

National Report on HABs in Korea

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I. INTRODUCTION

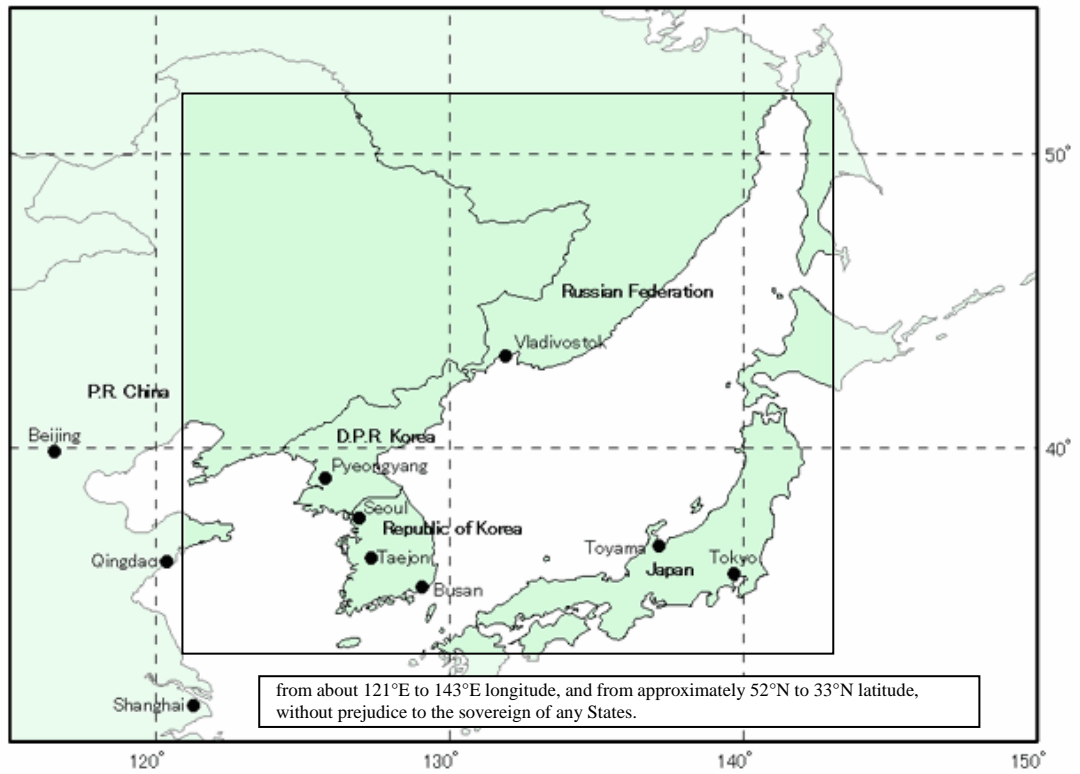
The geographic characteristic of Korea leads river to flow from the east to the west with runoffs discharging into the Yellow Sea and Korean strait. Moreover, the NOWPAP region in Korea is in shallow and semi-closed water system, in which mean water depth of Yellow Sea and the South Sea is 44 and 101m, 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.



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
<i>Cochlodinium polykrikoides</i>	20	9	10	15	20
<i>Prorocentrum minimum</i>	13	14	6	7	6
<i>Gymnodinium sanguineum</i>	10	4	-	5	-
<i>Heterosigma akashiwo</i>	7	12	5	7	5
<i>Skeletonema costatum</i>	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	<i>Cochlodinium polykrikoides</i>	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 km² 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.

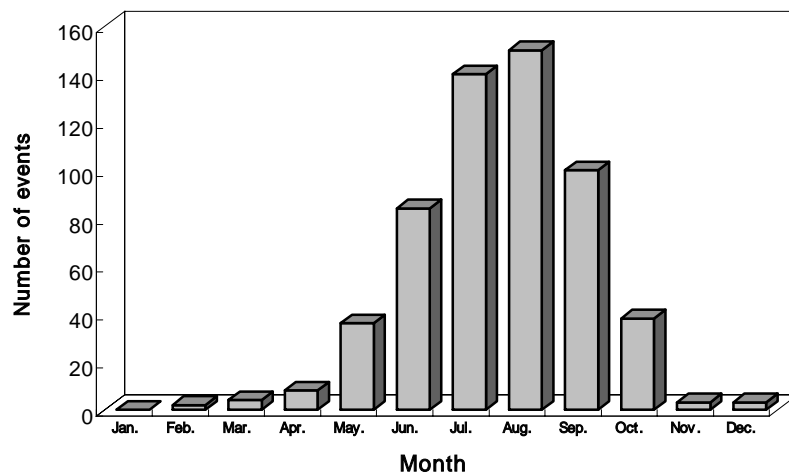


Figure 1. 1. Monthly variation of red tide events in the NOWPAP area of Korea since 1990.

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 red tide 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).

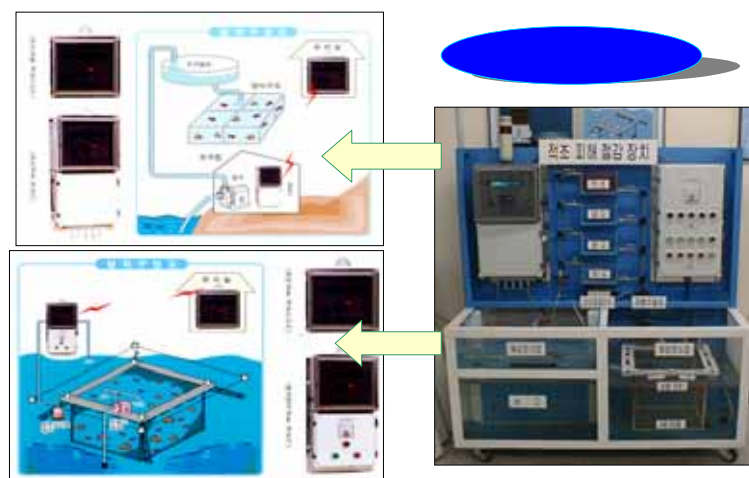


Figure 1.3. Automatic HAB alarm system.

1.7 Damage

The first fisheries damage in Korea occurred in 1981, reportedly, 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 dollar)
1981	<i>Karenia mikimotoi</i>	1.7
1992	<i>Gyrodinium sp.</i>	5
1993	<i>Cochlodinium polykrikoides</i>	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).

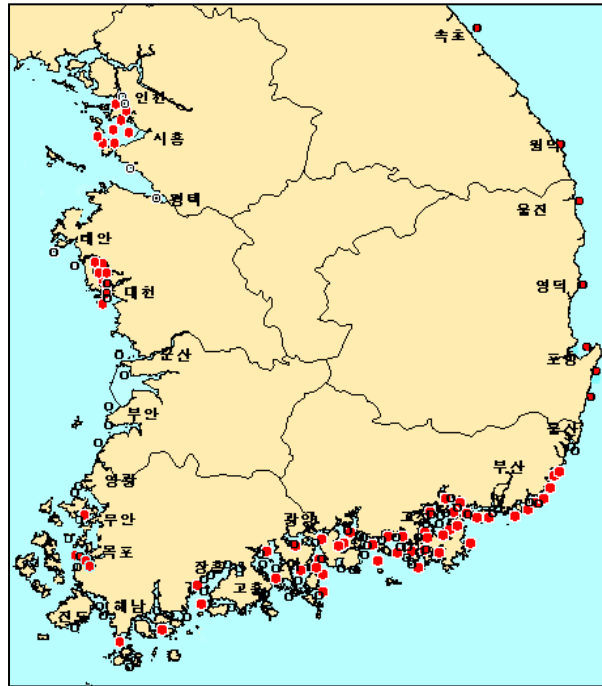


Figure 2. 1. Red tide monitoring station in theNOWPAP area of Korea.

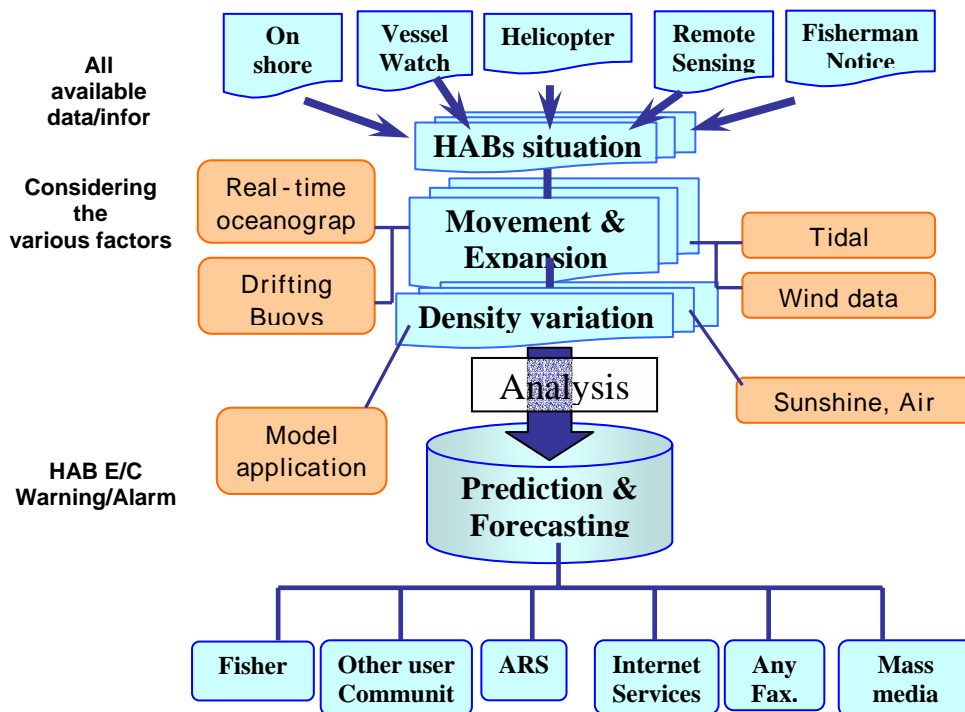


Figure 2. 2. Redtide monitoring, prediction and dissemination system in Korea

Table 2. 1. Red tide warning steps in Korea

Class	Rationale (<i>Cochlodinium</i> cell density and bloom size)
<i>Cochlodinium</i> Appearance	First detection of <i>Cochlodinium</i> vegetative cell, the triggering point of bloom initiation
Red Tide Attention	300cells/ml, bloom area within 2-5km radius equivalent to 12 to 78 km ²
Red Tide Alert	1,000cells/ml, bloom area over 5km radius equivalent to 79 km ²
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. multiseriata*, *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 cell 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.

