The Bioscan 5(4) : 531-536, 2010
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES

EFFECT OF HARMFUL ALGAL BLOOMS IN FAR EASTERN SEAS OF RUSSIA AND NECESSITY OF DEVELOPMENT OF COUNTERMEASURES

O. G. SHEVCHENKO* AND T. YU. ORLOVA
A.V. Zhirmunsky Institute of Marine Biology FEB RAS
17 Palchevskogo St., Vladivostok - 690 041, RUSSIA
E-mail: shevol@imb.dvo.ru

KEY WORDS
Coastal water
Phytoplankton

Received on :
02.10.2010

Accepted on :
21.11.2010

***Corresponding author**

ABSTRACT

A total of 25 red tide events were observed during 1992–2010 in the coastal waters of Far Eastern seas of Russia. No any cases of human poisoning or mass mortality of fish and shellfish were recorded. A total of 12 species caused red tides in study area during 1992 to 2010. Those species belonged to 4 taxonomic groups of phytoplankton: dinoflagellates, diatoms, raphidophytes and euglenophytes. Eleven toxic species were observed. Potentially toxic species belong to 2 groups of phytoplankton: dinoflagellates and diatoms. Diatoms of the genus *Pseudo-nitzschia* are known as domoic acid producing species (ASP). Five species *P. pungens, P. multiseries, P. multistriata, P. pseudodelicatissima* and *P. calliantha* were monitored in study area.Species of Dinophysis are capable of producing ocadaic acid, causing the syndrome of diarrhetic shellfish poisoning (DSP). Four species *Dinophysis acuminata, D. acuta*, *D. fortii* and *D. rotundata* were observed in the Far Eastern seas of Russia in 1992–2010. *D. acuminata* was the most common species in the study area.The genus Alexandrium of Dinoflagellates may cause the paralytic shellfish poisoning (PSP). Three potentially toxic species of the genus *Alexandrium*: *A. tamarense, A. acatenella* and *A. pseudogonyaulax* were observed in Russian waters in 1992–2010.

INTRODUCTION

Microalgae in marine and brackish waters regularly cause "harmful effects", considered from the human perspective, in that they threaten public health and cause economic damage to fisheries and tourism. Harmful Algal Blooms (HABs) are truly global phenomena, and evidence is mounting that the nature and extent of the problem has been expanding over the last several decades. HABs cause discoloration of water by mass occurrences of microalgae (true algal blooms that may or may not be 'harmful") and toxin-producing species (toxic "blooms" that may be harmful even in low cell concentrations) (Shumway, 1990; Anderson *et al.*, 2001; Landsberg, 2002).HABs tend to occur more frequently, causing serious damage on fishery production through mass mortality of fish and shellfish and on human health through fish/shellfish poisoning. Several anthropogenic forces might be considered to be involved in the formation of HAB. Among them are increased utilization of coastal waters for aquaculture and stimulation of plankton blooms by cultural eutrophication (Smayda, 1989, 1992; Hallegraeff, 1993). HAB problem, which is very pressing in many parts of the Pacific Ocean, is also urgent for the Far Eastern seas of Russia (Orlova *et al.*, 2002).

The main objective of this paper is to summarize all informations on the Harmful Algae Blooms and red tide events as observed during 1992–2010 in the coastal waters of Far Eastern seas of Russia.

MATERIALS AND METHODS

The eastern coast of Russia is a vast zone in the north-western part of the Pacific Ocean which includes the Sea of Japan, the Sea of Okhotsk and the Bering Sea. Due to the decrease in fish catch in the open part of the Pacific Ocean, a reorientation of the fisheries complex to coastal fishing and mariculture has been developed (Fig. 1).

