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SEASONAL AND LONG-TERM VARIABILITY OF MEIOFAUNA IN THE ENVIRONMENT FREQUENTLY AFFECTED BY HYPOXIA IN CENTRAL PART OF THE GULF OF TRIESTE

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ABSTRACT

The article deals with benthic meiofauna studied for three years in central part of the Gulf of Trieste. The obtained results present meiofauna's seasonal reproduction cycles and long-term trends in these cycles. The seasonal dynamics was in positive correlation with thermal conditions and salinity, and in negative correlation with oxygen and phytoplankton's chlorophyll in the bottom-water layer. A 2-month lag in meiofauna's dynamics was noted behind phytoplankton's seasonal cycle (spring and autumn blooms), while at a long-term scale a 3-year trend of growth in meiofauna's mean yearly abundances was observed.

Key words: seasonal dynamics, benthic meiofauna, Gulf of Trieste

INTRODUCTION

Meiofauna's seasonal dynamics is one of most often investigated topics as far as benthic fauna is concerned. The situation is quite different when dealing with long-term changes in meiofaunal communities, which have been studied to a much lesser extent, particularly periods exceeding one year. Such up to ten years lasting studies have been presented in various works, *e.g.* by Coull (1985, 1986), Eskin & Coull (1987), Rudnick *et al.* (1985), in contrast to numerous one year long investigations in coastal environments comparable with our coastal waters (*e.g.* Bovee & Soyer, 1974; Harris, 1972).

The research on meiofauna occurring in the Slovene part of the Gulf of Trieste has been till now focused on both topics, *i.e.* on its seasonal dynamics as well as on its long-term changes. In the latter we were involved for the first time in the 1992-1995 period, namely in connection with elsewhere poorly researched impacts of the lack of bottom-water oxygen (hypoxia and anoxia) on meiobenthos. The results of this research (Vrišer, 1996a, b, 1997) have shown an unexpectedly great meiofaunal variability, trophic links of its seasonal cycles with pelagic and benthic microflora, as well as its fairly contradictory and diverse response to fortnightly hypoxic conditions in autumn 1994. As the results have also indicated a need for a long-term monitoring, the investigations were repeated during the 1996-1999 period.

For financial reasons the research was somewhat limited although still carried out on the basis of similar methodology and with equal aims: to investigate seasonal dynamics of the total meiofauna and its main groups, to ascertain the impact of common and separate ecological factors of the physical environment on meiofauna in normal as well as in potentially hypoxic conditions, and to detect eventual signs of long-term oscillations or cycles.

METHODS

The meiofauna was sampled with monthly frequency in the years 1996, 1997 and 1998 in the same area as during the 1992-1995 period, *i.e.* in the centre of the Gulf of Trieste, 25 m deep. As a result of the troubles with the research vessel and unfavourable weather conditions, no sampling was carried out from January to April 1996, in June 1997 and from November to December 1998; no data are therefore available for these months.

Surface sediment containing meiofauna was taken with gravity core sampler (Meischner & Rumohr, 1974), 5 cm deep, always with three replicates. Meiofauna was extracted from fixed samples (5% formalin) by sieving

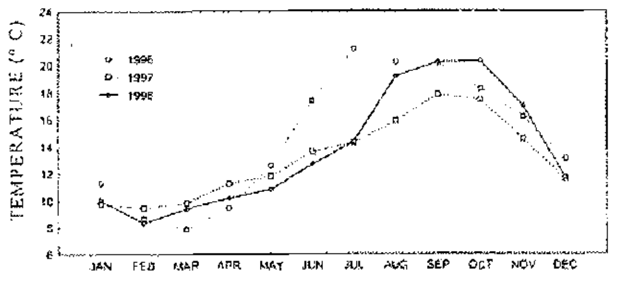

Fig. 1: Three year bottom - water layer dynamic (physical and chemical parameters) of the investigated area.
Sl. 1: Triletna dinamika fizikalnih in kemijskih parametrov v pridnenem vodnem sloju raziskovanega območja.

and decantation (Wieser, 1960), identified to major taxa, counted and statistically processed (Statsoft, Statistica 5.0).

