Preface

The Special Monitoring and 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 Pacific 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 Ministry of Environment, Japan. One of the main activities of CEARAC includes monitoring and assessment of Harmful Algal Blooms (HABs) under NOWPAP Working Group 3 (WG3).

In order to provide and to share information on the status of HABs in the NOWPAP region and to address issues to be tackled through CEARAC activities, the Integrated Report on Harmful Algal Blooms (HABs) for the NOWPAP Region was published in 2005.

After the publication of the Integrated Report, CEARAC developed the *Cochlodinium* Home Page and published the Booklet of Countermeasures against Harmful Algal Blooms in the NOWPAP Region based on the suggestions in the Integrated Report.

In addition, for sharing information on HABs in the NOWPAP region not only among the NOWPAP member states but also among other international organizations regularly, CEARAC implemented the HAB Case Study to establish the most effective and laboursaving way for sharing information in the 2008-2009 biennium.

Through these activities, new information on HABs status in the NOWPAP region has been collected. Furthermore, as five years have passed from the publication of Integrated Report, CEARAC updated the first edition by adding the latest information on HABs occurrences and other related items.

The CEARAC Secretariat would like to thank the CEARAC Focal Points for great contributions to the publication the Integrated Report on HABs for the NOWPAP Region (Second edition).

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Executive Summary

The NOWPAP region is an enclosed sea area which is surrounded by People's Republic of China, Democratic People's Republic of Korea, Japan, Republic of Korea and Russian Federation. There are 600 million people in the size of 1,700,000km^2 and this is one of the most populated areas in the world.

At one time, this area had serious problems by frequent occurrences of harmful algal bloom (HAB) because of increasing of nutrient inputs from land associated with economic development and increase of agricultural production in the surrounding countries. In recent years, the number of HABs has decreased compared to that in past years by establishment of sewage plants and appropriate treatment of discharged water; however, HABs still occur every year in this region. Moreover, HABs damage aquaculture fisheries which are conducted actively in this region because of increase of demand on fisheries resources. Thus, HABs are taken as a serious issue in this region.

In such a situation, NOWPAP CEARAC implemented a case study in 2008 to collect information effectively on the monitoring structures and HAB occurrences in the NOWPAP member states (China, Japan, Korea and Russia) and developed a common format for sharing information among the member states. The latest information on HAB in the NOWPAP member states was summarized as the HAB Case Study Report and CEARAC makes efforts to share the information continuously in the member states.

According to the case study reports from the member states, all the NOWPAP member states conduct regular red tide and shellfish poisoning monitoring and strengthen their systems of surveillance. In their regular monitoring, items on marine environment, such as water temperature, salinity and nutrients concentration are monitored with some varieties of items in each state, and analyzed the relationship between red tide occurrences and environmental condition. Each member state also sets the cell density of each causative species, which are part of scientific bases of issuing advisories and warnings, and makes efforts on reduction of damage on fisheries, particularly on marine cultures.

In 2006-2008, there were 10 occurrences of red tides in China; 208 in Japan; 21 in Korea and 31 in Russia in the case study areas. It is difficult to simply compare these numbers because of the different size of the case study area and monitoring frequency of each state; however, Japan had the biggest number.

Also, in Japan, the damage on fisheries by red tides has become bigger in recent years, for example, loss of 5 billion Japanese Yen on fisheries by *Chattonella antique* in Ariake Sea, Omura Bay and Yashiro Sea in 2010. On the other hand, in Korea, the number of red tides has significantly decreased since 2005: 10 per year to 5 on average. In addition, there have been no occurrences of *Cochlodinium* since 2009, so it seems that the pattern of HAB occurrences has changed in recent years.

There are 62 causative species reported in the NOWPAP region, and among them, *Heteroshigma akashiwo* is reported in all the member states. Characteristics of these species are not changed; however, some of their distribution has changed: *Cochlodinium* occurrences have moved toward the north in Japan and red tides by *Chaetoceros* have occurred in Russia.

All the member states have reported causative species of shellfish poisoning (6 PSP, 7DSP and 8 ASP) in their territorial waters; however, only PSP and DSP are reported in the NOWPAP region (PSP in Japan and DSP in China)

In the NOWPAP region, there are different techniques applied monitor red tides, collect information and reduce damage such as effective use of artificial satellite images, various molecular biological approaches to identify HABs and causative species on site.

We wish this report will contribute to widening knowledge on red tides/HABs in the NOWPAP region and promoting implementation of countermeasures in each NOWPAP member state.

1 Introduction

The first issue of HAB Integrated Report was published in 2005. The report provided useful information on harmful algal blooms in the Northwest Pacific (NOWPAP) region and pointed out the future activities which should be done as CEARAC activities for this region. Based on these suggestions, CEARAC developed the *Cochlodinium* Home Page and pamphlet in order to introduce information on *Cochlodinium polykrikoides*, which is one of the concerned species in the NOWPAP region.

In addition, in order to enhance activities for countermeasures against HABs, CEARAC collected the cases which used in member states or is under study in cooperation. This information is published as Booklet of Countermeasures against Harmful Algal Blooms (HABs) in the NOWPAP Region in 2007. The information on HABs collected through these CEARAC activities is disseminated from HAB Integrated Website established in 2009.

Thus, CEARAC conducted activities based on the suggestions in HAB Integrated Report (2005) from 2006, most of suggestions had been done. For the future, it is important to share the latest information on HABs in member states regularly. From such view point, CEARAC has implemented HAB Case Study to develop the most effective and laborsaving way for sharing HAB related information among NOWPAP member states in the 2008-2009 biennium. In the HAB Case Study, each member state has selected the target sea area where HABs occur frequently and HAB monitoring is conducted regularly. The selected target sea areas are shown in Table 1. Each member state introduced their monitoring framework, warning/action standards against HAB events and monitoring items in target sea area. The information is summarized and published as HAB Case Study Report by each member state. Based on the HAB Case Study Reports, CEARAC developed the common sheet for submission the latest HAB related information from member states. Using this common sheet, the latest information has been provided from 2008.

The aims of this Integrated Report are to share the current HABs problems in the NOWPAP Region not only among NOWPAP member states but also among other countries and international organizations. This report was updated by adding information which collected through HAB Case Studies in each member state during 2008-2010.

Table 1 Selected sea area in each member state for HAB Case Study

Country	Selected Area in HAB Case Study
China	Coastal area of Qingdao region and Dalian region
Japan	Northwest sea area of Kyushu region and Ariake Sea
Korea	South coast of Korea
Russia	Amurskii Bay, Vostok Bay and Aniva Bay

Figure 1 shows the approximate area of the NOWPAP region and target sea area selected in HAB Case Study. 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.

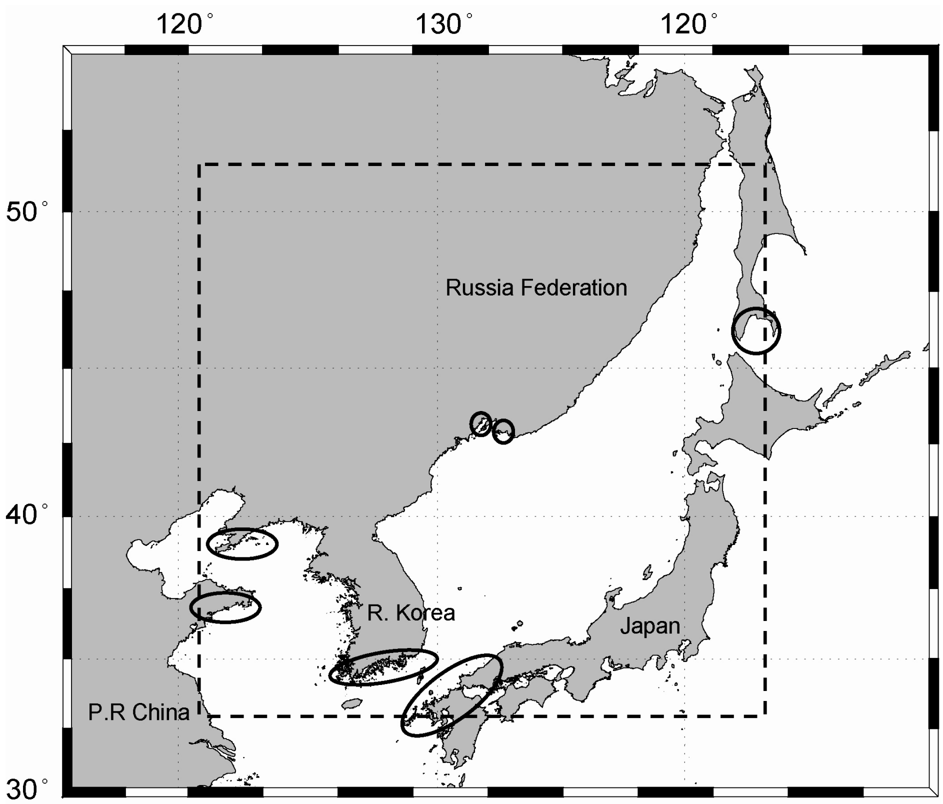


Figure 1 Area of the NOWPAP region
Dash line indicate the area of the NOWPAP region where covers approximately
121-143˚E longitude and 33-52˚N latitude without prejudice to the sovereign of any states.
Circles indicate Case Study Area of each member state.

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.

Scientific name of phytoplankton: In this report, scientific name of phytoplankton is based on the HAB Case Study Report of each member state. However, the name is different among NOWPAP members, the latest scientific name is used in this report. In addition, scientific name of the following species were changed. Previous names are in parenthesis:

Karenia mikimotoi (*Gymnodinium mikimotoi*)
Akashiwo sanguine (*Gymnodinium sanguineum*)
Mirionecta rubra (*Mesodinium rubrum*)

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.

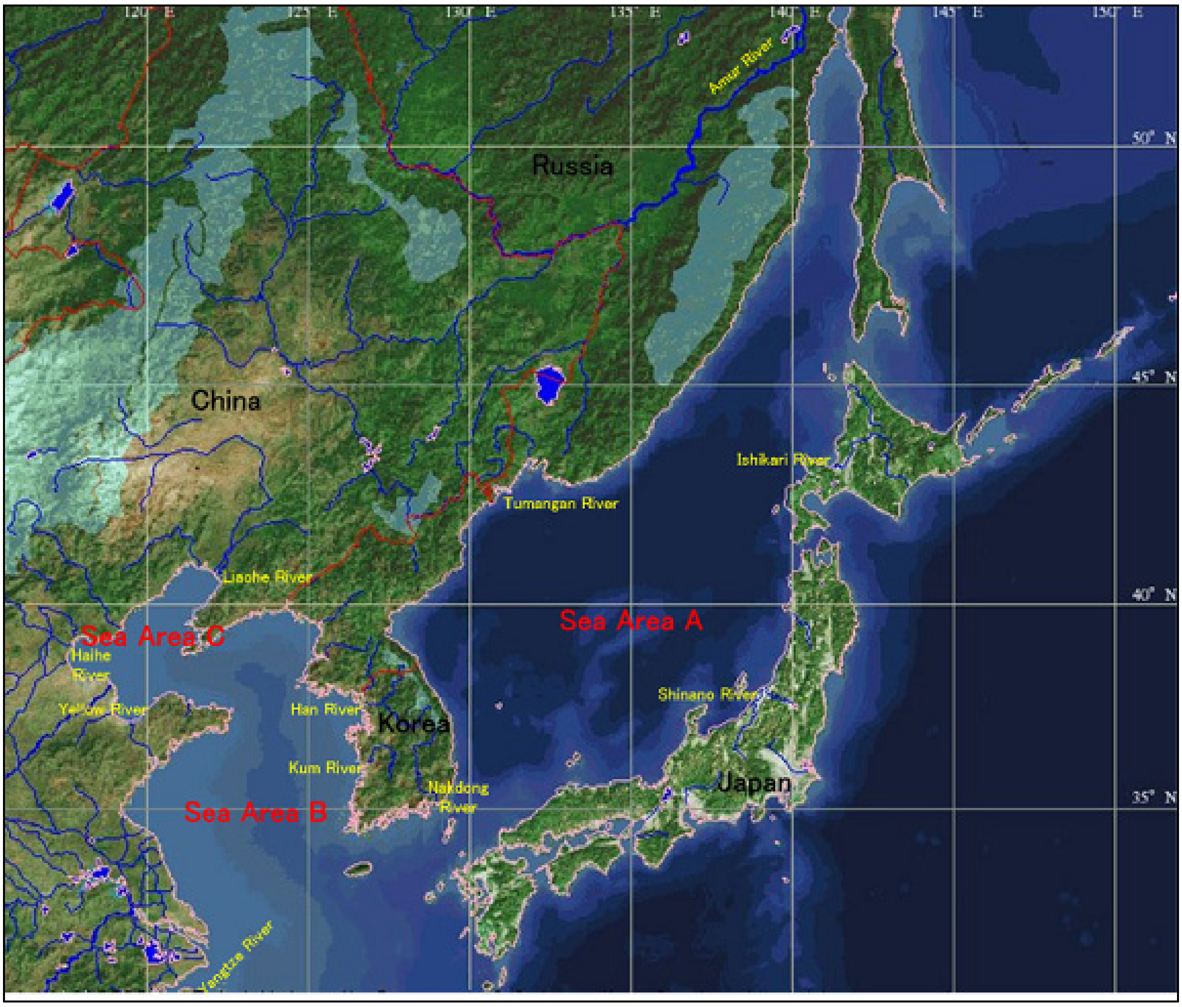


Figure 2 Geographic characteristics of the NOWPAP region

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 2 provides basic information on these sea areas.

Table 2 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 3 shows some of the major rivers that flow into the sea areas.

Table 3 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
	Razdolnaya	Russia	16,800	78
	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
	Nakdong	Korea	23,817	-
	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

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 Kuroshio Current, enters Sea Area A from the strait between Japan and Korea and flows northeastward. 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.

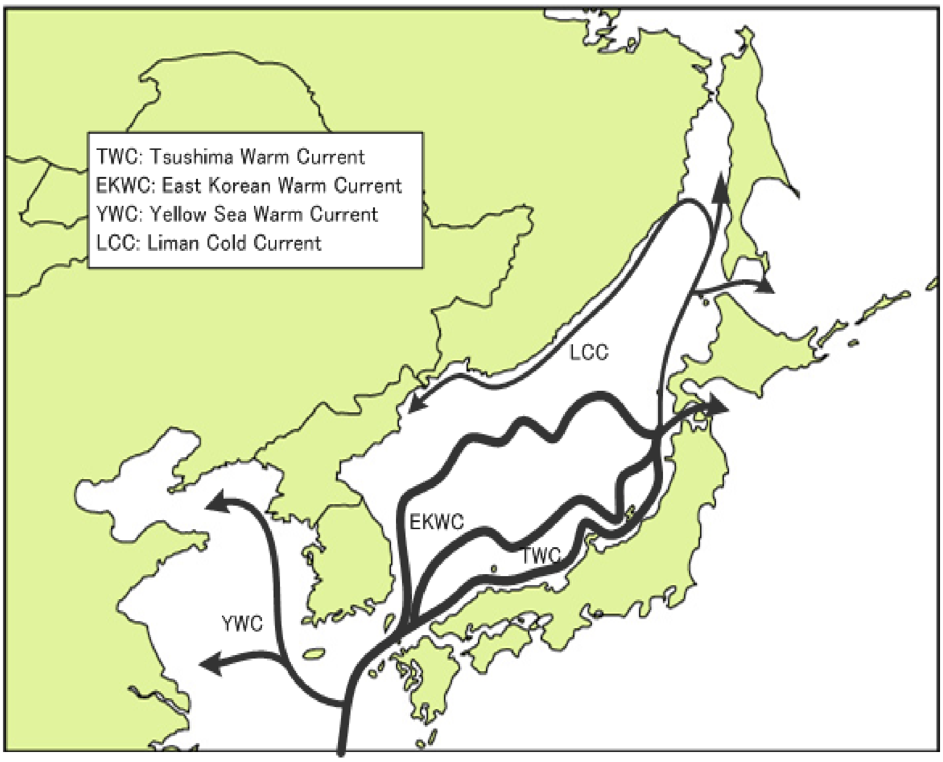


Figure 3 Major oceanographic currents in the NOWPAP region

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 580 million in 2010, in which approximately 85% are in the Chinese region. Approximately 33 and 50 million people inhabit the Japanese and Korean regions, respectively. Only 3.8 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.

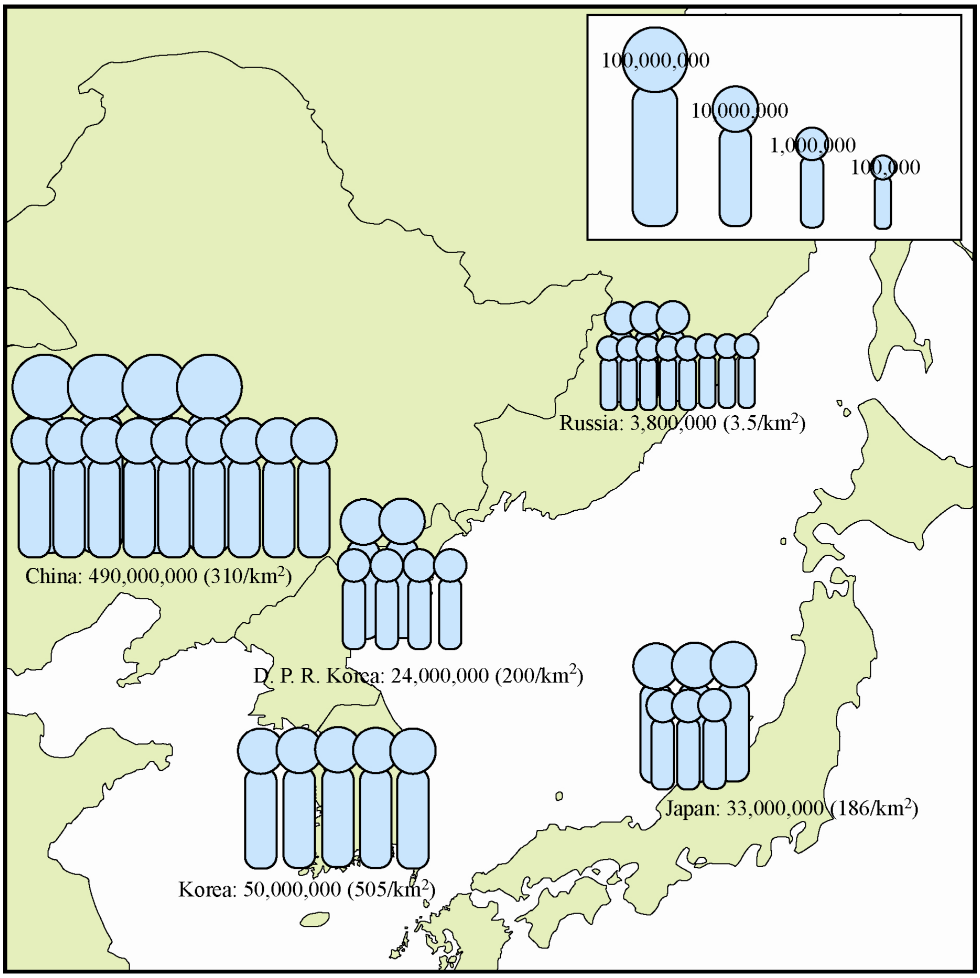


Figure 4 Population sizes and densities in the NOWPAP region's catchment areas

Source: China Population and Housing Census (2010), 2010 Population Census of Japan,

Population of China is sum of one in Heilongjiang Province, Jilin Province, Liaoning Province, Hebei Province, Henan Province, Shandong Province, Shanxi Province, Jiangsu Province, Anhui Province, Beijing, Tianjin Province, Shanghai
Population of Japan is sum of one in Hokkaido, Aomori Prefecture, Akita Prefecture, Yamagata Prefecture, Niigata Prefecture, Toyama Prefecture, Ishikawa Prefecture, Fukui Prefecture, Kyoto Prefecture, Hyogo Prefecture, Tottori Prefecture, Shimane Prefecture, Yamaguchi Prefecture, Fukuoka Prefecture, Saga Prefecture
Population of D.P.R. Korea and South Korea is national population.
Population of Russia is sum of one in Primorskii Krai, Khabarovsk Krai, Sakhalin Oblast

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 4 shows the types of aquaculture conducted in the NOWPAP region.

