

Mediterranean Marine Science

Vol 20, No 4 (2019)

special issue



Plankton community of trafficked ports as a baseline reference for Non Indigenous Species arrivals. Case study of the Port of Bar (South Adriatic Sea)

MILICA MANDIĆ, BRANKA PESTORIĆ, OLIVERA MARKOVIĆ, MIRKO DUROVIĆ, DRAGANA DRAKULOVIĆ

doi: [10.12681/mms.19135](https://doi.org/10.12681/mms.19135)

To cite this article:

MANDIĆ, M., PESTORIĆ, B., MARKOVIĆ, O., DUROVIĆ, M., & DRAKULOVIĆ, D. (2019). Plankton community of trafficked ports as a baseline reference for Non Indigenous Species arrivals. Case study of the Port of Bar (South Adriatic Sea). *Mediterranean Marine Science*, 20(4), 718–726. <https://doi.org/10.12681/mms.19135>

This paper was presented at “12th Panhellenic Symposium of Oceanography & Fisheries”, which was held at the Ionian University, Corfu, from 30th May to 3rd June 2018

Plankton community of trafficked ports as a baseline reference for Non Indigenous Species arrivals. Case study of the Port of Bar (South Adriatic Sea)

Milica MANDIĆ, Branka PESTORIĆ, Olivera MARKOVIĆ, Mirko ĐUROVIĆ and Dragana DRAKULOVIĆ

University of Montenegro, Institute of Marine Biology, Kotor, Montenegro

Corresponding author: mamilica@ucg.ac.me

Handling Editor: Christos ARVANITIDIS

Received: 27 November 2018; Accepted: 30 September 2019; Published on line: 18 October 2019

Abstract

Plankton (ichthyoplankton, zooplankton and phytoplankton) communities were studied in the temperate, shallow waters of the Port of Bar, one of the main cargo ports on the south-eastern Adriatic coast. Sampling was undertaken in February, April, June and October of 2015 at 12 stations using the BALMAS Port Baseline Survey protocol. The research was conducted to determine the presence of invasive and potentially toxic plankton species in the port as a result of the discharge of ballast water by ships. The most dominant species of ichthyoplankton were the eggs and larvae of the families Engraulidae, Bothidae and Sparidae, with a dominance of *Engraulis encrasicolus*, *Arnoglossus laterna* and *Diplodus annularis*. In addition to ichthyoplankton, sampling of phytoplankton and zooplankton was performed to assess the abundance and diversity of the species.

The most numerous zooplankton species throughout the investigated period were *Penilia avirostris*, *Euterpina acutifrons*, *Oithona nana*, *Acartia clausi*, *Centropages kroyeri*, *Paracalanus parvus*, Oncaeidae and the larvae of *Bivalvia*. One very unusual occurrence was the spawning of parrotfish, *Sparisoma cretense* (Linnaeus, 1758), a species with Atlantic origins and tropical affinities, whose presence throughout the Mediterranean has shown an increasing trend over the last decade. The most dominant species of phytoplankton were the diatoms *Chaetoceros affinis* and *Chaetoceros* spp., *Asterionellopsis glacialis*, *Pseudo-nitzschia* spp., *Thalassionema nitzschioides*, and the dinoflagellates *Gymnodinium* spp. and *Prorocentrum triestinum*. Potentially toxic species from the genus *Pseudo-nitzschia* reached an abundance of 10^4 cells L^{-1} . The toxic dinoflagellates *Prorocentrum cordatum* and *P. micans* reached values of 10^3 cells L^{-1} .

Although there were no HAOP species found during the survey, the presence of several potentially toxic and toxic phytoplankton species, whose impact is not sufficiently known, indicates the necessity of introducing regular monitoring activities and defining preventive protection measures.

Keywords: Fish eggs and larvae; zooplankton; phytoplankton; ballast water management; Adriatic Sea.

Introduction

Qualitative and quantitative analysis of the composition and diversity of species assemblages in the marine ecosystem is the basis for understanding the quality of the environment and the establishment of possible measures for its protection and improvement. The research of plankton communities, as an essential component of the monitoring of the marine ecosystem in the cargo port, aids the assessment of the state of the marine environment. In addition, it allows for monitoring of the entry of non-indigenous species, since maritime traffic is one of the primary pathways for introducing non-indigenous marine organisms (Barnes, 2002; Davidson *et al.*, 2009;

Mineur *et al.*, 2009; Wanless *et al.*, 2010). The impact of maritime transport on marine ecosystems in ports includes changes in water quality, changes in coastal hydrology, elevated noise levels and benthic contamination (Walker *et al.*, 2019).

With the aim of preventing, minimising and ultimately eliminating the risk to the environment, human health, property and resources from the transfer of harmful aquatic organisms and pathogens via ships' ballast waters and related sediments, the *International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention)* was adopted in 2004. Based on the requirements of the Convention and its additional Guidelines, and within the framework of the

European project BALMAS (Ballast Water Management System for Adriatic Sea Protection) the BALMAS Port Baseline Survey protocol was drawn up (Ninčević *et al.*, 2014). One of the main tasks of this research was to use the BALMAS Port Baseline Survey protocol to conduct research in the Port of Bar, which is defined as a particularly sensitive area for the introduction of harmful aquatic organisms and pathogens (HAOP). More than 1,000 alien species have been identified in Europe's seas (Werschkun *et al.*, 2014). Vilà *et al.* (2009) identified a list of the 100 most impacting species introduced into European waters. The transfer of invasive species occurs not only over larger distances, between continents, but also as a secondary spread in regional seas (David *et al.*, 2013). Few investigations regarding plankton communities have been conducted in the 12 ports of the Adriatic Sea, including the Port of Bar (Možetič *et al.*, 2017; Vidjak *et al.*, 2018).

The aim of this study is: to assess the biological status of plankton communities as an indicator of the health of the marine ecosystem; to determine the presence of non-indigenous, toxic and potentially toxic species in the water of the port as a consequence of ballast water discharge or pollution. The main goal is to contribute to the implementation of a monitoring system for ballast water and to propose adequate management measures for the protection and improvement of the quality of the marine ecosystem.

