Dinoflagellate assemblages in the Boka Kotorska Bay

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ABSTRACT

This study presents distribution of dinoflagellates in the semi-enclosed Boka Kotorska Bay. Samplings were performed twice per month from the June 2009 to the June 2010. Samples were taken on five positions in two parts of the Bay: inner, closer Kotor Bay and middle part of Boka Kotorska Bay (Tivat Bay). Maximum of dinoflagellates abundance was noticed in summer period, on position IMB (1.05 x 10^5 cells/l). Among the dinoflagellates, eight species that produce toxins were recorded: Dinophysis acuminata, D. acuta, D. caudata, D. fortii, D. hastata, D. sphaerica, Phalacroma rotundatum and Prorocentrum minimum.

These are the basic information concerning distribution of dinoflagellates in Boka Kotorska Bay. Knowledge that increase of human impact in the area and appearance of toxic dinoflagellates can cause serious problems to marine ecosystem could be useful for prevention.

Keywords: Dinoflagellates assemblages, toxic dinoflagellates, Boka Kotorska Bay.

INTRODUCTION

Reactions of phytoplankton organisms on fluctuations under different environmental conditions are rapid and very complex. Coastal area are characterized by high spatial and temporal variability of environmental parameters. Mainly due to the increasing of impact of
human activities on the functioning of coastal ecosystems, it is essential to
determine the basic phytoplankton assemblages in these areas (Cloern 1999).

In marine ecosystems, dinoflagellates, along with diatoms, are
important components of the phytoplankton. Approximately 90% of all
dinoflagellates species are marine, most of them distributed in temperate
waters and most prevalent in summer months (Taylor 1987).
Since dinoflagellates display very diverse ecophysiological characteristics,
generalizations about their roles in ecosystems are not easily made. 
Photosynthetic species play a role in marine primary production, but most
species are heterotrophic (Loeblich III 1984), and may be important grazers
on the larger phytoplankton. Some species may cause red tides and some
species produce potent neuro-toxins which may accumulate in the food
chain (Hallegraeff 1993).

Investigations of dinoflagellates populations were performed in
Adriatic Sea, with emphasis on their toxicity (Boni et al., 1992; Honsell et
al., 1996) and consequences on shellfish farms (Marasović et al., 1998;
Marasović et al., 2007; Ninčević et al., 2008).

In Boka Kotorska Bay mussel farming began in the 1980s and today
there are 16 farms using the system of the floating buoys and ropes. As
mussels are filter feeders which accumulate phytoplankton, the problem
can occur if there is a presence of toxic phytoplankton, mostly are
dinoflagellates that can caused negative human health consequences.

Several previous studies related to the Boka Kotorska Bay referred
to phytoplankton assemblages and include data of dinoflagellates
composition and density (Drakulović et al. 2011, 2012). Usually outbreaks
of harmful and toxic microalgea are observed in areas of the sea occupied
by mariculture installations (Probyn et al. 2001; Rhodes et al. 2001; Ventilla 1982).

This study aimed at forming a species list of dinoflagellates and showing their abundances. The purpose is to identify the dinoflagellates species and to emphasize species which have the potential to form harmful algae blooms and to get chance to estimate possible changes that can cause negative effect on humans’ health through consuming of infected mussels.

**MATERIALS AND METHODS**

Boka Kotorska Bay was investigated area in this study. Bay is situated in southeastern part of Adriatic Sea and it consists of four small Bays: Kotor Bay, Risan Bay, Tivat Bay and Herceg Novi Bay. Verige strait is the narrowest section of the Bay, which separate the inner Bay which belongs to the natural and culturo- historical region of Kotor, a World Heritage Site, from the rest of the Bay. The total surface area of Boka Kotorska Bay comprises 87.3 km². It is divided into three parts: inner, middle and external. Current study was conducted in inner and middle part of Boka Kotorska Bay (Kotor and Tivat Bay) (Figure 1, Table 1). Climate is of the Mediterranean type, and the precipitation regime is heavily influenced by mount Orjen which receives Europe’s heaviest precipitation with rain occurring seasonally (Magaš, 2002).

Sampling was carried out twice per month from the June 2009 to the June 2010. Materials for phytoplankton analysis was collected from five positions in the Boka Kotorska Bay. Three positions were in the Kotor Bay and two in the Bay of Tivat.