In Russia, the regular monitoring on HAB has been conducted by two laboratories: Laboratory of the Ecology of Shelf Communities at Institute of Marine Biology (FEB RAS) and Laboratory of Hydrobiology of the Sakhalin Scientific Research Institute of Fish Economy and Oceanography (SakhNIRO). Laboratory of the Ecology of Shelf Communities IMB FEB RAS carries out the observations on potentially toxic species since 1992. Laboratory of Hydrobiology SakhNIRO has started toxin-producing plankton observations in the coastal waters of Sakhalin Island since 2003.

Quantification of potentially toxic species is one of the basic routines in HABs monitoring. The samples were collected one to three times a month and weekly for summer, daily - during development of HABs.Bathometric samples of one litre were collected at different depths with intervals between sampling 2-5-m. Plankton net with mesh size 20 mkm was used only for qualitative analysis. Samples were fixed immediately after the collection by Acid Lugol's. Compound microscope was used for nanoplankton (2.0-20 mkm) Nojotta type Cell (0.05 mL)

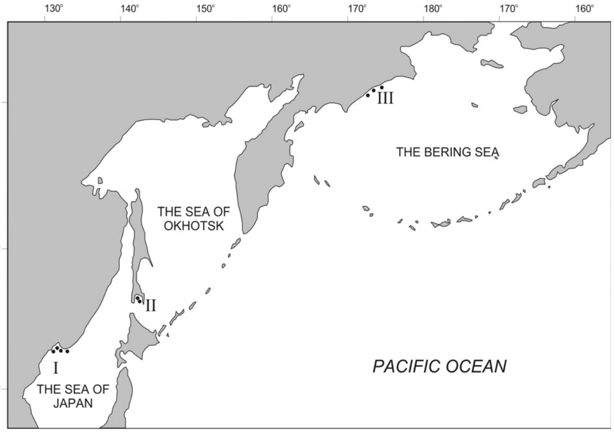

Figure 1: Map of phytoplankton sampling on the Far Eastern seas of Russia. I–Peter the Great Bay, Primorye coastal area, II–Aniva Bay, coastal waters of South Sakhalin Island, III–Bering Sea

300-400 X; for microplankton (> 20.0 mkm) – Sedgewick Rafter Cell (1 mL) 100 X. Biovolume was calculated from measurements of linear dimensions cells using appropriate geometric formulae. Standard form was used for storage of HABs monitoring data. This form include: sampling site, sampling depth, data, volume of sample, counting cell type, ID of the responsible person. The form was stored in paper file for the calculated concentrations and biomasses. After calculation, the file was stored in electronic form – in Excel.

RESULTS AND DISCUSSION

Two types of HAB are known in Russian coastal waters. The first type is "red tide", in which the water is discolored by high algal biomass. The second type is blooming of toxin-producing phytoplankton. In this paper, Red tide and Toxin producing Plankton are discussed separately.

Red tides events

In Russia, red tide refers to phenomena in which the coloring of seawater is observed due to the proliferation of plankton algae (so-called "algal blooms", up to millions of cells per litre).

A total of 25 red tide events were observed during 1992–2010 on the eastern coast of Russia. All 25 red tide events were harmless. No any cases of human poisoning or mass mortality of fish and shellfish were recorded. A total of 12 species caused red tides in Russian coastal area during 1992 to 2010. Those species belong to 4 taxonomic groups of phytoplankton: diatoms, dinoflagellates, raphidophytes and euglenophytes (Table 1).

Twelve species that caused red tide events were observed. Diatoms and dinoflagellates are the most common bloom-forming algae in Russian coastal waters. Dinoflagellates caused 10 red-tide events. *Noctiluca scintillans* causes most of the visible red tides recorded in the study area. *Prorocentrum minimum* has brought red tide events twice during the period of observations. *Oxyrrhis marina* caused water discoloration

