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ROMANIAN BLACK SEA MESOZOOPLANKTON'S SEASONAL DYNAMICS AND DISTRIBUTION DURING 2013-2020

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ABSTRACT

The analysis of the mesozooplankton community from the Romanian Black Sea waters revealed variations both from quantitative and qualitative point of view. A decrease in the number of identified taxa according to the season was observed, with a maximum of 25 taxa in the warm season and a minimum of 15 taxa in the cold season. The nonfodder component represented by *Noctiluca scintillans* recorded the highest density and biomass values in the warm season, in the cold season being less represented, fact highlighted by Simper analysis. The mesozooplanktonic fodder component showed variations of density and biomass, copepods and the meroplanktonic component representing the bulk of the community in the warm season. In the warm season, the group of Cladocera's recorded high density and biomass values, unlike in the cold season where they were very poorly represented. Other groups were better represented also in the warm season, showing a decrease in terms of abundance and biomass in the cold season.
Keywords: analysis, species, density, biomass, variations

AIMS AND BACKGROUND

Zooplankton, a dominant link between primary production and upper trophic levels, plays a pivotal role in shaping marine ecosystems, being used as environmental quality indicator due to its high dependence and fast responses to environmental variations. In addition, its contribution to nutrient regeneration and dissolved organic carbon release, supports the growth of phytoplankton and bacterioplankton (Banse, 1995).

A good understanding of how zooplankton communities vary seasonally and interannually is essential to assess the impact of anthropogenic activities and climate change, but establishing a baseline or reference for what is natural is not a trivial task. Repeated sampling at same locations does not guarantee that the same community is explored over time, changes in population quantitative structure and species composition over time may be biased by the inflow or exchange of populations between sampling events (Soreide *et al*., 2022).

The abundance and distribution of zooplankton can be affected among other factors by temperature, salinity, and primary production (Wang *et al*., 2021). Temperature directly affects zooplankton's physiological processes, such as ingestion, respiration, and reproductive development, with rates doubling or tripling with a 10°C temperature rise (Mauchline, 1998) but also indirectly by altering their food quantity and quality, competition, and predation patterns (Liu *et al*., 2022). Temperature associations have been observed in zooplankton distribution, species composition, biomass, and phenology, typically with seasonal processes occurring earlier during warmer years (Mackas *et al.* 2012)

To fully understand the functioning of pelagic ecosystems, knowledge about the seasonal and spatial distribution of zooplankton's qualitative and quantitative structure is indispensable, having strong implications for the planktonic food web (Hébert *et al*., 2017).

The aim of the paper is to analyse the mesozooplankton's qualitative and quantitative structure in relation to the seasons in which samples were collected, describing the community seasonal patterns.

EXPERIMENTAL

Samples were collected from stations within the marine monitoring network of the Romanian Black Sea coast (Fig. 1) during 2013-2020, in the warm (May-October) and cold season (November-April). A number of 533 mesozooplankton samples collected from 45 sampling stations were analysed, the highest number of samples being recorded in the warm season, in the cold season the sampling effort being lower, only in 2014, 2017 and 2020 expeditions were organised.

The collection of mesozooplankton samples was performed by vertically towing the net in the water mass, with a speed of 0.5-1 m /s, on standard horizons (10-0 m, 25-10 m, 50-25 m, 100 -50 m) in the warm season and in the entire water column, in the cold season.

Quantitative and qualitative mesozooplankton's samples processing was performed under Olympus SZX10 stereomicroscope. All plankters were counted in the Bogorov chamber (subsamples of 2 ml), until each of the three dominant taxonomic groups reached 100 individuals. For the estimation of large animals‘numbers, the whole sample was examined in a Petri dish. The number of individuals and mean individual weights were used for estimating the density as ind/m^{-3}, respectively the biomass as mg/m^{-3} wet weight (Alexandrov *et al*., 2014). Temperature was measured simultaneously with mesozooplankton sampling, using the CastAway CTD multiparameter.

