Report of HAB Case Study
in Amurskii Bay, Primorkii Krai, Russia

Dec. 2008

Contents

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.

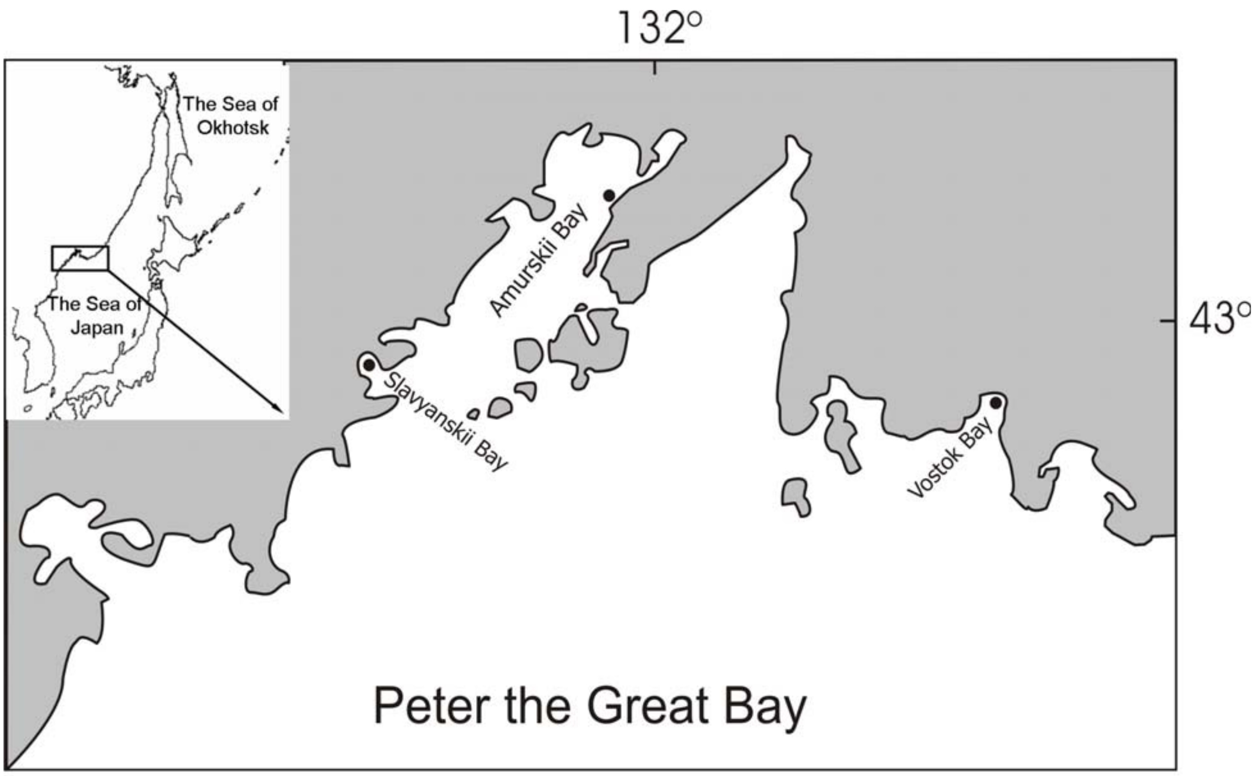

Figure 1. Target sea area for the case study of Russia

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. n 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 north-east (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 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 10 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 Primorskoye 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 -1.6^0C to -1.9^0) and maximum for August (20.8^0C to 23.1^0C). Average annual temperature of surface water is 7.8-8.3^0C (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 1. HAB warning/action standards of Primorskii Krai

HAB species	Warning level (cells/L)	Affected objects
Pseudo-nitzschia calliantha	500 000	Shellfish
Pseudo-nitzschia	500 000	Shellfish

delicatissima		
Pseudo-nitzschia fraudulenta	500 000	Shellfish
Pseudo-nitzschia multistriata	500 000	Shellfish
Pseudo-nitzschia multiseries	500 000	Shellfish
Pseudo-nitzschia seriata	500 000	Shellfish
Dinophysis acuminata	500	Shellfish
Dinophysis acuta	500	Shellfish
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 2007, a total 17 target HAB species were recorded in which 13 species are known as potentially toxic species and 7 species cause water blooms (Table 3). Those species are belonging to 3 taxonomic groups of phytoplankton: dinoflagellates (9 species), diatoms (6 species), raphidophytes (2 species).

Table 2. Target HAB species in Amurskii Bay, 1991–2007

Species	Red-tide causative/bloom-forming species	Toxic/potentially toxic species
Bacillariophyceae		
Pseudo-nitzschia calliantha		
Pseudo-nitzschia delicatissima	+	+
Pseudo-nitzschia fraudulenta		+

Pseudo-nitzschia multistriata		+
Pseudo-nitzschia multiseries	+	+
Pseudo-nitzschia seriata/pungens		+
Dinophyceae		
Dinophysis acuminata		+
Dinophysis acuta		+
Dinophysis fortii		+
Dinophysis norvegica		+
Dinophysis rotundata		+
Karenia mikimotoi	+	+
Noctiluca scintillans	+	
Prorocentrum minimum	+	+
Protoceratium reticulatum		+
Raphidophyceae		
Chattonella sp.	+	
Heterosigma akashiwo	+	

Source: Web site of A.V. Zhirmunskii Institute of Marine biology FEB RAS, Center of Monitoring of HABs & Biotoxins http://www.imb.dvo.ru/misc/toxicalgae/index.htm

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.

