Preface

The Special Monitoring & Coastal Environmental Assessment Regional Activity Centre (CEARAC) is one of the four Regional Activity Centres (RACs) to coordinate activities relevant to specific components of the Northwest Action Plan (NOWPAP), which was adopted in September 1994 as a part of the Regional Seas Programme of the United Nations Environment Programme (UNEP) by People's Republic of China, Japan, Republic of Korea, and Russian Federation.

CEARAC was founded in 1999 and is hosted by the Northwest Pacific Region Environmental Cooperation Center (NPEC), which was established in 1998 in Toyama, Japan, under the auspices of the Ministry of the Environment. One of the main activities of CEARAC includes monitoring and assessment of Harmful Algal Blooms (HABs) under NOWPAP Working Group 3 (WG3).

As one of the main activities of WG3, the 1st WG3 Meeting (Busan, Republic of Korea, 28-30 October 2003) approved that each of NOWPAP Members (China, Japan, Korea, or Russia) would make a national report on HABs in its own country and CEARAC would create an integrated report based on the national reports from the members. A book of National Reports on Harmful Algal Blooms (HABs) in the NOWPAP Region was published in November 2005.

The objectives of Integrate Report on HABs for the NOWPAP Region are to provide and to share information on the status of HAB in the NOWPAP Region, and to address issues to be tackled through CEARAC activities. To this end, common HAB issues in the NOWPAP Region are identified. This report was prepared by CEARAC in cooperation with experts and advisors of WG3. The 3rd NOWPAP Focal Points Meeting (Toyama, Japan, 15-16 September 2005) reviewed the draft and finally approved to publish it. The CEARAC Secretariat hopes that this report shows us broader perspectives of HAB issues in the whole NOWPAP Region.

The CEARAC Secretariat would like to thank the CEARAC Focal Points, the experts of WG3 and their colleagues for great contributions to publish this book of Integrated Report for HABs in the NOWPAP Region.

NOWPAP Working Group 3

Mr. Jianhui ZHANG
Associate Professor, Department of Ecological Monitoring, China National Environmental Monitoring Center, China

Mr. Mingjiang ZHOU
Professor, Institute of Oceanology, Chinese Academy of Sciences, China

Dr. Yasuwo FUKUYO
Professor, Asian Natural Environmental Science Center, The University of Tokyo, Japan

Dr. Osamu MATSUDA
Professor Emeritus, Hiroshima University, Japan

Dr. Sam-Geun LEE
Division Director, Fisheries Resources & Marine Environment Division, West Sea Fisheries Research Institute, NFRDI, Korea

Dr. Chang-Kyu LEE
Senior Scientist,
Marine Harmful Organisms Division,
Department of Oceanography and
Marine Environment, NFRDI, Korea

Dr. Vladimir SHULKIN
Head of Geochemical Laboratory, Pacific Geographical Institute, Russian Academy of Sciences, Russia

Dr. Tatiana ORLOVA
Senior Scientist, Institute of Marine Biology, Far Eastern Branch, Russian Academy of Sciences, Russia

Special Advisors of WG3

Dr. Hak-Gyoon KIM
Invitation Professor, Department of Oceanography, Pukyong National University, Korea

Dr. Songhui LU
Associate Professor, Institute of Hydrobiology, Jinan University, China

Secretariat

Special Monitoring & Coastal Environmental Assessment Regional Activity Centre (CEARAC)

5-5 Ushijima Shinmachi, Toyama
930-0856, Japan

Tel: +81-76-445-1571
Fax: +81-76-445-1581
URL: http://cearac.nowpap.org/

Contents

1 Introduction

The aims of this Integrated Report are to describe harmful algal blooms (HABs) problems in the Northwest Pacific Action Plan (NOWPAP) Region and to identify the necessary future activities of Special Monitoring & Coastal Environmental Assessment Regional Activity Centre (CEARAC) for tackling these problems. The information included in this report is mainly based on the National Reports submitted by the NOWPAP Members (China, Japan, Korea and Russia) in 2004. Useful supplementary data from other sources are also used in this Integrated Report.

Figure 1 shows the approximate area of the NOWPAP Region. The Integrated Report covers the part of the NOWPAP Region that is surrounded by the four countries and their related areas. The reason for the additional areas is that the sea areas outside of the boundary strongly influence the marine environment of the NOWPAP Region. On the other hand, the Pacific Ocean and the Seto Inland Sea of Japan are not included in this report because Working Group 3 (WG3) activities concentrate on problems relevant to the four countries, not to one country, of the NOWPAP Members.

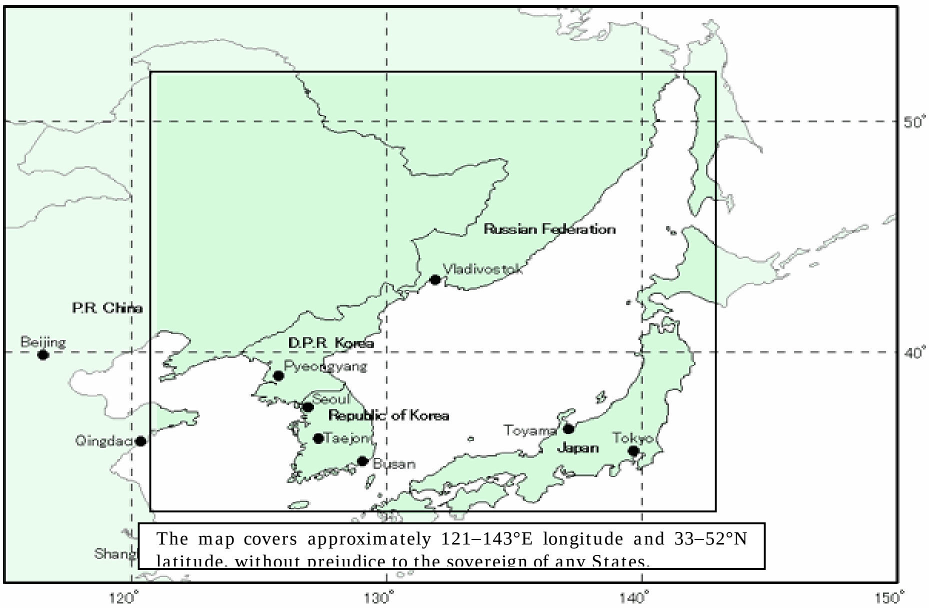

Figure 1 Area of the NOWPAP Region
(http://cearac.nowpap.org/nowpap/coverage.html)

1.1 Definitions

Since each NOWPAP Member has their own definition of a HAB, the first WG3 Meeting in Busan, Korea, in October 2003 agreed on specific definitions, as follows. The group agreed to use the scientific names of phytoplankton (referred to just as plankton after the definitions below) species as used in National Reports.

HAB: A proliferation of unicellular phytoplankton, which can cause massive fish or shellfish kills, contaminates seafood with toxins and alters aquatic ecosystems in ways that humans perceive as being harmful. There are two phenomena, the so called Red Tide and Toxin-producing Plankton.

Red Tide: Water discoloration by vastly increased unicellular phytoplankton that induces deterioration of aquatic ecosystems and occasionally fishery damage.

Toxin-producing Plankton: Phytoplankton species that produce toxins within its cell and contaminate fish and shellfish throughout the food chain.

1.2 Natural environment of the NOWPAP Region

This section provides a brief overview of the natural environment of the NOWPAP Region, focusing on the three major sea areas, major rivers and ocean currents. Figure 2 shows the geographic characteristics of the NOWPAP Region. Compared to Figure 1, Figure 2 includes some outside areas of the boundary of the NOWPAP Region in sea areas B and C. Data from these areas are included in this Report.

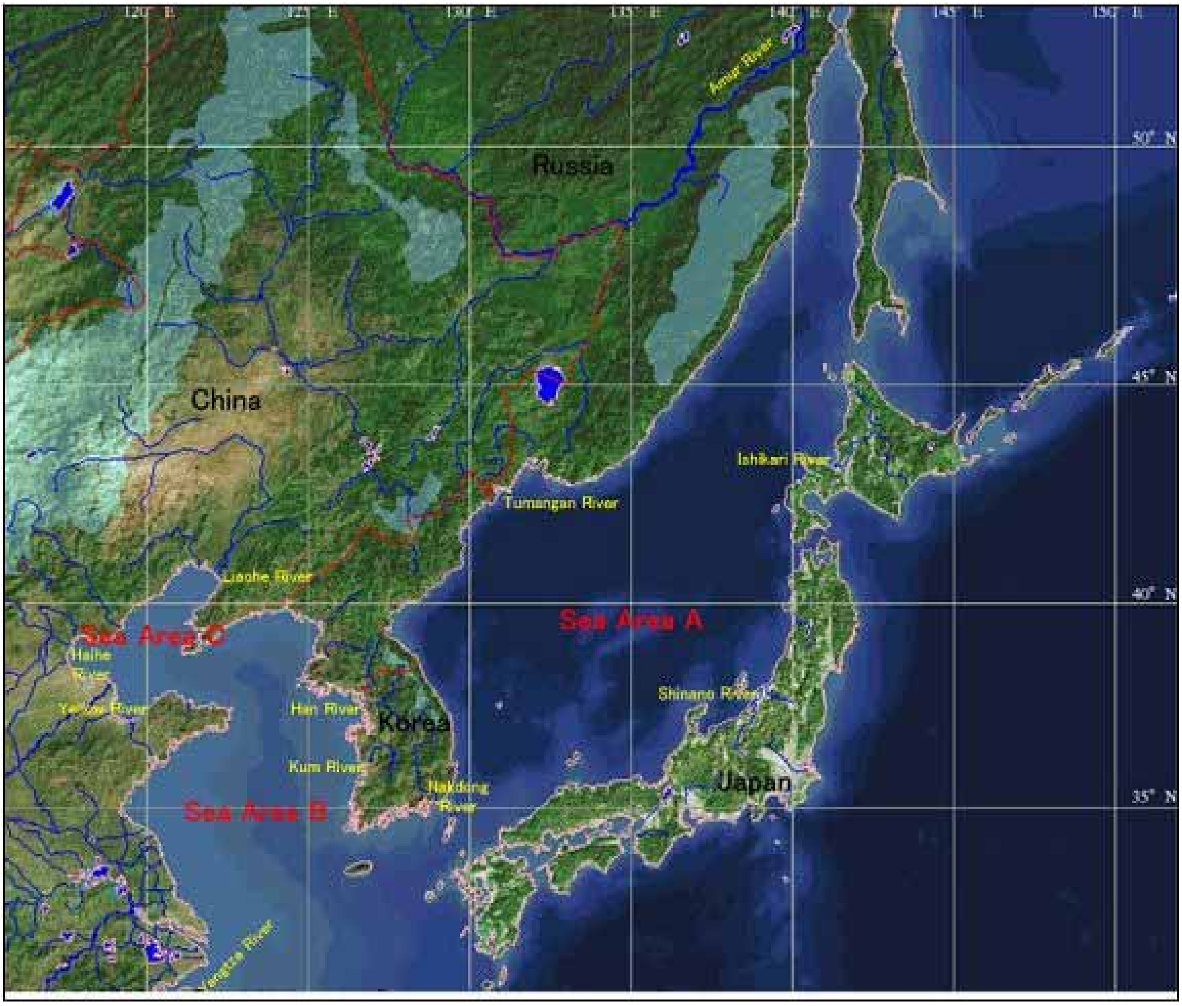

Figure 2 Geographic characteristics of the NOWPAP Region

1.2.1 Sea areas

As shown in Figure 2, sea areas A, B and C constitute the major part of the NOWPAP Region's sea area. Table 1 provides basic information on these sea areas.

Table 1 Basic Information on the three seas in the NOWPAP Region

	Sea Area A	Sea Area B	Sea Area C
Surface area (km^2)	1,300,000	400,000	7,284
Volume (km^3)	1,750,000	17,600	131
Average depth (m)	1,350	44	18
Maximum depth (m)	3,796	100	85

Source: EMECS (2003), Environmental Guidebook on the Enclosed Coastal Seas of the World.

Sea Area A is a semi-enclosed sea surrounded by Japan, the Korean Peninsula and Russia. It is connected to the open ocean through several straits. Sea Area A is the largest and deepest sea among the three sea areas.

Sea Area B is a semi-enclosed sea bounded by the Chinese mainland on the west, the Korean Peninsula on the east and the East China Sea on the south. The waters of Sea Area B are yellowish due to the large amount of yellow silt that discharges from the large Chinese rivers. The depth of Sea Area B is significantly shallower than that of Sea Area A, having an average depth of only 44 m.