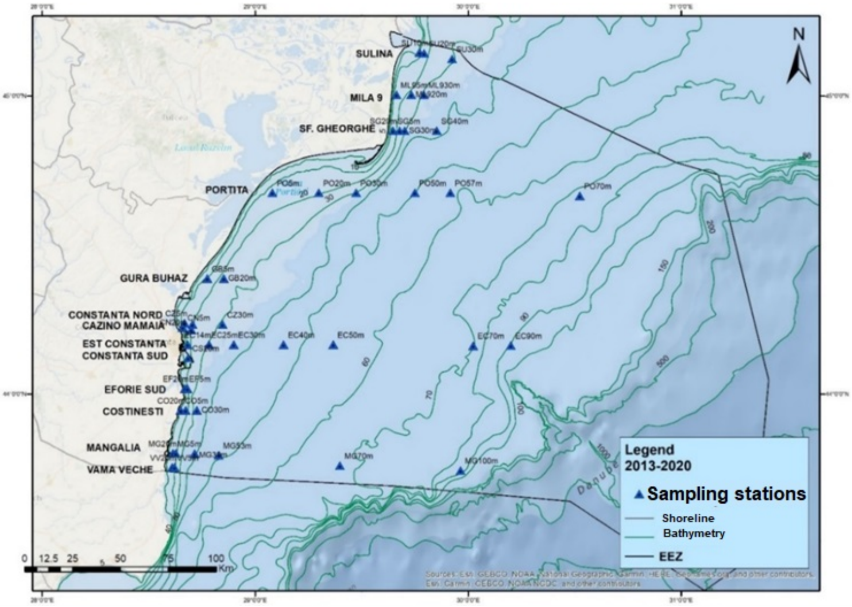

Fig. 1. Map of sampling stations – Romanian Black Sea, 2013-2020

For data analysis, Primer software was used, generating shade plots, box plots, Non-metric Multidimensional Scaling (n-MDS), SIMPER configuration, all data being square root transformed. Shade plots represent multivariate analysis that can fashion clear community structures, characterising responses of individual species across the sample, box plots enable to study the distributional characteristics of a group, SIMPER examines the relationships between species and sample patterns, with variables that are likely to contribute to any differences between identified groups; n-MDS is a mean of visualizing the similarity level of a data set (Clarke *et al*., 2015).

Ocean Data View (ODV), a software package for the interactive exploration, analysis and visualization of oceanographic data was used for displaying the differences in sea water temperature.

RESULTS AND DISCUSSION

Temperature is believed to be the most important factor structuring marine ecosystems, and zooplankton dynamics (Richardson, 2008). An analysis of the interactions between changing temperatures and the attributes of zooplankton communities provides valuable information for evaluating the condition of aquatic ecosystems and predicting future changes (Richardson, 2008).

The Black Sea water temperature during 2013-2020 varied between 5.20^{o}C and 24^{o}C (Fig. 2), with the highest variability in the warm season. According to Sakalli and Basusta (2017) in the last 34 years (1982–2015), most of the monthly Black Sea temperature fluctuations were during summer and autumn (Sakalli *et al.*, 2018). Mesozooplankton comprises poikilothermic animals, sensitive to temperature changes, which is one of the most important factors, driving its temporal and spatial distribution (Gubanova *et al*., 2022).

