Report of HAB Case Studies in Amurskii Bay, Vostok Bay and Aniva Bay (Sakhalin) in Russia

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1. Introduction

1.1. Objective

The objective of conducting the HAB case study in Amurskii Bay, Vostok Bay and Aniva Bay (Sakhalin) Iin Russia 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 areas

1.3.1. Location, boundary, population size and density

Location, boundary and population size and density of existing and newly added sea areas in Russia are shown in Figure 1 and Table 1.

1.3.1.1. Amurskii Bay (area AB)

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) with population density on 49.7 pers/km2. Large cities of Vladivostok (the biggest port in the Russian Far East with a population of 604 8000) and Ussuriysk (more than 152 700) and one of the largest recreational zones in the Far East are located here (Table 1).

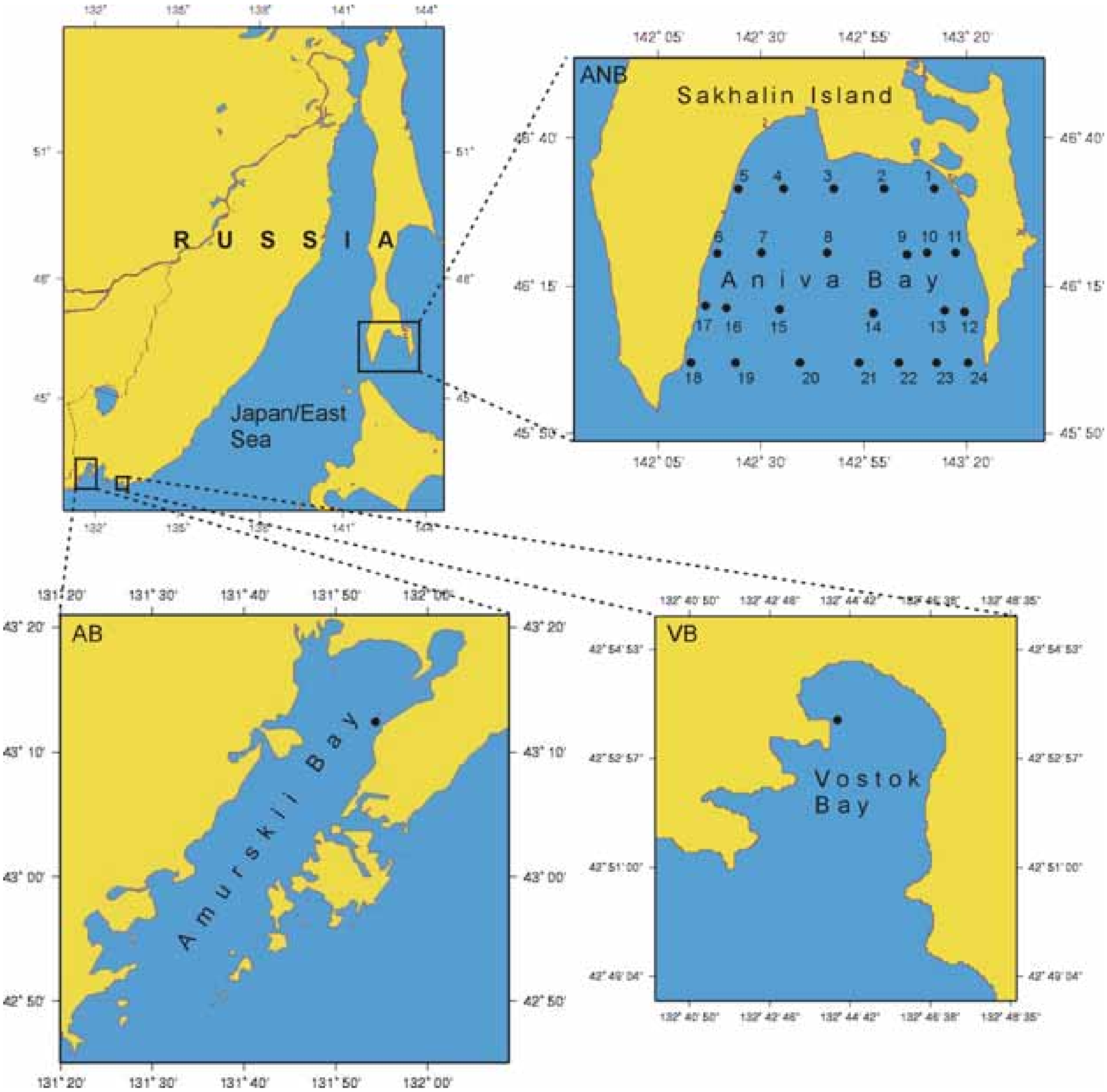

Figure 1. Target sea areas for the case study of Russia

1.3.1.2. Vostok Bay (area VB)

This target sea area is subarea of Peter the Great Bay (latitude 42°53' and longitude 132°40') (Figure 1). It area is 48 km^2. Biggest towns are Livadia and Yuzhno-Morskoi. The total population is 16 500 and density - 33 pers/km^2 (Table 1). This area is one of the largest recreational zones in the Far East and population here is increased 1.5-2 times during the summer months due to recreating activity.

1.3.1.3. Aniva Bay, Sakhalin (area ANB)

The target sea area covers the south part of Sakhalin Island (latitude 46°30' and longitude 142°44'). Aniva Bay is on of the largest bays on Sakhalin Island (Figure 1). It area is 4240 km^2. Biggest town is Korsakov. The total population is 43 300 and density – 13,5 pers/km^2 (Table 1).

Table 1. Some characteristic of the Amurskii Bay, Vostok Bay and Aniva Bay with major inputting rivers

Sub-areas of Peter the Great Bay	Area, km2	Coast line*, km	Major inputting rivers	Watershed area, km2	Run-off, km3	Population, 2009, thousand persons	Population density pers/km2
Amurskii Bay	997*	151	Narva	332	0.13	604.8[1]+134.9[2] + 152.7[3]	49.7
	101**		Barabashevka	576	0.32		
			Amba	242	0.19		
			Razdolnaya	16800	2.46		
Vostok Bay	48*	35	Litovka	399	0.15	16.5[4]	33.2
			Volchanka	98	0.06		
Aniva Bay	4240 *	243	Luitoga	1530	1.00	43.3[5]	13.5
			Susuya	823	0.52		
			Bystraya	276	0.18		
			Taranai	291	0.19		
			Urksh	293	0.19		

* - main property; ** - islands; [1] – Vladivostok; [2] – Razdolnaya valley; [3] - Ussuriisk; [4] – Livadia and Yuzhno-Morskoi; [5] – Korsakov and Aniva.

The major part of population lives in the cities. The contribution of rural population does not exceed 15%. There is clear 8.5-9.5% decrease trend in the population of the Peter the Great Bay watershed, including Amurskii Bay and Vostok Bay during last 20 years.

The population density is maximal on the Amurskii Bay watershed, and is minimal on the Aniva Bay watershed.

1.3.2. Environmental/geographical characteristics

Amurskii Bay 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. 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).

1.4. Additional characteristics of Amurskii Bay, Vostok Bay and Aniva Bay with major inputting rivers and aquaculture

The information on current status of rivers in existing (Amurskii Bay) and newly added sea areas (Vostok Bay and Aniva Bay) is shown in Table 1.

The data on location and type of aquaculture in the target sea areas in Russia are shown in Table 2.

Table 2. Location and type of aquaculture in the target sea areas in Russia

Target sea area	Locations of aquaculture area latitude/ longitude	Aquaculture farm	Type of aquaculture
1. Amurskii Bay	42^0 53’30,47” / $131^0$39’13,73”	LTD Zhilstroiserves”	Yesso scallop *M. yessoensis* and sea cucumber *Apostichopus japonicus*
	42^0 56’05,17” / $131^0$24’46,85”	Slavyanka Bay “Center for aquaculture of Far Eastern State Technical University”	yesso scallop *M. yessoensis*.
	43^0 02’49,00” / $131^0$34’56,89”	Perevoznaya Bay “Aquaculture farm “IP Zharkov” Center for aquaculture of Far Eastern State Technical University”	Yesso Scallop *M. yessoensis* and sea cucumber *Apostichopus japonicus*
2. Vostok Bay		No farms	
3. Aniva Bay (Sakhalin Island)	46^0 27’30,68” / 142^0 23’46,66”	“IP Lapin”	Yesso Scallop *M. yessoensis*
	46^0 28’30,08” / 142^0 23’47,00”	“IP Kobelev”	Yesso Scallop *M. yessoensis*
	46^0 37’23,06” / 142^0 27’16,40”	“IP Shushpanov”	Yesso Scallop *M. yessoensis*

Source: Center of aquaculture and coastal bioresources IMB FEB RAS e-mail: aqua_imb@hotmail.com Web site of A.V. Zhirmunskii Institute of Marine biology FEB RAS, Center of Monitoring of HABs & Biotoxins http://www.imb.dvo.ru

2. Methodology used in the case study

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 13 types of HAB species (Table 3).

Table 3. HAB warning/action standards of Primorskii Krai

HAB species	Warning level (cells/L)	Affected objects
Pseudo-nitzschia calliantha	500 000	Shellfish
Pseudo-nitzschia delicatissima	500 000	Shellfish
Pseudo-nitzschia fraudulenta	500 000	Shellfish
Pseudo-nitzschia multistriata	500 000	Shellfish
Pseudo-nitzschia multiseries	500 000	Shellfish
Pseudo-nitzschia seriata/pungens	500 000	Shellfish
Alexandrium tamarense	500	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 4 shows target HAB species for Amurskii Bay (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 2010, 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 4). Those species are belonging to 4 taxonomic groups of phytoplankton: dinoflagellates (9 species), diatoms (6 species), raphidophytes (2 species), chrysophytes (1 species). Table 4 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).

Table 4. Target HAB species in Amurskii Bay, 1991–2010

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		+
Skeletonema costatum	+	
Dinophyceae		
Alwxandrium tamarense		+
Dinophysis acuminata		+
Dinophysis acuta		+
Dinophysis fortii		+
Dinophysis norvegica		+
Dinophysis rotundata		+
Karenia mikimotoi	+	+
Noctiluca scintillans	+	

Protoceratium reticulatum		+
Crysophyceae		
Dinobryon balticum	+	
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 Amurskii Bay (AB) and Vostok Bay (VB). HABs monitoring survey has been conducted by Sakhalin Research Institute of Fisheries & Oceanography (SakhNIRO) in Aviva Bay (Sakhalin Island). Monitoring areas are shown in Figure 1 and Table 5.

Table 5. HAB monitoring organization and monitored sea areas

Monitoring organization	Monitored sea area
-A.V. Zhirmunskii Institute of Marine Biology FEB RAS http://www.imb.dvo.ru (1991-2006)	(AB) Amurskii Bay (HAB monitoring station of the A.V. Zhirmunskii Institute of Marine Biology FEB RAS)
-Center of Monitoring of HABs & Biotoxins A.V. Zhirmunskii Institute of Marine Biology FEB RAS http://www.imb.dvo.ru/misc/toxicalgae/index.htm (since 2007)	Amurskii Bay (HAB monitoring station of the A.V. Zhirmunskii Institute of Marine Biology FEB RAS)
-Center of Monitoring of HABs & Biotoxins A.V. Zhirmunskii Institute of Marine Biology FEB RAS http://www.imb.dvo.ru/misc/toxicalgae/index.htm (since 2007)	(VB) Vostok Bay (HAB monitoring station of the A.V. Zhirmunskii Institute of Marine Biology FEB RAS)
Sakhalin Research Institute of Fisheries & Oceanography (SakhNIRO) RAS http://www.sakhniro.ru (since 2000)	(ANB) Aniva Bay (HAB monitoring area of Sakhalin Research Institute of Fisheries & Oceanography (SakhNIRO)

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 6.

The case study is focused mainly on the results of the regular monitoring survey, which monitor HAB causative species,

Table 6. 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– 2008 October – December (2/month)
Shellfish poisoning survey	-To check presence of toxic species that induce shellfish poisoning -Contamination of shellfish	-Species that induce shellfish poisoning -Cell density	-Water temperature -Salinity		Shellfish contamination	Since September 2008- 3/year

Source: Center of Monitoring of HABs & Biotoxins A.V. Zhirmunskii 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 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 7 shows the monitoring parameters that will be referred in the HAB case study.

Table 7. 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

4.1.1 Status of HAB events in Amurskii Bay (AB)

For the period of observations from year 1991–2010, a total 71 HAB events were observed, in which no any cases of human poisoning or fishery damage were recorded. Records of HAB events from year 1991–2010 are provided in Annex I.

During the 19 years between 1991 and 2010, a total 30 HAB species were recorded in which 21 species caused water blooms (Figure 2). 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 2).