Sea Area C is the smallest and most enclosed sea within the NOWPAP Region. It is located to the northwest of Sea Area B, and these two sea areas are connected via a relatively wide strait. Sea Area C is even shallower than Sea Area B, with an average depth of 18 m. Sea Area C functions as an offshore gateway to Beijing.

1.2.2 Rivers

Numerous large and small rivers flow into the three sea areas. Table 2 shows some of the major rivers that flow into the sea areas.

Table 2 Major rivers that flow into the three sea areas

Sea Area	River	Country	Catchment area (km^2)	Flow rate (m^3/s)
A	Tumen	China, Russia	33,800	287
	Nakdong	Korea	23,817	794
	Tumnin	Russia	22,400	252
	Ishikari	Japan	14,330	400
	Shinano	Japan	11,900	518
B	Yangtze	China	1,807,199	29,000
	Han	Korea	26,018	1,171
	Kum	Korea	9,810	841
C	Yellow	China	752,443	1,820
	Haihe	China	264.617	717
	Liaohe	China	164,104	302

Sources: Northwest Pacific Region Environmental Cooperation Center: NPEC (2003), The State of the Environment of the Northwest Pacific Region.
River Bureau, Ministry of Land, Infrastructure and Transport (2002), River Discharges Year Book of Japan.
Ministry of Construction and Transportation (1998), Discharge Annual Report in Korea.
Pollution Monitoring Regional Activity Centre:POMRAC (In Press), National Reports on River and Direct Inputs of Contaminants into the Marine and Coastal Environment in the NOWPAP Region.

Some rivers reach enormous length and width, due to mainly their large catchment areas, and have a significant influence on the NOWPAP Region's sea areas. Despite their relatively small surface area, sea areas B and C receive large amounts of inflow from some of the largest rivers in China, such as the Yangtze and Yellow rivers. Comparing the sea areas above, the rivers in Sea Area A are not as large as those of the other sea areas, due to their relatively small catchment areas.

1.2.3 Major oceanographic currents in the NOWPAP Region

Two strong currents exist in Sea Area A, the Tsushima Warm Current and the Liman Cold Current. The Tsushima Warm Current, a branch of the larger Kuroshio Current, enters Sea Area A from the strait between Japan and Korea and heads toward the northeast. The Liman Cold Current runs along the Eurasian Continent from north to south.

The Tsushima Warm Current diverges into three smaller branches upon entering Sea Area A. The first branch runs along the coastline of the Japanese archipelago, and the second runs along the Korean Peninsula and then turns and meanders eastward. The third cuts across the center of Sea Area A. Eventually, the major bodies of these currents flow into the Pacific Ocean or the Sea of Okhotsk through the straits between Hokkaido and Honshu, and Hokkaido and Sakhalin, respectively. According to past records, the Tsushima Warm Current enters Sea Area A and exits into the Pacific Ocean approximately 2 months later. Some of the remaining current continues to travel northward, slowly cooling during its travel. Due to the shallowness of the strait between the Sakhalin and Russian mainland, part of this current turns around and heads south along the Eurasian Continent. Finally, it becomes the Liman Current.

The Kuroshio Current also diverges into sea areas B and C as the Yellow Sea Warm Current. Figure 3 is a schematic of the oceanographic currents of the NOWPAP Region.

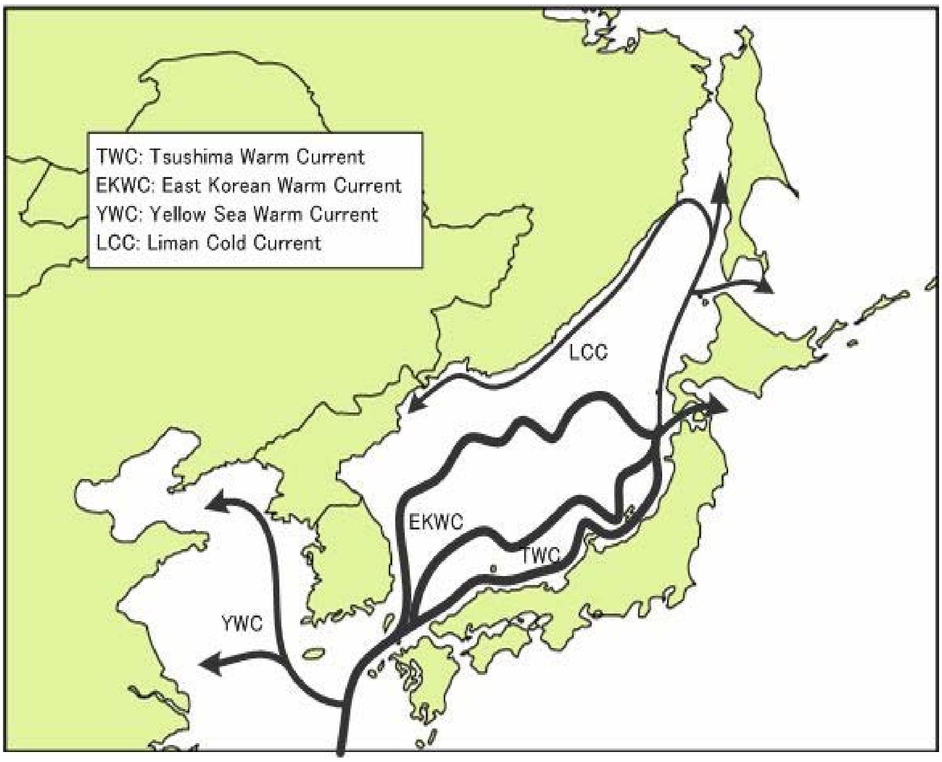

Figure 3 Major oceanographic currents in the NOWPAP Region

Source: Based on Yoon J.H. (1997), Bull. Jpn. Soc. Fish. Oceanogr., 61 (3): 300–303.

1.3 Social environment of the NOWPAP Region

1.3.1 Demography

The total population in the NOWPAP Region's catchment areas is approximately 560 million, in which approximately 85% are in the Chinese region. Approximately 34 and 47 million people inhabit the Japanese and Korean regions, respectively. Only 4.3 million people are in the Russian region. The population density is highest in Korea, followed by China and Japan. The population density in Russia is about one and a half to two orders of magnitude less than that of other NOWPAP Members. Figure 4 shows populations sizes and densities in the NOWPAP Region's catchment areas.

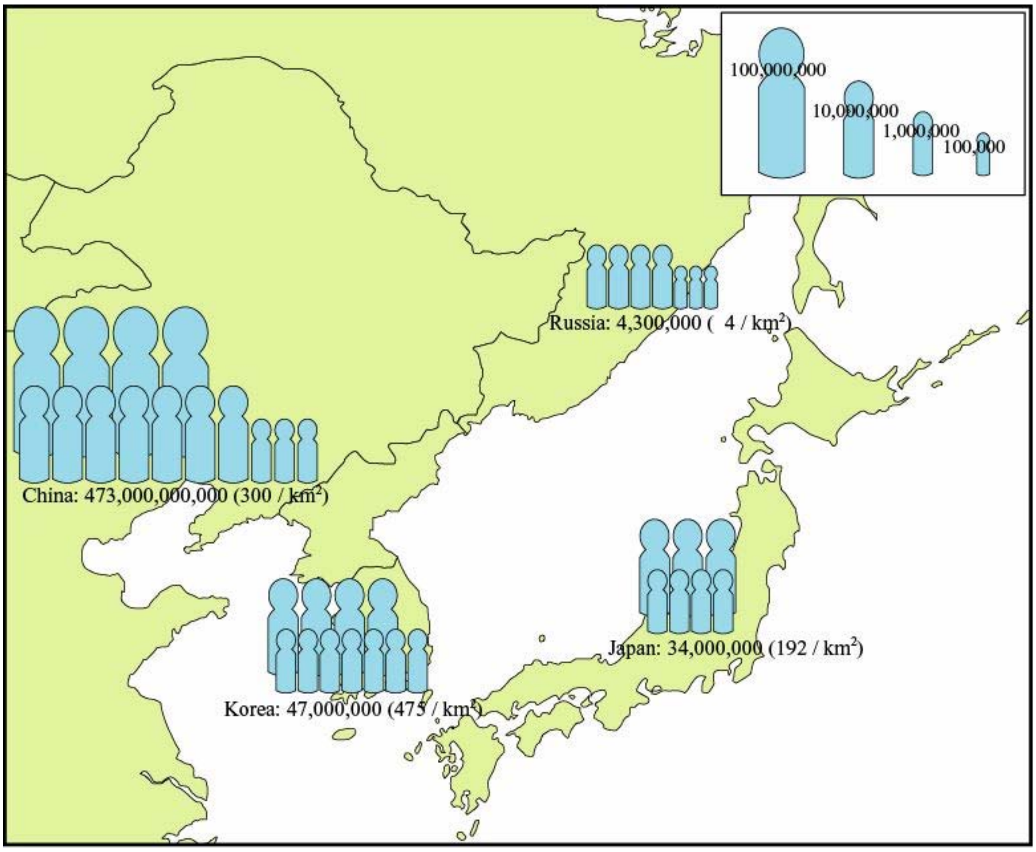

Figure 4 Population sizes and densities in the NOWPAP Region's catchment areas

Source: NPEC (2003), The State of the Environment of the Northwest Pacific Region.

1.3.2 Aquaculture

Various types of aquaculture are operated in the NOWPAP Region—cultivating fish, shellfish and seaweeds. Figure 5 shows the major aquaculture operating areas in the NOWPAP Region. Aquaculture is widely operated along the coasts of China, Japan and Korea. Aquaculture in Russia is presently operated only in limited areas, but it is expanding. Table 3 shows the types of aquaculture conducted in the NOWPAP Region.

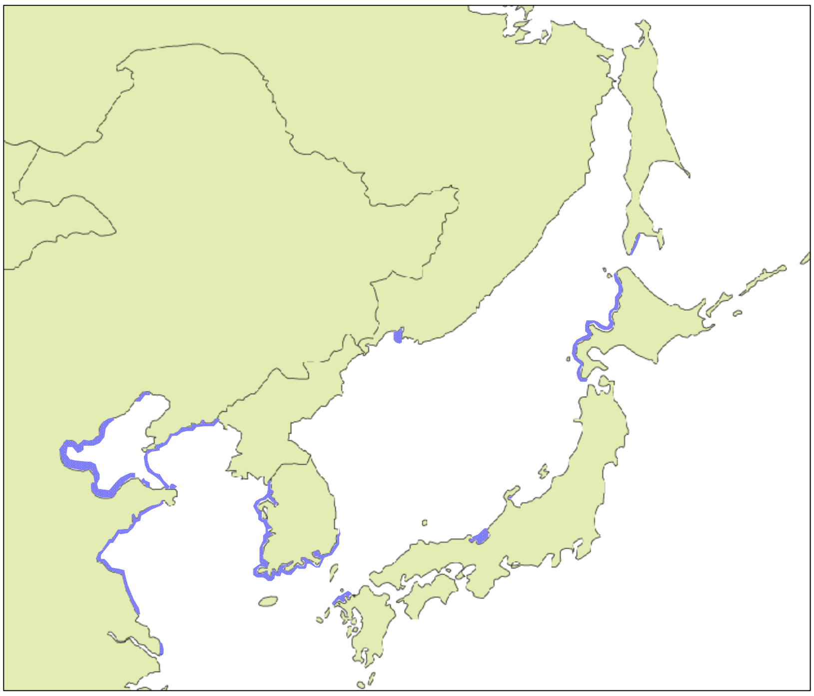

Figure 5 Major aquaculture areas in the NOWPAP Region

Sources: Yoon Y. H. (2001), Bull. Plankton Soc. Japan, 48 (2): 113–120.
Matsuoka K. (2004), Bull. Plankton Soc. Japan, 51 (1): 38–45.
Geological Institute, China Scientific Academy (1999); Chinese national atlas of natural resources.

Table 3 Types of aquaculture conducted in the NOWPAP Region

	Location	Type of aquaculture
China	Coast of Bohai Sea, Shandong Peninsula, Liaodong Peninsula	Tiger prawns, Scallop, Seaweeds, etc.
Japan	North coast of Kyushu West coast of Hokkaido	Amberjack, Red seabream Scallop
Korea	West and south coast	Bastard halibut, Amberjack, Rockfish
Russia	South coast of Sakhalin, Peter the Great Bay	Scallop, Seaweeds, Mussel, Cucumaria

2 HAB occurrence

2.1 Current HAB occurrences in the NOWPAP Region

In this chapter, the status of HABs in the NOWPAP Region is summarized. Information on red tides and toxin-producing plankton is presented separately.