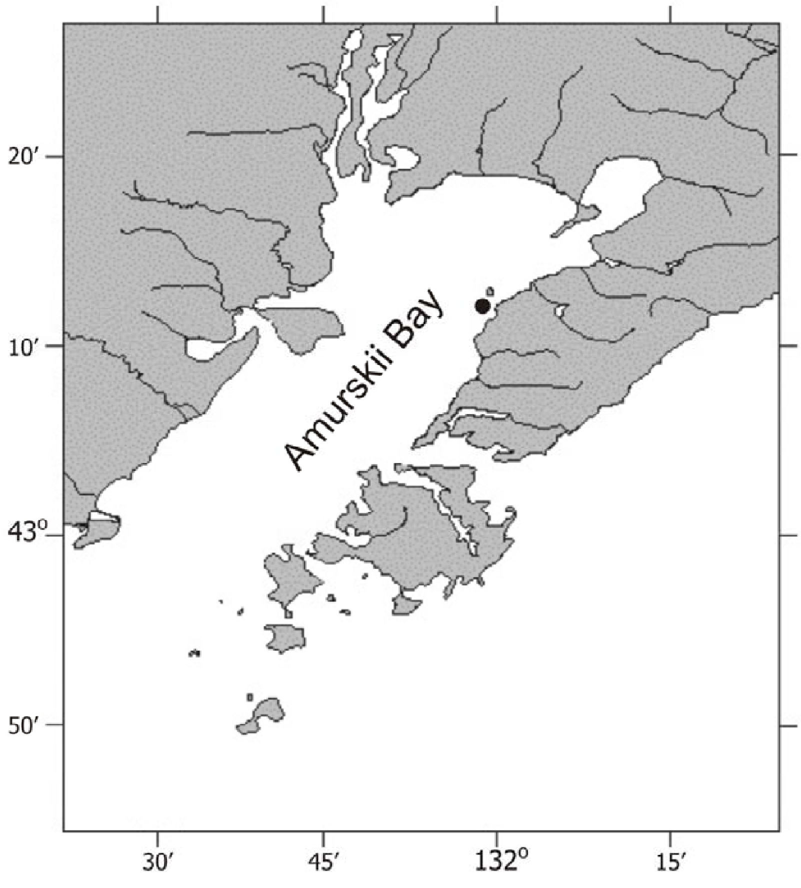

Figure 2. Monitored sea area (spot) in Amurskii Bay, Primorskii Krai.

Table 3. HAB monitoring organization and monitored sea area in Promirskii Krai

Monitoring organization	Monitored sea area
- Institute of Marine Biology FEB RAS http://www.imb.dvo.ru (1991-2006) -Center of Monitoring of HABs & Biotoxins Institute of Marine Biology FEB RAS http://www.imb.dvo.ru/misc/toxicalgae/index.htm (since 2007)	Amurskii Bay (HAB monitoring station of Institute of Marine Biology FEB RAS Amurskii Bay (HAB monitoring station of the Institute of Marine Biology FEB RAS

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

Survey type	Main objectives	Monitoring parameter				Monitoring frequency
		HAB	Water quality	Meteoro-logy	Other	
Regular HAB monitoring survey	To check presence of HAB spp.	-All HAB species -Total cell density -Water color	-Water temperature -Salinity -Heavy metals	Weather Ice cover		1991–1993 May–December (1-2/month); 1996–1998 January – May (4/month); 1999–2000 May – April (2/month); 2004– 2007 October – December (2/month)
Shellfish poisoning	-To check presence	-Species that	-Water temperature		Shellfish contamin	Since September

survey	of toxic species that induce shellfish poisoning -Contamination of shellfish	induce shellfish poisoning -Cell density	-Salinity		ation	2007- 3/year

Source: Center of Monitoring of HABs & Biotoxins of the Institute of Marine Biology FEB RAS http://www.imb.dvo.ru/misc/toxicalgae/index.htm

3.3. Data and information used

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

Table 5. Monitoring parameters referred in the HAB case study

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

4. Status of HAB events

4.1. Status of HAB events from year 1991-2007

For the period of observations from year 1991 - 2007, a total 41 HAB events were observed, in which no any cases of human poisoning or fishery damage were recorded. Records of HAB events from year 1991-2007 are provided in Annex I.

During the 17 years between 1991 and 2007, a total 28 HAB species were recorded in which 18 species caused water blooms (Figure 3). Those species are belonging to

5 taxonomic groups of phytoplankton: dinoflagellates, diatoms, raphidophytes, cryptophytes and euglenophytes. The most common bloom-forming species were diatoms (72% from the total number of HAB events) (Figure 3).

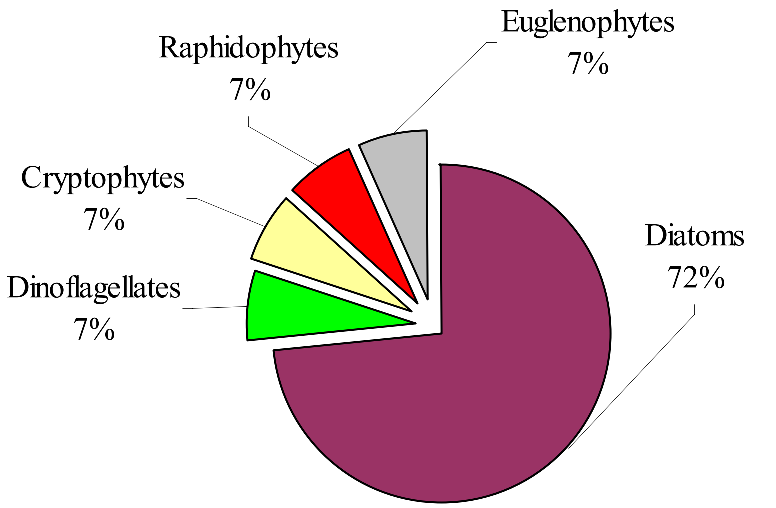

Figure 3. Percentage of bloom-forming species from year 1991-2007 in Amurskii Bay

