National Report on HABs in Korea

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I. INTRODUCTION

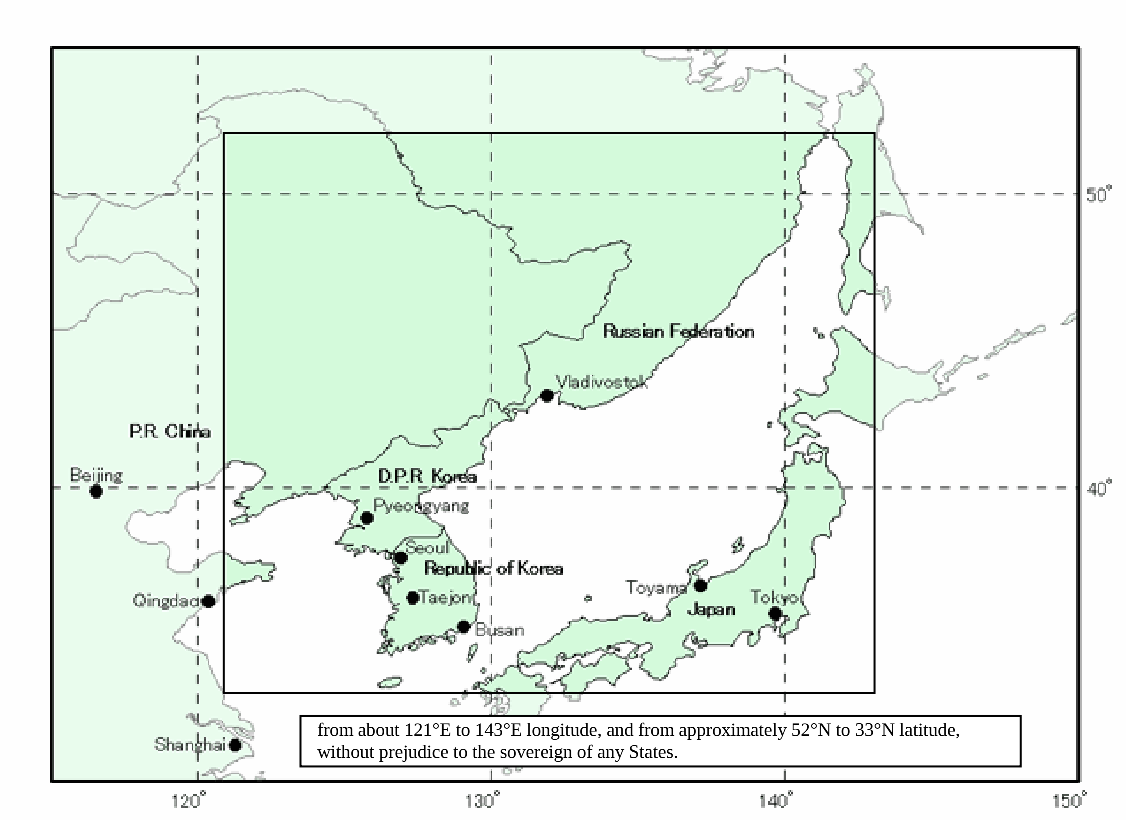
The geographic characteristic of Korea leads river to flow from the east to the west with runoffs discharging into the Yellow Sea and Korean strait. Moreover, the NOWPAP region in Korea is in shallow and semi-closed water system, in which mean water depth of Yellow Sea and the South Sea is 44 and 101m, respectively. Most of their continental shelf is stretched out to the whole seabed except eastern part of NOWPAP area of Korea whose mean depth is 1, 543m. Such vulnerability of coastal pollution without big water exchanges with offshore, demographic high occupancy of coastal area and voluminous wastewater runoffs make coastal waters eutrophic state of haunting red tides. Harmful Algal Blooms (HABs) by toxic and non-toxic micro algae have gained increasing attention over last three decades in Korea. Because harmful and toxin-producing micro algae have caused serious impact on aquaculture industry through mass mortality of culturing finfish and/or shellfish, and on human health through finfish or shellfish poisoning in Korea.

HABs in this report encompass both harmful and harmless red tides, and toxin-producing micro algal blooms in accordance with the definition of HAB agreed by 1st WG3 meeting in Busan, October 2003.

It is needed to close coordination within WG members in the Region among other things to solve HABs problems in NOWPAP Region. In addition, it is essential to have a common platform to develop the research, mitigation measures and proper political proposals.

The present national report was compiled following the guidelines and format proposed in the WG3 Meeting held in Busan, October 2003. Considering the requirement of the guidelines, this was prepared using existing data and information mainly from National Fisheries and Development Institute (NFRDI) responsible for the HABs monitoring and mitigation.

Since information on HABs in the NOWPAP area of Korea has not been supplied sufficiently so far, the present report, therefore, can be used as the basis to develop the complete understandings on HABs in NOWPAP areas.


Russian Federation
Vladivostok
P.R. China
Beijing
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Pyeongyang
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Republic of Korea
Qingdao
Taejon
Busan
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Japan
Tokyo
Shanghai
50°
40°
120°
130°
140°
150°
from about 121°E to 143°E longitude, and from approximately 52°N to 33°N latitude,
without prejudice to the sovereign of any States.

II. DATA AND INFORMATION USED

Data and publications issued by NFRDI and relevant organizations such as regional Maritime Affairs & Fisheries under Ministry of Maritime Affairs and Fisheries (MOMAF) and universities were utilized in this report.

1. Situation of HAB Occurrence

Both toxin-producing micro algae and non-toxic micro algae are responsible for red tide in Korea. Both of them are discussed in this report without separation. NFRDI have published the booklet “Situation of red tide in Korean coastal waters” annually or biannually since 1996. It describes red tide events, causative organisms, maximal cell density, locality with mapping, water temperature, etc for all the red tide occurred in Korean coastal waters. The data in the booklet is originated from the reports by either fisheries extension service centers or regional fisheries research institutes of NFRDI, responsible for the red tide monitoring program in Korea.

2. Monitoring

Monitoring activities were summarized based on the national monitoring program by NFRDI, fisheries extension service center and National Maritime police Agency in charge of the red tide monitoring.

3. Progress of Researches and Studies to Cope with HABs

In order to investigate the progress of researches and studies to cope with HABs in Korea, research papers published by Korean scientists were collected and categorized along with the detail fields. Therein, the progress and future directions of researches and studies to cope with HABs were discussed.

4. Literature Including Newly Obtained Information

Information on HAB literatures was obtained from HAB Reference Database which has been constructed by CEARAC/WG3. Literatures including newly obtained information were collected through either e-library or direct contact with the authors and categorized along with the detail fields.

5. Training Activities to Cope with HABs

Information on the training activities to cope with HABs in Korea were collected from the curriculum of training department belonging to NFRDI. The subject on the management of coastal environment relevant with red tide and shellfish poisoning were discussed among the curriculum.

6. National Priority to Cope with HAB

"National plans for the sustainable marine environment and conservation for 5 years" and "National plans to countermeasure red tide problems in Korea" issued by MOMAF and NFRDI, respectively, were used to discuss the national priority to cope with HAB.

7. Suggested Activity for the NOWPAP Region

Interviews with researchers and scientists of the relevant field were conducted to collect their ideas on necessary efforts to promote the solution of HAB problems.

III. RESULTS

1. Situation of HAB Occurrence

1.1 Causative Species

A total of 304 red tide events caused by 31 species in Korean coastal area of NOWPAP Region from 1999 to 2003 (Table 1.1.)

The principal taxonomic groups were dinoflagellates and diatoms (Table 1.1.). The top five major red tide causative species from 1999 to 2003 were listed in

Table 1.2. *Cochlodinium polykrikoides* led to mass mortality of culturing finfish and shellfish, while *Prorocentrum minimum, Gymnodinium sanguineum, Heterosigma akashiwo, , Prorocentrum micans* and *Skeletonema costatum* did not give rise to economic loss.

The representative harmful or toxic species, *Gymnodinium mikimotoi* and *Alexandrium tamarense* brought about red tide only a few events during 1999-2003 in Korean NOWPAP areas.

Table 1.1. Number of red tide events during 1999-2003

	1999	2000	2001	2002	2003
Dinoflagellate	58	55	38	45	38
Diatom	7	6	5	6	5
Mixed algae/ protozoa	10	8	13	8	2

Table 1.2. Major micro algal species responsible for red tide events during 1999-2003

Species	1999	2000	2001	2002	2003
Cochlodinium polykrikoides	20	9	10	15	20
Prorocentrum minimun	13	14	6	7	6
Gymnodinium sanguineum	10	4	-	5	-
Heterosigma akashiwo	7	12	5	7	5
Skeletonema coastatum	9	5	9	8	4

Source: NFRDI annual/biannual HAB report, “situation of red tide in Korean coastal waters”, 1999-2003.