In Kotor Bay, samples were taken from IMB and Orahovac on three depths (0 m, 5 and 10 m), and from Kotor-central on five depths (0m, 5,
10, 20 and 30m). In Tivat Bay, sampling were performed on position Sveta Nedelja on three depths (0 m, 5m and 10 m) and from site Tivat-central on five depths (0 m, 5m, 10m, 20m and 30 m).

Figure 1. Investigated area

Table 1. Investigated positions

<table>
<thead>
<tr>
<th>POSITION</th>
<th>SOUTH</th>
<th>EAST</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>KOTOR BAY</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Institute of Marine Biology-IMB</td>
<td>42° 26' 20.7&quot;</td>
<td>18° 45' 65.5&quot;</td>
</tr>
<tr>
<td>2. Orahovac</td>
<td>42° 29' 23.6&quot;</td>
<td>18° 45' 64.2&quot;</td>
</tr>
<tr>
<td>3. Kotor-central</td>
<td>42° 28' 43.6&quot;</td>
<td>18° 44' 40.8&quot;</td>
</tr>
<tr>
<td><strong>TIVAT BAY</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Tivat-central</td>
<td>42° 25' 91.0&quot;</td>
<td>18° 39' 40.8&quot;</td>
</tr>
<tr>
<td>5. Sveta Nedelja</td>
<td>42° 27'39.3&quot;</td>
<td>18° 40' 50.5&quot;</td>
</tr>
</tbody>
</table>
Samples were collected with Niskin sampler of 5 l. Physical parameters such as temperature, salinity and dissolved oxygen concentration were measured \textit{in situ} using a universal meter (Multiline P4; WTW). Nutrient (nitrates, nitrites, silicates and phosphates) concentrations were determined by standard colorimetric method (Strickland \textit{et al}. 1972) using a spectrophotometer type \textit{Perkin Elmer $\chi$ 2}. Phytoplankton samples were preserved in a 3 \% neutralized formaldehyde solution. After 24 h of sedimentation in sediment chambers, cells were enumerated using inverted microscope according to Utermöhl (1958). For determination of phytoplankton species, it was used appropriate key for the specified field of investigation (Hustedt 1959, Hasle & Syvertsen 1997, Round \textit{et al}. 1990, and Throndsen \textit{et al}. 2007).

\textbf{RESULTS AND DISCUSSIONS}

During the study, as we expect, in the summer period temperature showed maximum peak (26.83 °C), while in winter period it was noticed minimum temperature 7.2 °C (Table 2.).

Salinity varied during the study period, decreasing to a minimum value of 1\% at surface layer (Table 2.). The minimum value was due to the impact of rainfall, as recorded in the winter, but also the impact of the influx of fresh water through rivers that are present at the position Orahovac (the inner part of the Bay, Kotor Bay), where it was measured the lowest salinity.

Oxygen concentration ranged from 6.85 to 10.43 mg/l, which shows that the water of Boka Kotorska Bay is rich in oxygen (Table 2.). Sufficient oxygen concentration was throughout the study period, but it was lower in the summer and higher in the colder, winter period.
Concentration of nutrients in the Boka Kotorska Bay was generally high during the investigated period and favorable for phytoplankton development. The maximum value of nitrate was 25.88 µmol/l and it was recorded in April 2010 when the phytoplankton abundance was lower. Peak of phosphate concentration was noticed in January (0.97 µmol/l), while peak of silicate concentration was 75.08 µmol/l in January 2010 (Table 2). Statistica 7 and Primer 5 programs were used for statistical analyses and graphical presentations of physical, chemical, and biological data.

Dinoflagellates abundance varied during the investigated period. Maximum abundance of dinoflagellates ranged from $1.76 \times 10^3$ cells/l in June 2009, on Tivat position, to $1.05 \times 10^5$ cells/l in September 2009, on the position of IMB (Table 3).

Table 2. Maximum (Max.), minimum (Min.), AVG (mean) values and standard deviation (SD) of temperature (Temp.), salinity (Sal.), oxygen concentration (Oxy. Conc.), nitrate (NO$_3^-$), phosphate (PO$_4^{3-}$) and silicate (SiO$_4^{2-}$) from June 2009 to June 2010.