Study area

The Port of Bar (Fig. 1) is a moderately developed seaport located in the southern Adriatic Sea. It is a port of national importance and one of the most important cargo ports on the south-eastern Adriatic coast. It has a significant competitive advantage over the northern Adriatic ports, shortening the transit time and creating savings in the cost of maritime transport. It was established in 1909, while its present form was redeveloped in 1983, when a trans-shipment terminal was installed with a capacity of 4.5 million tons of cargo per year, representing about a

third of the port's projected capacity (Feasibility Study for the Port of Bar, 28 June 2014). The Port of Bar is a joint stock company, whose main business is handling and storing goods. The long-term operations of the port and the significant number of ships have caused a relatively high risk of introducing non-indigenous species through ballast waters.

Material and Methods

The sampling of plankton was carried out during 2015 (February, April, June and October). The sampling methodology of ichthyoplankton required the use of a WP2 plankton net with a mesh size of 300 μm . According to the Protocol, the sampling was performed at four predetermined stations (Fig. 1, Table 1), with the proviso that from each main position another two samples were taken at a distance of 10–15 m (a total of 12 stations were analysed during each season). Conductivity, temperature and pressure were recorded from the water column profile at each of the investigated stations. Zooplankton was sampled with a 125- μm mesh Nansen plankton net (55 cm in diameter, 150 cm in length). At each station, ichthyoplankton and zooplankton samples were collected through vertical net hauls in order to analyse the qualitative and quantitative composition. After sampling, the ichthyoplankton and zooplankton material was preserved in a 4% buffered formaldehyde solution.

The ichthyoplankton material was sorted using

Table 1. Geographical coordinates of 4 main sampling stations (WGS system).

Station	Latitude [degrees north]	Longitude [degrees east]
P1	42.05551°	19.05384°
P2	42.05155°	19.05019°
P3	42.05621°	19.04734°
P4	42.05811°	19.04831°

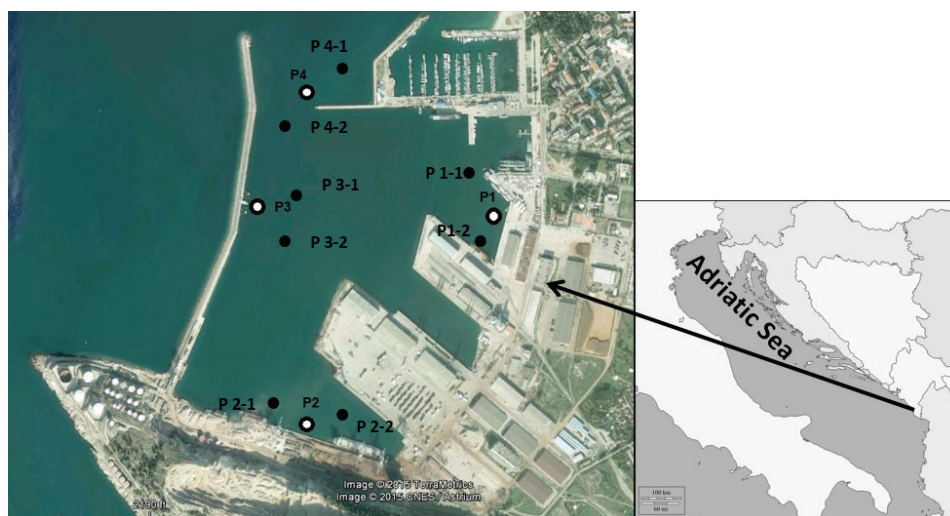


Fig. 1: Study area (Port of Bar) with 4 main sampling stations (white circles, P1-P4) and 8 additional stations (black circles, P1-1, P4-2).

NIKON SMZ 800 binocular equipped with a MOTIC camera. Determination of the material was made at the species level, and in cases when this was not possible, determination was done just at the genus level. The number of eggs, larvae and postlarvae was expressed as the number of individuals per m² of the sea surface, using the formula given by Tanaka (1973). Each sample of zooplankton was subsampled in the laboratory, depending on the abundance of individuals in the total sample. Zooplankton was counted from a representative sample of 1/64 of the total catch. After that, the entire material was carefully analysed in order to record any rare species. Zooplankton was presented as the number of individuals per m³.

Phytoplankton was sampled with 5-litre Niskin bottles, at three depths: the surface, middle and bottom (0.5 m, 5 m and 10 m, respectively). The samples were preserved in 250-ml plastic bottles using a 3% neutralized formaldehyde solution.

At each station micro-phytoplankton (>20 µm) was collected by vertical tows using a phytoplankton net with a mesh size of 20 µm for qualitative analysis. Another net sample was obtained by a horizontal tow at a depth of approximately 2 m. Samples for the determination of chlorophyll *a* were also collected at three depths: the surface, middle and bottom at each position using a 5-litre Niskin bottle.

Phytoplankton cells were identified and counted using a Leica DMI4000 B inverted microscope (Heerbrugg, Switzerland) in subsamples of 25 ml after 24 hours of sedimentation, following Utermöhl (1958). Enumeration was carried out using phase contrast and bright field illumination at magnifications of 100, 200 and 630×. At a 100× magnification, the entire chamber bottom was scanned for taxa larger than 30 µm, while abundant micro-phytoplankton (>20 µm) was counted at two transects at a magnification of 200×. The cell abundance was expressed by the number of cells/L. Due to the very shallow waters in the port (6-15 m), all the samples were taken at a maximum depth of 10 m.

Data analysis

The similarity between the most dominant plankton species was analysed using clustering analyses based on the Bray-Curtis similarity metric, applying a comparison of the abundance data. The Spearman's rank correlation routine in the Primer 5.0 computer package was used to identify the species that contributed most to the Bray-Curtis similarities of stations within the identified station groupings. The plankton community structure was linked to environmental variables (temperature and salinity) using Spearman's Rank Order Correlation. This analysis compares ordinations from abiotic configurations and selects the subset of environmental variables that provides the best match with the species presence.