2.1.1 Red tides

Table 4 summarizes the status of red-tide events in the NOWPAP Region. The approximate locations of red-tide events are shown in Figure 6 (p. 14). Despite the fact that the HAB monitoring does not cover all coastal areas in the NOWPAP Region (Section 3.1), red-tide events have been continuously recorded along the coastal areas with annual and spatial variations. Intensive fishery and aquaculture areas tend to have many records of red-tide occurrences.

To date, 75 red-tide producing plankton species have been recorded in the NOWPAP Region (Table 5). Three flagellate species (*Heterosigma akashiwo*, *Noctiluca scintillans*, *Prorocentrum minimum*) and one diatom species (*Skeletonema costatum*) have been recorded in the coastal waters of all the NOWPAP Members. All three of these flagellate species have caused extensive damage to local fisheries. Other common and damage-causing species include *Gymnodinium mikimotoi*, *G. sanguineum* and *Prorocentrum micans* (all flagellates). In recent years, *Cochlodinium polykrikoides* has caused serious damage to fisheries in Japan and Korea.

The extent of red tides within the NOWPAP Region is usually limited to less than 100 km^2 in the Japanese, Korean and Russian waters. Blooms in the Chinese waters, however, often extend over 100 km^2. More than 50% of the recorded blooms between 1990 and 2004 were larger than 100 km^2, and approximately 25% of them were larger than 1,000 km^2 (Table 4). One of the reasons for the difference in records between China and the other NOWPAP members could be due to their different data sources. In China, bloom size was mostly identified through aerial survey, whereas the other NOWPAP members collected data mainly from sea vessels.

Red tides are most frequent from spring to summer in the NOWPAP Region. Figure 7 shows the monthly patterns of red-tide events in the NOWPAP Region. The peak season in China is from June to August. The peak in Japan is in April, June and July. In Korea, there is a prominent peak in August. In Russia, the peak appears in June and July. The dominant red-tide species during the peak months are as follows. All of these plankton species are known to cause damage to fisheries.

China: *Noctiluca scintillans* (June and July)
Japan: *Noctiluca scintillans* (April), *Heterosigma akashiwo* (June)
Gymnodinium mikimotoi (July)
Korea: *Cochlodinium polykrikoides* (August)
Russia: *Noctiluca scintillans* and *Heterosigma akashiwo* (June)

Most red-tide events in the NOWPAP Region last for about 1 week. In rare cases, however, red tides have lasted for 1- 2 months (e.g. a *C. polykrikoides* bloom lasted for 62 days in Korea in 2003).

Several mitigation measures have been developed or are under development to counteract red-tide blooms. Clay spraying is one of the common methods employed in the NOWPAP Region.

Table 4 (1) Summary of recorded red-tide events in the NOWPAP Region

	China (Bohai and Yellow Sea)	Japan (Data from Kyushu region unless stated (1998–2002))	Korea (1999–2003 unless stated)	Russia (1992–2003 unless stated)[*1]
Number of events	84 red-tide events from 1990–2004.	150 red-tide events recorded, 19 were harmful.	304 red-tide events recorded.	23 red-tide events recorded. All events were harmless and caused no damage.
Causative species	See Table 5	See Table 5 (includes Honshu region)	See Table 5	See Table 5
Cell density	Maximum cell density recorded for the following major red-tide species: *Noctiluca scintillans* (49,000 cells/ml) *Skeletonema costatum* (72,000 cells/ml) *Ceratium furca* (1,250 cells/ml) *Gymnodinium* sp. (300,000 cells/ml)	*Gymnodinium mikimotoi* recorded the highest density at 117,980 cells/ml.	Each year *Cochlodinium polykrikoides* recorded the highest cell density. Maximum cell density was recorded in 2003 at 48,000 cells/ml.	*Eutreptiella gymnastica* recorded the highest density at 30,900 cells/ml.
Location of occurrence	Mainly along the coast of Sea Area C (Figure 6)	Mainly along the coast of northern Kyushu (Figure 6; includes Honshu region)	Along the entire coast except the northeast (Figure 6)	Some areas in Peter the Great Bay (Figure 6)
Size of bloom	Data from 1990–2004 <10 km^2: 18% 10–100 km^2: 29% 100–1,000 km^2: 30% $>1,000$ km^2: 23% Affected area generally larger in Sea Area C than Sea Area B.[*2]	<1 km^2: 51% 1–100 km^2: 48% >100 km^2: 1%	<1 km^2: 56% 1–100 km^2: 19% >100 km^2: 24% Large blooms were mostly by *C. polykrikoides*.	*Noctiluca scintillans* and *Prorocentrum minimum* blooms exceeded 1 km^2.
Duration	Most red tides lasted less than 1 week. However, a *Ceratium furca* bloom lasted for 40 days in 1998. *Eucampia zodiacus* and *Chaetoceros socialie* blooms lasted for 20 days.	Although there were variations, red-tide events tended to last around 1 week. 18 out of 150 events lasted more than 20 days.	Most red tide lasted less than 10 days, except for *C. polykrikoides*, which continued for 1–2 months.	*N. scintillans* and *Oxyrrhis marina* blooms lasted more than 20 days.

*1: There are no regular red-tide monitoring programs in Russia. The presented data are derived from ad hoc monitoring or research conducted by the IMB FEB RAS, 1992–2002

*2: Observation was mainly conducted through aerial survey.

Table 4 (2) Summary of recorded red-tide events in the NOWPAP Region

	China (Bohai and Yellow Sea)	Japan (Data from Kyushu region unless stated (1998–2002))	Korea (1999–2003 unless stated)	Russia (1992–2003 unless stated)[*1]
Seasonal pattern	Most frequent in July and August (1990–2004). See Figure 7 for details.	High frequency of red tides between April and September. Most frequent in June and July. See Figure 7 for details.	Red tides recorded from January to November. Most frequent in August. See Figure 7 for details.	Mostly observed between March and September. Most frequent in June and July. See Figure 7 for details.
Damage	Mass mortality of fish and shellfish by *Ceratium furca*, *Exuviaella cordata*, *Gymnodinium* sp., *G. sanguineum*, *N. scintillans* and *Prorocentrum* sp. Most serious damage recorded in 1989 by *Gymnodinium* sp. in Bohai Bay (economic loss of US$ 38 million).	Mass mortality of fish and shellfish by *Heterosigma akashiwo*, *Heterocapsa circularisquama*, *G. mikimotoi*, *C. polykrikoides* and *N. scintillans*. Most serious damage recorded in 1999 by *C. polykrikoides* (economic loss of US$ 7 million)	*C. polykrikoides* has caused damage to fisheries for most years since 1993. Economic loss of US$ 95 million in 1995 and US$ 19 million in 2003.	No damage recorded.
Mitigation measures	Regular monitoring (Chapter 3) Preventive measures: Effluent control (implementation of Blue Sea Action Plan); improvement of sewage system, public education Reactive measure: Aeration of seawater and fish-pen sinking in fish farms; clay spraying	Regular monitoring (Chapter 3) Preventive measures: Effluent control, improvement of sewage system, public education Reactive measures: Clay spraying	Regular monitoring (Chapter 3) Deployment of Automatic HAB Alarm System in aquaculture farms. Reactive measures: Clay spraying; Electrolytic Clay Dispenser (ECD)	No mitigation measures employed.

Table 5(1) Red-tide species recorded in the NOWPAP Region

Class	Genus and Species	China	Japan	Korea	Russia
Bacillariophyceae	*Asterionella* sp.		✔		
	Chaetoceros curvisetum		✔		
	Chaetoceros socialie	✔			
	Chaetoceros sp.		✔	✔	
	Coscinodiscus asteromphalus	✔			
	Coscinodiscus gigas			✔	
	Coscinodiscus sp.			✔	
	Ditylum brightwellii				✔
	Eucampia zodiacus	✔		✔	
	Eucampia sp.			✔	
	Leptocylindrus danicus	✔	✔	✔	
	Leptocylindrus sp.		✔		
	Navicula sp.	✔			
	Neodelphineis pelagica		✔		
	Nitzschia sp.		✔	✔	
	Pseudo-nitzschia calliantha				✔
	Pseudo-nitzschia multiseries				✔
	Pseudo-nitzschia pseudodelicatissima				✔
	Pseudo-nitzschia pungens[*1]			✔	✔
	Pseudo-nitzschia sp.		✔		
	Rhizosolenia delicatula		✔		
	Rhizosolenia fragilissima			✔	
	Rhizosolenia setigera			✔	
	Rhizosolenia sp.	✔	✔	✔	
	Skeletonema costatum	✔	✔	✔	✔
	Skeletonema sp.			✔	
	Thalassiosira decipiens			✔	
	Thalassiosira rotula			✔	
	Thalassiosira sp.		✔	✔	
Cyanophyceae	*Microcystis virdis*			✔	
Dinophyceae	*Alexandrium catenella*	✔	✔		
	Alexandrium fraterculus		✔		
	Alexandrium sp.			✔	
	Ceratium furca	✔	✔		
	Ceratium fusus			✔	
	Ceratium sp.			✔	
	Cochlodinium polykrikoides		✔	✔	
	Cochlodinium sp.		✔		
	Exuviaella cordata	✔			
	Exuviaella marina	✔			
	Dinophysis ovata	✔			

Table 5(2) Red-tide species recorded in the NOWPAP Region

Class	Genus and Species	China	Japan	Korea	Russia
Dinophyceae	*Gonyaulax spinifera*	✔			
	Gymnodinium mikimotoi	✔	✔	✔	
	Gymnodinium sanguineum	✔	✔	✔	
	Gymnodinium sp.			✔	
	Gyrodinium sp.	✔	✔		
	Heterocapsa circularisquama		✔		
	Heterocapsa sp.			✔	
	Heterocapsa triquetra			✔	
	Noctiluca scintillans[*2]	✔	✔	✔	✔
	Oxyrrhis marina				✔
	Prorocentrum balticum		✔		
	Prorocentrum dentatum		✔	✔	
	Prorocentrum micans	✔	✔	✔	
	Prorocentrum minimum	✔	✔	✔	✔
	Prorocentrum sigmoides		✔		
	Prorocentrum triestinum		✔	✔	
	Prorocentrum sp.			✔	
Raphidophyceae	*Chattonella antiqua*	✔	✔		
	Chattonella globosa				✔
	Chattonella marina	✔	✔		
	Fibrocapsa japonica		✔		
	Heterosigma akashiwo[*3]	✔	✔	✔	✔
Chrysophyceae	*Dictyocha fibula*			✔	
Eugrenophyceae	*Eutreptia lanowii*				✔
	Eutreptiella gymnastica		✔	✔	✔
	Eutreptiella sp.			✔	
Haptophyceae	*Phaeocystis* sp.	✔			
Cryptophyceae	*Chroomonas marina*			✔	
	Chroomonas salina			✔	
	Cryptomonas acuta			✔	
	Cryptomonas sp.			✔	
Prasinophyceae	*Pyramimonas* sp.		✔		
Ciliate	*Mesodinium rubrum*	✔	✔	✔	
	Tontonia sp.		✔		

*1: *Nitzschia pungens* is the synonym of *Pseudo-nitzschia pungens*. In this Report, *N. pungens* is referred to as *P. pungens.*

*2: *Noctiluca scintillans* is the sole species of the genus. Therefore, *Noctiluca* sp. is included into *N. scintillans*.

*3: *Heterosigma akashiwo* is the sole species of the genus. Therefore, *Heterosigma* sp. is included into *H. akashiwo*.