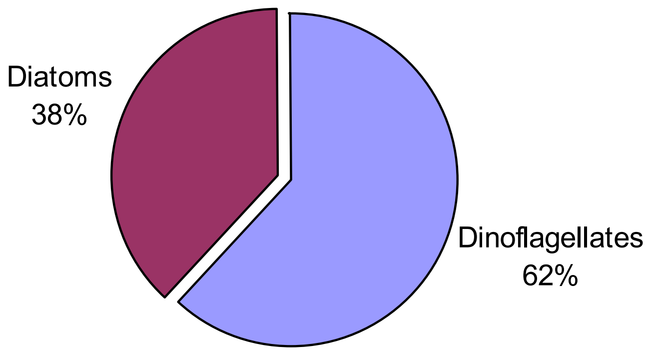

Figure 4. Percentage of potentially toxic species from year 1991-2007 in Amurskii Bay

From year 1991-2007, a total of 13 species, which are know 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. fraudulenta* 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 1991-2007. 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 17 years between 1991 and 2007, a total 41 bloom events were recorded, in which no any events induce damage or human poisoning. Total frequency of HAB has decreased in general (Figure 5).

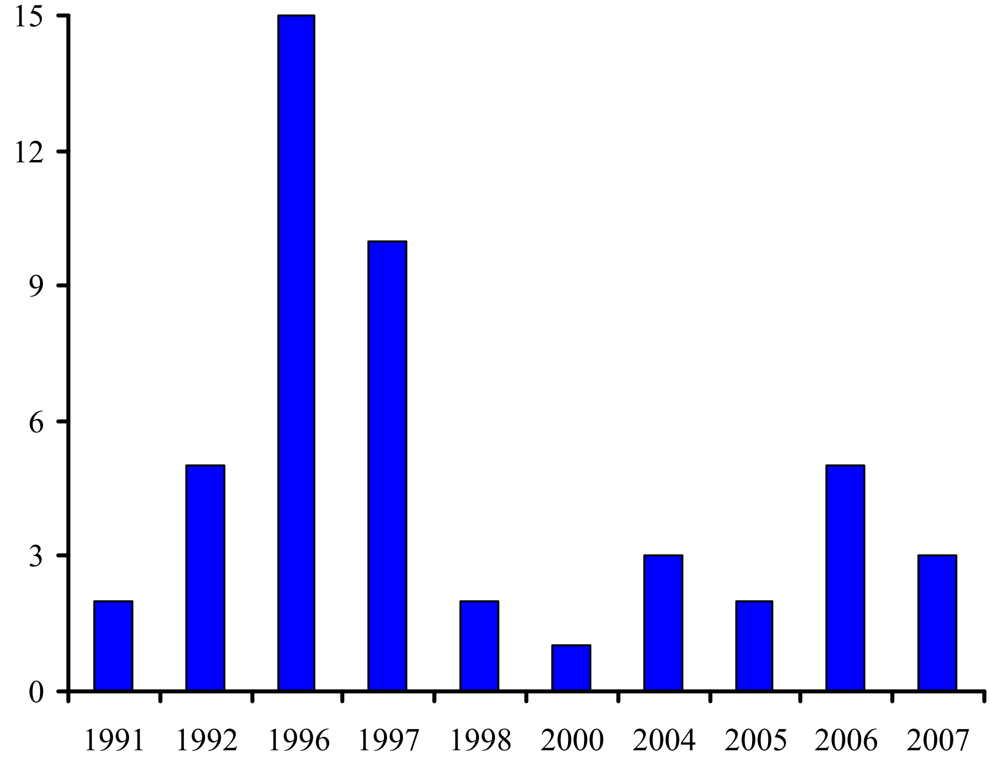

Figure 5. Number of bloom events by month in Amurskii Bay (1991–2007)

Source: Center of Monitoring of HABs & Biotoxins of the Institute of Marine Biology FEB RAS http://www.imb.dvo.ru/misc/toxicalgae/index.htm

4.3. Yearly trends of HAB season

According to the HAB data from 1991-2007, the highest peak season was high temperature season from July-August (Figure 6). No any cases of fishery damage or human poisoning were recorded.

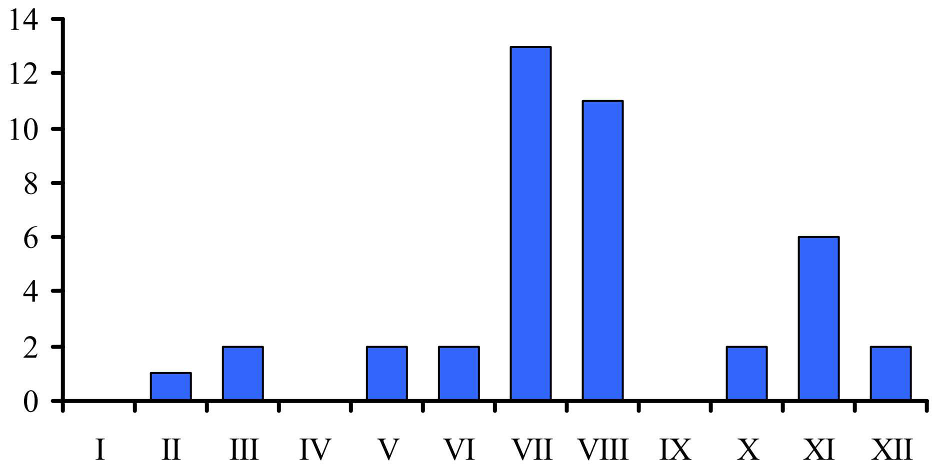

Figure 6. Number of HAB events by month in Amurskii Bay (1991–2007)