<table>
<thead>
<tr>
<th></th>
<th>Temp. (°C)</th>
<th>Sal. (°/°°)</th>
<th>Oxy conc. (mg/l)</th>
<th>NO$_3^-$ (µmol/l)</th>
<th>PO$_4^{3-}$ (µmol/l)</th>
<th>SiO$_4^{2-}$ (µmol/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>26.83</td>
<td>39.9</td>
<td>10.43</td>
<td>25.88</td>
<td>0.97</td>
<td>75.08</td>
</tr>
<tr>
<td>Min</td>
<td>7.2</td>
<td>1</td>
<td>6.85</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>AVG</td>
<td>17.63</td>
<td>31.29</td>
<td>8.93</td>
<td>2.59</td>
<td>0.18</td>
<td>5.82</td>
</tr>
<tr>
<td>SD</td>
<td>4.03</td>
<td>9.29</td>
<td>0.65</td>
<td>3.16</td>
<td>0.15</td>
<td>8.63</td>
</tr>
</tbody>
</table>

A peak of dinoflagellate in September 2009, on the surface layer ($1.05 \times 10^5$ cells/l) can be explained by decreasing of concentration of available nutrients. That resulting with stratification which causes reduction of the mixing of nutrients regenerated in the sediments with the warmer, upper layers of the water column. Important is that the reduced supply of nutrients favored the development of dinoflagellates in summer (Burić et al., 2007). Polat (2002) reported the dominance of dinoflagellates
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in summer period, when dinoflagellates were done more than 60% of the total plankton. Mainly after the spring "blooms" of diatoms, when the waters were poor with nutrients, favoring the development of dinoflagellates, which have lower requirements for nutrients (Thingstad & Sackshang, 1990). These are recorded by Bernardi-Aubry et al. (2004), when the maximum dinoflagellates occurred in June-July, after the development of diatoms. Noticed value of dinoflagellates differ from data quoted by Fanuko and Valčić (2011) for the Stella Maris Lagoon, where the maximum number of dinoflagellates was in the spring and the value does not exceed $10^4$ cells /l. Svensen et al. (2007) for eastern Adriatic sea found a highest number of dinoflagellates than was observed in this study.

Table 3. Mean value, minimum (Min), maximum (Max.), standard deviation (SD) of the dinoflagellates in the investigated period.

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean (cells/l)</th>
<th>Min.(cells/l)</th>
<th>Max.(cells/l)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>544</td>
<td>0</td>
<td>$1.76 \times 10^3$</td>
<td>$5.09 \times 10^2$</td>
</tr>
<tr>
<td>July</td>
<td>$2.76 \times 10^3$</td>
<td>40</td>
<td>$1.25 \times 10^4$</td>
<td>$2.98 \times 10^3$</td>
</tr>
<tr>
<td>August</td>
<td>$2.49 \times 10^3$</td>
<td>0</td>
<td>$1.88 \times 10^4$</td>
<td>$4.59 \times 10^3$</td>
</tr>
<tr>
<td>September</td>
<td>$5.16 \times 10^3$</td>
<td>200</td>
<td>$1.05 \times 10^5$</td>
<td>$1.72 \times 10^4$</td>
</tr>
<tr>
<td>October</td>
<td>930</td>
<td>80</td>
<td>$7.09 \times 10^3$</td>
<td>$1.33 \times 10^3$</td>
</tr>
<tr>
<td>November</td>
<td>$3.20 \times 10^3$</td>
<td>0</td>
<td>$5.13 \times 10^4$</td>
<td>$8.51 \times 10^3$</td>
</tr>
<tr>
<td>December</td>
<td>$2.17 \times 10^3$</td>
<td>40</td>
<td>$1.38 \times 10^4$</td>
<td>$3.19 \times 10^3$</td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>January</td>
<td>985</td>
<td>0</td>
<td>$2.48 \times 10^3$</td>
<td>$7.15 \times 10^2$</td>
</tr>
<tr>
<td>February</td>
<td>792</td>
<td>0</td>
<td>$2.37 \times 10^3$</td>
<td>$7.28 \times 10^2$</td>
</tr>
<tr>
<td>March</td>
<td>939</td>
<td>80</td>
<td>$4.67 \times 10^3$</td>
<td>$9.89 \times 10^2$</td>
</tr>
<tr>
<td>April</td>
<td>$1.98 \times 10^3$</td>
<td>0</td>
<td>$2.16 \times 10^4$</td>
<td>$4.29 \times 10^3$</td>
</tr>
<tr>
<td>May</td>
<td>$1.17 \times 10^3$</td>
<td>0</td>
<td>$8.17 \times 10^3$</td>
<td>$1.75 \times 10^3$</td>
</tr>
<tr>
<td>June</td>
<td>$6.68 \times 10^3$</td>
<td>40</td>
<td>$3.98 \times 10^4$</td>
<td>$1.13 \times 10^4$</td>
</tr>
</tbody>
</table>

