



## Mesozooplankton in the Diet of the Black Sea Shad *Alosa tanaica* (Grim, 1901) (Clupeiformes: Clupeidae) from the Northern Part of the Romanian Black Sea Waters

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**Abstract:** Mesozooplankton organisms, due to their very important role in the nutrition of fish larvae and juvenile fish, influence the state of fish stocks and have long-term effects on the demographics as well as composition and productivity of fish populations. In the autumn season, an expedition was carried out to collect data about the mesozooplankton community and *Alosa tanaica* fish population. The mesozooplankton component was represented by 19 taxa, with the fodder component being dominant. The group of Copepoda was best represented and had the highest density, followed by the meroplanktonic component. Totally, 120 Black Sea shad individuals were analysed in order to identify the mesozooplanktonic organisms that this species consumes. Seventeen taxa belonging to the mesozooplanktonic community were identified in the stomachs of *A. tanaica*. The identified items were species of Copepoda, Cladocera and meroplankton, the last being the one that had the major contribution to the fish diet. The stomach content analysis of *A. tanaica* revealed that the most frequently consumed mesozooplanktonic items were Decapoda larvae, especially those at the mysis stage.

**Key words:** Fodder, trophic spectrum, meroplankton, Copepoda, Cladocera

### Introduction

Zooplankton, as an assemblage of the major grazers in marine food webs, provides the principal energy pathway from phytoplanktonic primary producers to consumers at higher trophic levels (RICHARDSON 2008). Most fish species have a pelagic larval phase, which depends on the zooplankton as an important food source. Therefore, and because of their abundance, high diversity and vital ecosystem functions, zooplankton communities are crucial in the marine food web (RICHARDSON 2008). Availability of suit-

able zooplankton affects growth and survival of fish that feed on it; variations in zooplankton abundance and community composition influence the recruitment of important commercial fish species in both open and coastal waters (DÍAZ-GIL et al. 2014).

Research on fish food habits and feeding ecology are essential for understanding the roles within the ecosystems. The knowledge of feeding behaviours at marine fishes is essential for assessing fish stock, ecosystem modelling, prey selection, relationships between predator-prey size, feeding distribution and selection of habitats (THOMAS et al. 2018).

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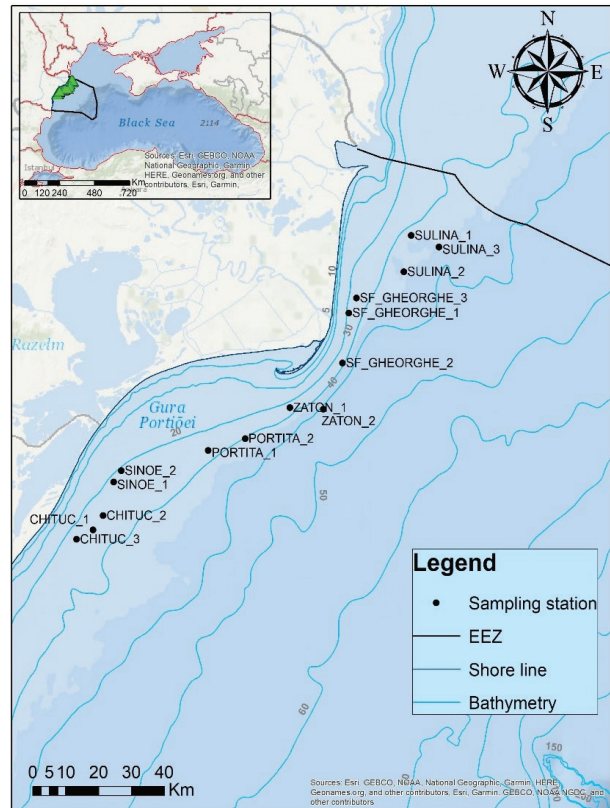
Mesozooplankton is a size-based fraction of the zooplankton community that includes taxa and stages with body length between 0.2 and 20 mm. Being the major consumer of the primary producers, mesozooplankton constitutes the food source of organisms at higher trophic levels, some of which are of high economic value (KOVALEV et al. 1998). Therefore, mesozooplankton can be divided into two components: the fodder (edible) component, which has nutritive values, and the non-fodder component, which is represented by only one species – *Noctiluca scintillans*.

*Alosa tanaica* (Grimm, 1901), known as Black Sea shad or Azov shad, is a marine anadromous species, which migrates for spawning from sea into freshwater lakes and rivers (ȚIGANOV et al. 2016). It feeds on a wide variety of zooplankton (crustaceans), insect larvae and small fish.

The aim of the study was to provide an overall description of the mesozooplankton community as well as its biomass and density being relevant for fisheries. The analysis of the gut contents of *A. tanaica* provided necessary information regarding the Black Sea shad feeding, emphasising the importance of the mesozooplankton community in the fish diet and thus being helpful in understanding interactions between organisms at different trophic levels.