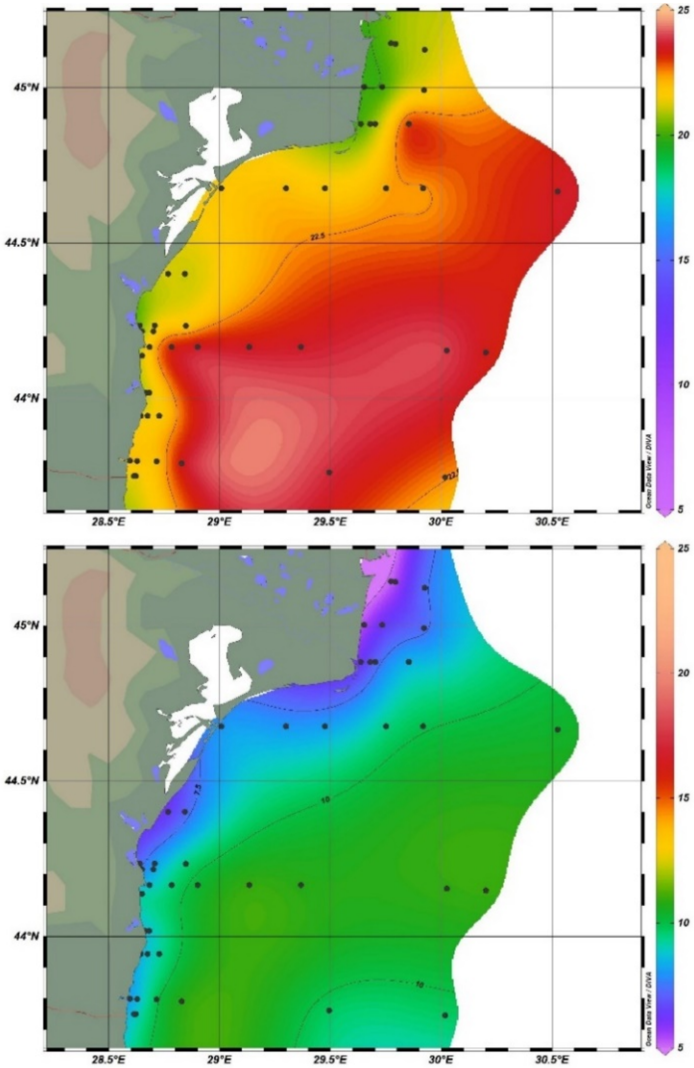

Fig. 2. Seawater temperature distribution in the Black Sea, warm (up) and cold (down) season 2013-2020

The analysis of the mesozooplankton community from the Romanian Black Sea coast highlighted variations both from qualitative and quantitative point of view.

The seasonal distribution of mesozooplankton species showed that in the warm season the number of identified taxa increased, while the mesozooplankton diversity was lower in the cold season, with a maximum of 25 taxa in the warm season and a minimum of 15 taxa in the cold one (Fig. 3). This may be due to the natural variability of the plankton but may also be attributed to the sampling effort which was much lower in the cold season. It is worth noting that in the years 2013, 2019 and 2020, when the highest number of taxa was identified, the expeditions were carried out in the warm season and covered the entire continental shelf of the Black Sea, the research effort being higher in comparison with the previous years when the expeditions only covered the southern or northern part of the coast.

The differences recorded in sea water temperatures, determine the seasonal alternation of thermophilic and cryophilic mesozooplankton organisms, the appearance in spring and the disappearance in autumn of warm water species, with the cooling of the water (Băcescu *et al.*, 1967). With the increase in water temperature, warm water species appear in the water mass, while those of cold water perform migrations in colder layers (Timofte, 2017).

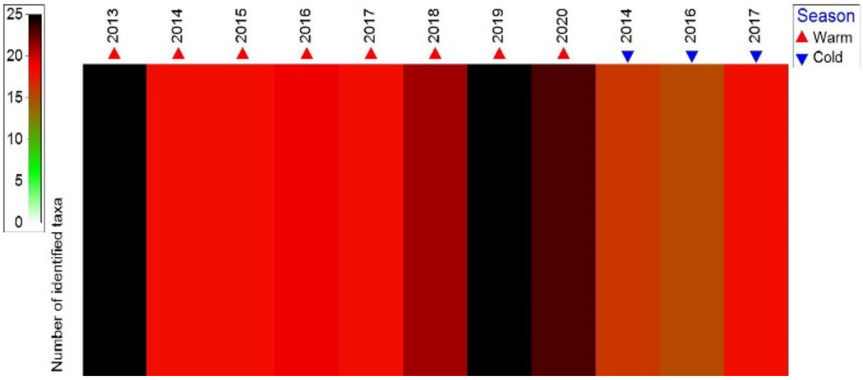

Fig. 3. Shade plot for mesozooplankton taxa, by season in 2013-2020

From the quantitative point of view, the high densities, and biomasses of the nonfodder component- *Noctiluca scintillans* in the warm season can be observed. Copepods *Acartia clausi* and *Pseudocalanus elongatus* were best represented both in cold and warm season. High densities and biomasses are noted for the species *Centropages ponticus* in the warm season, this species appearing in plankton only at higher water temperatures (Fig. 4).