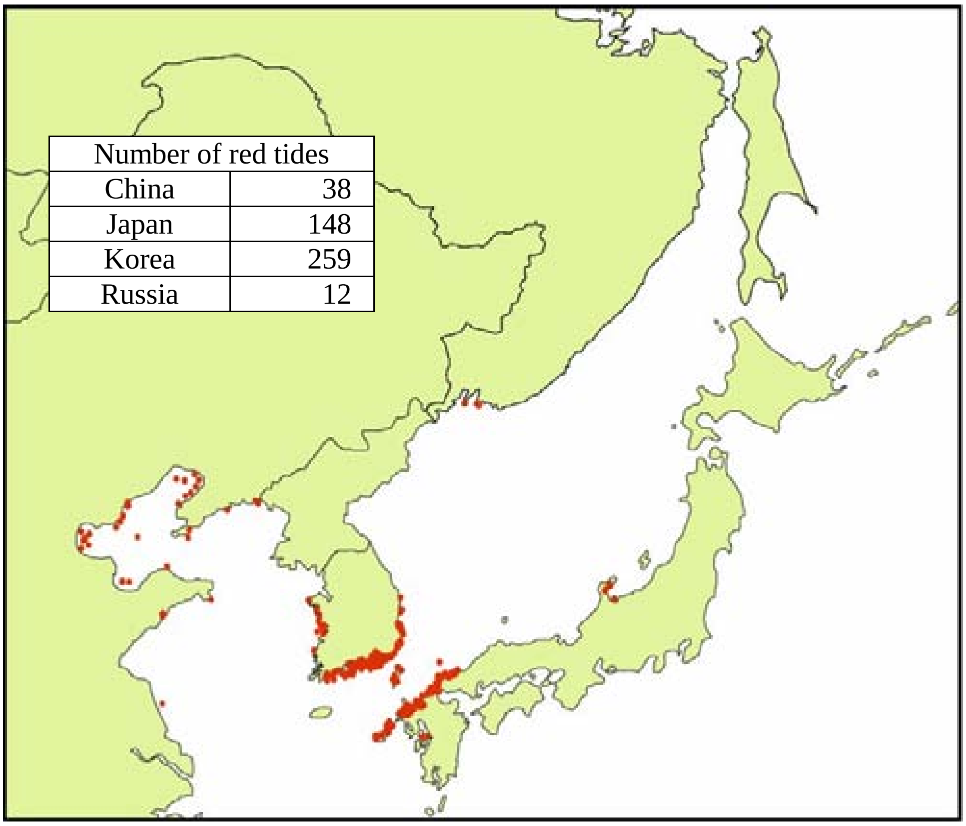

Figure 6 Locations of red tides in the NOWPAP Region in 1999–2002

Note: The number of red-tide events is reflected only over sea areas A, B and C in the NOWPAP Region.

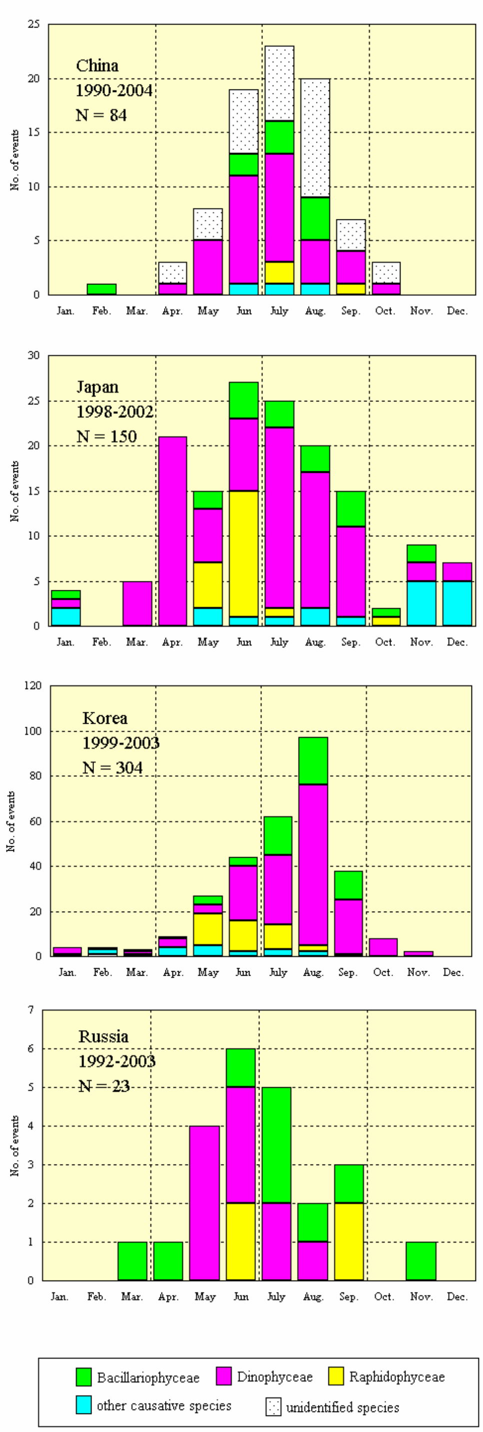

Figure 7 Seasonal patterns of red-tide occurrences in the NOWPAP Region

Note 1: Surveyed periods and sample numbers differ among the NOWPAP Members
Note 2: This graph is based on the red-tide events reported in the National Reports (Appendix ii)

2.1.2 Toxin-producing plankton and shellfish poisoning

Table 6 shows the status of toxin-producing plankton and shellfish poisoning in the NOWPAP Region. In this Report, toxin-producing species are separated into paralytic shellfish poisoning (PSP-), diarrhetic shellfish poisoning (DSP-) and amnesic shellfish poisoning (ASP-) inducing species rather than by their taxonomic classification.

A total of 20 toxin-producing plankton species have been recorded in the NOWPAP Region (Table 7). Six species were PSP-inducing species. All PSP species except *Gymnodinium catenatum* belong to the genus *Alexandrium*. The most commonly recorded PSP species in the NOWPAP Region was *A. tamarense*.
Nine of the ten DSP species recorded in the NOWPAP Region belong to the genus *Dinophysis*. The other was *Exuviaella marina,* which was recorded only in China. Among the *Dinophysis* species, *D. fortii* and *D. acuminate* were recorded in all of the NOWPAP Member seas.
Damage from ASP has not yet been recorded in the NOWPAP Region, although ASP-inducing *Pseudo-nitzschia* species were recorded in Russia and Korea.

PSP has been recorded in the Shangdong Peninsula and Lianyungang Area in China (Figure 8). Areas affected by PSP in Japan are concentrated in the western Japan (Kyushu and Chugoku) and Tohoku (Aomori Prefecture) regions, as shown in Figure 9. In Korea, PSP has recently affected shellfish harvesting areas on the southeastern coast. Russia has not been affected by PSP as yet.
DSP species have been recorded in the Shangdong Peninsula, Lianyungang Area and Sea Area C in China. In 1998, *Dinophysis ovata* blooms were recorded over an area of 5,000 km^2 in Sea Area C. Areas affected by DSP in Japan are mainly in the Hokkaido, Tohoku and Chugoku regions. In Korea, three *Dinophysis* species were recorded on the southeastern coast in 2002 and 2003, but it is uncertain whether or not there was any damage by the species. Russia has not been affected by DSP as yet.
In Russia, observations of PSP-, DSP- or ASP-inducing species are conducted mainly in the aquaculture areas. Figures 10–12 show the data arising from these observations. Although incidents of shellfish poisoning have not been reported in these aquaculture areas as yet, the presence of toxin-producing plankton has been recorded continuously.

In China, more than 600 people have suffered from shellfish poisoning since 1967, in which 30 fatalities have resulted from PSP. In Japan, approximately 900 people have suffered from PSP or DSP since 1976, including several deaths from PSP. In Korea, shellfish harvesting was banned on the southeastern coast in 2002 (April–May) and 2003 (April–June) due to *A. tamarense*.

China, Japan and Korea have implemented policies to prevent and reduce harm to people by toxic shellfish. These countries monitor the toxicity level of shellfish at harvest areas. When the toxicity level exceeds the quarantine limit set by the country, the authorities advise fishery markets to stop shipping or ban the harvest of shellfish until levels fall below the acceptable level.

Table 6 Status of toxin-producing plankton and shellfish poisoning in the NOWPAP Region

	China	Japan	Korea	Russia
Main toxin-producing species	*Alexandrium catenella*, *Dinophysis forti*, *D. acuminata*, *D. ovata* and *Exuviaella marina* (Table 7)	*Alexandrium tamarense*, *A. catenella*, *A. tamiyavanichii*, *Gymnodinium catenatum, Dinophysis forti*, *D. acuminata*, *D. caudate, D. intundibrus, D. mitra* and *D.rotundata* (Table 7)	*Alexandrium tamarense, Dinophysis forti*, *D. acuminata*, *D. caudate, D. rotundata* and *Pseudo-nitzschia pungens* (Table 7)	*Alexandrium tamarense*, *A. acatenella*, *A. pseudogonyaulax*, *Dinophysis forti*, *D. acuminata*, *D. acuta, D. norvegica, D. rotundata, Pseudo-nitzschia calliantha, P. multiseries, P. pseudodelicatissima* and *P. pungens* (Table 7)
Affected species	Information is available only for the southern region of China (outside the NOWPAP Region). PSP: Marine snail (*Nussarius succinstus*); Clam (*Soletellina diphos*; *Ruditapes phillipenensis*; *Pinna pectinata*); Mussel (*Perna viridis*)	PSP: Mediterranean blue mussel; Japanese oyster; noble scallop DSP: Mediterranean blue mussel; Japanese scallop	Information N/A	No shellfish poisoning reported.
Affected area	Shangdong Peninsula, Lianyungang Area and Sea Area C (Figure 8)	Mainly in Hokkaido, Tohoku and Chugoku regions (Figure 9)	Southeast coast (Gosung, Tongyoung, Jinhaeman)	No shellfish poisoning reported. Cell density of potential causative species recorded in certain areas (Figs.10–12)
Damage	More than 600 people have suffered from shellfish poisoning since 1967. 30 fatalities from PSP across the nation.	Approximately 900 people have suffered from PSP or DSP since 1976, including several deaths from PSP. No fatalities since 1980.	Stoppage of shellfish harvest in 2002 and 2003 in the southeast coast due to PSP.	No damage recorded.
Mitigation measures	Some State Oceanic Administration (SOA) laboratories and local fishery environmental laboratories conduct monitoring of toxin-producing plankton and shellfish poisoning.	Regular monitoring of main toxin-producing species and toxicity test of harvested shellfish. Shipping is voluntarily stopped if toxicity exceeds the Fishery Agency standard. (Voluntary Control) PSP: 20 cases of voluntary control from 1978 to 1999. Most cases lasted 2–4 months. DSP: 64 cases of voluntary control from 1978 to 1999. Duration of DSP was generally longer than for PSP. Some cases lasted over 5 months.	Regular monitoring of *Alexandrium* sp. and toxicity test of harvested shellfish. Harvest is stopped when the toxin level exceeds the quarantine limit.	No mitigation measures or monitoring.

Table 7 Toxin-producing plankton species recorded in the NOWPAP Region

	Species name	China	Japan	Korea	Russia
PSP	*Alexandrium acatenella*				✔
	Alexandrium tamarense		✔	✔	✔
	Alexandrium catenella	✔	✔		
	Alexandrium pseudogonyaulax				✔
	Alexandrium tamiyavanichii		✔		
	Gymnodinium catenatum		✔		
DSP	*Dinophysis fortii*	✔	✔	✔	✔
	Dinophysis acuminata	✔	✔	✔	✔
	Dinophysis acuta				✔
	Dinophysis caudata		✔		
	Dinophysis infundibrus		✔		
	Dinophysis mitra		✔		
	Dinophysis norvegica				✔
	Dinophysis ovata	✔			
	Dinophysis rotundata		✔	✔	✔
	Exuviaella marina	✔			
ASP*1	*Pseudo-nitzschia calliantha*				✔
	Pseudo-nitzschia multiseries				✔
	Pseudo-nitzschia pseudodelicatissima				✔
	Pseudo-nitzschia pungens			✔	✔

*1: Damage from ASP has not yet been recorded in the NOWPAP Region, although ASP inducing *Pseudo-nitzschia* species were recorded in Russia and Korea according to the National Report. ASP-inducing species probably also exist in China and Japan, but they have not being recorded due to different monitoring methods. ASP in the NOWPAP Region should be investigated in the future.