Dinoflagellate abundance varied depending on the depths and the largest value was at the surface layer ($5.1 \times 10^3$ cells/l) and then started to decrease. Duncan test run on abundance of dinoflagellates showed a statistically significant difference between surface and deeper layers (10m,
20 and 30 m) and between depth of 5 m and remaining deeper layers (Figure 2).

Figure 2. Mean abundance of dinoflagellates by depths

Decreased number of dinoflagellates was observed, going to the deeper layers, as was shown with negative correlation (Figure 3).

Depth (m): Abundance of dinoflagellates log (cells/l): $r = -0.2458$; $p = 0.0000004$

Figure 3. Correlation of dinoflagellates abundance and depths
The highest mean abundance of dinoflagellates was recorded at the position of IMB, while at other position was lower. Duncan's test run on dinoflagellates abundance showed statistically significant differences between IMB position and other positions (Figure 4).

Dinoflagellates abundance increased in the summer period, at higher water temperature, which was confirmed with positive correlation between these two parameters (Figure 6.)

Dinoflagellate abundance was negatively correlated with nitrate and silicate, and positively with phosphate (Figure 7, 8, 9). This coincided with the data noticed by Viličić et al. (2007) in the Lim Bay for silicates, and Svensen et al. (2006) in the eastern Adriatic for phosphate.
Position: Abundance of dinoflagellates log (cells/l): $r = -0.1079; p = 0.0275$

Figure 5. Correlation of dinoflagellates abundance and position

Temperature (°C): Abundance of dinoflagellates log (cells/l): $r = 0.2524; p = 0.0000002$

Figure 6. Correlation of dinoflagellates abundance and temperature
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**Figure 7.** Correlation of dinoflagellates abundance and nitrates concentration

**Figure 8.** Correlation of dinoflagellates abundances and phosphates concentration
Dinoflagellates are the most important group of marine phytoplankton, which produce biotoxins and harmful algal "blooms". A total of 83 species of dinoflagellates were recorded.

The dominant species (of which the number is greater than $10^3$ cells/l or which are present in more than 10% of the samples) were: Dinophysis fortii (22,97%), Diplopsalis lenticula (16,51%), Gonyaulax spp. (30,38%), Gymnodinium spp. (69,38%), Gyrodinium fusiforme (22,97%), Neoceratium furca (16,03%), N. fusus (11,96%), N. horridum (15,55%), N. tripos (15,79%), Oxytoxum sceptrum (11,00%), Prorocentrum compressum (12,92%), P. micans (62,92%), P. minimum (16,03%), Protoperidinium crassipes (17,22%), P. diabolum (13,88%), P. globulum (11,48%), Protoperidinium spp. (24,64%) i Scrippsiella sp. (20,10%).
Table 3. Lists of dinoflagellates determined in Boka Kotorska Bay from June 2009 to June 2010. (MAX. – maximum value; FR. – frequency of species; AVG. – mean value; SD. – standard deviation;).