## Materials and Methods

Both mesozooplankton and Black Sea shad samples were collected in October 2019 from 15 stations located along the Northern part of the Romanian Black Sea waters (Fig. 1). The collected samples were preserved in 4 % formaldehyde for further analysis in the laboratory. A total of 15 zooplankton samples were collected by vertical tows using a Juday net (0.1 m<sup>2</sup> mouth opening area, 150 µm mesh size) equipped with a flow meter in order to estimate the filtered water volume. The sampling column depth was 0–20 m, selected taking into account the reported high occurrence of pelagic fish in shallow waters (MULKANA 1966) and because the 0–20 m sampling column is characterised by the greatest abundance of both fish and mesozooplankton. Following ALEXANDROV et al. (2014), the mesozooplankton sample was homogenised and quantitative and qualitative processing was performed in a Bogorov chamber under Olympus SZX10. In the subsamples, all plankters were counted until each of the three dominant taxonomic groups reached 100 individuals. For estimation of the number of large animals, the whole sample was examined in a Petri dish. The number of individuals and mean individual weights were used for estimat-



**Fig. 1.** Map of sampling stations located along the Northern part of the Romanian Black Sea waters.

ing the density as ind.m<sup>-3</sup>, respectively the biomass as mg.m<sup>-3</sup> wet weight (ALEXANDROV et al. 2014).

Sampling of *A. tanaica* was made using a pelagic trawl of 36 m length, with the horizontal and vertical trawl openings being 24 m and 12 m, respectively. The collecting bag was of 7 mm mesh size.

The food array study on *A. tanaica* was performed by analysing the gastro-intestinal content. The length of each specimen was measured, each fish was weighted and, after dissection, the stomach was removed by longitudinal cut and weighted. The contents of each stomach were transferred to a Petri dish and identified under a stereomicroscope. The qualitative analysis consisted of an identification of the organisms in the gut contents. Food remains, which were not recognisable due to an advanced stage of digestion, were recorded as semi-digested food.

PRIMER software was used for statistical analyses, using the non-metric multidimensional scaling (NMDS) (KRUSKAL et al. 1978) to examine the relationships between the mesozooplankton community and the sampling stations. PRIMER was also used to assess species-specific contributions (SIMPER), similarity percentage values indicating the contribution of a particular species to the *A. tanaica* food

preference. Shade plots which represent multivariate analysis that sometimes can fashion clear community structures, characterising responses of individual (or groups of) species across the sample, were also obtained by using the PRIMER software (CLARKE et al. 2015).

To find out the feeding rhythm of the fish, Gastro-somatic index (GSI) was calculated using the formula:

$$GSI = 100 \times \text{Weight of the stomach} / \text{Weight of the fish}$$

Feeding intensity (FI) was studied by determining the stomach fullness degree and expressed by the following formula defined by HYNES (1950):

$$FI = 100 \times \text{Weight of ingested food} / \text{Weight of fish}$$

Frequency of occurrence (% FO<sub>i</sub>), representing the number of stomachs, in which each item occurs, was recorded and expressed as a percentage of the total number of stomachs examined:

$$\% FO_i = (N_i / N) \times 100$$

where % FO<sub>i</sub> is the frequency of occurrence of given food I, N<sub>i</sub> is the number of stomachs containing prey I, N is the total number of stomachs with food (MAHESH et al. 2019).

## Results

### Spatial distribution of the mesozooplankton community

Nineteen taxa were identified in the mesozooplankton community (Fig. 2). The copepods represented the bulk of the community, followed by the mero-

planktonic component. Out of the seven species of Copepoda, *Oithona similis* exhibited the highest density values, with a peak in the station SINOE\_1, followed by CHITUC\_2 and SULINA\_3. *Oithona davisae* dominated in the stations ZATON\_1, ZATON\_2 and CHITUC\_3 (Fig. 2).

Out of the five meroplanktonic taxa, Bivalvia, *Balanus* and Polychaeta reached the highest density values. *Balanus* and Polychaeta were the most abundant at the station SINOE\_1 while Bivalvia dominated at SF\_GHEORGHE\_3. The Decapoda and Gastropoda were registered with lower density values (Fig. 2). *Oikopleura dioica* reached the highest density values at the stations ZATON\_2, SINOE\_1, PORTIA\_2 and ZATON\_2 while *Parasagitta setosa* was recorded with low density values (Fig. 2).

Regarding the quantitative structure of the mesozooplankton community, variations were recorded. The fodder component of the community was dominant, reaching high values of density and biomass at most of the analysed stations, with a maximum at the station SINOE\_1 (Fig. 3). The non-fodder component was represented by *Noctiluca scintillans* and exhibited low density and biomass values.