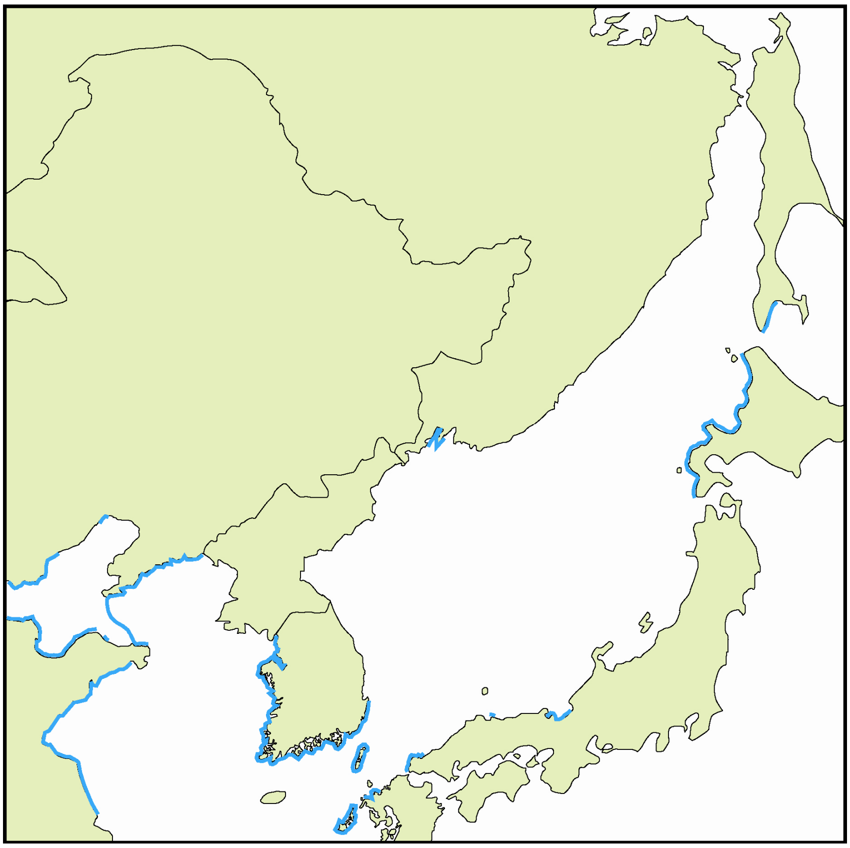


Figure 5 Major aquaculture areas in the NOWPAP region

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 4 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 Wakasa Bay West coast of Hokkaido	Amberjack, Red seabream, Yellowtail Tiger puffer, Red seabream, Yellowtail, Scallop
Korea	West and south coast	Bastard halibut, Amberjack, Rockfish
Russia	South coast of Sakhalin, Peter the Great Bay	Scallop, Seaweeds, Mussel, Cucumaria

2 Information on HAB monitoring

2.1 Monitoring framework and parameters of HAB in the NOWPAP region

Table 5 summarizes HAB monitoring organization in each member state. The locations of monitored areas are shown in figures 6.

Table 5 HAB monitoring organization in the NOWPAP member states

Country	Monitoring Organization	Monitored sea area
China	North China Sea Environmental Monitoring Centre	Qingdao coastal area
	National Marine Environmental Monitoring Centre	Zhangzi Island off Dalian
Japan	Yamaguchi Prefectural Fisheries Research Center	Coastal area of Yamaguchi Pref.
	Fukuoka Fisheries and Marine Technology Research Center	Northern Kyushu Fukuoka Bay, Karatsu Bay, Genkai Sea, Hibiki Sea, Ariake Sea
	Saga Prefectural Genkai Fisheries Promotion Center Saga Prefectural Ariake Fisheries Promotion Center	Northern Kyushu Karatsu Bay, Nagoyaura, Kariya Bay, Imari Bay Ariake Sea
	Nagasaki Prefectural Institute of Fisheries	Northern Kyushu Imari Bay, Hirado Western Kyushu Ohmura Bay, Tachibana Bay, Coasts of Kitamatsu, Kujyukushima, Coast of Seihei, Ariake Sea
	Shimane Prefectural Fisheries Technology Center	Coastal area of Shimane Pref.
	Tottori Prefectural Fisheries Experimental Station	Coastal area of Tottori Pref.
	Hyogo Fisheries Technology Institute	Coastal area of Hyogo Pref.
	Kyoto Prefectural Agriculture, Forestry and Fisheries Technology Center, Fisheries Technology Department	Coastal area of Kyoto Pref.
	Fukui Prefectural Fisheries Experimental Station	Coastal area of Fukui Pref.
	Ishikawa Prefecture Fisheries Research Center	Coastal area of Ishikawa Pref.
	Toyama Prefectural Fisheries Research Institute	Coastal area of Toyama Pref.
	Niigata Prefectural Fisheries and Marine Research Institute	Coastal area of Niigata Pref.

Country	Monitoring organization	Monitored sea area
Korea	National Fisheries Research and Development Institute - Southeast Sea Fisheries Research Institute - Southwest Sea Fisheries Research Institute	South coast covering inshore and offshore Southeastern area Southwestern area
	Local government - Fisheries station under Gyeongnam province: Tonyeong (TFS), Sacheon (SFS), Goseong (GFS), Geoje (GEF), Namhae (NFS) - Fisheries station under Jeonam province: Wando (WFS), Yeosoo (YFS), Goheung (GFS), Jangheung (JFS), Kangjin (KFS)	South coast targeted on potential HAB areas in inshore Southeastern area Southwestern area
Russia	A.V. Zhirmunskii Institute of Marine Biology, FEB RAS (1991-2006) Center of Monitoring of HABs & Biotoxins A.V. Zhimunskii Institute of Marine Biology, FEB RAS (2007-)	Amurskii Bay and Vostok Bay
	Sakhalin Research Institute of Fisheries & Oceanography	Aniva Bay

2.1.1 Monitoring of HAB

All NOWPAP members have a regular red tide monitoring program and toxin-producing plankton bloom to check presence of HAB species. Some country select target species for each monitoring and strengthen monitoring against these species. The list of target species in NOWPAP member states is shown in Table 6. Each member state set warning/action standards on some species in order to prevent the damage by these species (Table 7). In the NOWPAP region, ASP has not reported yet, however, Russia set the warning standards on ASP-inducing *Pseudo-nitzschia* species to prevent the damage of ASP.

In addition to regular monitoring, China, Japan and Korea conduct post red tide monitoring, and Korea conduct additional monitoring which focus on *Cochlodinium polykrikoides* blooms. The information on these monitoring is summarized as table 8.

Table 6 Target red tide species and toxin-producing plankton species

Country	Target red tide species	Target toxin-producing plankton species
China	*Mirionecta rubra* *Noctiluca scintillans* *Skeletonema costatum* *Heterosigma akashiwo* *Eucampia zodianus* *Chaetoceros affinis* *Chattonella marina*	
Japan	*Karenia mikimotoi* *Cochlodinium polykrikoides* *Heterocapsa circularisquama* *Chattonella antiqua* *Chattonella marina* *Heterosigma akashiwo*	*Dinophysis fortii* *Dinophysis acuminate* *Dinophysis caudate* *Gymnodinium catenatum* *Alexandrium catenella* *Alexandrium tamarense*
Korea	*Akashiwo sanguinea* *Cochlodinium polykrikoides* *Prorocentrum dentatum* *Prorocentrum minimum* *Ceratium furca* *Heterosigma akashiwo* *Noctiluca scintillans*	
Russia	*Pseudo-nitzschia delicatissima* *Pseudo-nitzschia multiseries* *Skeltonema costatum* *Karenia mikimotoi* *Noctiluca scintillans* *Dynobryon balticum* *Chattonella* sp. *Heterosigma akashiwo*	*Pseudo-nitzschia delicatissima* *Pseudo-nitzschia fraudulenta* *Pseudo-nitzschia multistriata* *Pseudo-nitzschia muitiseries* *Pseudo-nitzschia seriata/pungens* *Alexandrium tamarense* *Dinophysis acuminate* *Dinophysis acuta* *Dinophysis fortii* *Dinophysis norvegica* *Dinophysis rotundata* *Karenia mikimotoi* *Protoceratium reticulatum*

Table 7 Warning and action standards for each causative species

Country	Region	Species name	Warning/action standards (cell/ml)		Affected fish/shellfish
			Warning level	Action level	
China*1		*Mirionecta rubra*	500		
		Noctiluca scintillans	50		
		Skeletonema costatum	5,000		
		Heterosigma akashiwo	50,000		
		Eucampia zodianus	100		
		Chattonella marina	100		
		Alexandrium tamarense	1,000		
Japan	Yamaguchi Pref.*2	*Karenia mikimotoi*	500	5,000	
		Heterosigma akashiwo	5,000	50,000	
	Fukuoka Pref. *3	*Heterosigma akashiwo*	-	10,000	
	Saga Pref.				
	Nagasaki Pref. *4	*Chattonella antiqua*	1	10	Yellowtail, cockles etc.
		Chattonella marina	1	10	Yellowtail etc.
		Karenia mikimotoi	100	500	Fish, Shellfish, crustaceans etc.
		Cochlodinium polykrikoides	50	500	Yellowtail, rea seabream, pufferfish, striped jack etc.
		Heterosigma akashiwo	1,000	10,000	Yellowtail, grouper etc.
		Heterocapsa circularisquama	10	50	Shellfish (bivalves)
Korea*5		*Chattonella* spp.	2,500	5,000	
		Cochlodinium polykrikoides	300	1,000	
		Gyrodinium sp.	500	2,000	
		Karenia mikimotoi	1,000	3,000	
		Other dinoflagellates	30,000	50,000	
		Diatoms	50,000	100,000	
		Mixed blooms	40,000	80,000	
Russia*6		*Pseudo-nitzschia calliantha*	500		Shellfish
		Pseudo-nitzschia delicatissima	500		Shellfish
		Pseudo-nitzschia fraudulenta	500		Shellfish
		Pseudo-nitzschia multistriata	500		Shellfish
		Pseudo-nitzschia multiseries	500		Shellfish
		Pseudo-nitzschia seriata/pungens	500		Shellfish
		Alexandrium tamarense	0.5		Shellfish
		Dinophysis acuminate	0.5		Shellfish
		Dinophysis acuta	0.5		Shellfish
		Dinophysis fortii	0.5		Shellfish
		Dinophysis norvegica	0.5		Shellfish
		Dinophysis rotundata	0.5		Shellfish
		Protoceratium reticulatum	500		Shellfish

Source:*1 China Source
* 2 Yamaguchi Prefecture
(http://www.pref.yamaguchi.lg.jp/cms/a16500/uminari-top.html)
*3 Fukuoka Fisheries and Marine Technology Research Center
(http://www.sea-net.pref.fukuoka.jp/)
*4 Nagasaki Prefectural Institute of Fisheries
(http://www.marinelabo.nagasaki.jp/news/gyorendayori/H13/1307no75akasio-tyui.pdf)
*5 Korea Source
*6 Russia Source

2.1.2 Monitoring of shellfish poisoning

Monitoring of shellfish poisoning is conducted in order to prevent shipment and harvesting of contaminated shellfish by all NOWPAP member states.

All NOWPAP member states have quarantine limits for harvested shellfish. When the toxin level exceeds the limit, shipping and harvesting of shellfish is stopped until the toxin level returns to acceptable levels. The standard value for prevention on shipment of shellfish is 80μg (STX eq.)/100g of meat for PSP and 0.05 MU/g for DSP in China, 4MU/g wet weight for PSP and 0.05 MU/g wet weight for DSP in Japan, 80μg /100g meat for PSP in Korea, 0.8mg/kg of saxitoxin (mollusks) for PSP and 0.16mg/kg of okadaic acid (mollusks) for DSP and 20mg/kg of domoic acid (mollusks) and 30mg/kg of domoic acid (crab's internal) for ASP in Russia, respectively. Some researchers report that 1MU/g is equivalent to approximately 20μg (STX eq.)/100g.

2.2 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.

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
Regular red tide monitoring	Monitoring parameters	HAB	- Type of red tide species	- Type of red tide species - Cell density - Water color - Sedimentation	- Type of red tide species - Cell density - Water color	- Type of red tide species - Cell density - Water color
		Water quality	- Transparency - Nutrients - Index on pH*[1], DO*[2], Nutrient quality*[3], HAB risk*[4], Comprehensive risk*[5] (in Dalian coastal area)	- Water temperature - Salinity - DO - pH - COD - Transparency - Nutrients - Chlorophyll *a*	- Water temperature - Salinity - DO - Transparency - Nutrients - Chlorophyll *a*	- Water temperature - Salinity - Heavy metals
		Meteorology	- Weather - Wind direction/speed	- Weather - Cloud cover - Wind direction/speed - Precipitation - Daylight time		- Weather - Ice cover
		Others		Sediment quality		
	Monitoring frequency			Fukuoka Pref.: 1/month Saga Pref.: 1/month (May-October) Nagasaki Pref.: 1/month (June-October)	9/year (March-November)	1991-1993 May-Dec. (1-2/month) 1996-1998 Jan.-May (4/month) 1999-2000 May-Apr. (2/month) 2004-2008 Oct.-Dec. (2/month)

*1: pH index (D_{pH}): Classifying pH value as three grades in form of index value 1, 3 and 5, ranging from 7.5 to more than 9.5, and higher pH value it is, higher grade it will be.
*2: DO index (D_{DO}): ranging from less than 105% to over 110% is classified as three grades in form of index value 1, 3 and 5, and higher DO saturation it is, higher grade it will be.
*3: Nutrient quality index (D_U): D_U is issued by getting dissolved inorganic nitrogen, dissolved inorganic phosphorus and COD concentration into calculation together and finally drawing an eutrophication value (E), ranging from less than 0.7 to over 1.5. By classifying E into three grades in form of index value, 1, 3 and 5, D_U is determined, and higher E it is, higher grade it will be.
*4: HAB risk index (D_R): D_R is judged by 2 major aspects, Chl-a concentration and biomass of dominant species. Further illustrating, dominant species are classified into 5 types by its length. For each type, there is a classification according to biomass, representing by index value. Classified grades and index value of different dominant species types are same. Meanwhile, Chl-a is classified into coincident grades as biomass. Finally, D_R is drawn by putting Chl-a and biomass of dominant species together and classified according to grades of them. In practically using, D_R is classified into three grades initially, representing index value 1, 2-20 and 25, meaning low HAB risk, potential HAB risk and HAB occurrence respectively.

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

			China	Japan	Korea	Russia
Post red tide monitoring	Monitoring parameters	HAB	- Type of red tide species - Cell density - Bloom area	- Type of red tide species - Cell density - Bloom area - Water color	- Type of red tide species - Cell density - Bloom area - Water color	
		Water quality	- Water temperature - Salinity - DO	- Water temperature - Salinity - DO	- Water temperature - Salinity	
		Meteorology			Weather Coverage by cloud Wind direction/speed	
		Others				
	Monitoring frequency		Immediately after water discoloration	Immediately after water discoloration	Immediately after water discoloration	

Table 8 (3) Status of HAB monitoring in the NOWPAP Region

			China	Japan	Korea	Russia
Regular monitoring on shellfish poisoning	Monitoring parameters	HAB	- Type of toxin-producing plankton species	- Type of toxin-producing plankton species - Cell density - Water color	- Type of toxin-producing plankton species - Cell density - Water color	- Type of toxin-producing plankton species - Cell density
		Water quality		- Water temperature - Salinity - DO - pH - Transparency - Nutrients - Chlorophyll *a*	- Water temperature - Salinity - DO	- Water temperature - Salinity
		Meteorology				
		Others		- Toxin levels in shellfish (MU/g)	- Toxin levels in shellfish	- Toxin levels in shellfish
	Monitoring frequency			Toxin-producing plankton monitoring 12-16/year Toxin level monitoring 1/week until toxin levels in shellfish satisfy the regulatory standards	1/month Every week once toxin is detected (usually 30/year)	Since September 2008 3/year

2.3 Monitoring sites in target sea area for HAB Case Study in the NOWPAP Region

In HAB Case Study, each member state selected target sea area where HAB occur frequently. In these areas, organizations such as local fisheries institute conduct monitoring regularly to understand HAB occurrence and to measure the marine environmental situation.

The monitoring site in the target sea areas of each member state are shown in Figure 6.