- Reference List -

- Han, B.S. and Choi, J.K. 1991. A study on the environmental conditions and phytoplankton ecology in the tidal front area of the Yellow Sea. *Yellow Sea Research* 4: 39-55.
- Lee, J.B. and Yoo, K.I. 1991. Distribution of dinoflagellate cysts in Masan Bay, Korea. *The Journal of the Oceanological Society of Korea* 26(4): 304-312.
- Lee, J.B. and Matsuoka, K. 1994. Distribution of dinoflagellate cysts from surface sediments in southern Korean waters. *Proc. 2nd Int'l Symp. On Mar. Sci. Exploitation of Marine Resources* 1-20.
- Han, M.S., Kim, S.W. and Kim, Y.O. 1992. Occurrence of dinoflagellate *Alexandrium tamarense*, a causative organisms of paralytic shellfish poisoning in Chinhae Bay, Korea. *J. Plankton Research* 14(11): 1581-1592.
- Ahn, I.Y., Chung, H.S., Kang, J.S. and Kang, S.H. 1994 Preliminary studies on the ecology of neritic marine diatoms in Maxwell Bay, King George Island, Antarctica *The Korean Journal of Phycology* 9(1): 37-45.
- Chang, M. and Shim, J.H. 1994 An ecological study on the phytoplankton community of the Yellow Sea in February, 1986 *Ocean Research* 16(2): 95-109.
- Cho, K.A., Wui, I.S. and Choi, C.I. 1994 Ecological study of phytoplankton in the Kwang-Yang Bay. *Korean J. Environ. Biol.* 12(2): 137-150.
- Chang, M., Kim, W.S. and Lee, J.H. 1995 Phytoplankton blooms in the coastal waters of Korea-Red tides in Masan and Chinhae Bays *Ocean Research* 17(2): 137-156
- Lee, J.B. 1996. Phytoplankton community dynamics and marine environments in the southern and western coastal waters of Korea in May, 1996. *Bull. Mar. Res. Inst. Cheju Nat'l Univ.* 22: 149-162.
- Yang, S.R. 1997. Physiological adaptation of nitrate uptake by phytoplankton under simulated upwelling conditions. *Journal of Korean Fish. Soc.* 30(5): 709-715.
- Min, B.S. 1997. Differentiation of some environmental factors and planktonic communities of the two areas divided by the breakwater between Youngdo and Jodo, Busan. *Bull. Korean Fish. Soc.* 8(2): 61-67.
- Kim, Y.O. and Taniguchi, A. 1997. Seasonal variation of excystment pattern of the planktonic oligotrich ciliate *Strombidium conicum*. *Marine Biology* 128(2):207-212.
- Na, G.H., Park, K.D., Lee, S.H., Kim, G.H. and Nam, J.B. 1997. Diel migration of dinoflagellates, *Cochlodinium polykrikoides* in situ. *Journal of Aquaculture* 10(4): 457-462.
- Choi, M.S., Jun, B.O., Kang, Y.H. and Chung, I.K. 1997. Photosynthetic efficiency of a marine picoplankter *Pycnococcus provasolii* Guillard under various environmental conditions. *Algae* 12(2): 93-97.

- Lee, H.Y. and Greene, R.M. 1998. Species-specific growth rate of phytoplankton in the west pacific sector of the Southern Ocean. 1. *Prorocentrum scutellum* Schroder. J. Plant Biol. 41(4): 293-297.
- Kwak, J.K., Kim, H.J., Shin, G.H., Cho, M.G. and Han, B.H. 1998. Specific growth rates of microalgae in different types of model photobioreactors. J. Korean Fish. Soc. 31(4): 567-573.
- Lim, H.J. and Park, S.R. 1998. Fatty acid composition of concentrated phytoplanktons by cold storage and their effects on the larval survival of pacific oyster, *Crassostrea gigas*. J. Korean Fish. Soc. 31(4): 567-573.
- Cho, K.J. and Shin, J.K. 1998 Dynamics of inorganic N.P nutrient and planktonic algae during summer and winter in downstream of the Nakdong River. Korean J.Limnol.31(1):67-75.
- Jung, C.S., Choi, W.J., Kim, H.G., Jung, Y.G., Kim, J.B. and Lim, W.A. 1999. Interrelation between *Cochlodinium polykrikoides* blooms and community structure of zooplankton in the coastal waters around Namhaedo in the South Sea of Korea, 1998. Bull. Nat'l Fish. Res. Dev. Inst. Korea 57: 153-161.
- Choi, K.J., Ha, C.H., Han, M.S., Jeon, J.K., Kim, K.T., Lee, H.O. and Yoon, M.Y. 1999 Identificaiton and characterization of nitrate reductase in a marine dinoflagellate, *Alexandrium tamarense* Algae 14(3): 189-194.
- Seo, K.S. and Fritz, L. 2000. Cell-wall morphology correlated with vertical migration in the non-motile marine dinoflagellate *Pyrocystis noctiluca*. Marine Biology 137(4):589-594.
- Jeong, H.J., Park, J.K., Choi, H.Y., Yang, J.S., Shim, J.H., Shin, Y.K., Yih, W.H., Kim, H.S. and Cho, K.J. 2000. The outbreak of red tides in the coastal waters off Kohung, Chonnam, Korea. 2. The temporal and spatial variations in the phytoplanktonic community in 1997. Journal of the Korean Society of Oceanography 5(1): 27-36.
- Jeong, H.J., Park, J.K., Kim, J.S. and Kim, S.T. 2000. The outbreak of red ties in the coastal wters off Kohung, Chonnam, Korea. 3. The temporal and speatial variations in the heterotrophic dinoflagllates and ciliates in 1997. The Sea, Journal of the Korean Society of Oceanography 5(1); 37-46.
- Kim, H.C., Lee, C.K., Lee, S.G., Kim, H.G. and Park, C.K. 2001. Physico-chemical factors on the growth of *Cochlodinium polykrikoides* and nutrient utilization. J. Korean Fish. Soc. 34(5): 445-456.
- Han, M.S., Kim, Y.P. and Cattolico, R.A. 2002. Heterosigma akashiwo (Raphidophyceae) resting cell formation in batch culture: Starin identitiy versus physiological response. J. Phycol. 38: 304-317.
- Lee, C.K., Kim, H.C., Lee, S.G., Jung, C.S., Kim, H.G. and Lim, W.A. 2002. Abundance of harmful algae, *Cochlodinium polykrikoides*, *Gyrodinium impudicum* and *Gymnodinium catenatum* in the coastal area of South Sea of Korea and their effects of temperature,

salinity, irradiance and nutrient on the growth in culture. J. Korean Fish. Soc. 34(5), 536-544.

Kang, Y.S., Kim, H.G., Lim, W.A., Lee, C.K., Lee, S.G. and Kim, S.Y. 2002. An unusual coastal environment and *Cochlodinium polykrikoides* blooms in 1995 in the South Sea of Korea. Journal of the Korean Society of Oceanography 37(4): 212-223.

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.

- Reference List -

- Kim, C.H., Sako, Y. and Ishida, Y. 1993. Variation of toxin production and composition in axenic cultures of *Alexandrium catenella* and *A. tamarense*. Nippon Suisan Gakkaishi 59(4): 633-639.
- Kim, C.H. and Shin, J.B. 1997. Harmful and toxic red tide algal development and toxins production in Korean coastal waters. Algae 12(4): 269-276.
- Cho, E.S., Yun, S.J. Bae, H.M. and Lee, P.Y. 1999. Binding response of *Cochlodinium polykrikoides* to FITC-conjugated lectin probes following treatment with yellow loess. Bull. Nat'l Fish. Res. Dev. Inst. Korea 57: 141-144.
- Pyo, D.J., Lee, H.J., Park, K.Y. and Shine, H.D. 1999. Quantitative analysis of microcystins in shellfish using GC. Journal of the Korean Chemical Society 43(1): 30.-.
- Kim, C.S., Lee, S.G., Lee, C.K., Kim, H.G. and Jung, J. 1999. Reactive oxygen species as causative agents in the ichthyotoxicity of the red tide dinoflagellate *Cochlodinium polykrikoides*. Journal of Plankton Research 21(11): 2105-2115.
- Lee, H.O., Cheun, B.S., Watanabe, E. and Han, M.S. 2000. Comparison of HPLC analysis and channel biosensor in the detection of PSP toxin in natural *Alexandrium tamarense* population. Algae 15(1): 61-64.
- Kim, C.S., Lee, S.G. and Kim, H.G. 2000. Biochemical responses of fish exposed to a harmful dinoflagellate *Cochlodinium polykrikoides*. Journal of Experimental Marine Biology and Ecology 254: 131-141.
- Ahn, D.K., Park, Y.S., Park, J.G., Lee, S.J. and Lee, J.A. 2000. Quantification of DSP toxins in the mussels of the Jinhae Bay by fluorometric HPLC analysis and protein phosphatase inhibition assay Algae 15(4): 307-314.

- Choi, J.S., Lee, W.K., Son, B.W., Kim, D.S., Choi, H.D., Choi, J.S., Jung, J.H., Im, K.S. and Choi, W.C. 2000. Screening on radical scavenging activity of marine microalgae. *Kor. J. Pharmacogn.* 31(2): 252-255.
- Kim, C.S., Lee, S.G., Kim, H.G. and Lee, J.S. 2001. Screening for toxic compounds in the red tide dinoflagellate *Cochlodinium polykrikoides*: Is it toxic plankton? *Algae* 16(4): 457-462.
- Lee, I.C. and Yoo S.A. 2001. Characterization of 5-aminolevulinic acid dehydratase purified from *Anabaena cylindrical*. *Algae* 16(1): 59-65.
- Cho, E.S., Choi, B.D., Cho, Y.C., Kim, T.J. and Kim, H.G. 2001. Discrimination of three highly toxic *Alexandrium tamarense* (Dinophyceae) isolates using FITC-conjugated lectin probes. *Journal of Plankton Research* 23(1): 89-96.
- Kim, C.S., Lim, W.A. and Cho, Y.C. 2001. Mycosporine-like amino acids as the UV sunscreen with oxygen radical scavenging activity. *Bull. Nat'l Fish. Res. Dev. Inst. Korea* 60: 65-71.

3.3 Taxonomy of HAB Causative Species

Research on the ultra structure and phylogenetic tree among the micro algae by molecular biological approach has been the main study subjects.

