Report of HAB Case Studies
in Amurskii Bay, Primorkii Krai, Russia
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1. Introduction

1.1. Objective

The objective of conducting the HAB case study in Amurskii Bay in Primorski Krai is the same as for other the NOWPAP member states - to establish the most effective and laborsaving ways for sharing information on HAB events and associated oceanographic and meteorological conditions. In the case study, red-tide (bloom-forming) and toxin-producing species are referred as HAB species.

1.2. Definitions and rules used in the HAB case study

The scientific names in the “Integrated Report” and “Booklet on Countermeasures” are used in this case study.

1.3. Overview of the target sea area

1.3.1. Location and boundary

The target sea area covers the north part of Amurskii Bay (latitude 43°11’ and longitude 131°54’). Amurskii Bay is on of the largest secondary bays within Peter the Great Bay in the north-western part of the Sea of Japan (East Sea). The Amurskii Bay is the most developed area of Primorkii Krai (“Maritime Province”, or Primorye). Large cities of Vladivostok (the biggest port in the Russian Far East with a population of more than 630 000) and Ussuriysk (more than 160 000) and one of the largest recreational zones in the Far East are located here.

1.3.2. Environmental/geographical characteristics

The target sea is situated in the northwestern part of Peter the Great Bay (Figure 1). The coast of Muravyev- Amurskii Peninsila bounds it on the east, and the continental coast from the Razdolnaya River mouth to Bruce Peninsula, on the west.

1.3.2.1. Geomorphological characteristics

Amurskii Bay has greatly indented shores, with several shallow-water smaller bays and inlets. Amurskii Bay basin geologically is a synclinal zone of the northeastern strike (Vasiliev, Markov, 1974). It is a rather shallow basin with low hydrodynamics and muddy sedimentation. Coastal terraces and river valleys consist of loose deposits – sand, aleurite, a slit of the Pleistocene and Holocene epochs.
Steep and abrasive shore are found commonly at capes not higher than 20-30 m (Main Features..., 1961). The inner part of Amurskii Bay is situated in the Suifun subarea, i.e. in the southern end of the Western Primorye plain (Main Features..., 1961). The length of this part of the bay is 20 km and the width is about 15 km. A shallow-water Uglovoy Bay, limited by De-Friz Peninsula, is situated in the northeastern part of Amurskii Bay; Tavrichansky Estuary, which is the estuarine zone of the Razdolnaya River, in the northwestern part; and Peschanaya Inlet, in the southwestern one. The northern part of Amurskii Bay is shallow, with a mean depth of 10-15 m, with many stony and muddy sand banks, especially numerous in the northeast (Methods..., 1978; Petrenko, 1993). Bottom depths of Amurskii Bay gradually increase southward from 3-4 m in the north to 20 m on the beam of Peschany and Firsov Capes. Geographical and geological factors are major groups of factors exerting primary effect on the development of present-day exogenous processes and mobilization of detritus into the sea (Archikov, 1971; Petrenko, 1976). The key factor of the former group is a climatic one. Drastic temperature gradient down shores in winter and showery rains in summer substantially intensify transportation of sedimentary material to the coastal (Grigoryeva, 2008).
1.3.2.2. Hydrological regime

The Razdolnaya, Amba, Shmidtovka, Bogataya, and Pionerskaya rivers flow into the northern part of Amurskii Bay and have a great impact on hydrological and hydrochemical regime, as well as on the processes of deposit formation of this area. The runoff of these rivers is generally characterized by pronounced unevenness, being maximal in summer. In high-water years the summer discharge constitutes 70-91%, and in low-water years, 50-85% of the annual discharge (Stepanova, Bobrik, 1978).

The runoff of these rivers is generally characterized by pronounced unevenness, being maximal in summer. In high-water years the summer discharge constitutes 70-91%, and in low-water years, 50-85% of the annual discharge (Stepanova, Bobrik, 1978). The inner shallow-water part of Amurskii Bay classified as an estuarine zone (State..., 2005). The boundary between estuarine water body and the rest part of the bay was considered to be an isohaline of 31‰, which passes at 10-20 m of depth (Some peculiarities..., 1983).

Ice period lasts for 120-150 days depending on synoptic conditions of a year. The estuarine part of the bay completely freezes in late December, and in April the water area becomes cleared. The ice cover thickness ranges from 0.6 to 1.0 m, at the river mouth bar, 1.5-2.0 m (Grigoryeva, 2008).

Hydrological regime of Amurskii Bay depends on currents flowing round Muravyev-Amurskii Peninsula, river runoff distribution, and bottom and shore relief. The system of currents in Amurskii Bay presents the layout of the permanent branches of the Primorskoje Current flowing into Peter the Great Bay (Ivashchenko, 1993). These permanent currents transport water from the open part of the Sea of Japan/East Sea to the deep southern part of Amurskii Bay. They mainly enter along the eastern shore of Amurskii Bay, flow counterclockwise, and outflow along the western shore of the bay. The velocity of these currents is not more than 0.03-0.05 m/s (Grigoryeva, 2008).

Space-time changes of the currents in Amurskii Bay were determined to depend mainly on two factors: (1) regular vertical variations of tidal currents and turbulence and (2) unsteadiness of drift-gradient currents. It is calculated that drift-gradient currents account for 30%, tidal currents, for 8%, turbulence, for 44%, and interaction between the components, for 18% of the total kinetic energy of currents in the bay (Zaitsev, Yurasov, 1986). The wind and tidal currents together with diffusive processes are main factors having an effect on the distribution of pollutants in the northern part of Amurskii Bay (Zaitseva, 1981).

Water temperature in Amurskii bay shows distinct annual trend. Data of the HMS "Sad-Gorod" testify that minimum monthly temperature is registered for January and February (from −1.6°C to −1.9°C) and maximum for August (20.8°C to 23.1°C). Average annual temperature of surface water is 7.8-8.3°C (Climate..., 1978).
The value of salinity depends mainly on the rates of precipitation and evaporation, river discharge and water mixing processes, as well as the change of waters between the inner and the open part of the bay. Yearly salinity trend shows a maximum in January-February (32.9-35.4‰) and a minimum in July-August (20.4-31.0 ‰). Long-time average annual salinity grows from north to south from 26.5 to 33.5‰ (HMSs Climate…, 978). Long-term observations show that surface water of the inner part of Amurskii Bay are everywhere subject to freshening to a salinity value of 20-32‰, which at some sites may be as low as 1-12‰ (Rachkov, 2002; Luchin et al., 2005).