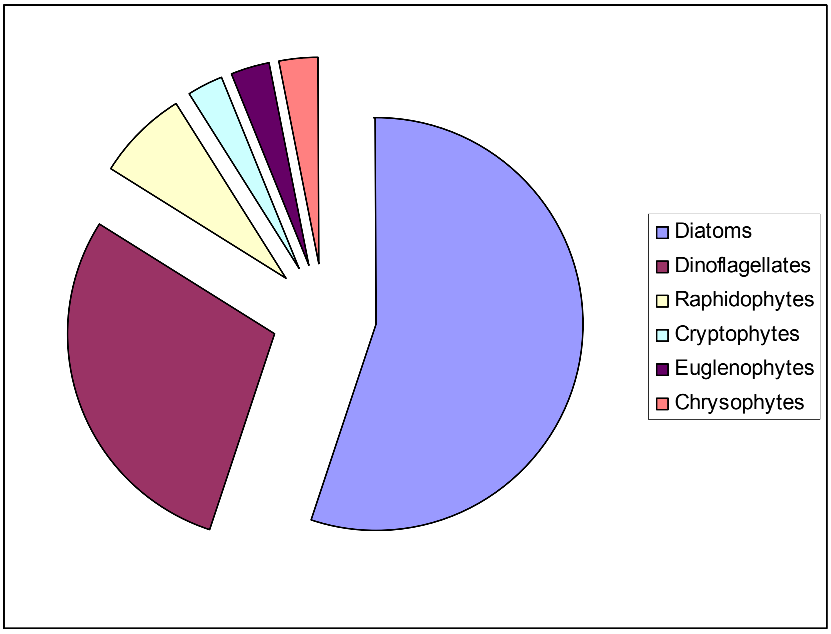

Figure 2. Percentage of bloom-forming species from year 1991-2010 in Amurskii Bay

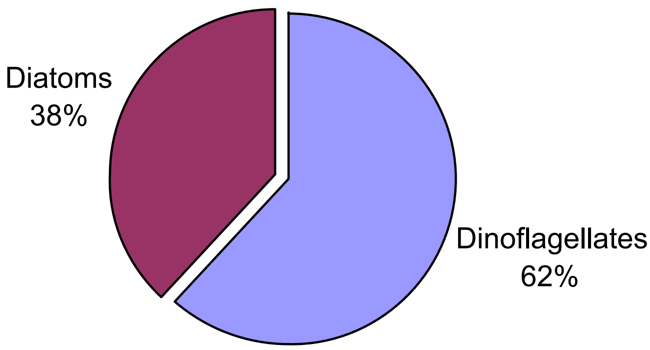

Figure 3. Percentage of potentially toxic species from year 1991-2010 in Amurskii Bay

From year 1991–2010, 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 3). 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. callianthа* (Table 3).

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 1991-2010. These species are *Dinophysis acuminata, D. acuta*, *D. fortii, D. norvegica, D. rotundata,* and *Protoceratium reticulatum* (Table 3). 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.

4.1.2. Yearly trends of HAB events

During the 19 years between 1991 and 2010, a total 46 bloom events were recorded, in which no any events induce damage or human poisoning. Total frequency of HAB has decreased in general (Figure 4). HAB events occurred most frequently during July-August and October (Figure 5).

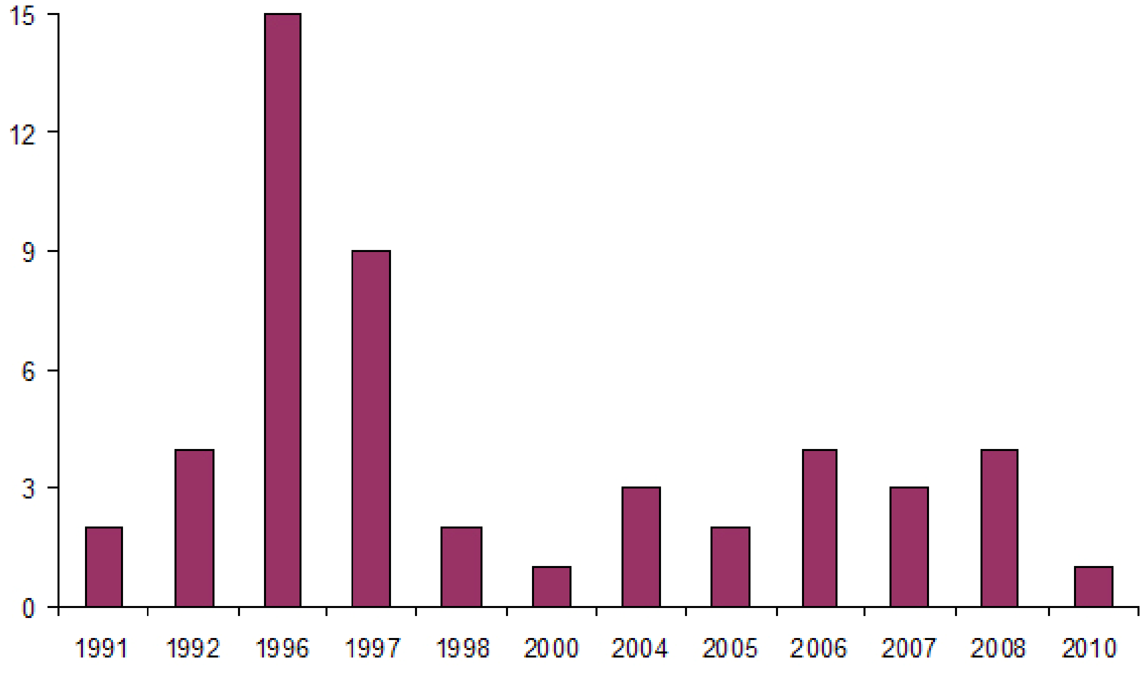

Figure 4. Number of bloom events by year in Amurskii Bay (1991–2010)

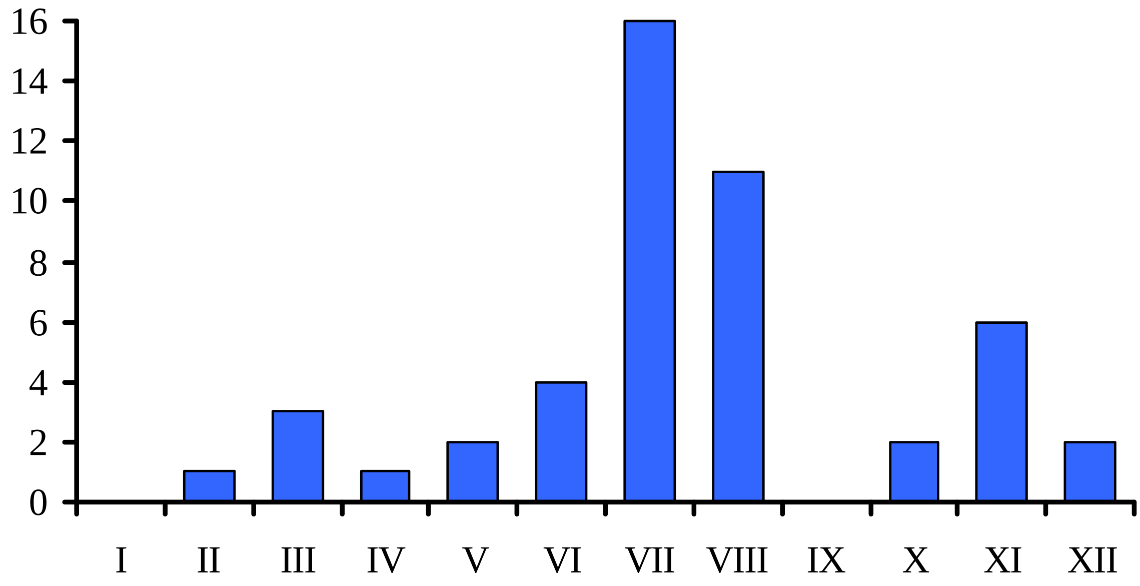

Figure 5. Number of bloom events by month in Amurskii Bay (1991–2010)

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

4.1.3. Yearly trends of Toxic plankton

From year 1991–2010, a total of 13 species, which are know to be toxic were observed in Amurskii Bay, which occurred most frequently during June-November (Figure 6).

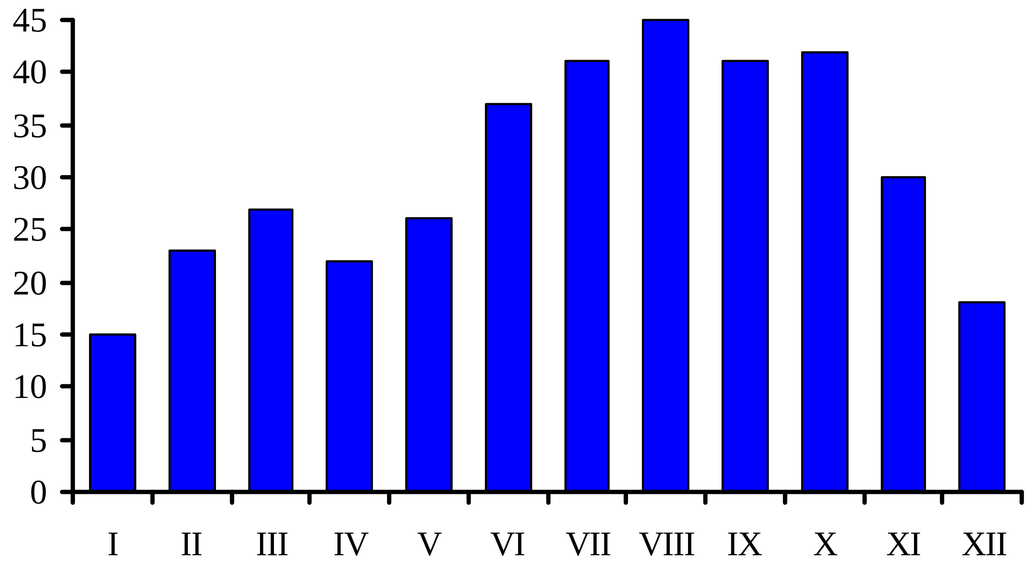

Figure 6. Number of potentially toxic species by month in Amurskii Bay (1991–2010)

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

4.1.4. Yearly trends of causative species

Table 8 shows the HAB species that were recorded in Amurskii Bay between 1991-2010 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 8. HAB species recorded in Amurskii Bay, 1991–2010 and their frequency of occurrences

Species	1991-1993	1996-1998	1999-2000	2004-2010	Total
Diatoms					
Chaetoceros affinis		55	4	13	72
Chaetoceros contortus		47	2	15	64
Chaetoceros curvisetus		20		6	26
Chaetoceros salsugineus		14		14	28
Leptocylindrus minimus		61		10	71
Pseudo-nitzschia calliantha				11	11
Pseudo-nitzschia delicatissima		19	2	24	45
Pseudo-nitzschia fraudulenta				2	2
Pseudo-nitzschia multistriata		1		6	7
Pseudo-nitzschia multiseries	10	4		1	15
Pseudo-nitzschia seriata/pungens		91	8	33	132
Skeletonema costatum		85	15	44	144
Thalassionema nitzschioides		69	13	47	129
Thalassiosira mala		11			11
Thalassiosira nordenskioeldii		50	8	37	75
Cryptophyceae					
Plagioselmis sp.		54		45	99
Dinoflagellates					
Dinophysis acuminate		80	5	24	108
Dinophysis acuta		15		3	18

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		13	59
Protoceratium reticulatum		4		5	9
Raphidophyceae					
Chattonella sp.	3		2		5
Heterosigma akashiwo		3		10	13
Chrysophyceae					
Dinobryon balticum				5	5
Euglenophyceae					
Euglena pascheri		1		1	2

4.2.1 Status of HAB events in Vostok Bay (VB)

For the period of observations from year 2001- 2009 a total 19 HAB events were observed, in which no any cases of human poisoning or fishery damage were recorded. Records of HAB events from year 2001-2009 are provided in Annex 2.

During the 9 years between 2001 and 2009, a total 11 HAB species were recorded (Figure 7). Those species are belonging to 3 taxonomic groups of phytoplankton: dinoflagellates, diatoms and raphidophytes.