<table>
<thead>
<tr>
<th>Dinoflagellates</th>
<th>MAX.</th>
<th>FR.</th>
<th>AVG.</th>
<th>SD.</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Amphidinium acutissimum</em> Schiller</td>
<td>160</td>
<td>2.87</td>
<td>2.01</td>
<td>12.99</td>
</tr>
<tr>
<td><em>A. lanceolatum</em> Schröder</td>
<td>40</td>
<td>0.48</td>
<td>0.19</td>
<td>2.76</td>
</tr>
<tr>
<td><em>Amphidinium</em> sp.</td>
<td>785</td>
<td>2.15</td>
<td>6.59</td>
<td>66.83</td>
</tr>
<tr>
<td><em>Corythodinium constrictum</em> (Stein) Taylor</td>
<td>40</td>
<td>0.72</td>
<td>0.29</td>
<td>3.38</td>
</tr>
<tr>
<td><em>C. tesselatum</em> (Stein) Loeblich Jr &amp; Loeblich III</td>
<td>40</td>
<td>0.96</td>
<td>0.38</td>
<td>3.90</td>
</tr>
<tr>
<td><em>Dinophysis acuminata</em> Clap. et Lachm.</td>
<td>600</td>
<td>5.26</td>
<td>5.07</td>
<td>35.16</td>
</tr>
<tr>
<td><em>D. acuta</em> Ehrenb.</td>
<td>40</td>
<td>0.24</td>
<td>0.10</td>
<td>1.96</td>
</tr>
<tr>
<td><em>D. caudata</em> Seville-Kent</td>
<td>240</td>
<td>6.22</td>
<td>4.31</td>
<td>20.37</td>
</tr>
<tr>
<td><em>D. fortii</em> Pav.</td>
<td>960</td>
<td>22.97</td>
<td>18.76</td>
<td>61.51</td>
</tr>
<tr>
<td><em>D. hastata</em> Stein</td>
<td>40</td>
<td>0.48</td>
<td>0.19</td>
<td>2.76</td>
</tr>
<tr>
<td><em>D. sphaerica</em> Stein</td>
<td>40</td>
<td>0.24</td>
<td>0.10</td>
<td>1.96</td>
</tr>
<tr>
<td><em>Dinophysis</em> sp.</td>
<td>40</td>
<td>0.24</td>
<td>0.10</td>
<td>1.96</td>
</tr>
<tr>
<td><em>Diplopsalis lenticula</em> Bergh</td>
<td>480</td>
<td>16.51</td>
<td>18.46</td>
<td>54.98</td>
</tr>
<tr>
<td><em>Diplopsalis</em> sp.</td>
<td>400</td>
<td>6.94</td>
<td>6.89</td>
<td>32.40</td>
</tr>
<tr>
<td><em>Dissodinium elegans</em> (Pav.) Matz.</td>
<td>120</td>
<td>1.91</td>
<td>1.15</td>
<td>9.12</td>
</tr>
<tr>
<td><em>Ebria tripartita</em> (Schumann) Lemmermann</td>
<td>40</td>
<td>0.48</td>
<td>0.19</td>
<td>2.76</td>
</tr>
<tr>
<td><em>Goniodoma polyedricum</em> (Pouchet) Jørg.</td>
<td>200</td>
<td>7.66</td>
<td>4.59</td>
<td>19.04</td>
</tr>
<tr>
<td><em>Gonyaulax digitale</em> (Pouchet) Kof.</td>
<td>80</td>
<td>1.91</td>
<td>0.86</td>
<td>8.93</td>
</tr>
<tr>
<td><em>G. hyalina</em> Ostenf.&amp; Schmidt</td>
<td>40</td>
<td>0.24</td>
<td>0.10</td>
<td>1.96</td>
</tr>
<tr>
<td><em>G. polygramma</em> Stein</td>
<td>1200</td>
<td>7.89</td>
<td>9.67</td>
<td>72.04</td>
</tr>
<tr>
<td><em>G. spinifera</em> (Clap. et Lachm.) Diesing</td>
<td>40</td>
<td>0.24</td>
<td>0.10</td>
<td>1.96</td>
</tr>
<tr>
<td><em>Gonyaulax</em> spp.</td>
<td>3.925</td>
<td>30.38</td>
<td>79.72</td>
<td>280.53</td>
</tr>
<tr>
<td><em>G. verior</em> Sournia</td>
<td>120</td>
<td>1.20</td>
<td>0.86</td>
<td>8.93</td>
</tr>
<tr>
<td><em>Gymnodinium cucumis</em> Schütt</td>
<td>40</td>
<td>0.24</td>
<td>0.10</td>
<td>1.96</td>
</tr>
<tr>
<td><em>Gymnodinium</em> spp.</td>
<td>28.286</td>
<td>69.38</td>
<td>578.14</td>
<td>1.990,76</td>
</tr>
<tr>
<td><em>Gyrodinium fusiforme</em> Kof. et Sw.</td>
<td>2.560</td>
<td>22.97</td>
<td>34.74</td>
<td>146.37</td>
</tr>
<tr>
<td><em>Gyrodinium</em> spp.</td>
<td>160</td>
<td>3.59</td>
<td>2.39</td>
<td>13.78</td>
</tr>
<tr>
<td><em>Heterodinium milneri</em> (Murr.&amp;Whitt.) Kof.</td>
<td>40</td>
<td>0.24</td>
<td>0.10</td>
<td>1.96</td>
</tr>
<tr>
<td><em>Neoceratium candelabrum</em> (Ehrenb.) Gomez , Moreira and Lopez-Garcia</td>
<td>80</td>
<td>0.48</td>
<td>0.29</td>
<td>4.37</td>
</tr>
<tr>
<td><em>N. carriense</em> Gourr.</td>
<td>80</td>
<td>1.91</td>
<td>0.96</td>
<td>7.27</td>
</tr>
<tr>
<td><em>N. contortum</em> (Gourr.) Cleve</td>
<td>40</td>
<td>0.24</td>
<td>0.10</td>
<td>1.96</td>
</tr>
<tr>
<td><em>N. furca</em> (Ehrenb.) Gomez , Moreira and Lopez-Garcia</td>
<td>1.240</td>
<td>16.03</td>
<td>13.21</td>
<td>67.70</td>
</tr>
<tr>
<td><em>N. fusus</em> (Ehrenb.) Gomez , Moreira and Lopez-Garcia</td>
<td>520</td>
<td>11.96</td>
<td>9.09</td>
<td>41.15</td>
</tr>
<tr>
<td><em>N. gravidum</em> (Gourr.)Gomez , Moreira and Lopez-Garcia</td>