- Reference List -

- Park, M.O. 1992. *In vivo* fluorescence characteristics of pteridine for identification of phytoplankton. *Bull. Korean Fish. Soc.* 25(3): 219-228
- Lee, S.G., Park, J.S. and Kim, H.G. 1993. Taxonomy of marine toxic flagellates occurring in the southern coastal waters of Korea. *Bull. Nat. Fish. Res. Dev. Agency* 48: 1-24.
- Lee, J.H., Kim, H.S., Park, C.W. and Chung, J. 1994. Morphological study of *Cyclotella pseudostelligera* Hust. (Bacillariophyceae). *The Korean Journal of Phycology* 9(2): 111-114
- Choi, J.K., Lee, J.H. and Lee, K. 1995. Taxonomic studies on diatoms in Korea. I. Classification system and koreanization of classification level. *The Korean Journal of Phycology* 10(supplement): 1-11.
- Cho, K.J. 1995. Fine structure of diatom *Stephanodiscus hantzschii* f. *tenuis* and *S. parvus* from the Nakdong River of Korea *The Korean Journal of Phycology* 10(2): 69-76.
- Yang, E.J. and Choi, J.K. 1996. Morphological study of centric diatom *Coscinodiscus oculus-iridis* Ehrenberg. *Algae* 11(1): 1-7.
- Kang, J.S., Kim, H.S. and Lee, J.H. 1996. Morphological variations of the marine diatom *Thalassiosira weissflogii* under culture conditions. *Algae* 11(1): 23-34.

- Lee, C.K., Lee, S.G. and Kim, H.G. 1999. Occurrence and abundance of three morphologically similar dinoflagellates, *Cochlodinium polykrikoides*, *Gyrodinium impudicum* and *Gymnodinium catenatum* in the southern coast of Korea. Bull. Nat'l Fish. Res. Dev. Inst. Korea 57: 131-139.
- Kim, M.R. and Chang, Y.K. 1997. Taxonomic studies on some species of *Pediastrum* Meyen in Korea. Algae 12(3): 159-165
- Cho, E.S., Kim, G.Y. and Cho, Y.C. 2001. Molecular analysis of morphologically similar dinoflagellates *Cochlodinium polykrikoides*, *Gyrodinium impudicum* and *Gymnodinium catenatum* based on internal transcribed spacer and 5.8S rDNA regions Algae 16(1): 53-57

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 1996 from which the yellow clay was practically introduced to the sea to remove the red tide.

- Reference List -

- Jeong, H.J. 1994. Predation effects of the calanoid copepod *Acartia tonsa* on a population of the heterotrophic dinoflagellate *Protoperidinium cf. divergens* in the presence of co-occurring red-tide dinoflagellate prey. Mar. Ecol. Prog. Ser. 111: 87-97
- Jeong, H.J. 1994. Predation by the heterotrophic dinoflagellate *Protoperidinium cf. divergens* on copepod eggs and early naupliar stages. Mar. Ecol. Prog. Ser. 114: 203-208.
- Jeong, H.J., Lee, C.W., Yih, W.H. and Kim, J.S. 1997. *Fragilidium cf. mexicanum*, a thecate mixotrophic dinoflagellate which is prey or and a predator on co-occurring thecate heterotrophic dinoflagellate *Protoperidinium cf. divergens*. Mar. Ecol. Prog. Ser. 115: 299-305.
- Choi, H.G., Kim, P.J., Lee, W.C.C., Yun, J., Kim, H.G. and Lee, H.J. 1998. Removal efficiency of *Cochlodinium polykrikoides* by yellow loess. J. Korean Fish. Soc. 31(1): 109-113.
- Jeong, H.J., Shim, J.H., Lee, C.W., Kim, J.S. and Koh, S.M. 1999. Growth and grazing rates of the marine planktonic ciliate *Strombidinopsis* sp. on red-tide and toxic dinoflagellates. JEM 46(1): 69-76.
- Hwang, J.Y. Jang, M.I. Kim, S.J. Cho, W.M. Ahn, B.S. Kang, S.W. 2000. Mineralogy and chemical composition of the residual soils (Hwangto) from South Korea. J. Miner. Soc. Korea 13(3): 147-163.

- Kang, S.J., Lim, S.I. and Lee, B.H. 2001. The removal of red-tide organisms by using microscreen and ozone. *Journal of Korea Technological Society of Water and Waste Water Treatment*.
- Kim, C.S., Bae, H.M. and Cho, Y.C. 2001. Control of harmful algal blooms by clay via photochemical reactions. *Algae* 16(1): 67-73.
- Park, H.K., Jung, E.Y., Lee, Y.J., Jung, J.M., Choi, S.Y. and Hong, Y.K. 2002. A study on the removal of *Microcystis aeruginosa* by coagulants of the ceramic-zeolite type and yellow loess. *J. of the Environmental Sciences* 11(4): 405-409.
- Kim, P.J., Heo, S. and Yun, S.J. 2002. Adsorption and removal mechanism of dissolved inorganic nutrients in seawater by yellow loess. *J. Korean Fish. Soc.* 35(2): 146-154.
- Park, M.G. 2002. Physiological ecology of parasitic dinoflagellate *Amoebophrya* sp. and harmful algal blooms. *Journal of the Korean Society of Oceanography* 7(3): 181-194.
- Jeong, H.J. et al. 2002. NaOCl produced by electrolysis of natural seawater as a potential method to control marine red tide dinoflagellate. *Phycologia* 41.
- Park, M.G. et al. .R. 2002. Effects of parasitism on diel vertical migration phototaxis/geotaxis, and swimming speed of the bloom-forming dinoflagellate *Akashiwo sanguinea*. *AME* 29:11-18.

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.

- Reference List -

- Cho, H.J., Kim, C.H., Moon, C.H. and Matsuok, K. 2003. Dinoflagellate cysts in recent sediments from the southern coastal waters of Korea. *Botanica Marina* 46(4): 332-337.
- Lee, H.O., Choi, K.H., Han, M.S. 2003. Spring bloom of *Alexandrium tamarense* in Chinhae Bay, Korea. *Aquatic Microbial Ecology* 33(3): 271-278.
- Yoo, J.S. 2003. Monitoring of Algal Bloom at Seomjin River Estuary, Southern Coast of Korea. *Algae* 18(4): 361-363.
- Park, J.S. and Yoon, Y.H. 2003. Marine environmental characteristics by distribution of dinoflagellate cysts in the southwestern coastal waters of Korea. 1. Spatio-temporal distribution of dinoflagellate cysts in Gamak Bay. *J. Kor. Fish. Soc.* 36(2): 151-156.
- Lim, W.A., Lee, C.K. 2004. Distributions and cellular characteristics of *Cochlodinium polykrikoides* in the eastern South Sea of Korea in early summer. *Journal of the Korea Society of Oceanography*. 9(3):106-109.

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.

- Reference List -

- Jeong, H.J., Park, K.H., Kim, J.S., Kang, H.J., Kim, C.H., Choi, H.J., Kim, Y.S., Park, J.Y. and Park, M.G. 2003. Reduction in the toxicity of the dinoflagellate *Gymnodinium catenatum* when fed on by the heterotrophic dinoflagellate *Polykrikos kofoidii*. *Aquat. Microb. Ecol.* 31: 307-312.
- Jung, J.M., Lee, Y.J., Park, H.K., Jung, E.Y. and Joo, G.J. 2003. The analysis of cyanobacterial neurotoxins by high-performance liquid chromatography-mass spectrometry. *Algae* 18(3): 233-238.

- Cho, E.S. Coats, E. 2004. Rapid monitoring for the potentially ichthyotoxic dinoflagellate *Cochlodinium polykrikoides* in Korean coastal waters using fluorescent probe tools. *J. Plankton Res.* 26(2): 175-180.
- Kim, C.H. Park, G.H. Kim, K.Y. 2004. Sensitive, accurate PCR assays detection harmful dinoflagellate *Cochlodinium polykrikoides* using a specific oligonucleotide primer set. *J. Fish. Sci. Tech.* 7(3): 122-129.
- Suh, Y.S. Lee, H.J. Lee, N.K. Ishizaka, J. 2004. Feasibility of red tide detection around Korean waters using satellite remote sensing. *J. Fish. Sci. Tech.* 7(3): 148-162.

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.

- Reference List -

- Jeong, H.J., Kim, J.S., Yoo, Y.D., Kim, S.T., Kim, T.H., Park, M.G., Lee, C.H., Seong, K.A., Kang, N.S. and Shim, J.H. 2003. Feeding by the heterotrophic dinoflagellate *Oxyrrhis marina* on the red-tide Raphidophyte *Heterosigma akashiwo*: a potential biological method to control red tides using mass-cultured grazers. *J. Eukaryot. Microbiol.* 50(4): 274-282.
- Kang, J.S., Kang, S.H., Lee, Y.H., Shim, J.H. and Lee, S.H. 2003. UV-B effects on growth and nitrate dynamics in Antarctic marine diatoms *Chaetoceros neogracile* and *Stellarima microtrias*. *Algae* 18(1): 13-20.
- Jeong, H.J. Kim, J.S. Kim, S.H. Song, J.Y. Lee, I.H. Lee, G.H. 2004. *Strombidinopsis jeokjo* n. sp. (Ciliophora: Choreotrichida) from the coastal waters off western Korea., morphology and small subunit ribosomal DNA gene sequence. *J. Eukaryot. Microbiol.* 51(4): 451-455.
- Jeong, H.J. Song, J.Y. Lee, C.H. Kim, S.T. 2004. Feeding by larvae of the mussel, *Mytilus galloprovinciales* on the red tide dinoflagellates. *Journal of Shellfish Research* 23(1): 185-195.

- Jeong, H.J. Yoo, Y.D. Kim, J.S. Kang, N.S. Kim, T.S. Kim, J.H. 2004. Feeding by the marine planktonic ciliate *Strombinopsis jeokjo* common heterotrophic dinoflagellate. *Aquat. Microb. Ecol.* 36: 181-187.
- Jeong, H.J. Yoo, Y.D. Kim, J.S. Kim, T.H. Kim, J.H. Kang, N.S. Yie, W.H. 2004. Mixotrophy in the phototrophic harmful alga *Cochlodinium polykrikoides* (Dinophyceae): Prey species, the effects of prey concentration, and grazing impact. *J. Eukaryot. Microbiol.* 51(5): 563-569.
- Jeong, H.J. Yoo, Y.D. Kim, S.T. Kang, N.S. 2004. Feeding by the heterotrophic dinoflagellate *Protoberidinium bipes* on the diatom *Skeletonema costatum*. *Aquat. Microb. Ecol.* 36: 171-179.
- Kim, J.S. Jeong, H.J. 2004. Feeding by the heterotrophic dinoflagellates *Gyrodinium aureolum* and *G. spirale* on the red-tide dinoflagellate *Prorocentrum minimum*. *Mar. Ecol. Prog. Ser.* 280: 85-94.
- Kwak, S.K. Jung, M. K. Lee, E.K. Cho, K.J. 2004. Removal and growth inhibition of red-tide organisms by blue-min treatment. *Algae* 19(1): 7-14.
- Park, M.G. 2003. Parasites and phytoplankton, with a special emphasis on dinoflagellate infections. *J. Phycol.* 39(1): 46.
- Sun, X-X., Han, K-N., Choi, J-K., Kim, E-K. 2004. Screening of surfactants for harmful algal blooms mitigation. *Marine Pollution Bulletin. Mar. Pollut. Bull.* 48(9): 937-945.
- Sun, X. Choi, J. 2004. Recovery and fate of three species of marine dinoflagellates after yellow clay flocculation. *Hydrobiologia* 519(1): 153-165.
- Yih, W.H. Kim, H.S. Jeong, H.J. Myung, G. Kim, Y.G. 2004. Ingestion of cryptophyte cells by the marine photosynthetic ciliate *Mesodinium rubrum*. *Aquat. Microb. Ecol.* 36: 165-170.
- Sun, X.X. Choi, J.K. Kim, E.K. 2004. A preliminary study on the mechanism of harmful algal bloom mitigation by use of sophorolipid treatment. *J. Exp. Mar. Biol. Ecol.* 304(1): 35-49.