2. Methodology used in the case study in Amurskii Bay, Primorski Krai

2.1. Methodology used in the case study

In the case study, red-tide (bloom-forming) and toxin-producing species are referred as HAB species. In Russia, red tide refers to phenomena in which the coloring of sea water is observed due to the proliferation of plankton algae (so-called “algal blooms”), when the concentration of plankton microalgae up to million of cells per liter.

The reports of the monitoring organization define a HAB event when over one HAB cell was recorded during the regular monitoring. The case study is cover all HAB events recorded in the monitoring reports, and is especially focused on species that are known as toxic and potentially toxic species in the area.

2.2. Warning/action standards against HAB events

In order to prevent shellfish contamination, monitoring organization in the target sea area has established HAB warning/action standards, which if exceeded will send warning to Local Government. Warning standards in Primorskii Krai are based on cell density and established for 12 types of HAB species (Table 1).

<table>
<thead>
<tr>
<th>HAB species</th>
<th>Warning level (cells/L)</th>
<th>Affected objects</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Pseudo-nitzschia calliantha</em></td>
<td>500 000</td>
<td>Shellfish</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia delicatissima</em></td>
<td>500 000</td>
<td>Shellfish</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia fraudulenta</em></td>
<td>500 000</td>
<td>Shellfish</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia multistriata</em></td>
<td>500 000</td>
<td>Shellfish</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia multiseries</em></td>
<td>500 000</td>
<td>Shellfish</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia seriata/pungens</em></td>
<td>500 000</td>
<td>Shellfish</td>
</tr>
<tr>
<td><em>Dinophysis acuminata</em></td>
<td>500</td>
<td>Shellfish</td>
</tr>
<tr>
<td><em>Dinophysis acuta</em></td>
<td>500</td>
<td>Shellfish</td>
</tr>
</tbody>
</table>
Dinophysis fortii	500	Shellfish
Dinophysis norvegica	500	Shellfish
Dinophysis rotundata	500	Shellfish
Protoceratium reticulatum	500 000	Shellfish

In the target sea area shellfish are monitored to check the presence of algal toxins (DSP, ASP, PSP). Safety limits are established by the Government, which are for PSP - 0.8 mg/kg of saxitoxin (mollusks); for DSP - 0.16 mg/kg of okadaic acid (mollusks) and for ASP - 20 mg/kg of domoic acid (mollusks) and 30 mg/kg of domoic acid (crab’s internal) (The Federal Legislative Act SanPIN 2.3.2.2401-08).

2.3. Target HAB species

There are no any data on fishery damage in the target sea area.

In this case study, the following type of HAB species are targeted and referred to as “target HAB species”:
- red-tide causative (bloom-forming) species in the target sea area;
- toxin-producing plankton (toxic and potentially toxic species).

Table 2 shows target HAB species for Primorskii Krai (information from web site of Centre for HABs and Biotoxins of the Institute of Marine Biology FEB RAS).

During the 17 years between 1991 and 2008, a total 19 target HAB species were recorded in which 13 species are known as potentially toxic species and 9 species cause water blooms (Table 3). Those species are belonging to 4 taxonomic groups of phytoplankton: dinoflagellates (9 species), diatoms (6 species), raphidophytes (2 species), chrysophytes (1 species).

### Table 2. Target HAB species in Amurskii Bay, 1991–2008

<table>
<thead>
<tr>
<th>Species</th>
<th>Red-tide causative/bloom-forming species</th>
<th>Toxic/potentially toxic species</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacillariophyceae</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pseudo-nitzschia calliantha</em></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia delicatissima</em></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia fraudulenta</em></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia multiserialata</em></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia multiseries</em></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia seriata/pungens</em></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Skeletonema costatum</em></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td><strong>Dinophyceae</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Dinophysis acuminata</em></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td><em>Dinophysis acuta</em></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td><em>Dinophysis fortii</em></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Organism</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>Dinophysis norvegica</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Dinophysis rotundata</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Karenia mikimotoi</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Noctiluca scintillans</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Prorocentrum minimum</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Protoceratium reticulatum</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Cryophyceae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dinobryon balticum</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Raphidophyceae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chattonella sp.</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Heterosigma akashiwo</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>


3. Monitoring framework and parameters of HAB

3.1. Monitoring framework

The Center of Monitoring of HABs & Biotoxins of the A.V. Zhirmunskii Institute of Marine Biology FEB RAS conducts HAB monitoring in Primorskii Krai. The monitored sea area is shown in Table 3 and Figure 2.

![Figure 2. Monitored sea area (spot) in Amurskii Bay, Primorskii Krai.](image)
Table 3. HAB monitoring organization and monitored sea area in Primorskii Krai

<table>
<thead>
<tr>
<th>Monitoring organization</th>
<th>Monitored sea area</th>
</tr>
</thead>
</table>

3.2. Monitoring parameters

In monitored sea area in Amurskii Bay, Primorskii Krai, two types of HAB related surveys are conducted: regular HAB monitoring survey and regular shellfish shellfish-poisoning survey. Regular HAB monitoring survey and shellfish poisoning survey are conducted regularly at fixed location irrespective of any HAB events.

The objective and monitoring parameters of each survey are showed in the Table 4. The case study is focused mainly on the results of the regular monitoring survey, which monitor HAB causative species,

Table 4. Objectives and monitoring parameters of each HAB survey

<table>
<thead>
<tr>
<th>Survey type</th>
<th>Main objectives</th>
<th>Monitoring parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>HAB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Total cell density</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Water color</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shellfish poisoning survey</td>
<td>-To check presence of toxic</td>
<td>-Species that induce</td>
</tr>
</tbody>
</table>
species that induce shellfish poisoning -Contamination of shellfish shellfish poisoning -Cell density


3.3. Data and information used

Information on HAB events is collected from publications and reports of A.V. Zhirmunskii Institute of Marine Biology FEB RAS and Center of Monitoring of HABs & Biotoxins A.V. Zhirmunskii Institute of Marine Biology FEB RAS. Table 5 shows the monitoring parameters that will be referred in the HAB case study.