<td>40</td>
<td>0.24</td>
<td>0.10</td>
<td>1.96</td>
</tr>
<tr>
<td><em>N. gibberum</em> (Gourr.) Gomez , Moreira and Lopez-Garcia</td>
<td>40</td>
<td>0.24</td>
<td>0.10</td>
<td>1.96</td>
</tr>
<tr>
<td>Dinoflagellates</td>
<td>MAX.</td>
<td>FR.</td>
<td>AVG.</td>
<td>SD.</td>
</tr>
<tr>
<td>----------------------</td>
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<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>N. horridum (Gran)</td>
<td>360</td>
<td>15,55</td>
<td>11,96</td>
<td>38,47</td>
</tr>
<tr>
<td>N. hexacantum (Gourr.)</td>
<td>80</td>
<td>1,20</td>
<td>0,57</td>
<td>5,51</td>
</tr>
<tr>
<td>N. kofoidii (Jørg.)</td>
<td>40</td>
<td>0,24</td>
<td>0,10</td>
<td>1,96</td>
</tr>
<tr>
<td>N. lineatum (Ehrenb.)</td>
<td>40</td>
<td>0,48</td>
<td>0,19</td>
<td>2,76</td>
</tr>
<tr>
<td>N. macroceros (Ehrenb.)</td>
<td>40</td>
<td>0,48</td>
<td>0,19</td>
<td>2,76</td>
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<tr>
<td>N. massiliense (Gourr.)</td>
<td>80</td>
<td>0,48</td>
<td>0,29</td>
<td>4,37</td>
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<tr>
<td>N. pentagonum (Gourr.)</td>
<td>240</td>
<td>2,39</td>
<td>1,82</td>
<td>16,17</td>
</tr>
<tr>
<td>Neoceratium sp.</td>
<td>40</td>
<td>0,96</td>
<td>0,38</td>
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<tr>
<td>N. trichoceros (Ehrenb.)</td>
<td>640</td>
<td>7,18</td>
<td>7,27</td>
<td>43,98</td>
</tr>
<tr>
<td>N. tripos (Müller)</td>
<td>2,080</td>
<td>15,79</td>
<td>26,70</td>
<td>159,20</td>
</tr>
<tr>
<td>Noctiluca scintillans (Macartney)</td>
<td>200</td>
<td>5,50</td>
<td>3,73</td>
<td>18,93</td>
</tr>
<tr>
<td>Ornithocercus heteroporus Kof.</td>
<td>280</td>
<td>0,48</td>
<td>0,77</td>
<td>13,83</td>
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<tr>
<td>Oxytoxum adriaticum Schiller</td>
<td>80</td>
<td>0,96</td>
<td>0,57</td>
<td>6,17</td>
</tr>
<tr>
<td>O. caudatum Schiller</td>
<td>160</td>
<td>0,24</td>
<td>0,38</td>
<td>7,83</td>
</tr>
<tr>
<td>O. laticeps Schiller</td>
<td>360</td>
<td>1,44</td>
<td>1,82</td>
<td>20,37</td>
</tr>
<tr>
<td>O. sceptrum (Stein) Schröder</td>
<td>600</td>
<td>11,00</td>
<td>14,26</td>
<td>60,56</td>
</tr>
<tr>
<td>O. sphaeroideum Stein</td>
<td>360</td>
<td>2,63</td>
<td>2,87</td>
<td>22,99</td>
</tr>
<tr>
<td>O. scolopax Stein</td>
<td>480</td>
<td>1,20</td>
<td>1,53</td>
<td>23,78</td>
</tr>
<tr>
<td>Oxytoxum sp.</td>
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<td>1,20</td>
<td>0,57</td>
<td>5,5</td>
</tr>
<tr>
<td>O. variabile Schiller</td>
<td>40</td>
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<td>0,10</td>
<td>1,96</td>
</tr>
<tr>
<td>Phalacroma rotundatum (Clap.et Lachm.) Kof. et Michener</td>
<td>160</td>
<td>7,42</td>
<td>3,92</td>
<td>16,50</td>
</tr>
<tr>
<td>Podolampas elegans Schütt</td>
<td>120</td>
<td>2,87</td>
<td>1,63</td>
<td>10,05</td>
</tr>
<tr>
<td>Prorocentrum compressum (Bailey) Abé ex Dodge</td>
<td>2,080</td>
<td>12,92</td>
<td>16,46</td>
<td>110,79</td>
</tr>
<tr>
<td>P. micans Ehrenb.</td>
<td>93.122</td>
<td>62,92</td>
<td>669,66</td>
<td>4,913,47</td>
</tr>
<tr>
<td>P. minimum (Pav.) Schiller</td>
<td>78.540</td>
<td>16,03</td>
<td>487,74</td>
<td>4,708,6</td>
</tr>
<tr>
<td>P. scutellum Schröder</td>
<td>160</td>
<td>1,44</td>
<td>0,96</td>
<td>9,55</td>
</tr>
<tr>
<td>Prorocentrum sp.</td>
<td>80</td>
<td>0,48</td>
<td>0,29</td>
<td>4,37</td>
</tr>
<tr>
<td>P. triestinum Schiller</td>
<td>1,570</td>
<td>3,35</td>
<td>6,74</td>
<td>79,37</td>
</tr>
<tr>
<td>Protoperidinium crassipes (Kof.) Bal.</td>
<td>400</td>
<td>17,22</td>
<td>13,11</td>
<td>40,34</td>
</tr>
<tr>
<td>P. conicum (Gran) Bal.</td>
<td>160</td>
<td>1,91</td>
<td>1,44</td>
<td>11,5</td>
</tr>
<tr>
<td>P. depressum (Bailey) Bal.</td>
<td>40</td>
<td>0,24</td>
<td>0,10</td>
<td>1,96</td>
</tr>
<tr>
<td>P. diabolum (Cleve) Bal.</td>
<td>480</td>
<td>13,88</td>
<td>10,81</td>
<td>38,31</td>
</tr>
</tbody>
</table>
Dinoflagellate assemblages in the Boka Kotorska Bay