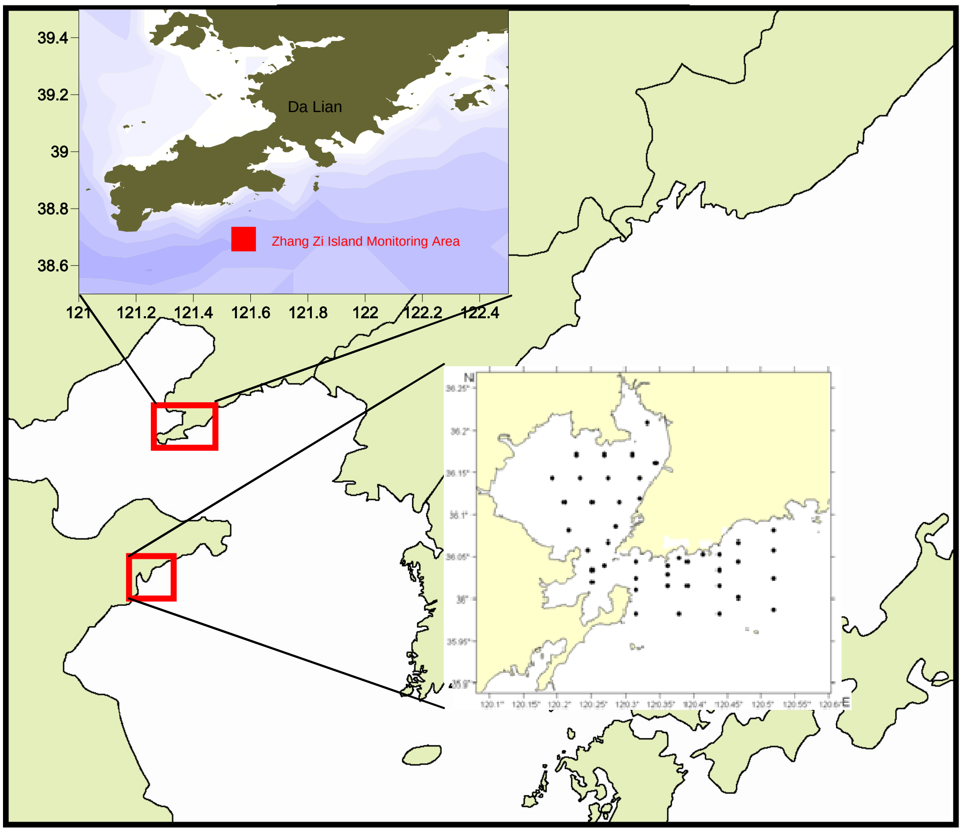


Figure 6-1 Locations of monitoring sites in China

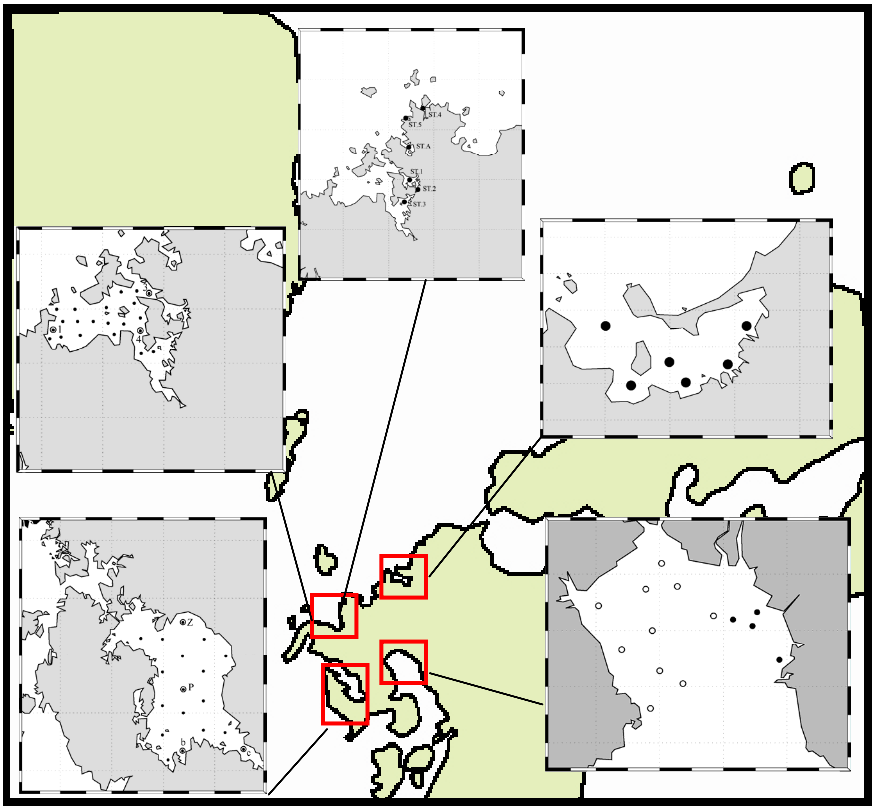


Figure 6-2 Locations of red tide monitoring sites in Japan

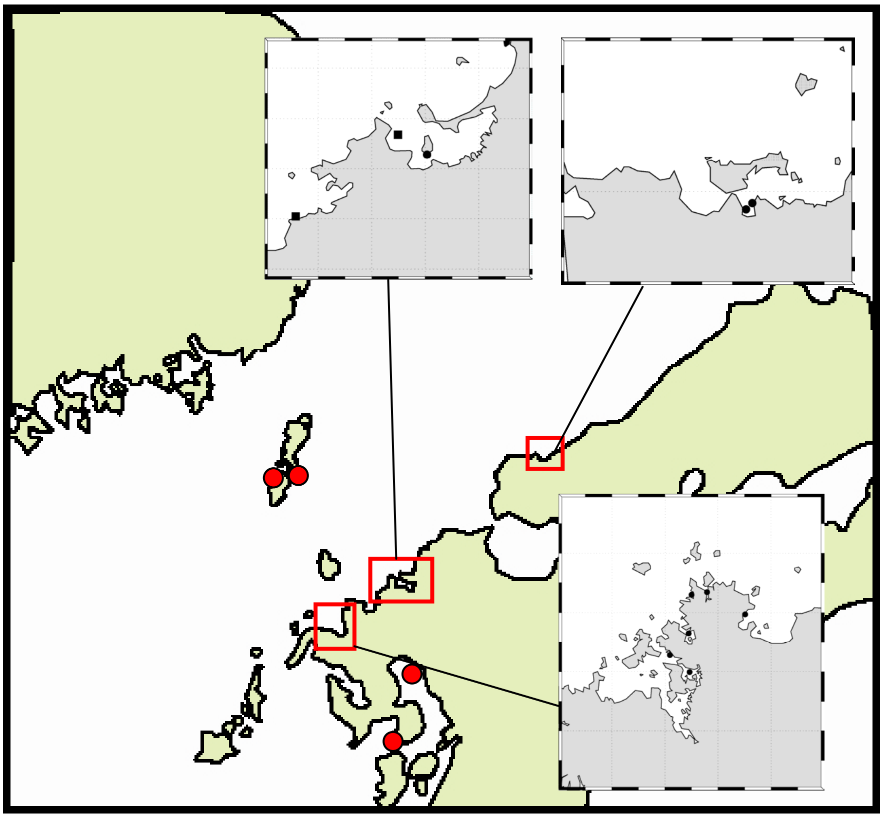


Figure 6-3 Locations of shellfish poisoning and toxin-producing plankton monitoring sites in Japan

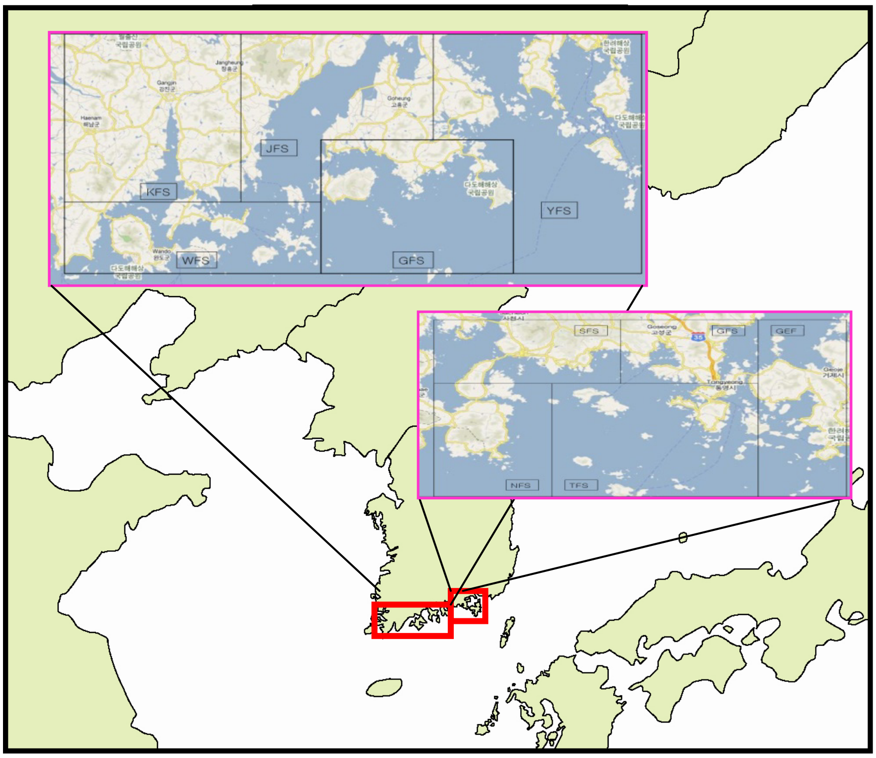


Figure 6-4 Locations of monitoring sites in Korea

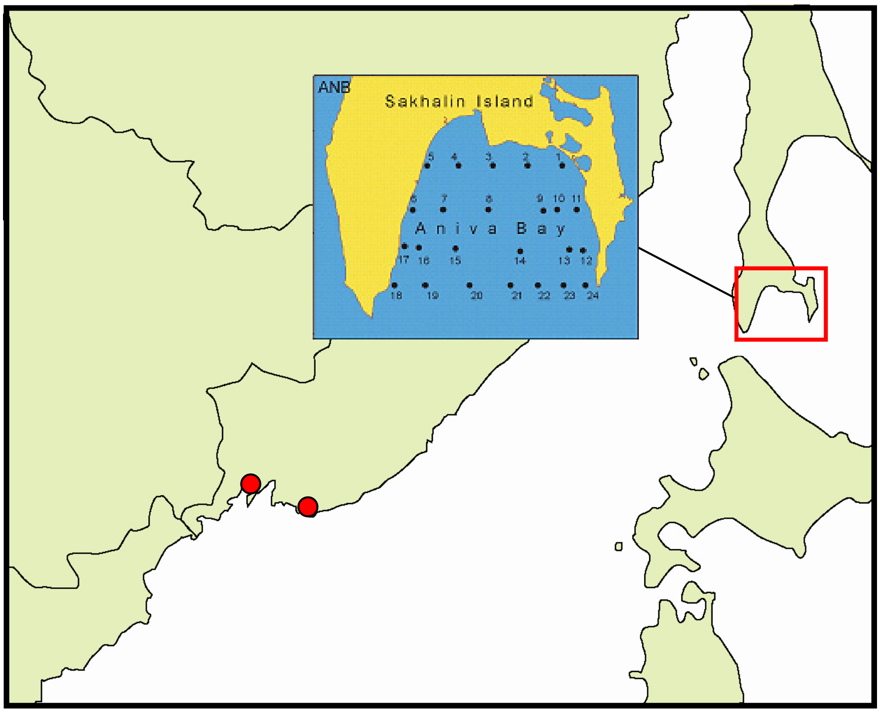


Figure 6-5 Location of monitoring sites in Russia

3 HAB occurrence in the NOWPAP region

The data on HAB occurrence in this report is based on the HAB Case Study Report made by each member state during 2008-2010. The period of data shown in this report is different among member states. The period of data in each member state is shown in Table 9. The difference is depended on the source of data, namely the year when the report on HAB occurrence in each member state is published.

Table 9 The period of data on HAB occurrence in the NOWPAP member states

Country	Period
China	1990 – 2009
Japan	2006 – 2008 (Northwestern sea area of Kyushu region), 2008 (Ariake Sea)
Korea	2007 – 2009
Russia	1991 – 2010 (Amurskii Bay), 2001 – 2009 (Vostok Bay), 2001 – 2002 (Aniva Bay)

3.1 Red tide occurrences in the NOWPAP region

Table 10 summaries the current status of red tide events in the NOWPAP region based on HAB Case Study Report of NOWPAP member states. 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, about 100 red-tide producing plankton species have been recorded in the NOWPAP Region (Table 11). In Table 11, red-tide plankton species observed in recent years (HAB Case Study Report) shown in parentheses.

Two flagellate species (*Heterosigma akashiwo, Noctiluca scintillans*) and one diatom species (*Skeletonema costatum*) had been recorded in the coastal waters of all the NOWPAP Members. All two of these flagellate species have caused extensive damage to local fisheries. Other common and damage-causing species include *Karenia mikimotoi*, *Akashiwo sanguinea* and *Prorocentrum micans* (all flagellates). *Cochlodinium polykrikoides* is one of concerned species which 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 (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.

Table 10 Summary of recent red-tide events in the NOWPAP Region

	China (Qingdao coastal area and Dalian coastal area)	Japan (Northwestern sea area of Kyushu region and Ariake Sea)	Korea (South coast of Korea)	Russia (Amurskii Bay, Vostok Bay and Aniva Bay)
Number of events	50 red-tide events from 1990–2009, of which 2 events led to fish-kills in Dalian coastal area.	1407 red-tide events recorded from 1979-2008, in which 122 events induced fishery damage. In this area, 278 red-tide events occurred during 2005-2008.	873 red-tide events recorded from 1995-2009, of which 209 events led to fish-kills in whole of Korean coast. In this area, 194 red-tide events occurred during 1995-2009.	41 red-tide events recorded. All events were harmless and caused no damage.
Causative species	See Table 11	See Table 11	See Table 11	See Table 11
Cell density	*Heterosigma akashiwo* recorded the highest density at 95,400cells/ml	The highest density is 173,000 cells/ml by multi-species red tide with *Heterocapsa rotundata* and *Amphidinium* sp.	In recent year, the low density of *Cochlodinium polykrikoides* bloom is observed, below 5,600 cells/ml. *Scrippsiella trochoidea* recorded the highest density at 15,000 cells/ml.	*Skeletonema costatum* recorded the highest density at 12,700 cells/ml in the Amurskii Bay.
Size of bloom	In Qingdao coastal area, *Mirionecta rubra* formed the largest red tide at 450km^2. In Dalian, the area of the largest red tide is 827km^2, however the causative species is unknown.	In the Ariake Sea, *Mirionecta rubra* formed the largest red tide at 171km^2. The area of other red tide events is less than 1km^2.	Large blooms were mostly by *C. polykrikoides* formed large bloom area about 40- 60 km^2.	There is no information on size of bloom.
Duration	Most red tides lasted less than 1 week. However, *Rhizosolenia delicatula* bloom lasted for 20 days in 2004.	Multi-species red tide with *Asterionella kariana* and *Skeltonema costatum* continued one month. Most of red tide events ended within one week.	The duration of *C. polykrikoides* bloom is 22-50 days in this area	The duration of *Prorocentrum triestinum* bloom is 76 days in the Amurskii Bay, however the duration of most of bloom less than 1 week in Vostok Bay and Aniva Bay.

Table 11 (1) Red-tide species recorded in the NOWPAP Region

Class	Genus and Species	China	Japan	Korea	Russia
Bacillariophyceae	*Asterionella* sp.		(✔)		
	Asterionellopsis glacialis				✔
	Chaetoceros curvisetum		(✔)		
	Chaetoceros socialis	(✔) ✔			
	Chaetoceros affinis				✔
	Chaetoceros contortus				✔
	Chaetoceros curvisetus				✔
	Chaetoceros salsugineus				✔
	Chaetoceros sp.	✔	(✔)	(✔)	
	Coscinodiscus asteromphalus	(✔) ✔			
	Coscinodiscus gigas			(✔)	
	Coscinodiscus sp.			(✔)	
	Ditylum brightwellii				(✔)
	Dactyliosolen fragilissimus				✔
	Eucampia zodiacus	(✔) ✔		(✔)	
	Eucampia sp.			(✔)	
	Leptocylindrus danicus	(✔)	(✔) ✔	(✔)	
	Leptocylindrus minimus				✔
	Leptocylindrus sp.		(✔)		
	Navicula sp.	(✔)		(✔)	
	Neodelphineis pelagic		(✔)		
	Nitzschia hybrid f. *hyaline*				✔
	Nitzschia sp.		(✔)		
	Pseudo-nitzschia calliantha				(✔) ✔
	Pseudo-nitzschia multiseries				(✔) ✔
	Pseudo-nitzschia pseudodelicatissima				(✔) ✔
	Pseudo-nitzschia pungens[*1]			(✔) ✔	(✔) ✔
	Pseudo-nitzschia delicatissima				✔
	Pseudo-nitzschia fraudulenta				✔
	Pseudo-nitzschia multistriata				✔
	Pseudo-nitzschia seriata				✔
	Pseudo-nitzschia sp.		(✔)		
	Rhizosolenia delicatula	✔	(✔)		
	Rhizosolenia fragilissima			(✔)	
	Rhizosolenia setigera			(✔)	
	Rhizosolenia sp.	(✔)	(✔) ✔	(✔)	
	Skeletonema costatum	(✔) ✔	(✔) ✔	(✔) ✔	(✔) ✔
	Skeletonema sp.		✔	(✔)	
	Thalassiosira decipiens			(✔)	
	Thalassiosira rotula			(✔)	
	Thalassiosira mala				✔
	Thalassiosira nordenskioeldii				✔
	Thalassiosira sp.	✔	(✔) ✔	(✔)	
	Thalassionema nitzschioides				✔
Cyanophyceae	*Microcystis virdis*			(✔)	

Table 11 (2) Red-tide species recorded in the NOWPAP Region

Class	Genus and Species	China	Japan	Korea	Russia
Dinophyceae	*Akashiwo sanguinea*			✔	
	Alexandrium catenella	(✔) ✔	(✔)		
	Alexandrium fraterculus		(✔)	✔	
	Alexandrium sp.			(✔)	
	Ceratium furca	(✔)	(✔) ✔	✔	
	Ceratium fusus		(✔)	(✔) ✔	
	Ceratium sp.			(✔)	
	Cochlodinium polykrikoides		(✔) ✔	(✔) ✔	
	Cochlodinium sp.		(✔)		
	Exuviaella marina	(✔)			
	Dinophysis ovata	(✔)			
	Scrippsiella trochoidea			(✔)	
	Scrippsiella sp.		✔		
Dinophyceae	*Gonyaulax spinifera*	(✔) ✔			
	Gonyaulax polygramma			✔	
	Karenia mikimotoi	(✔)	(✔) ✔	(✔)	
	Akashiwo sanguinea	(✔)	(✔) ✔	(✔) ✔	
	Gymnodinium instriatum		✔		
	Gymnodinium sp.			(✔)	
	Gyrodinium sp.	(✔)	(✔)		
	Heterocapsa circularisquama		(✔) ✔		
	Heterocapsa sp.	✔		(✔)	
	Heterocapsa triquetra			(✔) ✔	
	Heterocapsa rotundata				✔
	Noctiluca scintillans[*2]	(✔) ✔	(✔) ✔	(✔) ✔	(✔) ✔
	Noctiluca sp.		✔		
	Oxyrrhis marina				(✔)
	Prorocentrum balticum		(✔)		
	Prorocentrum dentatum		(✔) ✔	(✔) ✔	
	Prorocentrum micans	(✔)	(✔)	(✔)	
	Prorocentrum minimum	(✔)	(✔) ✔	(✔) ✔	(✔) ✔
	Prorocentrum sigmoides		(✔) ✔		
	Prorocentrum triestinum		(✔) ✔	(✔) ✔	✔
	Prorocentrum sp.		✔	(✔) ✔	
	Protoceratium reticulatum				✔
Raphidophyceae	*Chattonella antiqua*	(✔) ✔	(✔) ✔		
	Chattonella globosa				(✔) ✔
	Chattonella marina	(✔) ✔	(✔)		
	Chattonella sp.				✔
	Fibrocapsa japonica		(✔)		
	Heterosigma akashiwo[*3]	(✔) ✔	(✔) ✔	(✔) ✔	(✔) ✔
Chrysophyceae	*Dictyocha fibula*		✔	(✔)	
	Dinobryon balticum				✔
Eugrenophyceae	*Eutreptia lanowii*				(✔)
	Eutreptiella gymnastica		(✔)	(✔)	(✔)
	Eutreptiella sp.			(✔)	
	Euglena pascheri				✔
Haptophyceae	*Phaeocystis sp.*	(✔)			

Table 11 (3) Red-tide species recorded in the NOWPAP Region

Class	Genus and species	China	Japan	Korea	Russia
Cryptophyceae	*Chroomonas marina*			(✔)	
	Chroomonas salina			(✔)	
	Cryptomonas acuta			(✔)	
	Cryptomonas sp.			(✔)	
	Plagioselmis sp.				✔
Prasinophyceae	*Pyramimonas* sp.		(✔)		
Prumnesiophycidae	*Gephyrocapsa oceanica*		✔		
Ciliate	*Mirionecta rubra*	(✔) ✔	(✔) ✔	(✔) ✔	
	Tontonia sp.		(✔)		

The parenthesize parts indicate the species reported in the last HAB Integrated Report.

*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*.

*3: *Since 2000, the species which had been considered to be part of Gymnodinium have been divided into several genera, based on the nature of the apical groove and biochemistry*.

3.1.1 Red tides in China

In North Yellow Sea, 50 red tide events have been observed since 1990. 42 of them are observed in target sea area. In these events, fishery damage is only two cases.

