25 Mitigation and Controls of HABs

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25.1 Introduction

The impacts of harmful algal blooms (HABs) on public health and fisheries economics can be severe and are increasing along many coasts of the world. Other ecological impacts include the alteration of marine habitats and devastation of the coastal amenities. Commercial oysters and mussels along the Atlantic and Pacific coasts are exposed to paralytic, diarrhetic and amnesic shellfish poisoning (Oshima 1982; Yasumoto 1982; Sundström et al. 1990; Anderson et al. 2000; Landsberg 2002). Fish-killing HABs have become major threats to aquaculture industries in Asian countries (Chen 1993; Okaichi 1997; Dickman 2001; Kim 2005). Approximately 150 species of aquatic microalgae are harmful and toxic (Landsberg 2002). Such microalgae as *Chattonella antiqua* (Okaichi 1997), *Cochlodinium polykrikoides* (Kim 1998), *Heterosigma akashiwo* (Honjo 1992), *Karenia mikimotoi* (Iizuka and Irie 1966), *Heterocapsa circularisquama* (Matsuyama et al. 1995), and *Karenia brevis* (Ingersoll 1882) cause mass mortalities of wild and cultured fish almost every year.

In the USA during the 1987–1992 period, the total cost of HABs averaged $49 million per year (Anderson et al. 2000). In Korea, from 1995–2004, the estimated fisheries damage approximated 1.31 million US$ per year (Kim 2005). The average economic loss in Japan is over a billion yen per year (Imai 2005). Hong Kong's worst red tides, in 1998, caused fish kills valued at 10.3 million US$ (Dickman 2001). Nonetheless, predictive models and mitigation techniques are not developed enough to secure the safety of seafood and to minimize the impacts of HABs on commercial fisheries. The goal of mitigation and control of HABs is to protect public health, fisheries resources, and marine ecosystems. Present approaches focus on mitigation to prevent the impacts of HABs on fisheries resources and the aquaculture industry rather than public health.

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25.2 Mitigation Strategies and Control of HABs

A variety of mitigation strategies can be employed directly or indirectly to affect the size of a HAB population or its impacts. These can be classified into two categories: precautionary impact preventions, and bloom controls (Table 25.1). Bloom control can be categorized as either direct or indirect, depending upon whether the effort targets an existing bloom or strives to reduce future blooms, such as through alteration of pollution inputs and consumption of dissolved nutrient by beneficial diatom blooms (SCOR/GEOHAB 1998; Kim 2005).

25.2.1 Precautionary Impact Preventions

Precautionary impact prevention includes HAB monitoring, prediction, and emergent actions. The role of monitoring is to detect HABs and their associated toxins in algae or fish and shellfish. Prediction involves more scientific approaches based on the oceanography and ecology. Precautionary emergent actions are described in contingency plans for fish culture later in this chapter.

Monitoring for HABs requires identification of target species, determination of toxins, understanding oceanographic properties underlying population dynamics, and analysis of environmental and meteorological changes to build integrated prediction models. Sometimes, international and regional links are recommended to compare regional biodiversity and biogeography of harmful species. The Intergovernmental Oceanographic Commission

Table 25.1. Current mitigation and control strategies for HABs

Category	Before HAB	After HAB
Precautionary impact preventions	Monitoring Prediction Precautionary actions – Early harvesting – Provide less feed to fish – Prepare mitigation facilities – Clay, pump/aspirator	Emergent actions – Move pens to refuge site – Enclosure of fish cages – Water circulation – Oxygenation – Aeration – Ozonization
Bloom controls	Indirect controls – Reduce nutrient inputs – Modification of water circulation – Bio-remediation	Direct controls – Physical control – Chemical control – Biological control

(IOC) recommends the use of the Global Ocean Observing System (GOOS), whose broad portfolio of products and services allow the design of good cooperative monitoring and prediction systems. To make timely predictions, better monitoring tools must be developed.

Accurate forecasting of the timing and transport pathway of HABs can help fish farmers and other affected parties to take emergency actions. Some predictive models such as numerical models (Eilertsen and Wyatt 1998) and multiparameter ecosystem models (Allen 2004) have already been developed for some dinoflagellates blooms.

Thus far, however, truly practical predictive models of population and transport dynamics of important species have not yet been developed. Prediction models should be established on the basis of detailed understanding of the factors controlling the oceanographic and bloom dynamics (Allen 2004).

To maximize timeliness essential to protect the safety of cultured animals, all HAB information has to be distributed on a real-time basis. For example, the timing and transport pathways of HABs must be distributed immediately to all fish farmers through public communication networks such as television broadcasting, the Internet, facsimile and newsletter, automated telephone response systems (ARS), and SMS.