The non-metric multidimensional scaling (NMDS) performed for fodder and non-fodder biomass values revealed that the mesozooplankton community in the Northern part of the Romanian Black Sea area was significantly similar (80 %), apart from two stations SF\_GHEORGHE\_1 and SF\_GHEORGHE\_3 (Fig. 3), which were charac-

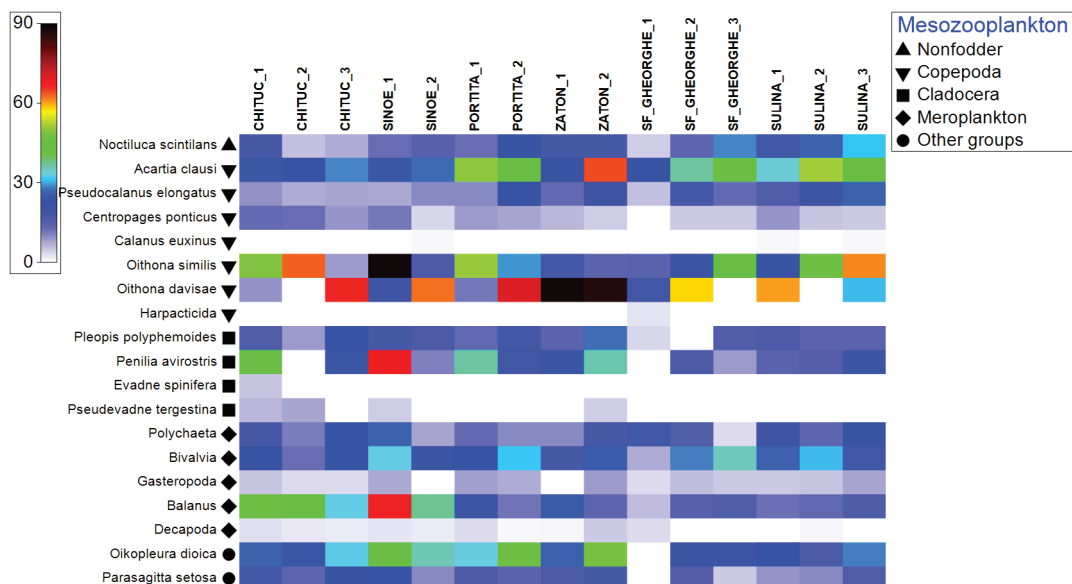


Fig. 2. Shade plot showing the density (ind.m<sup>-3</sup>) of the mesozooplankton taxa.

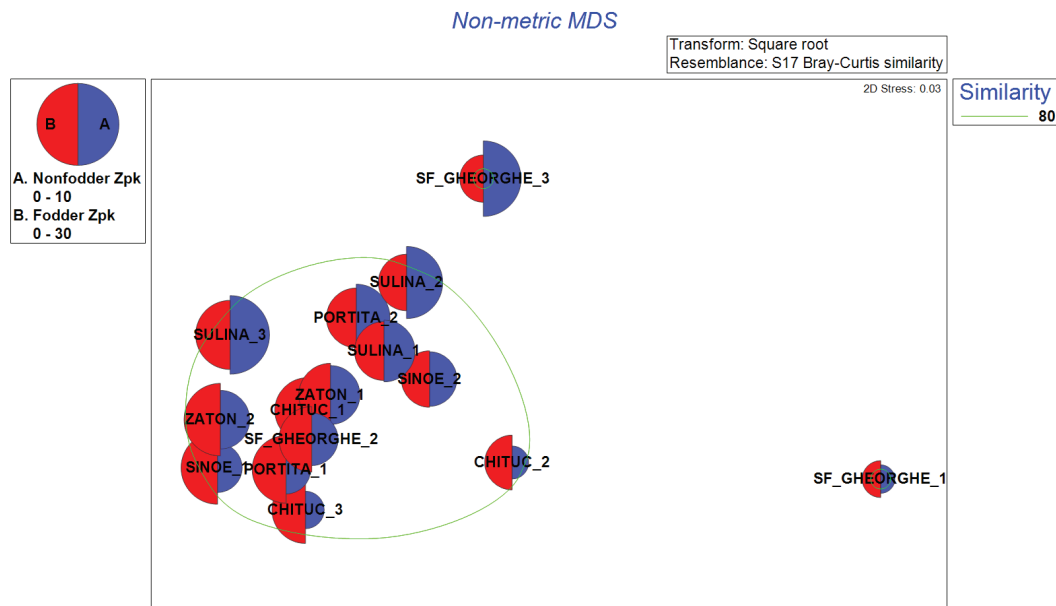


Fig. 3. A diagram of a NMDS analysis of fodder and non-fodder density values (ind.m<sup>-3</sup>).

terised by very low zooplankton diversity and biomass.

