The number of individuals was used for estimating the density as ind.m⁻³ (ALEXANDROV et al. 2014).

Sampling of *S. sprattus* was carried out with the help of a 36-m long pelagic trawl by surface trawling (0–5 m) at a vessel speed of 2.8–3.2 Nd, 30 minutes trawl duration, the horizontal opening of 24 m trawl, 12 m vertical, at depths between 10 m and 60–70 m (Fig. 1b). The trawl surveys for *S. sprattus* stock assessment are planned for spring and autumn season, applying the swept area method in the Romanian Black Sea area.

In order to establish the contribution of the mesozooplankton component in the nutrition of fish, the stomach content analysis method was used. *Sprattus sprattus* samples for stomach content analysis were collected from stations located along the continental shelf of the Black Sea (Table 1) in all three sectors: North (N), Central (C) and South (S) (Fig. 1c). A total of 307 fish individuals were collected and were further preserved in 4% formaldehyde for analysis in the laboratory. The total length (TL) of each specimen was measured, each fish was

Table 1. Sampling stations for *S. sprattus* stomach content analysis along the Romanian Black Sea waters.

No.	Profile	Station code	Sector	Latitude (N)	Longitude (E)	N
1	Mangalia	MG39m	S	43.8333	28.7000	36
2	Tuzla	TZL37m	S	44.0000	28.7833	30
3	Est Constanta	EC40m	C	44.1667	29.0000	30
4	Est Constanta	EC48m	C	44.1667	29.1333	31
5	Est Constanta	EC50m	C	44.1667	29.2500	30
6	Est Constanta	EC53m	C	44.1667	29.4000	30
7	Midia Navodari	MDN43m	N	44.3333	29.0000	30
8	Chituc	CHT24m	N	44.5000	29.0000	30
9	Gura Portita	PO50m	N	44.6667	29.5667	30
10	Gura Portita	PO55m	N	44.6667	29.7500	30

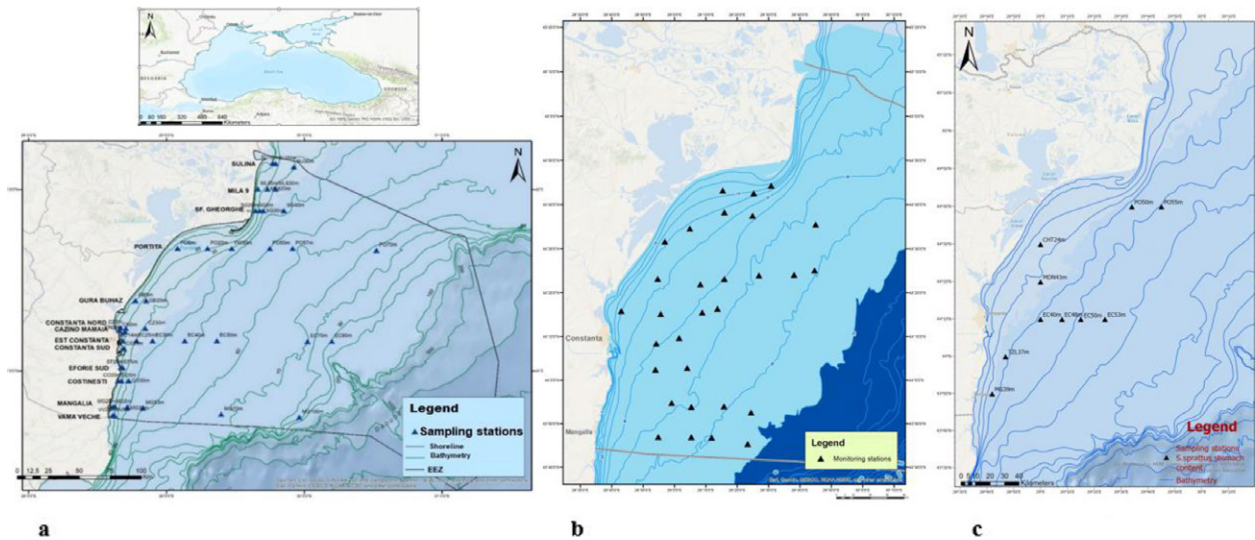


Fig. 1. Map of sampling stations along the Romanian Black Sea waters for mesozooplankton density determination (a), *S. sprattus* stock assesment (b) and *S. sprattus* stomach content analysis (c).

weighted and, after dissection, the stomach was removed by longitudinal cut and weighted again. The TL of *S. sprattus* ranged 6–11.5 cm. The content of each stomach were transferred to a Petri dish and identified under a binocular microscope. The qualitative analysis consisted of an identification of the organisms in the stomach contents.