1.2 Cell Density

The highest cell number observed during 1999-2003 was 48,000 cells/ml by *Cochlodinium polykrikoides* in August 2003 in Namhaedo area. The usual number of maximum cell density in the red tide in the NOWPAP area of Korea remains at the level of several thousands cells/ml.

Table 1.3 Maximum cell density of red tide causative organisms during 1999-2003

Year	Species	Max. cell density (cells/ml)	locality
1999	*Cochlodinium polykrikoides*	43,000	Yungdeok
2000	’’	15,000	Tongyoung
2001	’’	32,000	Geoje
2002	’’	30,000	Gyeongju
2003	’’	48,000	Namhae

Source: NFRDI annual/biannual HAB report, “situation of red tide in Korean coastal waters”, 1999-2003.

1.3 Location

Figure 1 (see appendicies) shows the area that experienced red tide event from 1999 to 2003 in the NOWPAP area of Korea. This reveals that the red tide events are more frequent in the southern part than in western or eastern part of Korea. The investigated area has suffered from 304 red tide events during 1999-2003. Most of the blooms were mainly observed in embayment and semi-enclosed area such as Jinhaeman, Buksinman, Ulsanman, etc except *Cochlodinium polykrikoides* blooms.

Red tide, in general, begins to occur from February to March almost every year, and shows its peak from August to September during which harmful algae, *Cochlodinium polykrikoides*, makes its blooms. Red tide by dinoflagellates are much more frequent than by diatoms.

There have been algal blooms by *Cochlodinium polykrikoides* almost every year particularly during high water temperature seasons in the NOWPAP area of Korea since early 1990s. The blooms occurred mostly in the South Sea and/or Eastern part of NOWPAP area in Korea, except year 1999 and 2000 when there were blooms even in the western part around Kunsan coastal area exceptionally.

1.4 Approximate suffered Area

In general, the area that red tides spread varies extremely depending on oceanographic, meteorological, and biological conditions. The dimension of approximately suffered areas by red tides are in most case less than several kilometers except *Cochlodinium polykrikoides* blooms which spread up to several hundred kilometers in the southern and/or eastern part of NOWPAP area in Korea. The red tides that exceed the area of 100 km^2 rarely occur in the NOWPAP area of Korea.

Table 1.4. Number of red tide events depending on the approximate suffered area during 1999-2003

Year	Dimension of red tide suffered area			
	1 Km^2	1- 100 Km^2	>100 Km^2	Total
1999	43	13	20	76
2000	45	16	8	69
2001	35	12	9	56
2002	30	10	15	59
2003	17	8	20	45

Source: NFRDI annual/biannual HAB report, “situation of red tide in Korean coastal waters”, 1999-2003.

1.5 Duration

(1) Duration of red tide

The duration of red tide by dinoflagellates and/or diatoms except by *Cochlodinium polykrikoides* is mostly less than 10 days. However, the duration of red tide by *Cochlodinium polykrikoides* is much longer, ranging from 1-2 months 29 days shown in Table 1. 5.

Table 1. 5. The duration of red tide by Cochlodinium polykrikoides in Korean coastal waters from 1999 to 2003

	1999	2000	2001	2002	2003
Days of duration	54	29	42	55	62

Source: NFRDI annual/biannual HAB report, “situation of red tide in Korean coastal waters”, 1999-2003.

(2) Seasonal variation of red tide occurrence

The red tides by dinoflagellates and diatoms have been observed almost all the year round irrespective of the season recently. The highest peak season was high water temperature season from June to September (Figure 1.1). The majority of the events during the high water temperature season were attributed to the *Cochlodinium polykrikoides* blooms.

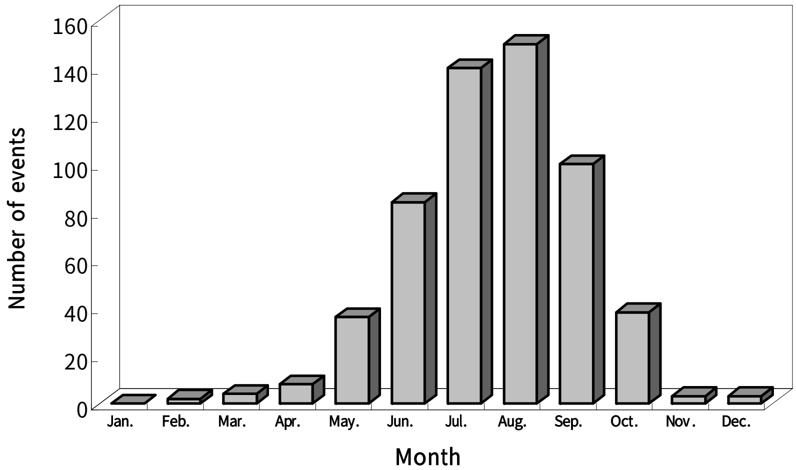

Figure 1. 1. Monthly variation of red tide events in the NOWPAP area of Korea since 1990.

1.6 Mitigation activity and effectiveness

Clay dispersion is the most popular way of removing the red tides in Korea. Red tide control by yellow clay composed of montmorillonite has been directly applied to aquaculture farm since 1996 to minimize fisheries damages by *Cochlodinium polykrikoides* blooms. The practical field application of the mitigation techniques by yellow clay allowed fisheries damages to be sharply reduced from about 95 millions US dollars in 1995 to several millions, thereafter, excluding exceptional year of 2003 when there was unusual mass mortality of abalone in the south-western part of Korea where high density of redtide had not occurred. Impacts on the ecosystems by clay dispersion, particularly on the benthos, have been assessed for more than 7 years. The impact on the aquatic animal was evaluated to be negligible from the result conducted by NFRDI although further long term study is needed to be continued.

Several devices for the mitigation of red tide have been developed by NFRDI or KORDI (Korean Oceanography Research and Development Institute) since 1996. Clay dispenser has been developed to increase the removal efficiency of HAB by enabling wild yellow clay to crumble into fine size and subsequently dispensing into the affected area by HAB. It is under practical application by local government responsible for mitigation during harmful algal bloom by *Cochlodinium polykrikoides*. Automatic HAB alarm system equipped with Chlorophyll and turbidity detecting sensor has been, also, developed in order that fisherman get warning sound or signals from the device whenever red tide occurs at the aquaculture site. Some of private land-based aquaculture sectors where there have been frequent harmful algal bloom near their farm established the device.

Special device, Electrolytic Clay Dispenser (ECD) that electrolyzed seawater and clay dispenser combined each other, has been developed and are under propagation in Korea, recently. The device is very useful in minimizing the quantity of clay, being dispersed and cumulated onto the bottom of the sea almost every year which might cause any impact on particularly benthos someday, and enhancing the removal efficiency compared to old style of clay dispenser.

Figure 1.2. Clay dispenser (left) and electrolytic clay dispenser combined with electrolytic seawater generator (right).

Figure 1.3. Automatic HAB alarm system.

1.7 Damage

The first fisheries damage in Korea occurred in 1981, reportedely, by harmful algae, *Karenia mikimotoi*. Thereafter, *Cochlodinium polykrikoides* blooms brought about mass mortality of finfish and shellfish almost every year in Korean coastal area since 1993. Particularly, there was huge harmful algal blooms in 1995, resulting in about 95 million dollars' fisheries damage (Table 1.6.). However, the economic impact by the species decreased sharply since then except year 2003 in which there was unusual bloom in the south-western part of NOWPAP area of Korea, resulting in mass mortality of abalone exceptionally.

Table 1. 6. Fishery damage by red tide in the NOWPAP area of Korea

Year	Species	Economic loss (million dollor)
1981	*Karenia mikimotoi*	1.7
1992	*Gyrodinium sp.*	5
1993	*Cochlodinium polykrikoides*	7
1995	〃	95
1996	〃	1.8
1997	〃	1.2
1998	〃	0.1
1999	〃	0.2
2000	〃	0.2
2001	〃	7
2002	〃	4
2003	〃	18.6

2. Monitoring

National Fisheries Research and Development Institute (NFRDI), Regional Maritime Affairs and Fisheries Office and National Maritime Police Agency (NMPA) under Ministry of Maritime Affairs and Fisheries (MOMAF) are responsible for red tide monitoring. Particularly, NFRDI fisheries extension service center are most responsible for the monitoring around coastal area, while NMPA is in charge of aerial observance by helicopter. Local government is responsible for the mitigation when red tide occurs rather than monitoring.

The regular monitoring stations and frequency are summarized in Figure 2.1. 77 stations and additional 92 stations over the Korean coastal waters are regularly monitored from February to November by NFRDI and fisheries extension service center, respectively. However, once harmful algal blooms initiate, all the relevant agencies including NMPA conduct their daily HAB monitoring. HAB suffered area, cell density of causative organisms, water color, water temperature, salinity are monitored in the survey. All the collected data from field survey, meteorology and remote sensing by NOAA and MODIS are sent to HAB Emergency Center under NFRDI. HAB Emergency center analyze all the data and publish daily HAB news letter including HAB information on the location map, prediction of strength and the direction of transportation. The HAB news letter is disseminated to fisherman and relevant organizations through fax, internet, ARS, SMS service and data-TV etc (Fig.2.2).