4.4 Others

Moon et al & Choi (2003) reported a list of phytoplankton including red tide causative species occurred in the NOWPAP area of Korea. They discussed the changes of abundance and species succession of phytoplankton in the southern part of the NOWPAP area in Korea.

- Reference List -

- Moon, S.G. and Choi, C.M. 2003. A list of important species and distribution of marine phytoplankton in Korea. *J. of the Environmental Sciences* 12(7): 725-733.

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 kinds 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 WESTPAC, 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.

References

- Ahn, D.K., Park, Y.S., Park, J.G., Lee, S.J. and Lee, J.A.2000. Quantification of DSP toxins in the mussels of the Jinhae Bay by fluorometric HPLC analysis and protein phosphatase inhibition assay. *Algae* 15(4): 307-314.
- An, K.H. 1998. Distribution of dinoflagellate cysts and growth characteristics of some harmful dinoflagellates in Korea. Ph.D. Thesis, Pukyong National University, Korea, 123pp.
- Cho, E.S. Costs, E. 2004. Rapid monitoring for the potentially ichthyotoxic dinoflagellate *Cochlodinium polykrikoides* in Korean coastal waters using fluorescent probe tools. *J. Plankton Res.* 26(2): 175-180.
- Cho, E.S., Kang, D.W. and Cho, Y.C.2000. Identification of *Cochlodinium polykrikoides* against *Gyrodinium impudicum* and *Gymnodinium catenatum* in field samples using FITC lectin probes. *J. Fish. Sci. Tech.* 3(2): 83-87.
- Cho, E.S., Kotaki, Y. and Park, J.G.2001. The comparison between toxic *Pseudo-nitzschia multiseriata* (Hasle) Hasle and non-toxic *P. pungens* (Grunow) Hasle isolated from Jinhae Bay, Korea.. *Algae* 16(3): 275-285.
- Cho, H.J. and Lee, J.B.2002. Growth rates of a heterotrophic dinoflagellate *Polykrikos kofoidii* and its gamete-like organism. *Bull. Mar. Environ. Res. Inst. Cheju Nat. Univ.* 26: 1-6.
- Choi, H.Y.2001. Oceanographic condition of the coastal area between Narodo Is. and Sorido Is.in the southern sea of Korea and Its relation to the disappearance of red-tide observed in summer 1998. *Journal of the Korean Society of Oceanography* 6(2): 49-62.
- Choi, M.Y., Kwak, S.K. and Cho, K.J..2000. Algal bloom and distribution of *Prorocentrum* population in Masan-Jinhae Bay. *Korean J. Environ. Biol.* 18(4): 447-456.
- Han, J.H., Kim, Y.S., Huh, M.D., Jeong, H.J. and Park, K.H.2001. Histological effect of sodium hypochlorite (NaOCl), exposed at red tide-killing concentrations, in rockfish and little neck clam. *KOR. J. ENVIRON. TOXICOL.* 16(2): 67-74.
- Han, M.S., J.K. Jeon and Y.H. Yoon., 1993. Distribution and toxin profiles of *Alexandrium tamarense* (Lebour) Balech (Dinoflagellate) in the southeastern coastal waters, Korea. *Korean J. Phycol.* 8(1), 7-13.
- Han, M.S., Kim, Y.P. and Cattolico, R.A.2002. *Heterosigma akashiwo* (Raphidophyceae) resting cell formation in batch culture: Starin identity versus physiological response. *J. Phycol.* 38: 304-317.

- Han, M.Y., Kim, W.T. and Kim, D.J. 2001. A theoretical consideration on the clay serearing method as a remedy for algal blooms in natural waters. *Journal of the Korean Society of Water and Wastewater* 15(3): 217-221.
- Han, Sangbok D., 1998. History of algal bloom records in Korean coastal waters. In: Harmful Algal Blooms in Korea and China. Proceedings of Korea-China Joint Symposium on Harmful Algal Blooms, Pusan Korea, 5-7, December 1997. 34-43.
- Jeong, H., Y. Yoo, J. Kim, T. Kim, J. Kim, N. Kang and W. Y, 2004. Mixotrophy in the Phototrophic Harmful Alga *Cochlodinium polykrikoides* (Dinophyceae): Prey Species, the Effects of Prey Concentration, and Grazing Impact. *J. Eukaryot. Microbiol.*, 51(5):563-569.
- Jeong, H.J. Kim, J.S. Kim, S.H. Song, J.Y. Lee, I.H. Lee, G.H. 2004. *Strombidinopsis jeokjo* n. sp. (Ciliophora: Choreotrichida) from the coastal waters off western Korea., morphology and small subunit ribosomal DNA gene sequence. *J. Eukaryot. Microbiol.* 51(4): 451-455.
- Jeong, H.J. Yoo, Y.D. Kim, J.S. Kim, T.H. Kim, J.H. Kang, N.S. Yie, W.H. 2004. Mixotrophy in the phototrophic harmful alga *Cochlodinium polykrikoides* (Dinophyceae): Prey species, the effects of prey concentration, and grazing impact. *J. Eukaryot. Microbiol.* 51(5): 563-569.
- Jeong, H.J. Yoo, Y.D. Kim, S.T. Kang, N.S. 2004. Feeding by the heterotrophic dinoflagellate *Protoperidinium bipes* on the diatom *Skeletonema costatum*. *Aquat. Microb. Ecol.* 36: 171-179.
- Jeong, H.J., Kim, H.R., Kim, K.I., Kim, K.Y., Park, K.H., Kim, S.T., Yoo, y.d., Song, J.Y., Kim, J.S., Seong, K.A., Yih, W.H., Pae, S.J., Lee, C.H., Huh, M.D. and Lee, S.H. 2002. NaOCl produced by electrolysis of natural seawater as a potential method to control marine red-tide dinoflagellates. *Phycologia* 41(6): 643-656.
- Jeong, H.J., Park, J.K., Choi, H.Y., Yang, J.S., Shim, J.H., Shin, Y.K., Yih, W.H., Kim, H.S. and Cho, K.J. 2000. The outbreak of red tides in the coastal waters off Kohung, Chonnam, Korea. 2. The temporal and spatial variations in the phytoplanktonic community in 1997. *Journal of the Korean Society of Oceanography* 5(1): 27-36.
- Jeong, H.J., Park, J.K., Kim, J.S. and Kim, S.T. 2000. The outbreak of red ties in the coastal wters off Kohung, Chonnam, Korea. 3. The temporal and speatial variations in the heterotrophic dinoflagllates and ciliates in 1997. *The Sea, Journal of the Korean Society of Oceanography* 5(1); 37-46.

- Jeong, H.J., Park, K.H., Kim, j.s., Kang, H.J., Kim, C.H., Choi, H.J., Kim, Y.S., Park, J.Y. and Park, M.G. 2003. Reduction in the toxicity of the dinoflagellate *Gymnodinium catenatum* when fed on by the heterotrophic dinoflagellate *Polykrikos kofoidii*. *Aquat. Microb. Ecol.* 31: 307-312.
- Jeong, J.C.2001. Detection of red tide patches using AVHRR and landsat TM data. *J. Environ. Impact Assesment* 10(1): 1-8.
- Jeong, S.Y., Park, Y.T. and Lee, W.J.2000. Isolation of marine bacteria killing red tide microalgae III. Algicidal effects of marine bacterium, *Micrococcus* sp. LG-5 against the harmful dinoflagellate, *Cochlodinium polykrikoides*. *Korean Fish. Soc.* 33(4): 331-338.
- Jung, C.S., W.J. Choi, H.K. Kim, Y.G. Jung, J.B. Kim and W.A. Lim. 1999. Interrelation between *Cochlodinium polykrikoides* blooms and community structure of zooplankton in the coastal waters around Namhaedo in the South Sea of Korea, 1998. *Bull. Nat'l. Fish. Res. Dev. Inst. Korea* 57, 153-161.
- Jung, J.M., Lee, Y.J., Park, H.K., Jung, E.Y. and Joo, G.J. 2003. The analysis of cyanobacterial neurotoxins by high-performance liquid chromatography-mass spectrometry. *Algae* 18(3): 233-238.
- Kang, Y.S., H.K. Kim, W.A. Lim, C.K. Lee, S.G. Lee and S.Y. Kim, 2002. An unusual coastal environment and *Cochlodinium polykrikoides* blooms in 1995 in the south sea of Korea. *J. of Kor. Soc. of Ocean.*, 37(4): 212-223.
- Kim, C.H. 1998. Development of PSP toxigenic dinoflagellates and toxin production in Korean coastal waters. In: *Harmful algal blooms in Korea and China*, edited by Kim, H.G., S.G. Lee and C.K. Lee, National Fisheries Research and Development Institute, Pusan, pp. 1-20.
- Kim, C.H. Park, G.H. Kim, K.Y. 2004. Sensitive, accurate PCR assays detection harmful dinoflagellate *Cochlodinium polykrikoides* using a specific oligonucleotide primer set. *J. Fish. Sci. Tech.*7(3): 122-129.
- Kim, C.S., B. Y. Jee and H. M. Bae, 2002. Structural alterations in the gill of the red sea bream, *Pagrus major*, exposed to the harmful dinoflagellate *Cochlodinium polykrikoides*. *J. Fish. Sci, Tech.* 5(1): 75-78.
- Kim, C.S., H. M. Bae and Y. C. Cho, 2001. Control of harmful algal blooms by clay via photochemical reactions. *Algae* 16(1): 67-73.
- Kim, C.S., Lee, S.G. and Kim, H.G.2000. Biochemical responses of fish exposed to a harmful dinoflagellate *Cochlodinium polykrikoides*. *Journal of Experimental Marine Biology and Ecology* 254: 131-141.