To find out the feeding intensity of the fish, the Gastro–somatic index (GaSI) was calculated using the formula (KRISHNA et al. 2016):

$$\text{Gastro Somatic Index (GaSI)} = 100 \times \frac{\text{Weight of the Stomach}}{\text{Weight of the Fish}}$$

Each food item occurred in stomachs is recorded and expressed as a percentage of the total number of fish stomachs examined:

$$\text{Frequency of Occurrence} - \% \text{ FOi} = \left(\frac{N_i}{N} \right) \times 100,$$

where % FOi is the frequency of occurrence of given food I, Ni is the number of stomachs containing prey I, N is the total number of stomachs with food item I (MAHESH et al. 2019).

PRIMER software was used for statistical analyses to examine the relationships between fish, the mesozooplankton community and the sampling stations. As a multivariate method based on the similarity coefficients between species or stations, non–metric MDS (Multi–Dimensional Scaling) was used in order to highlight the similarities between areas and years of study for the analysed biotic

components. Shade plots and visual displays in the form of the data matrix itself (CLARKE et al. 2014) were used in the analysis of mesozooplanktonic groups identified in the *S. sprattus* stomach content. ANOSIM tests for differences between similarity matrices by computing the global test–statistic R. R varies between 0 and 1, with an R–value closer to 1 indicating that similarities are high, while a value of zero indicates uniform similarities between the data analysed (CLARKE et al. 2014). Analysis of Similarity (ANOSIM) provides a way to statistically test whether there is a significant difference between two or more groups of sampling units and was used for testing significant differences between years and sectors based on the GaSi index for *S. sprattus* individuals.

We used ARCGIS PRO – professional mapping software, the newest professional (desktop) GIS (Geographic Information System) application from Esri for creating the distribution maps for the mesozooplankton component and *S. sprattus* agglomerations during 2018–2020, spring season.

Results

Dynamics of *S. sprattus* in relation to fodder mesozooplankton

With the greatest range of captures (20.00–99.99 t/km²) in the majority of stations, the northern sector had the strongest quantitative representation of *S. sprattus* population in 2018. Stations in the central and northern sectors recorded values ranging from 5.00 to 9.99 t/km², with the lowest abundances found in the southern sector (Fig. 2). The dominat-

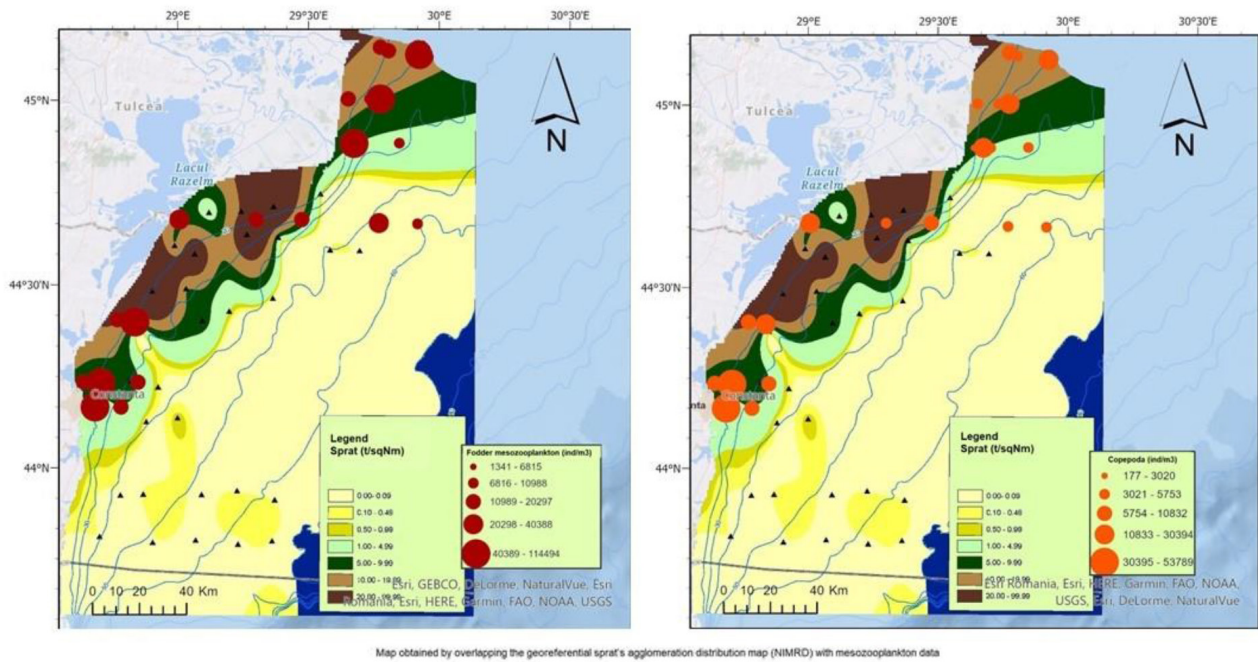


Fig. 2. Distribution of *S. sprattus* stocks along the Romanian Black Sea waters (source: Romanian Annual Report on the National Data Collection Program for Fisheries), fodder mesozooplankton and copepods densities in spring 2018.