Table 1: Effect of red tide events in Russian coastal waters in 1992–2010

Event No.	Location (name of the sea area)	Latitude,N	Longitude,E	Data/ Durationdd/ mm/yy-dd/mm/yy	Causative species	Maximum cell densitycells/L	Mitigation activity and effectiveness
1	Peter the Great Bay	43 11 7	132 16 6	15/06/1992	*Noctiluca scintillans*	450 000	no data
2	Amurskii Bay	43 15 3	131 90 2	25/06/1992	*Pseudo-nitzschia pungens/multiseries*	35 000 000	no data
3	Amurskii Bay	43 15 3	131 90 2	15/07/1992	*Prorocentrum minimum*	8 000 000	no data
4	Peter the Great Bay	43 11 7	132 16 6	05/06/1993	*Noctiluca scintillans*	500 000	no data
5	Amurskii Bay	43 15 3	131 90 2	31/07/1993	*Sceletonema costatum*	17400000	no data
6	Peter the Great Bay	43 11 7	132 16 6	25/05/1994	*Noctiluca scintillans*	550 000	no data
7	Peter the Great Bay	43 11 7	132 16 6	10/06/1995	*Noctiluca scintillans*	400 000	no data
8	Amurskii Bay	43 15 3	131 90 2	12/06/1995	*Heterosigma akashiwo*	5 000 000	no data
9	Amurskii Bay	43 15 3	131 90 2	29/07/1996	*Sceletonema costatum*	12 700 000	no data
10	Amurskii Bay	43 15 3	131 90 2	15/07/1997	*Sceletonema costatum*	3 000 000	no data
11	Amurskii Bay	43 15 3	131 90 2	03/11/1997	*Pseudo-nitzschia calliantha/pseudodelicatissima*	2 700 000	no data
12	Rynda Bay	43 2 5	131 78 7	11/09/2000	*Pseudo-nitzschia pungens*	1 690 000	no data
13	Rynda Bay	43 2 5	131 78 7	15/08/2000	*Ditylum brigthwellii*	1 400 000	no data
14	Golden Horn Bay	43 10 67	131 88 2	12/03/2001	*Eutreptia lanowii*	15 600 000	no data
15	Golden Horn Bay	43 10 67	131 88 2	10/04/2001	*Eutreptiella gymnastica*	30 900 000	no data
16	Golden Horn Bay	43 10 67	131 88 2	10/09/2001	*Chattonella globosa*	6 000 000	no data
17	Rynda Bay	43 2 5	131 78 7	15/05/2002	*Noctiluca scintillans*	700 000	no data
18	Amurskii Bay	43 15 3	131 90 2	09/07/2002 -25/07/2002	*Oxyrrhis marina*	20 000 000	no data
19	Amurskii Bay	43 15 3	131 90 2	01/08/2002 –06/08/2002	*Prorocentrum minimum*	11 940 000	no data
20	Amurskii Bay	43 15 3	131 90 2	03/09/2002	*Heterosigma akashiwo*	7 000 000	no data
21	Vostok Bay	42 88 7	132 72 9	05/05/2003	*Noctiluca scintillans*	970 000	no data
22	Amurskii Bay	43 15 3	131 90 2	11/05/2003 -17/06/2003	*Noctiluca scintillans*	800 000	no data
23	Amurskii Bay	43 15 3	131 90 2	17/06/2003	*Heterosigma akashiwo*	25 000 000	no data
24	Amurskii Bay	43 15 3	131 90 2	26/06/2008	*Sceletonema costatum*	5 526 400	no data
25	Amurskii Bay	43 15 3	131 90 2	25/06/2010	*Heterosigma akashiwo*	300000000	no data

Table 2: Results of Monitoring on toxin –producing plankton in Russian coastal waters in 1992–2010