<table>
<thead>
<tr>
<th>Dinoflagellates</th>
<th>MAX.</th>
<th>FR.</th>
<th>AVG.</th>
<th>SD.</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. divergens</em> (Ehrenb.) Bal.</td>
<td>80</td>
<td>3,35</td>
<td>1,82</td>
<td>10,39</td>
</tr>
<tr>
<td><em>P. globulum</em> (Stein) Bal.</td>
<td>400</td>
<td>11,48</td>
<td>8,99</td>
<td>35,41</td>
</tr>
<tr>
<td><em>P. leonis</em> (Pav.) Bal.</td>
<td>40</td>
<td>0,24</td>
<td>0,10</td>
<td>1,96</td>
</tr>
<tr>
<td><em>P. oceanicum</em> (Van Höffen) Bal.</td>
<td>40</td>
<td>1,44</td>
<td>0,57</td>
<td>4,76</td>
</tr>
<tr>
<td><em>P. pallidum</em> (Ostenf.) Bal.</td>
<td>40</td>
<td>0,24</td>
<td>0,10</td>
<td>1,96</td>
</tr>
<tr>
<td><em>P. paulsenii</em> (Pav.) Bal.</td>
<td>40</td>
<td>0,24</td>
<td>0,10</td>
<td>1,96</td>
</tr>
<tr>
<td><em>Protoperidinium</em> spp.</td>
<td>9.429</td>
<td>24,64</td>
<td>170,26</td>
<td>773,68</td>
</tr>
<tr>
<td><em>P. steinii</em> (Jørg.) Bal.</td>
<td>80</td>
<td>1,67</td>
<td>0,77</td>
<td>6,15</td>
</tr>
<tr>
<td><em>P. tuba</em> (Schiller) Bal.</td>
<td>80</td>
<td>1,91</td>
<td>1,05</td>
<td>8,01</td>
</tr>
<tr>
<td><em>Pselliodium vaubanii</em> Sournia</td>
<td>200</td>
<td>6,94</td>
<td>4,11</td>
<td>18,44</td>
</tr>
<tr>
<td><em>Pyrocysis lunula</em> (Schütt)</td>
<td>40</td>
<td>0,48</td>
<td>0,19</td>
<td>2,76</td>
</tr>
<tr>
<td>Schütt</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pyrophacus steini</em> (Schiller)Wal &amp; Dale</td>
<td>40</td>
<td>0,24</td>
<td>0,10</td>
<td>1,96</td>
</tr>
<tr>
<td><em>Scrippsiella</em> sp.</td>
<td>3.925</td>
<td>20,10</td>
<td>60,78</td>
<td>289,40</td>
</tr>
<tr>
<td><em>Torodinium robustum</em> Kof. &amp; Sw.</td>
<td>80</td>
<td>0,96</td>
<td>0,67</td>
<td>7,03</td>
</tr>
<tr>
<td><em>Torodinium</em> sp.</td>
<td>40</td>
<td>0,24</td>
<td>0,10</td>
<td>1,96</td>
</tr>
</tbody>
</table>