During 1990-2008, 29 red tide events were recorded in Qingdao coastal area (Table 12). Most frequently observed species were *Mirionecta rubra* and *Skeletonema costatum*.

In recent years, red tide occurrence area expanded. Jiaozhou Bay is major area during 90's, however, Fushan Bay became to another main area from early years of 21st century, moreover, in recent 5-6 years, the area expanded from western part (Lingshan Bay) to eastern part (Shazikou Bay) of Qingdao coastal area.

Table 12 Recent red tide occurrence in Qingdao coastal area

Occurrence date	Occurrence location	Causative species	Occurrence area
26 June, 1990	Jiaozhou Bay	*Mirionecta rubra*	$2km^2$
April, 1992	Jiaozhou Bay	-	-
12 May, 1992	East Qingdao area	-	-
August, 1992	Jiaozhou Bay	-	-
August, 1997	Center of Jiaozhou Bay	*Skeletonema costatum*	- (small)
3-8 July, 1998	Northeast part of Jiaozhou Bay	*Skeletonema costatum*	$10km^2$
8-15 June, 1999	Northeast part of Jiaozhou Bay	*Eucampia zodicacus*	- (small)
23-24 July, 1999	Jiaozhou Bay	*Skeletonema costatum*	$26km^2$
26 July, 1999	Fushan Bay	*Mirionecta rubra*	$60km^2$
20-23 July, 2000	Center of Jiaozhou Bay	*Noctiluca scintillans*	$92km^2$
4 April, 2001	Fushan Bay	*Noctiluca scintillans*	- (small)
11-12 June, 2001	Jiaozhou Bay	*Noctiluca scintillans*	$5km^2$
7-13 July, 2001	Mouth of Jiaozhou Bay	*Mirionecta rubra*	$9.8km^2$
28 Jun.-2 Jul., 2002	Fushan Bay	*Mirionecta rubra*	$60km^2$
July, 2003	Jiaozhou Bay	*Coscinodiscus asteromphalus*	$200km^2$
4-10 July, 2003	Tuandao Bay, Huiquan Bay	*Mirionecta rubra*	$450km^2$
February, 2004	Northeast part of Jiaozhou Bay	*Guinaradia delicatula*	- (small)
9-28 Feb., 2004	East part of Jiaozhou Bay	*Rhizosolenia delicatula*	$70km^2$
22-25 Mar., 2004	Northeast part of Jiaozhou Bay	*Thalassiosira nordenskÖldii*	$70km^2$
July, 2004	North part of Jiaozhou Bay	*Coscinodiscus asteromphalus*	- (small)
10 August, 2004	Fushan Bay	*Mirionecta rubra*	$50km^2$
12-17 June, 2005	Lingshan Bay	*Heterosigma akashiwo*	$80km^2$
August, 2006	Fushan Bay	*Mirionecta rubra*	$5km^2$
7- 10 June, 2007	Shazikou Bay	*Heterosigma akashiwo*	$70km^2$
20-23 Aug., 2007	Eastern coastal area	*Skeletonema costatum*	$15km^2$
25 -28 Sep., 2007	Shazikou Bay	*Gonyaulax spinifera*	$8km^2$
28-29 June, 2008	Jiaozhou Bay	*Heterocapsa sp.*	$5km^2$
7-8 Aug., 2008	Southern coastal area	*Chattonella antiqua*	$86km^2$
26 August, 2008	Fushan Bay	*Noctiluca scintillans*	$10km^2$

There are 13 red tide events occurred in Dalian coastal area since 1990 (Table 13). The dominant species in this area is *Noctiluca scintillans*. In Dalian, two bloom events caused by toxin-producing plankton, *Exuviaella marina* and *Alexandrium catenella* were occurred.

Dalian Bay and its surrounding were main red tide affected areas before 2000, however, Zhuanghe area became to another essential affected area in recent years.

Table 13 Recent red tide occurrence in Dalian coastal area

Occurrence date	Occurrence location	Causative species	Occurrence area
1990	Changhai area	-	-
11 August, 1993	Dalian Bay	-	40km^2
July, 1999	Dalian Bay	*Exuviaella marina*	
17-21 July, 1999	Dalian Bay	*Noctiluca scintillans*	100km^2
2 August, 2000	Zhuanghe area	-	827km2
6 September, 2004	Jinshatan	*Chattonella marina*	-
25 September, 2004	Jinshatan	*Alexandrium catenella*	-
25 June, 2005	Caotun area	*Noctiluca scintillans*	-
26 Aug.-3 Sep., 2005	Zhuanghe area	*Chaetoceros affinis*	16km^2
29 Aug.-2 Sep., 2005	Zhuanghe area	*Chaetoceros affinis*	16km^2
8 May, 2006	Zhuanghe area	*Noctiluca scintillans*	20km^2
27 February, 2008	Dalian Bay	*Thalassiosira nordenskioeldii, Skeletonema costatum*	108km^2
August, 2008	Xianghai Bay	*Chattonella marina*	5km^2

In target sea areas, the number of red tide events has increased significantly in recent years than before. Figure 7 shows the yearly trend of red tide events in these areas from 1990 to 2008. From 1999, the number of red tide events dramatically increased. 80% of red tide events occurred during June-August in Qingdao region, 75% of events occurred during July-September in Dalian, respectively. Locations of red tide events in recent years are shown in Figure 8.

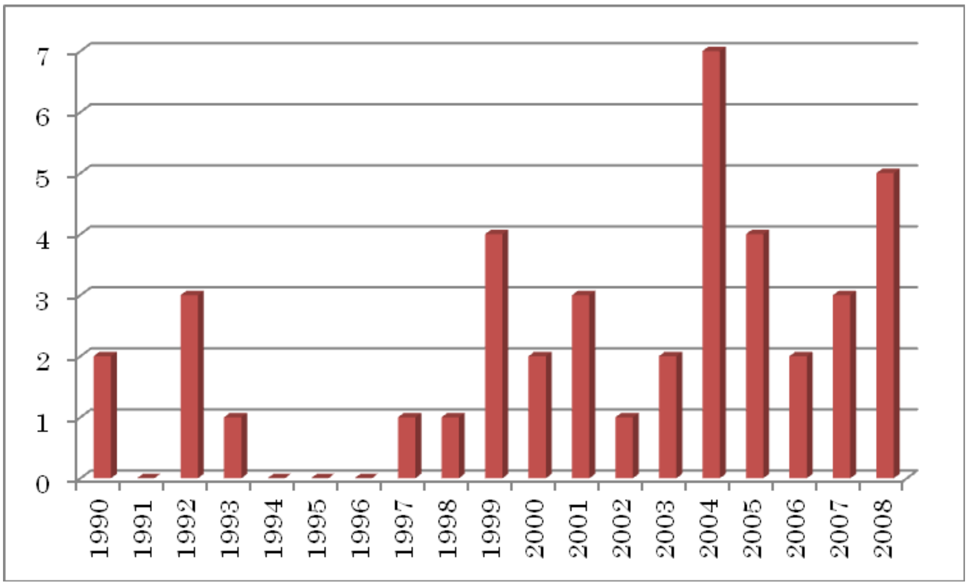


Figure 7 Yearly trend of red tide events in target sea areas

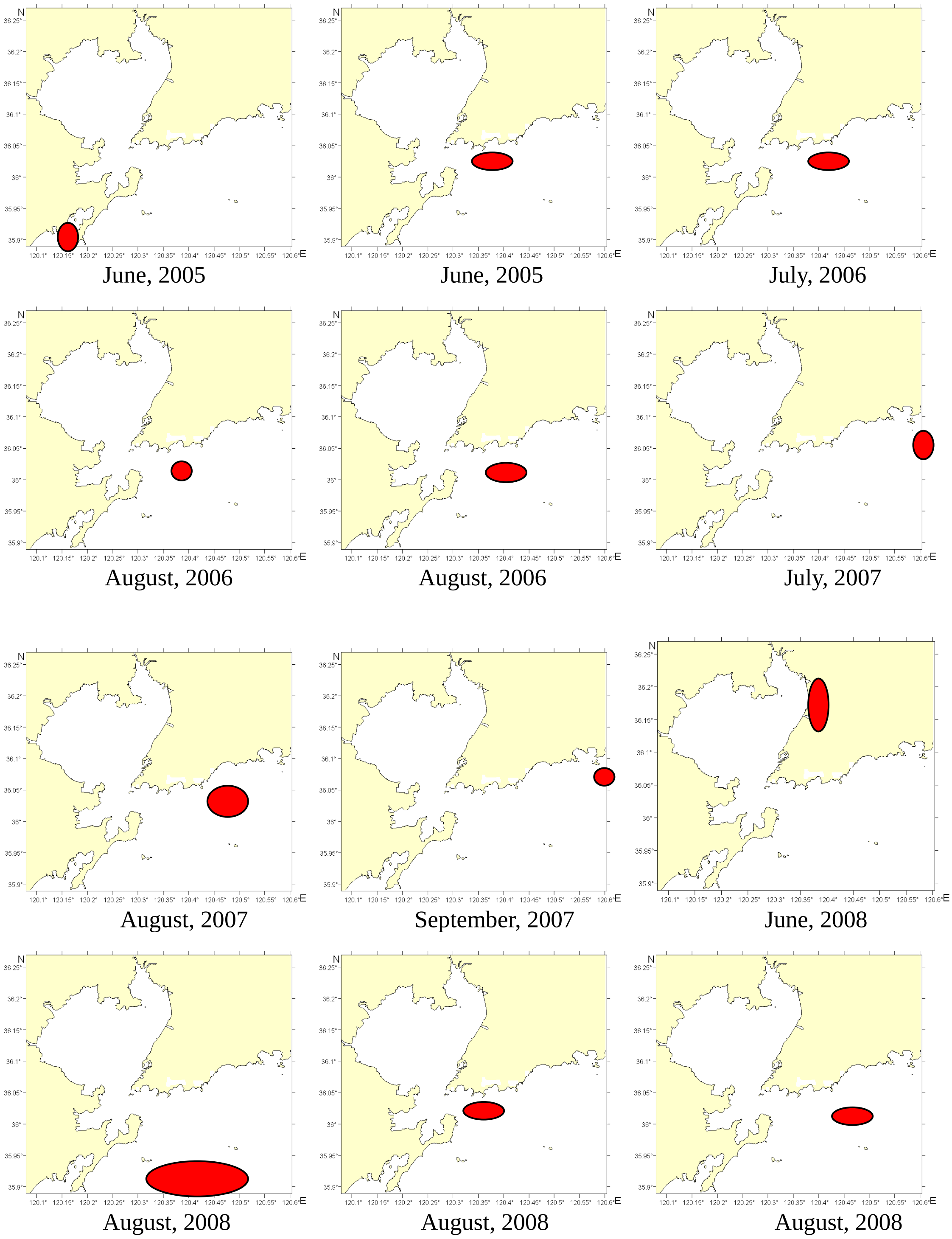


Figure 8 (1) Locations of red tide events in Qingdao coastal area

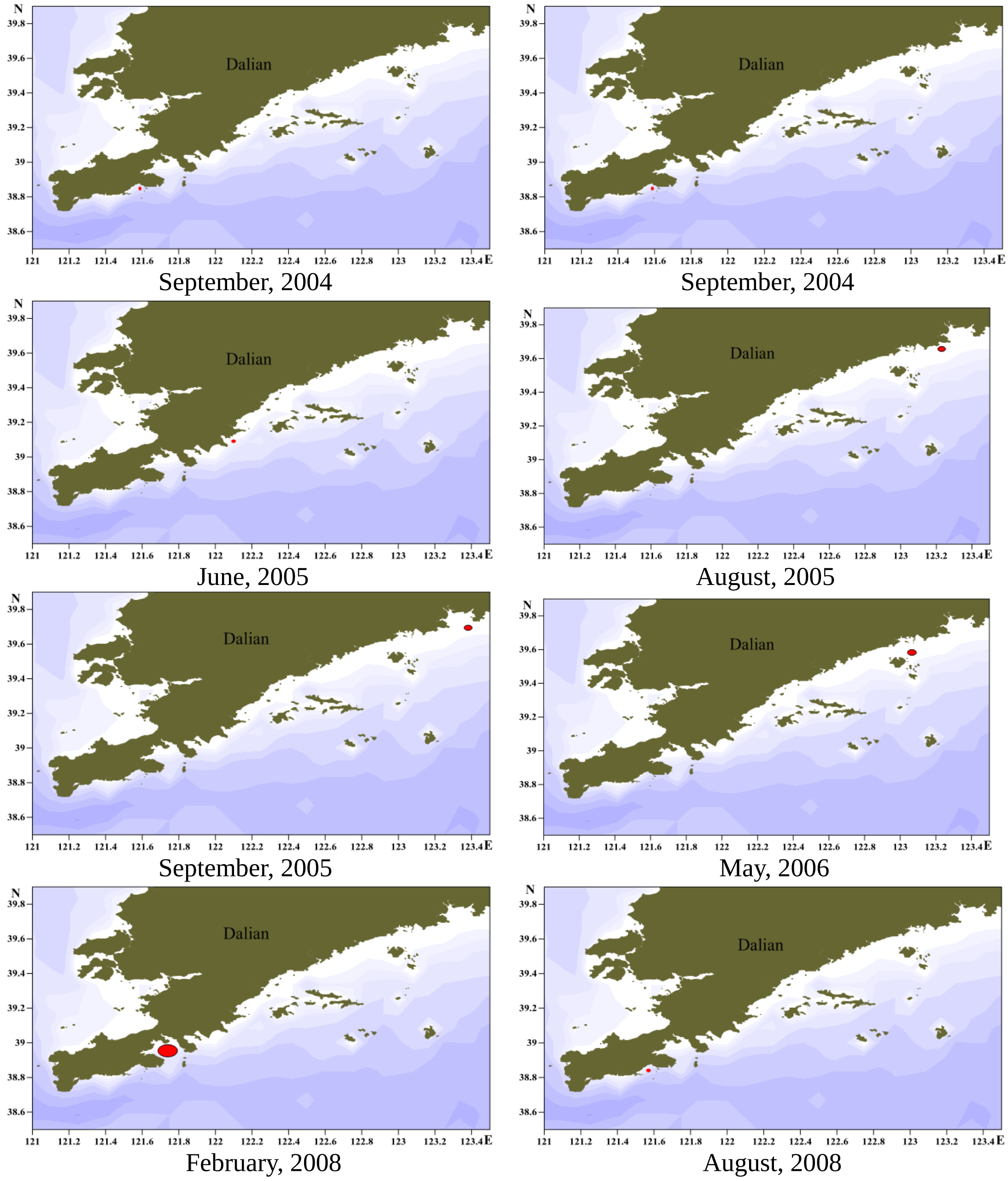


Figure 8 (2) Locations of red tide events in Dalian coastal area

3.1.2 Red tides in Japan

1,407 red tide events have been observed since 1979 in the northwestern sea area of Kyushu region, in which 122 events induced fishery damage. Figure 9 shows the number of red tide events by year. The annual number of red tide events fluctuated between 29-92 events, and was highest in 1980. During 2005-2008, 278 red tide events occurred in this area. 45% of them is occurred in the Ariake Sea. Figure 10 shows the location of red tide in the northwestern sea area of Kyushu region and the Ariake Sea during 3006-2008.

In regards to the red tide species that are known to induce fishery damage, *Cochlodinium polykrikoides* was recorded 42 times and its frequency has increased over recent years. *Karenia mikimotoi* was recorded 157 times and has been constantly being recorded from 1979-2008. *Heterocapsa circularisquama* was recorded 17 times and was all after 1996. *Chattonella antique* was recorded 12 times and was all after 1990. In 2008, fishery damage is small, economic loss is less than one million Japanese yen, however, fishery damage is over 15 million Japanese yen in 2006 and 2007. In recent years, *Karenia mikimotoi* is concerned red tide species which induced huge fishery damage.

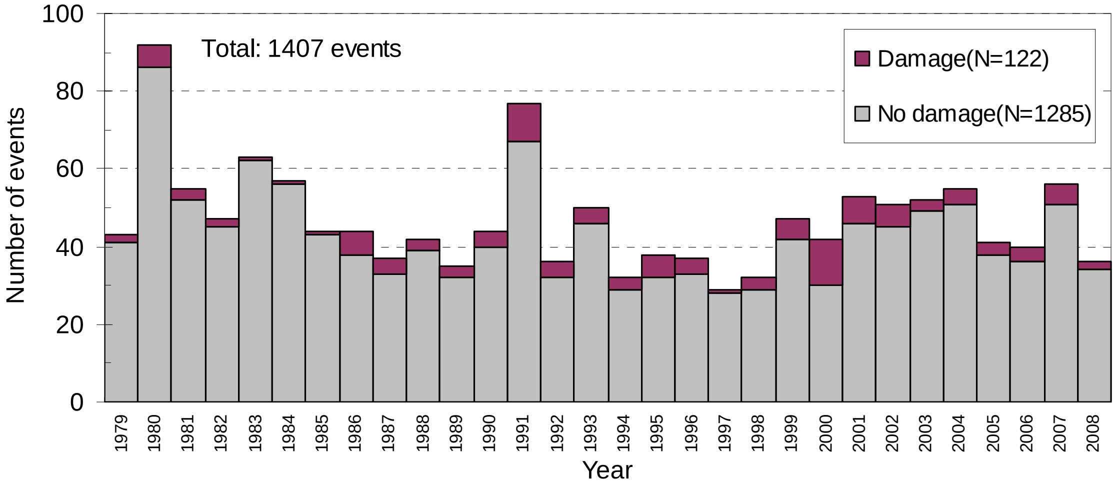
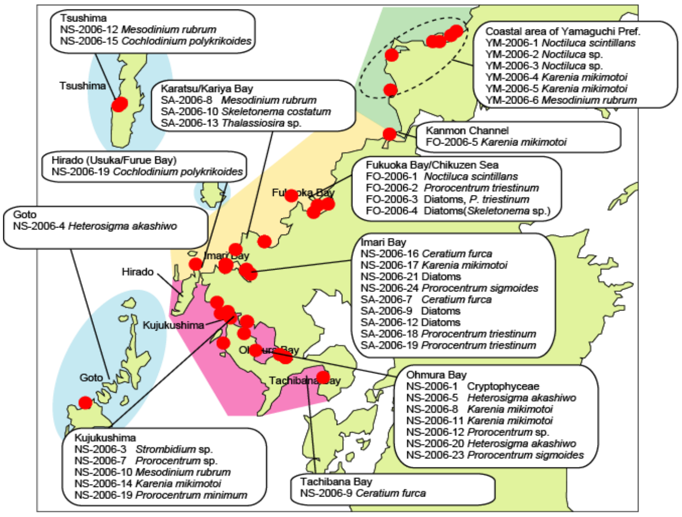
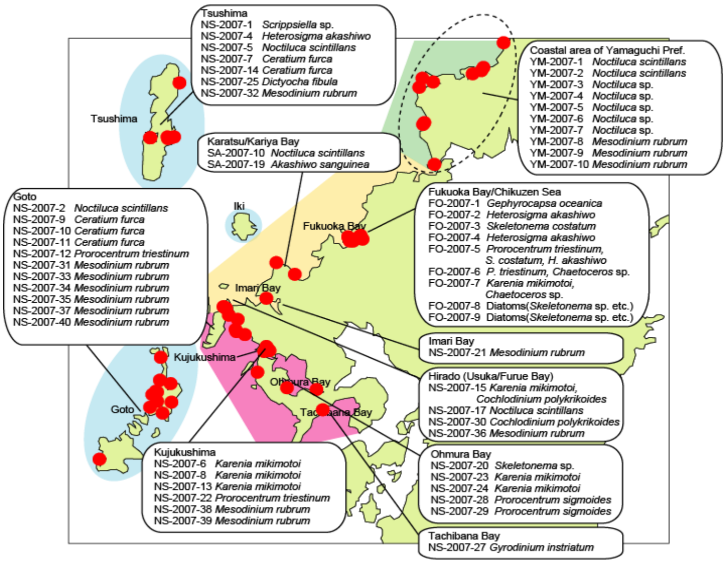