Types of shellfish poisoning	Causative species	Location(name of the sea area)	Latitude, N	Longitude, E	Datadd/mm/yy	Maximum cell densitycells/L	Toxicity
DAP	*Pseudo-nitzschia calliantha/pseudodelicatissima*	Amurskii Bay	43 15 3	131 90 2	03/11/1997	2 700 000	no data
DAP	*Pseudo-nitzschia calliantha/pseudodelicatissima*	Ussuriiskii Bay	43 75	132 26 66	17/09/2001	610 000	no data
DAP	*Pseudo-nitzschia calliantha/pseudodelicatissima*	Aniva Bay	46 320	142 260	15/11/2001	26 000	no data
DAP	*Pseudo-nitzschia calliantha/pseudodelicatissima*	Aniva Bay	46 020	143 140	02/04/2002	1181	no data
DAP	*Pseudo-nitzschia calliantha/pseudodelicatissima*	Aniva Bay	46 020	143 140	10/08/2002	2 171	no data
DAP	*Pseudo-nitzschia calliantha/pseudodelicatissima*	Amurskii Bay	43 15 3	131 90 2	15/10/2002	510 000	no data
DAP	*Pseudo-nitzschia calliantha/pseudodelicatissima*	Aniva Bay	46 320	142 260	10/11/2002	25 920	no data
DAP	*Pseudo-nitzschia calliantha/pseudodelicatissima*	Amurskii Bay	43 15 3	131 90 2	06/08/2007	83 385	no data
DAP	*Pseudo-nitzschia calliantha/pseudodelicatissima*	Amurskii Bay	43 15 3	131 90 2	05/09/2007	173 400	no data
DAP	*Pseudo-nitzschia calliantha/pseudodelicatissima*	Amurskii Bay	43 15 3	131 90 2	30/10/2007	1 540	no data
DAP	*Pseudo-nitzschia calliantha/pseudodelicatissima*	Amurskii Bay	43 15 3	131 90 2	09/11/2007	340	no data
DAP	*Pseudo-nitzschia calliantha/pseudodelicatissima*	Amurskii Bay	43 15 3	131 90 2	28/07/2008	8 800	no data
DAP	*Pseudo-nitzschia multiseries/pungens*	Amurskii Bay	43 15 3	131 90 2	25/06/1992	35 000 000	no data
DAP	*Pseudo-nitzschia multiseries/pungens*	Amurskii Bay	43 15 3	131 90 2	18/06/1993	1 100 000	no data
DAP	*Pseudo-nitzschia multiseries/pungens*	Minonosok Bay	42 60	130 85	15/09/1997	250 000	no data
DAP	*Pseudo-nitzschia multiseries/pungens*	Rynda Bay	43 2 5	131 78 7	06/06/2000	1 750 000	no data
DAP	*Pseudo-nitzschia multiseries/pungens*	Golden Horn Bay	43 10 67	131 88 2	15/08/2000	1 500 000	no data
DAP	*Pseudo-nitzschia multiseries/pungens*	Rynda Bay	43 2 5	131 78 7	11/09/2000	1 690 000	no data
DAP	*Pseudo-nitzschia multiseries/pungens*	Aniva Bay	46 320	142 260	10/08/2002	2 044	no data
DAP	*Pseudo-nitzschia multiseries/pungens*	Amurskii Bay	43 15 3	131 90 2	12/09/2002	1 400 000	no data
DAP	*Pseudo-nitzschia multiseries/pungens*	Aniva Bay	46 320	142 260	10/11/2002	48 384	no data
DAP	*Pseudo-nitzschia multiseries/pungens*	Amurskii Bay	43 15 3	131 90 2	17/09/2007	4 800	no data
DAP	*Pseudo-nitzschia multiseries/pungens*	Amurskii Bay	43 15 3	131 90 2	07/06/2008	640	no data
DAP	*Pseudo-nitzschia multiseries/pungens*	Amurskii Bay	43 15 3	131 90 2	14/07/2008	330	no data
DAP	*Pseudo-nitzschia multiseries/pungens*	Amurskii Bay	43 15 3	131 90 2	29/08/2008	1 320	no data
DAP	*Pseudo–nitzschia multistriata*	Amurskii Bay	43 15 3	131 90 2	04/03/2008	270	no data
DAP	*Pseudo–nitzschia multistriata*	Amurskii Bay	43 15 3	131 90 2	28/07/2008	1 257	no data
PSP	*Alexandrium acatenella*	Aniva Bay	46 320	142 260	10/07/2001	5 200	no data
PSP	*Alexandrium acatenella*	Aniva Bay	46 020	143 140	10/06/2002	1376	no data
PSP	*Alexandrium acatenella*	Vostok Bay	42 83 3	132 76 66	15/07/2001	200	no data
PSP	*Alexandrium pseudogonyaulax*	Amurskii Bay	43 15 3	131 90 2	12/07/1999	3 000	no data
PSP	*Alexandrium pseudogonyaulax*	Minonosok Bay	42 60	130 85	10/09/1999	6 100	no data
PSP	*Alexandrium tamarense*	Minonosok Bay	42 60	130 85	12/08/1999	5 600	no data
PSP	*Alexandrium tamarense*	Aniva Bay	46 320	142 260	15/08/2000	40 000	no data
PSP	*Alexandrium tamarense*	Aniva Bay	46 320	142 260	12/06/2001	3 500	no data
PSP	*Alexandrium tamarense*	Aniva Bay	46 320	142 260	15/07/2001	5 200	no data
PSP	*Alexandrium tamarense*	Vostok Bay	42 83 3	132 76 66	10/08/2001	300	no data
PSP	*Alexandrium tamarense*	Aniva Bay	46 020	143 140	10/06/2002	51 360	no data
DSP	*Dinophysis acuminata*	Amurskii Bay	43 15 3	131 90 2	15/07/1992	8 000	no data
DSP	*Dinophysis acuminata*	Minonosok Bay	42 60	130 85	10/06/1997	400	no data
DSP	*Dinophysis acuminata*	Amurskii Bay	43 15 3	131 90 2	15/08/1997	1 500	no data
DSP	*Dinophysis acuminata*	Amurskii Bay	43 15 3	131 90 2	15/06/1998	500	no data
DSP	*Dinophysis acuminata*	Amurskii Bay	43 15 3	131 90 2	07/07/1998	2 000	no data
DSP	*Dinophysis acuminata*	Rynda Bay	43 2 5	131 78 7	05/08/2000	11 000	no data
DSP	*Dinophysis acuminata*	Aniva Bay	46 020	142 130	10/08/2002	183	no data
DSP	*Dinophysis acuminata*	Aniva Bay	46 020	143 140	02/04/2002	302	no data