Source: Center of Monitoring of HABs & Biotoxins, of the Institute of Marine Biology FEB RAS http://www.imb.dvo.ru/misc/toxicalgae/index.htm

4.4. Yearly trends of causative species

Table 6 shows the HAB species that were recorded in Amurskii Bay between 1991-2007 and their frequency of occurrences. A total of 28 HAB species were recorded and the most frequent species were diatoms *Sceletonema costatum, Pseudo-nitzschia seriata/pungens*, *Thalassionema nitzschiodes* and dinoflagellate *Dinophysis acuminata* (Table 6).

Table 6. HAB species recorded in Amurskii Bay, 1991–2007 and their frequency of occurrences

Species	1991-1993	1996-1998	1999-2000	2004-2007	Total
Diatoms					
Chaetoceros affinis		55 *	4	12	71
Chaetoceros contortus		47 *	2	9	58
Chaetoceros curvisetus		20 *		4	24
Chaetoceros salsugineus		14 *		12 *	26

Leptocylindrus minimus		61 *		6	67
Pseudo-nitzschia calliantha				8	8
Pseudo-nitzschia delicatissima		19 *	2	18	39
Pseudo-nitzschia fraudulenta				2	2
Pseudo-nitzschia multistriata		1		4	5
Pseudo-nitzschia multiseries	10 *	4		1	15
Pseudo-nitzschia seriata/pungens		91	8	21	120
Sceletonema costatum		85 *	15	32 *	132
Thalassionema nitzschioides		69	13	38 *	120
Thalassiosira mala		11 *			11
Thalassiosira nordenskioeldii		50 *	8	28	86
Cryptophyceae					
Plagioselmis sp.		54 *		31	85
Dinoflagellates					
Dinophysis acuminata		80	5	16	101
Dinophysis acuta		15		2	17
Dinophysis fortii		1			1
Dinophysis norvegica		4			4
Dinophysis rotundata		8		1	9
Karenia mikimotoi		9		4	13
Noctiluca scintillans		14			14
Prorocentrum minimum	9 *	37 *		10	56
Protoceratium reticulatum		4		1	5
Raphidophyceae					
Chattonella sp.	3		2		5
Heterosigma akashiwo		3 *		8	11
Euglenophyceae					
Euglena pascheri		1		1 *	2

* Bloom-forming species (density of diatoms exceed $1{\cdot}10^6$ cells per L, density of dinoflagellates exceed $1{\cdot}10^5$ cells per L)

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

Records of HAB events in September 2005 –September 2006 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.*

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). HAB events occurred during June –December, and observed more frequently in June and October.

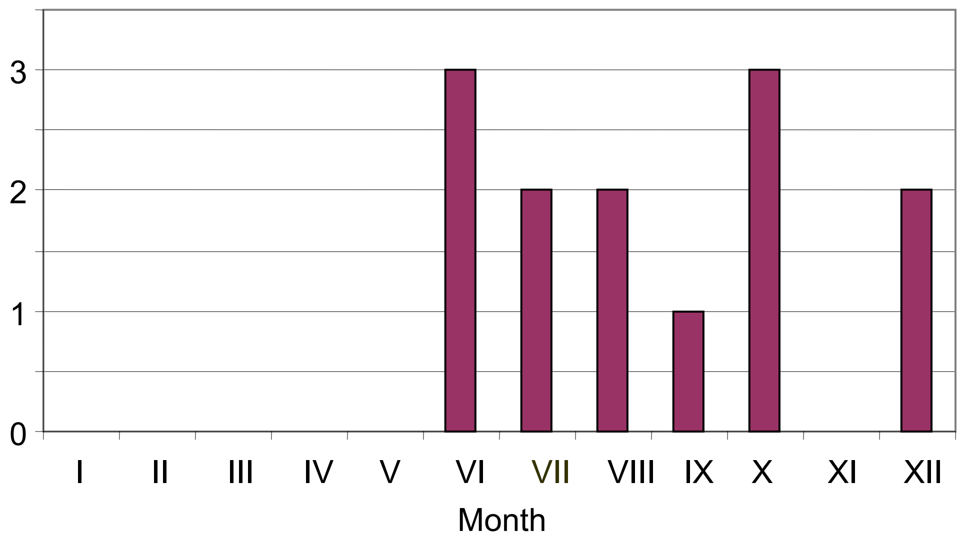

Figure 7. Number of HAB events by month in Amurskii Bay (September 2005 – September 2006)

5.3. Duration of HAB events

Table 7 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 7. Number of HAB events by duration (no. pf days)

	≤5	6-10	11-30	Total
Amurskii Bay	6	2	5	13
Total	6	2	5	13

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

5.4. Location of HAB events

Table 8 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 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 shows the location of the HAB events and causative species in Amurskii Bay in September 2005 – September 2006.