Audio-visual image transport systems are sometimes very efficient for exchanging oral and visual information. This provides the exchange of microscopic images between local laboratories and a central institute. This will permit overcoming the shortage of identification experts and budgetary restrictions, because this framework connects all the laboratories and terminals within one network system.

25.2.2 Direct and Indirect Bloom Controls

Since the first use of copper sulphate (Rounsefell and Evans 1958), a variety of chemicals, flocculants, and biological and physical techniques have been used in attempts to directly control HABs (Table 25.2).

Biological Control. Biological techniques apply top-down grazing and bottom-up bacterial decomposition. Some copepods and ciliates can graze dinoflagellates such as *C. polykrikoides* and *K. mikimotoi* (Jeong et al. 1999; Kim et al. 1999), but in reality, it is difficult to use them as HAB control agents due to a lack of facilities for mass culture and logistical problems. Viruses, parasites, and bacteria are also promising bottom-up control agents, as they can be abundant in marine systems, replicate rapidly, and sometimes are host-specific. Flagellates such as *Amoebophrya ceratii* and *Parvilucifera infectans* are well-known intracellular parasites of free-living dinoflagellates, including the genus *Alexandrium* (Taylor 1968). A possible use of a virus to

Table 25.2. Harmful algal bloom controls and available agents

Controls	Mechanisms	Available agent
Biological	Grazing (top-down)	Copepods, ciliates, bivalves
	Algicidal agents	Bacteria, viruses
	Parasites	*Amoebophrya, Parvilucifera*
	Enzymes	Mannosidase
Physical	Destruction	Ultrasound
	Electrolysis	NaOCl
	Removal	Skimmer, screen filter
	Isolation	Shield curtain, perimeter skirt
Chemical	Flocculants	Clays and long-chain polymers
	Surfactants	Sophorolipid, aponin
	Mucolytic coagulants	Cysteine compounds
	Metals and liquids	Copper, $Mg(OH)_2$, H_2O_2

control *H. akashiwo* and *H. circularisquama* has been reported (Nagasaki et al. 2005). Investigations of algicidal bacteria targeting a dinoflagellate *K. brevis* were conducted in the Gulf of Mexico (Doucette 2002). Algicidal microorganisms affecting red tides caused by *C. antiqua* and *H. akashiwo* were studied in northern Hiroshima Bay in the Seto Inland Sea (Imai et al. 1998).

Physical Control. Physical control involves removing the harmful algae cells using physical treatments such as skimming, isolation, ultrasonic destruction, and electrolyzation of seawater. Centrifugal separation equipment was used to remove *C. polykrikoides* cells in a land-based tank (Chang, pers. comm.), but the treatment of a number of different harmful algae was a difficult problem. Ultrasound was only effective over 50 cm in depth and was not useful at low cell concentrations (Shirota 1989).

Chemical Control. Copper sulphate was applied to control a red tide in Florida (Rounsefell and Evans 1958). However, it was found that dusting the sea with copper sulfate was too expensive as a control method for red tides, and copper was lethal to sensitive marine organisms. A chemical called "aponin", a sterol surfactant produced by the blue-green alga *Gomphosphaeria aponina*, was once suggested as a control agent for toxic *K. brevis* blooms (McCoy and Martin 1977). Microbial surfactant sophorolipids have also been used to control *C. polykrikoides* blooms (Choi et al. 2002). Other chemicals such as cysteine compounds (Jenkinson and Arzul 2001), octadecatetraenoic acid extracted from brown algae (Kakizawa et al. 1988), sodium hypochlorite produced by electrolysis of natural sea water (Kim et al. 2000), ozone (Rosenthal 1981), hydrogen peroxide as an extermination agent against cysts (Ichikawa et al. 1993), and magnesium hydroxide (Maeda et al. 2005) are in trial tests for the possibility of urgent suppression of red tides. Another study screened 4,300 chemicals against Florida's red tide algae but did not find one that was sufficiently potent and did not adversely affect other organisms (Marvin and Proctor 1964). Thereafter, chemical control options have received little attention, because most of the chemicals are likely to be non-specific and thus will kill co-occurring algae and other organisms indiscriminately. Each candidate chemical will require extensive testing for lethality, specificity, and general safety, and each must surmounts significant regulatory hurdles (Anderson et al. 2001).