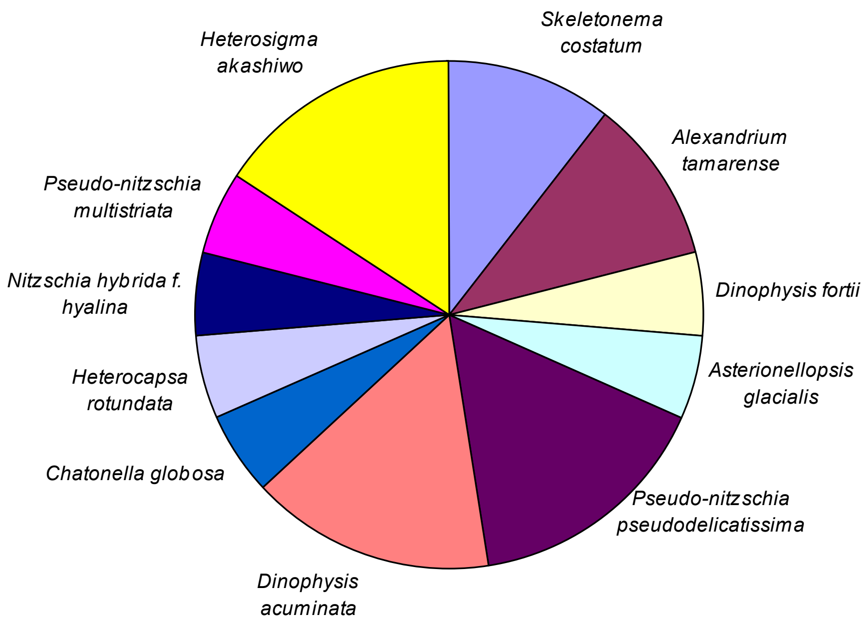

Figure 7. Percentage of HAB species from year 2001-2009 in Vostok Bay

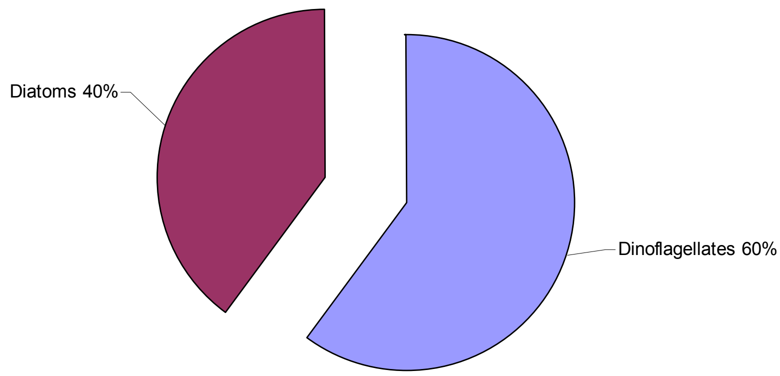

Figure 8. Percentage of group of potentially toxic species from year 2001-2009 in Vostok Bay

The most common HAB species were diatoms (45% from the total number of HAB events) (Figure 7). The most frequently observed HAB species were *Dinophysis acuminata, Pseudo-nitzschia pseudodelicatissima* and *Heterosigma akashiwo.*

From year 2001-2009, a total of 5 species, which are know to be toxic were observed in Vostok Bay. Potentially toxic species are belonging to 2 groups of phytoplankton: dinoflagellates (60% from the total number of potentially toxic species) and diatoms (40%) (Figure 8). Species of the genus *Alexandrium* are capable of producing toxins, which accumulates in the tissues of filter-feeding mollusks, causing the syndrome of paralytic shellfish poisoning (PSP). *Alexandrium tamarense,* which is known as PSP producing species, was observed in Vostok Bay in 2001-2009 (Table 9).

Species of the genus *Dinophysis* are capable of producing toxins, which accumulates in the tissues of filter-feeding mollusks, causing the syndrome of diarrhetic shellfish poisoning (DSP). Two species, which are known as DSP producing species, were observed in Vostok Bay in 2001-2009. These species are *Dinophysis acuminate* and *D. fortii* (Table 9).

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). Two species, which are known as ASP producing species, were observed in Vostok Bay in 2001-2009. These species are *Pseudo-nitzschia multistriata* and *Pseudo-nitzschia pseudodelicatissima* (Table 9).

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

4.2.2. Yearly trends of HAB events

During the 9 years between 2001 and 2009, a total 19 bloom events were recorded, in which no any events induce damage or human poisoning. 5 HAB events were observed in 2001, 3 HAB events – in 2009, 2 HAB events – in 2002, 2003, 2005 and 2006 and 1 HAB events – in 2004 and 2007 (Table 9). HAB events occurred most frequently in August (Figure 9).

Table 9. HAB events recorded in Vostok Bay, 2001-2009 and their frequency of occurrences

Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
Diatoms										
Asterionellopsis glacialis	1									1
Nitzschia hybrida f. hyalina									1	1
Pseudo-nitzschia multistriata									1	1
Pseudo-nitzschia pseudodelicatissima	1				1				1	3
Skeletonema costatum	1					1				2
Dinoflagellates										
Alexandrium tamarense	1					1				2
Dinophysis acuminata		1	1	1						3
Dinophysis fortii	1									1
Heterocapsa rotundata			1							1
Raphidophyceae										
Chatonella globosa		1								1

Heterosigma akashiwo					1	1	1			3

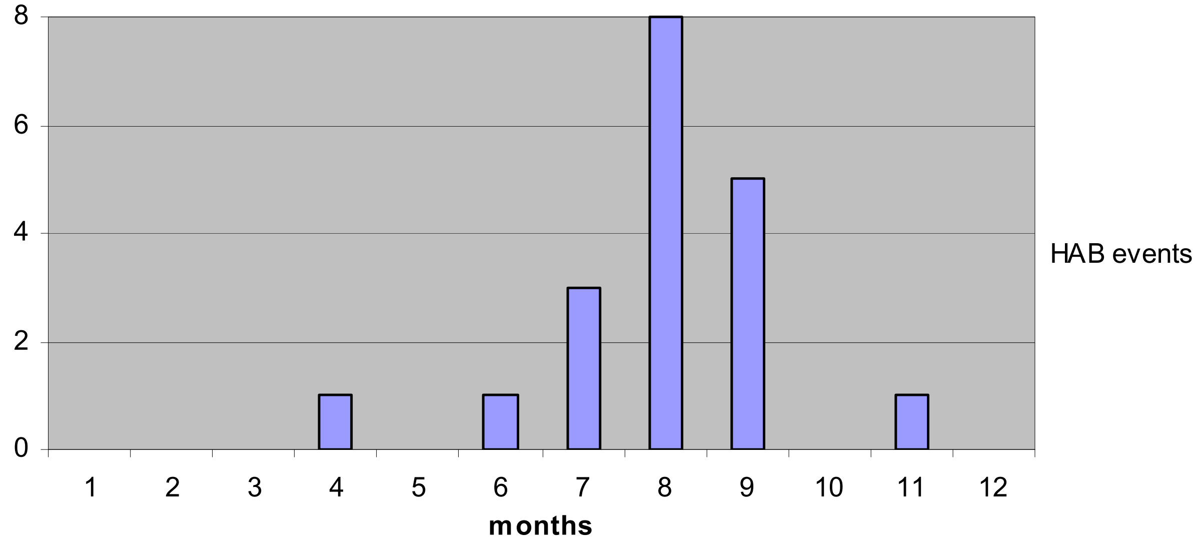

Figure 9. Number of HAB events by month in Vostok Bay

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

4.3.1. Status of HAB events in Aniva Bay (ANB)

For the period of observations from year 2001- 2002 a total 31 HAB events were observed, in which no any cases of human poisoning or fishery damage were recorded. Records of HAB events from year 2001-2002 are provided in Annex 3.

During the 2 years between 2001 and 2002, a total 9 HAB species were recorded (Figure 10). Those species are belonging to 3 taxonomic groups of phytoplankton: dinoflagellates, diatoms and raphidophytes.

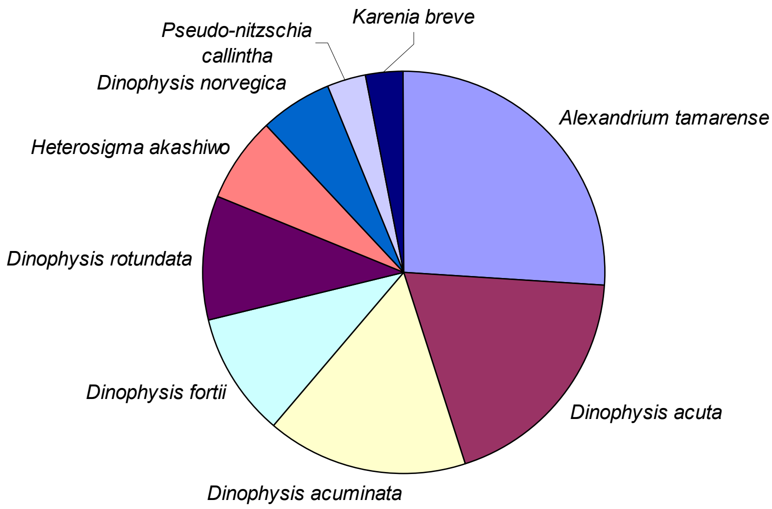

Figure 10. Percentage of HAB species from year 2001-2002 in Aniva Bay

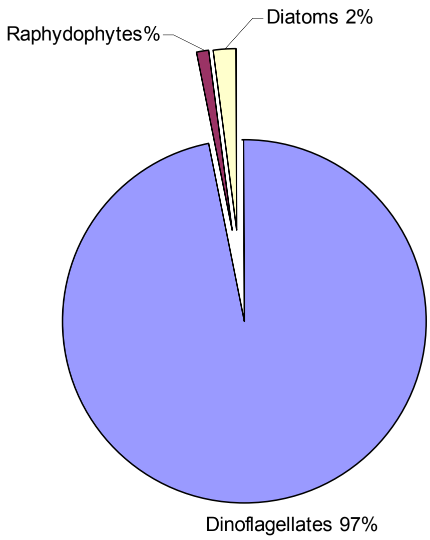

Figure 11. Percentage of potentially toxic species from year 2001-2002 in Aniva Bay

The most frequently observed HAB species were *Alexandrium tamarense* and *Dinophysis* spp. (*D. acuta, D. acuminata, D. fortii* and *D. rotundata*) (Figure 10). Dinoflagellates were dominated among potentially toxic species - 97% from the total number of toxic species (Figure 11).

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). *Pseudo-nitzschia* species were monitored in Aniva Bay (Table 10).
Species of the genus *Dinophysis* are capable of producing toxins, which accumulates in the tissues of filter-feeding mollusks, causing the syndrome of diarrhetic shellfish poisoning (DSP). Five species, which are known as DSP producing species, were observed in Aniva Bay in 2001-2002. These species are *Dinophysis acuminata, D. acuta*, *D. fortii, D. norvegica, D. rotundata* (Table 11).

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

4.3.2. Yearly trends of HAB events

During the 2 years between 2001 and 2002, a total 31 bloom events were recorded, in which no any events induce damage or human poisoning. 15 HAB events were observed in 2001 and 16 HAB events – in 2002 (Table 10). HAB events occurred most frequently in June and November (Figure 12).

Table 10. HAB events recorded in Aniva Bay, 2001-2002 and their frequency of occurrences

Species	2001	2002	Total
Diatoms			
Pseudo-nitzschia calliantha	1	0	1
Dinoflagellates			
Alexandrium tamarense	4	4	8
Dinophysis acuminata	2	3	5
Dinophysis acuta	2	4	6
Dinophysis fortii	2	1	3
Dinophysis norvegica	2	0	2
Dinophysis rotundata	0	3	3

Karenia breve	1	0	1
Raphidophyceae			
Heterosigma akashiwo	1	1	2

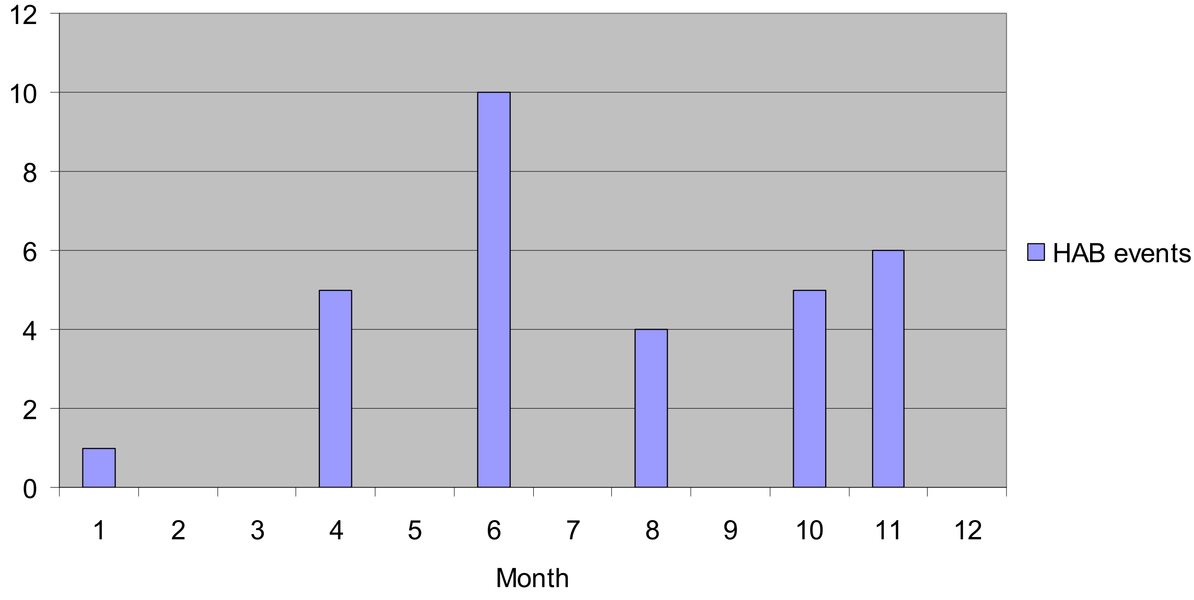

Figure 12. Number of bloom events by month in in Aniva Bay

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

4.3.3. Yearly trends of causative species

Table 11 shows the HAB species that were recorded in Aniva Bay between 2001-2002 and their frequency of occurrences. A total of 9 HAB species were recorded and the most frequent species were dinoflagellats *Alexandrium tamarense* and *Dinophysis* spp. (*D. acuminata, D. acuta, D. rotundata* and *diatom Pseudo-nitzschia calliantha.*

Table11. HAB species recorded in Aniva Bay, 2001-2002 and their frequency of occurrences

Species	2001	2002	Total
Diatoms			
Pseudo-nitzschia calliantha	5	11	16
Dinoflagellates			
Alexandrium tamarense	6	19	25
Dinophysis acuminata	4	10	14
Dinophysis acuta	6	9	15
Dinophysis fortii	5	1	6
Dinophysis norvegica	2	0	2
Dinophysis rotundata	1	13	14
Karenia breve	1	0	1
Raphidophyceae			
Heterosigma akashiwo	2	4	6

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

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

5.1.1. Number of HAB events in Amurskii Bay

Records of HAB events in Amurskii Bay August 2008 – August 2010 are provided in Annex I. In August 2008 – August 2010, a total of 24 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 seriata/pungens* and *P. delicatissima.*

5.1.2. Period of HAB events

According to the HAB data in August 2008 – August 2010, 50% of HAB species occurred in August–September (Figure 13). HAB events occurred during January, March, June – October, and observed more frequently from June to October.