As far as the fodder component is concerned, the group of the Copepoda was best represented, reaching the highest values of density at the stations ZATON\_2 (110 ind.m<sup>-3</sup>) and SINOE\_1 (95 ind.m<sup>-3</sup>) (Fig. 4a). Another fodder component with high density values was represented by the meroplanktonic component, with a peak at SINOE\_1 (71 ind.m<sup>-3</sup>) and CHITUC\_1 (55 ind.m<sup>-3</sup>). The group of the Cladocera and “Other groups” showed lower density values (Fig. 4a).

Based on the density values, the Bray-Curtis similarity showed that the stations SINOE\_1 – ZATON\_2, CHITUC\_3 – PORTITA\_1, ZATON\_1 – SULINA\_3, SULINA\_1 – SF\_GHEORGHE\_2 and SULINA\_2 – SF\_GHEORGHE\_3 had a resemblance of over 90 % (Fig. 4a).

The biomass values for the fodder component varied, with the Copepoda and “Other groups” exhibiting the highest biomass values. The Copepoda reached its maximum at the station SULINA\_3 (9 mg.m<sup>-3</sup>) and “Other groups” at ZATON\_2 (19 mg.m<sup>-3</sup>) (Fig. 4b). The Bray-Curtis similarity showed a resemblance of over 90% for SINOE\_2 – SULINA\_1, PORTITA\_2 – SULINA\_2, ZATON\_2 – PORTITA\_1, SF\_GHEORGHE\_2 – ZATON\_2 and CHITUC\_3 – SULINA\_3 (Fig. 4b).

#### Stomach content analysis of *Alosa tanaica*

Totally, 120 specimens of *A. tanaica* were analysed. The range of the length of the specimens varied between 9.8 and 23.4, with the length class of 13.2–

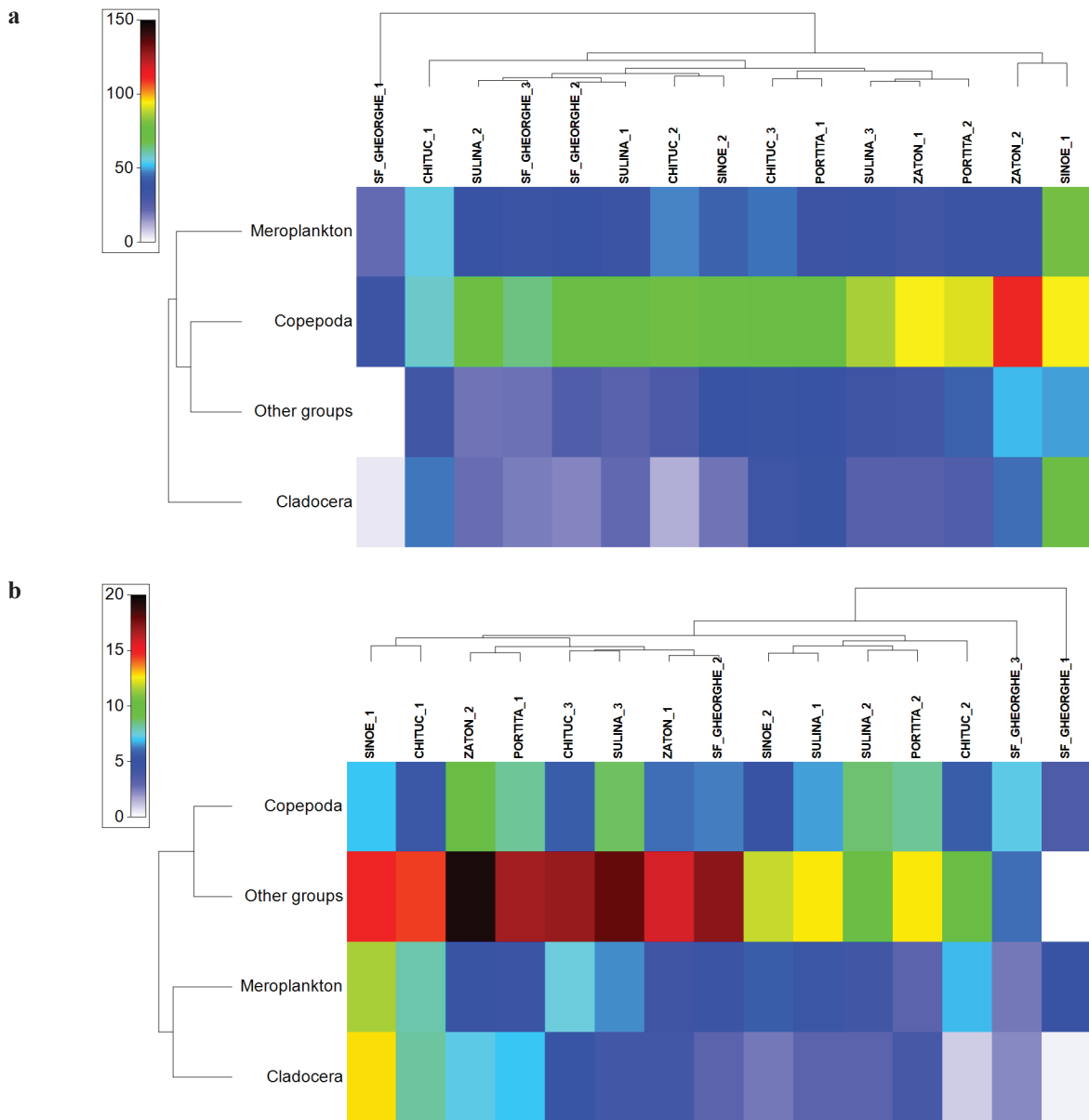
Table 1. The numerical composition of food items identified in the stomach content of *Alosa tanaica*.