Figure 8 Areas where shellfish toxicity has been recorded in coastal China

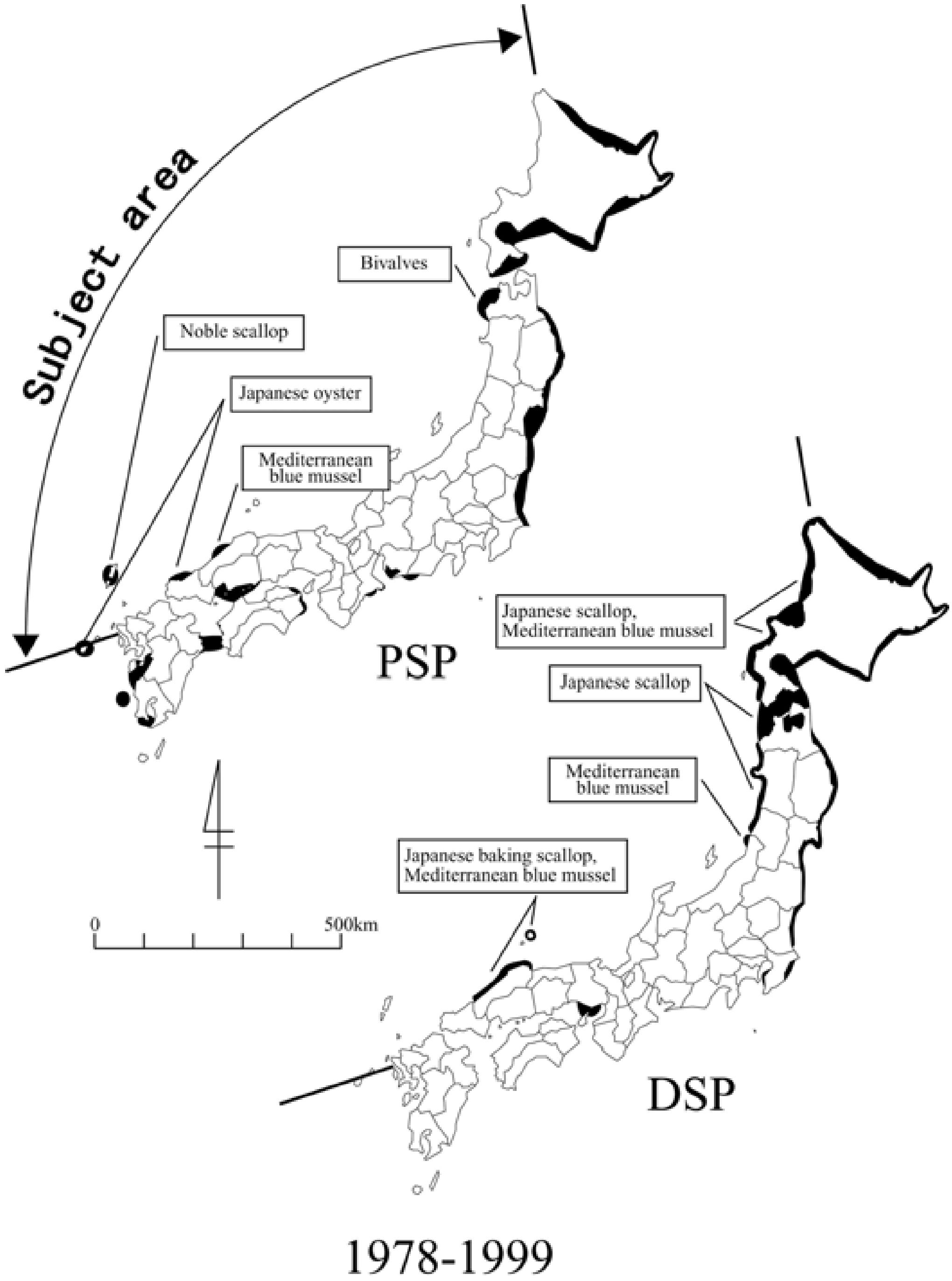

Figure 9 Areas that experienced voluntary control due to PSP and DSP contamination in Japan (1978–1999)

Source: Japan Fisheries Resource Conservation Association (JFRCA), 'Monitoring Report on Shellfish Poison in Japanese Fishery Products', 1999–2000.

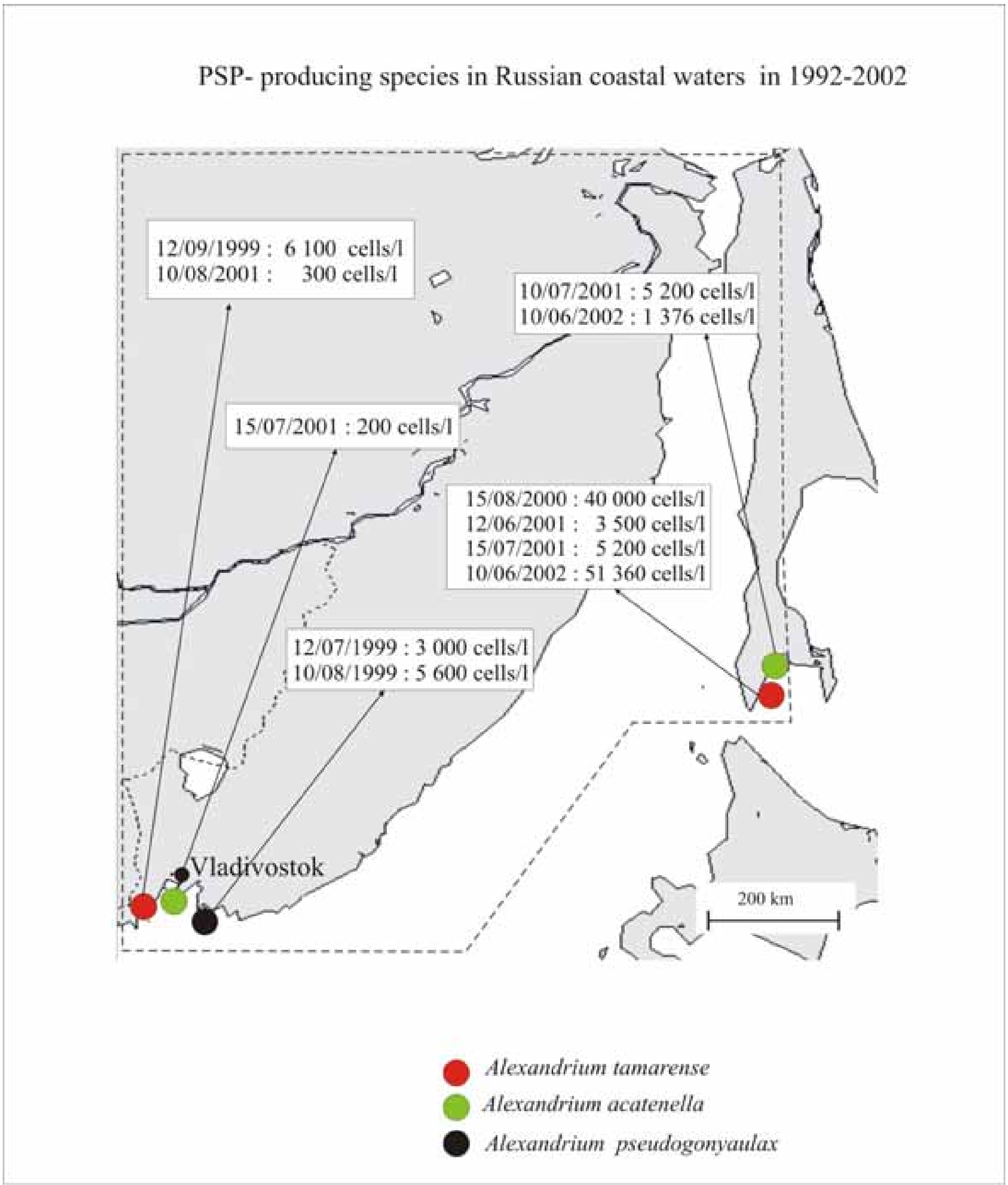

Figure 10 Dates of occurrences and maximum cell densities of *Alexandrium* species in Russian coastal waters in 1992–2002

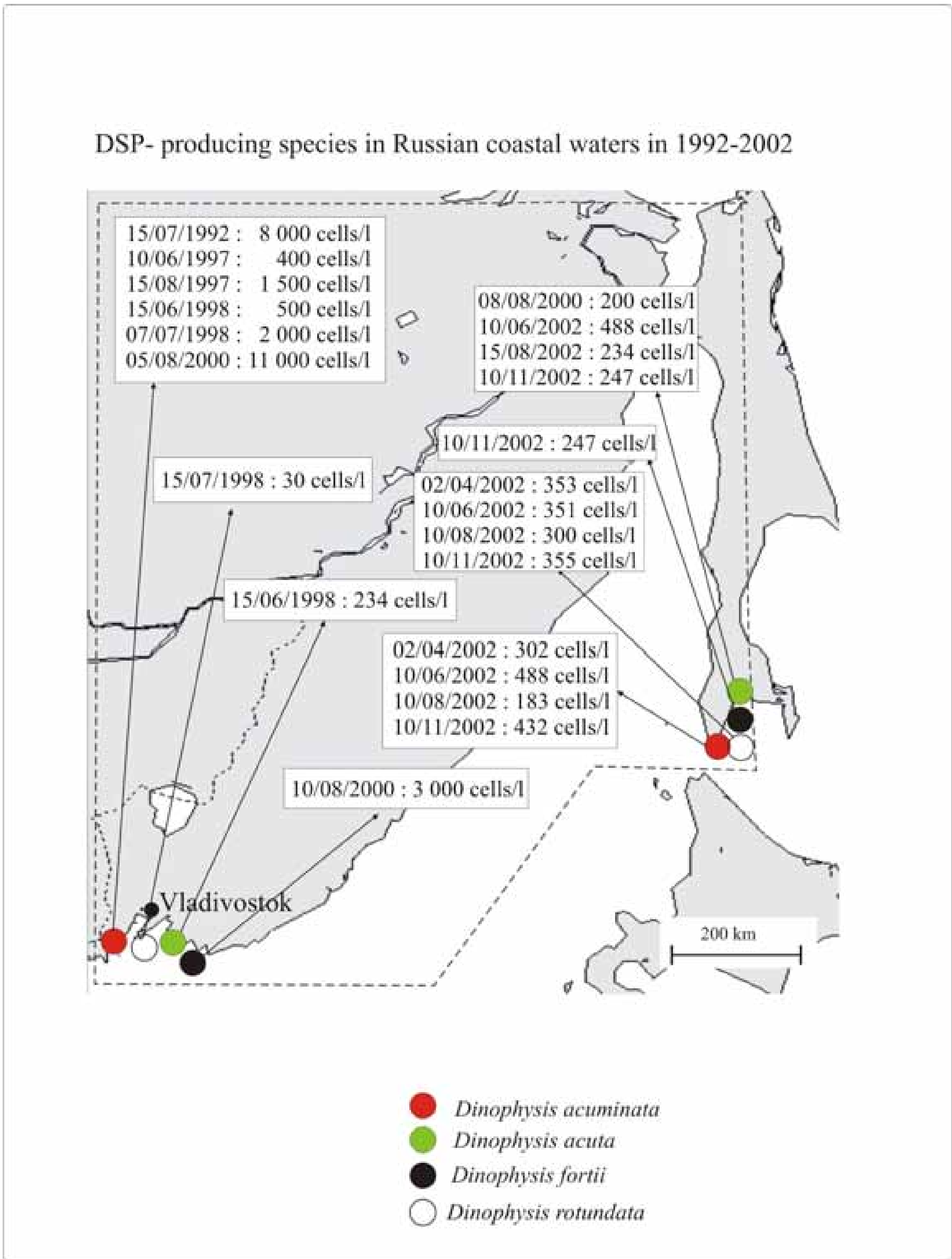

Figure 11 Dates of occurrences and maximum cell densities of *Dinophysis* species in Russian coastal waters in 1992–2002