### Table 5. Monitoring parameters referred in the HAB case study

<table>
<thead>
<tr>
<th>Monitoring parameter</th>
<th>Survey type</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAB</td>
<td>Regular HAB monitoring survey</td>
</tr>
<tr>
<td>-HAB species (dominant/causative spp.)</td>
<td></td>
</tr>
<tr>
<td>-Cell density</td>
<td></td>
</tr>
<tr>
<td>-Bloom area</td>
<td></td>
</tr>
<tr>
<td>Water quality</td>
<td>Regular HAB monitoring survey</td>
</tr>
<tr>
<td>-Water temp.</td>
<td></td>
</tr>
<tr>
<td>-Salinity</td>
<td></td>
</tr>
<tr>
<td>--Heavy metals</td>
<td></td>
</tr>
<tr>
<td>Meteorology</td>
<td>Regular HAB monitoring survey</td>
</tr>
<tr>
<td>-Weather</td>
<td></td>
</tr>
<tr>
<td>-Ice cover</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>Shellfish poisoning survey</td>
</tr>
<tr>
<td>Shellfish contamination</td>
<td></td>
</tr>
</tbody>
</table>

4. Status of HAB events


For the period of observations from year 1991 - 2008, a total 49 HAB events were observed, in which no any cases of human poisoning or fishery damage were recorded. Records of HAB events from year 1991-2008 are provided in Annex I.

During the 18 years between 1991 and 2008, a total 30 HAB species were recorded in which 20 species caused water blooms (Figure 3). Those species are belonging to 6 taxonomic groups of phytoplankton: dinoflagellates, diatoms, raphidophytes, cryptophytes, chrysophytes and euglenophytes. The most common bloom-forming
species were diatoms and dinoflagellates (55% and 29% from the total number of HAB events, respectively) (Figure 3).

**Figure 3.** Percentage of bloom-forming species from year 1991-2008 in Amurskii Bay

**Figure 4.** Percentage of potentially toxic species from year 1991-2008 in Amurskii Bay
From year 1991-2008, a total of 13 species, which are known to be toxic, were observed in Amurskii Bay. Potentially toxic species are belonging to 2 groups of phytoplankton: dinoflagellates and diatoms. Dinoflagellates were dominated among potentially toxic species - 62% from the total number of toxic species (Figure 4). Diatoms of the genus *Pseudo-nitzschia* are known as domoic producing species. Accumulating in the tissues of filter-feeding mollusks, this acid is transferred via the food chain and, when passed to humans, may cause serious neurological disorders. According to the symptoms, these cases were classified as Amnesic Shellfish Poisoning (ASP). Five *Pseudo-nitzschia* species were monitored in Amurskii Bay: *P. seriata/pungens*, *P. multiseries*, *P. delicatissima*, *P. fraudulent* and *P. calliantha* (Table 2).

Species of the genus *Dinophysis* and *Protoceratium reticulatum* are capable of producing toxins, which accumulates in the tissues of filter-feeding mollusks, causing the syndrome of diarrhetic shellfish poisoning (DSP). Six species, which are known as DSP producing species, were observed in Amurskii Bay in 1991-2008. These species are *Dinophysis acuminata*, *D. acuta*, *D. fortii*, *D. norvegica*, *D. rotundata*, and *Protoceratium reticulatum* (Table 2). Dinoflagellates *Karenia mikimotoi* and *Prorocentrum minimum* are known as ichthyotoxin producers.

In the follow sections, the yearly trends, main seasons and duration of HAB events are analyzed.

4.2. Yearly trends of HAB events

During the 18 years between 1991 and 2008, a total 45 bloom events were recorded, in which no any events induce damage or human poisoning. Total frequency of HAB has decreased in general (Figure 5). HAB events occurred most frequently during July-August and October (Figure 5.1).
4.3. Yearly trends of Toxic plankton

From year 1991-2008, a total of 13 species, which are known to be toxic were observed in Amurskii Bay, which occurred most frequently during June-November (Figure 6).
4.4. Yearly trends of causative species

Table 6 shows the HAB species that were recorded in Amurskii Bay between 1991-2008 and their frequency of occurrences. A total of 29 HAB species were recorded and the most frequent species were diatoms *Skeletonema costatum*, *Pseudo-nitzschia seriata/pungens*, *Thalassionema nitzschiodes* and dinoflagellate *Dinophysis acuminata* (Table 6).

Table 6. HAB species recorded in Amurskii Bay, 1991–2008 and their frequency of occurrences

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Diatoms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Chaetoceros affinis</em></td>
<td>55</td>
<td>4</td>
<td>13</td>
<td></td>
<td>72</td>
</tr>
<tr>
<td><em>Chaetoceros contortus</em></td>
<td>47</td>
<td>2</td>
<td>15</td>
<td></td>
<td>64</td>
</tr>
<tr>
<td><em>Chaetoceros curvisetus</em></td>
<td>20</td>
<td>6</td>
<td></td>
<td></td>
<td>26</td>
</tr>
<tr>
<td><em>Chaetoceros salsugineus</em></td>
<td>14</td>
<td></td>
<td>14</td>
<td></td>
<td>28</td>
</tr>
<tr>
<td><em>Leptocylindrus minimus</em></td>
<td>61</td>
<td>10</td>
<td></td>
<td></td>
<td>71</td>
</tr>
<tr>
<td>Phytoplankton Species</td>
<td>2005</td>
<td>2006</td>
<td>2007</td>
<td>2008</td>
<td></td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>Pseudo-nitzschia calliantha</td>
<td>9</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudo-nitzschia delicatissima</td>
<td>19</td>
<td>2</td>
<td>21</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Pseudo-nitzschia fraudulenta</td>
<td>2</td>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudo-nitzschia multistriata</td>
<td>1</td>
<td>6</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudo-nitzschia multiseries</td>
<td>10</td>
<td>4</td>
<td>1</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Pseudo-nitzschia seriata/pungens</td>
<td>91</td>
<td>8</td>
<td>26</td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>Skeletonema costatum</td>
<td>85</td>
<td>15</td>
<td>44</td>
<td>144</td>
<td></td>
</tr>
<tr>
<td>Thalassionema nitzschioides</td>
<td>69</td>
<td>13</td>
<td>47</td>
<td>129</td>
<td></td>
</tr>
<tr>
<td>Thalassiosira mala</td>
<td>11</td>
<td></td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thalassiosira nordenskioeldii</td>
<td>50</td>
<td>8</td>
<td>37</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Cryptophyceae</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Plagioselmis sp.</td>
<td>54</td>
<td>45</td>
<td>99</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dinoflagellates</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dinophysis acuminata</td>
<td>80</td>
<td>5</td>
<td>22</td>
<td>107</td>
<td></td>
</tr>
<tr>
<td>Dinophysis acuta</td>
<td>15</td>
<td>2</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dinophysis fortii</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dinophysis norvegica</td>
<td>4</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dinophysis rotundata</td>
<td>8</td>
<td>1</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Karenia mikimotoi</td>
<td>9</td>
<td>4</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noctiluca scintillans</td>
<td>14</td>
<td></td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prorocentrum minimum</td>
<td>9</td>
<td>37</td>
<td>11</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>Protoceratium reticulatum</td>
<td>4</td>
<td>2</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raphidophyceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chattonella sp.</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterosigma akashiwo</td>
<td>3</td>
<td>9</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chrysophyceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dinobryon balticum</td>
<td></td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Euglenophyceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Euglena pascheri</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. Status of recent HAB events and results of environmental monitoring