Mesozooplankton	Total number of identified items	%
Copepoda	34	1
Cladocera	164	7
Meroplankton	2263	92

Table 2. GSI& Feeding intensity for the specimens of *Alosa tanaica*.

Sampling station	GSI	Feeding intensity
CHITUC_1	2.1	0.6
CHITUC_2	2.2	0.6
SINOE_1	1.8	0.5
PORTITA_1	2.1	0.6
CHITUC_3	2.1	0.6
PORTITA_2	2.1	2.1
ZATON_2	2.0	0.6

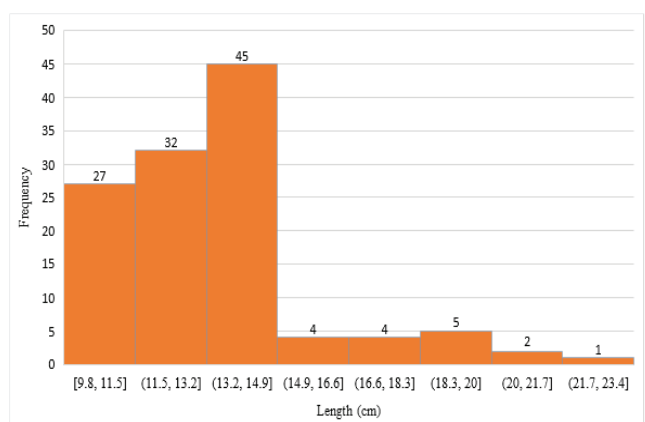
14.9 being frequent in the analysed samples (Fig. 5). The size-frequency distribution of females and males also significantly differed; in females (72), the dominant size was 11.8-13.8 cm while it was 12.4-14.8 cm in males (48). Seventeen taxa belonging to the mesozooplanktonic community were found in stomachs of *A. tanaica*, belonging to Copepoda, Cladocera and meroplankton (Table 1). The meroplankton component was the one that had the major contribution to the fish diet, with a total number of 2263 items, representing the main source of food, with a percentage of 92 %.



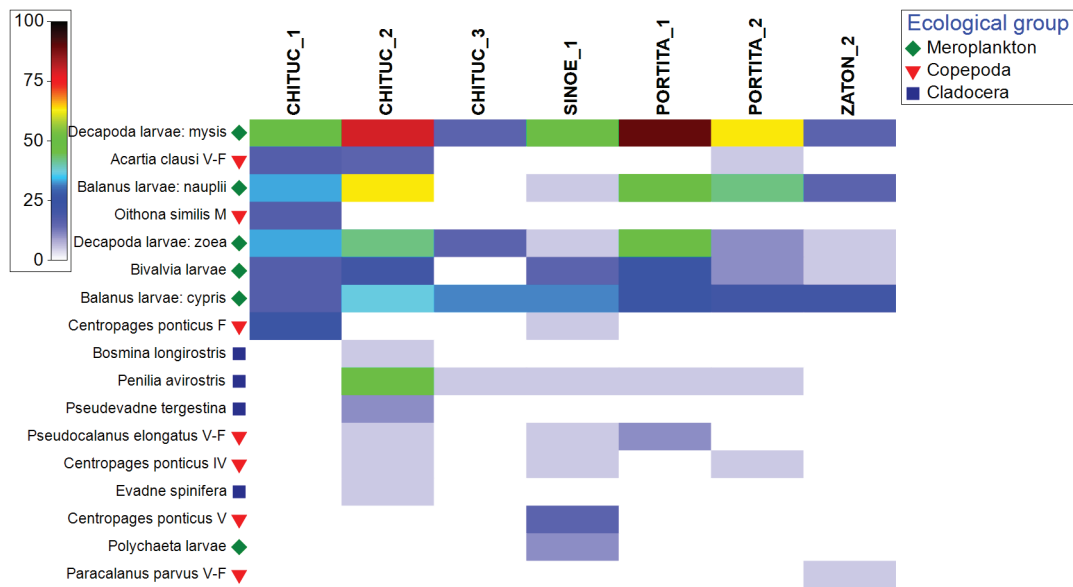
**Fig. 4.** Shade plot showing the density (ind.m<sup>-3</sup>) (a) and biomass (mg.m<sup>-3</sup>) (b) of fodder mesozooplankton.