Meiobenthic sampling was accompanied by physical and chemical measurements (temperature, salinity, oxygen) and measurements of chlorophyll biomass (Chl *a*) of the bottom- water layer, carried out with electronic fine-scale prophyler. A more detailed description of the used methods and a chart of the study area has been presented in one of the earlier papers (Vrišer, 1996a).

Due to drastically reduced financial support we were compelled to make use of gravity core sampler instead of carrying out manual sampling by SCUBA technique (as in the 1992-1995 period). Thus we had to give up the originally planned monthly measurements regarding the concentrations of benthic algae, sedimentation and the content of organic matter, and chemical characteristics of pore water of the sediment.

RESULTS

Ecological characteristics of the investigated area

The dynamics of the 3-year physical and chemical parameters is presented in figure 1. At the time of sampling, the seasonal oscillations of temperatures in the bottom-water layer ranged from the lowest winter values in February (8.5 - 9.5°C) to the highest summer values (18 - 21°C) with mean three-year temperature of 14.1°C.

The seasonal salinity oscillations showed expected raised values in the drier months of winter (December - February) and summer (July - September) and low values in the rainy months of spring (especially April 1997) and autumn (especially October 1996 and 1997). At the average salinity of 37.5‰, the measured extreme values ranged between 35.1 and 38‰.

Three-year movements of the oxygen content at the bottom showed a stable winter-spring period (January - April) of high values (90 - 100% saturation), a lower content (75%) in summer (June - July), and even lower content (70% or less) in early autumn when only 35% concentration of oxygen was measured in August 1997 and in October 1997 and 1998. The mentioned autumn minimums indeed neared hypoxic conditions, but the oxygen concentrations did not fall below the marginal value of 2 mg/l.

The sediment of the investigated station belongs, in geological terms, to silts situated between clayey silts of the coastal belt and silty sands of the open waters of the Gulf of Trieste. Granulometric structure: 65% silt, 25% clay, 10% sand (Ogorelec *et al.*, 1991).

Average amounts of the chlorophyll biomass (chlorophyll a) of the bottom pelagic microflora indicated periods of increased values in spring and autumn maximums: 1.9 mg/l in May and 4 mg/l in November. The latter was merely a statistical reflection of an extremely intensive algal bloom in autumn 1998.

Meiofauna

Structural and quantitative characteristics of the investigated meiofauna, *i.e.* its taxonomic structure (main groups and its abundance) are given, in the form of a summary statistical survey, in table 1. The dominant group (75% relative density) was represented by Nematoda, followed by Harpacticoida (12%) and Polychaeta (7%), while the following 12 groups (Turbellaria, Gastropoda, Bivalvia, Kinorhyncha, Acarina, Hydroidea, Ostracoda, Ophiuroidea, Amphipoda, Mysidacea, Cumacea, Decapoda) represented 6% of the entire meiofauna.

Seasonal dynamics of some more abundant meiofaunal groups are shown by diagrams of annual abundances (Fig. 2). The great majority of the groups showed low winter and high summer abundances. Characteristic

Tab. 1: Three year meiofauna abundance.
Tab. 1: Pregled triletnih abundančnih vrednosti meiofavne.

TAXA	Mean No./10 cm²	Rel. abundance %	Range No./10 cm²	SD of mean No.	SE of mean No.
total meiofauna	478.96	100.00	44 1338	296.95	31.30
Nematoda	361.29	75.43	16 1051	218.91	23.08
Harpacticoida	57.19	11.94	1 237	93.95	5.69
Polychaeta	35.09	7.33	3 114	25.15	2.65
Turbellaria	10.63	2.22	0 49	9.50	1.00
Gastropoda	4.53	0.88	0 5	1.07	0.11
Bivalvia	4.20	0.80	0 37	7.15	0.75
Kinorhyncha	2.77	0.58	0 21	4.42	0.47
Acarina	0.50	0.28	0 3	0.52	0.05
Hydroidea	0.49	0.22	0 7	1.29	0.14
Ostracoda	0.41	0.11	0 23	5.18	0.55
Ophiuroidea	1.36	0.07	0 30	4.01	0.42
Amphipoda	1.34	0.04	0 4	0.78	0.08
Mysidacea	1.04	0.00	0 1	0.11	0.01
Cumacea	1.03	0.00	0 1	9.48	1.00
Decapoda	0.02	0.00	0 1	0.15	0.02