Regarding the group of Cladocera's, it is observed that in the warm season it recorded higher densities and biomasses, unlike the cold season when it was low represented both qualitatively and quantitatively. In general, cladocerans are better represented from early spring to late autumn, with a rapid decline and even absence from the mesozooplankton component in winter (Pestorić *et al.*, 2010). High seawater temperatures cause blooms of *N. scintillans* and a high secondary production of thermophilic species such as *C. ponticus* and cladocerans (Muresan *et al.*, 2020).

The meroplanktonic component registered higher biomass and density values also in the warm season, this situation being also identified for the Other groups category.

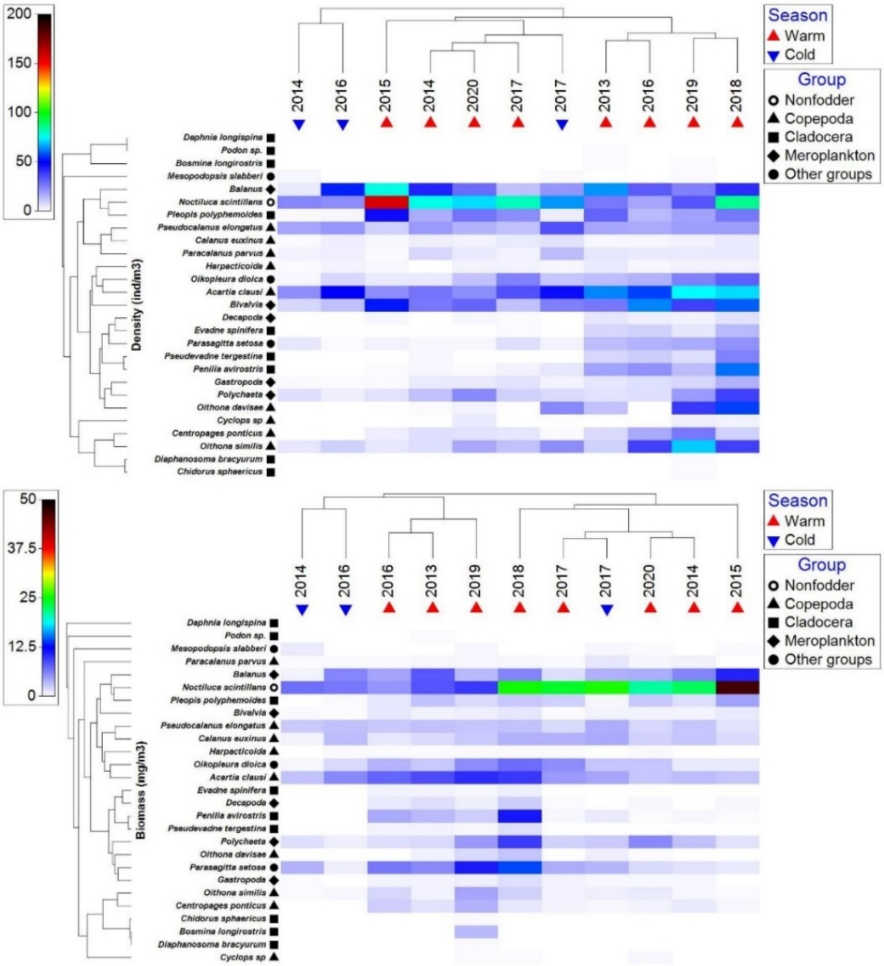

Fig.4. Matrix of mesozooplankton abundance and biomass in 2013-2020, by seasons

The mesozooplankton's species diversity increased in the warm period, copepods and cladocerans being best represented both in terms of quality and quantity (Băcescu *et al.*, 1967). This is also highlighted by the SIMPER analysis, which reveals that in the warm season, the main mesozooplanktonic groups that contributed to the community structure are represented by copepods, meroplankton and cladocerans, in contrast to the cold season, where the group of Cladocera is very low represented, contributing most to the average dissimilarity between the analysed seasons (Table 1).The SIMPER analysis for the warm and cold season highlights the large contribution that the nonfodder component represented by *N.scintillans* had in the warm season, in the cold season recording lower density values (Table 1). *Acartia clausi* recorded high density values in both seasons, dominating in the warm season (Table 1). The meroplanktonic elements Balanus and Bivalvia contributed most in the warm season in the cold season recording lower density values (Table 1).