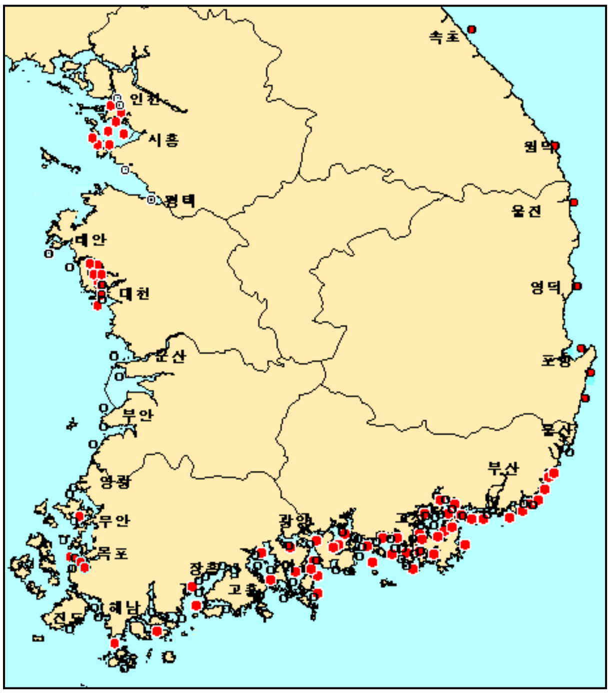

Figure 2. 1. Red tide monitoring station in theNOWPAP area of Korea.

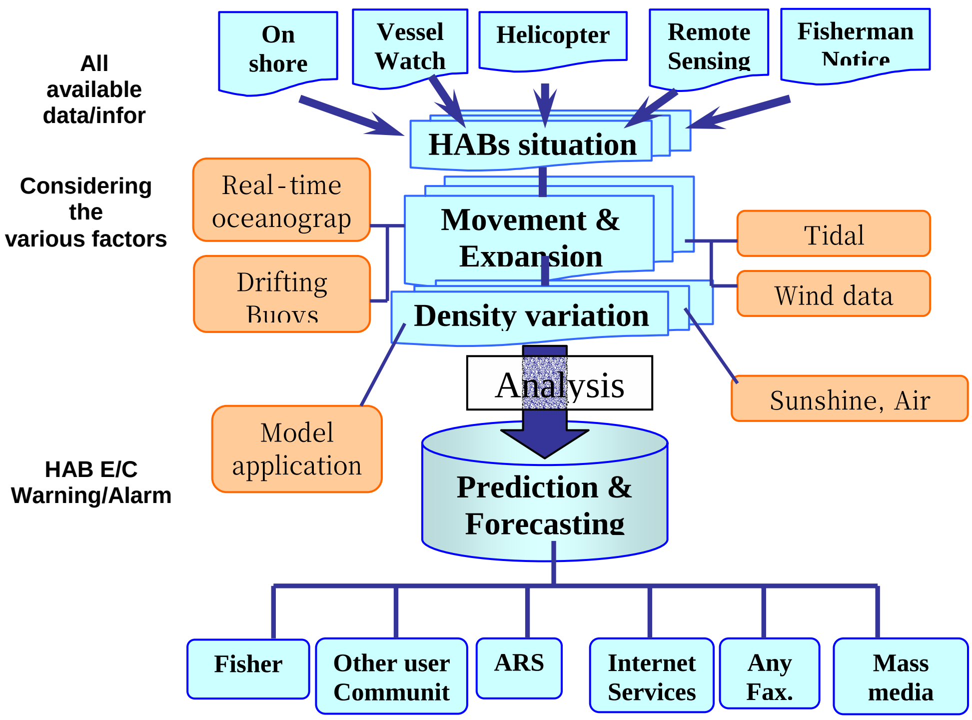

Figure 2. 2. Redtide monitoring, prediction and dissemination system in Korea

Table 2. 1. Red tide warning steps in Korea

Class	Rationale (*Cochlodinium* cell density and bloom size)
Cochlodinium Appearance	First detection of *Cochlodinium* vegetative cell, the triggering point of bloom initiation
Red Tide Attention	300cells/ml, bloom area within 2-5km radius equivalent to 12 to 78 ㎢
Red Tide Alert	1,000cells/ml, bloom area over 5km radius equivalent to 79 ㎢
Warning Lift	HABs are extinct, no risk of fisheries damages

For the prevention from shellfish poisoning and to sustain safe supply of shellfish products such as oyster, mussel and clam, food sanitation research team under NFRDI in collaboration with fisheries extension center conduct regular monitoring on the shellfish culture farm mainly located in the South Sea. More than 100 stations are weekly or biweekly monitored from February to November in Korean coastal waters. The regular monitoring station for shellfish poisoning is shown in Figure 2.3.

Data on potentially toxic species, which are known as causative organisms for Paralytic Shellfish Poisoning (PSP), Diarrheic Shellfish poisoning (DSP) and Domoic Acid Poisoning (DAP) are presented for the 2002-2003 (Table 2.2). The data presented for toxic species in this report are mainly targeted for the south eastern part of NOWPAP area in Korea (Gosung, Tongyoung and Jinhaeman) where there are many aquaculture farms.

Diatoms of the genus *Pseudo-nitzschia* are known as domoic acid producing species. Although several species such as *Pseudo-nitzschia pungens*, *P. multiseries*, *P. delicatissima*, *P. pseudodelicatissima* and *P. seriata* have been reported to be toxic, the diatoms was shown in genus level by representing *Pseudo-nitzschia* spp. in this data. The maximal cell density of *Pseudo-nitzschia* was 1,600,200 cells/L (April in 2002) and 270,900 cells/L (May in 2003).

Figure 2. 3. Paralytic Shellfish Poisoning monitoring stations in Korea

Pseudo-nitzschia was observed almost all the year round from February to November although the density was variable along with season and location. The ell density was comparatively higher in the spring than summer or fall. Also, *Pseudo-nitzschia* was observed almost all of the monitored area (Gosung, Tongyoung and Jinhaeman) irrespective of the locality. There is no any data on the approximate suffered area and damages by the genus *Pseudo-nitzschia*. In addition, any mitigation activity for the DAP producing species has not been applied in the NOWPAP area of Korea.

Species of the genus *Dinophysis* are capable of producing ocadaic acid, causing the syndrome of diarrhetic shellfish poisoning (DSP) mainly on the mollusks. Three DSP producing species, *Dinophysis acuminata, D. fortii and D. rotundata* were observed in Korean NOWPAP area in 2002-2003 (Table 2.2). The maximal cell density of *D. acuminata* was 1,300 cells/L (April in 2002) and 1,500 cells/L (June in 2003). *D. acuminata* was observed relatively more often in Jinhaeman and Tongyoung than Gosung, particularly, in the spring and early summer season in the NOWPAP area of Korea. The cell density of *D.*

fortii (max: 600 cells/L) and *D. rotundata* (max: 200 cells/L) was much lower than *D. acuminata*. There is no any data on the approximate suffered area and damages by the species.

Species of the genus *Alexandrium* is well known to cause the paralytic shellfish poisoning (PSP). Only one species of *A. tamarense*, PSP-producing species, was observed in the south eastern part of Korean NOWPAP area in 2002-2003 (Table 2.2). The maximal cell density of *A. tamarense* was 14,000 cells/L and 26,000 cells/L in 2002 and 2003, respectively. *A. tamarense* was mainly observed in the spring (April-June) and rarely in the fall (October). The location that *A. tamarense* appeared was restricted to Jinhaeman and Tongyoung over the monitored area of south eastern part of the NOWPAP area in Korea in 2002-2003.

Monitoring of shellfish poisoning, particularly, on the PSP toxin producing genus *Alexandrium* species is conducted regularly around the shellfish culture farms by National Fisheries Research and Development Institute (NFRDI) and Regional Maritime Affairs and Fisheries Office in order to prevent shellfish poisoning and sustain safe supply of shellfish products. The monitoring of shellfish poisoning is conducted at least more than once a month. However, monitoring frequency is increased to once a week when the toxin is detected in the meat or mid-gut gland of shellfish. NFRDI notifies fisherman not to harvest the shellfish when the toxin level exceeds over 80 ug/100g meat. There was an announcement for the banning of shellfish harvest from April 13 to May 16 and April 17 to June 19 in 2002 and 2003, respectively over the south eastern part of Korean NOWPAP area due to the PSP. Any mitigation activity for the PSP producing species has not been applied in the NOWPAP area of Korea.