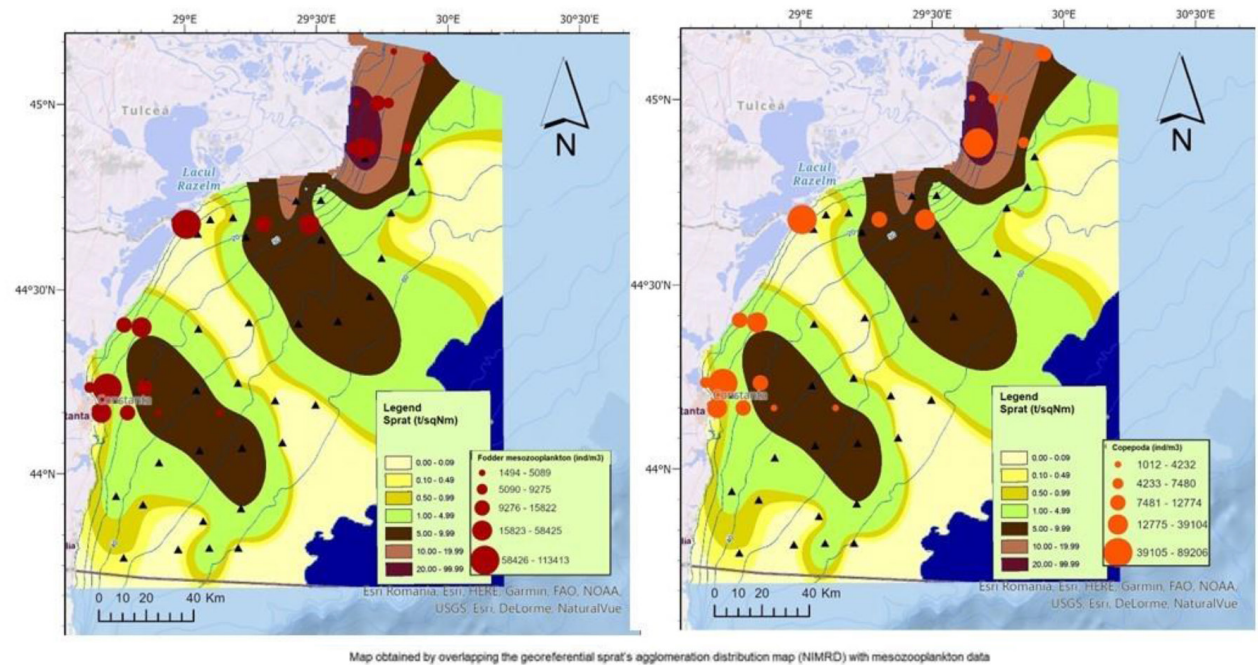


Fig. 3. Distribution of *S. sprattus* stocks along the Romanian Black Sea waters (source: Romanian Annual Report on the National Data Collection Program for Fisheries), fodder mesozooplankton and copepods densities in spring 2019.

ing group, copepods, most likely contributed to the formation of large fish agglomerations. In the same locations where *S. sprattus* was most prevalent, fodder mesozooplankton displayed high densities (Fig. 2).

Agglomerations of *S. sprattus* in 2019 presented the maximum range (20.00–99.99 t/km²)

in the northern sector, within a single station. The central sector was characterized by high densities (5.00–9.99 t/km²) while in the southern sector *S. sprattus* was lower represented (Fig. 3). The mesozooplankton trophic base was high, with the largest concentrations in the central and northern sectors, where *S. sprattus* was abundant (Fig. 3). Exhibit-