- Kim, C.S., Lee, S.G., Kim, H.G. and Lee, J.S. 2001. Screening for toxic compounds in the red tide dinoflagellate *Cochlodinium polykrikoides*: Is it toxic plankton?. *Algae* 16(4): 457-462.
- Kim, C.S., S. G. Lee, C.K. Lee, H. G. Kim and J. Jung, 1999. Reactive oxygen species as causative agents in the ichthyotoxicity of the red tide dinoflagellate *Cochlodinium polykrikoides*. *Journal of Plankton Research* 21(11): 2105-2115.
- Kim, H.C., Kim, D.M., Lee, D.I., Park, C.K. and Kim, H.G. 2001. Limiting nutrients of *Cochlodinium polykrikoides* red tide in Saryang Island coast by algal growth potential (AGP) assay. *J. Korean Fish. Soc.* 34(5): 457-464.
- Kim, H.C., Lee, C.K., Lee, S.G., Kim, H.G. and Park, C.K. 2001. Physico-chemical factors on the growth of *Cochlodinium polykrikoides* and nutrient utilization. *J. Korean Fish. Soc.* 34(5): 445-456.
- Kim, H.G. 1998. Harmful algal blooms in Korean coastal waters focused on three fish killing dinoflagellates. In: Harmful algal blooms in Korea and China, edited by Kim, H.G., S.G. Lee and C.K. Lee, National Fisheries Research and Development Institute, Pusan, pp. 1-20.
- Kim, H.G., Jung, C.S., Lim, W.A., Lee, C.K., Kim, S.Y., Youn, S.H., Choi, Y.C. and Lee, S.G. 2001. The spatio-temporal progress of *Cochlodinium polykrikoides* blooms in the coastal waters of Korea. *J. Korean Fish. Soc.* 34(6): 691-696
- Kim, H.G., W.J. Choi, Y.G. Jung, C.S. Jung, J.S. Park, K.H. An and C.I. Baek. 1999. Initiation of *Cochlodinium polykrikoides* Blooms and its environmental characteristics around the Narodo island in the western part of South Sea of Korea. *Bull. Nat'l. Fish. Res. Dev. Inst. Korea* 57, 119-129.
- Kim, H.G., Y.C. Cho, C.S. Jeong, H.M. Bae, B.C. Oh, C.K. Lee, E.S. Cho, C.S. Kim, W.A. Lim, S.H. Youn and J.B. Kim. 2000. Harmful Algal Blooms in Korean coastal waters in 1999. NFRDI HAB 2nd report. NFRDI, 206pp.
- Kim, K.H., Han, C.H., Lee, J.H., Kim, B.W. and Lee, B.K. 2002. Isolation of a specific antigen protein on cell membrane of *Cochlodinium polykrikoides*, red bloom algae. *Kor. J. Microbiol. Biotechnol.* 30(4): 320-324.
- Kim, P.J., Heo, S. and Yun, S.J. 2002. Adsorption and removal mechanism of dissolved inorganic nutrients in seawater by yellow loess. *J. Korean Fish. Soc.* 35(2): 146-154.
- Kim, S.J. and Cho, K.D. 2000. Removal of red tide organisms. 1. Flocculation of red tide organisms by using IOSP. *J. Korean Fish. Soc.* 33(5): 448-454.
- Kim, S.R., Cheong, E.H. and Ahn, T.S. 2001. A study on the nutrient removal with phytoplankton. *Korean J. Limnol.* 34(2): 133-139.

- Kim, Y.G., Park, M.G. and Yih, W.H. 2002. Host-parasite system in a red tide dinoflagellate *Prorocentrum minimum*: (1) Life cycle stages of the parasitic dinoflagellate *Amoebophrya* sp.. Journal of the Korean Society of Oceanography 7(4): 221-225.
- Kwak, S.K. Jung, M. K. Lee, E.K. Cho, K.J. 2004. Removal and growth inhibition of red-tide organisms by blue-min treatment. Algae 19(1): 7-14.
- Kwoun, C.H. and Cho, K.D. 2002. Numerical model for spreading of *Cochlodinium* bloom in the southern coastal waters in Korea. J. Korean Fish. Soc. 35(6): 568-577.
- Lee, C.K., Kim, H.C., Lee, S.G., Jung, C.S., Kim, H.G. and Lim, W.A. 2002. Abundance of harmful algae, *Cochlodinium polykrikoides*, *Gyrodinium impudicum* and *Gymnodinium catenatum* in the coastal area of South Sea OF Korea and their effects of temperature, salinity, irradiance and nutrient on the growth in culture. J. Korean Fish. Soc. 34(5), 536-544.
- Lee, C.K., S.G. Lee and H.G. Kim. 1999. Occurrence and abundance of three morphologically similar dinoflagellates, *Cochlodinium polykrikoides*, *Gyrodinium impudicum*, *Gymnodinium catenatum* in the southern coast of Korea. Bull. Nat'l. Fish. Res. Dev. Inst. Korea 57, 131-139.
- Lee, H.O., Cheun, B.S., Watanabe, E. and Han, M.S. 2000. Comparison of HPLC analysis and channel biosensor in the detection of PSP toxin in natural *Alexandrium tamarense* population. Algae 15(1): 61-64.
- Lee, H.O., Choi, K.H., Han, M.S. 2003. Spring bloom of *Alexandrium tamarense* in Chinhae Bay, Korea. Aquatic Microbial Ecology 33(3): 271-278.
- Lee, Y.S., Lee, J.S., Jung, R.H., Kim, S.S., Go, W.J., Kim, K.Y. and Park, J.S. 2001. Limiting nutrient on phytoplankton growth in Gwangyang Bay. Journal of the Korean Society of Oceanography 6(3): 201-210.
- Lee, Y.S., Park, Y.T., Kim, Y.S., Kim, K.Y., Park, J.S., Go, W.J., Jo, Y.J. and Park, S.Y. 2001. Countermeasure and outbreak mechanism of *Cochlodinium polykrikoides* red tide 1. Environmental characteristics on outbreak and disappearance of *C. polykrikoides* bloom. Journal of the Korean Society of Oceanography 6(4): 259-264.
- Lim, W.A., Jung, C.S., Lee, C.K., Cho, Y.C., Lee, S.G., Kim, H.G. and Chung, I.K. 2002. The outbreak, maintenance, and decline of the red tide dominated by *Cochlodinium polykrikoides* in the coastal waters off southern Korea from August to October, 2000. The Sea, Journal of the Korean Society of Oceanography 7(2): 68-77.

- Lim, W.A., Lee, C.K. 2004. Distributions and cellular characteristics of *Cochlodinium polykrikoides* in the eastern South Sea of Korea in early summer. *Journal of the Korea Society of Oceanography*. 9(3):106-109.
- Park, M.J., Lee, H.J., Lee, T.S., Kim, J.H. and Lee, T.H.2000. Change of paralytic shellfish poison components during bacterial detoxification. *J. Korean Fish. Soc.* 33(6): 550-553.
- Suh, Y., L. Jang, N. Lee and J. Ishizaka, 2004. Feasibility of Red Tide Detection Around Korean Waters Using Satellite Remote Sensing. *J. Fish. Sci. Tech.*, 7(3):148-162
- Sun, X-X., Han, K-N., Choi, J-K., Kim, E-K. 2004. Screening of surfactants for harmful algal blooms mitigation. *Marine Pollution Bulletin*. Mar. Pollut. Bull. 48:(9): 937-945.
- Sun, X. Choi, J. 2004. Recovery and fate of three species of marine dinoflagellates after yellow clay flocculation. *Hydrobiologia* 519(1): 153-165.
- Sun, X.X. Choi, J.K. Kim, E.K. 2004. A preliminary study on the mechanism of harmful algal bloom mitigation by use of sophorolipid treatment. *J. Exp. Mar. Biol. Ecol.* 304(1): 35-49.
- Yang, J.S., Choi, H.Y., Jeong, H.J., Jeong, J.Y. and Park, J.K.2000. The outbreak of red tides in the coastal waters off Kohung, Chonnam, Korea. 1. Physical and chemical characteristics in 1997. *Journal of the Korean Society of Oceanography* 5(1): 16-26.

Appendices

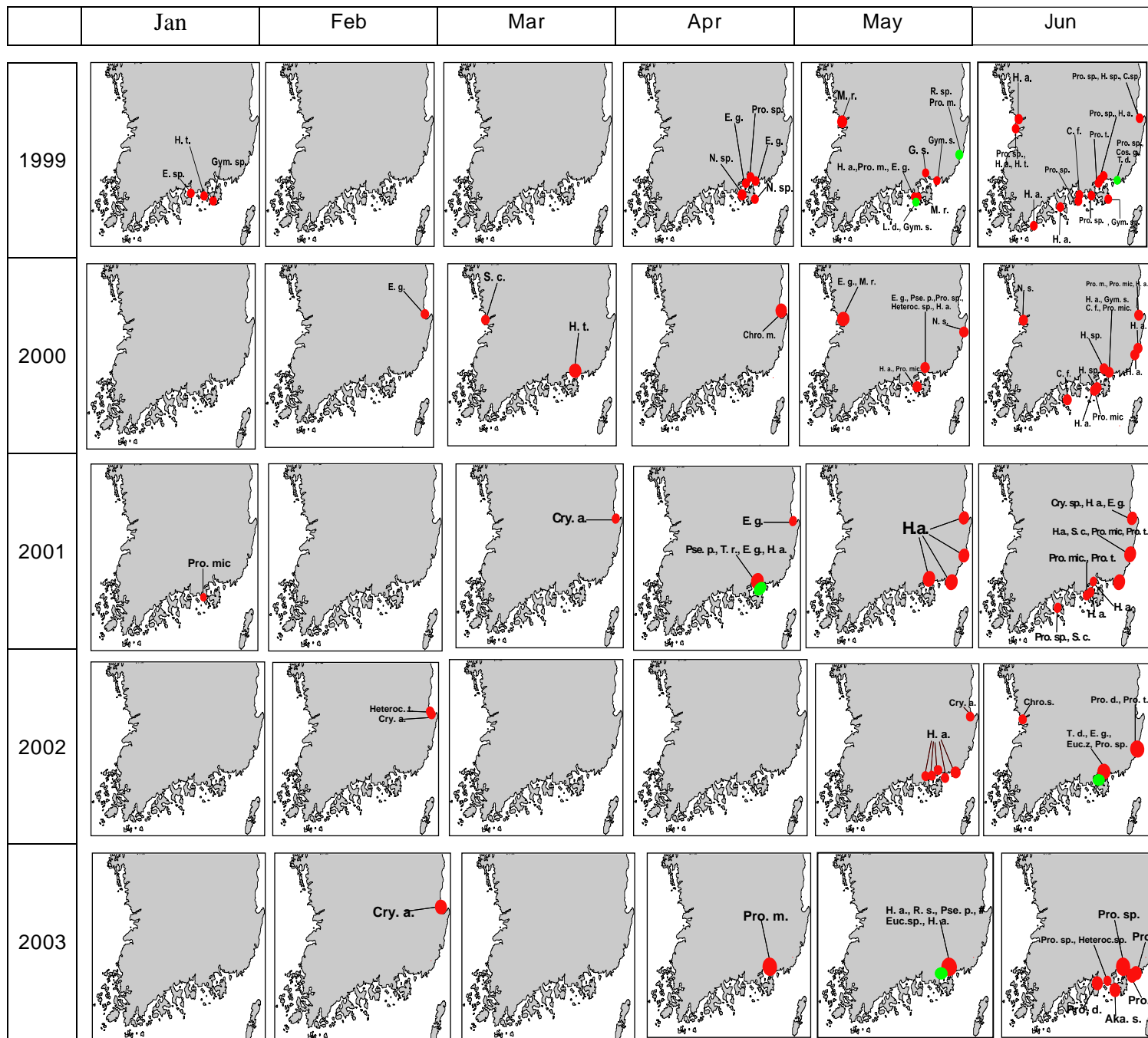
1. Red tide events in the NOWPAP area of Korea from 1999 to 2003
2. Occurrence of red tide in the NOWPAP area of Korea from 1999 to 2003
3. Occurrence of toxin-producing plankton in the NOWPAP area of Korea from 2002 to 2003
4. List of HAB references in Korea since 2000