The gastrosomatic index fluctuated throughout the sampling stations, with the maximum value at CHITUC\_2 and the lowest at SINOE\_1 (Table 2). The fullness index varied between 0.5 and 2.1, with the maximum value in PORTITA\_2 and the minimum in SINOE\_1 (Table 2).

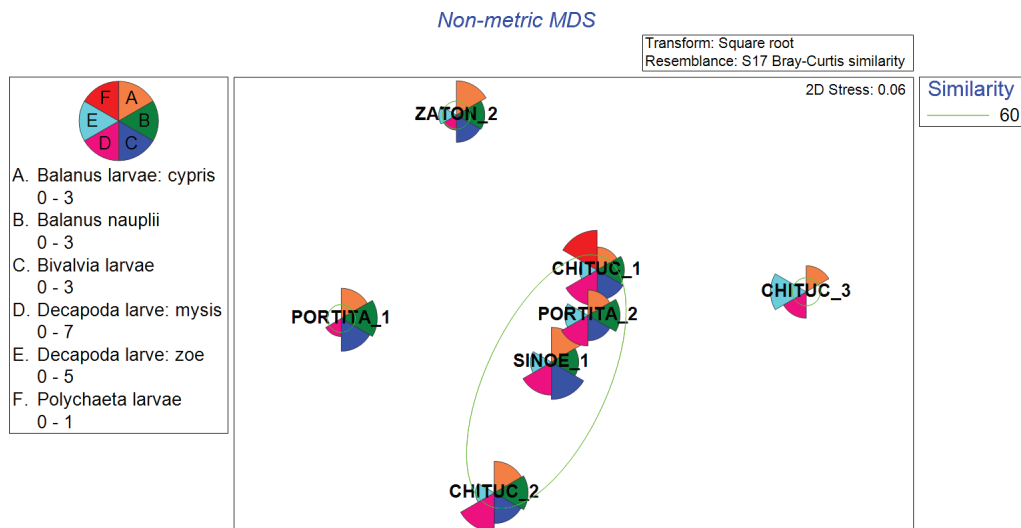
The stomach content analysis of *A. tanaica* revealed that the most frequent consumed mesozooplanktonic items were larvae of the Decapoda, especially those of the mysis stage. These meroplanktonic organisms were consumed at all stations, with the highest frequency of occurrence at individuals at stations PORTITA\_1 (89 %) and CHITUC\_2 (79 %) (Fig. 6). Another considerable consumed item was *Balanus cypris*, with the high-



**Fig. 5.** Size-frequency distribution of *Alosa tanaica*.



**Fig. 6.** Shade plot showing the Foi% of food items found in the stomach content of *Alosa tanaica*



**Fig. 7.** A diagram of a NMDS analysis based on meroplanktonic components from the stomach content of *Alosa tanaica*.

**Table 3.** Species-specific contributions, similarity percentage (SIMPER) for items consumed by *Alosa tanaica*.

Species	Average abundance	Average similarity	Sim/SD	Contribution %	Cumulative contribution %
Decapoda larvae: mysis	3.87	16.65	1.86	31.66	31.66
Balanus larvae: cypris	1.67	9.45	3.01	17.96	49.62
Balanus larvae: nauplii	1.57	7.26	1.42	13.8	63.42
Bivalvia larvae	1.55	6.96	1.44	13.24	76.66

est frequency of occurrence in stations CHITUC\_2 (37%), CHITUC\_3 and SINOE\_1 (32%). Zoea larvae of Decapoda had the highest occurrence in PORTITA\_1 (47%) and CHITUC\_2 (42%). *Balanus nauplii* were consumed in CHITUC\_2 (63%) and PORTITA\_1 (47%). Bivalvia larvae had the high-

est frequency occurrence in PORTITA\_1 (23%) and CHITUC\_2 (21%) (Fig. 7).

Among the copepods, *Acartia clausi* was preferred at the stations CHITUC\_1 and CHITUC\_2 but with low frequency values. *Penilia avirostris* was highly consumed by individuals in station

CHITUC\_2, with a frequency of occurrence of 47 % (Fig. 7).

The non-metric MDS performed for stomach contents of *A. tanaica* revealed a similarity of 60 % between stations CHITUC\_1, PORTITA\_2, SINOE\_1 and CHITUC\_2. These stations formed a single cluster due to the approximate average values of the meroplanktonic component, which was highly preferred as food item.