3. Progress of Researches and Studies to Cope with HAB

3.1 Mechanism of HAB Occurrence and Eco-physiology

The main target species for the study of HAB occurrence mechanism has been the *Cochlodinium polykrikoides* in addition to toxic micro algae such as *Alexandrium* spp., *Karenia mikimotoi, Pseudo-nitzschia* spp. and *Gymnodinium catenatum* in National Fisheries Research and Development Institute (NFRDI) and universities since 1995. This study mainly focused on cyst, bloom dynamics, environment and eco-physiology.

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3.2 Toxicity and Diagnosis of Harmful Algae

Studies on the toxicity of shellfish poisoning species and newly emerging potentially toxic algae such as *Alexandrium* spp., *Pseudo-nitzschia* spp., *Microcystis* spp., and *Cochlodinium polykrikoides*, and their early detection techniques by molecular biological techniques have been the main research outcomes.

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3.4 HAB Mitigation and Management

Researches on biological control of HAB by bacteria, parasites, copepods and ciliates, and physical control techniques by. yellow clay have been the major topics in this field. The impact on ecosystem by the application of control agents has, also, been studied since 19996 from which the yellow clay was practically introduced to the sea to remove the red tide.

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4. Literature Including Newly Obtained Information

Followings show major papers published in 2003 and 2004, which are stored in HAB Reference Database. Twenty five scientific papers on HAB researches are collected and categorized as follows.

The major target species were *Cochlodinium polykrikoides*, followed by toxic species such as *Alexandrium tamarense*, *Gymnodinium catenatum* and *Prorocentrum* spp. Scientific papers on HAB mitigation particularly relating with biological control was much more than any other subjects by showing about 60 % of the scientific papers published during this period.

4.1 Mechanism of HAB Occurrence and Eco-physiology

Cyst distribution on dinoflagellates were reported by Cho et al.(2003) and Park & Yoon (2003) describing the potentiality of red tide outbreak in the embayment of southern part of the NOWPAP area in Korea in which red tide outbreak is frequent almost every year.

Lim and Lee (2004) described morphological and cellular characteristics for the prototype of *Cochlodinium polykrikoides* vegetative cells detected in the southern part of the NOWPAP area in Korea in early June, two months earlier than its bloom initiation time.

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4.2 Toxicity and Diagnosis of Harmful Algae

Kim et al. (2004) reported on the sensitive and accurate PCR assays techniques mainly targeted for *Cochlodinium polykrikoides* enabling early detection of the swimming cells at an extremely low density. It was seemed to be used as one of promising tools for the study of bloom dynamics and the origin of the cells in future.

Also, Suh et al. (2004) studied on the feasibility of red tide detection around the NOWPAP area in Korea using satellite remote sensing. It was, some extent, possible to detect huge scale of algal bloom by satellite although further scientific data and technology are needed to be solved until practical application.

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4.3 HAB Mitigation and Management

Jeong et al. (2003, 2004) reported on the feeding by ciliates, *Strombinopsis jeokjo* and heterotrophic dinoflagellate, *Protoperidinium bipes, Gyrodinium domains* on red tide forming dinoflagellates such as *Prorocentrum minimum, Heterosigma akashiwo* and *Cochlodinium polykrikoides,* which could be a potential biological method to control red tide.

Sun et al. (2004) reported on the new HAB mitigation technology by the use of sophorolipid treatment. They could remove red tide forming dinoflagellates effectively at relatively low dosage compared to other agents.

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4.4 Others

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5. Training Activity to Cope with HAB

The following section describes the training activities on HAB conducted by national institute locally or nationally. It also includes international training programs attended by Korean scientists.

A non-profit organization, Korean International Cooperation Agency (KOICA), has conducted a training course every year on the aquaculture including the curriculum of red tide to advance the capacity building for personnel from developing or under developed countries. KOICA is the only organization that has such a concrete training activity on nation-wide basis in Korea.

Training department under NFRDI has, also, carried out training courses to educate the fishermen and governmental official relevant with red tide in Korea. In addition, marine harmful organism research team runs teaching programs, yearly, mainly targeted for the personnel engaged in HAB monitoring program in local government or regional fisheries agency by providing field applicable fundamental knowledge on the taxonomy of harmful algae and HAB monitoring including the skill of sampling, preservation and microscopic observation both in field and laboratory.

Table 5.1 Training courses on HAB held by governmental institutes in Korea

No	Name of training course	Trainee	Trainer	Period	Content	Responsible institute
1	Aquaculture	Personnel from developing or under developed countries	Experienced researcher from NFRDI and universities, etc.	4 weeks during June to August	Strategies for Red tide monitoring & mitigation	KOICA
2	Management of coastal environment	Personnel from local government or regional maritime affairs & fisheries responsible for the management of coastal environment	Experienced researcher from NFRDI and universities, etc	5 days during May to July	- Red tide monitoring & mitigation - Bloom biology of harmful algae	Training department in NFRDI
3	HACCP	- Personnel from local government, regional maritime affairs & fisheries, fisheries quality inspection service, etc. responsible for the sanitary or inspection for the fisheries products - Fisherman or staff of private company for fisheries products	Experienced researcher from NFRDI and universities, etc	5 days during May to July	- Shellfish poisoning	Training department in NFRDI
4	Taxonomy of micro algae	- Personnel from regional maritime affairs & fisheries , responsible for the red tide monitoring	Experienced researcher from HAB research team	One week during February to May	- sampling, fixation, taxonomy, - bloom biology - Shellfish poisoning	Marine harmful organism research team in NFRDI

Source: NFRDI home page (http://www.nfrdi.re.kr)

6. National Priority to Cope with HAB

This chapter introduces the activities to cope with HAB on a governmental level by the running of HAB monitoring network, HAB emergency center and HAB homepage. In addition, several kids of mitigation technology including devices have been developed and propagated to local government responsible for HAB mitigation to control HAB directly. This activities work effectively in timely informing fisherman and HAB relevant agency of HAB situation and direct controlling of HAB resulting in the minimization of fisheries damage from fish-killing *Cochlodinium* bloom.

Also, facilitation of international cooperation with IOC, SCOR, PICES, etc. is important to resolve HAB problems by sharing HAB information and/or organizing and conducting international collaborative program.

6.1 HAB monitoring program and practical application of mitigation techniques

Early warning of HAB situation and direct control of blooms could be very useful for fisherman or responsible agency to take action in order to minimize fisheries damages. For this Korea has organized HAB monitoring network on a governmental level over Korean coastal waters since 1995 when there was a massive harmful algal bloom by *Cochlodinium* with huge amount of fisheries damage, 95 million US dollars. In addition, NFRDI runs red tide emergency center during *Cochlodinium* bloom period where all the data from field survey and remote sensing including meteorology are collected and analyzed to publish HAB new letters, describing present situation and short term prediction on the development and direction of movement of the blooms. The HAB news letter is disseminated to fisherman and relevant organizations through fax, internet, ARS, SMS service and data-TV. NFRDI, Regional Maritime Affairs & Fisheries and National Maritime Police Agency under Ministry of Maritime Affairs and Fisheries are responsible for HAB monitoring over more than 170 stations around Korean coastal areas.

Yellow clay has been practically applied as one of control techniques on a governmental level since 1996 in order to minimize the impact on aquatic animal during the dense bloom by *Cochlodinium*. Moreover, several kinds of devices such as clay dispenser, electrolytic clay dispenser, automatic HAB alarm system, etc have been developed by national or private research institute to either maximize HAB removal efficiency with least amount of yellow clay or help fisherman perceive emergent HAB situation earlier. This activities on a governmental level have been evaluated to be overall successful by showing the decrease of fisheries damages from about 95 millions US dollars in 1995 to several millions.

A few fisherman and scientists are wondering on the possible side effect of yellow clay which has been dispersed since 1996 and estimated certain of amount of clay to be settled onto the bottom near coastal area. Thus, NFRDI is under study on the side effect by yellow clay dispersion for the several coasts in which from several ten tons of clay has been dispersed during every summer season to control *Cochlodinium* blooms.

There has been no any scientific evidence that distinctly affected to the ecosystem till now. However, this scientific study will be continued as a long term study in addition to the trial to minimize the amount of clay for the control of *Cochlodinium* blooms on a governmental level.

6.2 Cooperation with international organization

The Korean government supports the activities of international organizations related to HAB problems. The action plan for the Protection, Management and Development of the Marine and Coastal Environment of the Northwest Pacific Region (NOWPAP) and International Oceanographic Commission (IOC) have special activities or programs concerning HAB problems. North Pacific Marine Science Organization (PICES), also, has HAB Section to meet HAB problems by international cooperation.

NOWPAP is one of the Regional Seas Programme of the United Nations Environment Programme (UNEP). NOWPAP established the Special Monitoring & Coastal Environmental Assessment Regional Activity Centre (CEARAC) in 1999 in Toyama, Japan. CEARAC set the first target for coastal environmental assessment on HAB. Korean government supports CEARAC, one of four RACs under NOWPAP, to resolve emerging HAB problems in the Northwest Pacific Region along with other RACs.