cONT.......Table 2: Results of Monitoring on toxin –producing plankton in Russian coastal waters in 1992–2010

Types of shellfish poisoning	Causative species	Location(name of the sea area)	Latitude, N	Longitude, E	Datadd/mm/yy	Maximum cell densitycells/L	Toxicity
DSP	*Dinophysis acuminata*	Aniva Bay	46 320	142 260	15/06/2002	488	no data
DSP	*Dinophysis acuminata*	Aniva Bay	46 320	142 260	10/11/2002	432	no data
DSP	*Dinophysis acuminata*	Amurskii Bay	43 15 3	131 90 2	05/05/2008	4 480	no data
DSP	*Dinophysis acuminata*	Amurskii Bay	43 15 3	131 90 2	11/08/2008	1900	no data
DSP	*Dinophysis acuta*	Amurskii Bay	43 15 3	131 90 2	15/06/1998	234	no data
DSP	*Dinophysis acuta*	Aniva Bay	46 320	142 260	08/08/2000	200	no data
DSP	*Dinophysis acuta*	Aniva Bay	46 320	142 260	15/06/2002	488	no data
DSP	*Dinophysis acuta*	Aniva Bay	46 320	142 260	10/11/2002	247	no data
DSP	*Dinophysis fortii*	Vostok Bay	42 83 3	132 76 66	10/08/2000	3 000	no data
DSP	*Dinophysis fortii*	Aniva Bay	46 320	142 260	10/11/2002	247	no data
DSP	*Dinophysis rotundata*	Amurskii Bay	43 15 3	131 90 2	15/07/1998	30	no data
DSP	*Dinophysis rotundata*	Aniva Bay	46 210	142 330	15/06/2002	351	no data
DSP	*Dinophysis rotundata*	Aniva Bay	46 020	142 130	02/04/2002	353	no data
DSP	*Dinophysis rotundata*	Aniva Bay	46 210	143 060	10/08/2002	300	no data
DSP	*Dinophysis rotundata*	Aniva Bay	46 020	142 550	10/11/2002	355	no data