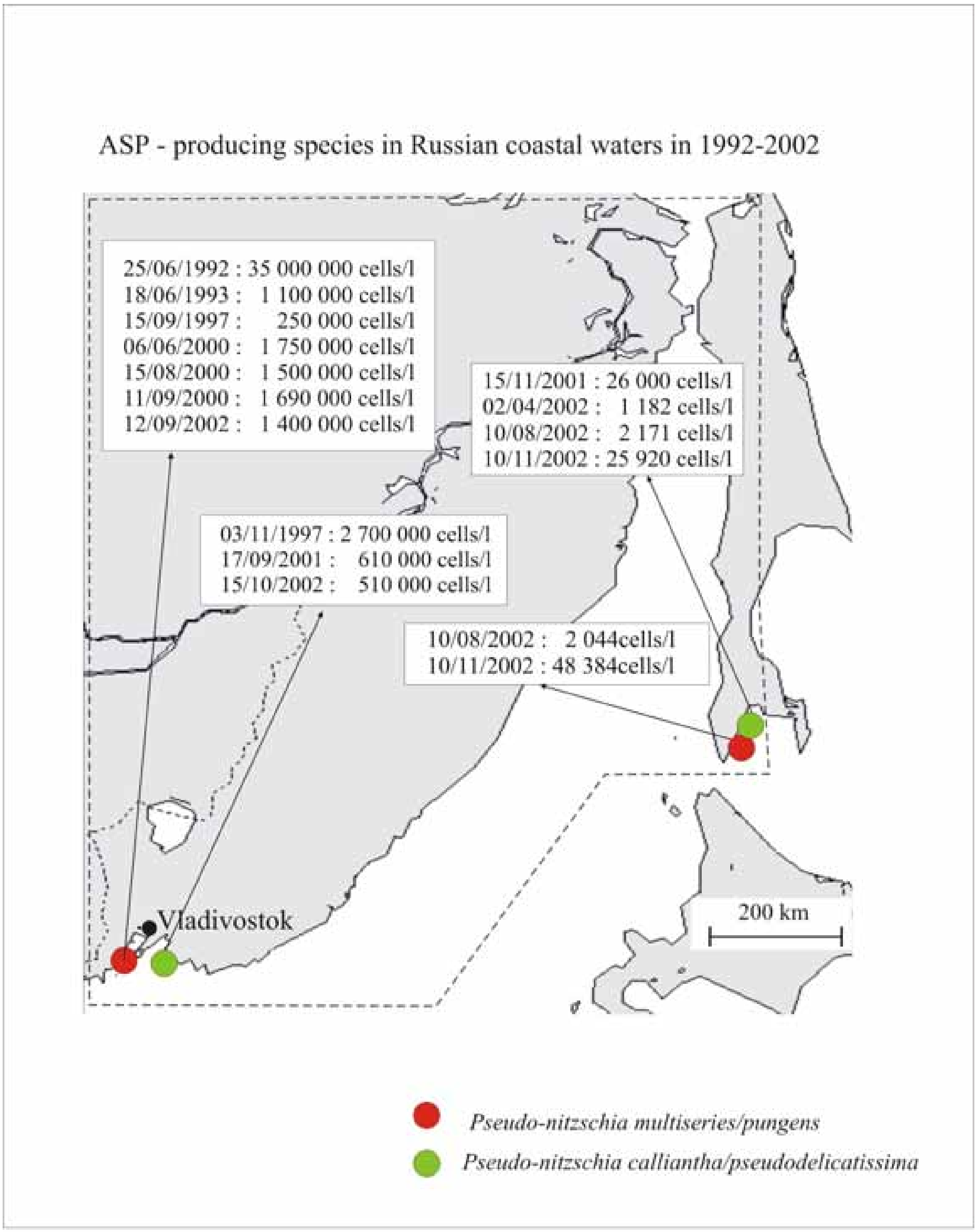

Figure 12 Dates of occurrences and maximum cell densities of *Pseudo-nitzschia* species in Russian coastal waters in 1992–2002

2.2 Common issues on HABs in the NOWPAP Region

2.2.1 Severe fishery damage caused by *Cochlodinium polykrikoides*

Red tides have frequently resulted in large mortality of fishery resources and huge economic losses to fisheries in the NOWPAP Region. They often occur in semi-enclosed areas, such as inlets and embayments, where aquaculture is often operated. Although various species are known to cause red tides, *C. polykrikoides* has caused the most serious damage to the fisheries in Japan and Korea in recent years. For example, in 1999 approximately US$ 7 million worth of fishery damage was recorded in Imari Bay, Kyushu, Japan. Even greater economic losses were recorded in Korea in 1995 and 2003, worth approximately US$ 95 million and US$ 19 million, respectively. The locations of *C. polykrikoides* blooms in the Japanese and Korean regions are plotted in Figure 13, the data of which are derived from National Reports and recent research papers.

To prevent or reduce future damage from *C. polykrikoides*, various studies have been conducted to understand the ecology of this species. Several studies have focused on the transportation mechanisms of *C. polykrikoides*. Miyahara et al. (2005) traced the movement of *C. polykrikoides* blooms that occurred along the Sea Area A coast of the Chugoku region in 2003, by referring to the satellite images of chlorophyll-a concentration (field measurements verified that the high chlorophyll-a concentration in the satellite images was predominantly due to *C. polykrikoides*). Figure 14 shows how the *C. polykrikoides* blooms moved along the coast of the Chugoku region. Miyahara et al. concluded that this particular bloom was most likely transported to the coast of the Chugoku region through the Tsushima Warm Current.

Kim et al. (2004) studied the impact of water temperature, salinity and irradiance on the growth rate of *C. polykrikoides*. The highest growth rate was recorded when the water temperature was 25 ℃, salinity was 34 ppt and irradiance was >90 $\mu mol/m^2/s$. Such physical parameters might explain the appropriate conditions for the *C. polykrikoides* blooms recorded in the Japanese (Kyushu) and Korean regions. All *C. polykrikoides* blooms occurred between August and October in these areas when the water temperature was close to 25 ℃. However, the optimum growth conditions of *C. polykrikoides* require further investigation through the collection of field data.

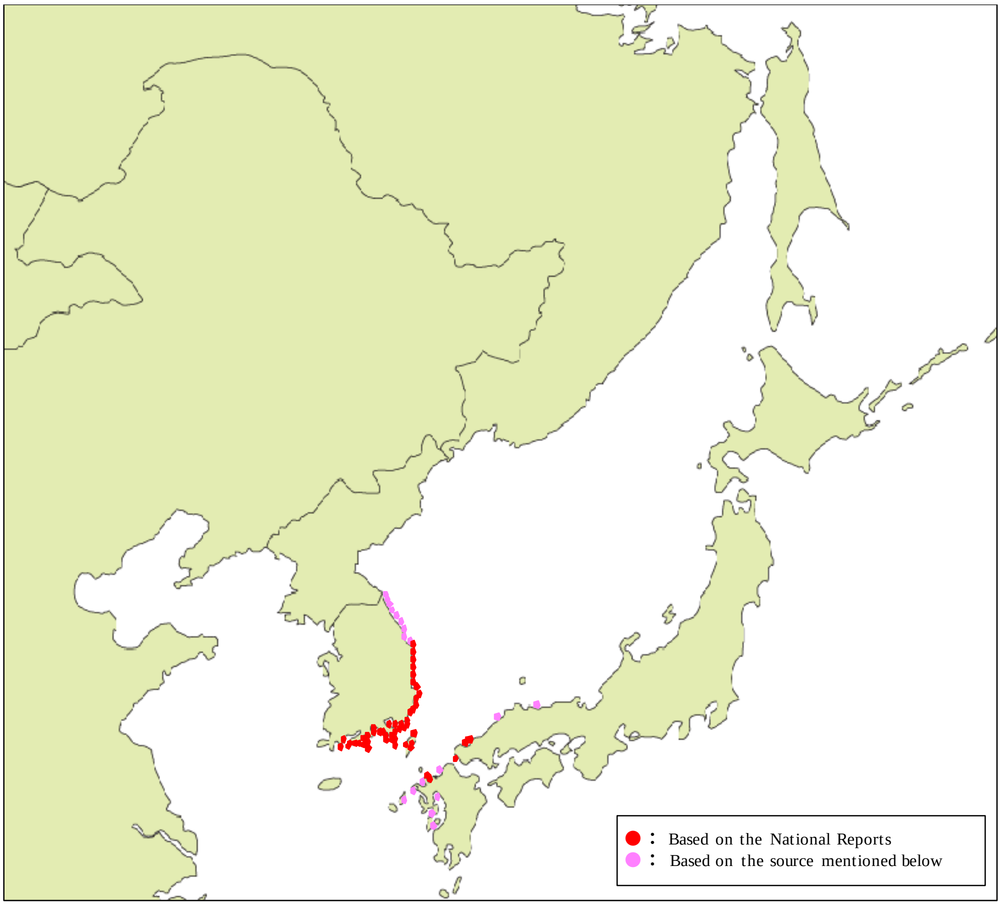

Figure 13 Locations of *C. polykrikoides* blooms in Japan and Korea

Sources: Yoon Y. H. (2001); A summary on the red-tide mechanisms of the harmful dinoflagellate, *Cochlodinium polykrikoides* in Korean coastal waters, Bull. Plankton Soc. Japan, 48 (2): 113–120.
Matsuoka K. (2004); Present status in study on a harmful unarmored dinoflagellate *Cochlodinium polykrikoides* Margalef., Bull. Plankton Soc. Japan, 51 (1): 38–45.

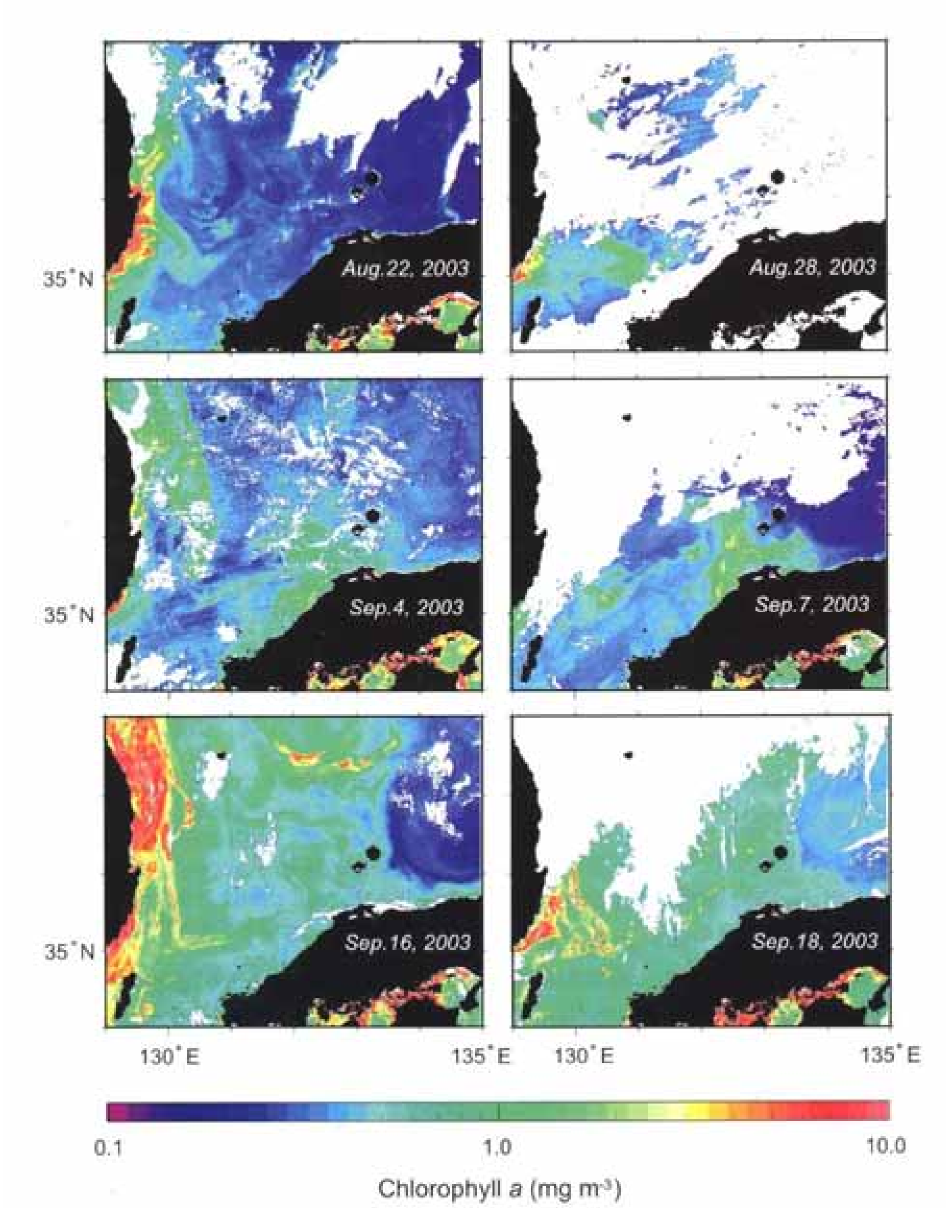

Figure 14 Movement of *C. polykrikoides* blooms along the coast of the Chugoku Region in Sea Area A

Note: The movement of *C. polykrikoides* blooms along the coast of the Chugoku region from September 4th to 7th is clearly seen in green. The spread of primary production on September 16th and 18th is thought to be caused by the typhoon on September 12th.

Source: Miyahara et al. (2005): A harmful bloom of *Cochlodinium polykrikoides* Margalef (Dinophyceae) in the coastal area of San-in, western part of the Japan Sea, in September 2003, Bull. Plankton Soc. Japan, 52(1),
11–18.

2.2.2 Threats of DSP and PSP

Shellfish poisoning is a common threat in the NOWPAP Region. In China, more than 600 people have suffered from shellfish poisoning since 1967, in which 30 cases were fatal. The majority of these fatalities were from PSP. In Japan, approximately 900 people have suffered from DSP and PSP since 1976. In Korea, shipping of shellfish was temporarily suspended in 2002 and 2003 due to PSP. Although there have been no reports of shellfish poisoning incidents in Russia as yet, the presence of various toxin-producing species have been recorded in Russian waters. Shellfish poisoning in Russia could become a major threat in the future, particularly due to the expansion of the aquaculture industry.