Based on the SIMPER analysis, it is obvious that the Decapoda larvae (mysis larvae) contributed most to the average similarity, being followed by *Balanus* and *Bivalvia* (Table 3).

## Discussion

In this study, the spatial distribution of the mesozooplankton community and its relation to the diet of *A. tanaica* individuals were investigated. The mesozooplankton community was mainly represented by Copepoda together with the meroplanktonic component, which are part of the fodder component. From the ecological point of view, copepods are important links in the aquatic food web, consuming microscopic algal cells of the phytoplankton and being eaten by juvenile fish and other planktivores. Meroplankton can represent a substantial part of the zooplankton community, its contributions to the total mesozooplankton density being higher in estuarine areas (STÜBNER et al. 2016).

In stations closely associated with the freshwater input which is higher in station SF\_GHEORGHE\_1 and SF\_GHEORGHE\_3, the mesozooplankton component was poorly represented from the quantitative point of view, variations in freshwater discharge affecting the abundance and distribution of mesozooplankton (OGHENEKARO et al. 2019).

The non-fodder component of the community, represented by *Noctiluca scintillans*, was poorly represented from the quantitative point of view, this being an advantage for both fish populations and mesozooplanktonic organisms. The outburst of *N. scintillans* is marked by a reduction in the other zooplankters, especially the copepods and can affect the clupeids, too. This may be due to the fact that the fishes belonging to the family Clupeidae feed mostly at the surface, where *N. scintillans* concentrates in high amounts (PRASAD 1958).

The size distribution graph of *A. tanaica* individuals shows a drastically reduced amount of large-sized specimens (over 14.9 cm). This might be due to the fact that samples for stomach analysis were selected randomly from the total catch and,

therefore, the overall representation of the population length frequency could be affected.

Values of Gastro-Somatic-Index (GSI) showed variations in each sampling station, depicting the medium feeding activity of the fish species during this time, which may be in correspondence with the breeding period (ȚIGANOV et al. 2016). During spawning season, the ovaries are substantially larger, filling the body cavity and transferring the energy content of the body to gonads, displacing and limiting the size of the digestive tract, thus limiting fish feeding (VALINASSAB et al. 2011). There is a clear variation in the feeding intensity, pattern of feeding intensity depending on the seasonality of prey abundance and the qualitative species composition (GARRIDO et al. 2008).

Individuals of *A. tanaica* consumed meroplanktonic items in high quantities, especially larvae of Decapoda, *Balanus* and *Bivalvia*. The Copepoda was scarcely preferred as food source, being consumed only at a few sampling stations. Particulate-feeding planktivores are size-selective predators, visually detecting, locating and attacking a single zooplankton individual. During ontogeny, fish often change their diet, exploiting a series of prey sizes, from phytoplankton and small zooplankton to larger prey, foraging mainly on holoplankton and meroplanktonic items (MADKOUR 2012), as also shown by the present study.

Clupeids have long been recognised 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 recognised that the diets of these fish reflect the composition of the ambient plankton communities (NYUNJA et al. 2002).

Taking into consideration that the mesozooplankton community was mainly represented by Copepoda and meroplankton, we can say that the analysis of the stomach content of *Alosa tanaica* is strongly related to the plankton community, exploiting the feeding resources that were available in the water column.

## Conclusions

The fodder component of the mesozooplankton community was dominant, reaching high values of density and biomass in all the analysed stations. The non-fodder component, which is represented by *Noctiluca scintillans*, showed low density and biomass values. The abundance and richness of fodder mesozooplankton in the study area explain why this region can represent a growth and feeding zone.

Variations in mesozooplankton abundance, biomass and community composition may affect recruitment of important commercial fish species. Knowledge of zooplankton dynamics is therefore essential for understanding the pelagic ecosystem, especially the lack of suitable mesozooplankton affecting the fish growth and survival and leading to a decline in fish catches.

The stomach content analysis at *A. tanaica* revealed that the most frequently consumed mesozooplanktonic items were larvae of Decapoda, especially the mysis stage, with the highest frequency of occurrence at individuals in stations PORTITA\_1. Another item highly consumed was *Balanus cypris*, with the highest frequency occurrence in stations CHITUC\_2, CHITUC\_3 and SINOE\_1. Zoea larvae of the Decapoda had the highest occurrence at PORTITA\_1 and CHITUC\_2. *Balanus nauplii* were consumed at CHITUC\_2 and PORTITA\_1, and Bivalvia larvae had the highest frequency occurrence at PORTITA\_1 and CHITUC\_2.