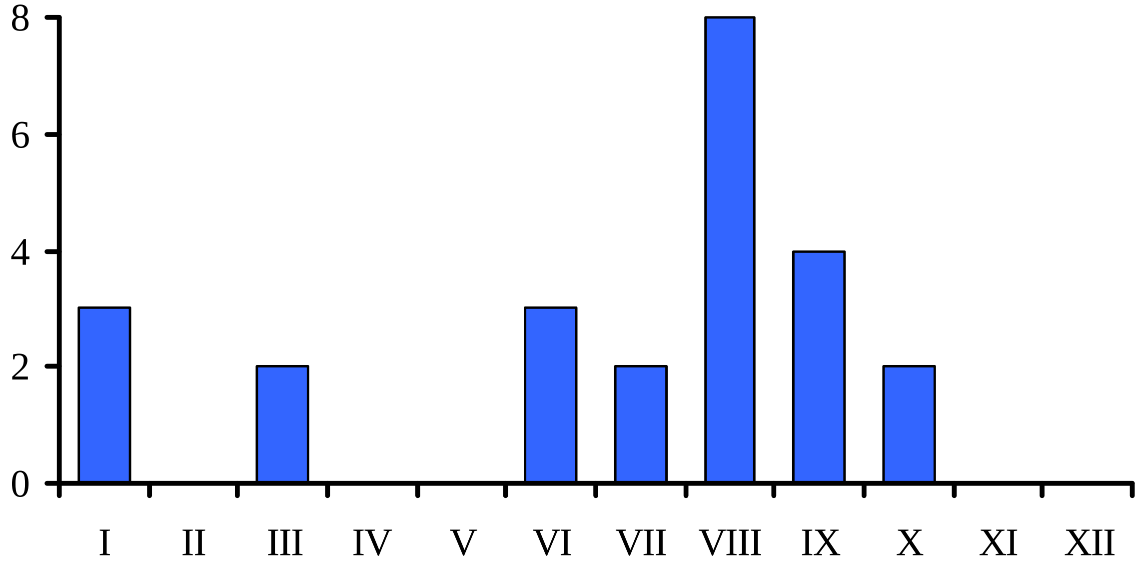

Figure 13. Number of HAB events by month in Amurskii Bay (August 2008 – August 2010)

5.1.3. Duration of HAB events

Table 12 shows the number of HAB events by duration (no. of days) in August 2008 – August 2010. A total of 18 events occurred in August 2008 – August 2010, in which 19 events between 6–10 days, 6 events between 11–30 days, 1 event were above 30 days. The longest bloom was 76 days forming by diatom *Prorocentrum triestinum,* which mass developed from August to October 2009. The longest HAB duration by potentially toxic species was 30 days. It was caused by dinoflagellate *Pseudo-nitzschia pungens,* which occurred during July – August 2010.

Table 12. Number of HAB events by duration (no. pf days)

	6-10	11-30	>30	Total
Amurskii Bay	17	6	1	
Total	17	6	1	24

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

5.1.4. Location of HAB events

Table 13 shows the number of HAB events by area. In August–December 2008, 7 events occurred in Amurskii Bay and caused mostly by potentially toxic dinoflagellates and diatoms *Pseudo-nitzschia* spp. In January–December 2009, 10 events occurred in Amurskii Bay. These events were caused by diatoms, dinoflagellates and bloom-forming *Prorocentrum triestinum*. In December–August 2010, 7 events occurred in Amurskii Bay and caused by potentially toxic diatoms *Pseudo-nitzschia* spp. and bloom-forming raphidophytes. Figure 14 shows the location of the HAB events and causative species in Amurskii Bay in August 2008 – August 2010.

Table 13. Number of HAB events by area in August 2008 – August 2010

Year	Sea area	No. of events	Causative species
August – December 2008	Amurskii Bay	7	*Pseudo-nitzschia delicatissima* *Pseudo-nitschia pungens* *Pseudo-nitschia calliantha* *Dinophysis acuminata* *Prorocentrum minimum* *Protoceratium reticulatum*
January – December 2009	Amurskii Bay	10	*Pseudo-nitschia cf. seriata* *Pseudo-nitschia pungens* *Pseudo-nitschia calliantha* *Dinophysis acuta* *Dinophysis acuminata* *Prorocentrum triestinum* *Prorocentrum minimum* *Protoceratium reticulatum*
January – August 2010	Amurskii Bay	7	*Pseudo-nitschia pungens* *Pseudo-nitschia cf. delicatissima* *Pseudo-nitschia cf. seriata* *Dactyliosolen fragilissimus* *Heterosigma akashiwo*

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

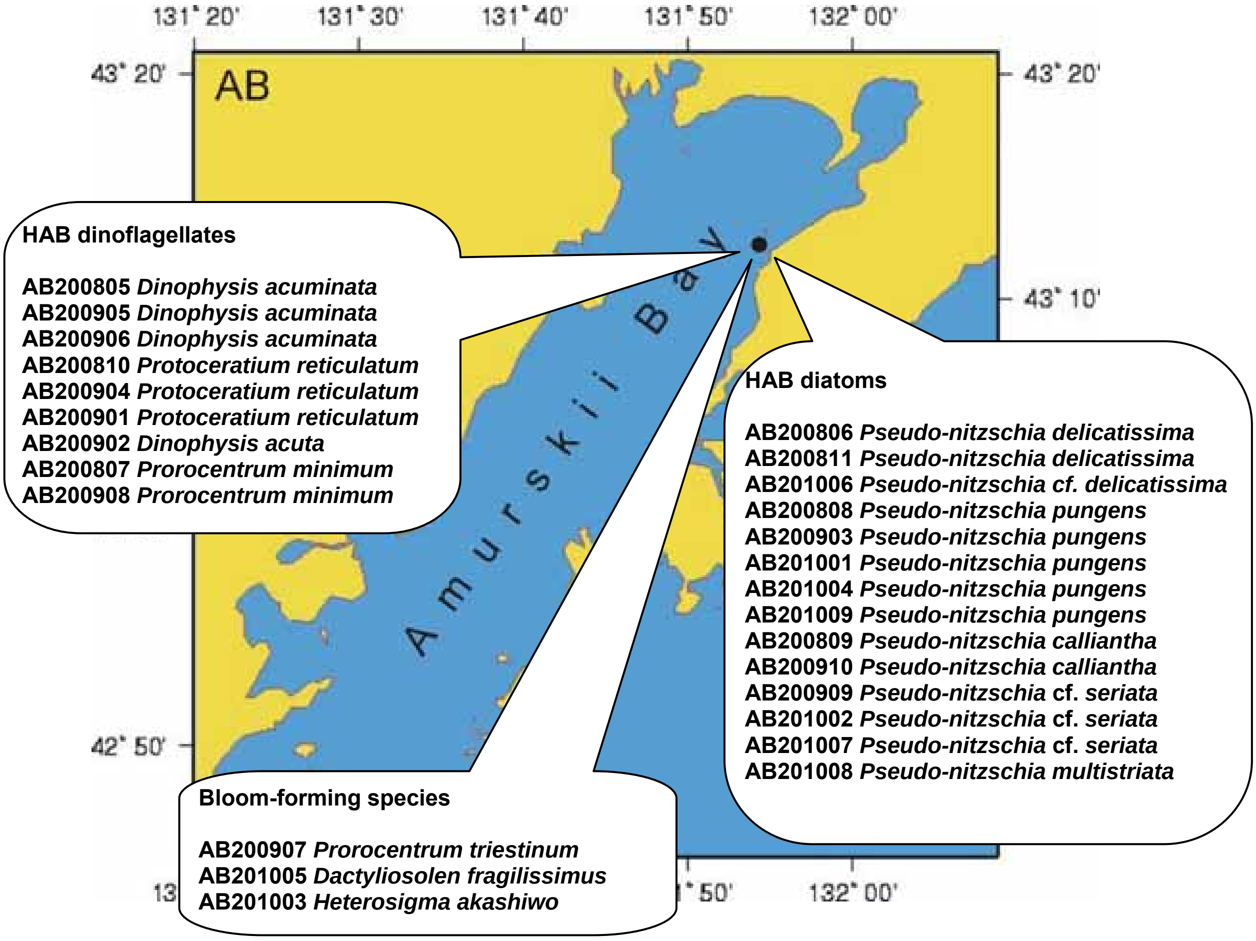

Figure 14. Location of HAB events (events no. and causative species) in Amurskii Bay (August 2008 – August 2010).

5.1.5. Causative species

Table 14 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 recoded. The most frequently observed species was bloom-forming diatom *Skeletonema costatum.* The most frequently observed potentially toxic species was diatoms *Pseudo-nitzschia seriata/pungens.*

Table 14. HAB species recorded in Amurskii Bay in August 2008 – August 2010 and their frequency of occurrences

Genus and Species	August 2008 – August 2010	Total
Chrysophyceae		
*Dinobryon balticum**	0	0

Bacillariophyceae		
*Chaetoceros salsugineus**	0	0
*Dactyliosolen fragilissimus**	1	1
Pseudo-nitzschia calliantha	2	2
Pseudo-nitzschia delicatissima	3	3
Pseudo-nitzschia fraudulenta	0	0
Pseudo-nitzschia multistriata	0	0
Pseudo-nitzschia multiseries	0	0
Pseudo-nitzschia seriata/pungens	7	7
*Skeletonema costatum**	0	0
Dinophyceae		
Dinophysis acuminata	3	3
Dinophysis acuta	1	1
Dinophysis fortii	0	0
Dinophysis norvegica	0	0
Dinophysis rotundata	0	0
Karenia mikimotoi	0	0
Noctiluca scintillans	0	0
Prorocentrum minimum	2	2
*Prorocentrum triestinum**	1	1
Protoceratium reticulatum	3	3
Raphidophyceae		
Chattonella sp.	0	0
Heterosigma akashiwo	1	1
Total number of samples		24

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

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

5.1.6. Maximum density of each HAB event

Table 15 shows the maximum density of each HAB event that occurred in Amurskii Bay in August 2008 – August 2010. Within these HAB events, the highest density was recorded in March 2010 by *Heterosigma akashiwo.* The recorded maximum density was 6 041 600 cell/L.

Table 15. Maximum density of HAB event that occurred in Amurskii Bay

Year	Event No.	Causative species	Maximum density ($cellsL^{-1}$)	Affected area
2008	AB200801	*Dinophysis acuminata*	1 900	No info.
2008	AB200802	*Pseudo-nitzschia delicatissima*	1 257	No info.
2008	AB200803	*Prorocentrum minimum*	942	No info.
2008	AB200804	*Pseudo-nitschia pungens*	1 320	No info.
2008	AB200805	*Pseudo-nitschia calliantha*	2 640	No info.
2008	AB200806	*Protoceratium reticulatum*	330	No info.
2009	AB200901	*Protoceratium reticulatum*	430	No info.
2009	AB200902	*Dinophysis acuta*	114	No info.
2009	AB200906	*Dinophysis acuminata*	2 571	No info.
2009	AB200907	*Prorocentrum triestinum*	508 800	No info.
2009	AB200908	*Prorocentrum minimum*	302	No info.
2009	AB200909	*Pseudo-nitschia pungens/seriata*	1 800	No info.
2009	AB200910	*Pseudo-nitschia calliantha*	19 200	No info.
2010	AB201003	*Heterosigma akashiwo*	6 041 600	No info.
2010	AB201004	*Pseudo-nitschia pungens/ seriata*	1 950	No info.
2010	AB201005	*Dactyliosolen fragilissimus*	1 860 000	No info.
2010	AB201006	*Pseudo-nitschia cf. delicatissima*	32 760	No info.

5.1.7. Status of HAB induced fishery damage

There is no any information of any fishery damage or human poisoning in Amurskii Bay in August 2008 – August 2010. The highest concentration of diarrhetic shellfish toxins (317 $\mu g \cdot kg^{-1}$) was registered in June 2009 in the bodies of *Crenomytilus grayanus* from Amurskii Bay, which was 2 times as high as the maximum permissible content (160 $\mu g \cdot kg^{-1}$) according to the Sanitary Regulations and Standarts 2.3.2.1078-01 approved by the RF State Committee for Health and Epidemiological Inspection and to the European Community Regulation 2002/225/EC. The highest concentration of amnesic shellfish toxins (0.5 $mg \cdot kg^{-1}$) was registered in July 2009 in the bodies of *Crenomytilus grayanus* from Amurskii Bay (see Annex_Common format_Russia_2011).

5.1.8. 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 16 shows target HAB species in Amurskii Bay between August 2008 and August 2010. A total 10 target HAB species were recorded. Those species are belonging to 2 taxonomic groups of phytoplankton: dinoflagellates (4 species) and diatoms (3 species).