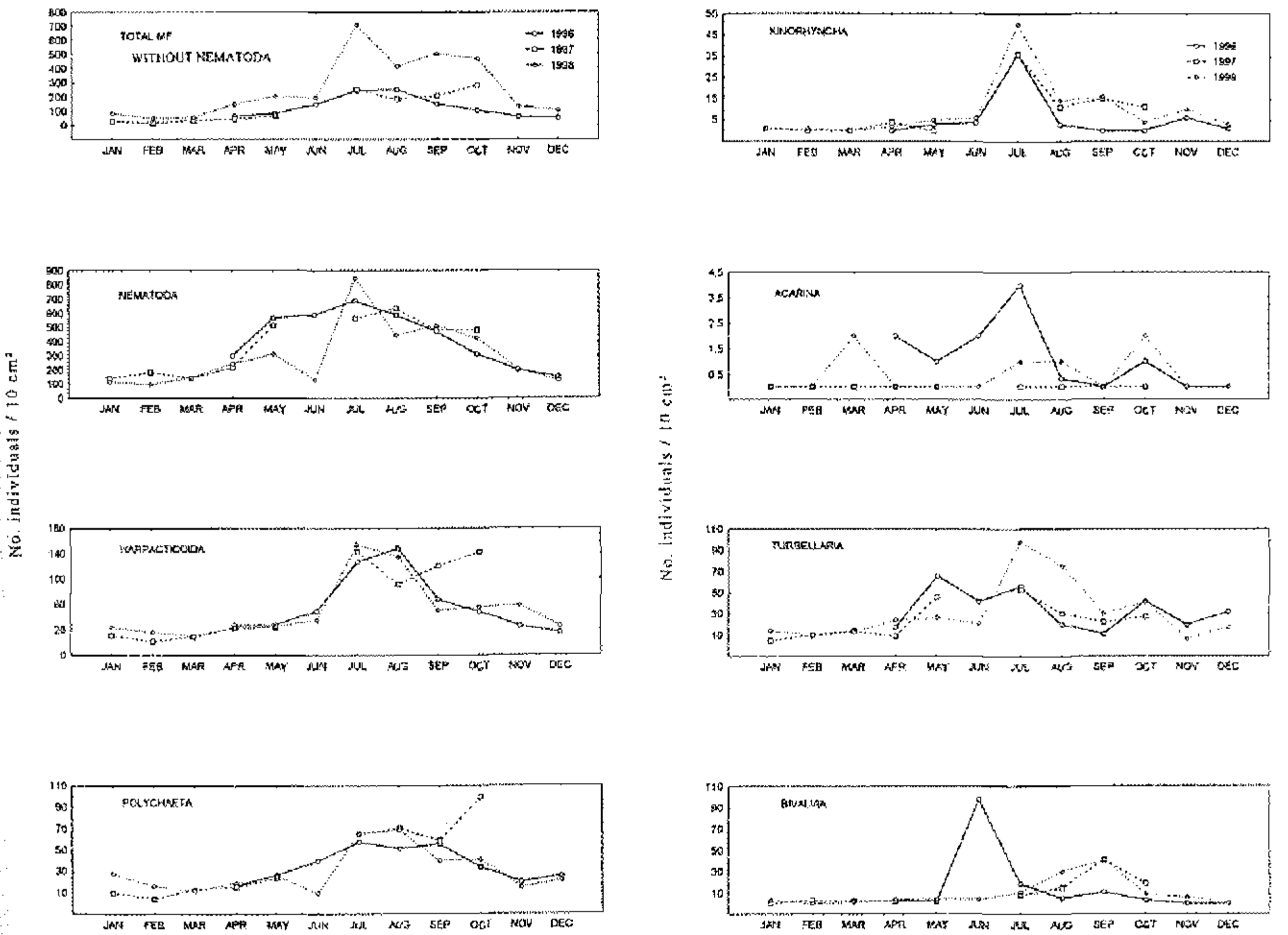

Fig. 2: Seasonal changes (1996, 97, 98) of some meiofaunal groups. Abundance as mean (No.ind./ 10cm²) or sum of 3 replicates (No.ind./30 cm²).