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

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

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

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



- 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.=*Dictyochoa fibula*
- Euc.z.=*Eucampia zodiacus*
- Euc.sp.=*Eucampia* sp.
- E.g.=*Eutreptiella gymnastica*
- E.sp.=*Eutreptiella* 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.

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

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

List of HAB references in Korea since 2000

- Ahn, D.K., Park, Y.S., Park, J.G., Lee, S.J. and Lee, J.A.2000. Quantification of DSP toxins in the mussels of the Jinhae Bay by fluorometric HPLC analysis and protein phosphatase inhibition assay. *Algae* 15(4): 307-314.
- Cho, E.S. Costs, E. 2004. Rapid monitoring for the potentially ichthyotoxic dinoflagellate *Cochlodinium polykrikoides* in Korean coastal waters using fluorescent probe tools. *J. Plankton Res.* 26(2): 175-180.
- Cho, E.S., Choi, B.D., Cho, Y.C., Kim, T.J. and Kim, H.G.2001. Discrimination of three highly toxic *Alexandrium tamarense* (Dinophyceae) isolates using FITC-conjugated lectin probes. *Journal of Plankton Research* 23(1): 89-96.
- Cho, E.S., Kang, D.W. and Cho, Y.C.2000. Identification of *Cochlodinium polykrikoides* against *Gyrodinium impudicum* and *Gymnodinium catenatum* in field samples using FITC lectin probes. *J. Fish. Sci. Tech.* 3(2): 83-87.
- Cho, E.S., Kang, D.W. and Cho, Y.C.2000. Impact of crude oil and dispersant on determination of calcium concentration in whole cell from *Cochlodinium polykrikoides*. *Algae* 15(2): 73-79.
- Cho, E.S., Kim, G.Y. and Cho, Y.C.2001. Molecular analysis of morphologically similar dinoflagellates *Cochlodinium polykrikoides*, *Gyrodinium impudicum* and *Gymnodinium catenatum* based on internal transcribed spacer and 5.8S rDNA regions. *Algae* 16(1): 53-57.
- Cho, E.S., Kim, G.Y., Oh, B.C., Rhodes, L.L. and Lee, J.D.2000. Discrimination of three species of dinoflagellates *Cochlodinium polykrikoides*, *Gyrodinium impudicum* and *Gymnodinium catenatum* using FITC-lectins. *Algae* 15(3): 175-178.
- Cho, E.S., Kim, H.G. and Cho, Y.C.2000. Sequence analysis of *Cochlodinium polykrikoides* isolated from Korean coastal waters using sequences of internal transcribed spacers and 5.8S rDNA. *Journal of the Korean Society of Oceanography* 35(3): 158-160.
- Cho, E.S., Kotaki, Y. and Park, J.G.2001. The comparison between toxic *Pseudo-nitzschia multiseriata* (Hasle) Hasle and non-toxic *P. pungens* (Grunow) Hasle isolated from Jinhae Bay, Korea.. *Algae* 16(3): 275-285.
- Cho, E.S., Rhodes, L.L. and Cho, Y.C.2000. Comparative lectin binding patterns of *Cochlodinium polykrikoides* Margalef. *Journal of the Korean Society of Oceanography* 35(3): 153-157.

- Cho, E.S.2002. Cluster analysis on the lectin binding patterns of marine microalgae. *Journal of Plankton Research* 25(3):309-315.
- Cho, H.J. and Lee, J.B.2002. Growth rates of a heterotrophic dinoflagellate *Polykrikos kofoidii* and its gamete-like organism. *Bull. Mar. Environ. Res. Inst. Cheju Nat. Univ.* 26: 1-6.
- Cho, H.J., Kim, C.H., Moon, C.H. and Matsuok, K. 2003. Dinoflagellate cysts in recent sediments from the southern coastal waters of Korea *Botanica Marina* 46(4): 332-337.
- Cho, H.J., Matsuoka, K., Lee, J.B. and Moon, C.H.2001. Dinoflagellate cyst assemblages in the surface sediments from the Northwestern East China Sea. *J. Fish. Sci. Tech.* 4(3): 120-129.
- Choi, A.R., Oh, H.M. and Lee, J.A.2002. Ecological study on the toxic *Microcystis* in the lower Nakdong River. *Algae* 17(3): 171-185.
- Choi, A.R., Park, J.H. and Lee, J.A.2002. Population dynamics and the toxin of *Anabaena* in the lower Naktong River. *Algae* 17(2): 95-104.
- Choi, H.Y.2001. Oceanographic condition of the coastal area between Narodo Is. and Sorido Is.in the southern sea of Korea and Its relation to the disappearance of red-tide observed in summer 19982. *Journal of the Korean Society of Oceanography* 6(2): 49-62.
- Choi, J.S., Lee, W.K., Son, B.W., Kim, D.S., Choi, H.D., Choi, J.S., Jung, J.H., Im, K.S. and Choi, W.C.2000. Screening on radical scavenging activity of marine microalgae. *Kor. J. Pharmacogn.* 31(2): 252-255.
- Choi, M.Y., Kwak, S.K. and Cho, K.J..2000. Algal bloom and distribution of *Prorocentrum* populaton in Masan-Jinhae Bay. *Korean J. Environ. Biol.* 18(4): 447-456.
- Han, J.H., Kim, Y.S., Huh, M.D., Jeong, H.J. and Park, K.H.2001. Histological effect of sodium hypochlorite (NaOCl), exposed at red tide-killing concentrations, in rockfish and little neck clam. *KOR. J. ENVIRON. TOXICOL.* 16(2): 67-74.
- Han, M.S., Kim, Y.P. and Cattolico, R.A.2002. *Heterosigma akashiwo* (Raphidophyceae) resting cell formation in batch culture: Starin identitiy versus physiological response. *J. Phycol.* 38: 304-317.
- Han, M.Y., Kim, W.T. and Kim, D.J.2001. A theoretical consideration on the clay spereaing method as a remedy for algal blooms in natural waters. *Journal of the Korean Society of Water and Wastewater* 15(3): 217-221.

- Jeong, H.J. Kim, J.S. Kim, S.H. Song, J.Y. Lee, I.H. Lee, G.H. 2004. *Strombidinopsis jeokjo* n. sp. (Ciliophora: Choreotrichida) from the coastal waters off western Korea., morphology and small subunit ribosomal DNA gene sequence. J. Eukaryot. Microbiol. 51(4): 451-455.
- Jeong, H.J. Song, J.Y. Lee, C.H. Kim, S.T. 2004. Feeding by larvae of the mussel, *Mytilus galloprovinciales* on the red tide dinoflagellates. Journal of Shellfish Research 23(1): 185-195.
- Jeong, H.J. Yoo, Y.D. Kim, J.S. Kang, N.S. Kim, T.S. Kim, J.H. 2004. Feeding by the marine planktonic ciliate *Strombinopsis jeokjo* common heterotrophic dinoflagellate. Aquat. Microb. Ecol. 36: 181-187.
- Jeong, H.J. Yoo, Y.D. Kim, J.S. Kim, T.H. Kim, J.H. Kang, N.S. Yie, W.H. 2004. Mixotrophy in the phototrophic harmful alga *Cochlodinium polykrikoides* (Dinophyceae): Prey species, the effects of prey concentration, and grazing impact. J. Eukaryot. Microbiol. 51(5): 563-569.
- Jeong, H.J. Yoo, Y.D. Kim, S.T. Kang, N.S. 2004. Feeding by the heterotrophic dinoflagellate *Protoperidinium bipes* on the diatom *Skeletonema costatum*. Aquat. Microb. Ecol. 36: 171-179.
- Jeong, H.J., Kang, H., Shim, J.H., Park, J.K., Kim, J.S., Song, J.Y. Choi, H.J. 2001. Interactions among the toxic dinoflagellate *Amphidinium carterae*, the heterotrophic dinoflagellate *Oxyrrhis marina*, and the calanoid copepods *Acartia* spp.. MEPS 218 : 77-86.
- Jeong, H.J., Kim, H.R., Kim, K.I., Kim, K.Y., Park, K.H., Kim, S.T., Yoo, y.d., Song, J.Y., Kim, J.S., Seong, K.A., Yih, W.H., Pae, S.J., Lee, C.H., Huh, M.D. and Lee, S.H. 2002. NaOCl produced by electrolysis of natural seawater as a potential method to control marine red-tide dinoflagellates. Phycologia 41(6): 643-656.
- Jeong, H.J., Kim, J.S., Yoo, Y.D., Kim, S.T., Kim, T.H., Park, M.G., Lee, C.H., Seong, K.A., Kang, N.S. and Shim, J.H. 2003. Feeding by the heterotrophic dinoflagellate *Oxyrrhis marina* on the red-tide Raphidophyte *Heterosigma akashiwo*: a potential biological method to control red tides using mass-cultured grazers. J. Eukaryot. Microbiol. 50(4): 274-282.
- Jeong, H.J., Kim, S.K., Kim, J.S., Kim, S.T., Yoo, Y.D. and Yoon, J.Y. 2001. Growth and grazing rates of the heterotrophic dinoflagellate *Polykrikos kofoidii* on red-tide and toxic dinoflagellates. J. Eukaryot. Microbiol. 48(3): 298-308.