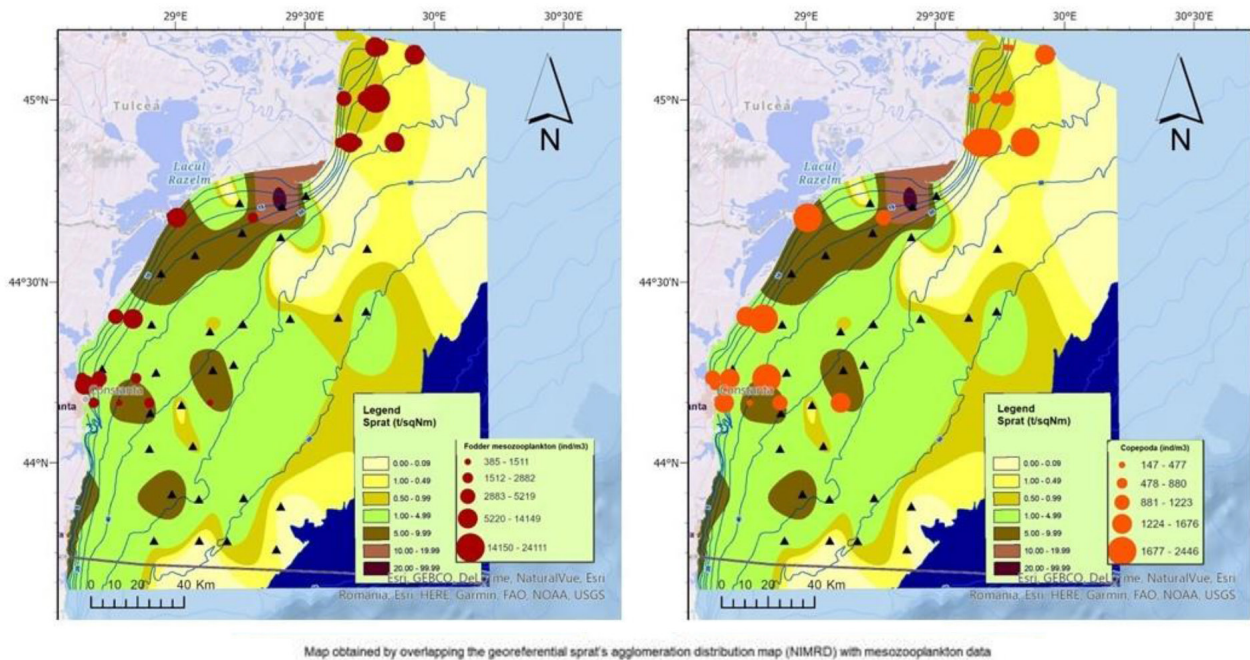


Fig. 4. Distribution of *S. sprattus* stocks along the Romanian Black Sea waters (source: Romanian Annual Report on the National Data Collection Program for Fisheries), fodder mesozooplankton and copepods densities in spring 2020.

Table 2. Descriptive statistics of prey items abundance in *S. sprattus* stomach content, along the Romanian Black Sea waters.

Identified taxa	Minimum	Maximum	Average	Standard deviation	Group
Balanus cypris	0.0	34.0	8.3	10.1	Meroplankton
Balanus nauplii	0.0	48.0	7.3	8.9	Meroplankton
Bivalvia	0.0	233.0	58.5	56.2	Meroplankton
Cladocera	0.0	156.0	31.2	47.5	Cladocera
Copepoda	29.0	563.0	258.6	142.4	Copepoda
Copepoda nauplii	0.0	48.0	9.6	13.5	Copepoda
Decapoda	0.0	3.0	0.5	0.8	Meroplankton
Oikopleura dioica	0.0	5.0	1.2	1.6	Other groups

ing maximum densities in each of the three sectors, copepods formed a suitable trophic base underpinning for the fish population. (Fig. 3).

Population of *S. sprattus* exhibited a homogeneous distribution of captures in 2020, with the highest density reported in a single station from the northern sector. *S. sprattus* catches in the central sector ranged from 5.00 to 9.99 t/km², with a similar pattern in the southern sector (Fig. 4). The density of fodder mesozooplankton was higher in the northern area (Fig. 4), with high copepod abundance in the central and northern sectors where *S. sprattus* also dominated (Fig. 4), which may indicate fish selectivity in terms of food components, with copepods preferred.

Stomach content analysis

Comprehending the correlation among fish, their favoured sustenance and their dispersion can facilitate the identification of possible feeding sites and offer insights into the forecast and management of fish populations. To analyse the stomach content of *S. sprattus*, industrial fish caught on the Romanian coast during the spring season of 2018–2020 were studied. Copepods of different development stages (that were in an advanced stage of digestion and thus not species-identifiable) were ingested by *S. sprattus* as prey. *Pleopis polyphemoides* (Cladocera), meroplanktonic items such as cirripeds with different development stages (*Balanus nauplii* and cypris), larvae of *Bivalvia* and Decap-