The IOC subcommittee for the Western Pacific (IOC/WESTPAC) has HAB program. IOC WESTPAP, also, conducts NEAR GOOS program, a regional program of the Global Ocean Observing System (GOOS) implemented by China, Japan, Korea and Russia.

PICES has made various efforts related to HAB problems. PICES member countries agreed to utilize HAB meta-database format of IOC/ICES at a joint PICES/IOC workshop on “HAB harmonization of data” in 2003 Honolulu meeting. HAB section under PICES is gathering HAE-DAT reports from member countries to check the usability and effectiveness of the HAE-DAT format.

Korean government supports the activities of IOC/WESTPAC and PICES by participating in the program actively as well as eager in providing various kinds of documents related to HAB.

7. Suggested Activity for the NOWPAP Region

This chapter suggests future action against the problems related with *Cochlodinium* blooms, in collaboration with other organization, and promotion of land based activities for NOWPAP region in near future. Considering that *Cochlodinium* not only give severe fisheries impact on aquacultures in Korea and Japan, but also might possibly suffer the NOWPAP countries in future along the regional currents, it is important for NOWPAP member to collaborate with other international organizations.

For the last two decades, the economic impacts of HABs on fisheries has increased with the increase of scale of HABs in China, Japan and Korea. Particularly, the blooms by fish killing *Cochlodinium polykrikoides* have been the direct and severe impacts on the coastal aquaculture industries in Korea and Japan. Therein, there is growing concerns to minimize fisheries damage by establishing early warning system from the initial stage and take emergent action against the blooms. Herein, information on the bloom mechanism, transportation, eco-physiology and mitigation techniques for the species would be essential to countermeasure against the blooms. In addition, collaborative research program to get scientific knowledge and networking for the monitoring and prediction of HABs among NOWPAP member countries would be very beneficial in resolving the problems.

NOWPAP/CEARAC has established *Cochlodinium* Corresponding Group (CCG) which would plays an important role in getting information on *Cochlodinium* and developing useful tools to mitigate HAB problems by collaboration among NOWPAP member countries in future. Thus, CCG composed of HAB experts from each NOWPAP should be supported on their governmental level to facilitate its activities.

Also, it would be important to monitor and control land-based pollutants which might play a key role in accelerating blooms in coastal areas of NOWPAP member countries. Thus, it is highly encouraged to develop appropriate policies and technologies to minimize the loading of land-based pollutants into the sea of NOWPAP area.

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Appendices

1. Red tide events in the NOWPAP area of Korea from 1999 to 2003
2. Occurrence of red tide in the NOWPAP area of Korea from 1999 to 2003
3. Occurrence of toxin-producing plankton in the NOWPAP area of Korea from 2002 to 2003
4. List of HAB references in Korea since 2000

i Red tide events in northern Kyushu coastal waters Inland during 1998-2002 (1)

Event No.	Location (name of the sea area): Location 1	Location 2	Duration dd/mm/yy-dd/mm/yy	Continuous days	Causative species ①	②	③	④	⑤	⑥	⑦	⑧	Max. cell density (cells/L) ①	②	③	④	⑤	⑥	⑦	⑧	mitigation activity and effectiveness	Damage: Fisheries resource	Human health
1	Tongyoung buksinman		01-01-99 -		*Heterocapsa triquetra*	CheckBox1							5,200,000										
2	Sachun hangchondong		23-01-99 -		*Eutreptiella sp.*								3,000,000										
3	Tongyoung hansanman		28-01-99 -		*Gymnodinium sp.*								780,000										
4	Tongyoung kwangdomyoun		19-04-99 -		*Noctiluca sp.*								830,000										
5	Masanman sanho		23-04-99 -		*Prorocentrum sp.*								########										
6	Geoje ilunmyoun		26-04-99 -		*Noctiluca sp.*								5,450,000										
7	Masan nanpo		26-04-99 -		*Eutreptiella gymnastica*								########										
8	Jinhaeman haengam		28-04-99 -		*Eutreptiella gymnastica*								########	1,260									
9	Gunsan naehang		01-05-99 -		*Mesodinium rubrum*								800,000										
10	Jinhaeman haengam		06-05-99 -		*Gymnodinium sanguineum*								1,320,000										
11	Ulsan		13-05-99 -		*Rhizosolenia sp.*								2,000,000	########									
12	Tongyoung, bubsongman, buksinm		15-05-99 -		*Heterosigma akashiwo*	Proro.minimum	Eutreptiella gymnastica						4,500,000	1,800,000	1,200,000								
13	Masanman		24-05-99 -		*Gymnodinium sanguineum*								3,960,000										
14	Tongyoung wonmoonman		24-05-99 -		Mesodinium rubrum								6,500,000										
15	Tongyoung buksinman		28-05-99 -		*Leptocylindrus danicus*	*Gymnodinium sanguineum*							7,300,000	1,460,000									
16	kunsan		02-06-99 -		*Heterosigma akashiwo*								########										
17	masanman	haengamman	04-06-99 -		*Prorocentrum sp.*	*Heterosigma akashiwo*							########	########									
18	Namhaegun		08-06-99 -		*Ceratium furca*								6,000,000										
19	Yeosu gamakmang		09-06-99 -		*Heterosigma akashiwo*								########										
20	Pohang youngilman		18-06-99 -		*Prorocentrum sp.*	*Ceratium furca*	*Heterosigma sp.*						650,000	400,000	920,000								
21	Tongyoung kwangdomyoun		18-06-99 -		*Prorocentrum sp.*								6,600,000										
22	Geojedo		19-06-99 -		*Prorocentrum sp.*	*Gymnodinium sp.*							330,000	760,000									
23	Tongyoung buksinman		21-06-99 -		*Prorocentrum triestinum*								5,600,000										
24	Namhae kangjinman		21-06-99 -		*Prorocentrum sp.*								1,350,000										
25	Pusan kadukdo		28-06-99 -		*Prorocentrum sp.*	*Coscinodiscus gigas*	*Thalassiosira decipiens*						########	1,000,000	100,000								
26	Wando		28-06-99 -		*Heterosigma akashiwo*								########										
27	kunsan		29-06-99 -		*Heterosigma akashiwo*	*Heterocapsa triquetra*							########	2,000,000										
28	Pohang youngilman		01-07-99 -		*Proro.triquetra*	*Heterosigma akashiwo*	*Chaetoceros sp.*						600,000	1,500,000	1,600,000	1,500,000							
29	Junnam young		06-07-99 -		*Noctiluca scintillans*								1,100,000										
30	Tongyoung buksinman		06-07-99 -		*Leptocylindrus danicus*								2,500,000										
31	Yeosu	dolsan	06-07-99 -		*Skeletonema costatum*	*Thalassiosira sp.*	*Ceratium furca*	*Prorocentrum sp.*					2,000,000	5,600,000	250,000	1,700,000							
32	Namhaedo kangjinman		07-07-99 -		*Chaetoceros sp.*								1,600,000										
33	Junnam		08-07-99 -		*Chaetoceros sp.*	*Coscinodiscus gigas*	*Ceratium furca*	*Prorocentrum sp.*					1,500,000	2,000,000	1,400,000	300,000							
34	Pohang youngilman		21-07-99 -		*Prorocentrum triestinum*	*Prorocentrum micans*							6,200,000	1,500,000									
35	Buankun widomyoun		22-07-99 -		*Noctiluca scintillans*								1,000,000										
36	Jinhaeman	Masan	22-07-99 -		*Prorocentrum dentatum*	*Ceratium furca*							4,180,000										
37	Gosung		07-08-99 -		*Gymnodinium sp.*								########										
38	Asanman		08-08-99 -		Mesodinium rubrum								4,537,000										
39	Namhaekun	hadongkun	10-08-99 -		*Heterosigma sp.*	*Chaetoceros sp.*							2,000,000	3,000,000									
40	Yeosu	Kamakman	10-08-99 -		*Chaetoceros sp.*	*Skeletonema costatum*	*Nitzschia sp*	*Rhizosolenia sp.*					########	########	3,600,000	1,100,000							
41	Ulsan		11-08-99 -		*Skeletonema costatum*	*Chaetoceros sp.*							########	########									
42	Chunsuman		11-08-99 -		*Chaetoceros sp.*	*Thalassiosira decipiens*	*Skeletonema costatum*	*Microcystis virdis*					########	7,500,000	5,000,000	########							
43	Masan, sanho, dukdong		11-08-99 -		*Skeletonema costatum*	*Rhizosolenia fragilissima*							1,760,000	2,840,000									
44	Goheung		11-08-99 - 26/09/99	35	*Cochlodinium polykrikoides*								260,000								Clay dispersion		
45	Yeosu hwajungmyoun		11-08-99 - 22/09/99	34	*Cochlodinium polykrikoides*								50,000								Clay dispersion		
46	Pohang youngilman		13-08-99 -		*Prorocentrum sp.*	*Heterosigma sp.*	*Skeletonema costatum*						2,500,000	1,500,000	2,000,000								
47	Namhaekun sangju		14-08-99 - 17/09/99	33	*Cochlodinium polykrikoides*								300,000								Clay dispersion		
48	Tongyoung		14-08-99 - 01/10/99	45	*Cochlodinium polykrikoides*								500,000								Clay dispersio	finfish died	
49	geojedo		16-08-99 -		*Gymnodinium sanguineum*								1,870,000										
50	Ulsan		17-08-99 -		*Chaetoceros sp.*	*Prorocentrum sp.*	*Thalassiosira sp.*						200,000	500,000	200,000								
51	Masan	Jinhaeman	17-08-99		*Gymnodinium sanguineum*	*Ceratium sp.*							5,280,000	1,760,000									
52	Geojedo		18-08-99 -		*Gymnodinium sanguineum*	*Ceratium sp.*							1,980,000	3,700,000									
53	Masanman		19-08-99 -		*Skeletonema costatum*								3,440,000										
54	Jinhaeman		19-08-99 -		*Gymnodinium sanguineum*								3,080,000										
55	Geojedo		21-08-99 -		*Gymnodinium mikimotoi*								7,500,000										
56	Gosung		21-08-99 - 06/09/99	8	*Cochlodinium polykrikoides*								2,700,000								Clay dispersion		
57	Wando		24-08-99 - 25/09/99	28	*Cochlodinium polykrikoides*								500,000								Clay dispersion		
58	Geojedo		25-08-99 - 02/10/99	24	*Cochlodinium polykrikoides*								1,700,000								Clay dispersion		
59	Janghueng		25-08-99 - 20/09/99	22	*Cochlodinium polykrikoides*								4,000,000								Clay dispersion		
60	Pusan		28-08-99 - 03/09/99	5	*Cochlodinium polykrikoides*								1,100,000								Clay dispersion		
61	Ulsan		29-08-99 - 07/09/99	9	*Cochlodinium polykrikoides*								4,500,000								Clay dispersio	finfish died	
62	Kyoungju		29-08-99 - 06/09/99	9	*Cochlodinium polykrikoides*								3,000,000								Clay dispersion		
63	Pohang youngilman		31-08-99 - 09/09/99	11	*Cochlodinium polykrikoides*								3,000,000								Clay dispersion		
64	Jinhaeman		31-08-99 - 07/09/99	10	*Cochlodinium polykrikoides*								7,890,000								Clay dispersion		
65	Pohang		02-09-99 - 09/09/99	11	*Cochlodinium polykrikoides*								3,800,000										
66	Janghueng		06-09-99 -		*Gymnodinium sp.*								4,300,000								Clay dispersion		
67	Namhae		06-09-99 -		*Chaetoceros sp.*								1,000,000								Clay dispersion		
68	Geojedo		13-09-99 -		*Gymnodinium sanguineum*								500,000										
69	Gokun		14-09-99 -		*Gymnodinium sp.*								2,500,000										
70	Wonmunman		15-09-99 -		*Prorocentrum triestinum*								3,100,000										
71	Gosung		15-09-99 -		*Gymnodinium sanguineum*	*Gymnodinium fissum*							3,000,000										
72	Kadukdo		15-09-99 -		*Gymnodinium sp.*								300,000										
73	Junnam		15-09-99 -		*Gymnodinium sp.*								265,000										
74	Masanman		15-09-99 -		*Skeletonema costatum*								1,500,000										
75	Geojedo		15-09-99 -		*Gymnodinium sanguineum*								400,000										
76	Geojedo		15-09-99 -		*Gymnodinium mikimotoi*								2,300,000										