Records of HAB events in September 2005 – August 2008 are provided in Annex I.
5.1. Number of HAB events

Records of HAB events in Amurskii Bay between September 2005-September 2006 are provided in Appendix II. In September 2005-September 2006, a total of 12 HAB events were recorded. No any cases of fishery damage or human poisoning were recorded. The most frequently observed species was bloom-forming diatom *Thalassionema nitzschioides*. The most frequently observed potentially toxic species were diatoms *Pseudo-nitzschia delicatissima* and *P. pungens*.

Records of HAB events in Amurskii Bay August 2007 – August 2008 are provided in Appendix II. In September 2007-September 2008, a total of 29 HAB events were recorded. No any cases of fishery damage or human poisoning were recorded. The most frequently observed potentially toxic species were diatoms *Pseudo-nitzschia delicatissima* and *P. pungens*.

5.2. Period of HAB events

According to the HAB data in September 2005-September 2006, 52% of HAB species occurred in December (Figure 7.1). HAB events occurred during June – December, and observed more frequently in June and October.

![Figure 7.1. Number of HAB events by month in Amurskii Bay (September 2005 – September 2006).](image-url)
According to the HAB data in August 2007 – August 2008, 45% of HAB species occurred in August–September (Figure 7.2). HAB events occurred during from March to November, and observed more frequently from June and October.

![Figure 7.2. Number of HAB events by month in Amurskii Bay (August 2007 – August 2008)](image)

5.3. Duration of HAB events

Table 7.1 shows the number of HAB events by duration (no. of days) in September 2005- September 2006. A total of 13 events occurred in September 2005-September 2006, in which 6 events were under 5 days, 2 events between 6-10 days, 5 events between 11-30 days. The longest HAB duration was 28 days by bloom-forming diatom *Thalassionema nitzschioides*, which occurred during June-July. The longest HAB duration by potentially toxic species was 25 days. It was caused by *Pseudo-nitzschia delicatissima* in December.

<table>
<thead>
<tr>
<th></th>
<th>≤5</th>
<th>6-10</th>
<th>11-30</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amurskii Bay</td>
<td>6</td>
<td>2</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>2</td>
<td>5</td>
<td>13</td>
</tr>
</tbody>
</table>

Table 7.2 shows the number of HAB events by duration (no. of days) in August 2007 – August 2008. A total of 29 events occurred in August 2007 – August 2008, in which 11 events between 6–10 days, 3 events between 11–30 days, 5 events were above 30 days. The longest bloom was 47 days forming by diatom *Skeletonema costatum*, which mass developed from June to August. The longest HAB duration by potentially toxic species was 70 days. It was caused by dinoflagellate *Dinophysis acuminata*, which occurred during May-July.

<table>
<thead>
<tr>
<th></th>
<th>6-10</th>
<th>11-30</th>
<th>&gt;30</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amurskii Bay</td>
<td>10</td>
<td>3</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>7</td>
<td>12</td>
<td>29</td>
</tr>
</tbody>
</table>

Source: Center of Monitoring of HABs & Biotoxins A.V. Zhirmunskii Institute of Marine Biology FEB RAS (2007)
http://www.imb.dvo.ru/misc/toxicalgae/index.htm

5.4. Location of HAB events

Table 8.1 shows the number of HAB events by area. In September-December 2005, 7 events occurred in Amurskii Bay and caused mostly by potentially toxic diatoms *Pseudo-nitzschia* spp. In January –September 2006, 6 events occurred in Amurskii Bay. These events were caused by dinoflagellates and bloom-forming diatoms. Figure 8.1 shows the location of the HAB events and causative species in Amurskii Bay in September 2005 – September 2006.

<table>
<thead>
<tr>
<th>Year</th>
<th>Sea area</th>
<th>No. of events</th>
<th>Causative species</th>
</tr>
</thead>
<tbody>
<tr>
<td>September-December 2005</td>
<td>Amurskii Bay</td>
<td>7</td>
<td><em>Pseudo-nitzschia calliantha</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Pseudo-nitzschia fraudulent</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Pseudo-nitzschia multistriata</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Pseudo-nitzschia delicatissima</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Pseudo-nitzschia pungens</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Pseudo-nitzschia seriata</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Prorocentrum minimum</em></td>
</tr>
<tr>
<td>January-September 2006</td>
<td>Amurskii Bay</td>
<td>6</td>
<td><em>Dinophysis rotundata</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Dinophysis acuminata</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Dinophysis acuta</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Karenia mikimotoi</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Chaetoceros salsugineus</em></td>
</tr>
</tbody>
</table>
Figure 8. 1. Location of HAB events (events no. and causative species) in Amurskii Bay (September 2005 – September 2006).