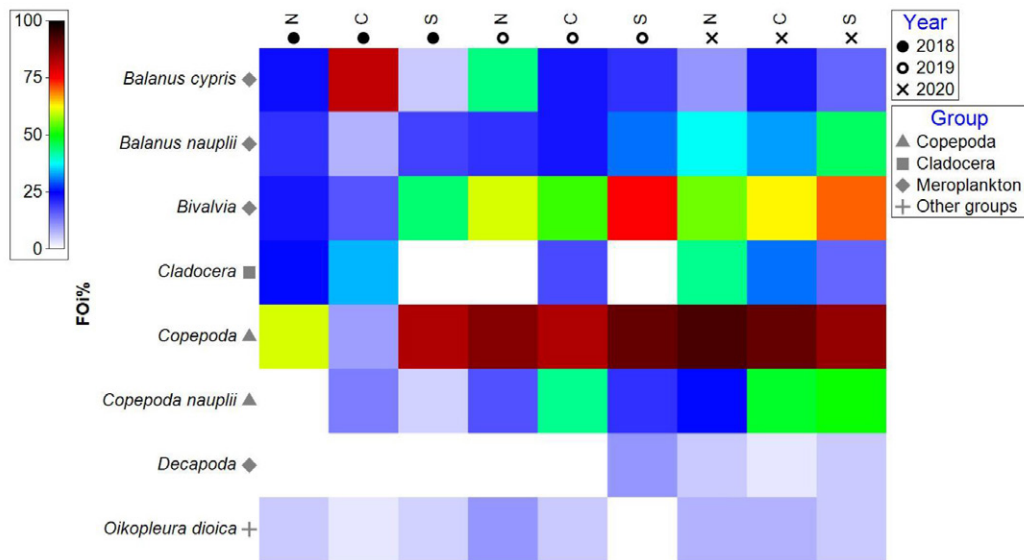


Fig. 5. Shade plot of the prey items FOi % found in *S. sprattus* stomach content along the Romanian Black Sea waters, by sectors and years.

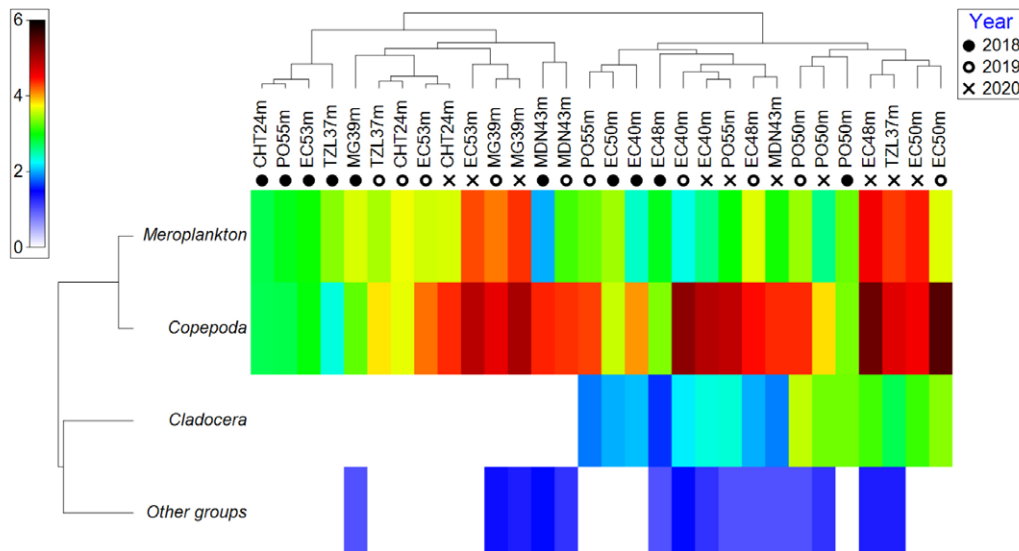


Fig. 6. Matrix of the mesozooplankton groups consumed by *S. sprattus* along the Romanian Black Sea waters, by stations and years.

oda and the tunicate *Oikopleura dioica* were also identified (Table 2).

Analysing the mesozooplanktonic community frequency of occurrence in 2018 by sectors, it is observed that, in the northern sector, an area dominated by higher nutrients concentrations from the Danube’s input, copepods and meroplankton had the highest values (Fig. 5). In the central sector, *Balanus cypris* recorded the highest FOi and in the southern sector, copepods and meroplankton were preferred as a food source. Contrary to the other two sectors, where copepod nauplii in the northern sector and cladocerans in the southern sector

were not found in *S. sprattus* stomach contents, *S. sprattus* specimens in the central sector consumed all seven identified prey items (Fig. 5). In 2019, it was observed that the copepod group presented the highest frequencies in all three sectors, followed by *Bivalvia* larvae (Fig. 5). Other meroplanktonic elements, such as *Balanus cypris* in the northern sector and *Balanus nauplii* in the central sector, were consumed by *S. sprattus*, reports of Decapoda larvae being limited to the southern sector (Fig. 5). The highest FOi for copepods, *Balanus nauplii*, and *Bivalvia* larvae was observed in the southern sector, indicating their significant contribution and