The diversity of plankton communities was analysed using the Shannon diversity index (*H'*). Diversity indices are measures of community attributes that are often used

as indicators of the environmental conditions (Clarke & Warwick, 1994). Diversity analysis was carried out for each investigated position on the basis of the season. The Shannon diversity index allowed the individuation of the importance of rare species in the sample. It was calculated according to the following formula (Krebs, 1999):

$$H' = - \sum_{i=1}^s (p_i) (\log_2 p_i)$$

where *p_i* is the proportion of the *i*-th species in the sample, and *s* is the number of species in the sample. The value of the Shannon index increases with an increasing number of species. In practice it has been shown that for biological communities the value of *H'* does not exceed 5.0 (Krebs, 1999).

Results

A total of 17 species of pelagic eggs and the larvae of fish belonging to 11 families were found during the investigated period (Table 2).

The dominant species of ichthyoplankton were the eggs and larvae of the families Engraulidae, Bothidae and Sparidae, with an abundance of 5–56 eggs m⁻² for *Engraulis encrasicolus*, 5–41 eggs m⁻² for *Diplodus annularis* and 5–36 eggs m⁻² for *Arnoglossus laterna*.

In February 2015, from a total of 12 samples, the early development stages of fish were found in only two samples with a very low abundance (3.3 eggs/larvae m⁻²). All the other samples were negative for ichthyoplankton,

Table 2. List of ichthyoplankton species by season (x, presence in the samples).

Species	February	April	June	October
<i>Arnoglossus laterna</i>	x	x	x	
<i>Buglossidium luteum</i>		x		
<i>Callionymus pusillus</i>			x	
<i>Callionymus risso</i>	x			
<i>Centrolophus niger</i>			x	
<i>Diplodus annularis</i>		x	x	
<i>Engraulis encrasicolus</i>			x	
<i>Gobius</i> sp.				x
<i>Lithognathus mormyrus</i>			x	
<i>Mullus</i> sp.			x	
<i>Sciaena umbra</i>			x	
<i>Scomber japonicus</i>				x
<i>Scomber scombrus</i>				x
<i>Scophthalmus maximus</i>		x		
<i>Serranus scriba</i>			x	
<i>Sparisoma cretense</i>				x
undetermined			x	

which was expected due to the relatively low depths at which sampling was carried out (6–10 m). In April 2015, eight stations tested positive for the presence of the early life stages of fish, while in July all the samples tested positive for ichthyoplankton with a higher degree of diversity and abundance in the range of 3.3–26.6 eggs/larvae m⁻². The most dominant species were *D. annularis* and *A. laterna*. In October, only six stations tested positive for ichthyoplankton with the presence of *Sparisoma cretense*, *Scomber scombrus*, *S. japonicus* and larvae of *Gobius sp.* During the October spawning the intensity was very low (3.3 eggs/larvae m⁻²).

The qualitative and quantitative analyses of the zooplankton species composition showed the presence of 60 different species. The most abundant (more than 90% of the total) were *Penilia avirostris* (1–794 individuals m⁻³), *Euterpina acutifrons* (4–368 ind. m⁻³), *Oithona nana* (8–144 ind. m⁻³), *Acartia clausi* (4–112 ind. m⁻³), *Centropages kroyeri* (2–96 ind. m⁻³), *Paracalanus parvus* (3–96 ind. m⁻³), Oncaidae (13–341 ind. m⁻³) and the larvae of *Bivalvia* (4–192 ind. m⁻³) (Table 3).

The qualitative and quantitative analyses of the phytoplankton species composition showed the presence of 141 different species. The most dominant species of phytoplankton were the diatoms *Chaetoceros affinis* and *Chaetoceros spp.* which reached 10⁵ cells L⁻¹. *Asterionellopsis glacialis*, *Pseudo-nitzschia spp.* and *Thalassionema nitzschiioides* reached abundances of up to 10⁴ cells L⁻¹. The dinoflagellates *Gymnodinium spp.* and *Prorocentrum triestinum* reached abundances of up to 10⁴ cells L⁻¹. Potentially toxic species from the genus *Pseudo-nitzschia* reached an abundance of 10⁴ cells L⁻¹. The toxic dinoflagellates *Prorocentrum cordatum* and *P. micans* reached values of 10³ cells L⁻¹ (Table 4). For phytoplankton and zooplankton, only the dominant species were presented.

Table 3. Dominant zooplankton species (in order of contribution, %).

Species	% of contribution	min (ind. m ⁻³)	max (ind. m ⁻³)
<i>Penilia avirostris</i>	16.77	1	793.6
<i>Euterpina acutifrons</i>	16.22	4	368
Oncaidae	13.42	15	350
Bivalvia larvae	10.58	4	400
<i>Acartia clausi</i>	5.17	4	112
<i>Oithona nana</i>	4.67	24	144
<i>Paracalanus parvus</i>	4.18	4	96
<i>Centropages kroyeri</i>	4.07	2	140.8
Gastropoda larvae	3.64	4	85.3
<i>Oithona similis</i>	2.93	0.5	96

Environmental data

The hydrographical data was processed in the Ocean Data View software package (Schlitzer, 2018). Comparative analysis of the data for temperature and salinity showed no anomalies caused by the inflow of water from rivers, underground sources or changes in salinity and surface temperature caused by precipitation. The sea water temperature varied from 11.4°C to 23.3°C, depending