Table 1. SIMPER Similarity Percentages - Mesozooplankton's species contribution based on densities (ind/m^{-3}), 20013-2020, by season

GROUP WARM					
Average Similarity: 62.18					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Noctiluca scintillans	68.12	12.39	1.49	19.92	19.92
Acartia clausi	45.82	8.97	2.73	14.43	34.35
Balanus	39.78	7.57	2.16	12.18	46.52
Bivalvia	37.77	7.34	2.69	11.8	58.33
Pleopis polyphemoides	24.7	5.31	3.24	8.54	66.87
Pseudocalanus elogatus	15.76	3.87	3.41	6.22	73.09
GROUP COLD					
Average Similarity: 58.48					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Acartia clausi	39.41	15.66	3.72	26.78	26.78
Noctiluca scintillans	36.4	12.22	4.01	20.9	47.68
Pseudocalanus elogatus	23.67	9.82	5.29	16.8	64.48
Bivalvia	14.56	4.84	6.82	8.28	72.76

GROUPS WARM & COLD						
Average Dissimilarity = 46.51						
	Group Warm	**Group Cold**				
SPECIES	Av. Abund	Av. Abund	Av. Diss	Diss /SD	Contrib %	Cum. %
Noctiluca scintillans	68.12	36.4	8.17	1.09	17.57	17.57
Balanus	39.78	25.53	5.19	1.33	11.15	28.72
Bivalvia	37.77	14.56	4.41	1.4	9.48	38.2
Pleopis polyphemoides	24.7	1.56	4.39	2.15	9.43	47.63
Acartia clausi	45.82	39.41	3.84	1.51	8.25	55.88
Oithona similis	23.85	11.77	3.08	1	6.63	62.51
Oithona davisae	13.58	7.57	2.53	1	5.44	67.95
Penilia avirostris	14.69	1.61	2.23	0.92	4.8	72.75

The box plot diagrams for total mesozooplankton in warm and cold season of 2013-2020 highlighted the dominance of the nonfodder component, both in terms of density and biomass, in the warm period (Fig. 5). It should be noted that the average biomass of nonfodder component in the warm season was much higher than the average biomass recorded by the fodder component, which indicates that smaller organisms dominated during the warm season.

In the cold period of 2013-2020, the nonfodder mesozooplankton did not record high density and biomass value, the fodder component being dominant (Fig. 5). This may be due to the natural variability of the plankton but may also be attributed to the sampling effort which was much lower in the cold season.