Source : Kyushu Fishery Coordination Office, “Situation of Red Tide in the Seas surrounding Kyushu Island”, 1999-2003.

i Red tide events in northern Kyushu coastal waters Inland during 1998-2002 (2)

Event No.	Location (name of the sea area)		Duration	Continuous days	Causative species								Max. cell density (cells/L)								mitigation activity and effectiveness	Damage	
	Location 1	Location 2	dd/mm/yy-dd/mm/yy		①	②	③	④	⑤	⑥	⑦	⑧	①	②	③	④	⑤	⑥	⑦	⑧		Fisheries resource	Human health
77	Ulsan		10-09-99 -		*Gymnodinium sp.*								3,000,000										
78	Tongyoung		25-09-99 -		*Gymnodinium sanguineum*								1,100,000										
79	Jinhaeman		27-09-99 -		*Prorocentrum sp.*								8,500,000										
80	Namhae		28-09-99 -		*Skeletonema costatum*								8,000,000										
81	Gosungkun		02-10-99 -		*Prorocentrum minimum*								1,300,000										
82	Junbuk		12-10-99 -		*Cochlodinium polykrikoides*								250,000										
83	Chungnam		21-10-99 -		*Cochlodinium polykrikoides*								500,000										
84	Pohang		17-02-00		*Eutreptiella gymnastica*								########										
85	kunsan		02-03-00		*Skeletonema costatum*								########										
86	Jinhaeman		20-03-00		*Heterocapsa triquetra*								1,350,000										
87	Pohang		01-04-00		*Chromonas marina*								########										
88	kunsan		01-05-00		*Eutreptiella gymnastica*	Mesodinium rubrum							########	1,500,000									
89	Masanman		02-05-00		*Eutreptiella gymnastica*	*Pseudonitzschia pungens*	*Eutreptiella gymnastica(5.4)*						5,700,000	2,550,000	########								
90	Masanman		17-05-00		*Prorocentrum sp.*	*Heterocapsa sp.*							7,700,000										
91	Masanman		23-05-00		*Heterosigma akashiwo*								########										
92	Kyoungju		25-05-00		*Noctiluca scintillans*								1,500,000										
93	Tongyoung		29-05-00		*Heterosigma akashiwo*	*Prorocentrum micans*							1,560,000	780,000									
94	Jinhaeman		02-06-00		*Heterosigma akashiwo*	*Gymnodinium sanguineum*							########	1,120,000									
95	Onsanman	JangsangPohang	07-06-00		*Heterosigma akashiwo*	*Heterosigma akashiwo*							1,150,000	########									
96	Masanman	Hangamman	14-06-00		*Heterosigma*	*Ceratium furca*	*Proro. Micans*						6,740,000	1,530,000									
97	Buksinman		15-06-00		*Heterosigma*								700,000										
98	Bubsongman		16-06-00		*Proro. Micans*								3,200,000										
99	Pohang		19-06-00		*Proro. Minimum*	*Proro. Micans*							########	5,000,000									
100	kunsan		21-06-00		*Noctiluca scintillans*								########										
101	Yeosu		24-06-00		*Ceratium furca*								1,080,000										
102	Tongyoung		27-06-00		*Heterosigma akashiwo*								########										
103	Pohang		30-06-00		*Heterosigma akashiwo*								5,000,000										
104	Geojedo		01-07-00		*Proro. Minimum*								300,000										
105	Chungbuk		03-07-00		*Ceratium sp.*	*Noctiluca scintillans*							600,000										
106	Kamakman		03-07-00		*Heterosigma akashiwo*	*Ceratium sp.*							2,040,000	320,000									
107	Geojedo		04-07-00		*Noctiluca scintillans*								650,000										
108	Chunsuman		04-07-00		*Proro. Micans*	*Ceratium sp.*							3,000,000	300,000									
109	Jinhaeman		05-07-00		*Heterosigma akashiwo*								########										
110	Pusan		06-07-00		*Heterosigma akashiwo*	*Proro. Micans*							########										
111	Ulsan		10-0700		*Prorocentrum triestinum*								3,000,000										
112	Geojedo		14-07-00		*Gymnodinium sanguineum*								1,300,000										
113	Jinjuman		14-07-00		*Ceratium furca*								840,000										
114	Yeosu		18-07-00		*Chaetoceros sp.*	*Skeletonema costatum*							5,710,000	1,520,000									
115	Tongyoung		18-07-00		*Rhizosolenia sp.*								4,300,000										
116	Masan		18-07-00		*Proro. dentatum*								########										
117	kunsan		19-07-00		*Noctiluca scintillans*								5,000,000										
118	Inchun		20-07-00		Mesodinium rubrum								5,000,000										
119	Geojedo		20-07-00		*Proro. Minimum*								750,000										
120	Junnam		20-07-00		*Heterosigma akashiwo*								########										
121	kadukdo		27-07-00		*Heterosigma akashiwo*								4,200,000										
122	Ulsan		28-07-00		*Prorocentrum sp.*								1,500,000										
123	Masanman		29-07-00		*Prorocentrum sp.*								########										
124	Geojedo		02-08-00		*Noctiluca scintillans*								700,000										
125	Jinhaeman		07-08-00		*Rhizosolenia sp.*								4,800,000										
126	Haengamman		08-08-00		*Proro. Sp. Thala.decipiems*								1,200,000	2,700,000									
127	Ulsan		08-08-00		*Prorocentrum sp.*								########										
128	Pohang		08-08-00		*Skeletonema costatum*								########										
129	Kyoungbuk		08-08-00		*Noctiluca scintillans*								1,000,000										
130	Onsanman		11-08-00		*Prorocentrum sp.*	*Heterosigma akashiwo*							5,000,000	1,000,000									
131	JangsangPohang		14-08-00		*Prorocentrum sp.*								2,300,000										
132	Pohang		17-08-00		*Skeletonema costatum*								9,000,000										
133	Kyoungju		21-08-00		*Ceratium furca*								1,500,000										
134	Ulsan		21-08-00		*Ceratium furca*								450,000										
135	Ulsan		22-08-00		*Prorocentrum triestinum*								40,000										
136	Junnam		22-08-00		*Chaetoceros sp.*	*Coscinodiscus gigas*							193,000										
137	Junnam		22-08-00		*Prorocentrum minimum*								########										
138	Junnam		22-08-00		*Prorocentrum minimum*								4,800,000										
139	Ulsan		24-08-00		*Prorocentrum minimum*								########										
140	Onsanman		24-08-00		*Thalassiosira decipiens*								########										
141	Kyoungbuk		25-08-00		*Ceratium furca*								180,000										
142	Onsanman		28-08-00		*Thalassiosira rotula*								640,000										
143	Pohang		28-08-00		*Chaetoceros sp.*	*Skeletonema costatum*	*Ceratium furca*						6,800,000	6,000,000	400,000								
144	Ulsan		28-08-00		*Pyrocystis sp.*								40,000										
145	Ulsan		29-08-00		*Prorocentrum dentatum*	*Thalassiosira rotula*							84,000	128,000									
146	Yeosu		22-08-00 10/09/00	19	*Cochlodinium polykrikoides*								910,000								Clay dispersion		
147	Tongyoung		24-08-00 11/09/00	19	*Cochlodinium polykrikoides*								900,000								Clay dispersio	finfish died	