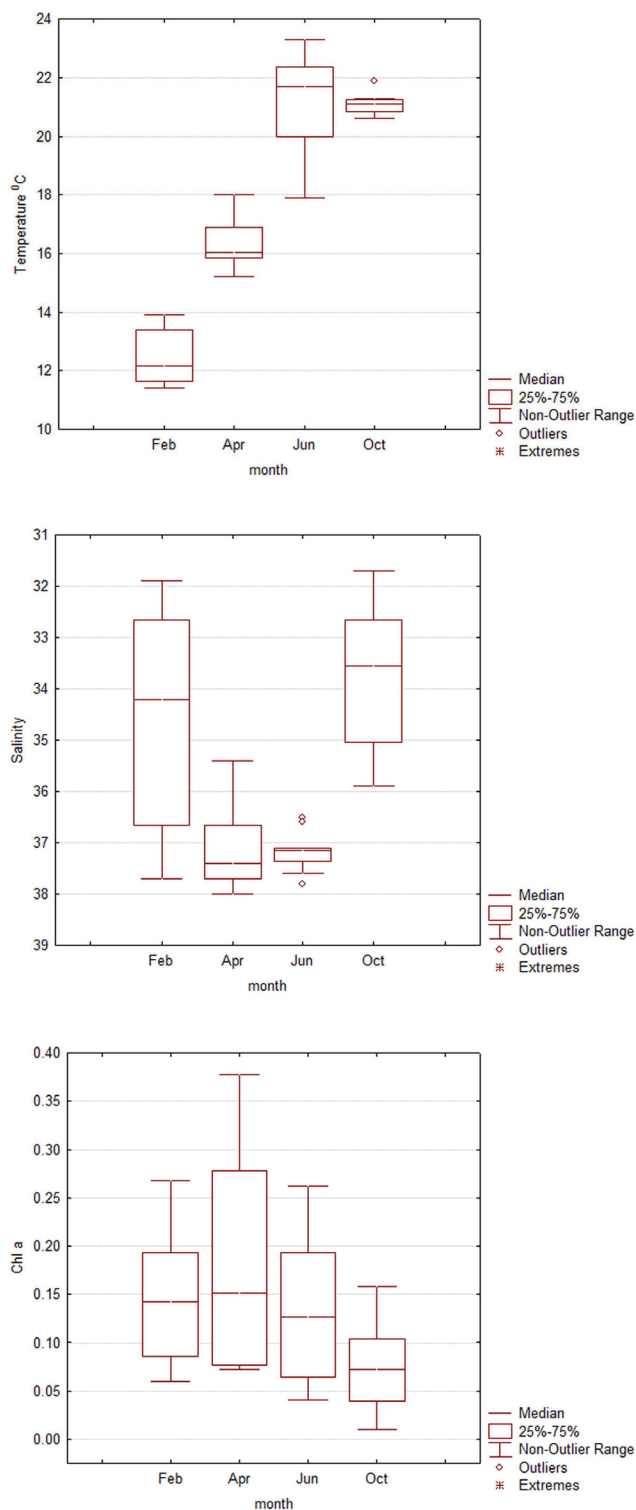


Fig. 2. Box plot diagram – Temperature (T °C), Salinity (PSU) and Chlorophyll a (mg/m3) variations according to seasons.

Table 4. Dominant phytoplankton species (in order of contribution % and presence in different part of water column. surf – surface; midd – middle; bott – bottom).

Species	water column	% of contribution	min cells/L	max cells/L
<i>Chaetoceros</i> spp.	surf	17.14	3,140	154,645
<i>Chaetoceros affinis</i>	surf	8.69	1,570	100,480
<i>Pseudo-nitzschia</i> spp.	surf	5.26	706	22,765
<i>Gymnodinium</i> spp.	surf	3.70	600	41,605
<i>Bacteriastrum hyalinum</i>	surf	3.22	200	49,455
<i>Asterionellopsis glacialis</i>	surf	2.87	480	28,560
<i>Prorocentrum triestinum</i>	surf	1.94	40	32,185
<i>Thalassionema nitzschioides</i>	surf	0.85	640	7,080
<i>Calyptrosphaera oblonga</i>	surf	0.85	523	9,420
<i>Chaetoceros danicus</i>	surf	0.66	10,990	11,775
<i>Chaetoceros</i> spp.	midd	10.38	1,570	71,435
<i>Chaetoceros affinis</i>	midd	4.17	360	29,830
<i>Pseudo-nitzschia</i> spp.	midd	3.73	1,570	21,195
<i>Asterionellopsis glacialis</i>	midd	3.10	1,000	30,160
<i>Bacteriastrum hyalinum</i>	midd	2.28	440	32,185
<i>Thalassionema nitzschioides</i>	midd	1.05	600	7,720
<i>Calyptrosphaera oblonga</i>	midd	1.04	523	7,850
<i>Gymnodinium</i> spp.	midd	1.00	785	7,605
<i>Chaetoceros danicus</i>	midd	0.59	7,065	13,345
<i>Rhabdosphaera tignifer</i>	midd	0.43	785	7,065
<i>Chaetoceros</i> spp.	bott	6.80	1,570	65,155
<i>Pseudo-nitzschia</i> spp.	bott	4.45	785	33,755
<i>Chaetoceros affinis</i>	bott	4.15	120	51,025
<i>Thalassionema nitzschioides</i>	bott	0.87	520	4,640
<i>Bacteriastrum hyalinum</i>	bott	0.75	4,710	21,195
<i>Asterionellopsis glacialis</i>	bott	0.53	1,600	6,760
<i>Gymnodinium</i> spp.	bott	0.48	785	4,710
<i>Calyptrosphaera oblonga</i>	bott	0.36	1,570	3,140
<i>Navicula</i> spp.	bott	0.35	280	3,400
<i>Syracosphaera pulchra</i>	bott	0.22	785	3,140

on the investigated season, while the salinity ranged from 31.7 to 38.0 PSU (Fig. 2). Although the investigation was conducted in shallow water, fluctuations of salinity in the entire water column were observed, which extended from the surface down to a depth of 12 m.

The value of chlorophyll *a* ranged from 0 to 0.378 mg/m³ with a fluctuation from the surface to the maximum sampling depth, without any regular changes in relation to depth. The box plot diagram showed no statistically significant differences in the values of temperature ($p = 0.9591$), salinity ($p = 0.8759$) and chlorophyll *a* ($p = 0.0511$) between stations, such differences were obvious between seasons ($p = 0.001$, $p = 0.00000003$ and $p = 0.0176$, respectively) (Fig. 2).