Table 8.2 shows the number of HAB events by area. In August–December 2007, 12 events occurred in Amurskii Bay and caused mostly by potentially toxic diatoms *Pseudo-nitzschia* spp. In January–August 2008, 6 events occurred in Amurskii Bay. These events were caused by dinoflagellates, diatoms and bloom-forming raphidophytes. Figure 8.2 shows the location of the HAB events and causative species in Amurskii Bay in August 2007 – August 2008.
Table 8.2. Number of HAB events by area in August 2007 – August 2008

<table>
<thead>
<tr>
<th>Year</th>
<th>Sea area</th>
<th>No. of events</th>
<th>Causative species</th>
</tr>
</thead>
<tbody>
<tr>
<td>August-December 2007</td>
<td>Amurskii Bay</td>
<td>12</td>
<td>Pseudo-nitzschia calliantha</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pseudo-nitzschia delicatissima</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pseudo-nitzschia pungens</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Heterosigma akashiwo</td>
</tr>
<tr>
<td>January-August 2008</td>
<td>Amurskii Bay</td>
<td>6</td>
<td>Pseudo-nitzschia delicatissima</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pseudo-nitzschia multistriata</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pseudo-nitzschia pungens</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dinophysis acuminata</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Heterosigma akashiwo</td>
</tr>
</tbody>
</table>


Figure 8.2. Location of HAB events (events no. and causative species) in Amurskii Bay (August 2007 – August 2008).
5.5. Causative species

Table 9.1 shows the HAB species that were recorded in Amurskii Bay in September 2005-September 2006 and their frequency of occurrences. A total of 19 HAB species were recorded. The most frequently observed species was bloom-forming diatom *Thalassionema nitzschioides*. The most frequently observed potentially toxic species were diatoms *Pseudo-nitzschia delicatissima* and *P. pungens*.

Table 9.1. HAB species recorded in Amurskii Bay in September 2005 – September 2006 and their frequency of occurrences

<table>
<thead>
<tr>
<th>Genus and Species</th>
<th>September 2005-September 2006</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacillariophyceae</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chaetoceros salsugineus</td>
<td>6 * 6</td>
<td>6</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia calliantha</em></td>
<td>3 3</td>
<td>3</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia delicatissima</em></td>
<td>8 8</td>
<td>8</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia fraudulenta</em></td>
<td>1 1</td>
<td>1</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia multistriata</em></td>
<td>4 4</td>
<td>4</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia multiseries</em></td>
<td>0 0</td>
<td>0</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia seriata/pungens</em></td>
<td>8 8</td>
<td>8</td>
</tr>
<tr>
<td><em>Thalassionema nitzschioides</em></td>
<td>14 * 14</td>
<td>14</td>
</tr>
<tr>
<td><strong>Dinophyceae</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Dinophysis acuminata</em></td>
<td>7 7</td>
<td>7</td>
</tr>
<tr>
<td><em>Dinophysis acuta</em></td>
<td>2 2</td>
<td>2</td>
</tr>
<tr>
<td><em>Dinophysis fortii</em></td>
<td>0 0</td>
<td>0</td>
</tr>
<tr>
<td><em>Dinophysis norvegica</em></td>
<td>0 0</td>
<td>0</td>
</tr>
<tr>
<td><em>Dinophysis rotundata</em></td>
<td>1 1</td>
<td>1</td>
</tr>
<tr>
<td><em>Karenia mikimotoi</em></td>
<td>1 1</td>
<td>1</td>
</tr>
<tr>
<td><em>Noctiluca scintillans</em></td>
<td>0 0</td>
<td>0</td>
</tr>
<tr>
<td><em>Prorocentrum minimum</em></td>
<td>5 5</td>
<td>5</td>
</tr>
<tr>
<td><em>Protoceratium reticulatum</em></td>
<td>0 0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Raphidophyceae</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Chattonella</em> sp.</td>
<td>0 0</td>
<td>0</td>
</tr>
<tr>
<td><em>Heterosigma akashiwo</em></td>
<td>0 0</td>
<td>0</td>
</tr>
<tr>
<td>Total number of samples</td>
<td></td>
<td>27</td>
</tr>
</tbody>
</table>
* Bloom-forming species (density exceed $1 \cdot 10^6$ cells per L)


Table 9.2 shows the HAB species that were recorded in Amurskii Bay in August 2007 – August 2008 and their frequency of occurrences. A total of 11 HAB species were recorded. The most frequently observed species was bloom-forming diatom *Skeletonema costatum*. The most frequently observed potentially toxic species were diatoms *Pseudo-nitzschia delicatissima* and *P. seriata/pungens*.

![Table 9.2. HAB species recorded in Amurskii Bay in August 2007 – August 2008 and their frequency of occurrences](http://www.imb.dvo.ru/misc/toxicalgae/index.htm)
Table 10.1 shows the maximum density of each HAB event that occurred in Amurskii Bay in September 2005-September 2006. Within these HAB events, the highest density was recorded in July 2006 by Thalassionema nitzschioides. The recorded maximum density was 2 000 000 cell/L.

<table>
<thead>
<tr>
<th>Year</th>
<th>Event No.</th>
<th>Causative species</th>
<th>Maximum density (cellsL⁻¹)</th>
<th>Affected area</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>AB200501</td>
<td>Pseudo-nitzschia calliantha</td>
<td>200 000</td>
<td>No info.</td>
</tr>
<tr>
<td>2005</td>
<td>AB200502</td>
<td>Pseudo-nitzschia fraudulenta</td>
<td>38 000</td>
<td>No info.</td>
</tr>
<tr>
<td>2005</td>
<td>AB200503</td>
<td>Pseudo-nitzschia multistriata</td>
<td>800 000</td>
<td>No info.</td>
</tr>
<tr>
<td>2005</td>
<td>AB200504</td>
<td>Pseudo-nitzschia delicatissima</td>
<td>80 000</td>
<td>No info.</td>
</tr>
<tr>
<td>2005</td>
<td>AB200505</td>
<td>Pseudo-nitzschia pungens</td>
<td>60 000</td>
<td>No info.</td>
</tr>
<tr>
<td>2005</td>
<td>AB200506</td>
<td>Prorocentrum minimum</td>
<td>100 000</td>
<td>No info.</td>
</tr>
<tr>
<td>2005</td>
<td>AB200507</td>
<td>Pseudo-nitzschia seriata</td>
<td>9 100</td>
<td>No info.</td>
</tr>
<tr>
<td>2006</td>
<td>AB200601</td>
<td>Dinophysis rotundata</td>
<td>500</td>
<td>No info.</td>
</tr>
<tr>
<td>2006</td>
<td>AB200602</td>
<td>Thalassionema nitzschioides</td>
<td>2 000 000</td>
<td>No info.</td>
</tr>
<tr>
<td>2006</td>
<td>AB200603</td>
<td>Dinophysis acuminata</td>
<td>12 800</td>
<td>No info.</td>
</tr>
<tr>
<td>2006</td>
<td>AB200604</td>
<td>Dinophysis acuta</td>
<td>500</td>
<td>No info.</td>
</tr>
<tr>
<td>2006</td>
<td>AB200605</td>
<td>Karenia mikimoto</td>
<td>18 000</td>
<td>No info.</td>
</tr>
<tr>
<td>2006</td>
<td>AB200606</td>
<td>Chaetoceros salsugineus</td>
<td>1 600 000</td>
<td>No info.</td>
</tr>
</tbody>
</table>
Table 10.2 shows the maximum density of each HAB event that occurred in Amurskii Bay in August 2007 – August 2008. Within these HAB events, the highest density was recorded in August 2007 by *Skeletonema costatum*. The recorded maximum density was 8 698 000 cell/L.