Table 16. Target HAB species in Amurskii Bay, August 2008–August 2010

Target HAB species	Bloom-forming species	Toxic/potentially toxic species	Maximum density (cellsL^{-1})
Diatoms			
Dactyliosolen fragilissimus	+		1 860 000
Pseudo-nitzschia calliantha		+	19 200
Pseudo-nitzschia delicatissima		+	32 760
Pseudo-nitzschia pungens/ seriata		+	1 950
Dinoflagellates			
Dinophysis acuminata		+	2 571
Dinophysis acuta		+	114
Prorocentrum minimum		+	942
Prorocentrum triestinum	+		508 800
Protoceratium reticulatum		+	430
Raphidophyceae			
Heterosigma akashiwo	+		6 041 600

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

According to the HAB data in August 2008–August 2010, target HAB species occurred in January, March, June–October (Figure 15) and observed more frequently in August.

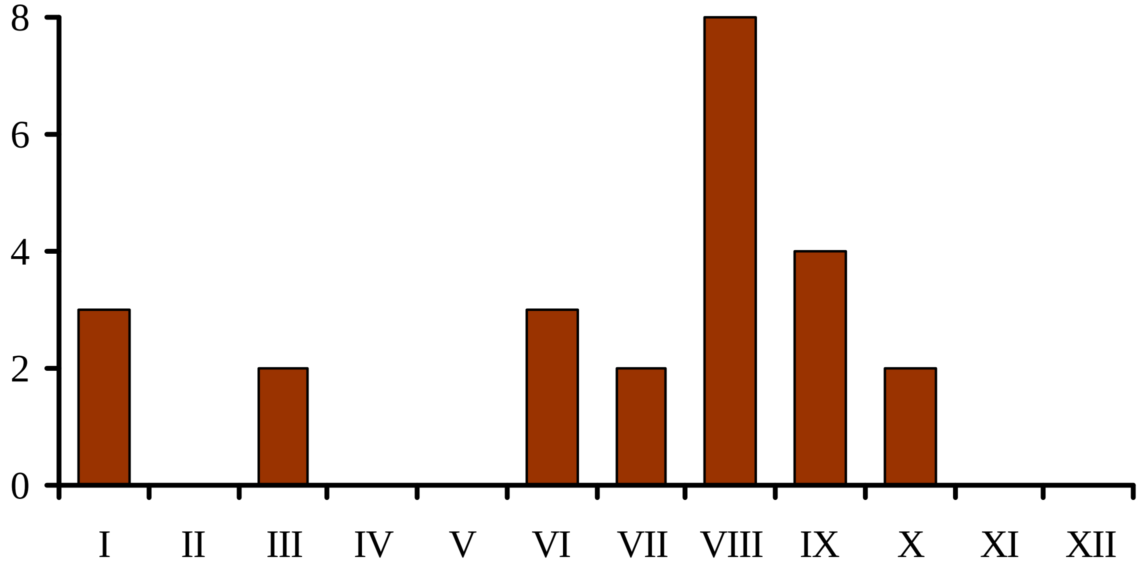

Figure 15. Number of target HAB species by month in Amurskii Bay (August 2008 – August 2010).

5.1.9. Environmental monitoring results during HAB events

During the post-HAB survey, water temperature and salinity were measured. Table 17 shows the data obtained for each HAB event. During the HAB events, water temperature ranged between -1.8 – 23.5^{0}C, salinity between 19 – 34‰.

Table 17. Data of post-HAB surveys in Amurskii Bay

Year	Event No.	Duration	Water temp. (C^0)	Salinity, ‰
2008	AB200801	*Dinophysis acuminata*	20,5	22 – 33
2008	AB200802	*Pseudo-nitzschia delicatissima*	20,5	26 – 31
2008	AB200803	*Prorocentrum minimum*	20,5-20,9	22.5 – 33
2008	AB200804	*Pseudo-nitschia pungens*	20,9	19 – 34
2008	AB200805	*Pseudo-nitschia calliantha*	20,9	19 – 32
2008	AB200806	*Protoceratium reticulatum*	20,9	28

2009	AB200807	*Pseudo-nitschia delicatissima*	15,2	28
2009	AB200901	*Protoceratium reticulatum*	-1,8	19 – 31
2009	AB200902	*Dinophysis acuta*	-1,7	31 – 34
2009	AB200903	*Pseudo-nitschia pungens*	14,1	22.5 – 32
2009	AB200904	*Protoceratium reticulatum*	14,1	30
2009	AB200905	*Dinophysis acuminata*	14,1–17,2	30
2009	AB200906	*Dinophysis acuminata*	22,5–23	20-27
2009	AB200907	*Prorocentrum triestinum*	23–10,5	20
2009	AB200908	*Prorocentrum minimum*	19	25
2009	AB200909	*Pseudo-nitschia cf. seriata*	10,5	30,55
2010	AB200910	*Pseudo-nitschia calliantha*	10,5	30,55
2010	AB201001	*Pseudo-nitschia pungens*	-1,8	32,99
2010	AB201002	*Pseudo-nitschia cf. seriata*	-1,8	32,99
2010	AB201003	*Heterosigma akashiwo*	-1	33-34
2010	AB201004	*Pseudo-nitzschia pungens*	22,5–23,5	22,59
2010	AB201005	*Dactyliosolen fragilissimus*	22,5	22,59
2010	AB201006	*Pseudo-nitschia cf. delicatissima*	23,5	27,74
2010	AB201007	*Pseudo-nitschia cf. seriata*	23,5	19 – 29

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

5.2.1. Number of HAB events in Vostok Bay

For the period of observations from year 2001- 2009 a total 19 HAB events were observed, in which no any cases of human poisoning or fishery damage were recorded. Records of HAB events from year 2001-2009 are provided in Annex 2.

5.2. 2. Period of HAB events

According to the HAB data in 2001- 2009, 42% of HAB events occurred in August (Figure 16). HAB events occurred during April –November, and observed more frequently from June to September.

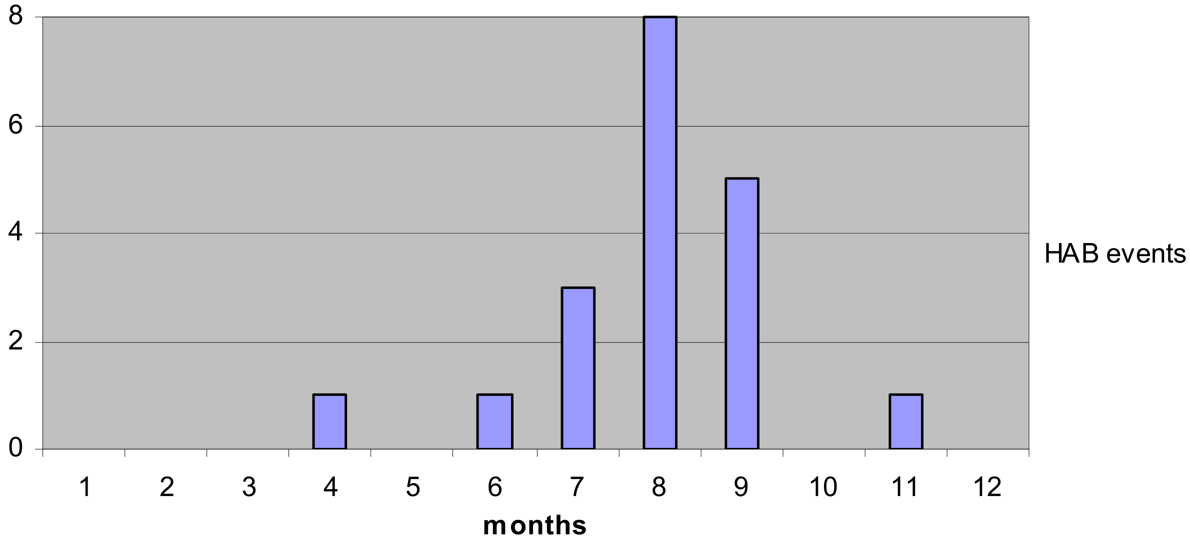

Figure 16. Number of HAB events by month in Vostok Bay (2001 – September 2009).

5.2. 3. Duration of HAB events

Table 18 shows the number of HAB events by duration (no. of days) in 2001- 2009. A total of 19 events occurred in 2001- 2009, in which 2 events were equal-to-or-greater-than 12 days and 17 events less-then 15 days.

Table 18. Number of HAB events by duration (no. pf days)

	<15	≥12	Total
Vostok Bay	17	2	19
Total	17	2	19

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

5.2. 4. Location of HAB events

Table 19 shows the number of HAB events by area. In 2001, 5 events occurred in Vostok Bay and caused by diatoms *Skeletonema costatum, Asterionellopsis glaciales,* *Pseudo-nitzschia pseudodelicatissima* and dinoflagellates *Alexandrium tamarense* and *Dinophysis fortii.* In 2002, 2003 and 2005 in Vostok Bay were observed in 2 HAB events per year. Dinoflagellates and raphydophytes were causative species.

In 2006, 3 events occurred in the study area. These events were caused by dinoflagellates, diatoms and raphydophytes. Figure 17 shows the location of the HAB events and causative species in Vostok Bay in August 2001 – September 2009.

Table 19. Number of HAB events by area in 2001-2009

Year	Sea area	No. of events	Causative species
2001	Vostok Bay	5	*Skeletonema costatum* *Alexandrium tamarense* *Dinophysis fortii* *Asterionellopsis glacialis* *Pseudo-nitzschia pseudodelicatissima*
2002	Vostok Bay	2	*Dinophysis acuminata* *Chatonella globosa*
2003	Vostok Bay	2	*Dinophysis acuminata* *Heterocapsa rotundata*
2004	Vostok Bay	1	*Dinophysis acuminata*
2005	Vostok Bay	2	*Heterosigma akashiwo* *Pseudo-nitzschia pseudodelicatissima*
2006	Vostok Bay	3	*Alexandrium tamarense* *Heterosigma akashiwo* *Skeletonema costatum*
2007	Vostok Bay	1	*Heterosigma akashiwo*
2008	Vostok Bay	0	
2009	Vostok Bay	3	*Nitzschia hybrida f. hyalina* *Pseudo-nitzschia multistriata* *Pseudo-nitzschia pseudodelicatissima*

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

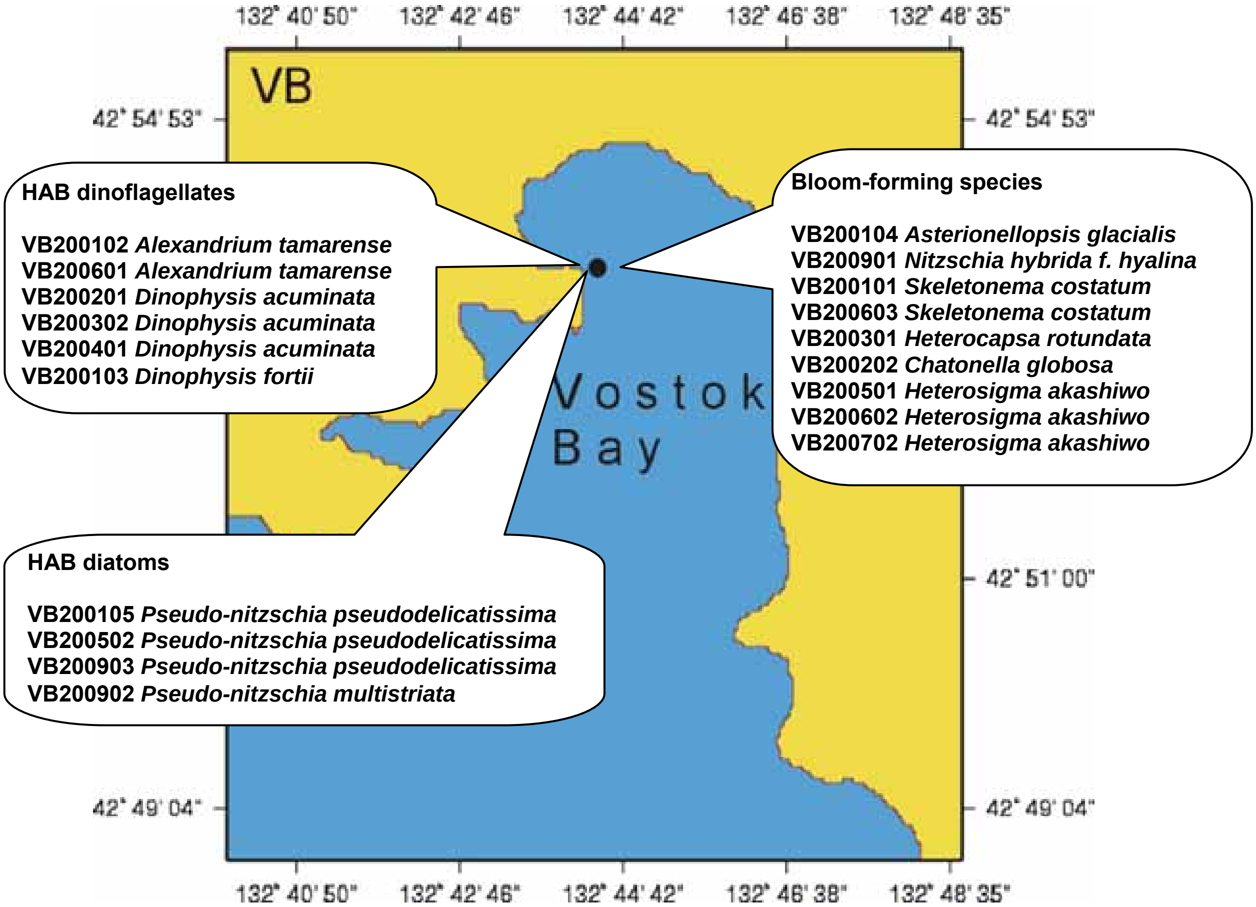

Figure 17. Location of HAB events (causative species) in Vostok Bay (2001 – 2009).