Flocculant Clays. One promising non-chemical strategy involves the treatment of blooms with flocculant clays, which scavenge particles (including algal cells) from seawater and carry them to bottom sediments. The properties of cation exchange and plasticity are the most important characteristics for their use as flocculants for harmful microalgae. Clay minerals include kaolinite, illite, and montmorillonite. The first clay experiments were done in Japan to control *Olisthodiscus* sp. (Shirota and Adachi 1976), and then in Korea to control *Prorocentrum triestinum* (Kim 1987). Recently, clay has been widely applied to control HABs in Japan (Shirota and Adachi 1976), Korea (Kim 1987), China (Yu et al. 1994), and the USA (Sengco et al. 2000). As for the specific mechanisms, Shirota (1989) suggested that the clay not only flocculates and removes cells by sedimentation, but that some cells are killed by aluminum eluted from the clay by ion exchange. It was found that the concentrations of iron, aluminum and TiO_2 in clay were proportional to the removal rate of *C. polykrikoides*, such that the higher the concentration of iron and aluminum, the higher the removal rate (Kim et al. 2001).

Cochlodinium polykrikoides Blooms and Clay Control in Korea. In Korea, yellow clay was first applied to control a dinoflagellate *P. triestinum* bloom in 1986 (Kim 1987). Numerous of clays have been subsequently applied in fish farms to control blooms of the fish-killing dinoflagellate *C. polykrikoides*. When montmorillonite clay was sprinkled on a concentration of 1,000 cells/ml of *C. polykrikoides*, 74 % of the living cells were removed at a clay concentration of 2 g/ml, and 98 % at 4 g/ml, within 30 min (Kim 1998). In a field survey of *C. polykrikoides* blooms, the removal rates ranged from 74 to 85 % in 30 min after dispersion (Table 25.3), and the more the iron and aluminum, the higher the removal rate (NFRDI 1999). The removal rate of *C. polykrikoides* according to the density and elapsed time is summarized in the following table (NFRDI 1999).

In terms of toxicity of yellow clay to fish and shellfish, including abalone and flatfish, there were no significant impacts at a clay concentration of 20 g/l within 24 h (NFRDI 1999). A 5-year survey of benthic fauna at the clay dispersal site near Tongyong city, Korea, where clay has been distributed

Table 25.3. Removal rates (%) of *C. polykrikoides* according to the bloom density and elapsed time after clay dispersions

Bloom density (cells/ml)	Removal rate (%) of clay dispersion (10g/l) Just after	After 30 min	After 60 min
100–500	40–50	74–76	80–83
500–1,000	50–55	76–78	85–88
1,000–3,000	55–65	74–85	84–92

every year since 1996, showed no changes in the species composition, diversity and abundance of benthos (NFRDI 1999). Thus, clay has been widely applied by local governments for the control of fish-killing *C. polykrikoides* blooms.

A guidebook, "HABs and Clay Dispersion" has been published and distributed to all stakeholders for adequate clay dispersion in Korea and Japan (NFRDI 1997; JFA 1982). This guidebook recommends that clay minerals be powdered to a particle size of less than 50 μm, and dispersed at concentrations of 100–400 g/m^2 by mixing with seawater at mid-day (because the *C. polykrikoides* cells migrate to subsurface layers in mid-day). Taking into account the diffusion and sinking rate of clay minerals, the surface area of clay dispersion at fish cages would be about three times that of the area of the cages in order to protect fish staying at the bottom of the cage in mid-day. The interval for dispersion time is 30–40 min, taking into account the sinking rate of clay and the 10–m depth of the fish pens. The clay is dispersed in the tidal currents so that it drifts in the direction of the fish farm. If HABs are already inside of the fish cages, clay suspensions are dispersed in a "merry-go-round" fashion (Fig. 25.1). Acknowledging that the higher the density of *C. polykrikoides*, the better the removal efficiency of the clay, the local government recommends dispersing the clay when the density exceeds 1,000 cells /ml, the level of a "Red Tide Alert", taking into account the expenses and manpower for clay dispersion.

As mentioned above, Japan, Korea, China, and the USA use dispersed clays and/or have performed pilot studies for controlling dinoflagellate blooms. Clay mitigation seems to be promising, but environmental risk assessments should be carefully implemented to clarify the chronic impacts of clays on the marine ecosystem.

Eutrophication is a major cause of the initiation of HABs. Thus, enclosed or semi-enclosed bays are highly susceptible to harmful and toxic blooms due to their relatively shallow depths, restricted circulation and input of anthropogenic nutrients from land runoff. Therefore, reduction of terrestrial nutrients is the best way to reduce the outbreaks of HABs in such locations (SCOR/GEOHAB 1998).