Number of identified mesozooplankton prey
2018-2020

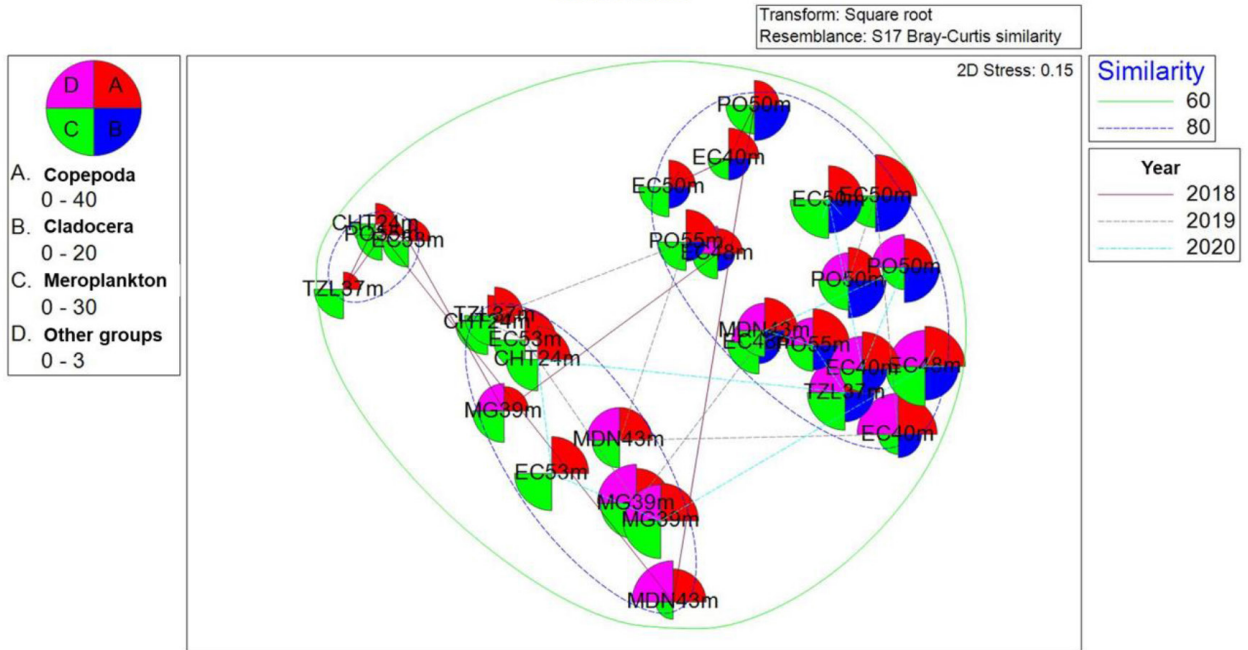


Fig. 7. Non-metric multidimensional scaling (NMS) ordination based on prey items identified in *S. sprattus* stomachal content along the Romanian Black Sea waters, by years.

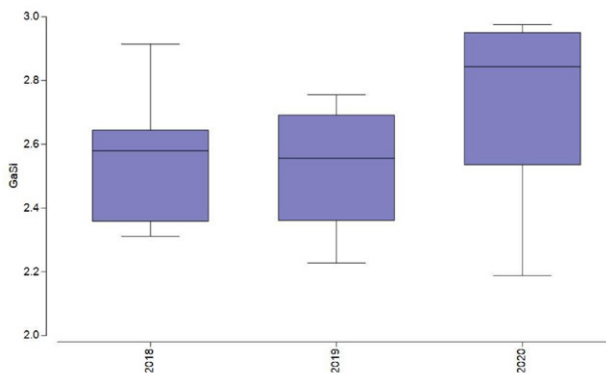


Fig. 8. Box plot diagrams of GaSI index in *S. sprattus* along the Romanian Black Sea waters, by years.

setting the southern sector apart from the northern and central ones (Fig. 5). Mesozooplankton's FOi in 2020 showed that copepods had the highest values in all three sectors, being followed by Bivalvia larvae and *Balanus* cypris stage. Notably, consumption of *Cladocera* was observed in all sectors, with the northern sector exhibiting greater values (Fig. 5). Copepod nauplii were preferred as food in the central and southern sectors and Decapoda larvae and *Oikopleura dioica* were consumed in all three sectors but in lower quantities (Fig. 5).

Overall, the qualitative structure of the ingest-

ed mesozooplankton prey consisted mostly of meroplankton and copepods, while cladocerans and other groups were occasionally preferred by *S. sprattus* (Fig. 6). Notably, copepod consumption increased in 2019 and 2020 compared to 2018. While meroplankton consumption was mostly steady across the three years, it experienced a notable increase in 2020, confined to particular sampling stations located in the central sector (Fig. 6).