only once during 1992–2010 in this area. Diatoms during the present analysis caused 7 events. Electron microscopy revealed the presence of five species of *Pseudo-nitzschia*, which caused 3 events of water discoloration: *P. pungens, P. multiseries, P. multistriata, P. pseudodelicatissiam* and *P. calliantha*. *Skeletonema costatum* has caused 4 red-tide events. *Ditylum brightwellii* brought water discoloration event only once during 1992–2010 in this area. Raphidophytes caused 5 red-tide events: those algae were *Heterosigma akashiwo* and *Chattonella globosa*. Two cases of water discoloration were caused by euglenophytes: *Eutreptiella gymnastica* and *Eutreptia lanowii*. The maximum cell density observed in 1992–2006 was 30 900 000 cells/L of *Eutreptiella gymnastica* in April 2001 in Primorye coastal area. The usual number of maximum cell density in the red tide events in this area remains at the level of several million cells/L.

Red tides events were observed sporadically from April to September and peaks of red tides were in July, August and September. Flagellates are dominants as species that caused red tides in 1992–2010. Red tide events tend to last around one week. Only red tide events caused by *Noctiluca scintillans* and *Oxyrrhis marina* lasted more than 20 days and observed from March to September in the study area in 1992–2010. The main months of red tide events were July, August and September in the investigated area. Red tides, caused by *Noctiluca scintillans* were registered in May–June. Euglenophytes viz. *Eutreptiella gymnastica* and *Eutreptia lanowii* caused water discoloration in March–April.

Toxin Producing Plankton

Some microalgae have ability to produce potent toxins that can find their way through the food chain to humans, causing a variety of gastrointestinal and neurological diseases such as Paralytic Shellfish Poisoning (PSP), Diarrheic Shellfish poisoning (DSP) and Amnesic Shellfish Poisoning (ASP). Eleven species, which are known to be toxic, were observed in the Far East seas of Russia. Potentially toxic species belonged to 2 groups of phytoplankton viz. dinoflagellates and diatoms.

Pseudo-nitzschia a genus of Diatoms is known as domoic acid producing species (ASP) (Rao *et al.*, 1988; Bates *et al.*, 1989; Martin *et al.*, 1990). Five species viz.*Pseudo-nitzschia pungens, P. multiseries, P. multistriata, P. pseudodelicatissima* and *P. calliantha* were monitored in the study area. *Pseudo-nitzschia* species were common in Russian waters. Density of *P. multiseries/pungens* group in Primorye coastal area varied from 330 to 35000000 cells/L. Density of this species ranged from 2044 to 48384 cells/L in the coastal waters of South Sakhalin Island in 1992–2010. Highest density (35000000 cells/L) of potentially toxic *P. multiseries/pungens* group was observed in Primorye coastal area in 1992. *P. calliantha/ pseudo delicatissima* group was observed in the coastal waters of South Sakhalin Island at highest density of 26000 cells/L. Maximum concentration (2700000 cells/L) of *P. calliantha/ pseudodelicatissima* group was found in Primorye coastal area in 1997. *P. multistriata* was registered in Primorye coastal area only. Density of *P. multistriata* varied from 270 cells/L to 1257 cells/L (Table 2).

