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Article

Zooplankton as an indicator of trophic conditions in marina basin, Tivat bay

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Abstract: This paper presents the results of zooplankton abundance on three sites in marina Porto Montenegro in Tivat Bay. The occurrence of protozoa *Noctiluca scintillans* during the spring month and cladocera *Penilia avirostris* during the summer months is significant. The maximum value of *Noctiluca scintillans* was 4096 ind/m^3, while *Penilia avirostris* reached 7632 ind/m^3. Gelatinous organisms generally did not have a significant contribution in total zooplankton, except the appearance of hydromedusa *Obelia* spp. in January, when it reached the maximum value of 70 ind/m^3. A total of 61 taxa in 11 zooplankton groups were recorded. The maximum value of Margalef's richness index was in winter, 3.93 while the minimum calculated value was in summer, only 1.34.

Keywords: water quality; zooplankton abundance; marina; diversity index

1. Introduction

When studying the distribution and seasonal cycles of marine zooplankton, researchers have to face the fact that the sea is a highly dynamic system with continuous movements and mixing of water masses. The most important factors that influence the quality of zooplankton are the depth of the water columns, the tropical status of a given area and the temperature regime [1]. The succession of species and groups of zooplankton, along with the changes in their abundance, during the year represents an integrated response of the ecosystem to the hydrometeorological conditions [2].

For instance, the temperature is a key parameter affecting organism physiology influencing respiration, feeding, growth rate, body size, and generation time. These effects of hydroclimatic forcing on plankton communities occur continually in the system (i.e. the effects over a generation time are transferred to the next generation).

Planktonic organisms also have a short generation time meaning a quick turn over, and the effects of environmental changes can rapidly cascade up the food web and affect the whole ecosystem [2]. Because of their sensitivity to hydroclimatic conditions and their capacity to quickly react to a changing environment, several studies have shown that plankton is useful indicators to monitor marine ecosystems, water masses and hydroclimatic changes [2].

Zooplankton is initially the main prey item for almost all fish larvae and represents their principal food resource, having a considerable influence on their survival, greater than temperature [3]. Thus, natural and anthropogenic factors, which can strongly affect zooplankton, can in turn also affect fish larvae survival and therefore breeding success and fish stocks. Porto Montenegro marina is under high anthropogenic influence. During one year the harbor was visited by more than 2200 yachts [4]. Montenegro is becoming a very important region for nautical tourism in the Adriatic Sea in recent years. Continuous monitoring of trophic state and introduced species in such area is elementary because it is necessary to determine the measure of pressure that the region can withstand without irreversible consequences for the environment.

2. Materials and Methods

Porto Montenegro is a harbour for luxury yachts and is situated within the eastern part of Tivat Bay in Boka Kotorska Bay (Montenegro). Harbour covers around 0.35 km2 of sea area, with 700 m length and 500 m width approximately. The maximum depth is around 13 m [4].

In the period from March 2015 to February 2016 research was conducted at three locations in marina Porto Montenegro in Tivat Bay.

Samplings of seawater for hydrographic analysis were taken monthly with 5-litre Niskin water sampling bottle at depths of 0.5 m and 5 m. The values of the main physical parameters were measured immediately after sampling using a MultiLine 4. Zooplankton samples were collected monthly by vertical tows using a 125-µm mesh Nansen plankton net (55 cm in diameter, 150 cm in length) at three fixed stations P0, P1 and P2. The collected zooplankton material was preserved in 4% formaldehyde-seawater solution. All zooplankton identifications were performed using a Nikon SMz800 stereomicroscope. Each sample was sub-sampled in the laboratory, depending on the abundance of individuals in the total sample. Zooplankton was counted from the representative sample of 1/64 of the total catch. After that, the entire material was carefully analyzed to record any less abundant species.

Figure 1. Map of sampling sites.

3. Results and Discussion

A seasonal pattern of temperature was noticed during the survey (Figure 2). The maximum temperature value was recorded in July 2016 (28.6 °C) at P0 location while the minimum was recorded in January 2016 (10.8 °C) at P2 location. Salinity values showed significant fluctuations with freshwater input what caused salinity decrease in October and February. Minimum value, 21.9 was recorded in February 2016. The maximum salinity value, 37.5, was noticed in the bottom layers in July 2015 December. Both mentioned values are related to the P2 location.