Table 8. Number of HAB events by area in September 2005-September 2006

Year	Sea area	No. of events	Causative species
September-December 2005	Amurskii Bay	7	*Pseudo-nitzschia calliantha* *Pseudo-nitzschia fraudulenta* *Pseudo-nitzschia multistriata* *Pseudo-nitzschia delicatissima* *Pseudo-nitzschia pungens* *Pseudo-nitzschia seriata* *Prorocentrum minimum*
January-September 2006	Amurskii Bay	6	*Dinophysis rotundata* *Dinophysis acuminate* *Dinophysis acuta* *Karenia mikimotoi* *Chaetoceros salsugineus* *Thalassionema nitzschioides*

Source: Center of Monitoring of HABs & Biotoxins of the Institute of Marine Biology FEB RAS http://www.imb.dvo.ru/misc/toxicalgae/index.htm

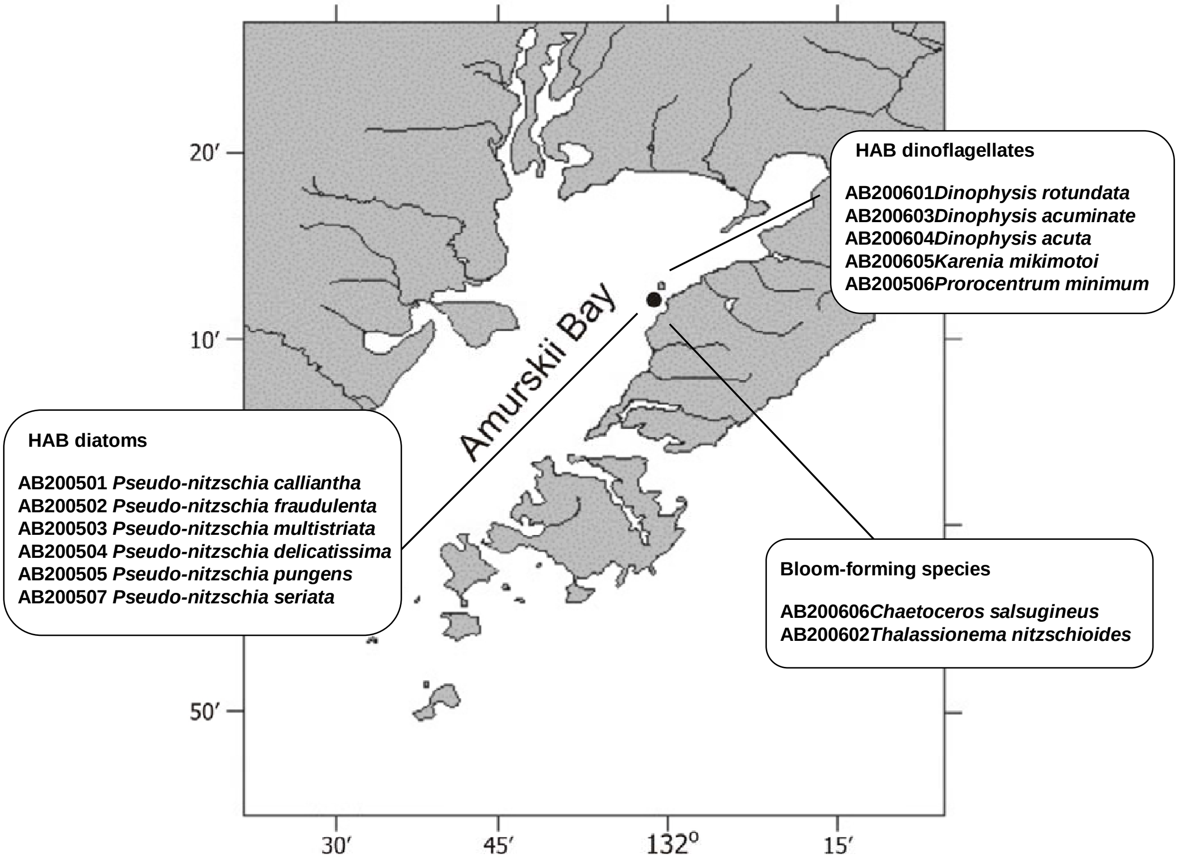

Figure 8. Location of HAB events (events no. and causative species) in Amurskii Bay (September 2005 – September 2006).

5.5. Causative species

Table 9 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 recoded. 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. HAB species recorded in Amurskii Bay in September 2005 – September 2006 and their frequency of occurrences

	September 2005-	

Genus and Species	September 2006	Total
Bacillariophyceae		
Chaetoceros salsugineus	6 *	6
Pseudo-nitzschia calliantha	3	3
Pseudo-nitzschia delicatissima	8	8
Pseudo-nitzschia fraudulenta	1	1
Pseudo-nitzschia multistriata	4	4
Pseudo-nitzschia multiseries	0	0
Pseudo-nitzschia seriata/pungens	8	8
Thalassionema nitzschioides	14 *	14
Dinophyceae		
Dinophysis acuminate	7	7
Dinophysis acuta	2	2
Dinophysis fortii	0	0
Dinophysis norvegica	0	0
Dinophysis rotundata	1	1
Karenia mikimotoi	1	1
Noctiluca scintillans	0	0
Prorocentrum minimum	5	5
Protoceratium reticulatum	0	0
Raphidophyceae		
Chattonella sp.	0	0
Heterosigma akashiwo	0	0
Total number of samples		27

* Bloom-forming species (density exceed $1 \cdot 10^6$ cells per L)

Source: Center of Monitoring of HABs & Biotoxins of the Institute of Marine Biology FEB RAS http://www.imb.dvo.ru/misc/toxicalgae/index.htm

5.6. Maximum density of each HAB event

Table 10 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 10. **Maximum density of HAB event that occurred in Amurskii Bay**