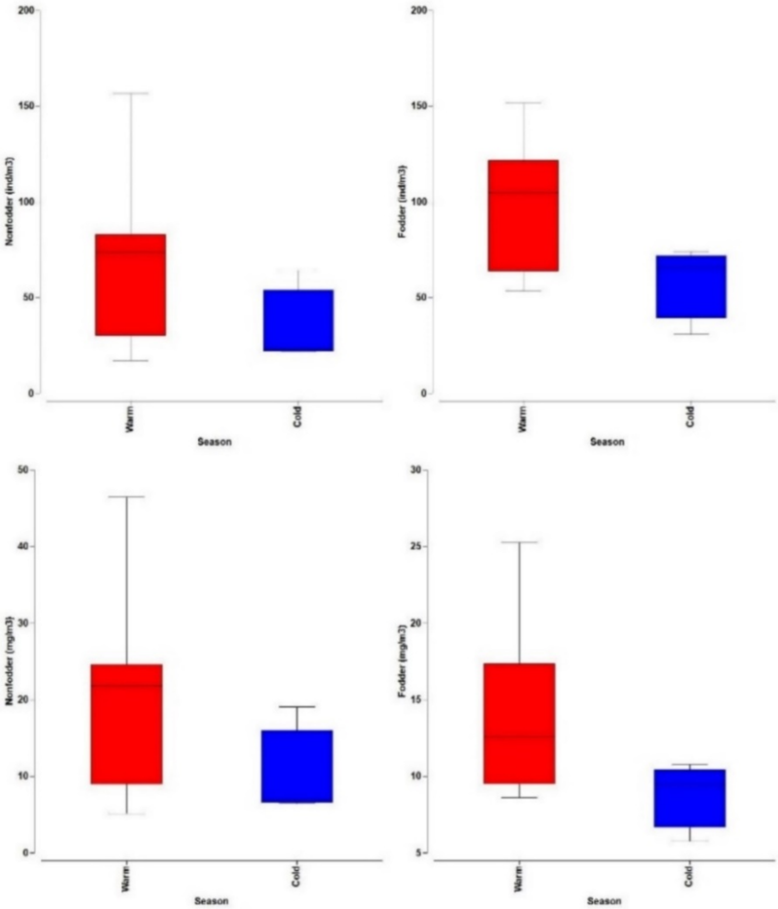

Fig. 5. Box plot diagrams for total mesozooplankton density and biomass values in 2013-2020, by season

A high similarity is observed between the analyzed years based on the mean values of biomass and density for total mesozooplankton. Thus, based on the average density values, an 80% similarity cluster is observed for the warm season of 2013, 2016 and 2019 and another cluster with 80% similarity between the warm season of 2020, 2014, 2017 and the cold season of 2017 (Fig. 6). The cold season of 2014 formed a single cluster due to the very low average densities and biomasses recorded by the mesozooplanktonic fodder and nonfodder component, this being explained by the lower number of collected samples (Fig.6).

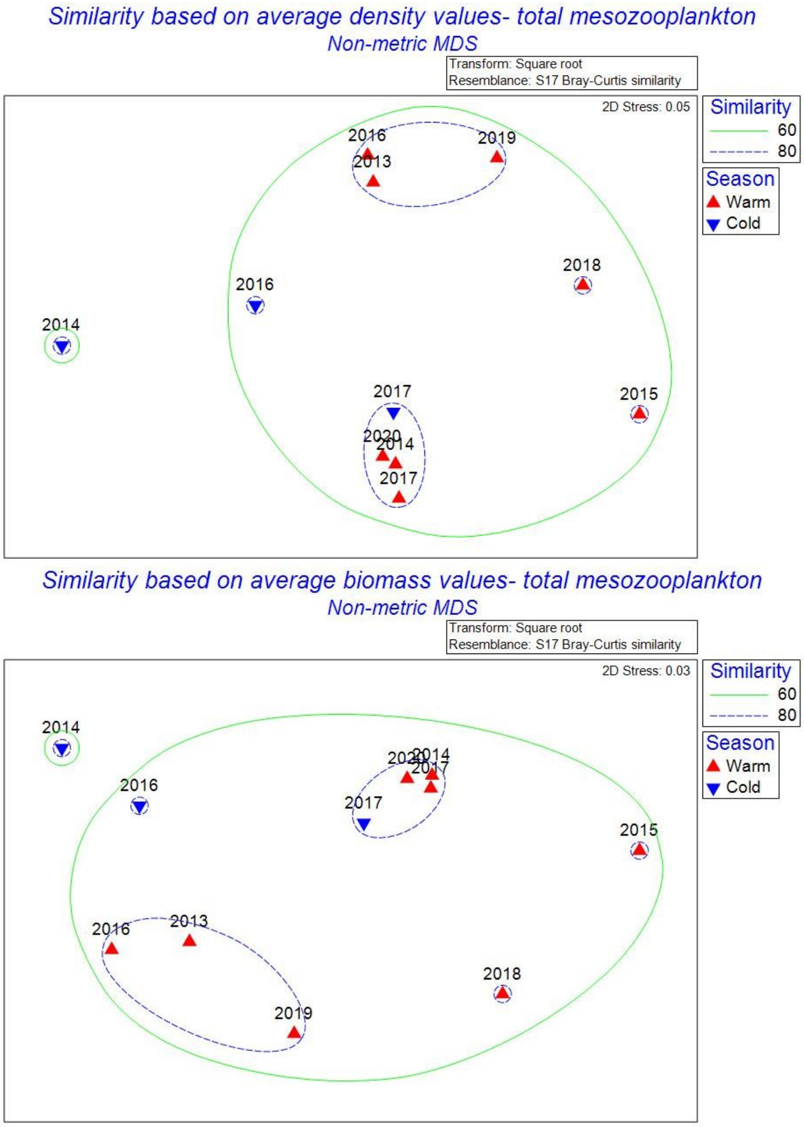

Fig. 6. NMDS analysis for total mesozooplankton density and biomass values in 2013-2020, by season

The mesozooplanktonic fodder component in the warm and cold season of 2013-2020 showed variations for average values of density and biomass. Copepods and the meroplanktonic component were quantitatively best represented in the warm season. Worth noting in the warm season is also the group of cladocerans that recorded higher average values of density and biomass, unlike in the cold season where they were very poorly represented (Fig. 7).