Sl. 2: Sezonske spremembe (1996, 97, 98) posameznih skupin meiofavne. Abundanca kot srednja vrednost (št.os./10cm²) ali vsota osebkov (št.os./30cm²) treh paralelk.

of the annual abundance cycle of the dominant Nematoda was a distinct summer peak (July), followed by somewhat weaker maximum in autumn (September). The winter Nematoda maximum lasted from December to March. Harpacticoida reached the summer maximum in July and August. This was followed by a decrease to the autumn stagnation (October, November), and this by an explicit winter-spring depression from December to April. Seasonal development of Polychaeta showed a summer increase in density with the peak in August (the few rare deviations can be assessed as atypical).

Meiofauna's long-term trends were monitored with an estimate of mean annual abundances for the 3-year 1996-1999 period (Fig. 3). In the entire meiofauna and in the first three leading groups the abundance was on the increase in this period. While a more distinct rise was noted in Nematoda and, consecutively, in the entire meiofauna in the 1997-1998 period, the mean annual abundance in Harpacticoida and Polychaeta was on the increase largely in 1996-1997.

Tab. 2: Pearson's correlation coefficients for meiofaunal taxon correlations with temperature, salinity, oxygen and phytoplankton (Chl a).
Tab. 2: Pearsonovi korelacijski koeficienti taksonomskih skupin meiofavne s temperaturo, slanostjo, kisikom in fitoplanktonom (Chl a).

TAXA	temperature	salinity	oxygen	chlorophyll a
Meiofauna	+0.66^{x}	-0.02	-0.54^{x}	-0.16
Nematoda	+0.61^{x}	-0.05	-0.50^{x}	-0.18
Harpacticoida	+0.66	+0.00	-0.55^{x}	-0.01
Polychaeta	+0.65^{x}	+0.07	-0.69^{x}	-0.20
Turbellaria	+0.47^{x}	-0.05	-0.24	-0.14
Gastropoda	+0.55^{x}	+0.16	-0.20	-0.16
Bivalvia	+0.53^{x}	+0.20	-0.31	-0.08
Kinorhyncha	+0.42^{x}	-0.07	-0.24	-0.02
Acarina	+0.35	+0.23	+0.06	
Hydroidea	+0.23	+0.14	+0.15	-0.08
Ostracoda	+0.33	-0.07	-0.01	-0.07
Ophiuroidea	+0.34	+0.03	-0.47^{x}	-0.13
Amphipoda	+0.51^{x}	+0.11	-0.25	+0.21
Mysidacea	+0.15	+0.05	+0.01	
Cumacea	+0.30	+0.23	-0.24	-0.05
Decapoda	+0.27	+0.02	-0.44^{x}	+0.13

^{x} sign. at
$p < 0.05$

The relation between the selected ecological factors (temperature, salinity, oxygen, chlorophyll a) and meiofauna was checked with Pearson's correlation coefficient (Tab. 2). The coefficients show predominantly positive correlation of the entire meiofauna and its groups with temperature and salinity, while the correlation with the chlorophyll biomass and oxygen content is negative.

The mean 3-year course of the seasonal cycle of the bottom plankton microflora (microphytopelagic biomass