Source : Kyushu Fishery Coordination Office, "Situation of Red Tide in the Seas surrounding Kyushu Island", 1999-2003.

A.sp.=*Alexandrium* sp.

Aka.s.=*Akashiwo sanguinea*

C.f.=*Ceratium fusus*

C.sp.=*Ceratium* sp.

Ch.sp.=*Chaetoceros* sp.

Ch.ps.= *Chaetoceros pseudocurvisetum*

Chro.m.=*Chromonas marina*

Chro.s.=*Chromonas salina*

C.p.=*Cochlodinium polykrikoides*

Cos.g.=*Coscinodiscus gigas*

Cos.sp.=*Coscinodiscus* sp.

Cra.sp=*Cratium* sp.

Cry.a.=*Cryptomonas acuta*

Cry.sp.= *Cryptomonas* sp.

D.f.=*Dictyocha fibula*

Euc.z=*Eucamphia zodiacus*

Euc.sp.=*Eucamphia* sp.

E.g.=*Eutrepteiella gymnastica*

E.sp=*Eutrepteiella* sp.

Gym.m.=*Gymnodinium mikimotoi*

Gym.s.=*Gymnodinium sanguineum*

Gym. sp.=*Gymnodinium* sp.

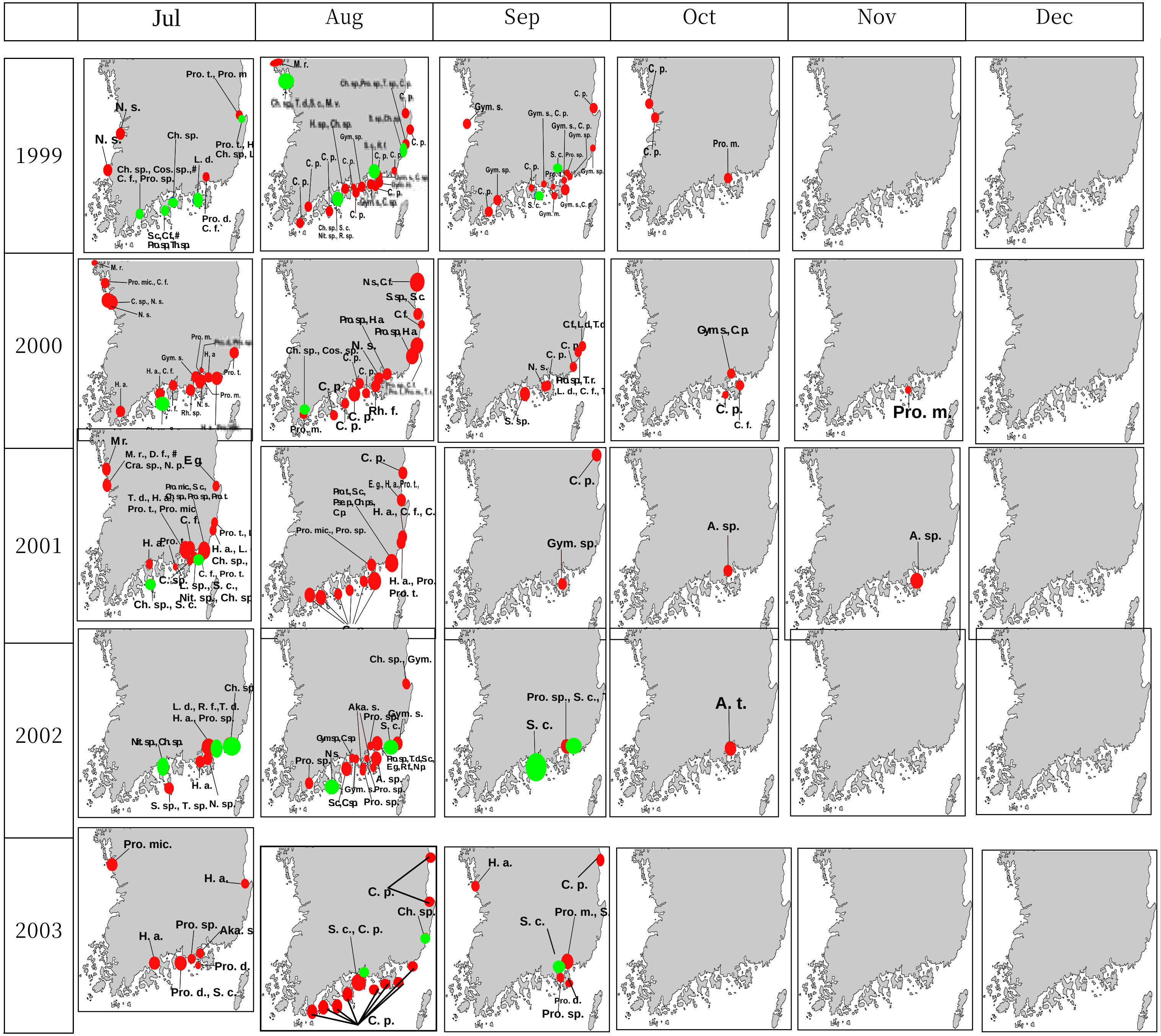
H.t.=*Heterocapsa triquetra*

Heteroc.sp.=*Heterocapsa* sp.

Heteroc.t.=*Heterocapsa triquetra*

H.a.=*Heterosigma akashiwo*

H.sp= *Heterosigma* sp.



L.d.=*Leptocylindrus danicus*

L.sp.=*Leptocylindrus* sp.

M.r.=*Mesodinium rubrum*

M.v.=*Microcystis virdis*

N.p.= *Nitzschia pungens*

Nit.sp.=*Nitzschia* sp.

N.sp.=*Notiluca* sp.

N.s.= *Notiluca scintillans*

Pro.d.=*Procentrum dentatum*

Pro.sp.=*Prorocentrum* sp.

Pro.m.=*Prorocentrum minimum*

Pro.mic=*Prorocentrum micans*

Pro.t.=*Prorocentrum triestinum*

Pse.p.=*Psedonitzschia pungens*

R.f.=*Rhizosolenia fragilissima*

R.s.=*Rhizosolenia setigera*

R.sp.=*Rhizosolenia* sp.

S.c.=*Skeletonema costatum*

S.sp.= *Skeletonema* sp.

T.d.=*Thalassiosira decipiens*

T.r.= *Thalassiosira rotula*

T.sp.= *Thalassiosira* sp.