- Jeong, H.J., Park, J.K., Choi, H.Y., Yang, J.S., Shim, J.H., Shin, Y.K., Yih, W.H., Kim, H.S. and Cho, K.J.2000. The outbreak of red tides in the coastal waters off Kohung, Chonnam, Korea. 2. The temporal and spatial variations in the phytoplanktonic community in 1997. *Journal of the Korean Society of Oceanography* 5(1): 27-36.
- Jeong, H.J., Park, J.K., Kim, J.S. and Kim, S.T.2000. The outbreak of red ties in the coastal wters off Kohung, Chonnam, Korea. 3. The temporal and speatial variations in the heterotrophic dinoflagllates and ciliates in 1997. *The Sea, Journal of the Korean Society of Oceanography* 5(1); 37-46.
- Jeong, H.J., Park, K.H., Kim, j.s., Kang, H.J., Kim, C.H., Choi, H.J., Kim, Y.S., Park, J.Y. and Park, M.G. 2003. Reduction in the toxicity of the dinoflagellate *Gymnodinium catenatum* when fed on by the heterotrophic dinoflagellate *Polykrikos kofoidii*. *Aquat. Microb. Ecol.* 31: 307-312.
- Jeong, H.J., Yoo, Y.D. and Kim, J.S.2002. Outbreak of red tides in the coastal waters off the southern Saemankeum areas, Jeonbuk, Korea 2. Temporal variations in the heterotrophic dinoflagellates and ciliates in the summer-fall of 1999. *Journal of the Korean Society of Oceanography* 7(3): 140-147.
- Jeong, J.C.2001. Detection of red tide patches using AVHRR and landsat TM data. *J. Environ. Impact Assesment* 10(1): 1-8.
- Jeong, S.Y., Park, Y.T., Kim, M.C., Choi, S.C., Seong, H.K., Kim, J.Y., Kim, T.U. and Lee, W.J.2000. Isolation of marine bacteria killing red tide microalgae IV. Characteristics of algicidal substances, produced form *Micrococcus* sp. LG-5 and the effects on marine organisms. *Korean Fish. Soc.* 33(4): 339-347.
- Jeong, S.Y.,Park, Y.T. and Lee, W.J.2000. Isolation of marine bacteria killing red tide microalgae III. Algicidal effects of marine bacterium, *Micrococcus* sp. LG-5 against the harmful dinoflagellate, *Cochlodinium polykrikoides*. *Korean Fish. Soc.* 33(4): 331-338.
- Jo, E.Y. Cha, J.H., Kim, M.K. and Kim, K.T.2000. Studies on the ecosystem in the Yeong-II Gulf of Korea: I. Species composition and diversity of phytoplankton communities. *Algae* 15(1): 49-59.
- Jung, J.A., Jo, E.Y., Cha, J.H., Kim, M.K. and Kim, K.T.2001. Community structures of phytoplanktons according to environmental factors in the coastal waters of Ullungdo and Tokdo Islands. *Algae* 16(3): 325-335.
- Jung, J.M., Lee, Y.J., Park, H.K., Jung, E.Y. and Joo, G.J. 2003. The analysis of cyanobacterial neurotoxins by high-performance liquid chromatography-mass spectrometry. *Algae* 18(3): 233-238.

- Kang, J.S., Kang, S.H., Lee, Y.H., Shim, J.H. and Lee, S.H. 2003. UV-B effects on growth and nitrate dynamics in Antarctic marine diatoms *Chaetoceros neogracile* and *Stellarima microtrias*. *Algae* 18(1): 13-20.
- Kang, S.H., Kang, J.S., Lee, S.H., Kim, D.S. and Kim, D.Y. 2000. Importance of polar phytoplankton for the global environmental change. *Korean J. Environ. Biol.* 18(1): 1-202.
- Kang, Y.S. and Choi, J.K. 2001. Ecological characteristics of phytoplankton communities in the coastal waters of Gori, Wulseong, Uljin and Youngkwang 1. Species composition and distribution (1992-1996). *Algae* 16(1): 85-111.
- Kang, Y.S., Kim, H.G., Lim, W.A., Lee, C.K., Lee, S.G. and Kim, S.Y. 2002. An unusual coastal environment and *Cochlodinium polykrikoides* blooms in 1995 in the South Sea of Korea. *Journal of the Korean Society of Oceanography* 37(4): 212-223.
- Kim, C.H. Park, G.H. Kim, K.Y. 2004. Sensitive, accurate PCR assays detection harmful dinoflagellate *Cochlodinium polykrikoides* using a specific oligonucleotide primer set. *J. Fish. Sci. Tech.* 7(3): 122-129.
- Kim, C.S. and Cho, Y.C. 2000. Screening for antioxidant activity in some red tide dinoflagellates. *Algae* 15(1): 23-28.
- Kim, C.S., Bae, H.M. and Cho, Y.C. 2001. Control of harmful algal blooms by clay via photochemical reactions. *Algae* 16(1): 67-73.
- Kim, C.S., Bae, H.M., Yun, S.J., Cho, Y.C. and Kim, H.G. 2000. Ichthyotoxicity of a harmful dinoflagellate *Cochlodinium polykrikoides*: Aspect of hematological responses of fish exposed to algal bloom. *J. Fish. Sci. Tech.* 3(2): 111-117.
- Kim, C.S., Jee, B.Y. and Bae, H.M. 2002. Structural alterations in the gill of the red sea bream, *Pagrus major*, exposed to the harmful dinoflagellate *Cochlodinium polykrikoides*. *J. Fish. Sci. Tech.* 5(1): 75-78.
- Kim, C.S., Lee, S.G. and Kim, H.G. 2000. Biochemical responses of fish exposed to a harmful dinoflagellate *Cochlodinium polykrikoides*. *Journal of Experimental Marine Biology and Ecology* 254: 131-141.
- Kim, C.S., Lee, S.G., Kim, H.G. and Lee, J.S. 2001. Screening for toxic compounds in the red tide dinoflagellate *Cochlodinium polykrikoides*: Is it toxic plankton?. *Algae* 16(4): 457-462.
- Kim, C.S., Lim, W.A. and Cho, Y.C. 2001. Mycosporine-like amino acids as the UV sunscreen with oxygen radical scavenging activity. *Bull. Nat'l Fish. Res. Dev. Inst. Korea* 60: 65-71.

- Kim, D.S., Cho, K.D. and Park, C.K.2001. The oceanic environmental property in the Jindong Bay of the red-tide appearance area. J. of the Korean Environmental Sciences Society 10(2): 159-166.
- Kim, D.S., Kang, S.H., Kim, D.Y., Lee, Y.H. and Kang, Y.C.2001. v. Ocean and Polar Research 23(2): 77-95.
- Kim, H.C., Kim, D.M., Lee, D.I., Park, C.K. and Kim, H.G.2001. Limiting nutrients of *Cochlodinium polykrikoides* red tide in Saryang Island coast by algal growth potential (AGP) assay. J. Korean Fish. Soc. 34(5): 457-464.
- Kim, H.C., Lee, C.K., Lee, S.G., Kim, H.G. and Park, C.K.2001. Physico-chemical factors on the growth of *Cochlodinium polykrikoides* and nutrient utilization. J. Korean Fish. Soc. 34(5): 445-456.
- Kim, H.G., Jung, C.S., Lim, W.A., Lee, C.K., Kim, S.Y., Youn, S.H., Choi, Y.C. and Lee, S.G.2001. The spatio-temporal progress of *Cochlodinium polykrikoides* blooms in the coastal waters of Korea. J. Korean Fish. Soc. 34(6): 691-696
- Kim, H.W., Hwang, S.J. and Joo, G.J.2000. Zooplankton grazing on bacteria and phytoplankton in a regulated large river (Nakdong River, Korea). Journal of Plankton Research 22(8): 1559-1577.
- Kim, J.I., Lim, J.H., Lee, J.W. and Lee, H.B.2002. Phylogenetic relationship of *Microcystis* (Cyanophyceae) based on partial 16S rRNA gene sequences in Korea. Algae 17(3): 153-159.
- Kim, J.S. Jeong, H.J. 2004. Feeding by the heterotrophic dinoflagellates *Gyrodinium domains* and *G. spirale* on the red-tide dinoflagellate *Prorocentrum minimum*. Mar. Ecol. Prog. Ser. 280: 85-94.
- Kim, K.H., Han, C.H., Lee, J.H., Kim, B.W. and Lee, B.K.2002. Isolation of a specific antigen protein on cell membrane of *Cochlodinium polykrikoides*, red bloom algae. Kor. J. Microbiol. Biotechnol. 30(4): 320-324.
- Kim, P.J., Heo, S. and Yun, S.J.2002. Adsorption and removal mechanism of dissolved inorganic nutrients in seawater by yellow loess. J. Korean Fish. Soc. 35(2): 146-154.
- Kim, S.H., Choi, C.N., Cha, W.S., Cheong, K.H. and Jung, O.J.2000. Effect of ultraviolet radiation on the mortality rate of the marine dinoflagellate *Amphidinium carterae* causing a red tide. J. of the Korean Environmental Sciences Society.
- Kim, S.J. and Cho, K.D.2000. Removal of red tide organisms. 1. Flocculation of red tide organisms by using IOSP. J. Korean Fish. Soc. 33(5): 448-454.