The analysis of fish stomach content provides information regarding the feeding patterns, representing an important aspect for fisheries management, being the basis for understanding trophic interactions in aquatic food webs

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## References

- ALEXANDROV B., ARASHKEVICH E., GUBANOVA A. & KORSHENKO A. 2014. Manual for mesozooplankton sampling and analysis in the Black Sea monitoring (Black Sea Commission), 41 p.
- CLARKE K. R. & GORLEY R. N. 2015. PRIMER v7: User Manual/Tutorial. PRIMER-E, Plymouth, 296 p.
- DÍAZ-GIL C., WERNER M., LÖVGREN O., KALJUSTE O., GRZYB A., MARGOŃSKI P. & CASINI M. 2014. Spatio-temporal composition and dynamics of zooplankton in the Kalmar Sound (western Baltic Sea) in 2009–2010. *Boreal Environmental Research* 19: 323–335.
- GARRIDO S., MURTA A. G., MOREIRA A., FERREIRA M. J. & ANGÉLICO M. M. 2008. Horse mackerel (*Trachurus trachurus*) stomach fullness off Portugal: index calibration and spatio-temporal variations in feeding intensity, *ICES Journal of Marine Science* 65 (9): 1662–1669.
- HYNES H. 1950. The food of freshwater sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*), with a review of methods used in studies of the food of fishes. *Journal of Animal Ecology* 19 (1): 36–58.
- JAMES A. G. 1988. Are clupeid microphagists herbivorous or omnivorous? A review of the diets of some commercially important clupeids. *South African Journal of Marine Science* 7 (1): 161–177.
- KOVALEV A., NIERMANN U., MELNIKOV V., BELOKOPYTOV V., UYSAL Z., KIDEYŞ A. E., ÜNSAL M. & ALTUKHOV D. 1998. Long-term changes in the Black Sea zooplankton: the role of natural and anthropogenic factors. In: IVANOV L. I. & OGUZ T. (Eds.): *Ecosystem Modeling as a Management Tool for the Black Sea*. Dordrecht: Kluwer Academic Publishers, pp. 221–234.
- KRUSKAL J. B. & WISH M. 1978. *Multidimensional Scaling*. Sage University Paper Series on Quantitative Applications in the Social Sciences, No. 07-011, Sage Publications, Newbury Park.
- MADKOUR F. 2012. Feeding ecology of the round sardinella, *Sardinella aurita* (Family: Clupeidae) in the Egyptian Mediterranean waters. Marine Science Department, Faculty of Science, Port Said University, Egypt.
- MAHESH V., REKHA J. & GOP A. 2019. Stomach content analysis techniques in fishes. Demersal Fisheries Division, ICAR-Central Marine Fisheries Research Institute.
- MULKANA M. S. 1966. Habits of juvenile fishes in two Rhode Island estuaries. *Gulf Research Reports* 2 (2): 97–167.
- NYUNJA J. A., MAVUTI K. M. & WAKWABI E. O. 2002. Trophic ecology of *Sardinella gibbose* (Pisces: Clupeidae) and *Atherinomorous lacunosus* (Pisces: Atherinidae) in Mt-wapa Creek and Wasini Channel, Kenya, West. *Indian Ocean Journal of Marine Science* 1 (2): 181–189.
- Oghenekaro E. U. & Chigbu P. 2019. Dynamics of mesozooplankton assemblage in relation to environmental factors in the Maryland coastal bays. *Water* 11 (10): 2133
- PRASAD R. 1958. A note on the occurrence and feeding habits of *Noctiluca* and their effects on the plankton community and fisheries. *Proceedings of the Indian Academy of Sciences* 47 (6): 331–337.
- RICHARDSON A. J. 2008. In hot water: zooplankton and climate change, *ICES Journal of Marine Science* 65: 279–295.
- STÜBNER E. I., SØREIDE J. E., REIGSTAD M., MARQUARDT M. & BLACHOWIAK-SAMOLYK K. 2016. Year-round meroplankton dynamics in high-Arctic Svalbard. *Journal of Plankton Research* 38 (3): 522–536.
- THOMAS S. M., CHADHA N. K., PADINHATE P., PURAYIL S. B., KANDIYIL A.P, KAVUNGAL V., JOSEPH I., BANRJEI SAWANT P. & ABHIJITH R. 2018. The Food and Feeding Habits of Goldsilk Seabream, *Acanthopagrus berda* (Forsskal, 1775) *Turkish Journal of Fisheries and Aquatic Science* 19 (7): 605–614.
- ŢIGANOV G., OPREA L. & MAXIMOV V. 2016. Studies regarding the biological parameters of Azov Shad (*Alosa tanaica*, Grimm, 1901) from the Romanian Black Sea Coast. *Bulletin UASVM Animal Science and Biotechnologies* 73 (1): 1–6.
- VALINASSAB T., JALALI S., HAFEZIEH M. & ZARSHENAS G. A. 2011. Evaluation of some feeding indices of *Pomadasys kaakan* in the Northern Persian Gulf. *Iranian Journal of Fishery Sciences* 10 (3): 497–504.

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