### Table 10.2. Maximum density of HAB event that occurred in Amurskii Bay

<table>
<thead>
<tr>
<th>Year</th>
<th>Event No.</th>
<th>Causative species</th>
<th>Maximum density (cells L⁻¹)</th>
<th>Affected area</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>AB200701</td>
<td><em>Chaetoceros salsugineus</em></td>
<td>42 500</td>
<td>No info.</td>
</tr>
<tr>
<td>2007</td>
<td>AB200702</td>
<td><em>Pseudo-nitzschia calliantha</em></td>
<td>173 400</td>
<td>No info.</td>
</tr>
<tr>
<td>2007</td>
<td>AB200703</td>
<td><em>Pseudo-nitzschia delicatissima</em></td>
<td>83 400</td>
<td>No info.</td>
</tr>
<tr>
<td>2007</td>
<td>AB200704</td>
<td><em>Pseudo-nitzschia pungens</em></td>
<td>4 800</td>
<td>No info.</td>
</tr>
<tr>
<td>2007</td>
<td>AB200705</td>
<td><em>Skeletonema costatum</em></td>
<td>8 698 000</td>
<td>No info.</td>
</tr>
<tr>
<td>2007</td>
<td>AB200706</td>
<td><em>Karenia mikimotoi</em></td>
<td>1 000</td>
<td>No info.</td>
</tr>
<tr>
<td>2007</td>
<td>AB200707</td>
<td><em>Prorocentrum minimum</em></td>
<td>7 000</td>
<td>No info.</td>
</tr>
<tr>
<td>2007</td>
<td>AB200708</td>
<td><em>Heterosigma akashiwo</em></td>
<td>10 000</td>
<td>No info.</td>
</tr>
<tr>
<td>2008</td>
<td>AB200801</td>
<td><em>Dinobryon balticum</em></td>
<td>1 054 000</td>
<td>No info.</td>
</tr>
<tr>
<td>2008</td>
<td>AB200802</td>
<td><em>Pseudo-nitzschia multistriata</em></td>
<td>1 300</td>
<td>No info.</td>
</tr>
<tr>
<td>2008</td>
<td>AB200803</td>
<td><em>Dinophysis acuminata</em></td>
<td>4 500</td>
<td>No info.</td>
</tr>
</tbody>
</table>

5.7. Status of HAB induced fishery damage

There is no any information of any fishery damage or human poisoning in Amurskii Bay in September 2005 – August 2008.

5.8. Status of target species

In this case study, the following type of HAB species are targeted and referred to as “target HAB species”:

- red-tide causative (bloom-forming) species in the target sea area;
- toxin-producing plankton (toxic and potentially toxic species).

Table 11.1 shows target HAB species in Amurskii Bay between September 2005 and September 2006. A total 11 target HAB species were recorded. Those species are belonging to 2 taxonomic groups of phytoplankton: dinoflagellates (5 species), diatoms (6 species).
Table 11.1. Target HAB species in Amurskii Bay, September 2005-September 2006

<table>
<thead>
<tr>
<th>Target HAB species</th>
<th>Bloom-forming species</th>
<th>Toxic/potentially toxic species</th>
<th>Maximum density (cellsL⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diatoms</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pseudo-nitzschia calliantha</em></td>
<td>+</td>
<td></td>
<td>200 000</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia fraudulenta</em></td>
<td>+</td>
<td></td>
<td>38 000</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia multistriata</em></td>
<td>+</td>
<td>+</td>
<td>800 000</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia delicatissima</em></td>
<td>+</td>
<td>+</td>
<td>80 000</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia pungens</em></td>
<td>+</td>
<td>+</td>
<td>60 000</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia seriata</em></td>
<td>+</td>
<td></td>
<td>9 100</td>
</tr>
<tr>
<td><strong>Dinoflagellates</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Prorocentrum minimum</em></td>
<td>+</td>
<td></td>
<td>100 000</td>
</tr>
<tr>
<td><em>Dinophysis rotundata</em></td>
<td>+</td>
<td></td>
<td>500</td>
</tr>
<tr>
<td><em>Dinophysis acuminata</em></td>
<td>+</td>
<td></td>
<td>12 800</td>
</tr>
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<td><em>Dinophysis acuta</em></td>
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<tr>
<td><em>Karenia mikimotoi</em></td>
<td>+</td>
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<td>18 000</td>
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</table>


According to the HAB data in September 2005-September 2006, target HAB species occurred in June-December (Figure 9.1) and observed more frequently in October.

![Figure 9.1/ Number of Target HAB species by month in Amurskii Bay (September 2005 – September 2006).](image-url)
Table 11.2 shows target HAB species in Amurskii Bay between August 2007 and August 2008. A total 9 target HAB species were recorded. Those species are belonging to 2 taxonomic groups of phytoplankton: dinoflagellates (3 species) and diatoms (3 species).

### Table 11.2. Target HAB species in Amurskii Bay, August 2007–August 2008

<table>
<thead>
<tr>
<th>Target HAB species</th>
<th>Bloom-forming species</th>
<th>Toxic/potentially toxic species</th>
<th>Maximum density (cellsL⁻¹)</th>
</tr>
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<tbody>
<tr>
<td>Chrysophyceae</td>
<td></td>
<td></td>
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<tr>
<td><em>Dinobryon balticum</em></td>
<td>+</td>
<td></td>
<td>1 054 000</td>
</tr>
<tr>
<td>Diatoms</td>
<td></td>
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<td></td>
</tr>
<tr>
<td><em>Pseudo-nitzschia calliantha</em></td>
<td>+</td>
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<td>173 400</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia multisiliata</em></td>
<td>+</td>
<td>+</td>
<td>1 300</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia delicatissima</em></td>
<td>+</td>
<td></td>
<td>83 400</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia pungens</em></td>
<td>+</td>
<td></td>
<td>4 800</td>
</tr>
<tr>
<td><em>Skeletonema costatum</em></td>
<td>+</td>
<td></td>
<td>8 698 000</td>
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<tr>
<td>Dinoflagellates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Prorocentrum minimum</em></td>
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<td></td>
<td>7 000</td>
</tr>
<tr>
<td><em>Dinophysis acuminata</em></td>
<td>+</td>
<td></td>
<td>4 500</td>
</tr>
<tr>
<td><em>Karenia mikimotoi</em></td>
<td>+</td>
<td></td>
<td>1 000</td>
</tr>
<tr>
<td>Raphidophyceae</td>
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<td></td>
<td></td>
</tr>
<tr>
<td><em>Heterosigma akashiwo</em></td>
<td>+</td>
<td></td>
<td>10 000</td>
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</table>