The category Other groups was much better represented also in the warm season, in the cold season recording lower average values for density and biomass. Seasonal variability is also evident within the fodder component, the cold season being characterised by lower values compared to those in the warm season (Fig. 7).

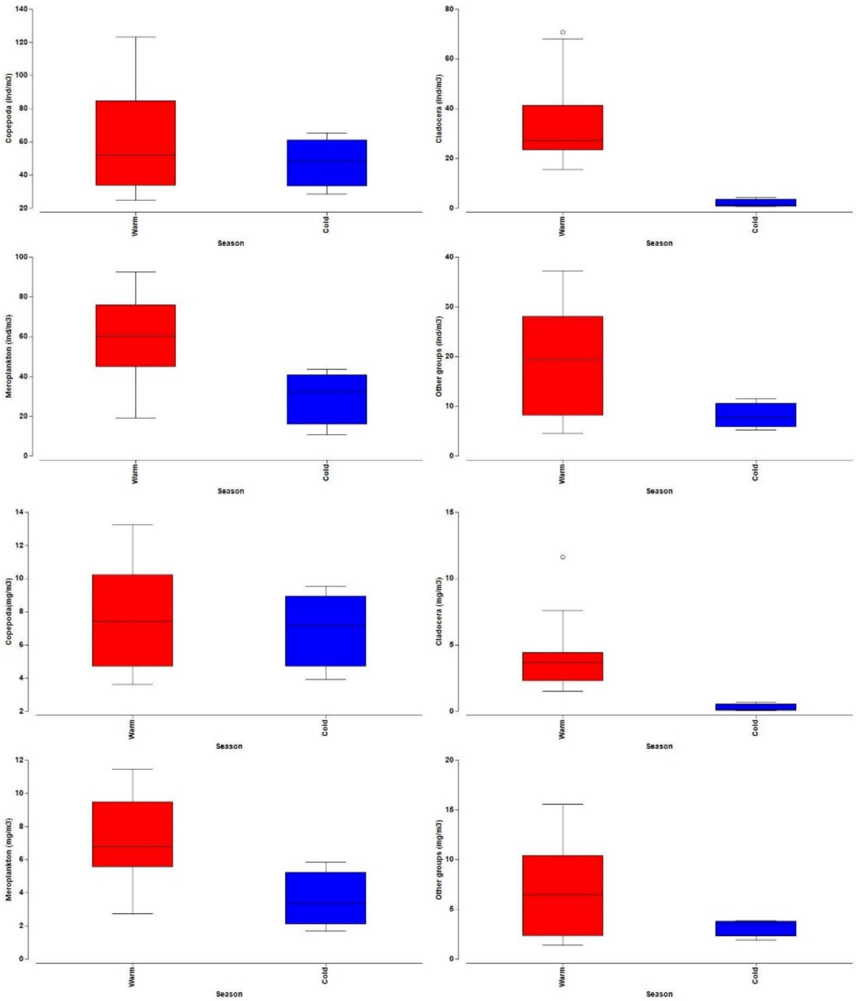

Fig. 7. Box plot diagrams for fodder mesozooplankton density and biomass values in 2013-2020, by season

Similarities of 60% and 80% for mean values of density and biomass recorded by fodder mesozooplankton were observed, by forming similarity clusters. Thus, for the average values of density, clusters are observed between the years 2016 and 2017, the cold season, and for the average values of biomass, the formation of two clusters is noted, as follows a cluster for the warm season of 2013, 2016 and 2019 and another for the warm season of 2014, 2017, 2020 and the cold season of 2016 and 2017 (Fig. 8). It is noteworthy that the cold season of 2014 was the weakest represented from a quantitative point of view, this year being the lowest values of average density and biomass (Fig. 8).