Figure 9 Yearly trend of red tide events in target sea area


Tsushima
NS-2006-12 Mesodinium rubrum
NS-2006-15 Cochlodinium polykrikoides
Coastal area of Yamaguchi Pref.
YM-2006-1 Noctiluca scintillans
YM-2006-2 Noctiluca sp.
YM-2006-3 Noctiluca sp.
YM-2006-4 Karenia mikimotoi
YM-2006-5 Karenia mikimotoi
YM-2006-6 Mesodinium rubrum
Tsushima
Karatsu/Kariya Bay
SA-2006-8 Mesodinium rubrum
SA-2006-10 Skeletonema costatum
SA-2006-13 Thalassiosira sp.
Kanmon Channel
FO-2006-5 Karenia mikimotoi
Hirado (Usuka/Furue Bay)
NS-2006-19 Cochlodinium polykrikoides
Fukuoka Bay/Chikuzen Sea
FO-2006-1 Noctiluca scintillans
FO-2006-2 Prorocentrum triestinum
FO-2006-3 Diatoms, P. triestinum
FO-2006-4 Diatoms(Skeletonema sp.)
Goto
NS-2006-4 Heterosigma akashiwo
Fukuoka Bay
Imari Bay
NS-2006-16 Ceratium furca
NS-2006-17 Karenia mikimotoi
NS-2006-21 Diatoms
NS-2006-24 Prorocentrum sigmoides
SA-2006-7 Ceratium furca
SA-2006-9 Diatoms
SA-2006-12 Diatoms
SA-2006-18 Prorocentrum triestinum
SA-2006-19 Prorocentrum triestinum
Imari Bay
Hirado
Kujukushima
Ohmura Bay
Goto
Tachibana Bay
Ohmura Bay
NS-2006-1 Cryptophyceae
NS-2006-5 Heterosigma akashiwo
NS-2006-8 Karenia mikimotoi
NS-2006-11 Karenia mikimotoi
NS-2006-12 Prorocentrum sp.
NS-2006-20 Heterosigma akashiwo
NS-2006-23 Prorocentrum sigmoides
Kujukushima
NS-2006-3 Strombidium sp.
NS-2006-7 Prorocentrum sp.
NS-2006-10 Mesodinium rubrum
NS-2006-14 Karenia mikimotoi
NS-2006-19 Prorocentrum minimum
Tachibana Bay
NS-2006-9 Ceratium furca


Tsushima
NS-2007-1 Scrippsiella sp.
NS-2007-4 Heterosigma akashiwo
NS-2007-5 Noctiluca scintillans
NS-2007-7 Ceratium furca
NS-2007-14 Ceratium furca
NS-2007-25 Dictyocha fibula
NS-2007-32 Mesodinium rubrum
Coastal area of Yamaguchi Pref.
YM-2007-1 Noctiluca scintillans
YM-2007-2 Noctiluca scintillans
YM-2007-3 Noctiluca sp.
YM-2007-4 Noctiluca sp.
YM-2007-5 Noctiluca sp.
YM-2007-6 Noctiluca sp.
YM-2007-7 Noctiluca sp.
YM-2007-8 Mesodinium rubrum
YM-2007-9 Mesodinium rubrum
YM-2007-10 Mesodinium rubrum
Tsushima
Karatsu/Kariya Bay
SA-2007-10 Noctiluca scintillans
SA-2007-19 Akashiwo sanguinea
Goto
NS-2007-2 Noctiluca scintillans
NS-2007-9 Ceratium furca
NS-2007-10 Ceratium furca
NS-2007-11 Ceratium furca
NS-2007-12 Prorocentrum triestinum
NS-2007-31 Mesodinium rubrum
NS-2007-33 Mesodinium rubrum
NS-2007-34 Mesodinium rubrum
NS-2007-35 Mesodinium rubrum
NS-2007-37 Mesodinium rubrum
NS-2007-40 Mesodinium rubrum
Iki
Fukuoka Bay
Fukuoka Bay/Chikuzen Sea
FO-2007-1 Gephyrocapsa oceanica
FO-2007-2 Heterosigma akashiwo
FO-2007-3 Skeletonema costatum
FO-2007-4 Heterosigma akashiwo
FO-2007-5 Prorocentrum triestinum, S. costatum, H. akashiwo
FO-2007-6 P. triestinum, Chaetoceros sp.
FO-2007-7 Karenia mikimotoi, Chaetoceros sp.
FO-2007-8 Diatoms(Skeletonema sp. etc.)
FO-2007-9 Diatoms(Skeletonema sp. etc.)
Imari Bay
Imari Bay
NS-2007-21 Mesodinium rubrum
Kujukushima
Hirado (Usuka/Furue Bay)
NS-2007-15 Karenia mikimotoi, Cochlodinium polykrikoides
NS-2007-17 Noctiluca scintillans
NS-2007-30 Cochlodinium polykrikoides
NS-2007-36 Mesodinium rubrum
Ohmura Bay
Goto
Tachibana Bay
Kujukushima
NS-2007-6 Karenia mikimotoi
NS-2007-8 Karenia mikimotoi
NS-2007-13 Karenia mikimotoi
NS-2007-22 Prorocentrum triestinum
NS-2007-38 Mesodinium rubrum
NS-2007-39 Mesodinium rubrum
Ohmura Bay
NS-2007-20 Skeletonema sp.
NS-2007-23 Karenia mikimotoi
NS-2007-24 Karenia mikimotoi
NS-2007-28 Prorocentrum sigmoides
NS-2007-29 Prorocentrum sigmoides
Tachibana Bay
NS-2007-27 Gyrodinium instriatum

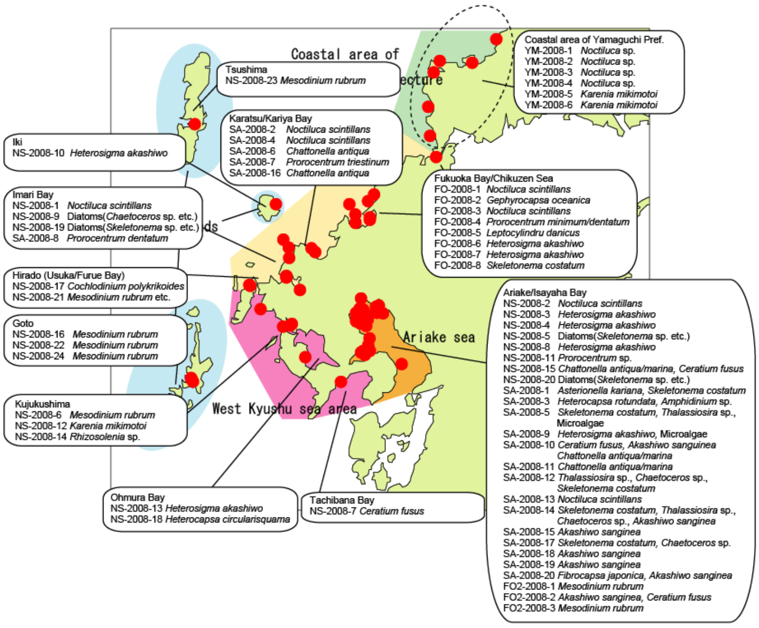
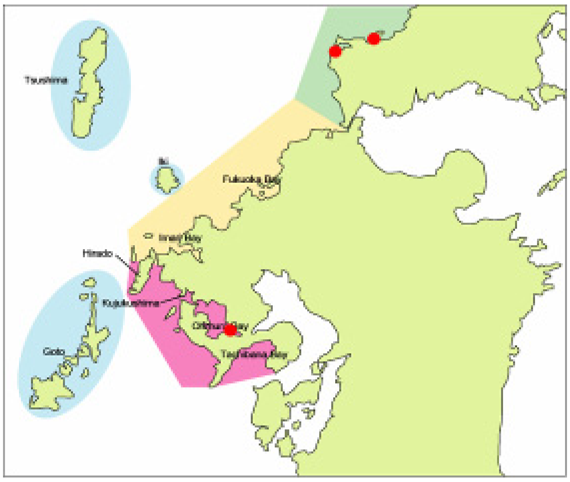
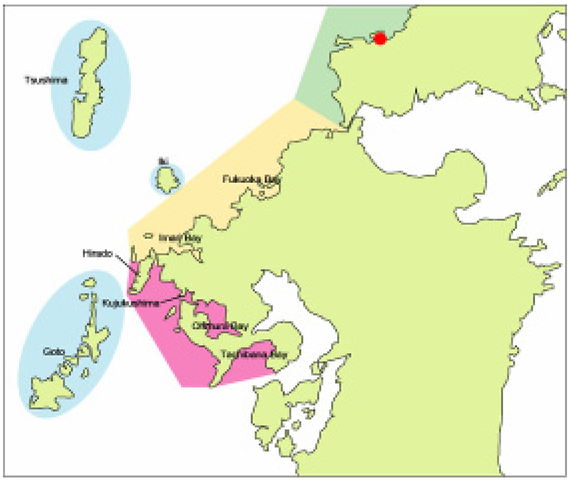

Coastal area of
Tsushima
NS-2008-23 Mesodinium rubrum
ecture
Coastal area of Yamaguchi Pref.
YM-2008-1 Noctiluca sp.
YM-2008-2 Noctiluca sp.
YM-2008-3 Noctiluca sp.
YM-2008-4 Noctiluca sp.
YM-2008-5 Karenia mikimotoi
YM-2008-6 Karenia mikimotoi
Iki
NS-2008-10 Heterosigma akashiwo
Karatsu/Kariya Bay
SA-2008-2 Noctiluca scintillans
SA-2008-4 Noctiluca scintillans
SA-2008-6 Chattonella antiqua
SA-2008-7 Prorocentrum triestinum
SA-2008-16 Chattonella antiqua
Fukuoka Bay/Chikuzen Sea
FO-2008-1 Noctiluca scintillans
FO-2008-2 Gephyrocapsa oceanica
FO-2008-3 Noctiluca scintillans
FO-2008-4 Prorocentrum minimum/dentatum
FO-2008-5 Leptocylindru danicus
FO-2008-6 Heterosigma akashiwo
FO-2008-7 Heterosigma akashiwo
FO-2008-8 Skeletonema costatum
Imari Bay
NS-2008-1 Noctiluca scintillans
NS-2008-9 Diatoms(Chaetoceros sp. etc.)
NS-2008-19 Diatoms(Skeletonema sp. etc.)
SA-2008-8 Prorocentrum dentatum
ds
Hirado (Usuka/Furue Bay)
NS-2008-17 Cochlodinium polykrikoides
NS-2008-21 Mesodinium rubrum etc.
Ariake/Isayaha Bay
NS-2008-2 Noctiluca scintillans
NS-2008-3 Heterosigma akashiwo
NS-2008-4 Heterosigma akashiwo
NS-2008-5 Diatoms(Skeletonema sp. etc.)
NS-2008-8 Heterosigma akashiwo
NS-2008-11 Prorocentrum sp.
NS-2008-15 Chattonella antiqua/marina, Ceratium fusus
NS-2008-20 Diatoms(Skeletonema sp. etc.)
SA-2008-1 Asterionella kariana, Skeletonema costatum
SA-2008-3 Heterocapsa rotundata, Amphidinium sp.
SA-2008-5 Skeletonema costatum, Thalassiosira sp., Microalgae
SA-2008-9 Heterosigma akashiwo, Microalgae
SA-2008-10 Ceratium fusus, Akashiwo sanguinea Chattonella antiqua/marina
SA-2008-11 Chattonella antiqua/marina
SA-2008-12 Thalassiosira sp., Chaetoceros sp., Skeletonema costatum
SA-2008-13 Noctiluca scintillans
SA-2008-14 Skeletonema costatum, Thalassiosira sp., Chaetoceros sp., Akashiwo sanginea
SA-2008-15 Akashiwo sanginea
SA-2008-17 Skeletonema costatum, Chaetoceros sp.
SA-2008-18 Akashiwo sanginea
SA-2008-19 Akashiwo sanginea
SA-2008-20 Fibrocapsa japonica, Akashiwo sanginea
FO2-2008-1 Mesodinium rubrum
FO2-2008-2 Akashiwo sanginea, Ceratium fusus
FO2-2008-3 Mesodinium rubrum
Goto
NS-2008-16 Mesodinium rubrum
NS-2008-22 Mesodinium rubrum
NS-2008-24 Mesodinium rubrum
Ariake sea
Kujukushima
NS-2008-6 Mesodinium rubrum
NS-2008-12 Karenia mikimotoi
NS-2008-14 Rhizosolenia sp.
West Kyushu sea area
Ohmura Bay
NS-2008-13 Heterosigma akashiwo
NS-2008-18 Heterocapsa circularisquama
Tachibana Bay
NS-2008-7 Ceratium fusus

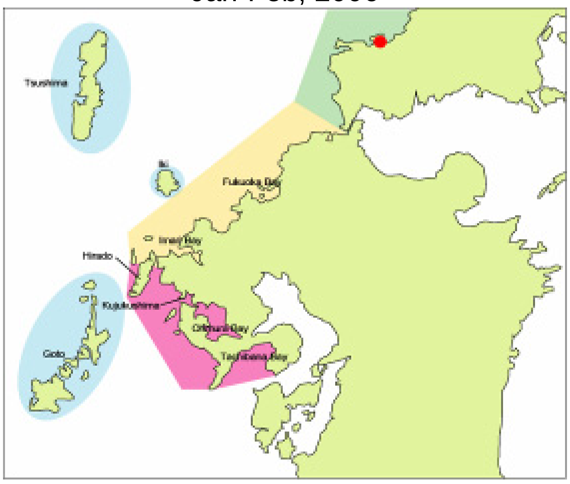
Figure 10 (1) Location of red tide from 2006 to 2008 in target sea area