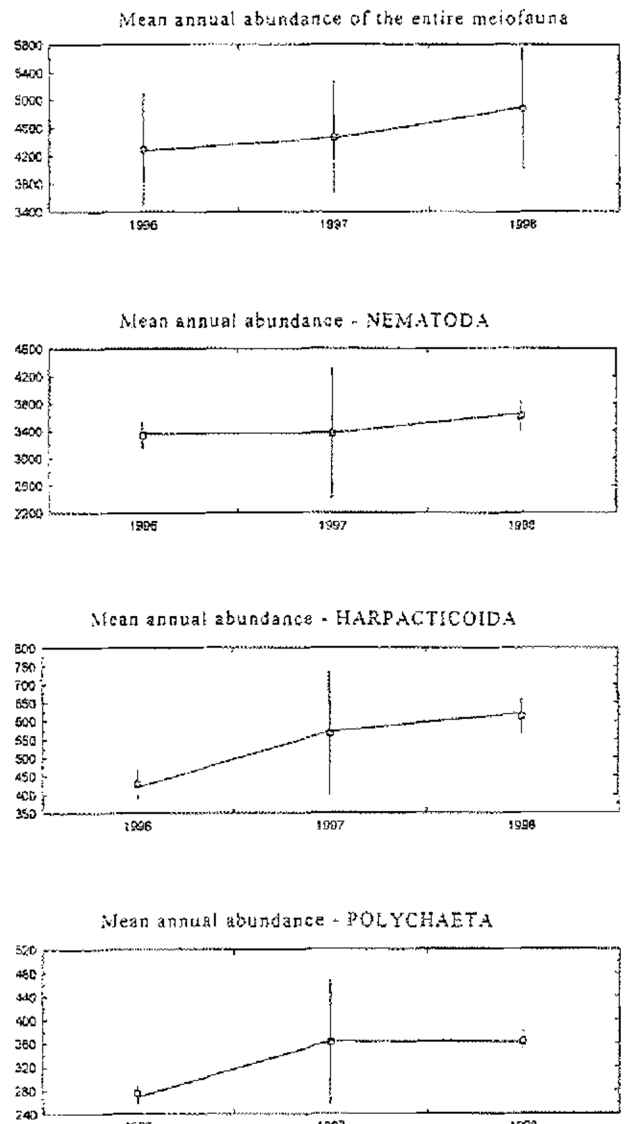

Fig. 3: Yearly mean abundances (+-SE) of total meiofauna and some dominant groups.
Sl. 3: Srednje letne abundance (+-SE) celotne meiofavne in nekaj vodilnih skupin.

- chlorophyll a) and meiofauna is shown in figure 4. The 1996-1999 Nematoda abundance curve is, very much as noticed during the earlier investigations in 1992-1995, to a certain extent a repetition of the changes in the chlorophyll biomass, this time with even greater (2-month) lag. Thus the Nematoda follow algal blooms in March and May with successive maximums in May and July, while the smaller algal increase in August is probably reflected in somewhat slowed down decrease in the Nematoda abundance in September and October. At the end of the research period in December the meiofauna did not yet respond to the exceptionally intense autumn phytoplankton blooms in November 1998. Harpacticoida reached the summer maximum, the same as Nematoda, in July, two months after algal blooms (in May), while in the sparse Polychaeta the seasonal lag seems less distinct.

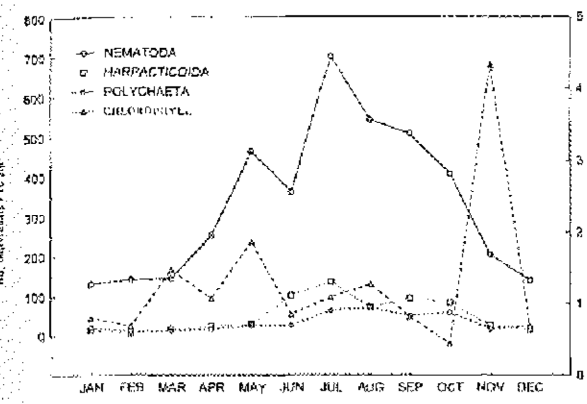

Fig. 4: Three year mean seasonal dynamic of dominant meiofaunal groups and phytoplankton (Chl a).
Sl. 4: Triletna srednja sezonska dinamika treh vodilnih skupin meiofavne in fitoplanktona (Chl a).

DISCUSSION

The results of the investigations carried out from 1996 to 1999 on seasonal and long-term meiofaunal variations in central part of the Gulf of Trieste showed fairly similar qualitative relations, seasonal cycles and the impacts of the ecological factors as some previously investigations in the same place in 1992-1995. As quantitative changes (by a third lower abundances) manifested themselves for already mentioned methodological reasons (sampling with gravity core instead of by diver), no direct comparisons between absolute abundances of both periods are possible.

Meiofaunal seasonality more or less confirmed the previously obtained characteristics, especially as far as most abundant groups are concerned, and less in respect of rarer species, where some greater "anomalous" deviations from seasonal pattern were noted. This problem, however, could be solved only with a selective sampling of substantially larger series of samples.

In Nematoda, Harpacticoida and Polychaeta their distinct summer culmination (particularly in July) follows the spring phytoplankton blooms (in May). In Nematoda a slight autumn rise is perceived after the July peak, which is also notable in Harpacticoida and especially in Polychaeta - in 1997, for example, very distinctly, and in other years very scantily. The three-year observations thus confirmed and more or less clarified the picture of seasonal changes in the investigated groups of the studied fauna.