Based on the type of mesozooplanktonic prey identified in *S. sprattus* specimens, similarities of 80% between all years were found. The establishment of the cluster that includes CHT24m – EC53m – EC50m – TZL37 stations in 2018 is noteworthy, as it resulted from the consumption of copepods and meroplankton, prey items belonging to the Cladocera and other groups were not identified in *S. sprattus* stomach content (Fig. 7).

GaSI index averages in spring 2018–2020 did not vary significantly, high values being recorded, indicating an intense feeding during the entire period (Fig. 8). Considerable resemblance between the stations and years is noted based on the average values of GaSI (Fig. 9). As a result, we observed 80% of the conclusions were in agreement with ANOSIM, which, using the GaSI index, indicated no discernible variations across the years and sectors (Fig. 10).

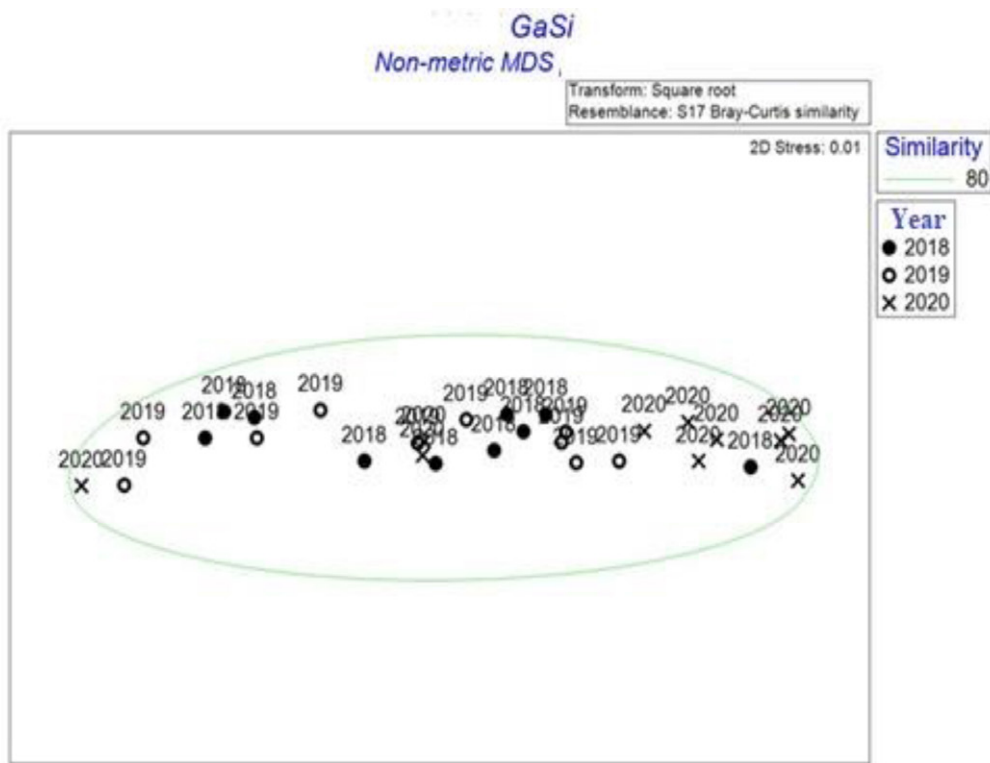


Fig. 9. Non-metric multidimensional scaling (NMDS) analysis of the GaSI index in *S. sprattus* along the Romanian Black Sea waters, by sampling stations.