Data analysis

Analysis of the diversity index shows the average diversity during each season. The value of the Shannon index was 0.56–1.86, 1.79–2.45 and 1.32–2.18 for ichthyoplankton, zooplankton and phytoplankton, respectively (as an average value per station) (Fig. 3).

Analysis of Spearman's rank correlation (Table 5) between the species abundance and environmental factors (temperature and salinity) showed a positive correlation ($p < 0.01$) with temperature for *Chaetoceros* spp., *Pseudo-nitzschia* spp. and *P. avirostris*, while a positive correlation with salinity was evident only for *Gymnodinium* spp and *A. laterna*. The dendrogram of the Bray-Curtis similarity showed an important similarity between the samples for October and June and for February and April (Fig. 4).

Table 5. Spearman's Rank Order Correlation between dominant species and main environmental parameters (in order of correlation).

Spearman's Rank Order Correlation	Temperature (°C)	Salinity
<i>Gymnodinium</i> spp.	0.518*	0.655**
<i>Engraulis encrasicolus</i>	0.552*	0.599*
<i>Diplodus annularis</i>	0.522*	0.537*
<i>Penilia avirostris</i>	0.851***	0.176
<i>Chaetoceros</i> spp.	0.658**	-0.155
<i>Chaetoceros affinis</i>	0.634**	-0.160
<i>Pseudo-nitzschia</i> spp.	0.685**	-0.275
<i>Arnoglossus laterna</i>	0.072	0.625**
<i>Euterpina acutifrons</i>	0.497*	-0.109
<i>Serranus scriba</i>	0.345	0.161
<i>Oithona nana</i>	0.144	-0.179
<i>Bacteriastrum hyalinum</i>	0.138	-0.051
<i>Oncaeidae</i>	-0.215	0.258
<i>Acartia clausi</i>	-0.219	0.162
<i>Callionymus risso</i>	-0.431	0.239
<i>Bivalvia</i> larvae	-0.452	0.399

*p < 0.05; **p < 0.01; ***p < 0.001

Discussion

This research was done in order to assess the presence of non-indigenous and/or potentially toxic species of ichthyoplankton, zooplankton and phytoplankton. Although it was conducted in a very small part of the Port of Bar and there were no occurrences of HAOP species in the investigated area, it provides quality recommendations for

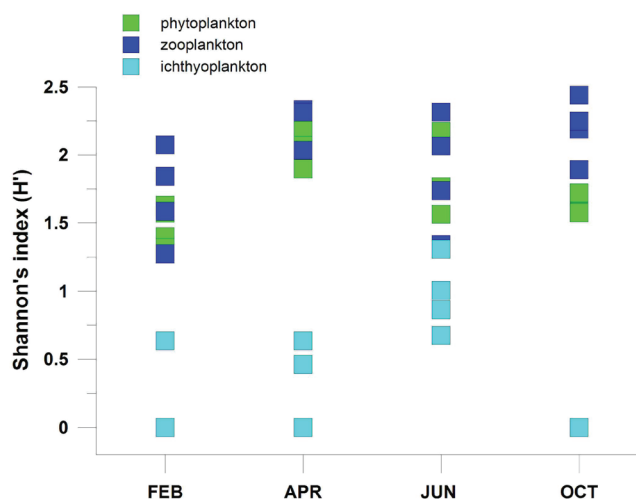


Fig. 3: Shannon index for ichthyoplankton, zooplankton and phytoplankton (average values for all investigated stations).

the improvement of the port's management measures in improving the ecological status, especially in the case of ballast water monitoring. Plankton samples were taken in order to form a baseline study of the communities before starting ballast water monitoring in ships' tanks.

The qualitative and quantitative composition of ichthyoplankton showed a relatively low rate of diversity, except during June. By comparing the research with other Mediterranean areas, and taking into account the limitations of the investigated area – the very shallow waters and a small number of stations – it can be concluded that the general diversity of ichthyoplankton was high, although the spawning intensity was very low during the autumn and winter periods. In the Mar Menor lagoon in south-east Spain, a study of the qualitative and quantitative composition of ichthyoplankton at 20 positions during monthly sampling showed the presence of