5.2.5. Causative species

Table 20 shows the HAB species that were recorded in Vostok Bay in August 2001 – September 2009 and their frequency of occurrences. A total of 11 HAB species were recoded. The most frequently observed species were *Heterosigma akashiwo* and potentially toxic *Pseudo-nitzschia pseudodelicatissima* and *Dinophysis rotundata.*

Table 20. HAB species recorded in Vostok Bay in August 2001 – September 2009 and their frequency of occurrences

Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
Diatoms										
*Asterionellopsis glacialis**	1									1
*Nitzschia hybrida f. hyaline**									1	1
Pseudo-nitzschia multistriata									1	1
Pseudo-nitzschia	1				1				1	3

pseudodelicatissima										
*Skeletonema costatum**	1					1				2
Dinoflagellates										
Alexandrium tamarense	1					1				2
Dinophysis acuminata		1	1	1						3
Dinophysis fortii	1									1
*Heterocapsa rotundata**			1							1
Raphidophyceae										
Chatonella globosa		1								1
Heterosigma akashiwo					1	1	1			3

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

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

5.2.6. Maximum density of each HAB event

Table 21 shows the maximum density of each HAB event that occurred in Vostok Bay in August 2001 – September 2009. Within these HAB events, the highest density was recorded in August 2006 by *Skeletonema costatum.* The recorded maximum density was 8 229 000 cell/L.

Table 21. Maximum density of HAB event that occurred in Vostok Bay

Year	Event No.	Causative species	Maximum density ($cellsL^{-1}$)	Affected area
2001	VB200104	*Asterionellopsis glacialis*	1191000	No info.
2009	VB200901	*Nitzschia hybrida f. hyalina*	8121600	No info.
2009	VB200902	*Pseudo-nitzschia multistriata*	3800	No info.
2001	VB200105	*Pseudo-nitzschia pseudodelicatissima*	686000	No info.
2006	VB200603	*Skeletonema costatum*	8229000	No info.
2006	VB200601	*Alexandrium tamarense*	5000	No info.
2002	VB200201	*Dinophysis acuminata*	500	No info.
2001	VB200103	*Dinophysis fortii*	500	No info.
2003	VB200301	*Heterocapsa rotundata*	1426000	No info.
2002	VB200202	*Chatonella globosa*	600	No info.
2005	VB200501	*Heterosigma akashiwo*	161000	No info.

5.2.7. Status of HAB induced fishery damage

There is no any information of any fishery damage or human poisoning in Vostok Bay in August 2001 – September 2009. The highest concentration of diarrhetic shellfish toxins (72 μg·kg^{-1}) was registered in May 2010 in the bodies of *Mytilus trossulus* from Vostok Bay. The highest concentration of amnesic shellfish toxins (0.1 mg·kg^{-1}) was registered in January 2010 in the bodies of *Crenomytilus grayanus* and *Mytilus trossulus* from Vostok Bay (see Annex_Common format_Russia_2011).

5.2.8. 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 22 shows target HAB species in Vostok Bay between August 2001 and September 2009. A total 11 target HAB species were recorded. Those species are belonging to 3 taxonomic groups of phytoplankton: dinoflagellates, diatoms and raphidophytes.

Table 22. Target in Vostok Bay, August 2001– September 2009

Target HAB species	Bloom-forming species	Toxic/potentially toxic species	Maximum density (cellsL^{-1})
Diatoms			
Asterionellopsis glacialis	+		1191000
Nitzschia hybrida f. hyalina	+		8121600
Pseudo-nitzschia multistriata		+	3800
Pseudo-nitzschia pseudodelicatissima		+	686000
Skeletonema costatum	+		8229000
Dinoflagellates		+	
Alexandrium tamarense		+	5000
Dinophysis acuminata		+	500
Dinophysis fortii		+	500
Heterocapsa rotundata	+		1426000

Raphidophyceae			
Chatonella globosa	+		600
Heterosigma akashiwo	+		161000

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

5.2.9. Environmental monitoring results during HAB events

During the post-HAB survey, water temperature and salinity were measured. Table 23 shows the data obtained for each HAB event. During the HAB events, water temperature ranged between 3 – 23.5^{0}C, salinity between 24.46 – 33.6‰.

Table 23. Data of post-HAB surveys in Vostok Bay

Year	Event No.	Duration	Water temp. (C^0)	Salinity, ‰
2001	VB200101	*Skeletonema costatum*	22.4-23.5	28.58
2001	VB200102	*Alexandrium tamarense*		
2001	VB200103	*Dinophysis fortii*		
2001	VB200104	*Asterionellopsis glacialis*	14.7	33.6
2001	VB200105	*Pseudo-nitzschia pseudodelicatissima*	14.7	33.6
2002	VB200201	*Dinophysis acuminata*	16.4	32.08
2002	VB200202	*Chatonella globosa*		
2003	VB200301	*Heterocapsa rotundata*	6.20	33.37
2003	VB200302	*Dinophysis acuminata*	17.5	33.23
2004	VB200401	*Dinophysis acuminata*	23,2	28,54
2005	VB200501	*Heterosigma akashiwo*	20.3	
2005	VB200502	*Pseudo-nitzschia pseudodelicatissima*	3	32,6
2006	VB200601	*Alexandrium tamarense*	22.6	30.6
2006	VB200602	*Heterosigma akashiwo*	22.6	30.6
2006	VB200603	*Skeletonema costatum*		
2007	VB200701	*Heterosigma akashiwo*		
2009	VB200901	*Nitzschia hybrida f. hyalina*	15.4	28.27
2009	VB200902	*Pseudo-nitzschia multistriata*	16.2	24.46
2009	VB200903	*Pseudo-nitzschia pseudodelicatissima*	16.2-14.7	24.46-31.17

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

5.3.1. Number of HAB events in Aniva Bay

Records of HAB events in Aniva Bay between January 2001-November 2002 are provided in Appendix 3. During the 2 years between 2001 and 2002, a total 31 bloom events were recorded, in which no any events induce damage or human poisoning. 15 HAB events were observed in 2001 and 16 HAB events – in 2002.

5.3. 2. Period of HAB events

According to the HAB data in January 2001-November 2002, 43% of HAB species occurred in June (Figure 18).

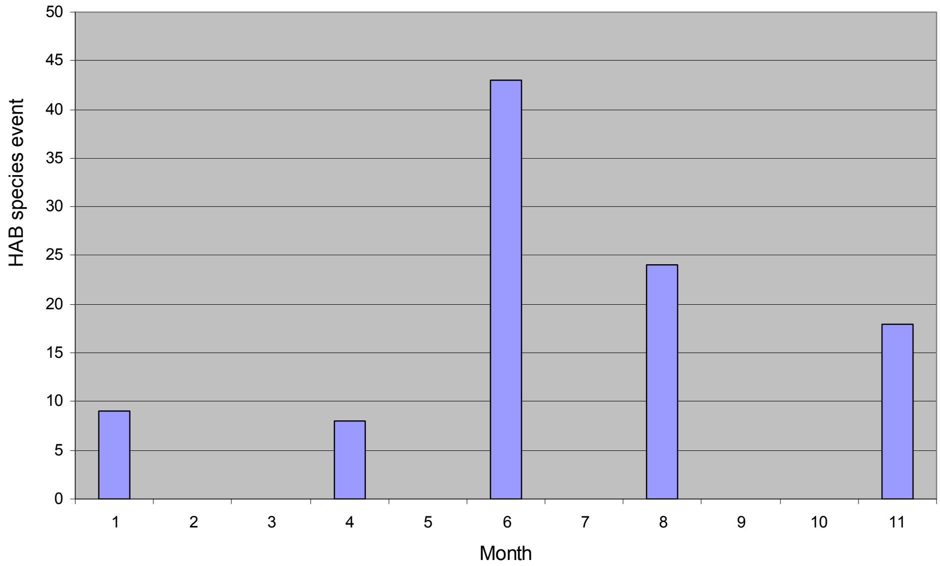

Figure 18. Number of HAB species by month in Aniva Bay (January 2001 – November 2002).

5.3.3. Duration of HAB events

There are no data on duration of HAB events in Aniva Bay in January 2001-November 2002.

5.3. 4. Location of HAB events

Table 24 shows the number of HAB events by area. In January-November 2001, 15 events occurred in Aniva Bay and caused mostly by potentially toxic dinoflagellate. In January – November 2002, 16 events occurred in Aniva Bay. These events were caused mostly by dinoflagellates too. Figure 19 shows the location of the HAB events and causative species in Aniva Bay in January 2001 -November 2002.

Table 24. Number of HAB events by area in January 2001-November 2002

Year	Sea area	No. of events	Causative species
January-November 2001	Aniva Bay	15	*Pseudo-nitzschia calliantha, Alexandrium tamarense, Dinophysis acuminate, Dinophysis acuta, Dinophysis fortii, Dinophysis norvegica, Dinophysis rotundata, Karenia breve, Heterosigma akashiwo*
January-November 2002	Aniva Bay	16	*Pseudo-nitzschia calliantha, Alexandrium tamarense, Dinophysis acuminate, Dinophysis acuta, Dinophysis fortii, Dinophysis rotundata, Heterosigma akashiwo*

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

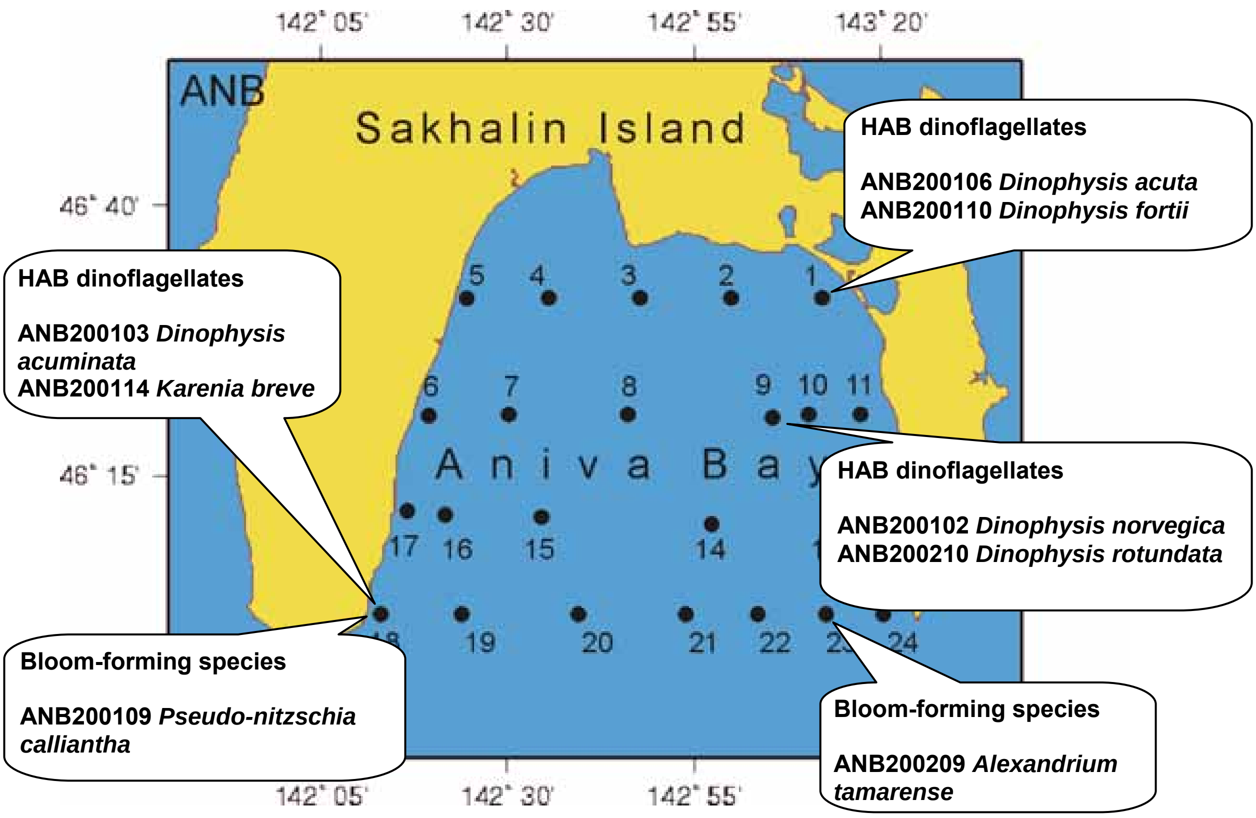

Figure 19. Location of HAB events (events no. and causative species) in Aniva Bay (January 2001 – November 2002).