3 Information on HAB monitoring

3.1 Monitoring activities in the NOWPAP Region

Table 8 summarizes the current status of HAB monitoring in the NOWPAP Region. The locations of monitored areas are shown in figures 15 and 16.

3.1.1 Monitoring red tides

Apart from Russia, all NOWPAP Members have a regular red-tide monitoring program, although monitoring efforts and methods vary among members. In China and Japan, red-tide monitoring sites are distributed sporadically over the country, and are usually conducted in areas with high aquaculture activities. In Korea, red-tide monitoring sites are distributed densely over the entire coast. Regular monitoring in Russia has not yet been established, and this is partly due to the small number of aquaculture farms along the Far East coast. However, realizing the recent increases in red-tide events and their potentially negative effects to fisheries, The Institute of Marine Biology Far Eastern Branch Russian Academy of Sciences (IMB FEB RAS) has conducted several red-tide (monitoring and) studies on an ad hoc basis.
Red-tide monitoring in China, Japan and Korea are mainly conducted by fisheries research organizations. Other national institutes also provide valuable information on red tides, through aerial surveys, satellite data and so on. In the case of a significant red-tide event, various institutes collaborate to conduct trace monitoring and implement effective countermeasures. Korea has a particularly well established inter-organization cooperation scheme for such cases through the NFRDI (National Fisheries Research & Development Institute) HAB Emergency Center.

3.1.2 Monitoring of toxin-producing plankton

Monitoring of toxin-producing plankton is conducted in China, Japan and Korea, usually by fisheries research organizations. In Japan, monitoring is conducted in selected shellfish-producing areas.
In Japan and Korea, monitoring usually focuses on particular target species. However, each fisheries research organization sets its own target for different species. In Japan, *Alexandrium* species and *Gymnodinium catenatum* are usually monitored for PSP, and *Dinophysis* species are monitored for DSP. In Korea, *Alexandrium tamarense* is monitored in the southeastern region, near aquaculture farms.

3.1.3 Monitoring of shellfish poisoning

Monitoring of shellfish poisoning is conducted in China, Japan and Korea, usually by fisheries research organizations. In Japan and Korea, this type of monitoring is conducted in shellfish-producing areas.
All NOWPAP Members have quarantine limits for harvested shellfish. When the toxin level exceeds the limit, shipping or harvesting of shellfish is stopped until the toxin level returns to acceptable levels. The limit for PSP in China, Korea and Russia is 80 μg (STX eq.)/100g of whole meat. Japan applies Mouse Units (MU) for expressing the toxin level. The Japanese standards are 4MU/g for PSP and 0.05MU/g for DSP. Some researchers report that 1MU/g is equivalent to approximately 20 μg (STX eq.)/100g.

3.2 Common issues on monitoring activities in the NOWPAP Region

Although HAB monitoring is conducted by all NOWPAP Members, there is some variation among members in monitoring methods and effort. Such variation has resulted from differences in HAB problems, and the restrictions of personnel, technology and finance. For example, Russia does not have as strong a demand for HAB monitoring as do Japan and Korea, since Russian aquaculture activities are still relatively small.

Local variations in monitoring schemes also confound HAB data comparisons within and between regions, and this is particularly apparent in China and Japan. For example, in Japan, the method of HAB monitoring varies with each prefectural fisheries laboratory. This variation occurs because fisheries laboratory conduct HAB monitoring in accordance with indigenous species and their monitoring budget. As a result, a consistent methodology for HAB monitoring has not been established nationwide. Furthermore, monitoring could be stopped if prefectural fisheries laboratories cannot obtain finance for HAB monitoring.

Table 8 (1) Status of HAB monitoring in the NOWPAP Region

		China		Japan			Korea		Russia
Red tide (regular monitoring)	Major implementing organization	Branch office of SOA	SEPA Department of Agriculture Fishery environmental laboratories of local government	Fishery laboratories of prefectural governments	Kyushu Fisheries Coordination Office	Japan Coast Guard	NFRDI NFRDI fisheries extension service center	National Maritime Police Agency (NMPA)	No regular government monitoring program. However, IMB FEB RAS conduct observations on ad hoc basis.
	Method	Vessel monitoring Satellite remote sensing Aerial monitoring	Information N/A	Temperature, salinity, chlorophyll-a, nutrients, cell density monitored at fixed points (some labs do not monitor all of these parameters)	Water color (visual observation) and water temperature (infrared sensor) monitored through aerial survey.	Information N/A	Cell density of *C. polykrikoides*. Precaution and warnings issued when *C. polykrikoides* cell density exceeds 300 cells/ml and 1,000 cells/ml, respectively.	Aerial survey	Information N/A
	Location	4 monitoring sites in the Yellow and Bohai seas. See Figure 15 for location.	Information N/A	Usually limited to small areas such as in enclosed bays. See Figure 15 for monitored sites.	4 flight routes over the Kyushu coastal area.	Offshore areas	169 stations. See Figure 15 for location.	Information N/A	Coastal waters of Primorye and South Sakhalin Island.
	Frequency	Information N/A	Information N/A	Differs among laboratories. Mainly during spring to summer.	6–8 flights during June to October.	Information N/A	February–November	Information N/A	Ad hoc basis
Red tide (trace monitoring)		After the initiation of a red tide, fishery environmental laboratories conduct plankton sampling and, when necessary, continue tracking. SOA also participates in tracking when required.		After the initiation of a red tide, fishery laboratories conduct plankton sampling and, when necessary, continue tracking.			After the initiation of a red tide, the HAB Emergency Center in NFRDI collects relevant information to predict future movement of the red tide. The information is then disseminated to fishermen and relevant organizations.		Trace monitoring not conducted.
Toxin-producing plankton	Implementing organization	Some SOA laboratories and local fishery environmental laboratories. Monitoring network under construction.		Fishery laboratories of prefectural governments			NFRDI and Regional Maritime Affairs and Fisheries Office		No official regular monitoring program. However, IMB FEB RAS and SakhNIRO conduct observations on an ad hoc basis.
	Method	Information N/A		Cell density of *Alexandrium* species and *Gymnodinium catenatum* are usually monitored for PSP, and *Dinophysis* species for DSP. However, the target species may differ among laboratories.			Cell density of *A. tamarense* is regularly monitored.		Cell density of certain toxin-producing plankton studied.
	Location	Information N/A		Usually in shellfish production areas. See Figure 16 for monitored sites.			Near the shellfish farms in the southeast coast.		Coastal waters of Primorye and South Sakhalin Island.
	Frequency	Information N/A		Differs among laboratories.			Information N/A		Ad hoc basis

Table 8 (2) Status of HAB monitoring in the NOWPAP Region

		China	Japan	Korea	Russia
Shellfish poisoning	Implementing organization	Some SOA laboratories and local fishery environmental laboratories. Monitoring network under construction.	Fishery laboratories of prefectural governments	NFRDI and Regional Maritime Affairs and Fisheries Office	Monitoring not conducted.
	Method	Information N/A	Measurement of toxin level in the midgut gland.	Measurement of toxin level in the meat or midgut gland.	-
	Location	Information N/A	Usually in shellfish production areas. See Figure 16 for monitored sites.	Shellfish farms in the western and southern coastal area. Over 100 stations. See Figure 16 for monitored sites.	-
	Frequency	Varies with local harvest season.	At least monthly during the harvest season. Frequency increases to weekly if a high risk of poison is suspected.	At least more than once a month. Frequency increases when toxin is detected in the shellfish.	-
	Shipping and/or harvest stoppage	Stoppage of harvesting and shipping when PSP toxin level exceeds the Department of Agriculture standard (80 μg/100g of whole meat). DSP toxin level must be non-detectable.	Voluntary stoppage of shipping when toxin level exceeds the Fishery Agency standard (PSP: 4MU/g; DSP: 0.05MU/g). Shipping can recommence when toxicity level remains below the standard for 2 weeks.	Stoppage of harvesting when PSP toxin level exceeds 80 μg/100g meat.	Maximum permissible level. PSP: 80 μg/100g wet mollusk tissue. DSP: No detection of ocadaic acid.

Figure 15 Locations of red-tide monitoring organizations and sites in the NOWPAP Region (including trace monitoring)

Note 1: Green plots show the locations of monitoring organizations. For China, only SOA marine red-tide monitoring organizations are shown. Other Chinese monitoring organizations, such as SEPA (State Environmental Protection Administration) and Department of Agriculture, are not included in this figure.

Note 2: Monitoring sites (red plots) in this figure are based only on National Reports.

Figure 16 Location of toxin-producing plankton and shellfish poisoning monitoring organizations and sites in the NOWPAP Region

Note 1: Green plots show the locations of monitoring organizations.

Note 2: The monitoring sites (red plots) in this figure are based only on National Reports. Sites do not necessarily monitor both toxin-producing plankton and shellfish poisoning.

4 Studies to cope with HABs

Table 9 shows the main HAB studies conducted in the NOWPAP Region, categorized into the mechanism of HAB occurrences, toxicity analysis, taxonomy and mitigation measures.

The bloom mechanisms of harmful species were investigated in relation to various physical, chemical and biological environmental parameters. Target species include *Alexandrium* spp., *Gymnodinium* sp. and *C. polykrikoides*. Some studies have focused on the interspecific relationships among plankton, bacteria and virus species as a key to initiate or eradicate the population of harmful plankton species.

Toxicity analysis is one of the hot topics in HAB research. The effectiveness of various new assay or bioassay techniques is being tested to improve their detection abilities. The toxicity of various harmful species, including intraspecific variation, is also studied.

Recent studies on plankton taxonomy incorporate molecular biology techniques for species identification, intraspecific genetic variation, and so on.

Possible new mitigation measures are constantly being researched in the NOWPAP Region. The physical control of HABs through clay spraying is a well studied method and has already been implemented in some areas. However, its environmental impact is still of concern. The use of surfactants has also been considered in some studies. The biological control of HABs has been recently considered as an effective option by some researchers. Biological methods may control HABs by introducing organisms that graze (e.g. zooplankton, other micro algae, etc) or infect (viruses, bacteria) the target plankton species, although the ecological impact needs to be examined carefully.

The forecasting of HABs is another major research topic in the NOWPAP Region. The use of satellite remote sensing is considered the most effective tool for forecasting HABs. Neural network techniques and numerical simulation models are also being studied for predicting the occurrence and movement of blooms.

Table 9 Major HAB studies conducted in the NOWPAP Region

Category	China	Japan	Korea	Russia
Mechanism of HAB occurrence	Relationship of nutrient level with HABs Relationship of zooplankton community structure with HABs Bloom mechanism of A. tamarense Relationship of macronutrients with HABs Relationship of Alexandrium sp. growth with bacteria Relationship of A. tamarense growth with Fe and Mn	Bloom mechanism of PSP inducing species with *Alexandrium* spp. and *Gymnodinium catenatum* Relationship of bacteria/viruses with red-tide senescence Relationship of water temp., salinity and irradiance with *Cochlodinium polykrikoides* growth	Relationship of zooplankton community structure with *C. polykrikoides* blooms Relationship of physico-chemical factors (water temp., salinity, irradiance and nutrients) with *C. polykrikoides* blooms	Bloom mechanism of diatom *Chaetoceros salsugineus* and Oxyrrhis marina Relationship of nutrient level, stratification and water temp. with recent increase of HABs
Toxicity analysis	Toxicity analysis of HABs using bioassays, HPLC and LC-MS	Toxicity analysis with high performance liquid chromatography and mass chromatography Effectiveness of ELISA method	Toxicity analysis of *C. polykrikoides*, *Alexandrium* spp., *Microcystis* spp. and *Pseudo-nitzschia* spp.	Toxicity analysis of different genetic populations of *A. tamarense*
Taxonomy	Identification of dinoflagellates by a two dimensional proteome reference map Molecular identification of different *Alexandrium* spp. strains	Development of molecular biology techniques to distinguish plankton populations	Ultrastructure and phylogeny of microalgae using molecular biology techniques	Identification of A. tamarense subpopulations using molecular biology techniques
Mitigation measures	Coagulation rate of clay with HAB species Monitoring and forecasting of HABs by remote sensing Control of HABs using yellow clay and surfactants	Biological control of HABs using viruses, bacteria, macroalgae HAB prediction with neural network technique	Early detection of HABs using molecular biology techniques Biological control of HABs using bacteria, parasites, copepods and ciliates Control of HABs using yellow clay and surfactants Environmental impact of control agents Red-tide detection using satellite remote sensing	Information N/A

5 Training activities to cope with HABs

5.1 Training activities in the NOWPAP Region

Table 10 shows the types of training courses conducted by the NOWPAP Members. The majority of courses are related to red tides, shellfish monitoring and HAB mitigation, with main participants coming from monitoring organizations, research institutes and universities. China operates some training courses for different trainee groups. Japan has invited local fishermen and aquaculture operators into these training programs, since their participation is vital for HAB monitoring and mitigation. Korea has conducted red-tide training courses for technicians of developing countries, together with various other training courses. There are currently no national HAB training programs in Russia.