Year	Event No.	Causative species	Maximum density (cellsL^{-1})	Affected area
2005	AB200501	*Pseudo-nitzschia calliantha*	200 000	No info.
2005	AB200502	*Pseudo-nitzschia fraudulenta*	38 000	No info.
2005	AB200503	*Pseudo-nitzschia multistriata*	800 000	No info.
2005	AB200504	*Pseudo-nitzschia delicatissima*	80 000	No info.
2005	AB200505	*Pseudo-nitzschia pungens*	60 000	No info.
2005	AB200506	*Prorocentrum minimum*	100 000	No info.
2005	AB200507	*Pseudo-nitzschia seriata*	9 100	No info.
2006	AB200601	*Dinophysis rotundata*	500	No info.
2006	AB200602	*Thalassionema nitzschioides*	2 000 000	No info.
2006	AB200603	*Dinophysis acuminate*	12 800	No info.
2006	AB200604	*Dinophysis acuta*	500	No info.
2006	AB200605	*Karenia mikimotoi*	18 000	No info.
2006	AB200606	*Chaetoceros salsugineus*	1 600 000	No info.

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-September 2006.

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 shows target HAB species in Amurskii Bay between September 2005 and September 2007. 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. Target HAB species in Amurskii Bay, September 2005-September 2007

Target HAB species	Bloom-forming species	Toxic/potentially toxic species	Maximum density (cellsL^{-1})
Diatoms			
Pseudo-nitzschia calliantha	+		200 000
Pseudo-nitzschia fraudulenta		+	38 000
Pseudo-nitzschia multistriata	+	+	800 000
Pseudo-nitzschia delicatissima		+	80 000
Pseudo-nitzschia pungens		+	60 000
Pseudo-nitzschia seriata		+	9 100
Dinoflagellates			
Prorocentrum minimum		+	100 000
Dinophysis rotundata		+	500
Dinophysis acuminate		+	12 800
Dinophysis acuta		+	500
Karenia mikimotoi		+	18 000

Source: Web site of Institute of Marine biology FEB RAS, Center of Monitoring of HABs & Biotoxins http://www.imb.dvo.ru/misc/toxicalgae/index.htm

According to the HAB data in September 2005- September 2006, target HAB species occurred in June-December (Figure 9) and observed more frequently in October.

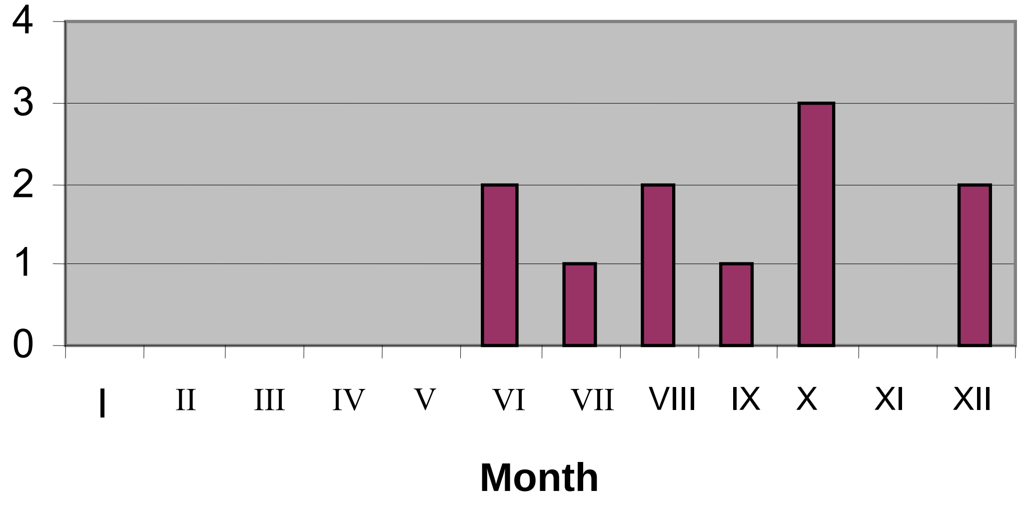

Figure 9. Number of Target HAB species by month in Amurskii Bay (September 2005 – September 2006).

5.9. Environmental monitoring results during HAB events

During the post-HAB survey, water temperature and salinity were measured. Table 12 shows the data obtained for each HAB event. During the HAB events, water temperature ranged between 22 - -1,8-C^0, salinity between 17-352‰.

Table 12. Data of post-HAB surveys in Amurskii Bay

Year	Event No.	Duration	Water temp. (C^0)	Salinity, ‰
2005	AB200501	*Pseudo-nitzschia calliantha*	6 - 12	32 - 33
2005	AB200502	*Pseudo-nitzschia fraudulenta*	3.8 x 10^3	8
2005	AB200503	*Pseudo-nitzschia multistriata*	0.8 x 10^6	15
2005	Ab200504	*Pseudo-nitzschia delicatissima*	-1.7– -1.8	33 - 35
2005	AB200505	*Pseudo-nitzschia pungens*	-1.7	34 - 35
2005	AB200506	*Prorocentrum minimum*	12	33

2005	AB200507	*Pseudo-nitzschia seriata*	20	31
2006	AB200601	*Dinophysis rotundata*	-1.7	34
2006	AB200602	*Thalassionema nitzschioides*	13 - 20	20 - 29
2006	AB200603	*Dinophysis acuminata*	13 - 22	17 – 20
2006	AB200604	*Dinophysis acuta*	13	17
2006	AB200605	*Karenia mikimotoi*	20	20
2006	AB200606	*Chaetoceros salsugineus*	5	33

Source: Center of Monitoring of HABs & Biotoxins of the Institute of Marine Biology FEB RAS http://www.imb.dvo.ru/misc/toxicalgae/index.htm