Species of Dinoflagellate belonging to genus *Alexandrium* may cause the paralytic shellfish poisoning (PSP). PSP was most harmful because of its acuteness of symptoms and high fatality cases (Prakash and Taylor, 1966; Larsen and Moestrup, 1989; Hallegraeff, 1991). Three potentially toxic species of the genus *Alexandrium* viz. *A. tamarense, A. acatenella* and *A. pseudogonyaulax* were observed in study area in 1992–2010. *A. tamarense* was the most common species in Russian coastal waters. Density of *A. tamarense* varied from 300 to 51360 cells/L in this area in 1992–2010. Maximum concentration of this species was observed in the coastal waters of South Sakhalin Island in 2002. Potentially toxic species *A. acatenella* was more abundant in the study area and concentration of this species varied from 1376 to 5200 cells/L. *A. pseudogonyaulax* was observed only in Primorye coastal area. Highest density of this species was 6100 cells/L in 1999 (Table 2). Laboratory of Hydrobiology SakhNIRO observed the seasonal changes of saxitoxin concentration in the tissues of scallop *Mizuhopecten yessoensis* caused by *Alexandrium tamarense* in Aniva Bay (South Sakhalin Isl.) from May to October 2004. Material was analyzed for saxitoxin by the immunoassay method. Saxitoxin content in scallop muscles and mantles did not exceed the permissible level (PL – 80 mkg/100g) for Russia (Mogilnikova and Konovalova, 2005).

Dinophysis is capable of producing ocadaic acid, which accumulates in the tissues of filter-feeding mollusks, causing the syndrome of diarrhetic shellfish poisoning (DSP) (Lee *et al.,* 1989; Taylor *et al.,* 1995; Marcaillou-Le Baut *et al.,* 2001). Four species, which are known as DSP producing species, were observed in Far Eastern seas of Russia in 1992–2010. These species encountered were *Dinophysis acuminata, D. acuta*, *D. fortii* and *D. rotundata*. *D. acuminata* was the most common species in the study area. Density of *D. acuminata* varied from 400 to 11000 cells/L in 1992–2010. Maximum concentration of this species was registered in the coastal waters of Primorye in 2000. Density of this species ranged from 183–488 cells/L in 1992–2010. Maximum concentration (3000 cells/L) of *D. fortii* was observed in the western part of Russian waters in 2000. Density of potentially toxic *D. acuta* in in Russian coastal waters varied from 183 to 432 cells/L. Maximum concentration of *D. rotundata* (355 cells/L) was registered in the coastal waters of South Sakhalin Island in 2002 (Table 2).

There are no data available on damage or negative consequences of HABs in Russian waters. Present level of aquaculture production in Russian Far East is not so advanced as in the other countries and practical damage from HAB events is not significant so far. Apparently, the absence of the problem with consequences of HABs explains the absence of countermeasures to terminate and mitigate red tides in Russian waters.

The national priority to cope with HABs is the prevention of HABs in Russian waters through monitoring activity and proper arrangement of aquaculture strategy. Methods to cope with HABs must be based on prevention, since consequences of HABs for marine ecosystems are, as a rule, irreversible. Now, most mitigation and control strategies are not sufficiently well tested to permit rapid implementation. For solving the problem of biological safety of the Russian marine waters, it is necessary to perform obligatory HAB monitoring to assess actual or potential anthropogenic effects on HAB events such as aquacultural activities or the introduction of novel species through discharge of ballast water to estimate the pre-existing normal (baseline) conditions and their variability and to distinguish anthropogenic changes from those attributable to natural variance.It is particularly important for biodiversity and stability of coastal marine ecosystems.

REFERENCES

Anderson, D. M., Andersen, P., Bricelj, V. M., Cullen, J. J. and Rensel, J. E. 2001. Monitoring and management strategies for harmful algal blooms in coastal waters. *IOC UNESCO, Techn. Ser.* p. 268.

Bates, S. S., Bird, C. J. and do Freitas, A. S. W. 1989. Pennate diatom *Nitzschia pungens* as primary source of domoic acid, a toxin in schellfish from eastern Prince Edward Island, Canada. *Can. J. Fish. Aquat. Sci.* **46(7):** 1203-1215.