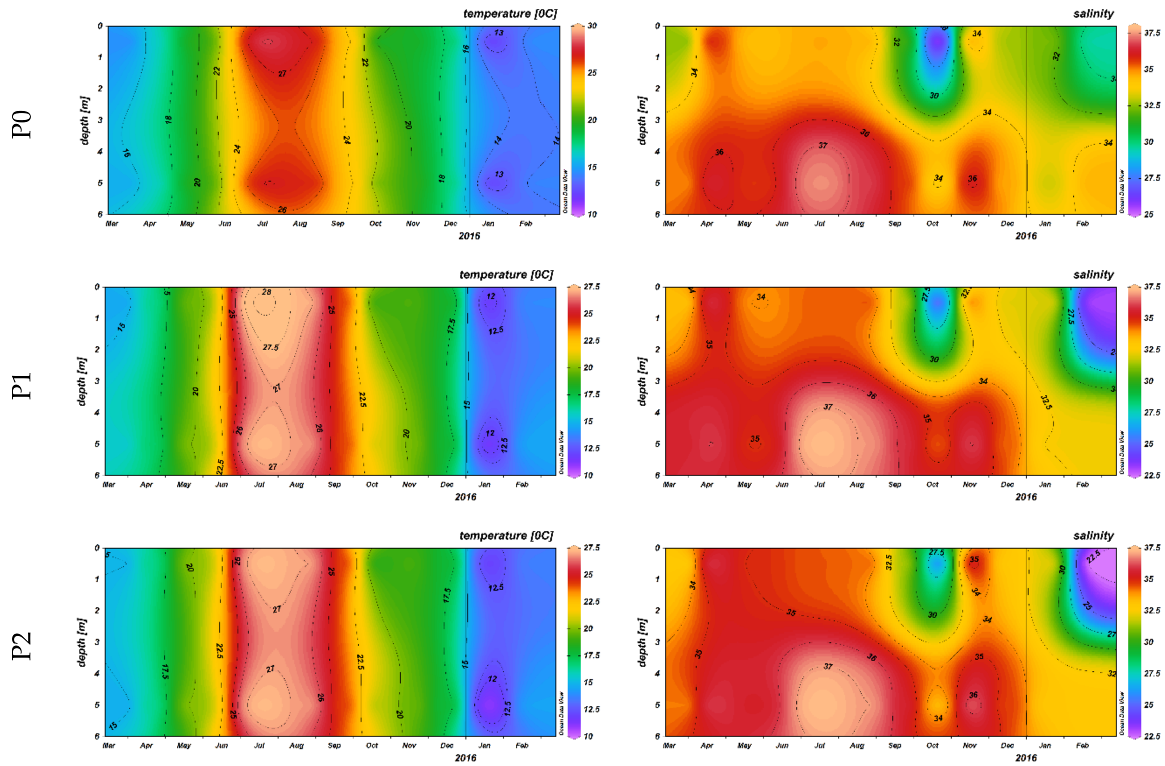

Figure 2. Temporal variability of temperature and salinity at investigated sites.

During the year-long monitoring in the Porto Montenegro marina, from March 2015 to February 2016, a total of 12 monthly samplings were performed at three permanent sampling sites, P0, P1 and P2. A total of 61 taxa in 11 zooplankton groups were recorded. Groups are Protozoa, Hydromedusae, Siphonophorae, Ostracoda, Cladocera, Copepoda, Pteropoda, Appendicularia, Chaetognatha, Thaliacea, and meroplanktonic organisms. The highest abundance, 10,819 ind/m^3 was recorded in August at site P2 (Figure 3).