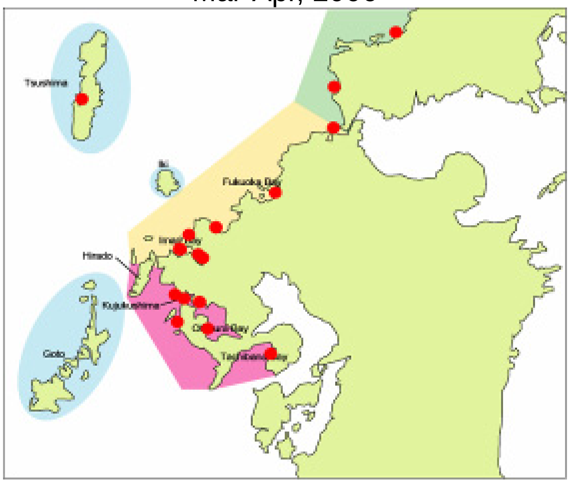
Jan-Feb, 2006



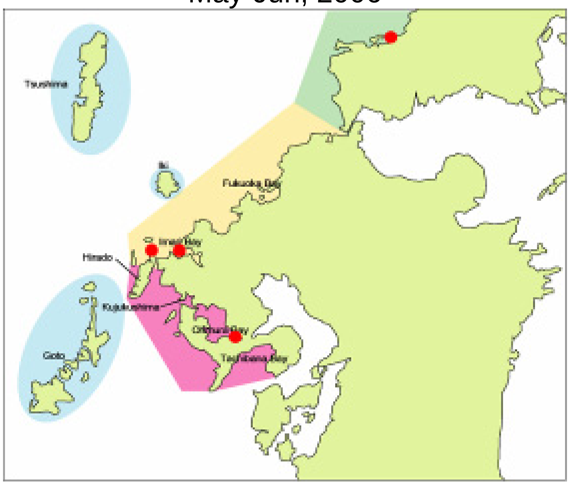
Mar-Apr, 2006



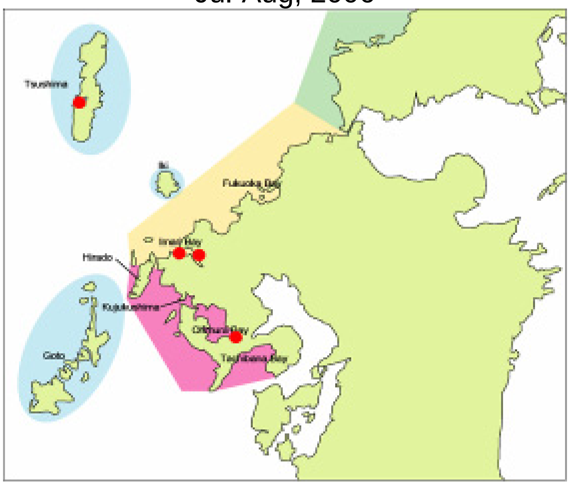
May-Jun, 2006



Jul-Aug, 2006



Sep-Oct, 2006



Nov-Dec, 2006

Figure 10-1 Location of red-tide events by months in 2006

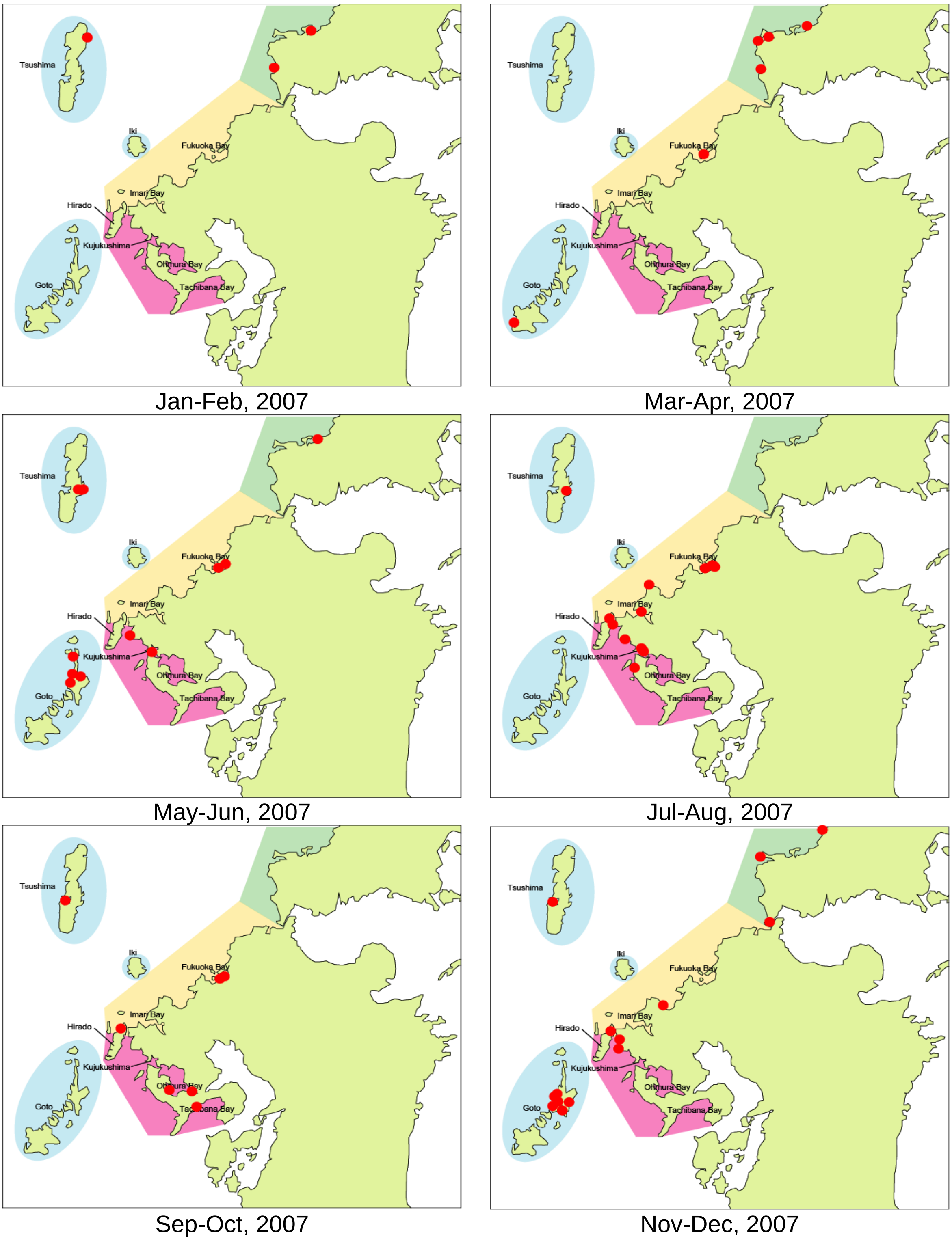
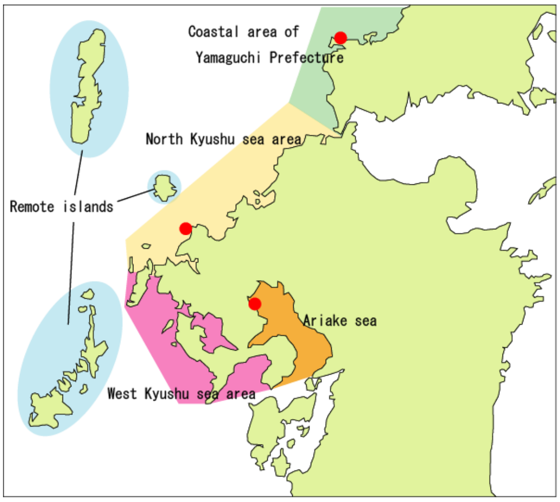
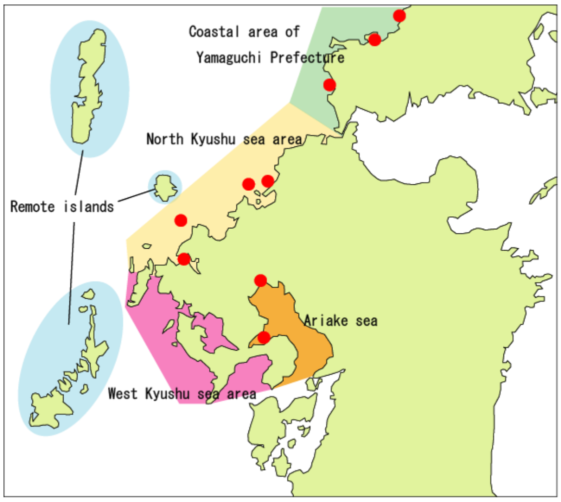


Figure 10-2 Location of red-tide events by months in 2007



Jan-Feb, 2008



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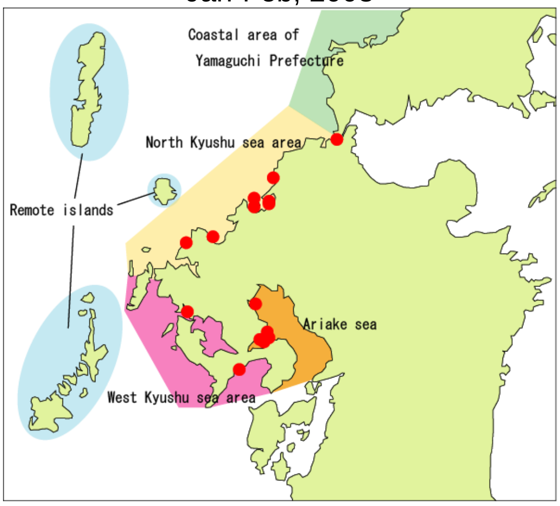
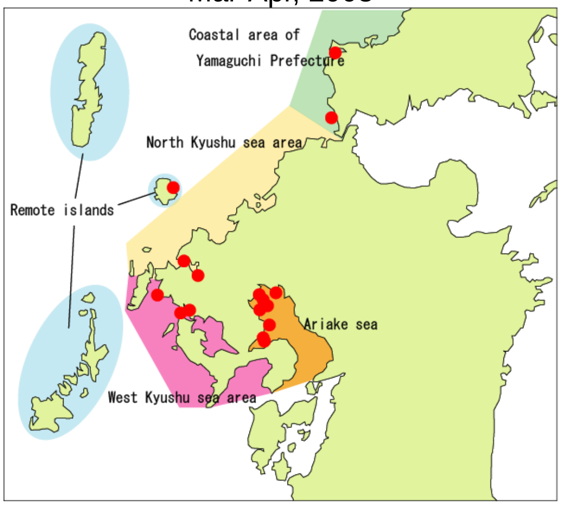
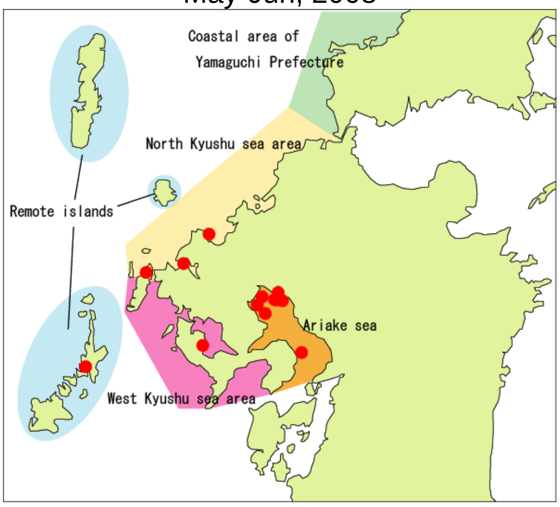


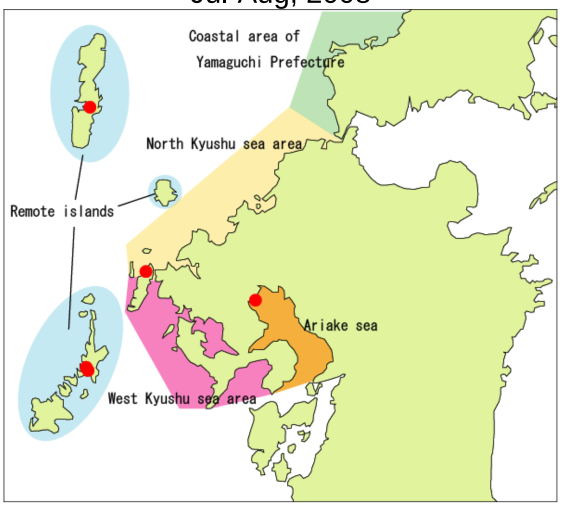
May-Jun, 2008



Jul-Aug, 2008



Sep-Oct, 2008



Nov-Dec, 2008

Figure 10-3 Location of red-tide events by months in 2008

3.1.3 Red tides in Korea

In whole of Korean coast, 873 red tide events have been observed since 1995. 179 of them are observed in target sea area. However, the number of red tide has sharply decreased since 2005 with showing less than 6 events a year (Figure 11). In recent year, *C. polykrikoides* blooms clearly decrease and there has not been any fish kill in target sea area since 2008.

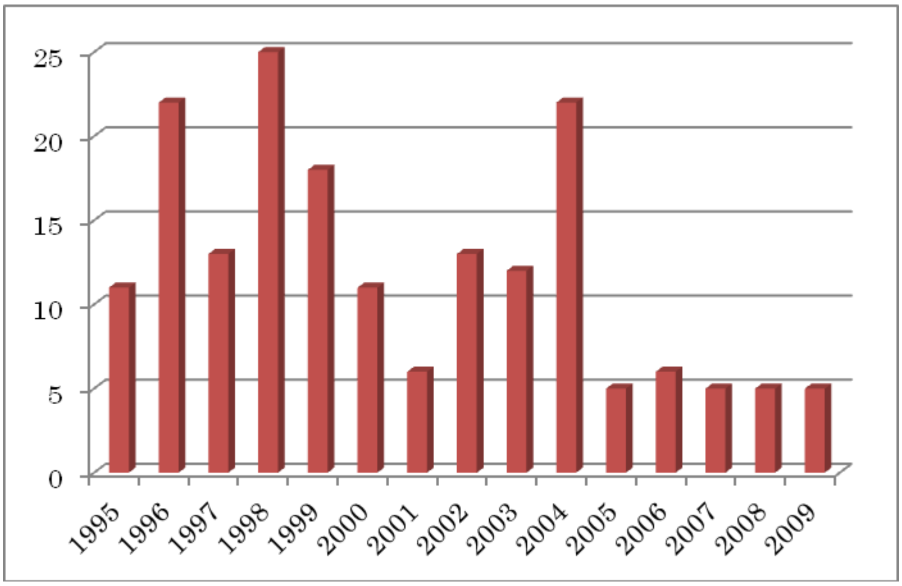


Figure 11 Yearly trend of red tide events in target sea areas

During 2007-2009, 16 red tide events were recorded in south coast of Korea (Table 14). Most frequently observed species was *C. polykrikoides* (9 events).

Table 14 Recent red tide occurrence in south coast of Korea

Occurrence date	Occurrence location	Causative species	Occurrence area
24-30 July, 2007	Tongyeong Dosan	*Akashiwo sanguinea*	-
6 Aug.-15 Sep., 2007	Namhae Mizo	*C. polykrikoides*	50 km^2
9 Aug.-12 Sep., 2007	Tongyeong Sarang Suyou-do	*C. polykrikoides*	70 km^2
11 Aug.-1 Sep., 2007	Goseong Bay	*C. polykrikoides*	3 km^2
3-9 September, 2007	Jinju Bay	*C. polykrikoides*	2 km^2
19-29 October, 2007	Upper Sarang-do	*C. polykrikoides*	2 km^2
4 Aug.-23 Sep., 2008	Tongyeong Dosan	*C. polykrikoides*	40 km^2
8 Aug.-22 Sep., 2008	Namhae Mizo	*C. polykrikoides*	60km^2
16-25 Sep., 2008	Tongyeong Sarang Suyou-do	*C. polykrikoides*	60km^2
29 Aug.-5 Sep., 2008	Goseong Bay	*C. polykrikoides*	3km^2
11-20 Sep., 2008	Jinju Bay	*C. polykrikoides*	2km^2
August 2009	Donghae-myeon	*C. furca*	0.8km^2
11-19 August, 2009	Nam-myeon	*A. fraterculus*	2km^2
11-13 August, 2009	Tae-do	*G. polygramma*	3km^2
24-26 August, 2009	Chilcheon-do	*S. trochoidea*	2km^2
1-9 November, 2009	Sandong eunjeom	*Gymnodinium.* sp.	0.5km^2

In target sea areas, more than 60% of red tide events occurred both in July and August. *C. polykrikoides* was major species in this period. Another fish killing species, *Chattonella* spp. has

made bloom in west coast from July to August. Duration of red tide events was 5-50 days in the target area. The duration showed a big difference depending on causative species: 22-50 days in *C. polykrikoides* and 5-11 days in other dinoflagellates. Longer duration of *C. polykrikoides* than any other dinoflagellate was estimated to be related to longer duration of available nutrients in the offshore where nutrients is consistently supplied by currents. Moreover, patches of *C. polykrikoides* spread to neighboring areas by wind or currents where available nutrients are abundant.
Figure 12-1, -4 show the spatial distribution of red tide affected area from 2007 to 2009.

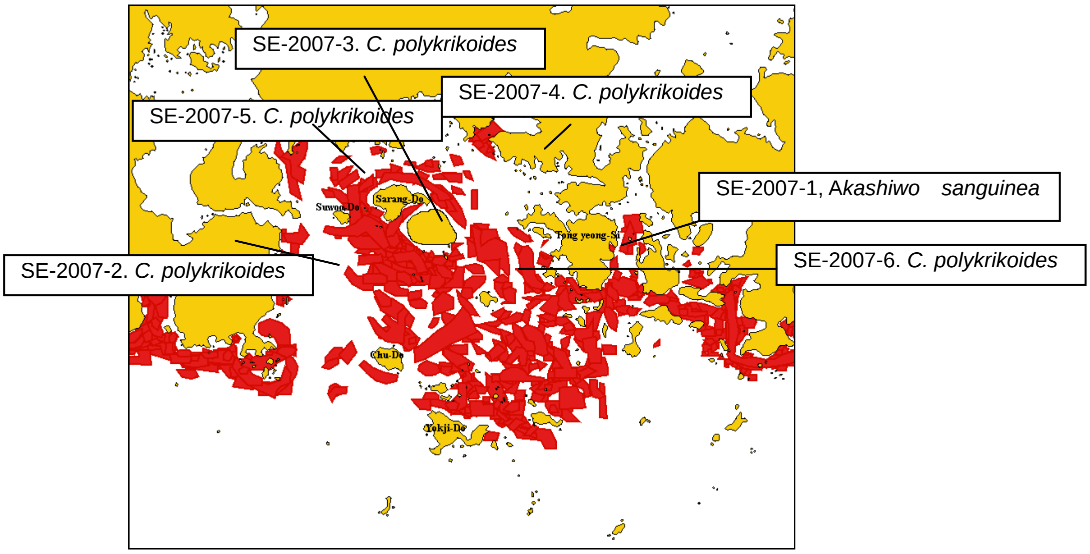


Figure 12-1. Spatial distribution of HABs in 2007
(red area indicates HAB affected dimension).

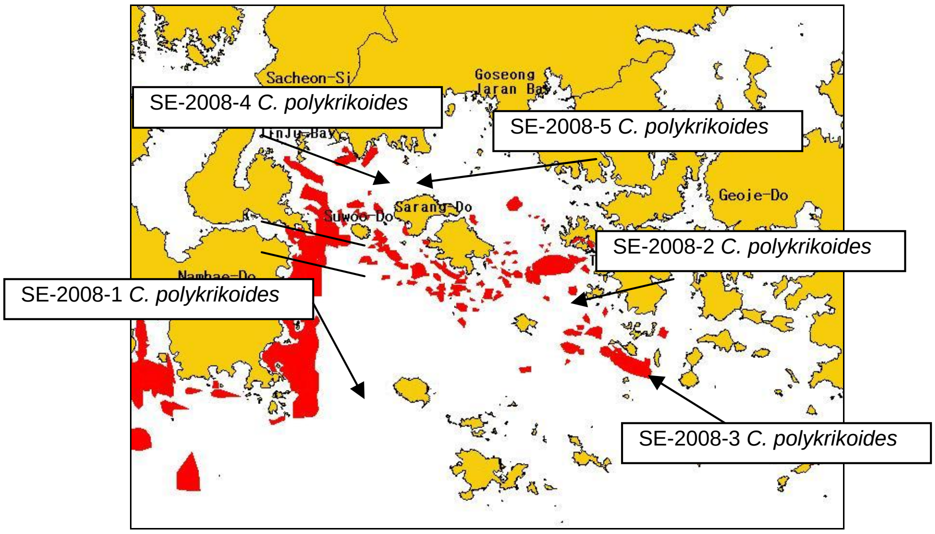
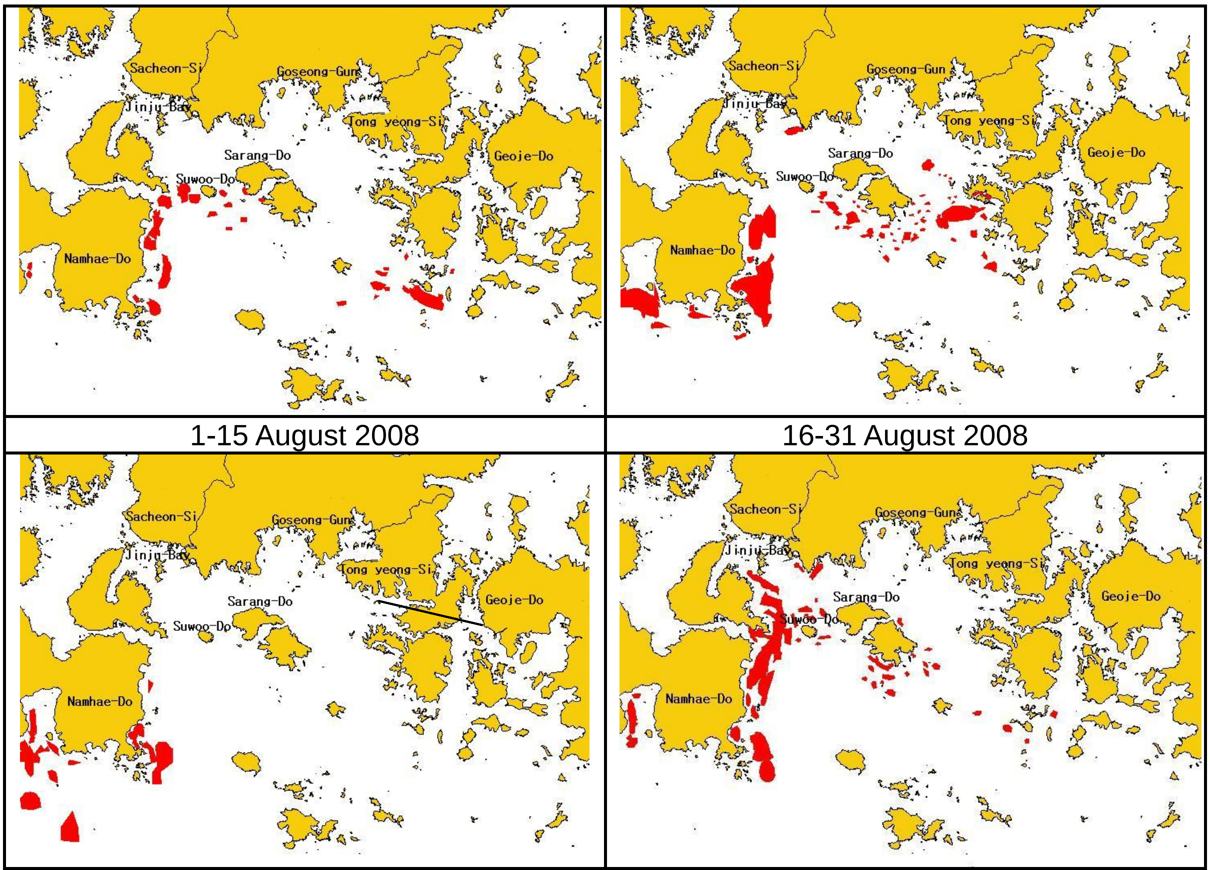


Figure 12-2. Cumulative spatial distribution of HABs in 2008
(red area indicates HAB affected dimension).



1-15 August 2008	16-31 August 2008
1-15 September 2008	16-22 September 2008

Figure 12-3. Changes of HAB affected areas in every half a month
(red area indicates HAB affected dimension).