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

Para-meter	chl-OC2	Chl-OC3	K490	flh	nLw-412	nLw-443	NLw-469	NLw-488	NLw-531	NLw-551	NLw-555
Ratio CO/DB	3.0	2.3	4.3	2.9	-17.4	-63.3	-397.	40	3.0	1.95	2.0
Errors	7%	3%	21%	250%	24%	22%	18%	36%	2%	10%	8%

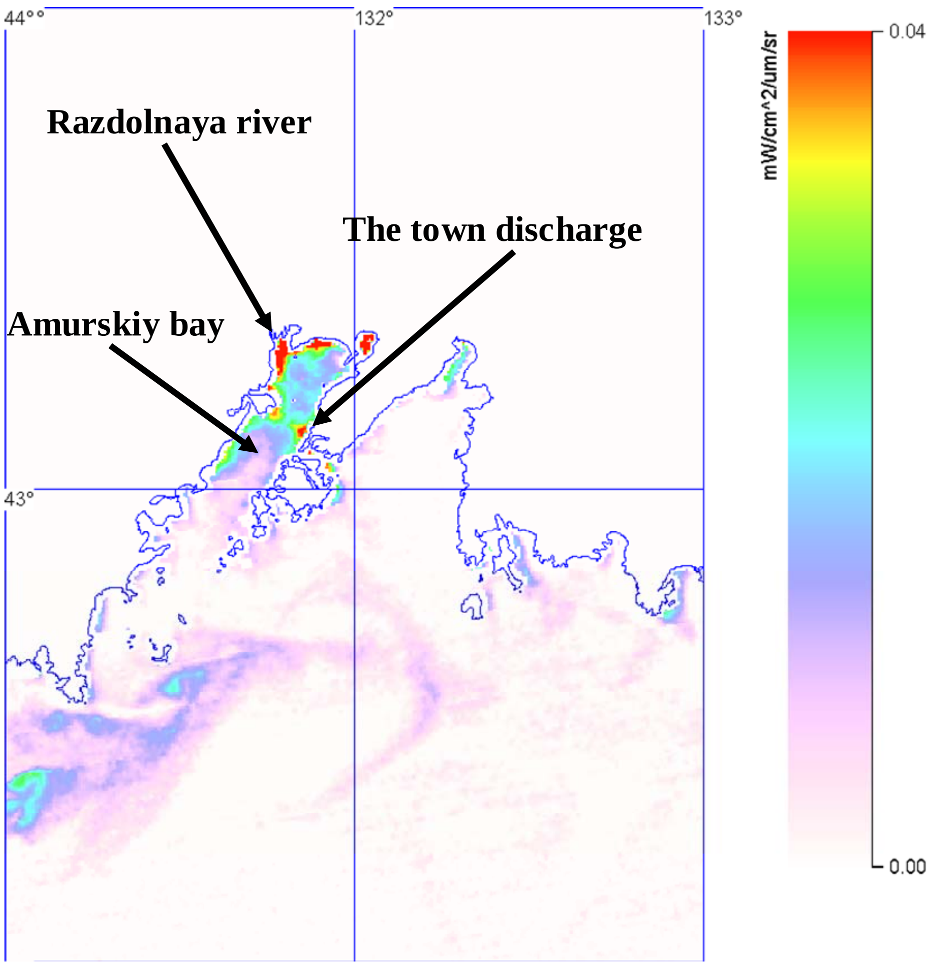

Figure 10. Fluorescence by MODIS imagery in Amurskiy bay in August ,28, 2006.

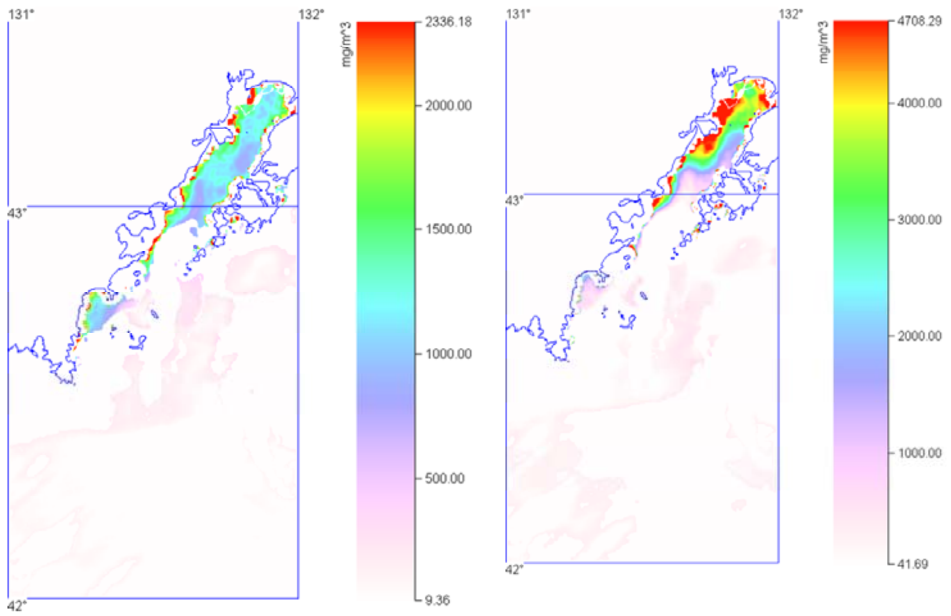

Figure 11. Spectral properties estimation on MODIS imagery for diatoms *Coscinodiscus oculus-iridis* (left) and *Ditylum brightwelli* (right), in Amurskiy bay in August, 31.2006.