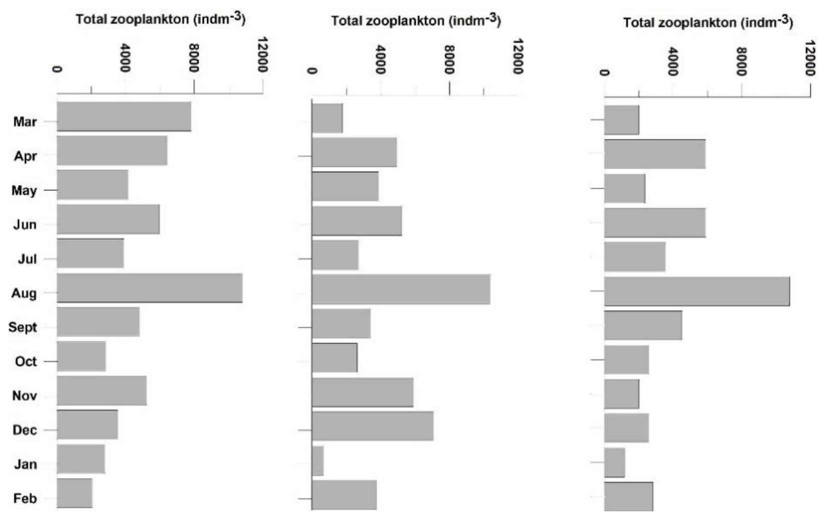

Figure 3. Temporal distribution of total zooplankton at three investigated sites.

Table 1. Simper analysis related to seasons.

Spring	Avg., ind/m³ [1]	Con., %	Cum., %
Noctiluca scintillans	1760.71	46.59	46.59
Evadne spinfera	241.78	8.68	55.27
Oithona nana	216.18	8.31	63.58
Acartia clausi	215.11	7.89	71.48
Penilia avirostris	151.82	5.58	77.06
Paracalanus parvus	190.58	5.57	82.63
Oithona similis	99.56	3.71	86.34
Oncaeidae like	56.89	2.89	89.22
Oikopleura longicauda	60.44	2.46	91.69
Summer	**Avg., ind/m³**	**Con., %**	**Cum., %**
Penilia avirostris	2755.79	55.14	55.14
Bivalvia	418.61	21.05	76.2
Euterpina acutifrons	205.51	6.34	82.54
Gastropoda	155.97	6.08	88.62
Centropages kroyeri	181.81	6.01	94.63
Autumn	**Avg., ind/m³**	**Con., %**	**Cum., %**
Penilia avirostris	696.38	39.43	39.43
Oithona nana	200.58	27.72	67.15
Oncaeidae like	205.1	6.19	73.34
Paracalanus parvus	61.92	5.42	78.75
Oithona similis	47.75	4.79	83.54
Euterpina acutifrons	63.54	3.13	86.67
Oikopleura longicauda	48.31	3.08	89.76
Evadne spinfera	43.1	2.87	92.63
Winter	**Avg., ind/m³**	**Con., %**	**Cum., %**
Oncaeidae like	625.22	41.58	41.58
Acartia clausi	139.42	9.39	50.97
Penilia avirostris	127.53	8.99	59.96
Oithona nana	95.76	8.4	68.36
Paracalanus parvus	56.38	4.68	73.04
Euterpina acutifrons	91.9	3.62	76.66
Centropages kroyeri	45.55	3.14	79.8
Bivalvia	81.54	2.98	82.78
Sagitta sp.	25.92	2.24	85.02
Oithona similis	21.37	1.99	87.01
Gastropoda	14.5	1.91	88.92
Oikopleura longicauda	48.57	1.51	90.43

[1] Avg - average abundance; Con - contribution; Cum - cumulative contribution.

Protozoan *Noctiluca scintillans* were dominant during the spring sampling period, with an average percentage ratio of 47% and the maximum value of 4096 ind/m^3 (Table 1). The flowering of *N. scintillans* in the north Adriatic in the 1970s was linked to eutrophication [5]. Values of the appearance of this species correspond with abundance previously recorded in the Tivat Bay [6], as well as the values recorded previously in the central Adriatic [7]. The availability of phytoplankton as potential prey is one of the main variability factors [8].

During the summer and autumn sampling periods, *Penilia avirostris* was the dominant species, with 55% and 40% mean percentage ratio in total zooplankton, respectively. *P. avirostris* is a typical thermophile species with an optimum fast growth temperature of 25 °C [9]. Along the eastern coast of the Bay, the highest values for this species don't exceed 10,000 ind/m^3. The abundance recorded in the Porto Montenegro marina falls within these limits, as the maximum recorded abundance of total cladocerans was 7632 ind/m^3 in August at P2 sampling site.