According to the HAB data in August 2007–August 2008, target HAB species occurred in March–November (Figure 9.2) and observed more frequently in August.
5.9. Environmental monitoring results during HAB events

During the post-HAB survey between September 2005 and September 2006, water temperature and salinity were measured. Table 12.1 shows the data obtained for each HAB event between September 2005 and September 2006. During the HAB events, water temperature ranged between 22 - -1.8°C, salinity between 17-352‰.

Table 12.1. Data of post-HAB surveys in Amurskii Bay (September 2005- September 2006).

<table>
<thead>
<tr>
<th>Year</th>
<th>Event No.</th>
<th>Duration</th>
<th>Water temp. (°C)</th>
<th>Salinity, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>AB200501</td>
<td>Pseudo-nitzschia calliantha</td>
<td>6 - 12</td>
<td>32 - 33</td>
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<tr>
<td>2005</td>
<td>AB200502</td>
<td>Pseudo-nitzschia fraudulenta</td>
<td>3.8 x 10^3</td>
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<td>2005</td>
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<td>Pseudo-nitzschia multistriata</td>
<td>0.8 x 10^6</td>
<td>15</td>
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</table>
During the post-HAB survey in Amurskii Bay during August 2007 – August 2008, water temperature and salinity were measured. Table 12.2 shows the data obtained for each HAB event. During the HAB events, water temperature ranged between -1.8 – 23.5°C, salinity between 19 – 34‰.

Table 12.2. Data of post-HAB surveys in Amurskii Bay (August 2007 – August 2008).

<table>
<thead>
<tr>
<th>Year</th>
<th>Event No.</th>
<th>Duration</th>
<th>Water temp. (°C)</th>
<th>Salinity, ‰</th>
</tr>
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<tbody>
<tr>
<td>2007</td>
<td>AB200701</td>
<td>Chaetoceros salsugineus</td>
<td>-1.7 – 23</td>
<td>22 – 33</td>
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<td>2007</td>
<td>AB200702</td>
<td>Pseudo-nitzschia calliantha</td>
<td>6.5 – 20.9</td>
<td>26 – 31</td>
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<td>2007</td>
<td>AB200703</td>
<td>Pseudo-nitzschia delicatissima</td>
<td>15.2 – 23.5</td>
<td>22.5 – 33</td>
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<tr>
<td>2007</td>
<td>AB200704</td>
<td>Pseudo-nitzschia pungens</td>
<td>-1.6 – 23.5</td>
<td>19 – 34</td>
</tr>
<tr>
<td>2007</td>
<td>AB200705</td>
<td>Skeletonema costatum</td>
<td>5.5 – 23.5</td>
<td>19 – 32</td>
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<tr>
<td>2007</td>
<td>AB200706</td>
<td>Karenia mikimotoi</td>
<td>26</td>
<td>28</td>
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<td>Year</td>
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<td>Range</td>
<td>Percentage</td>
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<td>2007</td>
<td>AB200707</td>
<td><em>Prorocentrum minimum</em></td>
<td>20.5</td>
<td>28</td>
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<td>2007</td>
<td>AB200708</td>
<td><em>Heterosigma akashiwo</em></td>
<td>6.5 – 23.2</td>
<td>19 – 31</td>
</tr>
<tr>
<td>2008</td>
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<td><em>Dinobryon balticum</em></td>
<td>-1.8 – 5.5</td>
<td>31 – 34</td>
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<tr>
<td>2008</td>
<td>AB200802</td>
<td><em>Pseudo-nitzschia multistriata</em></td>
<td>-1.8 – 23.5</td>
<td>22.5 – 32</td>
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<td>2008</td>
<td>AB200803</td>
<td><em>Dinophysis acuminata</em></td>
<td>9 – 23</td>
<td>19 – 29</td>
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</table>


6. Eutrophication monitoring with satellite image

6.1. Framework of Satellite image monitoring

Source: Institute of Automation and Control Processes, Far-Eastern Branch of Russian Academy of Sciences by Dr. Anatoly Alexanin.

The main task is satellite monitoring of harmful algal blooms (HABs).

The Amurskiy bay characteristics are:

- Significant amount of solid suspended matter comes in the bay by Razdolnaya river;
- The town discharge has both solid suspend matter and coloured dissolved organic matter;
- Shallow waters are near the shore line;
- The wind in August is from the land. Mineral dust in atmosphere.

Two ways the task solution:

- Use of "standard" ocean colour products and a knowledge about the regional peculiarities of plankton species bloom for interpretation of the satellite images.
- Phytoplankton species detection on the based of the plankton species peculiarities of its sun light diffusion and absorption in the sea water.

Shallow water problem:

The first results have been received to use the propagation model for Chlorophyll-a and suspended matter estimation.

Source: O. Kopelevich and oth., Institute of Oceanology RAS, E-mail: Oleg@sio.rssi.ru
Table 12. Parameter ratios and estimation errors

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<tr>
<th>Parameter</th>
<th>chl-OC2</th>
<th>Chl-OC3</th>
<th>K490</th>
<th>flh</th>
<th>nLw-412</th>
<th>nLw-443</th>
<th>nLw-469</th>
<th>nLw-488</th>
<th>nLw-531</th>
<th>nLw-551</th>
<th>nLw-555</th>
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</thead>
<tbody>
<tr>
<td>Ratio CO/DB</td>
<td>3.0</td>
<td>2.3</td>
<td>4.3</td>
<td>2.9</td>
<td>-17.4</td>
<td>-63.3</td>
<td>-397</td>
<td>40</td>
<td>3.0</td>
<td>1.95</td>
<td>2.0</td>
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<tr>
<td>Errors</td>
<td>7%</td>
<td>3%</td>
<td>21%</td>
<td>250%</td>
<td>24%</td>
<td>22%</td>
<td>18%</td>
<td>36%</td>
<td>2%</td>
<td>10%</td>
<td>8%</td>
</tr>
</tbody>
</table>

Figure 10. Fluorescence by MODIS imagery in Amurskiy bay in August 28, 2006.
Figure 11. Spectral properties estimation on MODIS imagery for diatoms *Coscinodiscus oculus-iridis* (left) and *Ditylum brightwelli* (right), in Amurskiy bay in August, 31.2006.