Among the dinoflagellates, eight species that produce toxins were recorded: *Dinophysis acuminata, D. acuta, D. caudata, D. fortii, D. hastata, D. sphaerica, Phalacroma rotundatum, Prorocentrum minimum*. According to this research, the concentration of toxic dinoflagellates still isn't alarming, but there are certain findings where their number was increased. Regarding aquaculture, there are 16 shellfish farms cultivating mostly mussels, and 2 fish farms rearing seabass/seabream registered in the Boka Kotorska Bay. They are the main point for water filtration and potentially toxic substances. So the presence of the toxic phytoplankton species such as *Dinophysis* species indicate the importance of monitoring and research in the case of possible occurring of algal blooms in this area.
where is present active shellfish farming. This study revealed the toxic
dinoflagellate *Dinophysis fortii* occurred at abundances 960 cells/l. This is
serious because even at low concentrations of just over 1000 cells/l
dinoflagellate *Dinophysis* spp. is harmful to humans (Marcaillou-Le Baut
*et al.* 1993).

High value of dinoflagellates was already noticed in Boka Kotorska Bay
by Drakulović *et al.* 2012. They noticed abundance of *Prorocentrum
micans* in order to 10^6 cells /l. Presence of toxic dinoflagellate
*Prorocentrum minimum* was recorded in Boka Kotorska Bay among the
dominant species in the phytoplankton assemblage, with a maximum
abundance reaching 3.97×10^4 cells /l by Bosak *et al.* 2011. Finding of toxic
species indicate the need for more intensive research and monitoring.
Through more intensive monitoring of phytoplankton composition
presence of toxic species and potential blooms of harmful algae can be
confirmed. That can give us the possibility to react on time as these
negative changes will affect shellfish farming activities.

**REFERENCES**

Bernardi-Aubry, F., A. Berton, M. Bastianini, G. Socal & F. Acri (2004): Phytoplankton
succession in a coastal area of the NW Adriatic, over a 10-year sampling period

and temporal distribution in a highly stratified estuary (Zrmanja, Adriatic Sea),

of diarrhoeotic shellfish poisoning in the northern Adriatic Sea. In R. A.
Vollenweider, R. Marchetti, & R. Viviani (Eds.), Marine coastal eutrophication

Bosak, S., T. Šilović, Z. Ljubešić, G. Kušpilić, B. Pestorić, S. Krivokapić & D.Viličić
(2011): Phytoplankton size structure and species composition as an indicator of
Dinoflagellate assemblages in the Boka Kotorska Bay