5.3.5. Causative species

Table 25 shows the HAB species that were recorded in Aniva in January 2001 – November 2002 and their frequency of occurrences. A total of 9 HAB species were recoded. The most frequently observed species were dinoflagellate *Alexandrium tamarense* and *Dinophysis* spp..

Table 25. HAB species recorded in Aniva in January 2001 – November 2002 and their frequency of occurrences

Genus and Species	January 2001 – November 2002	Total
Diatoms		
*Pseudo-nitzschia calliantha**	16	16
Dinoflagellates		
*Alexandrium tamarense**	25	25
Dinophysis acuminate	14	14
Dinophysis acuta	15	15
Dinophysis fortii	6	6
Dinophysis norvegica	2	2
Dinophysis rotundata	14	14
Karenia breve	1	1
Raphidophyceae		
Heterosigma akashiwo	6	6
Total number of samples		99

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

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

5.3.6. Maximum density of each HAB event

Table 26 shows the maximum density of each HAB event that occurred in Aniva Bay in January 2001 – November 2002. Within these HAB events, the highest density was recorded in September 2001 by *Pseudo-nitzschia calliantha.* The recorded maximum density was 612444 cell/L.

Table 26. Maximum density of HAB event that occurred in Aniva Bay

Year	Event No.	Causative species	Maximum density (cellsL^{-1})	Affected area
2001	ANB200109	*Pseudo-nitzschia calliantha*	612444	No info.
2002	ANB200209	*Alexandrium tamarense*	50137	No info.
2001	ANB200108	*Heterosigma akashiwo*	6603	No info.
2001	ANB200103	*Dinophysis acuminata*	1728	No info.
2001	ANB200102	*Dinophysis norvegica*	1216	No info.
2001	ANB200106	*Dinophysis acuta*	712	No info.
2001	ANB200110	*Dinophysis fortii*	638	No info.
2002	ANB200210	*Dinophysis rotundata*	500	No info.
2001	ANB200114	*Karenia breve*	500	No info.

5.3.7. Status of HAB induced fishery damage

There is no any information of any fishery damage or human poisoning in Aniva Bay. The highest concentration of paralytic shellfish toxins (107,5 μg·100g^{-1}) was registered in September 2004 in the bodies of *Mizuhopecten yessoensis* from Aniva Bay, which was higher than the maximum permissible content (80 μg·100g^{-1}) according to the Sanitary Regulations and Standarts 2.3.4.050-96 approved by the RF State Committee for Health and Epidemiological Inspection and to the European Community Regulation 853/2004/EC. The highest concentration of amnesic shellfish toxins (110 mg·kg^{-1}) was registered in September 2004 in the bodies of *Mizuhopecten yessoensis* from Aniva Bay (see Annex_Common format_Russia_2011).

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 27 shows target HAB species in Amurskii Bay between January 2001 and November 2002. A total 9 target HAB species were recorded. Those species are belonging to 3 taxonomic groups of phytoplankton: dinoflagellates (7 species), diatoms (1 species) and raphydophytes (1 species).

Table 27. Target HAB species in Aniva Bay, January 2001 – November 2002

Target HAB species	Bloom-forming species	Toxic/potentially toxic species	Maximum density (cellsL^{-1})
Diatoms			
Pseudo-nitzschia calliantha	+	+	612444
Dinoflagellates			
Alexandrium tamarense	+	+	50137
Dinophysis acuminata	+		1728
Dinophysis acuta	+		712
Dinophysis fortii	+		638
Dinophysis norvegica	+		1216
Dinophysis rotundata	+		500
Karenia breve	+		500
Raphydophytes			
Heterosigma akashiwo	+		6603

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

6. Eutrophication monitoring with satellite image

6.1. Framework of the satellite monitoring

There are two satellite centers that make sea monitoring regularly – the Center of Roshydromet in Khabarovsk (subdivision of Russian meteorological service) and the Center of Far-Eastern branch of Russian Academy of Sciences (Vladivostok). Every day charts are available last years: sea surface temperature (SST) (Figure 20), chlorophyll-a concentrations (OC-3 algorithm, MODIS images), ice (RGB-images).

New data are available now after the launch of METEOR-M 1 – 6 visual charnels of 60-100m spatial resolution (KMSS-radiometer). KMSS has wide FOV (near 900 km). Three KMSS radiometers will operate in the nearest 2-3 years after the launchings of METEOR-2 and 3. As the result, every day monitoring of the sea bio-parameters will be possible (under good cloudy conditions). It's important especially for sea farms, that allocated in small bays usually, and the common satellite data of 0.5-1 km spatial resolution is impossible to use because of the land presence in near shore pixels.

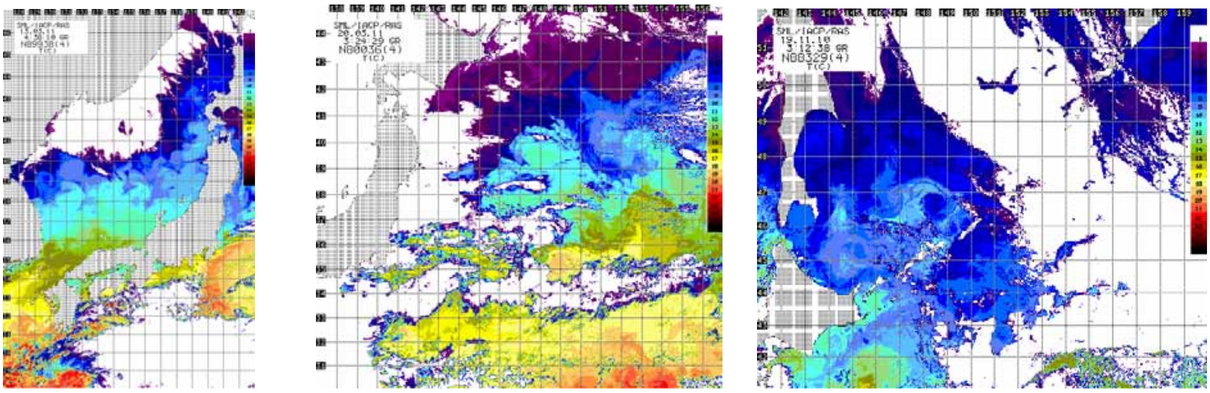

Figure 20. Sea surface temperature charts of a satellite single pass, the main regions of satellite monitoring.

Detailed every day monitoring is fulfilled for two problem bays of Far East of Russia – Sakhalin bay and Peter the Great bay. Last one includes two more small bays (Amurskii and Vostok). The SeaDAS program package (6.1 version) is used now for computation more 200 parameter charts of sea and atmosphere over it. Metedata of monitoring of Peter the Great bay are presenter in Figure 21. The same every day monitoring is carried out for other problem bays of NOWPAP project - Ariake, Shandong Peninsula, “South Sea” and Toyama Bay. The data are allocated in ftp://ftp.satellite.dvo.ru/pub/modis and have free access. They have two formats – HDF and special format. Free software is available (program Glance) for the last format. It can be taken at sight http://www.satellite.dvo.ru.

Figure 21. A metadata sample of every day monitoring of Peter the Great bay (images of SST or Chlorophyll-a concentration).

6.2. Methods for bio-parameter monitoring.

About 90% of the radiation intensity signal registered by a satellite in the visible spectral bands is connected with light scattering on atmosphere aerosols. The calculation of atmospheric contribution into the remotely measured radiation intensities is a part of biooptical algorithm called as "atmospheric correction algorithm". The MUMM atmospheric correction realized in the SeaDAS program package (Ruddick et al. 2000, 2006) was used as the basic for satellite monitoring. The algorithm is based on processing of near infrared (NIR) spectral bands data for aerosol type detection. The approach designed for the open ocean waters was extended for use over turbid waters. The main idea of the MUMM atmospheric correction is to use the spatial homogeneity of NIR spectrum instead of the assumption of zero water-leaving radiance for NIR bands. As the result, the popular algorithm for chlorophyll-a concentration (OC3) may be use for the Case II waters – high trophic waters, where the algal blooming has the maximal intensity usually. And more, Carder algorithm (Kendall et al., 2003) has shown a good agreement with in situ chlorophyll-a measurements both Case I, Case II waters and waters polluted by town simultaneously (Salyuk, 2010). Thus, it is possible to use different bio-optical parameters for looking for harmful algal species.

Satellite information allows to find the most interesting objects for the investigations. It is used for pointing out the objects for a research vessel. The charts of the follow parameters are used for this goal: chlorophyll-a concentration (*chl*), fluorescence line height (*flh*), turbidity (diffuse attenuation coefficient K490), photosynthesis effectiveness, homogeneity of algal species composition, dominant species size (Figure 22). Photosynthesis capacity $F=flh/chl$ is used as a parameter of photosynthesis effectiveness (the value is inversely proportional to the effectiveness). It allows to find the areas, where phytoplankton concentration will grow. The ratio of phytoplankton scattering coefficient $b_{bp}(\lambda)$ to absorption one $a_{ph}(\lambda)$ for a selected spectral band is used as a parameter of homogeneity of algal species composition, where λ is the wave length. The ratio may be used for detection of areas with sharp change of the species composition and/or significant change of an admixture concentration. The scattering coefficient growth with the growth of spectral band frequency is used as a parameter characterized dominant species size. The growth is inversely proportion to the dominant species size usually. Joint analysis of the parameters mentioned allows looking for interesting sea objects.

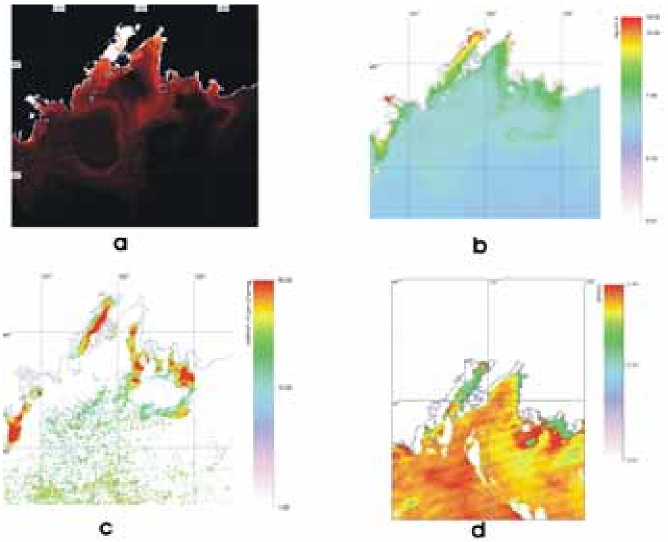

Figure 22. Bio-optical parameter charts of Peter the Great bay on August 24, 2009. a – diffuse attenuation coefficient K490; b – chlorophyll-a concentration (OC3 algorithm); c – photosynthesis capacity F; d - a parameter of homogeneity of alga species composition (λ=412 ηm, Carder algorithm).

Significant variability of species composition in a sea makes the task of HAB detection very difficult. The main goal is to know the sets of dominant algal species for the region under consideration and the season. To solve the task, it is necessary to answer on follow questions:

- How many algal species are composed the main biomass in the water samples?
- Is the species diversity significant in the bay?
- What is the variability of average size of algal sells?
- What is harmful species diversity?
- When is it possible to look for a concrete harmful species?

An analysis of properties of algal species composition has been carried out for Peter the Great bay. The measurements for almost 10 years (Figure 23) have been processed in according to the questions formed. The results have shown that alga biodiversity is not so heavy obstacle. There are about 60 % of phytoplankton biomass in an arbitrary species composition in the bay in average (Figure 24). Four dominant species “take” about 90% of composition biomass. It was allowed to form the tables of dominating species by biomass for different parts of the bay and for each month.

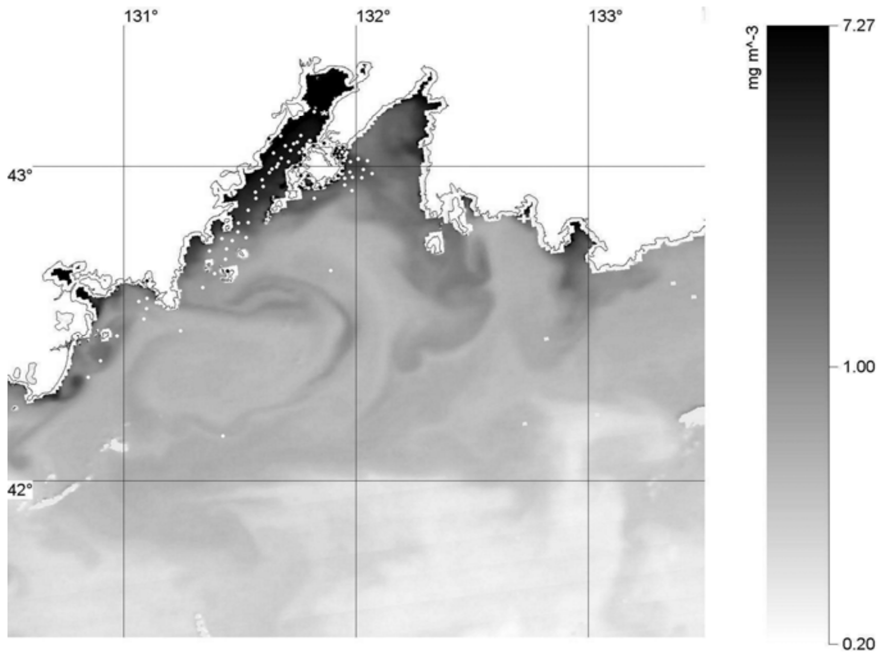

Figure 23. Chlorophyll-a concentration on August 31, 2009 in the Peter the Great Bay and points of algal composition measurements. Total amount measurements ~500. * - IMB station, + - Vostok station.