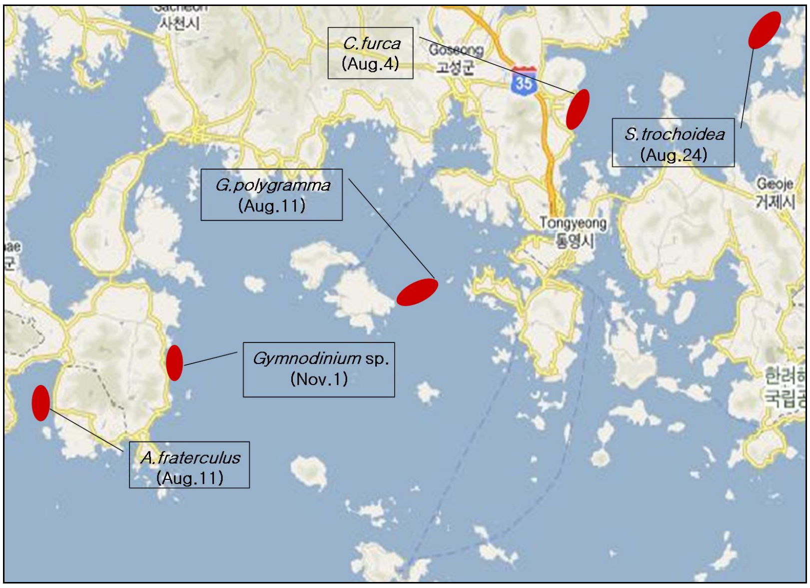


Figure 12-4. Spatial distribution of HABs in 2009
(red area indicates HAB affected dimension)

3.1.4 Red tides in Russia

In target sea area, 53 red tide events and a total 20 red tide species have been observed since 1991, in which no any cases of fishery damage were recorded. Most of red tide events occurred in the Amurskii Bay and the Vostok Bay. In Aniva Bay, one red tide event by *Heterosigma akashiwo* was occurred. Figure 13 shows the yearly trend of red tide events in target sea area. In recent years, red tide event occurred constantly in this area.
Table 15 and Figure 14 indicate the location and causative species of red tide in target sea area.

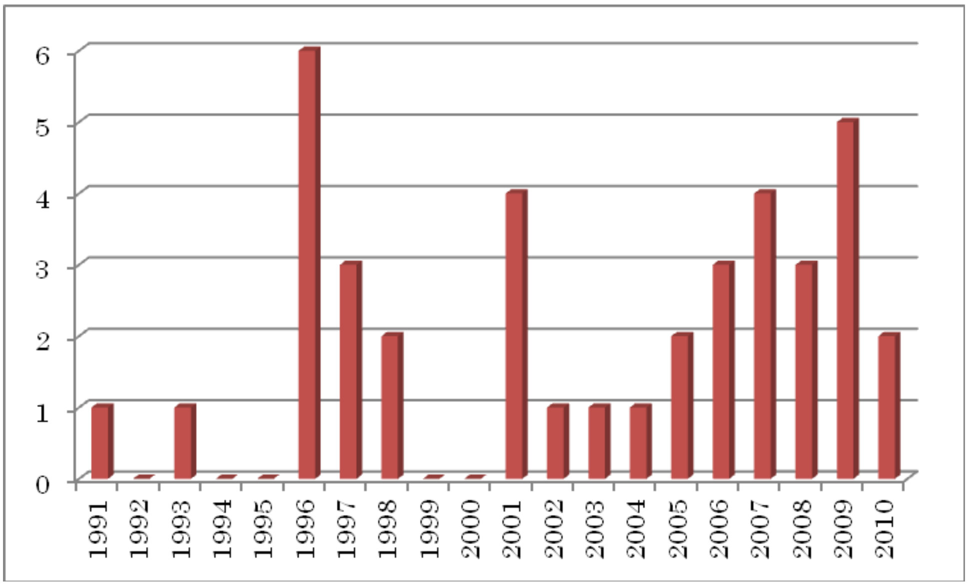


Figure 13 Yearly trend of red tide events in target sea areas

Table 15 Recent red tide occurrence in Amurskii Bay, Vostok Bay and Aniva Bay

Occurrence date	Occurrence location	Causative species	Occurrence area
8 Jul.-12 Aug., 1991	Amurskii Bay	*Prorocentrum minimum*	-
19 November, 1993	Amurskii Bay	*Chattonella* sp.	
28 February, 1996	Amurskii Bay	*Heterosigma akashiwo*	
2-16 July, 1996	Amurskii Bay	*Noctiluca scintillans*	
8 Jul.-30 Aug, 1996	Amurskii Bay	*Chaetoceros affinis*	
5-12 August, 1996	Amurskii Bay	*Chaetoceros curvisetus*	-
4 Nov.-16 Dec., 1996	Amurskii Bay	*Leptocylindrus minimus*	
22 Jul.-30 Aug., 1996	Amurskii Bay	*Skeletonema costatum*	
4 May-4 Jun., 1997	Amurskii Bay	*Chaetoceros contortus*	
29 July, 1997	Amurskii Bay	*Thalassiosira mala*	
19-28 August, 1997	Amurskii Bay	*Protoceratium reticulatum*	
5-12 March, 1998	Amurskii Bay	*Plagioselmis* sp.	
26 Jan.-17 Feb., 1998	Amurskii Bay	*Thalassiosira nordenskioeldii*	
13 August, 2001	Aniva Bay	*Heterosigma akashiwo*	
16 August, 2001	Vostok Bay	*Skeletonema costatum*	
30 September, 2001	Vostok Bay	*Asterionellopsis glacialis*	
14 July, 2002	Vostok Bay	*Chatonella globosa*	

23 April, 2003	Vostok Bay	*Heterocapsa rotundata*	
17 November, 2004	Amurskii Bay	*Chaetoceros salsugineus*	
12 July, 2005	Amurskii Bay	*Euglena pascheri*	
1 September, 2005	Vostok Bay	*Heterosigma akashiwo*	
5 Jun.-3 Jul., 2006	Amurskii Bay	*Thalassionema nitzschioides*	
4 August, 2006	Vostok Bay	*Heterosigma akashiwo*	
20 August, 2006	Vostok Bay	*Skeletonema costatum*	
6-20 August, 2007	Amurskii Bay	*Skeletonema costatum*	
8 August, 2007	Vostok Bay	*Heterosigma akashiwo*	
20 August, 2007	Amurskii Bay	*Heterosigma akashiwo*	
30 October, 2007	Amurskii Bay	*Heterosigma akashiwo*	
7 June, 2008	Amurskii Bay	*Heterosigma akashiwo*	
29 August, 2008	Amurskii Bay	*Prorocentrum minimum*	
15 September, 2008	Amurskii Bay	*Protoceratium reticulatum*	
11 January, 2009	Amurskii Bay	*Protoceratium reticulatum*	
8 June, 2009	Amurskii Bay	*Protoceratium reticulatum*	
4 July, 2009	Vostok Bay	*Nitzschia hybrid f. hyalina*	
2 August, 2009	Amurskii Bay	*Prorocentrum triestinum*	
9 September, 2009	Amurskii Bay	*Prorocentrum minimum*	
30 March, 2010	Amurskii Bay	*Heterosigma akashiwo*	
30 July, 2010	Amurskii Bay	*Dactyliosolen fragilissimus*	

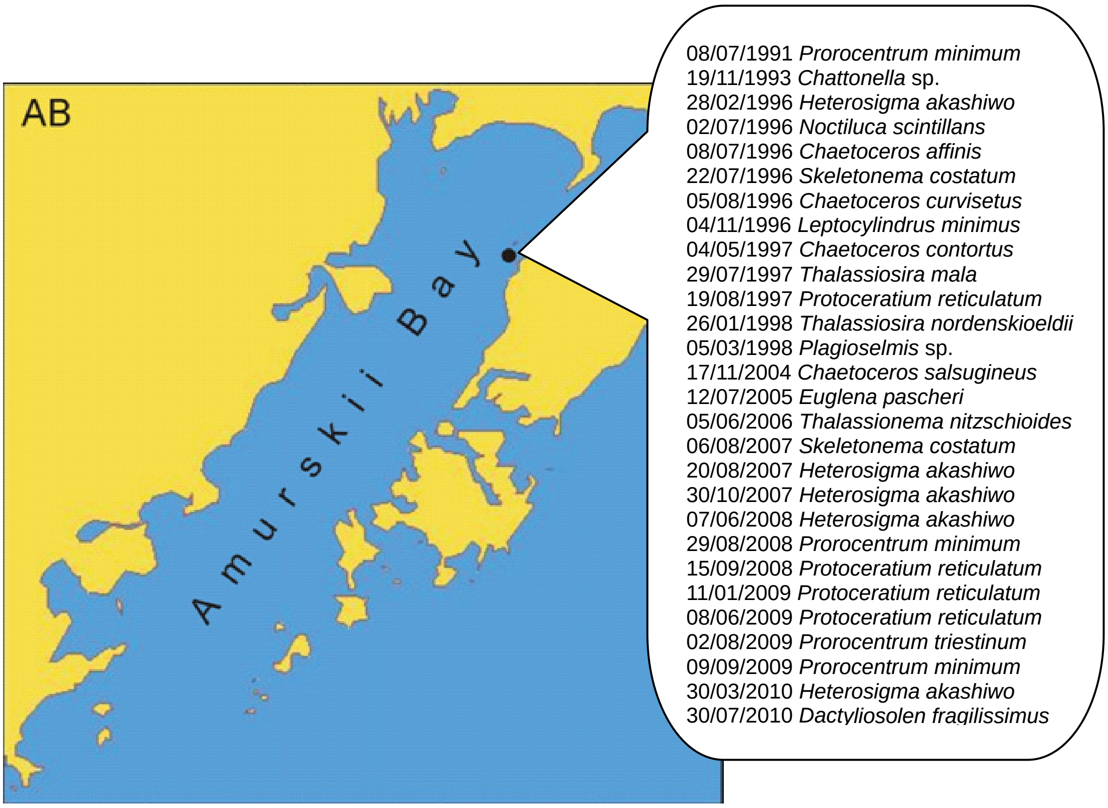


Figure 14-1 Location of red tide event in Amurskii Bay

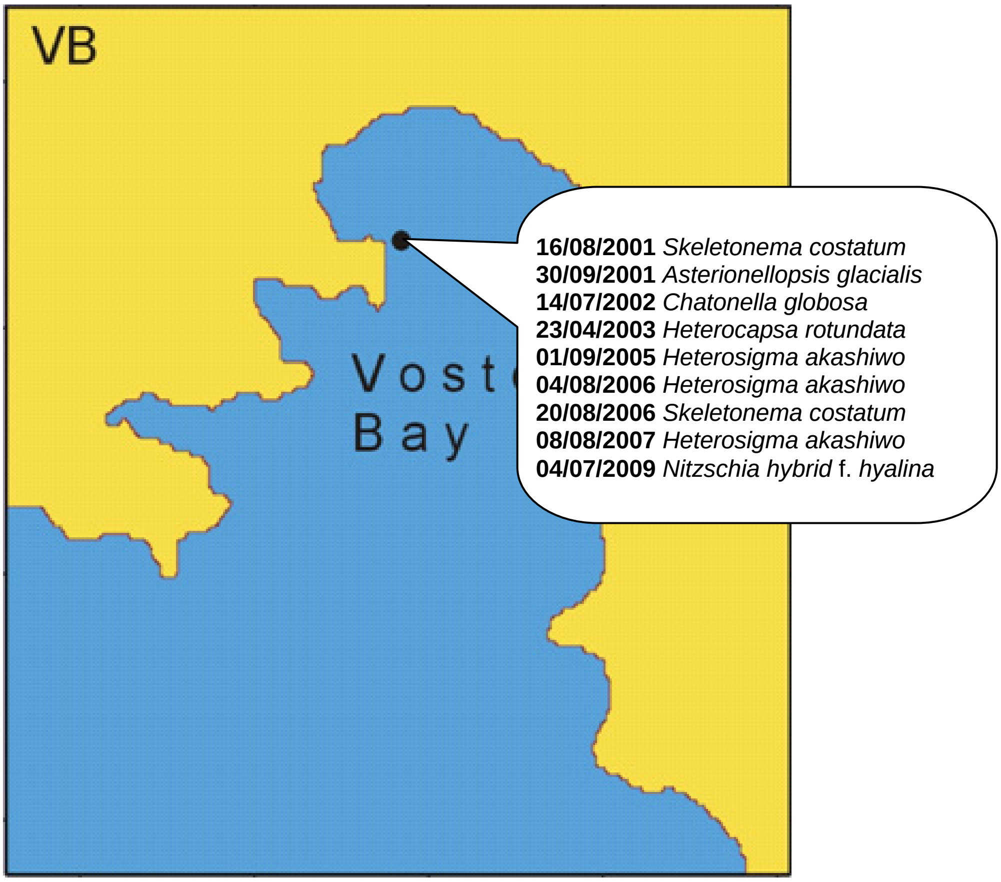


Figure 14-2 Location of red tide event in Vostok Bay

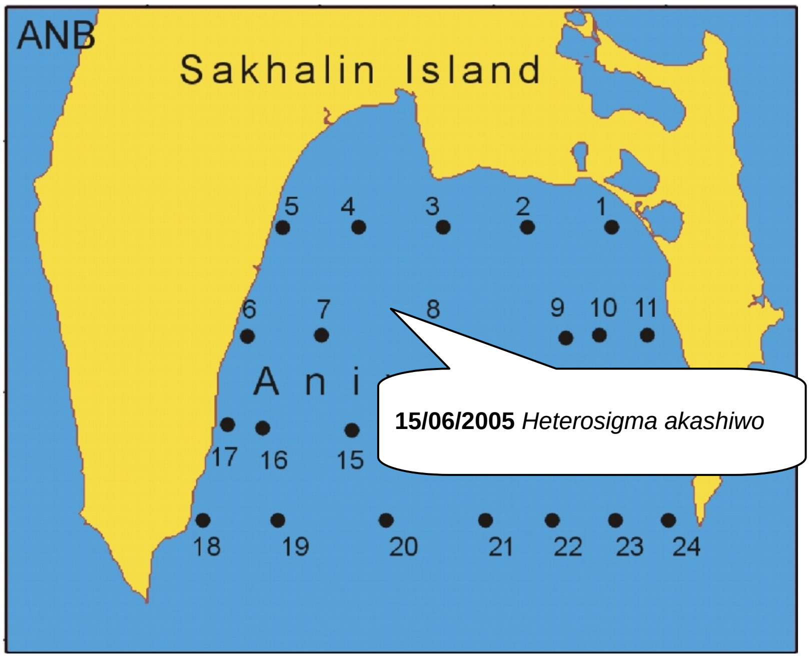


Figure 14-3 Location of red tide event in Aniva Bay

3.2 Toxin-producing planktons and shipment stoppage in the target sea area

Table 16 shows the status of toxin-producing plankton and shellfish poisoning in the target sea areas in each member state. 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. All NOWPAP member states conduct regular monitoring on shellfish poisoning, PSP, DSP, ASP-inducing species are monitored.

A total of 26 toxin-producing plankton species have been recorded in the last HAB Integrated Report. In the other hand, in the HAB Case Study Reports, the number of toxin-producing plankton species decreased and the total is 18 species including 4 new *Pseudo-nitzschia* species (Table 17).

Six species were PSP-inducing species including *Alexandrium* sp., *Gymnodinium catenatum*. The most commonly recorded PSP species in the NOWPAP Region was *A. tamarense*. However, in recent years, *Gymnodinium catenatum* induces PSP poisoning in Japan.
PSP species, *Alexandrium tamarense*, *A. catenella* and *Gymnodinium catenatum* was reported in the HAB Case Study Report of all NOWPAP member states. In China, Korea and Russia, poisoning is not recorded. However, in Japan, PSP was detected 13 times during 2006-2008. In four cases of them, shipment stoppage was conducted because toxin level exceed safety limit.

Nine of the ten DSP species were 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. In HAB Case Study Report, *Dinophysis* species were reported in Japan and Russia.
DSP species have been recorded in China, Japan and Russia.
Exuviaella marina bloom was occurred in the Dalian Bay in China and DSP was detected. However, the damage to fishery and human health by this poisoning was not reported.
Damage from DSP has not been recorded in Japan during 2006-2008 and Russia has not been affected by DSP as yet.

ASP-inducing *Pseudo-nitzschia* species were mainly recorded in Russia. In Korea, only *Pseudo-nitzschia pungens* was observed. In the NOWPAP region, the damage caused ASP has not reported yet.

Table 16 Status of toxin-producing plankton and shellfish poisoning in the target sea areas in each member state

	China	Japan	Korea	Russia
Main toxin-producing species	*Alexandrium tamarense*	*A. tamarense*, *A. catenella*, *Gymnodinium catenatum*, *Dinophysis fortii*, *D. acuminata*, *D. caudata*		*A. tamarense*, *Dinophysis fortii*, *D. acuminata*, *D. acuta, D. norvegica, D. rotundata, Protoceratium reticulatum Pseudo-nitzschia calliantha, P. delicatissima, P. fraudulenta,P. multistriata, P. multiseries, P. seriata/pungens,*
Observed toxin-producing species in recent years	*Alexandrium catenella Exuviaella marina*	*Alexandrium catenella Gymnodinium catenatum Dinophysis fortii D. acuminata D. caudata*	Any toxin-producing species are reported in recent years.	*Alexandrium tamarense Dinophysis fortii D. acuminata, D. acuta D. norvegica, D. rotundata Pseudo-nitzschia calliantha P. multiseries, P. pseudodelicatissima P. pungens, P. delicatissima P. fraudulenta, P. multistriata P. seriata*
Affected species	No information	PSP: Mediterranean blue mussel; Japanese oyster; Noble scallop DSP: Mediterranean blue mussel; Japanese scallop	No information	PSP: *Mizuhopecten yessoensis* DSP: *Crenomytilus grayanus*, *Mytilus trossulus* ASP: *Crenomytilus grayanus*, *Mytilus trossulus*, *Mizuhopecten yessoensis*
Damage	In 1999, damage to human health by DSP was occurred.	DSP exceeded safety limit caused by *Gymnodinium catenatum* were occurred in the Sensaki Bay in 2006, 2007 and 2008, in the Yuya Bay in 2007 and in the Tamanoura Bay in 2007.	No shellfish poisoning was reported	No damage to fishery and human health reported, however, toxin level higher than standards were observed in each area.
Mitigation measures	Regular monitoring to check abundance of toxin producing species and toxin content in the shellfish meat. PSP toxin safety limit is 80μg(saxitoxin)/100g meat.	Regular monitoring to check abundance of toxin producing species and toxin content in the shellfish meat. PSP toxin safety limit is 4MU/g wet weight. DSP toxin safety limit is 0.05MU/g wet weight. In principal, shipment of shellfish will be stopped until the toxin levels return to acceptable levels for 3 consecutive inspections..	Regular monitoring to check abundance of toxin producing species and toxin content in the shellfish meat at the over 100 stations around shellfish aquaculture farm. PSP toxin safety limit is 80μg/100g meat.	Regular monitoring to check abundance of toxin producing species and toxin content in the shellfish meat. PSP toxin safety limit is 0.8mg(saxitoxin)/kg meat. DSP toxin safety limit is 0.16mg(okadaic acid)/kg meat ASP toxin safety limit is 20mg(domoic acid)/kg meat for mollusks and 30mg(domoic acid)/kg meat for crab's internal

Table 17 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		(✔) ✔		
	Gymnodinium sp.			✔	
DSP	*Dinophysis fortii*	(✔)	(✔) ✔	(✔)	(✔) ✔
	Dinophysis acuminate	(✔)	(✔) ✔	(✔)	(✔) ✔
	Dinophysis acuta				(✔) ✔
	Dinophysis caudate		(✔) ✔		
	Dinophysis infundibrus		(✔)		
	Dinophysis mitra		(✔)		
	Dinophysis norvegica				(✔) ✔
	Dinophysis ovate	(✔)			
	Dinophysis rotundata		(✔)	(✔)	(✔) ✔
	Exuviaella marina	(✔) ✔			
ASP*1	*Pseudo-nitzschia calliantha*				(✔) ✔
	Pseudo-nitzschia multiseries				(✔) ✔
	Pseudo-nitzschia pseudodelicatissima				(✔) ✔
	Pseudo-nitzschia pungens			(✔)	(✔) ✔
	Pseudo-nitzschia delicatissima				✔
	Pseudo-nitzschia fraudulenta				✔
	Pseudo-nitzschia multistriata				✔
	Pseudo-nitzschia seriata				✔

The parenthesize parts indicate that the species reported in the last HAB Integrated Report.