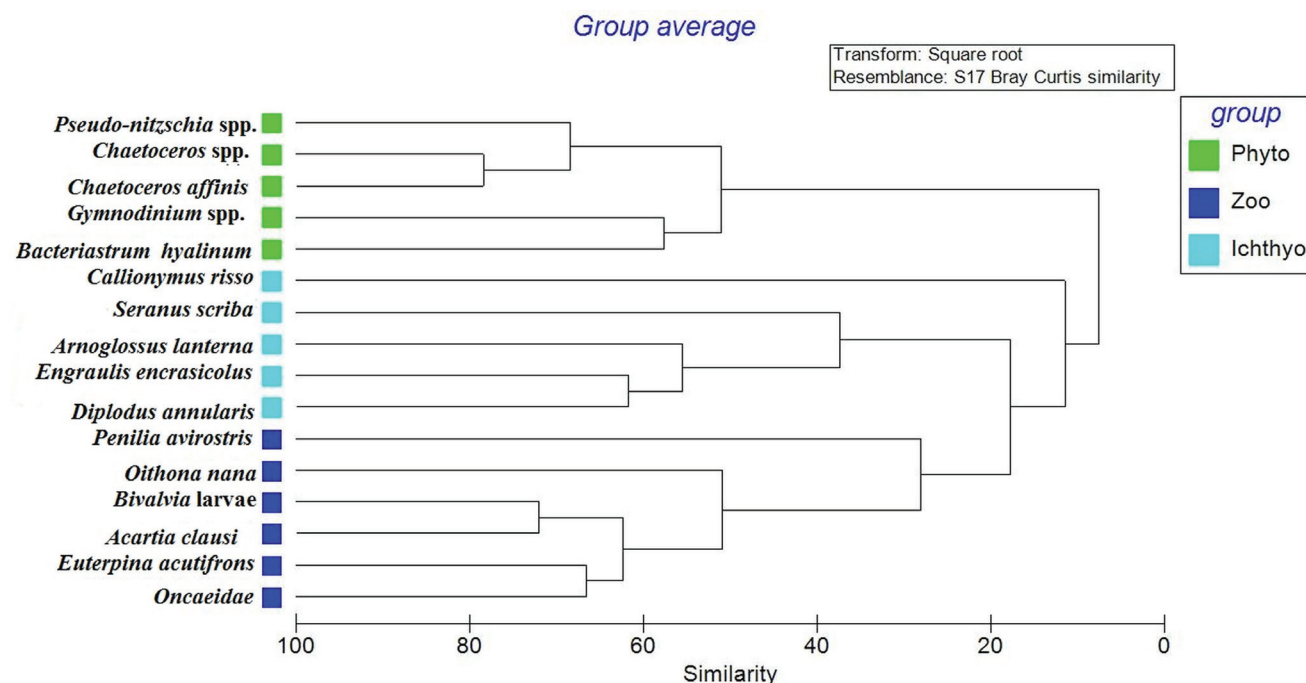


Fig. 4: Cluster analysis of all sampling seasons related to different plankton communities

36 species from 14 families in the lagoon's waters (Perez-Ruzafa *et al.*, 2004). In the Boka Kotorska Bay, during a three-year seasonal research on the abundance and diversity of ichthyoplankton, the presence of 35 different species was determined (Mandić *et al.*, 2014). In the harbour area of Porto Montenegro (Boka Kotorska Bay, south Adriatic Sea) a similar diversity of ichthyoplankton species was recorded (Pestorić *et al.*, 2018). Larval fish communities and their spatial distribution are the result of adult spawning strategies and environmental influences (Franco-Gordo *et al.*, 2008; Sabatés *et al.*, 2007). This can also be influenced by the specificity of the study area, i.e. the vicinity of the coast and continental runoff and upwelling areas (Matsuura, 1996; Lopes *et al.*, 2006). It can be concluded that the small area of the Port of Bar and the protection from the wind play a significant role in the spatial distribution and retention of ichthyoplankton. Poor water circulation, the effect of the waves or winds (as important factors that influence the dispersion of the early development stages of fish) are limiting factors for the aggregation of adult fish and their spawning in the port area. Despite the low intensity and unfavourable conditions for spawning (different sources of pollution, noise and disturbance of the seafloor due to anchoring, as well as other port activities), there were still a significant number of different fish species found during the survey. The seasonal pattern of abundance and diversity of ichthyoplankton is consistent with the occurrence of seasonality in other (non-port) seas (Li *et al.*, 2014).

What is very interesting is the occurrence of the larval stages of *Sparisoma cretense*. This species has an Atlantic origin and tropical affinities, with its presence in the Adriatic confirmed in 2000 (Dulčić & Pallaoro, 2001; Guidetti & Boero, 2001). Its growing presence along the entire Mediterranean coast during the last decade is considered as an indicator of tropicalisation (Kruschel *et al.*, 2012; Astruch *et al.* 2016). It is very likely that this species has established its population and that spawning is only a confirmation of the favourable environmental conditions for growth, development, nutrition and reproduction in the area of the south Adriatic coast, and likely in the wider area. It is important to stress that, for the purpose of better comparability of the data with other similar research areas, it is necessary to standardise the sampling methodology of ichthyoplankton. This would require using a WP2 plankton net with a mesh size of 200 µm (instead of 300 µm), which is commonly used for vertical sampling of ichthyoplankton.

In the case of zooplankton, among the most dominant species during this investigation were species of the genera Cladocera and Copepoda. As in other coastal areas, the species from those genera are usually dominant in mesozooplankton (Vidjak *et al.*, 2006; Vidjak *et al.*, 2007; Pestorić *et al.*, 2017). They play a very important trophodynamic role due to fact that they are food for carnivorous plankton (especially fish larvae and pelagic fish species) (Cheng & Chao, 1982; Beaugrand *et al.*, 2003). Many studies have shown that zooplankton can be used as indicator for monitoring the state of a marine ecosystem during a period of climate change (Beaugrand *et al.*,

2003; Eloire *et al.*, 2010).

In the majority of plankton studies, salinity and temperature have been shown to be among the most important parameters affecting the distribution and abundance of plankton (Harris *et al.*, 2000; Esteves *et al.*, 2000; Mouny & Dauvin, 2002; Beaugrand *et al.*, 2003). This study confirmed the correlation of certain species with temperature and salinity. Since it was a very shallow and confined area, variability of the environmental parameters was expected to be more intense than in the open sea (Belmonte *et al.*, 2013).

Although there were no HAOP species found during the present survey, several phytoplankton genera (*Pseudo-nitzschia* spp., *Prorocentrum cordatum* and *P. micans*), which are toxic and/or potentially toxic, indicate the necessity of establishing measures for the regular monitoring of the port in order to define preventive protection measures. Those species were dominant throughout the water column (surface, middle and bottom) and their harmful effect is still not known. Potentially toxic diatom species from the genus *Pseudo-nitzschia* are permanently present in the phytoplankton community in the Mediterranean and in the Adriatic Sea (Orsini *et al.*, 2002; Quiroga, 2006; Bosak *et al.*, 2009; Drakulović *et al.* 2012; Drakulović *et al.* 2016; Drakulović *et al.*, 2017). Species from this genus are able to produce domoic acid, which is responsible for amnesic shellfish poisoning (ASP) (Bates *et al.*, 1998). The composition of domoic acid, its distribution and relation with physico-chemical parameters still needs to be clarified, and some domoic acid records have even been confirmed in the northern Adriatic (Marić *et al.*, 2011).

In addition to the current proposed monitoring of the invasive and non-indigenous species, it is crucial to monitor the total diversity of species for the purpose of comparative analysis, preventive measures and improvement of the ecological status of the port. In order to prevent the risk of introducing non-indigenous, potentially toxic or toxic species through ballast water, it is important to regularly monitor plankton communities throughout the port and the wider area. Only a long-term data series, or a search for resting stages in the sediment, could indicate the real state of the diversity and abundance of species, as well as the connection between plankton communities in relation to the environmental conditions and possible sources of pollution.