5.2 Common issues on training activities in the NOWPAP Region

Each NOWPAP Member has realized the importance of capacity building for improving HAB monitoring (Report of the First Meeting of NOWPAP Working Group 3), and China, Japan and Korea have conducted various training programs. However, these countries have carried out the promotion of concrete techniques for HAB monitoring practice and toxin analysis in their own training programs. Since NOWPAP Members conduct these training programs individually, there could be some differences in the knowledge and techniques of the trainees. Therefore, the sharing of common knowledge, standardization of techniques for HAB monitoring and toxin analysis, and the implementation of common HAB monitoring training program among NOWPAP Members are now being considered.

Table 10 Types of HAB training courses conducted in the NOWPAP Region

	Targeted personnel	Host organization	Subject
China	Personnel involved in red tides and shellfish poisoning in the monitoring centers of SOA	Information N/A	Lectures on red-tide monitoring and toxin analysis
	Personnel from universities and research institutes involved in red-tide and shellfish poisoning research	Information N/A	Lectures on HPLC techniques for PSP and DSP detection
	Personnel from universities and research institutes involved in fisheries research	Information N/A	Lectures and discussions on disease control in aquaculture farms
	Personnel from coastal local governments involved in environmental monitoring, including red tides	Information N/A	Lectures on red-tide monitoring, species identification and toxin analysis
Japan	Technicians of local government fisheries laboratories	Japan Fisheries Resource Conservation Association (JFRCA)	Lectures on latest HAB information. Exercises in sampling, sample preservation, species identification, toxin analysis etc.
	Local fishermen and aquaculture operators	Local Governments	Lectures on HAB mechanisms, mitigation measures, monitoring etc.
Korea	Technicians of developing countries	Korean International Cooperation Agency (KOICA)	Lectures on red-tide monitoring and mitigation.
	Personnel involved in coastal zone management in local government or regional maritime affairs & fisheries	NFRDI	Lectures on red-tide monitoring and mitigation. Lectures on HAB mechanisms.
	Technicians involved in sanitation and inspection of fishery products. Personnel from private fishery companies	NFRDI	Lectures on shellfish poisoning
	Personnel involved in red-tide monitoring in regional maritime affairs & fisheries	NFRDI	Exercises in sampling, sample preservation, species identification, toxin analysis etc.

6 Suggested activities for HABs in the NOWPAP Region

6.1 National activities to cope with HABs

According to the National Report on HABs of each country, NOWPAP Members conduct one or more national activities concerning HABs. Table 11 shows the national activities that are currently implemented to cope with HAB problems.

Table 11 Implemented national activities to cope with HABs in the NOWPAP Region

China	Japan	Korea	Russia
➢ Regular monitoring of red tides ➢ Use of clay spraying to control HABs (only in limited areas)	➢ Regular monitoring of red tides, toxin-producing plankton and shellfish poisoning ➢ Operation of HAB database (includes information on past HAB events) ➢ Use of clay spraying to control HABs (only in limited areas)	➢ Regular monitoring of red tides and shellfish poisoning ➢ Dissemination of HAB information to concerned organizations and fishermen through the HAB Emergency Center ➢ Use of clay spraying and electric clay dispensers to control *Cochlodinium* blooms ➢ Use of automatic HAB alarm system in aquaculture farms for early detection of HABs	➢ No national programs implemented yet apart from HAB related research activities

Monitoring of red tides is currently implemented in Japan, China and Korea. China and Korea have a well established national monitoring scheme through the NFRDI and SOA, respectively, whereas monitoring is not conducted under a national scheme in Japan.

Clay spraying is a common red-tide mitigation method employed in China, Japan and Korea. Its use is limited to certain areas and situations because of concerns regarding its negative effects on the environment. Korea has developed an automatic HAB alarm system, which provides early red-tide warnings to fishermen.

Slight differences in proposed national activities are inevitable among NOWPAP Members, since each member has their own particular problems and priorities for HABs. For example, Russia's HAB monitoring system is still in its development stage, in which administrative reform is a priority for future development. On the other hand, Korea already has a well developed HAB monitoring system, based on the Integrated Coastal Zone Management Strategy.

In principal, all NOWPAP Members have their own priorities for developing a more effective monitoring system and mitigation measure. The use of satellite remote sensing is considered an effective tool for red-tide monitoring by all NOWPAP Members, and many research activities have focused on this area. Biological control of HABs is another option being studied by some NOWPAP Members.

6.2 Suggested future activities for HABs in the NOWPAP Region

The National Report on HABs of each country made suggestions for NOWPAP future activities concerning HABs. Table 12 lists the suggested future activities for HABs in the NOWPAP Region.

Table 12 Suggested future activities concerning HABs in the NOWPAP Region

China	Japan	Korea	Russia
➢ Development of a common data and information network for HAB monitoring (C1) ➢ Cooperation and exchange of information with other relevant organizations, such as WESTPAC and PICES (C2)	➢ Action against *Cochlodinium* blooms through continuation of CCG and the organization of joint programs with WESTPAC/TTR (J1) ➢ Cooperation with other UNEP Action Plans (e.g. East Asia Sea Action Plan) (J2) ➢ Exchange of information with other organizations to avoid unnecessary overlap of activities (J3) ➢ Development of appropriate policies and technologies to control input of land-based nutrients into the seas of the NOWPAP Region (J4)	➢ Action against *Cochlodinium* blooms through continuation of CCG, and implementation of collaborative research programs within the NOWPAP Members (K1) ➢ Development of appropriate policies and technologies to control inputs of land-based pollutants into the seas of the NOWPAP Region (K2)	➢ Research and analysis on the influence of land-based nutrients and pollutants on HABs in coastal zones. (R1) ➢ Cooperation and exchange of information with other relevant organizations. such as WESTPAC and PICES (R2) ➢ Continuation of international training programs (R3)

Note: The suggestions of each country are numbered, which will be referred in Table 13 (e.g. the third suggestion of Japan is abbreviated as J3).

Japan and Korea consider activities for *Cochlodinium polykrikoides* control to be important. Damage caused by this species to fisheries is severe in these countries. The area of *C. polykrikoides* occurrence tends to be expanding in the NOWPAP Region. Even though such damage is not currently found in the China and Russia seas of the NOWPAP Region, this species could become a problem in the future. Therefore, NOWPAP Members should treat *C. polykrikoides* as a common problem and cooperate to conduct activities concerning this species. In 2004, the *Cochlodinium* Corresponding Group (CCG) started to work cooperatively on the species. This group activity should be encouraged to become more effective and cooperative (Suggestion 1 in Table 13).

China, Japan and Russia emphasize the importance of cooperation within the NOWPAP Region, as with other international organizations that are involved in HABs, such as Intergovernmental Oceanographic Commission (IOC)/IOC Sub-Commission for the Western Pacific (WESTPAC) and North Pacific Marine Science Organization (PICES). Valuable information could be exchanged, and activities could be demarcated through the process. Some objectives of this cooperation are to avoid overlapping activities of researches and the exchange of valuable information, enabling WG3 activities on HABs to be more efficient in solving HAB problems (Suggestion 2 in Table 13).

China suggests that there should be the development of a common data and information network for HAB monitoring. China has developed the ‘China Harmful Algal Bloom WebPages (www.china-hab.cn)’ and a website of the ‘National Basic Research Priority Project-China Ecology and Oceanology of Harmful Algae Blooms' (embedded in the former website). These information systems are expected to enable prompt responses to HAB occurrences and the accumulation of scientific knowledge about HABs. Japan has constructed the 'Marine Environmental Watch Project (http://www.nowpap3.go.jp/jsw/eng/index.html)' and 'Website of Remote Sensing of the Japanese Coastal Guard (http://www.cearac-project.org/wg4/portalsite/)' which provides satellite remote sensing images of chlorophyll-a. These data can be useful to investigate HABs. NOWPAP WG3 has developed a 'HAB Reference Database (http://www.cearac-project.org/wg3/hab-ref-db/)' and '*Cochlodinium* Homepage (http://www.cearac-project.org//wg3/cochlo-entrance/)'. The former provides a scientific reference on HABs to NOWPAP Members, and the latter introduces *Cochlodinium*, which is one of the HAB genera of greatest concern in the NOWPAP Region. Further development of such a database and information network for NOWPAP should promote a common and deeper understanding of HABs (Suggestion 3 in Table 13).

Japan, Korea and Russia believe that more effective policies and technologies are needed to control the discharge of land-based nutrients (e.g. effluent control and improvement of sewage treatment systems). In order to help policy makers implement new policies and encourage the private sector to invent new technologies, NOWPAP WG3 could provide data on nutrient sources, river water quality or nutrient loads in cooperation with NOWPAP WG1 and WG2, and provide information about preventive measures that the NOWPAP Members have conducted since the 1970s (Suggestion 4 in Table 13).

It is desirable that a collaborative monitoring program is developed within the NOWPAP Region to construct a resource of common knowledge about HABs in the region. In reality, however, each country has already long established their own approaches and programs, including using their own definitions of words (e.g. names of species), such that adapting to another program could be difficult. It is really challenging to develop a collaborative monitoring program in the region, but NOWPAP WG3 should make efforts to construct a quasi-collaborative monitoring program with feasible activities to share common information about HABs among the NOWPAP Members. This is not mentioned in National Reports but is an ultimate goal of NOWPAP WG3 (Suggestion 5 in Table 13). Suggestions for future activities about HABs in the NOWPAP Region are summarized in Table 13. Five suggestions are made for WG3 future activities.

Table 13 Summary of suggestions for future activities about HABs in the NOWPAP Region

1. **To facilitate research and study of *Cochlodinium* through CCG activities** (J1, K1)
2. **To cooperate with other international organizations that are involved in HABs** (C2, J2, J3, R2, R3)
3. **To establish a common understanding of HABs through the development of a database and information network** (C1)
4. **To help make a policy on the control of land-based nutrient discharges** (J4, K2, R1)
5. **To seek a collaborative approach for HAB monitoring for the NOWPAP Region**

Note: The abbreviation inside the parenthesis shows the suggesting country (e.g. J1 means the first suggestion of Japan). See Table 12 for details.

When considering the priorities for WG3 over the next few years from the five suggestions above, actions regarding suggestions 1 and 4 highlight the ‘promotion of mitigation’. WG3 developed their knowledge of HABs in the NOWPAP Region, through working on National Reports, the Integrated Report, the HAB Reference Database and CCG activities in the past four years. These commitments meant that WG3 has been unable to prioritise the ‘promotion of mitigation’ listed on the work plan proposed in the FPMs and WG3 Meetings, but it may now be timely to do so. Also, collecting case studies of mitigation measures might be an option for WG3 activities over the next few years.

The immediate topic for future cooperative work of CCG is to establish countermeasures against damage by *Cochlodinium* red tides. The present report describes current mitigation methods to prevent damage caused by such red tides. It should be noted that these mitigations have a very limited effect, and red-tide events continue to increase. It means that the further development of countermeasures is necessary for the conservation, sustainable development and utilization of the NOWPAP coastal region and its environment.

The need to establish effective countermeasures against HABs is not limited to *Cochlodinium*, but also applies to other HAB species. Some NOWPAP Members are already implementing some mitigation measures against HABs, although with varying efforts and methods. Research in this field is an ongoing process by NOWPAP Members.

All NOWPAP Members need to have preventive measures to mitigate red-tide occurrences, such as in the control of nutrient discharges. Japan has implemented laws and set standards since 1970 on nutrient control and the water quality of effluents, rivers and sea areas. It is important that NOWPAP Members share information on preventive measures conducted in their areas in order to make better policies on the control of land-based nutrient discharges.

In conclusion, one of the primary future activities of WG3 should be the collection and compilation of detailed information related to HAB mitigation measures. This information includes both preventive measures (e.g. water and sediment quality standards, laws and regulation, etc.) and countermeasures (e.g. clay spraying) against red tides or HABs.