Hallegraeff, G. M. 1991. Aquaculturists Guide to Harmful Australian Microalgae, Hobart: Fishing Industry Training Board of Tasmania; CSIRO Division of Fisheries.

Hallegraeff, G. M. 1993. A review of harmful algal blooms and their apparent global increase. *Phycologia*. **32(2):** 77–79.

Landsberg, J. H. 2002. The effects of harmful algal blooms on aquatic organisms. *Reviews in Fish. Sci.* **10:** 113–390.

Larsen, J. and Moestrup, Q. 1989. Guide to Toxic and Potentially Toxic Marine Algae. Copenhagen: Fish Inspection Service, Ministry of Fisheries.

Lee, J. S., Igarashi, T., Fraga, S., Dahl, E., Hovgaard, P. and Yasumoto, T. 1989. Determination of diarrhetic toxins in various dinoflagellate species. *J. Appl. Phycol. l.* **1:** 147"152.

Marcaillou-Le Baut, C., Gentien, P., Lunven, M., Le Grand, J., Mondeguer, F., Daniélou, M. M., Crassous, M. P. and Youénou, A. 2001. Dinophysis acuminate distribution and specific toxin content in relation to mussel contamination. Harmful Algae Blooms 2000. *IOC UNESCO.* pp. 356–359.

Martin, J., Haya, K., Burridge, L. and Wildish, D. 1990. *Nitzschia pseudodelicatissima* – a source of domoic acid in the Bay of Fundy, eastern Canada. *Mar. Ecol. Prog. Ser.* **67:** 177–182.

Mogilnikova, T. A. and Konovalova, N. V. 2005. Saxitoxin content in the Aniva Bay scallops caused by seasonal blooming of toxic phytoplankton. Abstract of 14th Annual Meeting of PICES (North Pacific Marine Science Organization). Vladivostok, September 29- October 9, WEQ Poster-2453, p. 194.

Orlova, T. Yu., Selina, M. S., Lilly, E. L., Kulis, D. M. and Anderson, D. M. 2002. Morphogenetic and toxin composition intraspecific variability of *Alexandrium tamarense* from the Russian East coast. Abstract 10th Inter. Conference on Harmful algae, Florida, USA, 21-25 October, 2002. p. 220.

Prakash, A. and Taylor, F. J. R. 1966. A "Red water" Bloom of *Gonyaulax acatenella* in the Strait of Georgia and its Relation to Paralytic Shelfish Toxicity. *J. Fish. Bd. Can.* **23:** 1256–1270.

Red tides. 2003. Ed. T. Okaichi. Tokyo: TERRAPUB. Kluwer Academic Publishers. p. 440.

Shumway, S. E. 1990. A review of the effects of algal blooms on shellfish and aquaculture. *J. World Aquacul. Soc.* **21:** 65–104.

Smayda, T. J. 1989. Primary production and the global epidemic of phytoplankton blooms in the sea: a linkage? Cosper E. M., Bricelj E. M., Carpenter E. J. (Eds). Novel Phytoplankton Blooms. Springer-Verlag, New York. pp. 449–484.

Smayda, T. J. 1992. Global epidemics of noxious phytoplankton blooms and food chain consequences in large ecosystems. Sherman K., Alexander L. M., Gold B. D. (Eds). Food Chains, Models and Management of Large Marine Ecosystems. *Westview Press. San Francisco.* pp. 275–307.

Subba Rao, D. V., Quilliam, M. A. and Pocklington, R. 1988. Domoic acid – a neurotoxic amino acid produced by the marine diatom *Nitzschia pungens* in culture. *Can. J. Fish. Aquat. Sci.* **45**(**12**)**:** 2076–2079.

Taylor, J. R., Fukuyo, Y. and Larsen, J. 1995. Taxonomy of harmful dinoflagellates. Manual on harmful marine microalgae. Paris: IOC of UNESCO. pp. 283–317.