● : *Dinoplagellates*

● : *Diatoms*

Table 2.2. Occurrence of toxin-producing plankton in the NOWPAP Area of Korea from 2002 to 2003

Type of shellfish poisoning	Causative species	Location			Date	Max. cell density	Damage
		Name of area	Latitude, N	Longitude, E	(dd-mm-yy)	(cells/L)	(fisheries/human)
DAP	***Pseudo-nitzschia*** spp.	Gosung	34.87-34.94	128.26-128.35	24-04-2002	16 400	no data
DAP	***Pseudo-nitzschia*** spp.	Tongyoung	34.67-34.83	128.35-128.53	24-04-2002	1 600 200	no data
DAP	***Pseudo-nitzschia*** spp.	Jinhaeman	34.88-35.17	128.40-128.80	24-04-2002	230 800	no data
DAP	***Pseudo-nitzschia*** spp.	Gosung	34.87-34.94	128.26-128.35	27-05-2002	800	no data
DAP	***Pseudo-nitzschia*** spp.	Tongyoung	34.67-34.83	128.35-128.53	27-05-2002	69 600	no data
DAP	***Pseudo-nitzschia*** spp.	Jinhaeman	34.88-35.17	128.40-128.80	27-05-2002	4 400	no data
DAP	***Pseudo-nitzschia*** spp.	Tongyoung	34.67-34.83	128.35-128.53	20-06-2002	800	no data
DAP	***Pseudo-nitzschia*** spp.	Jinhaeman	34.88-35.17	128.40-128.80	20-06-2002	9 800	no data
DAP	***Pseudo-nitzschia*** spp.	Gosung	34.87-34.94	128.26-128.35	18-10-2002	6 400	no data
DAP	***Pseudo-nitzschia*** spp.	Tongyoung	34.67-34.83	128.35-128.53	18-10-2002	126 400	no data
DAP	***Pseudo-nitzschia*** spp.	Jinhaeman	34.88-35.17	128.40-128.80	18-10-2002	371 600	no data
DAP	***Pseudo-nitzschia*** spp.	Gosung	34.87-34.94	128.26-128.35	13-11-2002	1 200	no data
DAP	***Pseudo-nitzschia*** spp.	Tongyoung	34.67-34.83	128.35-128.53	13-11-2002	9 200	no data
DAP	***Pseudo-nitzschia*** spp.	Jinhaeman	34.88-35.17	128.40-128.80	13-11-2002	25 200	no data
DAP	***Pseudo-nitzschia*** spp.	Jinhaeman	34.88-35.17	128.40-128.80	04-02-2003	28 400	no data
DAP	***Pseudo-nitzschia*** spp.	Jinhaeman	34.88-35.17	128.40-128.80	05-03-2003	3 200	no data
DAP	***Pseudo-nitzschia*** spp.	Tongyoung	34.67-34.83	128.35-128.53	17-03-2003	6 800	no data
DAP	***Pseudo-nitzschia*** spp.	Jinhaeman	34.88-35.17	128.40-128.80	17-03-2003	6 100	no data
DAP	***Pseudo-nitzschia*** spp.	Gosung	34.87-34.94	128.26-128.35	07-04-2003	4 000	no data
DAP	***Pseudo-nitzschia*** spp.	Tongyoung	34.67-34.83	128.35-128.53	07-04-2003	3 600	no data
DAP	***Pseudo-nitzschia*** spp.	Jinhaeman	34.88-35.17	128.40-128.80	07-04-2003	38 400	no data
DAP	***Pseudo-nitzschia*** spp.	Jinhaeman	34.88-35.17	128.40-128.80	23-04-2003	11 000	no data
DAP	***Pseudo-nitzschia*** spp.	Gosung	34.87-34.94	128.26-128.35	12-05-2003	600	no data
DAP	***Pseudo-nitzschia*** spp.	Tongyoung	34.67-34.83	128.35-128.53	12-05-2003	37 800	no data
DAP	***Pseudo-nitzschia*** spp.	Jinhaeman	34.88-35.17	128.40-128.80	12-05-2003	270 900	no data
DAP	***Pseudo-nitzschia*** spp.	Tongyoung	34.67-34.83	128.35-128.53	27-05-2003	800	no data
DAP	***Pseudo-nitzschia*** spp.	Jinhaeman	34.88-35.17	128.40-128.80	27-05-2003	1 800	no data
DAP	***Pseudo-nitzschia*** spp.	Tongyoung	34.67-34.83	128.35-128.53	02-06-2003	2 300	no data
DAP	***Pseudo-nitzschia*** spp.	Jinhaeman	34.88-35.17	128.40-128.80	24-09-2003	10 400	no data
DAP	***Pseudo-nitzschia*** spp.	Gosung	34.87-34.94	128.26-128.35	15-10-2003	12 000	no data
DAP	***Pseudo-nitzschia*** spp.	Tongyoung	34.67-34.83	128.35-128.53	15-10-2003	23 400	no data
DAP	***Pseudo-nitzschia*** spp.	Jinhaeman	34.88-35.17	128.40-128.80	15-10-2003	12 600	no data
DAP	***Pseudo-nitzschia*** spp.	Gosung	34.87-34.94	128.26-128.35	04-11-2003	8 000	no data
DAP	***Pseudo-nitzschia*** spp.	Tongyoung	34.67-34.83	128.35-128.53	04-11-2003	25 500	no data
DAP	***Pseudo-nitzschia*** spp.	Jinhaeman	34.88-35.17	128.40-128.80	04-11-2003	9 800	no data

PSP	*Alexandrium tamarense*	Tongyoung	34.67-34.83	128.35-128.53	24-04-2002	3 200	no data
PSP	*Alexandrium tamarense*	Jinhaeman	34.88-35.17	128.40-128.80	24-04-2002	4 600	no data
PSP	*Alexandrium tamarense*	Jinhaeman	34.88-35.17	128.40-128.80	27-05-2002	800	no data
PSP	*Alexandrium tamarense*	Jinhaeman	34.88-35.17	128.40-128.80	20-06-2002	1 200	no data
PSP	*Alexandrium tamarense*	Tongyoung	34.67-34.83	128.35-128.53	18-10-2002	14 000	no data
PSP	*Alexandrium tamarense*	Jinhaeman	34.88-35.17	128.40-128.80	18-10-2002	12 400	no data
PSP	*Alexandrium tamarense*	Jinhaeman	34.88-35.17	128.40-128.80	23-04-2003	26 000	no data
PSP	*Alexandrium tamarense*	Tongyoung	34.67-34.83	128.35-128.53	12-05-2003	300	no data
PSP	*Alexandrium tamarense*	Tongyoung	34.67-34.83	128.35-128.53	27-05-2003	1000	no data
PSP	*Alexandrium tamarense*	Jinhaeman	34.88-35.17	128.40-128.80	02-06-2003	100	no data
DSP	*Dinophysis acuminata*	Tongyoung	34.67-34.83	128.35-128.53	24-04-2002	1 300	no data
DSP	*Dinophysis acuminata*	Jinhaeman	34.88-35.17	128.40-128.80	27-05-2002	1 200	no data
DSP	*Dinophysis acuminata*	Tongyoung	34.67-34.83	128.35-128.53	20-06-2002	400	no data
DSP	*Dinophysis acuminata*	Jinhaeman	34.88-35.17	128.40-128.80	20-06-2002	200	no data
DSP	*Dinophysis acuminata*	Jinhaeman	34.88-35.17	128.40-128.80	17-03-2003	800	no data
DSP	*Dinophysis acuminata*	Jinhaeman	34.88-35.17	128.40-128.80	23-04-2003	1 300	no data
DSP	*Dinophysis acuminata*	Tongyoung	34.67-34.83	128.35-128.53	12-05-2003	100	no data
DSP	*Dinophysis acuminata*	Jinhaeman	34.88-35.17	128.40-128.80	12-05-2003	400	no data
DSP	*Dinophysis acuminata*	Tongyoung	34.67-34.83	128.35-128.53	27-05-2003	1 000	no data
DSP	*Dinophysis acuminata*	Gosung	34.87-34.94	128.26-128.35	02-06-2003	500	no data
DSP	*Dinophysis acuminata*	Tongyoung	34.67-34.83	128.35-128.53	02-06-2003	200	no data
DSP	*Dinophysis acuminata*	Jinhaeman	34.88-35.17	128.40-128.80	02-06-2003	1 500	no data
DSP	*Dinophysis fortii*	Tongyoung	34.67-34.83	128.35-128.53	04-08-2003	100	no data
DSP	*Dinophysis fortii*	Jinhaeman	34.88-35.17	128.40-128.80	04-08-2003	600	no data
DSP	*Dinophysis fortii*	Jinhaeman	34.88-35.17	128.40-128.80	24-09-2003	200	no data
DSP	*Dinophysis rotundata*	Jinhaeman	34.88-35.17	128.40-128.80	15-10-2003	200	no data
DSP	*Dinophysis rotundata*	Jinhaeman	34.88-35.17	128.40-128.80	04-11-2003	200	no data

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