Acknowledgements

This work was supported by European funds through IPA Strategic project "Ballast water management system for the Adriatic Sea Protection - BALMAS" No 1°str./0005

References

Astruch, P., Bonhomme, P., Goujard, A., Rouanet, E., Boudourisque, C. *et al.*, 2016. Provence and Mediterranean warm-

- ing: the parrotfish *Sparisoma cretense* is coming. *Rapports de la Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée* 41, 362.
- Barnes, D.K.A., 2002. Invasions by marine life on plastic debris. *Nature*, 416, 807-808.
- Bates, B.B., Garrison, D.L., Horner, R.A., 1998. Bloom dynamics and physiology of domoic acid producing *Pseudo-nitzschia* species. In Anderson, D.M., Cembella, A. D., Hallegraeff, G.M., (Eds.), *Physiological Ecology of Harmful Algal Blooms* Springer-Verlag, Berlin. 267-292.
- Beaugrand, G., Brander, K.M., Lindley, J.A., Souissi, S., Reid, P.C., 2003. Plankton effect on cod recruitment in the North Sea. *Nature*, 426, 661-664.
- Belmonte, G., Vaglio, I., Rubino, F., Alabiso, G., 2013. Zooplankton composition along the confinement gradient of the Taranto Sea System (Ionian Sea, south eastern Italy). *Journal of Marine Systems*, 128, 222-238.
- Bosak, S., Burić, Z., Đakovac, T., Viličić, D., 2009. Seasonal distribution of plankton diatoms in Lim Bay, northeastern Adriatic Sea. *Acta Botanica Croatica*, 68, 351-365.
- Cheng, C., Chao, W.C., 1982. Studies on the marine Cladocera of China II. Distribution. *Acta Oceanologica Sinica*, 4, 731-74.
- Clarke, K.R., Warwick, R.M. 1994. Change in marine communities: an approach to statistical analysis and interpretation. Plymouth, UK: PRIMER-E Ltd.
- David, M., Gollasch, S., Pavliha, M., 2013. Global ballast water management and the “same location” concept – a clear term or a clear issue? *Ecological Applications* 23, 331-338.
- Davidson, I.C., Sytsma, M., Ruiz, G., 2009. Ship fouling: a review of an enduring worldwide vector of nonindigenous species. Report to the California State lands Commission, Marine Invasive Species Program, Sacramento, California. 47 pp.
- Drakulović, D., Pestorić, B., Cvijan, M., Krivokapić, S., Vuksanović, N. 2012. Distribution of phytoplankton community in Kotor Bay (south-eastern Adriatic Sea). *Central European Journal of Biology*, 7 (3), 470-486.
- Drakulović, D., Pestorić, B., Kraus, R., Ljubimir, S., Krivokapić, S., 2016. Phytoplankton community and trophic state in Boka Kotorska Bay. In: Joksimović A., Djurović M., Semenov A., Zonn I., Kostianoy A. (Eds) *The Boka Kotorska Bay Environment. The Handbook of Environmental Chemistry*, Springer, 54, 169-201.
- Drakulović, D., Gvozdenović, S., Joksimović, D., Mandić, M., Pestorić, B., 2017. Toxic and potentially toxic phytoplankton in the mussel and fish farms in the transitional area of Montenegrin coast (South-Eastern Adriatic Sea). *Turkish Journal of Fisheries and Aquatic Sciences*, 17, 885-900.
- Dulčić, J., Pallaoro, A., 2001. Some new data on *Xyrichtys novacula* (Linnaeus, 1758) and *Sparisoma cretense* (Linnaeus, 1758) from the Eastern Adriatic. *Annales, Series Historia Naturalis*, 11 (1), 35-40.
- Eloire, D., Somerfield, P.J., Conway, D.V.P., Halsband-Lenk, C., Harris, R. *et al.*, 2010. Temporal variability and community composition of zooplankton at Station L4 in the Western Channel: twenty years of sampling. *Journal of Plankton Research*, 32, 657-679.
- Feasibility Study for the Port of Bar. 2014. Project “Transnational Enhancement of ECOPORT8 network” TEN ECO-PORT project – Code SEE/D/0189/2.2/X, 40p.
- Franco-Gordo, C., Godínez-Domínguez, E., Suárez-Morales, E., Freire, J., 2008. Interannual and seasonal variability of the diversity and structure of ichthyoplankton assemblages in the central Mexican Pacific. *Fisheries Oceanography* 17, 178-190.
- Guidetti, P., Boero, F., 2001. Occurrence of the Mediterranean parrotfish *Sparisoma cretense* (Perciformes: Scaridae) in south-eastern Apulia (south-east Italy). *Journal of the Marine Biological Association of the U.K.* 81(4), 717-718.
- Harris, R.P., Wiebe, P.H., Lenz, J., Skjoldal, H.R., Huntley, M., 2000. ICES Zooplankton Methodology Manual. Academic Press, London, 685 pp.
- Krebs, C.J., 1999. *Ecological Methodology*, 2nd Ed. Addison Wesley Longman, Menlo Park, California, USA, 620 pp.
- Kruschel, C., Zubak, I., Schultz, S.T., 2012. New record of the parrotfish, *Sparisoma cretense*, and the cleaver wrasse, *Xyrichtys novacula*, by visual census in the Southern Adriatic. *Annales. Series Historia Naturalis*, 22, 47-53.
- Li, K., Yin, J., Huang, L., Lin, Z., 2014. Seasonal variations in diversity and abundance of surface ichthyoplankton in the northern South China Sea. *Acta Oceanologica Sinica*, 33 (12), 145-154.
- Lopes, R., Katsuragawa, M., Dias, J.F., Montú, M.A., Muelbert, J.H., *et al.* 2006. Zooplankton and ichthyoplankton distribution on the southern Brazilian shelf: an overview. *Scientia Marina* 70, 189-202.
- Mandić, M., Regner, S., Gačić, Z., Đurović, M., Marković, O. *et al.*, 2014. Composition and diversity of ichthyoplankton in the Boka Kotorska Bay (South Adriatic Sea). *Acta Adriatica*, 55 (1), 229-244.
- Marić, D., Ljubešić, Z., Godrijan, J., Viličić, D., Ujević, I. *et al.*, 2011. Blooms of the potentially toxic diatom *Pseudo-nitzschia calliantha* Lundholm, Moestrup & Hasle in coastal waters of the northern Adriatic Sea (Croatia). *Estuarine, Coastal and Shelf Science*, 92 (3), 323-331.
- Matsuura, Y., 1996. A probable cause of recruitment failure of the Brazilian sardine *Sardinella aurita* population during the 1974/75 spawning season. *South African Journal of Marine Sciences* 17, 29-35.
- Mineur, F., Johnson, M.P., Maggs, C.A., 2009. Macroalgal introductions by hull fouling on recreational vessels: Seaweeds and sailors. *Environmental Management* 42, 667-676.
- Mouny, P., Dauvin, J. C., Bessineton, C., Elkaim, B., Simon, S., 1998. Biological components from the Seine estuary: first results. In *Oceans, Rivers and Lakes: Energy and Substance Transfers at Interfaces* (pp. 333-347). Springer, Dordrecht.
- Mozetič, P., Cangini, M., Francé, J., Bastianini, M., Bernardi A. *et al.*, 2017. Phytoplankton diversity in Adriatic ports: Lessons from the port baseline survey for the management of harmful algal species. *Marine Pollution Bulletin*.
- Ninčević Gladan, Ž., Magaletti, E., Scarpato, A. *et al.*, 2014. BALMAS Port Baseline Survey Protocol. Protocol. BALMAS project. Work package 5.1. 23 pp.
- Orsini, L., Sarno, D., Procaccini, G., Poletti, R., Dahlmann, J. *et al.*, 2002. Toxic *Pseudo-nitzschia multistriata* (Bacillariophyceae) from the Gulf of Naples: morphology, toxin analysis and phylogenetic relationships with other *Pseudo-nitzschia* species. *European Journal of Phycology*, 37,