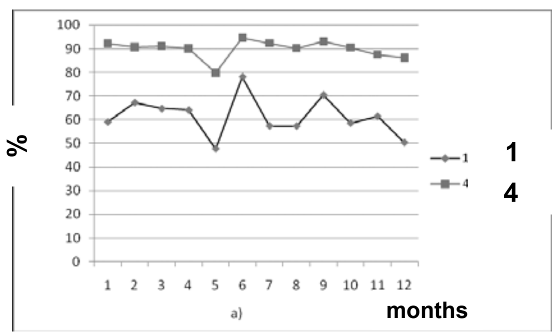

Figure 24. Average percent of biomass of one dominant alga (1) and four dominant algae (4).

The problem of classification of algal genera, based on the remote sensing data, requires the analysis of algae biomass distribution. This study provides the analysis of algae spatial and temporal variations in the Peter the Great Bay. While 116 algal genera were observed, only few genera have dominated. Usually the dominant genus occupied about 60% of sample's biomass (minimal value is 20% usually) and 4 dominant genera occupied about 90% of biomass. It was found, that spatial and temporal variations of algal biomass are significant, but the percentage characteristics of few dominant genera is relatively stable. The effective cross-section of algae in the samples is very changeable and this feature looks promising for classification problem.

Algae composition analysis has demonstrated that, the same algal genera are propagated in different parts of the Bay. For a Bay region and month selected the set of algae dominated, that occupies about 90% of monthly biomass, is rather small – not more 10 genera usually. Most of the alga genera (~75%) do not reach mono domination state (more 50% of sample biomass).

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 *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; 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 Amursii 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.

The problem of classification of algal genera, based on the remote sensing data, requires the analysis of algae biomass distribution. This study provides the analysis of algae spatial and temporal variations in the Peter the Great Bay. While 116 algal genera were observed, only few genera have dominated. Usually the dominant genus occupied about 60% of sample's biomass (minimal value is 20% usually) and 4 dominant genera occupied about 90% of biomass. It was found, that spatial and temporal variations of algal biomass are significant, but the percentage characteristics of few dominant genera is relatively stable. The effective cross-section of algae in the samples is very changeable and this feature looks promising for classification problem.

Algae composition analysis has demonstrated that, the same algal genera are propagated in different parts of the Bay. For a Bay region and month selected the set of algae dominated, that occupies about 90% of monthly biomass, is rather small – not more 10 genera usually. Most of the alga genera (~75%) do not reach mono domination state (more 50% of sample biomass).

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Appendix

Annex 1.Records of HAB events in Amurskii Bay, 1991–2010

Duration (Start)			Duration (End)			Contin. days	Species	Density (cells L^{-1})	Temp. (^oC)	Salinity, psu
Year	Month	Day	Year	Month	Day					
Chrysophytes										
2008	3	4	2008	4	7	34	*Dinobryon balticum*	1.05×10^6	-1.8-5.5	30.6-33.6
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	*Skeletonema 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
2007	8	6	2007	8	20	14	*Skeletonema costatum*	8×10^6	20.0-23.0	26.8-28.0
2007	8	6	2007	9	17	42	*Pseudo-nitzschia delicatissima*	83×10^3	20.0-22.0	26.8-32.7
2007	9	17	2007	10	9	22	*Pseudo-nitzschia pungens*	4.8×10^3	12.0-20.0	30.5-32.7
2007	9	5	2007	9	17	12	*Pseudo-nitzschia calliantha*	173×10^3	20.0-22.0	30.2-32.7
2007	10	30	2007	10	30	7	*Pseudo-nitzschia calliantha*	1.5×10^3	6.5	31.2
2007	11	9	2007	11	9	7	*Pseudo-nitzschia delicatissima*	0.3×10^3	6.8	31.9
2008	3	4	2008	3	4	7	*Pseudo–nitzschia multistriata*	0.3×10^3	-1.8	32.6
2008	6	7	2008	6	7	7	*Pseudo–nitzschia pungens*	0.6×10^3	16.7	18.8
2008	7	28	2008	9	29	62	*Pseudo–nitzschia delicatissima*	8.8×10^3	15.2-23.5	22.5-30.5
2008	7	14	2008	7	14	7	*Pseudo–nitzschia pungens*	0.3×10^3	23.2	26.0
2008	7	28	2008	7	28	7	*Pseudo–nitzschia multistriata*	1.3×10^3	23.5	22.5
2008	6	26	2008	8	11	47	*Skeletonema costatum*	5.5×10^3	17.8-23.5	22.6-26.8
2008	8	29	2008	9	15	18	*Pseudo–nitzschia pungens*	1.3×10^3	20.5-20.9	28.1-29.8
2008	8	29	2008	8	29	7	*Pseudo-nitzschia delicatissima*	1.3×10^3	20,5	28,17
2008	8	29	2008	9	15	14	*Pseudo-nitschia pungens*	1.3×10^3	20,5	28,17

2008	9	15	2008	9	15	7	*Pseudo-nitschia calliantha*	2.6×10^3	20,9	29,78
2008	9	29	2008	9	29	7	*Pseudo-nitschia delicatissima*	0.5×10^3	15,20	30,55
2009	6	8	2009	6	8	7	*Pseudo-nitschia pungens*	0.2×10^3	14,10	30
2009	10	26	2009	10	26	7	*Pseudo-nitschia cf. seriata*	1.8×10^3	10,5	30,55
2009	10	26	2009	10	26	7	*Pseudo-nitschia calliantha*	19.2×10^3	10,5	30,55
2010	1	28	2010	2	10	13	*Pseudo-nitschia pungens*	0.5×10^3	-1,8	32,99
2010	1	28	2010	2	10	13	*Pseudo-nitschia cf. seriata*	0.2×10^3	-1,8	32,99
2010	7	30	2010	8	31	30	*Pseudo-nitzschia pungens*	2×10^3	22,5–23,5	22,59
2010	7	30	2010	7	30	7	*Dactyliosolen fragilissimus*	1.8×10^6	22,5–23,5	22,59
2010	8	31	2010	8	31	7	*Pseudo-nitschia cf. delicatissima*	32.8×10^3	24	27,74
2010	8	31	2010	8	31	7	*Pseudo-nitschia cf. seriata*	0.8×10^3	24	27,74
							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
2008	5	5	2008	7	14	70	*Dinophysis acuminata*	$4 .4 \times 10^3$	9.0-23.3	18.8-28.6
2008	8	11	2008	8	11	7	*Dinophysis acuminata*	$1 .9 \times 10^3$	20.5	26.7
2008	8	29	2008	8	29	7	*Prorocentrum minimum*	0.9×10^3	20,5-20,9	28,17
2008	9	15	2008	9	15	7	*Protoceratium reticulatum*	0.3×10^3	20,9	29,78
2009	1	11	2009	1	11	7	*Protoceratium reticulatum*	0.3×10^3	-1,8	32,99
2009	3	12	2009	3	12	7	*Dinophysis acuta*	0.1×10^3	0,50	33,08
2009	6	8	2009	6	8	7	*Protoceratium reticulatum*	0.4×10^3	14,10	30
2009	6	8	2009	7	1	22	*Dinophysis acuminata*	1.4×10^3	14,1–17,2	30
2009	8	2	2009	8	25	23	*Dinophysis acuminata*	2.6×10^3	22,5–23	20–27
2009	8	2	2009	10	26	76	*Prorocentrum triestinum*	0.5×10^6	23–10,5	20
2009	9	9	2009	9	9	7	*Prorocentrum minimum*	0.3×10^3	19	25
							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
2007	8	20	2007	8	20	7	*Heterosigma akashiwo*	$7. 9 \times 10^6$	23.2	26.8
2007	10	30	2007	10	30	7	*Heterosigma akashiwo*	$9. 8 \times 10^6$	6.5	31.2
2008	6	7	2008	6	7	7	*Heterosigma akashiwo*	$1. 9 \times 10^6$	16.2	18.8

2010	3	30	2010	3	30	7	*Heterosigma akashiwo*	6.0×10^{6}	-1	
							Euglenophytes			
2005	07	12				< 7	*Euglena pascheri*	1.5×10^{6}	-1.7	35

Annex 2.

Records of HAB events in Vostok Bay in 2001-2009

Event No.	Duration (Start)			Duration (End)			Continuous days	Species	Density (cells L^{-1})	Temp. (^{o}C)	Salinity, psu
	Year	Month	Day	Year	Month	Day					
	2001	08	16				>12	*Skeletonema costatum*	5250000	23	28.58
	2001	08	29				<15	*Alexandrium tamarense*	1600		
	2001	08	29				<15	*Dinophysis fortii*	500		
	2001	09	30				<15	*Asterionellopsis glacialis*	1191000	14.7	33.6
	2001	09	30				<15	*Pseudo-nitzschia pseudodelicatissima*	686000	14.7	33.6
	2002	07	14				<15	*Dinophysis acuminata*	500	16.4	32.08
	2002	07	14				<15	*Chatonella globosa*	600		
	2003	04	23				<15	*Heterocapsa rotundata*	1426000	6.20	33.37
	2003	06	30				<15	*Dinophysis acuminata*	100	17.5	33.23
	2004	08	01				<15	*Dinophysis acuminata*	200	23,2	28,54
	2005	09	01				<15	*Heterosigma akashiwo*	161000	20.3	
	2005	11	01				<15	*Pseudo-nitzschia pseudodelicatissima*	87000	3	32,6
	2006	08	04				<15	*Alexandrium tamarense*	5000	22.6	30.6
	2006	08	04				<15	*Heterosigma akashiwo*	38000	22.6	30.6
	2006	08	20				<15	*Skeletonema costatum*	8229000		
	2007	08	08				<15	*Heterosigma akashiwo*	19000		
	2009	07	04				<15	*Nitzschia hybrida f. hyalina*	8121600	15.4	28.27
	2009	09	01				<15	*Pseudo-nitzschia multistriata*	3800	16.2	24.46
	2009	09	01				>15	*Pseudo-nitzschia pseudodelicatissima*	159000	16.2	24.46

Annex 3. Records of HAB events in Aniva Bay in April 2001-Nowember 2002

Event No.	Duration (Start)			Duration (End)			Continuous days	Species	Density (cells L^{-1})	Temp. (^{o}C)	Salinity, psu
	Year	Month	Day	Year	Month	Day					
ANB200101	2001	04	11	-	-	-	-	*Alexandrium tamarense*	3408	-	-
ANB200102	2001	04	11	-	-	-	-	*Dinophysis norvegica*	1216	-	-
ANB200103	2001	04	11	-	-	-	-	*Dinophysis acuminata*	1728	-	-
ANB200104	2001	06	16	-	-	-	-	*Alexandrium tamarense*	27412	-	-
ANB200105	2001	06	16	-	-	-	-	*Alexandrium tamarense*	13688	-	-
ANB200106	2001	06	16	-	-	-	-	*Dinophysis acuta*	712	-	-
ANB200107	2001	06	16	-	-	-	-	*Dinophysis acuminata*	500	-	-
ANB200108	2001	08	13	-	-	-	-	*Heterosigma akashiwo*	6603	-	-
ANB200109	2001	08	14	-	-	-	-	*Pseudo-nitzschia calliantha*	612444	-	-
ANB200110	2001	10	03	-	-	-	-	*Dinophysis fortii*	638	-	-
ANB200111	2001	10	03	-	-	-	-	*Alexandrium tamarense*	648	-	-
ANB200112	2001	10	03	-	-	-	-	*Dinophysis norvegica*	500	-	-
ANB200113	2001	10	03	-	-	-	-	*Dinophysis acuta*	500	-	-

ANB200114	2001	10	03					*Karenia breve*	500		
ANB200115	2001	11	17					*Dinophysis fortii*	500		
ANB200201	2002	01	16					*Dinophysis acuta*	500		
ANB200202	2002	04	10					*Dinophysis rotundata*	500		
ANB200203	2002	04	10					*Dinophysis acuminata*	500		
ANB200204	2002	06	15					*Heterosigma akashiwo*	100		
ANB200205	2002	06	15					*Dinophysis acuta*	500		
ANB200206	2002	06	15					*Alexandrium tamarense*	15660		
ANB200207	2002	06	15					*Alexandrium tamarense*	14190		
ANB200208	2002	06	15					*Alexandrium tamarense*	13678		
ANB200209	2002	06	15					*Alexandrium tamarense*	50137		
ANB200210	2002	08	16					*Dinophysis rotundata*	500		
ANB200211	2002	08	16					*Dinophysis acuta*	500		
ANB200212	2002	11	10					*Dinophysis acuta*	500		
ANB200213	2002	11	10					*Dinophysis fortii*	500		
ANB200214	2002	11	10					*Dinophysis acuminata*	500		
ANB200215	2002	11	10					*Dinophysis acuminata*	500		
ANB200216	2002	11	10					*Dinophysis rotundata*	500		