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 Ussuriysk 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 *Sceletonema 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).

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;

3) the density of the non-diatom component of the phytoplankton increased.

HABs monitoring results in Amurskii Bay are consistent with the previously reported data on the changes in the composition of phytoplankton in other eutrophic waters (Marasovic, Pucher-Petkovic, 1991; Mihnea, 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

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Appendix

Annex I. Records of HAB events in Amurskii Bay, 1991–2007

Duration (Start)			Duration (End)			Contin. days	Species	Density (cells L^{-1})	Temp. (^oC)	Salinity, psu
Year	Month	Day	Year	Month	Day					
Diatoms										
1996	07	08	1996	08	30	31	*Chaetoceros affinis*	1.9×10^6	19 - 23	27 - 28
1997	05	04	1997	06	04	32	*Chaetoceros contortus*	1.3×10^6	11 - 12	29 - 30
1996	08	05	1996	08	12	7	*Chaetoceros curvisetus*	1.5×10^6	20 - 21	25 - 27
2004	11	17				< 7	*Chaetoceros salsugineus*	1.6×10^6	5	33
1996	11	04	1996	12	16	42	*Leptocylindrus minimus*	1.9×10^6	1 - 7	34 - 35
1997	11	11	1997	11	19	8	*Pseudo-nitzschia calliantha*	0.5×10^6	1 - 5	34 - 35
1997	09	04	1997	11	19	66	*Pseudo-nitzschia delicatissima*	2.7×10^6	1 - 19	31 - 35
2005	10	26				< 7	*Pseudo-nitzschia fraudulenta*	3.8×10^3	8	34
2005	10	05	2005	10	26	21	*Pseudo-nitzschia multistriata*	0.8×10^6	15	33
1992	06	25	1992	07	10	16	*Pseudo-nitzschia pungens / multiseries*	11.0×10^6		
2005	09	04				< 7	*Pseudo-nitzschia seriata*	9.1×10^3	20	31
1996	07	22	1996	08	30	39	*Sceletonema costatum*	12.7×10^6	20 - 23	27 - 30
2006	06	05	2006	07	03	28	*Thalassionema nitzschioides*	2.0×10^6	13 - 20	20 - 29
1997	07	29				< 7	*Thalassiosira mala*	3.0×10^6	23	24
1998	01	26	1998	02	17	22	*Thalassiosira nordenskioeldii*	1.1×10^6	-0.5 - -2	34 - 35
Cryptophytes										
1998	03	05	1998	03	12	7	*Plagioselmis* sp.	1.1×10^6	-0.8 - -1	33
Dinoflagellates										
1997	06	13	1997	07	22	50	*Dinophysis acuminata*	12.8×10^3	15 - 20	28 – 30
1996	06	19				< 7	*Dinophysis acuta*	0.8×10^3	13	31
1996	07	29				< 7	*Dinophysis fortii*	0.2×10^3	23	24
1997	06	04				< 7	*Dinophysis norvegica*	0.06×10^3	12	31
1998	03	26				< 7	*Dinophysis rotundata*	0.6×10^3	0.2	33
1997	10	17	1997	11	03	17	*Karenia mikimotoi*	7.2×10^3	5 - 11	33 – 35
1996	07	02	1996	07	16	14	*Noctiluca scintillans*	1.6×10^3	17 - 20	28 - 30
1991	07	08	1991	08	12	25	*Prorocentrum minimum*	7.6×10^6		
1997	08	19	1997	08	28	9	*Protoceratium reticulatum*	0.4×10^3	20 - 23	24 - 28
Raphidophytes										
1993	11	19				< 7	*Chattonella* sp.	0.8×10^6		
1996	02	28	1996	03	28	28	*Heterosigma akashiwo*	1.0×10^6	-1 - 1	33 – 34
Euglenophytes										
2005	07	12				< 7	*Euglena pascheri*	1.5×10^6	-1.7	35

Annex II

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

Event No.	Duration (Start)			Duration (End)			Continuous days	Species	Density (cells L^{-1})	Temp. (^oC)	Salinity, psu
	Year	Month	Day	Year	Month	Day					
AB200501	2005	10	20	2005	10	28	6	*Pseudo-nitzschia calliantha*	200 000	6 - 12	32 - 33
AB200502	2005	10	26				< 5	*Pseudo-nitzschia fraudulenta*	38 000	8	34
AB200503	2005	10	05	2005	10	26	21	*Pseudo-nitzschia multistriata*	800 000	15	33
AB200504	2005	12	05	2005	12	30	25	*Pseudo-nitzschia delicatissima*	80 000	-1.7– - 1.8	33 - 35
AB200505	2005	12	05	2005	12	29	24	*Pseudo-nitzschia pungens*	60 000	-1.7	34 - 35
AB200506	2005	10	20				< 5	*Prorocentrum minimum*	100 000	12	33
AB200507	2005	09	04	2005	09	10	6	*Pseudo-nitzschia seriata*	9 100	20	31
AB200601	2006	03	01				< 5	*Dinophysis rotundata*	500	-1.7	34
AB200602	2006	06	05	2006	07	03	28	*Thalassionema nitzschioides*	2 000 000	13 - 20	20 - 29
AB200603	2006	06	20	2006	07	03	13	*Dinophysis acuminata*	12 800	13 - 22	17 – 20
AB200604	2006	06	20				< 5	*Dinophysis acuta*	500	13	17
AB200605	2006	07	03				< 5	*Karenia mikimotoi*	18 000	20	20
AB200606	2006	07	03				< 5	*Chaetoceros salsugineus*	1 600 000	5	33