*1: Damage from ASP has not yet been recorded in the NOWPAP Region, although ASP inducing *Pseudo-nitzschia* species were recorded in Russia. 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.

3.3 Common issues on HABs in the NOWPAP Region

3.3.1 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. In specially in Korea, C. polykrikoides is causative species of all HAB events in the last 15 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.

To predict and warn *C. polykrikoides* bloom based on the scientific data, Korea conduct specific monitoring focused on *C. polykrikoides* bloom. This monitoring is conducted before, during and after *C. polykrikoides* blooms usually from June to October. For detection of spatial distribution of *C. polykrikoides* bloom, satellite images of SST and Chlorophyll-a were applied. *C. polykrikoides* bloom in Korea occurred in huge scale in offshore area. The information on SST and Chlorophyll-a are helpful parameters for the prediction of *C. polykrikoides* bloom. In 2008, *C. polykrikoides* bloom which made large scale bloom as long as several ten kilometers was detected by satellite images (Table 18).

After 2005, *C. polykrikoides* blooms occurred in Japan and Korea continuously, however, the number of occurrences and damage to fishery became smaller than past years. The locations of *C. polykrikoides* blooms in the Japanese and Korean regions are plotted in Figure 15, the data of which are derived from National Reports, recent research papers and HAB Case Study Reports.

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 16 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 ºC, salinity was 34 ppt and irradiance was >90μmol/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 ºC. However, the optimum growth conditions of *C. polykrikoides* require further investigation through the collection of field data.

3.3.2 Fishery damage caused by *Chattonella antiqua* in Yatsushiro Sea

From 2008, Fisheries damage caused by Chattonella antiqua is quite serious in Yatsushiro Sea. Yatsushiro Sea, out of NOWPAP region, is adjacent sea area of Ariake Sea and there are many aquaculture farms. In 2008, the amount of fisheries damage is 184 million Japanese yen (about 2 million US $). After that, the damage became bigger, 2.9 billion Japanese yen in 2009, 5.3 billion in 2010. The damage caused by Chattonella antiqua expanded Ariake Sea and Omura Bay, Chattonella antiqua is most concerned species in Kyushu region.

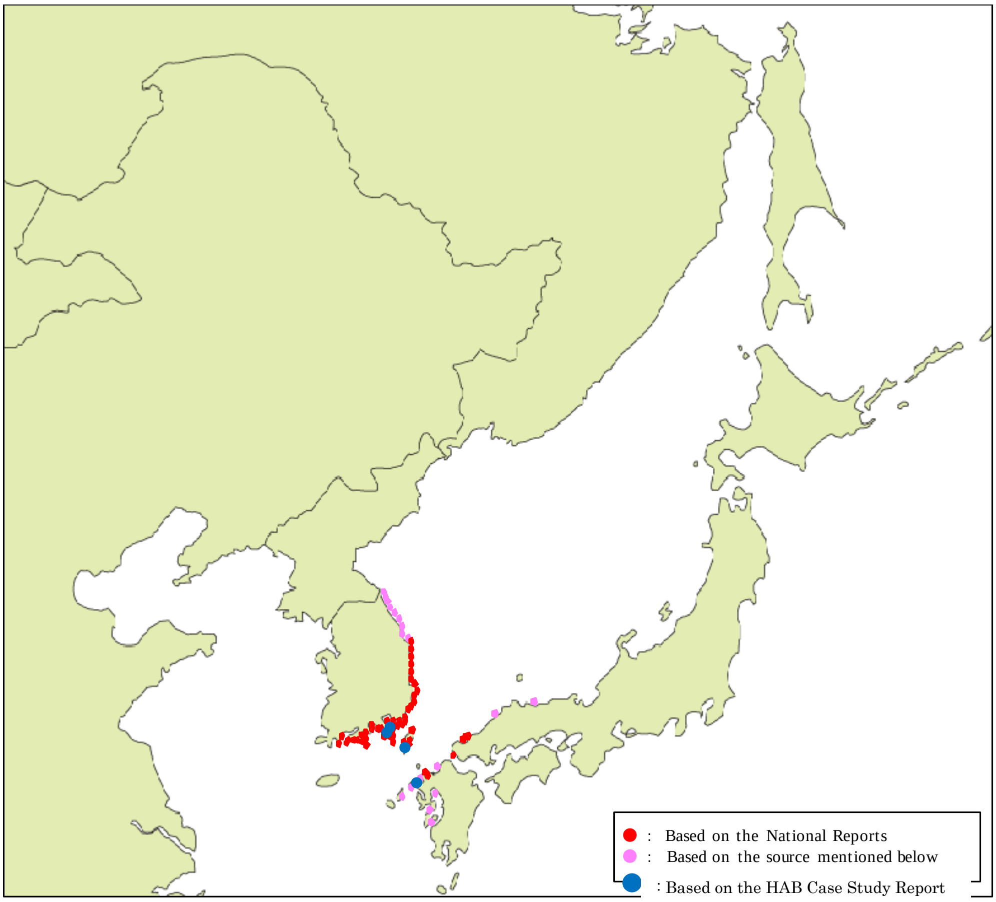


Figure 15 Locations of *C. polykrikoides* blooms in Japan and Korea

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.

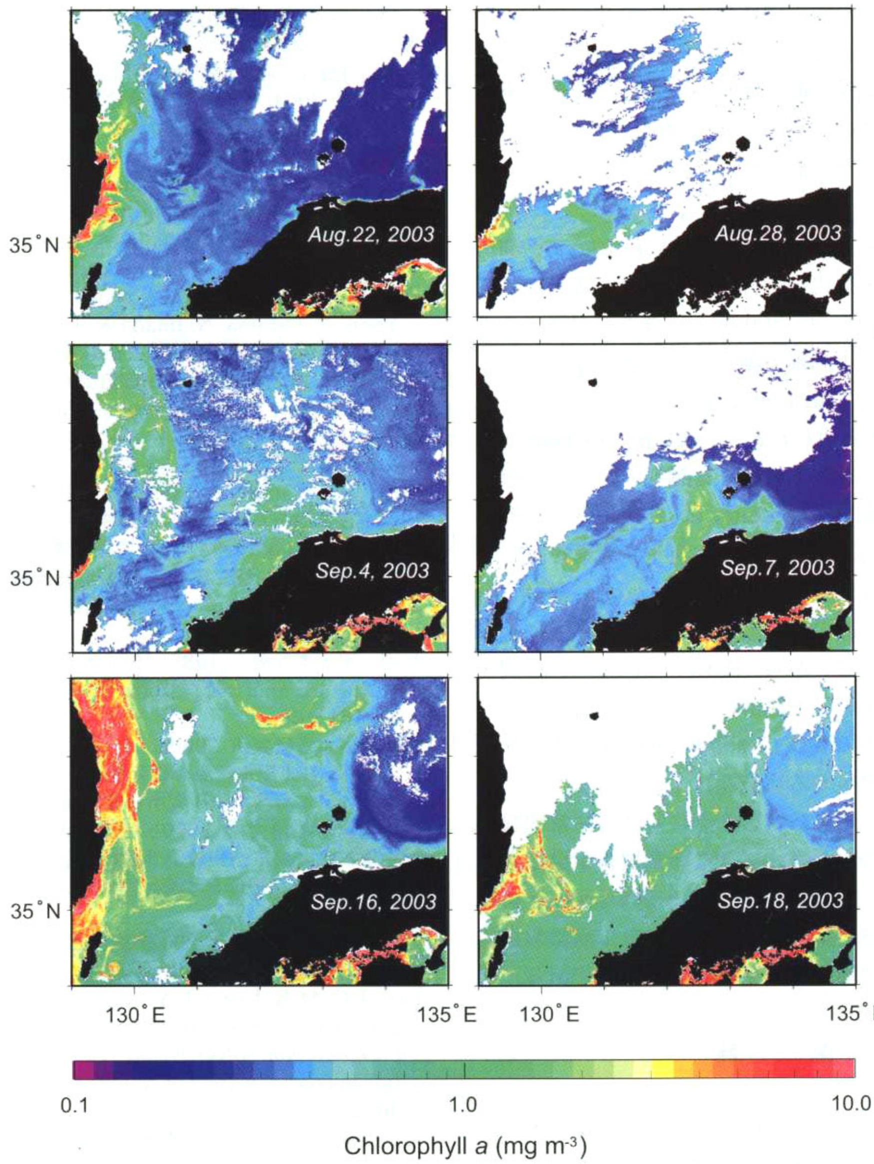
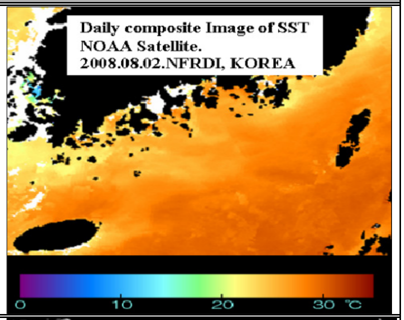
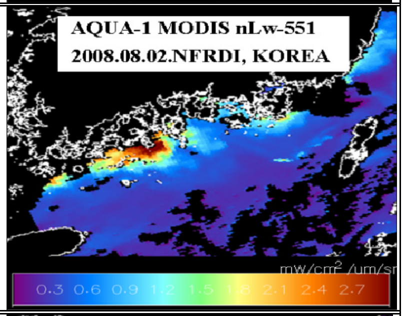
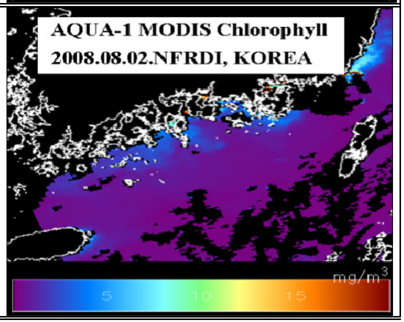


Figure 16 Movement of *C. polykrikoides* blooms along the coast of the Chugoku Region in Sea Area A

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.

Table 1. Satellite images during HAB events in the South Sea of Korea

Year	Event No.	Duration	Spot	SST, nLw 551, Chl-a
2008	SE-2008-1	Aug. 2, 2008	South Sea of Korea (Sea surface temperature image)	
2008	SE-2008-1	Aug. 2,2008	South Sea of Korea (nLw 551 image)	
2008	SE-2008-1	Aug. 2,2008	South Sea of Korea (chlorophyll-a image)	

3.3.3 Massive bloom of green macroalgae *Ulva prolifera*

Green tides which caused by huge volume of green macro-algae occur under eutrophication status. In the NOWPAP region, eutrophication is one of significant issue on marine environment.
In June 2008, a massive bloom of the green macroalgae *Ulva prolifera* occurred in the coastal area of Qingdao in the Yellow Sea. The bloom covered 2,400 km^2 and 1 million tones of algae had been cleared.
It was shown using satellite images and numerical circulation model that the origin of this bloom is nearshore Subei Bank where aquaculture of the seaweed *Prorphyra yezoensis* is conducted (Chuanmin Hu *et al.* 2010). The patches of *Ulva prolifera* were appeared nearly every year between April and July 2000-2009 in the Yellow Sea and East China Sea. However, the mechanisms of extensive bloom are unclear. .

3.3.4 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.

4 Challenging studies to cope with HABs

4.1 Remote sensing techniques

Satellites are one of the useful tools for red tide monitoring. Although there are some challenges to be solved such as differences between sizes of actual red tides and resolution of satellite images and disturbance by clouds, satellite images are being utilized in red tide monitoring in the NOWPAP Region with its advantages of obtaining information of wider areas (Tang *et al*. (2003), Ishizaka *et al*. (2006), Ahn *et al*. (2006)). In Korea, it is one of the effective tools for *Cochlodinium* monitoring.

In addition to be used for identifying distribution of different Chlorophyll-a concentration on the sea surface and estimating areas of red tide occurrences, satellite images are recently used as a new determination tool of red tides by different wavelength ranges (He *et al.* (2008), Takahashi *et al*. (2009)).

As highly-resolution images such as ALOS have become available, it is expected that red tide monitoring with satellite images will be more promoted globally. Even in species identifying, which was difficult to be done by satellite images, Global Ecology and Oceanography of Harmful Algal Blooms（GEOHAB）established a new Working Group for this issue to promote more researches on it.

Satellite images are used not only for monitoring but also for forecasting the movement of red tides and reduction of damage by red tides. When a red tide occurs close to marine culture areas, it may be drifted by ocean currents and give damages to the areas. The course of the movement of red tide will be forecasted by flow field and distribution of red tide with satellite images, and then appropriate countermeasures will be taken (e.g. moving preserves and feed withdrawal) to minimize the damage. At present, these approaches are being verified, and when the techniques are established, recommendation towards damage prevention will be provided based on the tools.

Moreover, more studies for understanding red tides by combining in-situ monitoring and remote sensing monitoring with numerical simulation have been promoted (Onitsuka et al. (2010)). In the NOWPAP region, there are incidents of red tide damage given to remote areas from its cause. For example, when *Cochlodinium* red tide occurred along Korean coastal waters and was transferred by the current to the coastal area of Japan, the Sanin region was damaged by the red tide. Such transboundary transfer of red tide will be forecasted by usage of satellite images and numerical simulation and application of them can lead to minimization of the damage. Thus, expectation of the technical advancement is high.

4.2 Molecular genetic techniques

The most important thing for prevention of red tide damage is early identification of the causative species and its cell density and taking appropriate countermeasures against reduction of the damage. In short, the shorter time it takes to identify species on site and calculate the cell density, the less damage the sea areas get by HABs. However, not all the people conducting HAB monitoring are familiar with species identification. In-situ prompt identification and measurement of cell numbers also require high expertise. Therefore, it is necessary to develop an easy and fast way of species identification and cell density measurement which any person can apply.

At present, a molecular biological approach using unique DNA marker of each species is applied. FISH (Fluorescent In Situ Hybridization) method, real-time PCR (Polymerase Chain Reaction) and LAMP (Loop-Mediated Isothermal Amplification) method are the methods based on this approach. FISH method detects presence or absence of target plankton in the sea by designing complementary probes in DNA markers on species-specific rRNA which is marked with fluorescent pigment. By the fluorescent degree, the approximate cell number is also estimated (Hosoi-Tanabe, S. and Sako Y (2006), Takao, Y. et al. (2007), Nishitani G. et al. (2007)). Another method often use is real-time PCR (Kamikawa *et al*. (2005), (2006), Kai *et al*. (2006), Kamikawa *et al*. (2007)). Different from the FISH method, this method identifies species by primers with peculiar DNA marker. Real-time PCR is also used for cysts, so it is applicable to species developing cysts and to identify presence of cysts in sediments.

LAMP method is the most simplified method of them, which can amplify target gene sequences at a given temperature (around 65 degrees Celsius) without special reagent or tools. Efficiency of amplification is also good, so it is possible to identify species at low cost.

These methods can set probes and primers for each plankton and there are probes developed in many species. These methods can be applied to detect presence of specific plankton which is difficult for identification by the shapes. Even the people without enough knowledge can conduct species identification, therefore, the methods are being applied in many areas in the world.

By now, Mouse Assay and High Speed Liquid Chromatography have been popular for detection of shellfish poisoning; however, another quicker and easier method using biological techniques, ELISA（Enzyme Linked Immunosorbent Assay）method was developed (Kawatsu *et al*. (2002)). This method is to set detective quantitation of antigen by checking enzyme reaction. With the method, OA, DTX1, 2 and 3 can be detected quickly and accurately.

There are many HAB causative species (e.g. *Cochlodinium*) occurring in the NOWPAP region, and studies on them such as identifying populations distributed in each sea area at gene level and understanding their transfer to other sea areas, expansion of distribution and its mechanism (Hosoi-Tanabe et al. (2006), Kim and Kim (2007), Kim et al. (2008), Iwataki et al. (2008), Mikulaki et al. (2008), Nagai et al. (2009)). A new method focusing on macrosattelite, which is known as a molecular marker with advanced polymorphism is under development to understand the status of transfer by genetic variation in one species (Nagai et al. (2006A, B)). .

All the methods mentioned above are useful for quick identification of red tide and shellfish poisoning causative species. If any person can identify causative species without any profound knowledge, it can lead to quick response to the red tide occurrence and reduction of its damage. Simple methods at low cost are needed to be developed.

4.3 Countermeasures against HABs

There have been various techniques (e.g. clay spraying) applied to reduce the damages of red tides, and CEARAC collected information of these existing countermeasures in the NOWPAP region and published “Booklet of Countermeasures against Harmful Algal Blooms (HABs) in the NOWPAP Region” (2007). The booklet introduces physical countermeasures using clay and flocculant as well as chemical ones with chemical substances and chemical reaction and biological ones with bacteria and viruses. When clay or chemical substances are sprayed, they may worsen the marine environment. Thus, using sediment in the environment is being studied for settling red tide problems. Sediments already existing in the environment include algicidal viruses, so it is expected that using them will be more effective by clay absorption and the viruses. This technical development is needed in the near future.

5 Conclusion

The number of HAB problems in the NOWPAP region has decreased comparing to decades ago; however, they still give significant damage to fisheries at present. Thus, it is necessary to understand the status and mechanism of HAB occurrences in the NOWPAP region and to address them using existing and new technologies and methods mentioned in Chapter 4. Some technologies are still under development, and their advancement and establishment will contribute to reduction of HAB damages in the NOWPAP region.

One big demerit of them is that they are all responses after red tides occur. So, it is also necessary to establish the environment where no red tides occur.

The NOWPAP region is one of the areas in the world, where eutrophication is problematic by rapid economic development in the surrounding countries, concentration of population along the coastal areas and increase of agricultural production. Eutrophication can cause red tides, so it is necessary to improve the status of eutrophication of the NOWPAP region and recover the area with the natural nutrient level and natural material circulation.

Taking consideration these present status and goals, CEARAC developed common procedures to evaluate the status of eutrophication for the NOWPAP region and implemented assessment in the selected sea areas of each NOWPAP member state. The assessment items include direct factors of nutrient enrichment (e.g. nutrient concentration in the sea area), nutrient input from land, number of red tide occurrences and chlorophyll-a concentration.

After implementation of the assessments, each member state understood their own challenges. Their practical countermeasures will improve the status of eutrophication and lead to reduction of red tide occurrences in the NOWPAP region.

On the other hand, problems on eutrophication cannot be solved by mere reduction of nutrient loads. For example, in Japan, despite reduction of land-based nutrient loads, the number of red tide occurrences hasn’t decreased. This may because the current conditions of marine ecosystem are different from traditional one and the process of material circulation by worsened marine environment in the past.

In order to solve HAB problems in the NOWPAP region, it is necessary to improve the status of eutrophication and improve knowledge on the status of ecosystem including HAB causative species for developing effective countermeasures.

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