- Kim, S.R., Cheong, E.H. and Ahn, T.S.2001. A study on the nutrient removal with phytoplankton. *Korean J. Limnol.* 34(2): 133-139.
- Kim, Y.G., Park, M.G. and Yih, W.H.2002. Host-parasite system in a red tide dinoflagellate *Prorocentrum minimum*: (1) Life cycle stages of the parasitic dinoflagellate *Amoebophrya* sp.. *Journal of the Korean Society of Oceanography* 7(4): 221-225.
- Kwak, S.K. Jung, M. K. Lee, E.K. Cho, K.J. 2004. Removal and growth inhibition of red-tide organisms by blue-min treatment. *Algae* 19(1): 7-14.
- Kwak, S.K., Choi, M.Y. and Cho, K.J.2001. Distribution and occurrence frequency of red-tide causing flagellates in the Masan-Jinhae Bay. *Algae* 16(2): 315-323.
- Kwak, S.K., Lee, O.H. and Cho, K.J.2001. Photoadaptation of photosynthesis in red-tide causative algae. *Algae* 16(2): 295-302.
- Kwoun, C.H. and Cho, K.D.2002. Numerical model for spreading of *Cochlodinium* bloom in the southern coastal waters in Korea. *J. Korean Fish. Soc.* 35(6): 568-577.
- Lee, C.K., Kim, H.C., Lee, S.G., Jung, C.S., Kim, H.G. and Lim, W.A.2002. Abundance of harmful algae, *Cochlodinium polykrikoides*, *Gyrodinium impudicum* and *Gymnodinium catenatum* in the coastal area of South Sea OF Korea and their effects of temperature, salinity, irradiance and nutrient on the growth in culture. *J. Korean Fish. Soc.* 34(5), 536-544.
- Lee, H.O., Cheun, B.S., Watanabe, E. and Han, M.S.2000. Comparison of HPLC analysis and channel biosensor in the detection of PSP toxin in natural *Alexandrium tamarense* population. *Algae* 15(1): 61-64.
- Lee, H.O., Choi, K.H., Han, M.S. 2003. Spring bloom of *Alexandrium tamarense* in Chinhae Bay, Korea. *Aquatic Microbial Ecology* 33(3): 271-278.
- Lee, I.C. and Yoo S.A.2001. Characterization of 5-aminolevulinic acid dehydratase purified from *Anabaena cylindrical*. *Algae* 16(1): 59-65.
- Lee, J.B. and Shin, B.2000. Seasonal variation of phytoplankton around Jeju harbor. *Bull. Mar. Res. Inst. Cheju Nat. Univ.* 24: 79-85.
- Lee, J.B., Choa, J.H., Kand, D.W., Go, Y.B. and Oh, B.C.2000. Bioecological characteristics of coral habitats around Moonsom, Cheju Island, Korea: II. Community dynamics of phytoplankton and primary productivity. *Algae* 15(1): 37-47.
- Lee, J.B., S, B. and Lee, M.H.2001. Seasonal dynamics of microalgal assemblage at tidepools in the southern intertidal zone of Cheju Island, Korea. *Algae* 16(2): 197-207.

- Lee, J.H. and Youn, S.M.2000. Water quality and phytoplankton communities in Yeolja Bay of Korea. *Algae* 15(1): 61-64.
- Lee, J.H., Chae, J.H., Kim, W.R., Jung, S.W. and Kim, J.M.2001. Seasonal variation of phytoplankton and zooplankton communities in the coastal waters off Tongyeong in Korea. *Ocean and Polar Research* 23(3): 245-253.
- Lee, T.K., Park, M.W., Shin, K.S. and Chang, M.2000. Comparison on growth and biochemical composition of *Gymnodinium sanguineum* and *Skeletonema costatum* grown in different N, P concentrations. *Korean J. Environ. Biol.* 18(4): 395-401.
- Lee, Y.S., Lee, J.S., Jung, R.H., Kim, S.S., Go, W.J., Kim, K.Y. and Park, J.S.2001. Limiting nutrient on phytoplankton growth in Gwangyang Bay. *Journal of the Korean Society of Oceanography* 6(3): 201-210.
- Lee, Y.S., Park, Y.T., Kim, Y.S., Kim, K.Y., Park, J.S., Go, W.J., Jo, Y.J. and Park, S.Y.2001. Countermeasure and outbreak mechanism of *Cochlodinium polykrikoides* red tide 1. Environmental characteristics on outbreak and disappearance of *C. polykrikoides* bloom. *Journal of the Korean Society of Oceanography* 6(4): 259-264.
- Lim, W.A., Jung, C.S., Lee, C.K., Cho, Y.C., Lee, S.G., Kim, H.G. and Chung, I.K.2002. The outbreak, maintenance, and decline of the red tide dominated by *Cochlodinium polykrikoides* in the coastal waters off southern Korea from August to October, 2000. *The Sea, Journal of the Korean Society of Oceanography* 7(2): 68-77.
- Lim, W.A., Lee, C.K. 2004. Distributions and cellular characteristics of *Cochlodinium polykrikoides* in the eastern South Sea of Korea in early summer. *Journal of the Korea Society of Oceanography*. 9(3):106-109.
- Moon, S.G. and Choi, C.M. 2003. A list of important species and distribution of marine phytoplankton in Korea. *J. of the Environmental Sciences* 12(7): 725-733.
- Park, H.K., Jung, E.Y., Lee, Y.J., Jung, J.M., Choi, S.Y. and Hong, Y.K.2002. A study on the removal of *Microcystis aeruginosa* by coagulants of the ceramic-zeolite type and yellow loess. *J. of the Environmental Sciences* 11(4): 405-409.
- Park, J.G., Huh, S.H. and Jeong, H.J.2001. Phytoplankton in Chinhae Bay: I. Photosynthetic properties and primary production in variant light environments. *Algae* 16(2): 189-196.

- Park, J.S. and Yoon, Y.H. 2003. Marine environmental characteristics by distribution of dinoflagellate cysts in the southwestern coastal waters of Korea. 1. Spatio-temporal distribution of dinoflagellate cysts in Gamak Bay. J. Kor. Fish. Soc. 36(2): 151-156.
- Park, M.G. 2003. Parasites and phytoplankton, with a special emphasis on dinoflagellate infections. J. Phycol. 39(1): 46.
- Park, M.G. 2002. Physiological ecology of parasitic dinoflagellate *Amoebophrya* and harmful algal blooms. Journal of the Korean Society of Oceanography 7(3): 181-194.
- Park, M.J., Lee, H.J., Lee, T.S., Kim, J.H. and Lee, T.H. 2000. Change of paralytic shellfish poison components during bacterial detoxification. J. Korean Fish. Soc. 33(6): 550-553.
- Park, M.J., Lee, H.J., Lee, T.S., Park, J.H. and Jang, D.S. 2000. Isolation and characterization of paralytic shellfish poison detoxification bacteria. J. Korean Fish. Soc. 33(6): 546-549.
- Seo, K.S. and Fritz, L. 2000. Cell-wall morphology correlated with vertical migration in the non-motile marine dinoflagellate *Pyrocystis noctiluca*. Marine Biology 137(4): 589-594.
- Seo, K.S. and Fritz, L. 2000. The cytoskeletal network during division in the marine dinoflagellates, *Pyrocystis lunula* and *P. noctiluca*. Algae 15(3): 137-141.
- Shin, J.K. and Cho, K.J. 2000. The impact on water quality from blue-green algae *Microcystis* of natural phytoplankton by algal assay. J. of the Korean Environmental Sciences Society.
- Shynn, B. and Lee, J.B. 2002. Spatial and temporal distribution of picoplankton, nonoplankton and microplankton in Jungmun coastal waters of Jeju Island, Korea. The Sea, Journal of the Korean Society of Oceanography 7(2): 78-86.
- Suh, Y.S., Lee, H.J., Lee, N.K., Ishizaka, J. 2004. Feasibility of red tide detection around Korean waters using satellite remote sensing. J. Fish. Sci. Tech. 7(3): 148-162.
- Suh, Y.S., Kim, J.H. and Kim, H.G. 2000. Relationship between sea surface temperature derived from NOAA satellites and *Cochlodinium polykrikoides* red tide occurrence in Korean coastal waters. J. of the Korean Environmental Sciences Society.
- Sun, X-X., Han, K-N., Choi, J-K., Kim, E-K. 2004. Screening of surfactants for harmful algal blooms mitigation. Marine Pollution Bulletin. Mar. Pollut. Bull. 48(9): 937-945.

- Sun, X. Choi, J. 2004. Recovery and fate of three species of marine dinoflagellates after yellow clay flocculation. *Hydrobiologia* 519(1): 153-165.
- Sun, X.X. Choi, J.K. Kim, E.K. 2004. A preliminary study on the mechanism of harmful algal bloom mitigation by use of sophorolipid treatment. *J. Exp. Mar. Biol. Ecol.* 304(1): 35-49.
- Yang, J.S., Choi, H.Y., Jeong, H.J., Jeong, J.Y. and Park, J.K. 2000. The outbreak of red tides in the coastal waters off Kohung, Chonnam, Korea. 1. Physical and chemical characteristics in 1997. *Journal of the Korean Society of Oceanography* 5(1): 16-26.
- Yang, S.R., Song, H.S., Moon, C.H., Kwon, K.Y. and Yang, C.H. 2001. Changes in marine environment and primary production due to freshwater input in the Nakdong estuary. *Algae* 16(2): 165-177.
- Yih, W.H. Kim, H.S. Jeong, H.J. Myung, G. Kim, Y.G. 2004. Ingestion of cryptophyte cells by the marine photosynthetic ciliate *Mesodinium rubrum*. *Aquat. Microb. Ecol.* 36: 165-170.
- Yoo, J.S. 2003. Monitoring of Algal Bloom at Seomjin River Estuary, Southern Coast of Korea. *Algae* 18(4): 361-363.
- Yoo, J.S., Fukuyo, Y., Cheun, B., Lee, S.G. and Kim, H.G. 2000. Toxic algal bloom caused by dinoflagellate *Alexandrium tamarense* in Chindong Bay, Korea. *J. Fish. Sci. Tech.* 3(1): 26-32.
- Yoo, Y.D., Jeong, H.H., Shim, J.H., Park, J.Y., Lee, K.J., Yih, W.H., Kweon, H.K., Pae, S.J. and Park, J.K. 2002. Outbreak of red tides in the coastal waters off the southern Saemankeum areas, Jeonbuk, Korea. 1. Temporal and spatial variations in the phytoplankton community in the summer-fall of 1999. *Journal of the Korean Society of Oceanography* 7(3): 129-139.
- Yoon, H.J., Kim, Y.S., Yoon, Y.H. and Kim, S.W. 2002. Study on monitoring and prediction for the occurrence of red tide in the middle coastal area in the South Sea of Korea. 1. The relationship between the occurrence of red tide and the meteorological factors. KIMICS.
- Yoon, Y.H. and Park, J.S. 2000. The analysis of variational characteristics on water quality and phytoplankton by principal component analysis (PCA) in Kogum-sudo, southwestern part of Korea. *J. of the Korean Environmental Sciences Society* 9(1): 1-11.
- Yoon, Y.H. 2000. Distributional characteristics and seasonal fluctuations of phytoplankton community in Haechang Bay, southern Korea. *J. Korean Fish. Soc.* 33(1): 43-50.

- Yoon, Y.H.2000. On the spatio-temporal distributions of nutrients and chlorophyll a concentration, and the environmental factors on the variation of phytoplankton biomass in the Shiahae, southwestern part of Korean peninsula. Korean J. Environ. Biol. 18(1): 77-93.
- Yoon, Y.H.2001. On the spatio-temporal distributions of water quality and chlorophyll a, and the environmental factors on the variation of the phytoplankton biomass in the Mokpo coastal waters, southwestern Korea during low temperature season. J. KSWQ Jan. 17(1): 1-13.