Figure 11 shows alga species detection and its spectral properties estimation on MODIS imagery in Amurskiy bay in August 2006.

To make efficient HAB monitoring it is necessary to measure spectral properties of each species in a laboratory for each alga life stage. An easy way and inexpensive realisation of monitoring technology creation is to organise the regular measurements on any test sea area near a shore of the Amursky bay. It should be lidar and/or spectroradiometer remote measurements from the shore and in situ measurement of alga composite and water radiation properties both in deep and shallow waters. Lidar sounding of the atmosphere together with AMSU atmosphere profiles should allow controlling the key atmosphere parameters: aerosol particle size, its height, humidity, ozone and others.

7. Conclusion

7.1. The relationship between HABs and environmental parameters
Amurskii Bay is characterized by the greatest eutrophic level in Peter the Great Bay, Sea of Japan. These water areas are adversely affected by industrial waste products and municipal sewage of Vladivostok as well as by agricultural and municipal sewage of Ussuriiysk that are transported to the sea by terrigenous runoff and by the waters of Razdolnaya River, respectively Ogorodnikova et al., 1997, Vaschenko, 2000). High concentrations of nitrates and nitrites, as well as an increase in the phytoplankton primary production (Tkalin, 1993), suggest that the eutrophic level of Amurskii Bay increased during the period of the early 1980s through the early 1990s. A comparative analysis of the peaks of density and biomass of HAB species showed that both density and biomass of HAB species increased during Summer-Autumn period. For instance, the greatest values of microalgal densities (12,7 million cells/l) were recorded in the study area in July, due to massive development of diatom Skeletonema costatum - an indicator of organic pollution of sea water (Yamada et al., 1983). High values of total phytoplankton and S. costatum density suggest that in summer 1991 and 1996, the bay’s waters were hypereutrophic. From 1997 till 2007, the total phytoplankton and S. costatum densities were less than in 1991 and 1996. It is consistent with a decrease of the bay’s water trophicity to intermediate between eutrophic and hypereutrophic levels in summer from 1999 till 2007.

From year 1991-2007, a total of 13 species, which are know to be toxic were observed in Amurskii Bay, which occurred most frequently during June-November. A significant increase in the density of the non-diatom component of phytoplankton was observed in Amursky Bay. During the summer—autumn period of 1991, an intensive bloom of the dinoflagellate P. minimum (7,6 million cells /L) was recorded in Amurskii Bay. Considerable density of non-diatom microalgae was observed due to the massive development of euglenophytes, cryptophytes and raphydophytes (more than 1 million cells/L) previously not reported for this region (Annex 1).

In summary, the following trends in the phytoplankton composition were revealed: 1) total density and biomass increased; 2) the density of the diatom S. costatum, increased significantly; and 3) the density of the non-diatom component of the phytoplankton increased. Multi-year monitoring of the phytoplankton dynamics in Amurskii Bay showed that total phytoplankton density, as well as in frequency and intensity of water blooms in the early 1990s have been increasing. Our results are consistent with the previously reported data on the changes in the composition of phytoplankton in other eutrophic waters (Marasovic, Pucher-Petkovic, 1991; Miheoa,
1997), as well as with the results of hydrochemical investigations of the study area (Tkalin et al., 1993).

### 7.2. The application options of satellite image for monitoring HAB events:

Main difficulties:

- Bio-optical algorithms do not work in coastal area usually. Bottom influence in the shallow waters is the main problem. Another problem is an influence of different impurities such as suspended sediments and other contamination.

- Atmosphere correction errors are significant, especially in the coastal zone (no good aerosol models for atmosphere formed over the land). As the sequence the normalise water leaving radiance in violet and red spectral bands is wrong or negative.

- No dominant algae in the water. Plankton community consists of 10 and more species and each alga concentration is less 20% of total bio-mass usually. It is difficult to solve the identification task correctly.

- Water leaving radiance has significant dependence on the alga stage of life. Radiance characteristics in the end of bloom have low coincidence with ones in the beginning stage.

- Alga species detection is invert mathematical task. Such tasks have no single solution usually and rather sensitive to data errors. Heterogeneity of alga distribution in depth and plankton migration makes difficult the solution verification.

- Low spatial and radiance resolution of satellite information.

**Source:** Institute of Automation and Control Processes, Far-Eastern Branch of Russian Academy of Sciences by Dr. Anatoly Alexanin.

To make efficient HAB monitoring it is necessary to measure spectral properties of each species in a laboratory for each alga life stage. An easy way and inexpensive realisation of monitoring technology creation is to organise the regular measurements on any test sea area near a shore of the Amursky bay. It should be lidar and/or spectroradiometer remote measurements from the shore and in situ measurement of alga composite and water radiation properties both in deep and shallow waters. Lidar sounding of the atmosphere together with AMSU atmosphere profiles should allow controlling the key atmosphere parameters: aerosol particle size, its height, humidity, ozone and others.
8. References


Appendix

<table>
<thead>
<tr>
<th>Duration (Start)</th>
<th>Duration (End)</th>
<th>Contin. days</th>
<th>Species</th>
<th>Density (cells L⁻¹)</th>
<th>Temp. (°C)</th>
<th>Salinity, psu</th>
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</thead>
<tbody>
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**Diatoms**

**Cryptophytes**

**Dinoflagellates**

**Raphidophytes**

**Euglenophytes**
### Annex II.1.

Records of HAB events in Amurskii Bay in September 2005-September 2006

<table>
<thead>
<tr>
<th>Event No.</th>
<th>Duration (Start)</th>
<th>Duration (End)</th>
<th>Continuous days</th>
<th>Species</th>
<th>Density (cells L⁻¹)</th>
<th>Temp. (°C)</th>
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### Annex I.2. Records of HAB events in Amurskii Bay in August 2007–August 2008
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