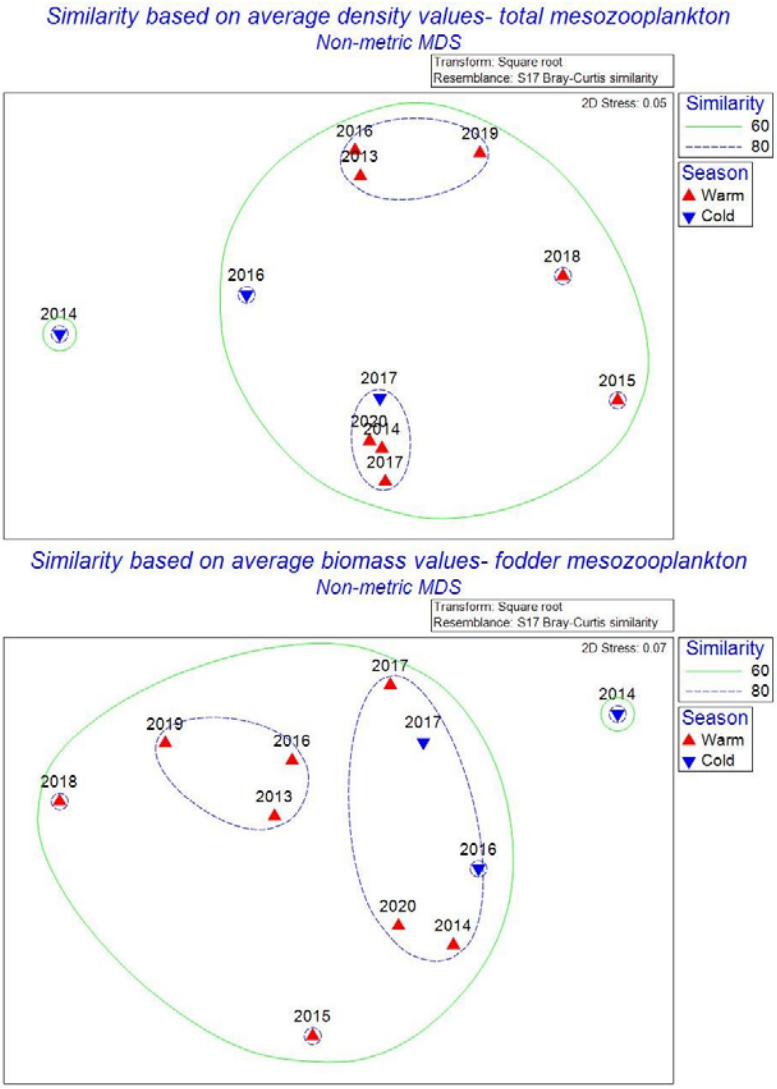

Fig. 8. NMDS analysis for fodder mesozooplankton density and biomass values in 2013-2020, by season

CONCLUSIONS

The seasonal distribution of mesozooplankton species revealed a higher number of taxa identified in the warm season (25), the cold season being characterized by a maximum number of 15 taxa.

From a quantitative point of view, the dinoflagellate *Noctiluca scintillans* representative of the nonfodder mesozooplanktonic component reached the highest density and biomass values in the warm season, in the cold season being characterized by lower values.

From the mesozooplanktonic fodder category, copepods *Acartia clausi* and *Pseudocalanus elongatus* were best represented both in the cold and warm seasons, and cladocerans recorded high values for density and biomass only in the warm season. The meroplanktonic component reached its maximum development also in the warm season, this situation being also identified for the Other groups category.

Following the quantitative analysis of the mesozooplankton community from 2013-2020, it emerged that there are variations in density and biomass values for the fodder and nonfodder components, in the warm season the average values of density and biomass being much higher than the values recorded in the cold season These variations are due to the natural variability of the component, to which is added the number of collected samples and the season.

Biomass and density values recorded by total mesozooplankton generated the formation of high similarity clusters (80%) for the years 2013, 2016 and 2019 warm season and for 2020, 2014, 2017 warm season and cold season of 2017. The year 2014, the cold season, stands out due to the very low average densities and biomasses recorded by the fodder and nonfodder mesozooplanktonic component.

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