- 247-257.
- Perez-Ruzafa, A., Quispe-Becerra, J.I., Garcia-Charton, J.A., Marcos, C., 2004. Composition, structure and distribution of the ichthyoplankton in a Mediterranean coastal lagoon. *Journal of Fish Biology*, 64 (1), 202-218.
- Pestorić, B., Drakulović, D., Hure, M., Gangai Zovko, B., Onofri, I. *et al.*, 2017. Zooplankton Community in the Boka Kotorska Bay In: Joksimović A., Djurović M., Semenov A., Zonn I., Kostianoy A. (Eds) The Boka Kotorska Bay Environment. *The Handbook of Environmental Chemistry*, Springer, 54, 231-270.
- Pestorić, B., Drakulović, D., Mandić, M., Abbate, C., 2018. Distribution changes of plankton communities in the harbour Porto Montenegro (South Adriatic Sea). *Studia Marina*, 31 (2), 5-31.
- Quiroga, I., 2006. *Pseudo-nitzschia* blooms in the Bay of Banyuls-sur-Mer, northwestern Mediterranean Sea. *Diatom Research*, 21, 91-104.
- Sabatés, A., Olivar, M.P., Salat, J., Palomera, I., Alemany, F., 2007. Physical and biological processes controlling the distribution of fish larvae in the NW Mediterranean. *Progress in Oceanography* 74, 355-376.
- StatSoft Inc. 2004. STATISTICA (Data Analysis Software System), Version 7, www.statsoft.com
- Tanaka, S., 1973. Stock Assessment by means of ichthyoplankton surveys. *FAO Fisheries Technical Paper*, 122, 33-51.
- Vidjak, O., Bojanić, N., Kušpilić, G., Marasović, I., Ninčević, G.Ž. *et al.*, 2006. Annual variability and trophic relations of the mesozooplankton community in the eutrophicated coastal area (Vranjic Basin, eastern Adriatic Sea). *Journal of the Marine Biological Association of the United Kingdom*, 86, 19-26.
- Vidjak, O., Bojanić, N., Kušpilić, G., Ninčević Gladan, Ž., Tičina, V. 2007. Zooplankton community and hydrographical properties of the Neretva Channel (eastern Adriatic Sea). *Helgoland Marine Research*, 61 (4), 267-282.
- Vidjak, O., Bojanić, N., de Olazabal, A., Benzi, M., Brautović, I. *et al.* 2018. Zooplankton in Adriatic port environments: Indigenous communities and non-indigenous species. *Marine Pollution Bulletin*.
- Vilà, M., Basnou, C., Gollasch, S., Josefsson, M., Pergl, J. *et al.*, 2009. One hundred of the most invasive alien species in Europe. In: DAISIE (Ed.), *Handbook of Alien Species in Europe*. Invading Nature: Springer Series in Invasion Ecology 3. Springer Science, Business Media, BV, 12, 265-268.
- Walker, T.R., Adebambo, O., Del Aguila Feijoo, M.C., Elhaimer, E., Hossain, T. *et al.*, 2019. Chapter 27 - Environmental Effects of Marine Transportation, Editor(s): Charles Sheppard, *World Seas: an Environmental Evaluation* (Second Edition), Academic Press, 2019, Pages 505-530.
- Wanless, R.M, Scott, S., Warwick, H.H., Sauer, T.G.A., Glass, J.P. *et al.*, 2010. Semisubmersible rigs: a vector transporting entire marine communities around the world. *Biological Invasions* 12, 2573-2583.
- Werschkun, B., Banerji, S., Basurko, O.C., David, M., Fuhr, F. *et al.*, 2014. Emerging risks from ballast water treatment: The run-up to the International Ballast Water Management Convention, *Chemosphere*, 112, 256-266.
- Utermöhl, H., 1958. For the supplement of quantitative phytoplankton methodology [Zur Vervollkommung der quantitativen Phytoplankton Methodik], *Limnologie*, 9, 1-38 (in German).