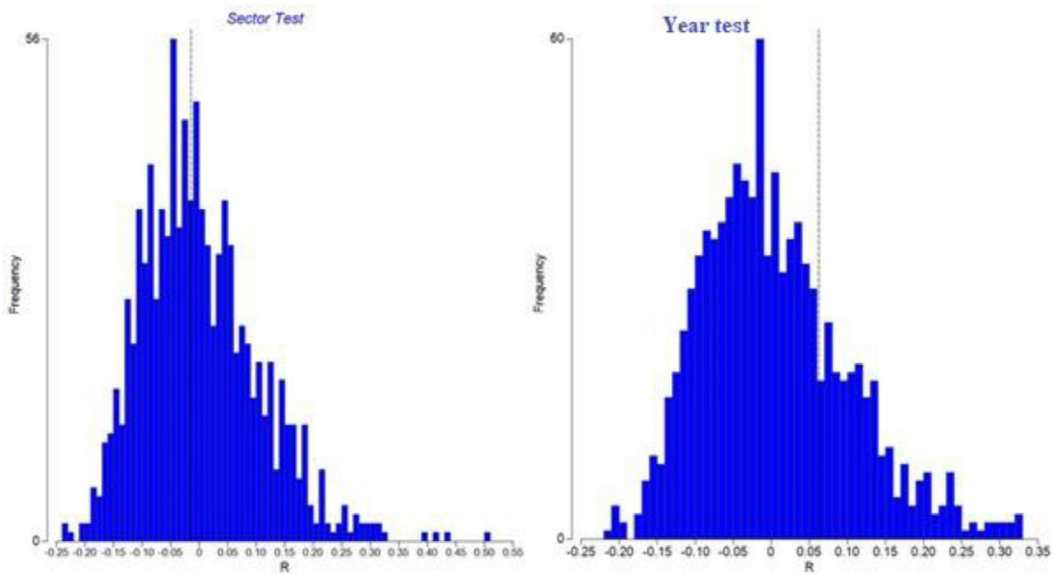


Fig. 10. Multivariate analysis of similarities (ANOSIM) between sectors (left) and years (right) based on *S. sprattus* GaSI index, along the Romanian Black Sea waters.

Discussion

Being the first pelagic fish arriving to the Romanian Black Sea coast in spring (PORUMB 1995), *S. sprattus* is settling initially in the south and then migrates northward to the Danube Delta. In the north-

western part of the Black Sea, there are favourable condition for development due to the high plankton production is stimulated by the Danube River inputs of nutrients, dissolved organic matter (DOM) and particulate organic matter (POM) and the existence of a large continental shelf (PETRANU 1997). Con-

sequently, this production constitutes an abundant food resource for zooplankton and fish (BĂNARU & HARMELIN-VIVIEN 2009). In the northern sector, the movement of superficial waters from shallow to deeper seawater is almost permanent (due to the action of the fluvial current), which is why *S. sprattus* quantities are higher (CAUTIȘ 1958), a situation encountered during 2018–2020, too. The northwestern part of the Black Sea is an important feeding and reproduction area for pelagic fish species (PORUMB 1995) and the foraging strategies of pelagic fish species in this system match the environmental variability to maximise survival and reproduction.

The quantity and quality of food resources that are available determine the migration patterns of *S. sprattus*, a cold-water species (ALHEIT et al. 2012). It migrates to the north and northwest in the spring to feed and reproduce, spending the winter south of the Black Sea (MAXIMOV et al. 2002).

According to distribution maps of *S. sprattus* catches in connection to the density of fodder mesozooplankton, the fish population had a plentiful trophic basis, mostly produced by copepods and meroplankton that recorded high densities. Copepods are the main group of mesozooplankton on the Romanian coast, especially in the north area (BĂNARU & ONCIU 2007). The association between high catch values of *S. sprattus* and the fodder mesozooplankton, which is well represented quantitatively and supports the optimal growth of fish stocks, was observed over the entire analysed period. Typically, Individuals of *S. sprattus* feed on copepods, but also on cladocerans, crustacean eggs and larvae, mollusc larvae, mysids and phytoplankton (BĂNĂRESCU 1964, OVEN et al. 1997). Copepods were found to be among the most important prey items in the diet of *S. sprattus* throughout the spring season of 2018–2020. Additional research conducted in the Black Sea revealed that *S. sprattus* primarily prefers and consumes copepods (80%) (MIHNEVA et al. 2018, BIȘINICU et al. 2020). Copepods, part of the mesozooplanktonic fodder component, represent the major prey of juvenile fish in the natural habitat due to their adequate nutritional value (GAMBOA et al. 2019). Prey items belonging to cladocerans, meroplankton (larvae of Bivalvia, Decapoda and *Balanus*) and *Oikopleura dioica* were also found in *S. sprattus* stomach content, this being in accordance with other studies, too (MIHNEVA et al. 2015).

As demonstrated by the current study, GaSI values indicate that *S. sprattus* had a high feeding intensity during the examined period, the spring season showing the most active feeding intensity as also documented by other studies (CAUTIȘ 1958). Clupei-

ds have long been recognized as opportunistic foragers that feed on suitable food, as encountered in the habitat. This leads to flexible results in feeding cycles depending on local conditions (JAMES 1988). It has been commonly recognized that the diets of these fish reflect the composition of the ambient plankton communities (NYUNJA et al. 2002).

Conclusions

Large agglomerations of *S. sprattus* were observed by the catches in spring 2018–2020, particularly in the northern sector. This could have been caused by the high copepod abundance values in this sector, which was induced by Danube River inflows promoting plankton productivity. Another reason is also the movement of superficial waters from shallow to deeper seawater, which is almost permanent in the northern sector.

The mesozooplankton community had high density, with copepods prevailing in the community according to distribution maps. Thus, it was observed that throughout the entire examined time, *S. sprattus* as well as the fodder mesozooplankton component recorded high abundance values, enabling the optimal development of fish stocks.

The stomach content analysis of sprats revealed their predilection for copepods and meroplankton. The consumption of meroplankton remained rather stable, peaking in 2020 but only at a few sampling stations, while copepods were substantially consumed in 2019 and 2020.

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