During the winter sampling period, taxon *Onceaidae*-like dominated in the total zooplankton, with 42% of the average percentage ratio. Apart from this group, cyclopoid *Oithona nana* was also abundant, as were the calanoid copepods *Acatria clausi* and *Paracalanus parvus*. *Penilia avirostris* was also recorded, but not in large numbers. Its unusual appearance was previously recorded in Boka Kotorska Bay [10] and can be tied to unusually high water temperatures in winter months and development of phytoplankton organisms as the potential prey for this cladoceran species.

Gelatinous organisms generally did not have a significant contribution in total zooplankton, except the appearance of hydromedusa *Obelia* spp. in January at site P2, when it reached the maximum value of 70 ind/m^3. Higher values for this species during winter months have been recorded previously in the Tivat Bay (up to 341 ind/m^3), which can be linked to periods of increased chlorophyll a concentration [11]. The appearance of an increased number of gelatinous organisms has a negative influence on the ecosystem state due to their high feeding capacity. Changes in composition and abundance of Hydromedusae can point to long-term faunistic and climate changes [12]. Occasional appearances of certain hydromedusae in high abundance, as well as their low relative percentage ratio in total abundance, can indicate a degradation of the ecosystem in this area. Such occurrences have been previously recorded in Boka Kotorska Bay [11].

Allochthonous species of siphonophores, *Muggiaea alantica*, dominated over the autochthonous species *Muggiaea kochi* in the Adriatic since 1996 [13], and this situation has been confirmed during this monitoring.

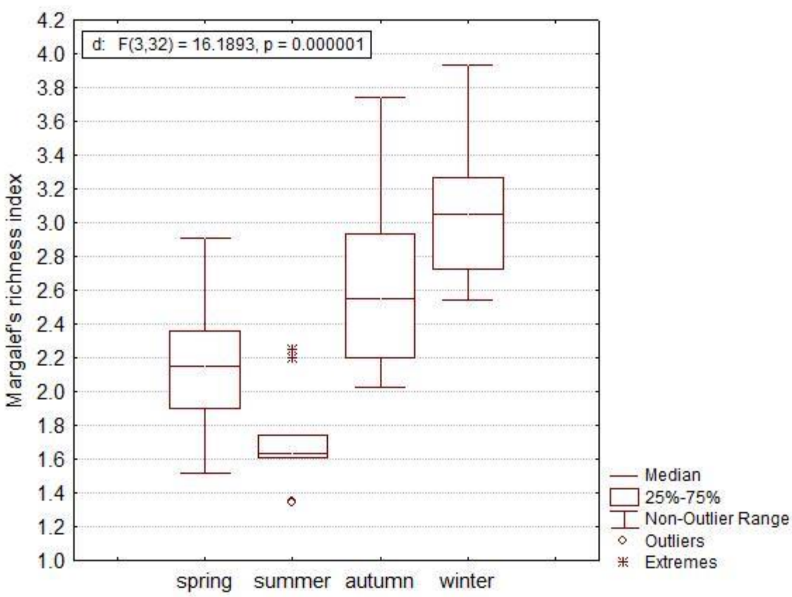

Figure 4. Margalef's richness index at investigated locations.

Even though the highest total abundance was determined in the summer, the diversity index shows that in the summer the least taxa concerning the abundance were recorded. The highest Margalef's richness index was calculated during the winter season reaching 3.93. The minimum value of Margalef's richness index was in summer, 1.34 because of the predomination of one species *Penilia avirostris*.

4. Conclusions

During the year-long monthly monitoring of zooplankton in the Porto Montenegro marina, no new species were identified. Montenegro, like many other countries in the Adriatic and Mediterranean, faces a growing problem caused by the introduction of new species. Since ports and harbors represent locations where such occurrences are generally first noted, continuous monitoring is necessary to register any changes in the ecosystem functioning.

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Conflicts of Interest: The authors declare no conflict of interest.

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