The response of meiofauna to some ecological factors was similar to that in 1992-1995: positive Pearson's correlation coefficients with temperature and salinity, and negative coefficients with the oxygen content and pelagic chlorophyll. A special attention as far as the ecological factors are concerned deserves to be given particularly to plankton chlorophyll, especially in its relation to meiofauna. The already mentioned trophic links between meiofauna and primary producers (Vrišer, 1996) have been described by many studies (Blanshard, 1990; Fleeger *et al.*, 1989; Grant & Schwinghamer, 1987; Montagna *et al.*, 1995; Rudnick *et al.*, 1985).

In comparison with a one-month lag of meiofauna behind seasonal blooming cycle of benthic one-celled algae (as shown by a few years old data), the processes of sedimentation, accumulation and decomposition from one-celled pelagic algae into bacterial agglomerations and bottom organic detritus are probably responsible for a similar but greater two-month lag of the meiofaunal cycle behind the rhythm of phytoplankton. To confirm this thesis, a carefully planned and distinctly lasting study of simultaneous monitoring of environmental phytoplanktonic, phytobenthic and meiofaunistic components would be needed.

As no true hypoxic conditions occurred in the research period, this phenomenon could not be investigated anew. The oxygen level was therefore not critical even for hypoxically sensitive macrobenthos. From our earlier investigations as well as from literature (Dauer & Alden, 1995), a substantially greater meiobenthos' ability to survive in hypoxic conditions is known.

The seemingly illogical meiofauna's negative correlation with oxygen and phytoplankton chlorophyll is explainable with meiofauna's phase or seasonal lag: the curves of meiofauna, especially Nematoda, and of both ecological factors are almost in alternation!

We interprete our results that the seasonal cycles of meiofauna in the investigated area are directly controlled particularly by temperature, by oxygen more or less periodically in stressful hypoxic conditions, and indirectly and thus behind time by phytoplankton through complex processes of sedimentation and decomposition in direction from pelagic to benthic trophic levels, most probably in combination with other mechanisms, such as competition and predation.

Although the changed sampling methodology prevent us, as already said, to make direct comparisons with earlier abundances, the yearly mean values of the key groups and the whole show a 3-year rising trend in the meiofauna's abundance. This trend upwards indicate, in connection with the 3-year trend of decline established during earlier investigations, a first possible trace of long-term oscillations hiding behind the "curtain" of seasonal dynamics. For a clearer picture, at least a 10-year continued observations would be necessary.

For this very reason and for the sake of other already mentioned open questions, we shall resume the investigations in this particular sphere.

SEZONSKE IN VEČLETNE SPREMEMBE MEIOFAVNE V OKOLJU POGOSTO PRIZADETIM S HIPOKSIJAMI V OSREDNJEM DELU TRŽAŠKEGA ZALIVA

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POVZETEK

V triletnem obdobju 1996-99 smo z mesečno frekvenco raziskovali meiofavno v centru Tržaškega zaliva. Rezultati študije, ki je nadaljevanje starejših raziskav iz let 1992-95, so pokazali podobno sezonsko dinamiko in vpliv nekaterih ekoloških faktorjev na meiofavno. Prevladovali so Nematoda s 75% relativne abundance, sledili so Harpacticoida (12%) in Polychaeta (7%), preostalih 12 skupin je predstavljalo skupno 6%. Raziskave so nekoliko izostrile in dopolnile dosedanje poznavanje sezonskih sprememb meiobentosa, ki pri vodilnih skupinah kaže izrazito povišane poletne gostote in manjši jesenski maksimum. Opazili smo dvomesečni časovni zamik sezonskega cikla meiofavne za letnim ciklom fitoplanktona. Časovna razlika morda ustreza procesom sedimentacije in razgradnje fitoplanktona v organski detrit sedimenta kot pomembnega prehranjevalnega vira meiofavne. V raziskovanem obdobju ni bilo hipoksičnih razmer. Srednja enoletna povprečja celotne meiofavne in vodilnih skupin kažejo triletni trend naraščanja abundanc in tako sledijo triletnemu trendu upadanja, vidnega iz starejših opazovanj.

Ključne besede: sezonska dinamika, bentoška meiofavna, Tržaški zaliv

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