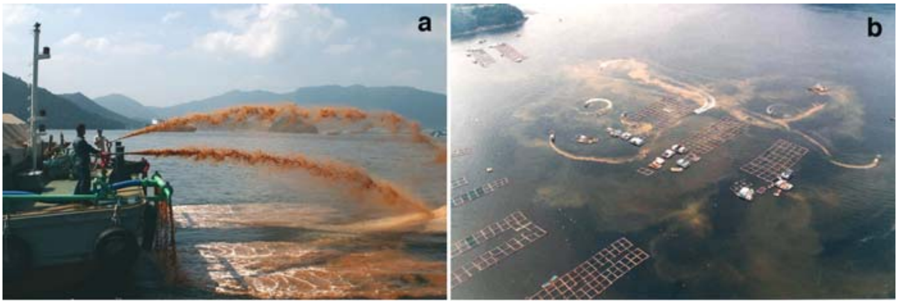

Fig. 25.1. Photos showing clay dispersion **a** using an application ship equipped with a seawater electrolization system and **b** an aerial view of clay dispersion around the fish cages

Nutrients/Eutrophication. A case has been made that increases in nutrients are linked to increases in the frequency and abundance of HABs (Granéli et al. 1999). It follows that a reduction in pollution would lead to a decrease in bloom frequency. There are two classic examples; one is that the number of red tides began to decrease by reduction of industrial and domestic effluents in the Seto Inland Sea of Japan (Okaichi 1997), and the other is the diminishing of picoplanktonic green tides by opening of a channel to the ocean and by the gradual demise of the duck-farming business in Great South Bay and Moriches Bay on Long Island, New York, USA (SCOR/GEOHAB 1998).

In some cases, changes in N:P:Si ratios influence species composition (Smayda and Borkman 2005) and beneficial species might be encouraged; therefore, nutrient ratios and their effects on the growth of harmful algae and species composition should be considered as important indirect controls.

Bio-Manipulation. Human modification of physical structure of the ecosystem may be considered to conserve, establish or re-establish a biological community that may prevent HABs (SCOR/GEOHAB 1998). This is termed „bioremediation“, and is applicable as one component of integrated coastal zone management. An example might be the establishment of populations of benthic filter feeders to control populations of HABs. Another might be artificial aeration to mix the water column, favoring species that thrive in well-mixed waters over those requiring stratification. Another possibility is to stimulate blooms of diatoms instead of harmful dinoflagellates in summer by inducing germination of diatoms (Itakura 2002).

The design and evaluation of bio-manipulation strategies requires a fundamental understanding of associated processes, such as grazing losses, or the influence of water-column mixing on species succession.

Modification of Water Circulation. In some semi-enclosed areas, HABs linked to either local eutrophication or restricted circulation can be minimized by changing the circulation of water masses to optimize flushing of nutrient-rich water and HAB species (SCOR/GEOHAB 1998). Tidal dams that are designed to open the upper gate to allow entry of flood tides into a bay and open the lower gate to flush bottom eutrophicated waters during the ebb tides are examples of how tidal circulation may be enhanced. Again, this requires understanding of linkages between hydrography, nutrient loading, and bloom dynamics, of which little is known for most HAB species. Aeration may be useful in mitigating such small-scale blooms in fish farms by breaking down stratification.

25.2.3 Contingency Plans for Fish Culture

The goal of precautionary actions is to minimize the impacts on commercial fish and shellfish by taking mitigation actions prior to the development of high-density HABs. In Korea and Japan, early harvesting, reducing densities of cultured fish, quantities of fish food and metabolic substances, and disease diagnosis are highly recommended for marine fish culture. For land-based fish culture, compressed oxygen and pumps, filtering apparatus, and HAB warning machines are essential facilities (Anderson et al. 2001; Kim 1999). Clay stock and clay application ships near the areas of predicted HABs are important standby measures of local governments.

Mechanisms of mass mortalities of fish include ichthyotoxins produced by harmful algae, suffocation by gill-clogging and lack of dissolved oxygen especially at night, and reactive oxygen substances (ROS) on the gill membranes (Kim et al. 1999). Therefore, emergent measures are important to alleviate the direct cause of mass mortalities of cultured fish.

One of these emergent measures in Korea is to disperse yellow clay on fish farms, and another is to protect cultured animals either by transportation of fish cages into a zone free of HABs, or by enclosure of fish cages to prevent exposure of fish to HABs. Transportation of fish cages away from an area affected by fish-killing blooms to a known offshore refuge site has been widely practiced by mariculturists in Japan and Korea. The primary equipment for the transportation is a towing tugboat and a refuge container to accommodate transferred fish. Wave breakers can serve as refuge containers. Enclosure of fish cages has been done by shield curtains or perimeter skirts whose shape and deployment resembles purse seines. Enclosed fish can survive for 1–2 weeks and sometimes up to a month if no food is provided. Aeration is needed to reduce fish mortality by increasing dissolved oxygen concentrations in water exposed to fish gills. Atmospheric air can be introduced into the fish cages via aspiration with air-blowers or compressors. Pumping bottom waters and dispersing them on the surface of fish cages helps supply oxygen and dilutes high surface densities of harmful algae.

A final choice of releasing culture fish into the wild sea just before the invasion of HABs can be considered, due to the likelihood of fish survival and adaptability in the natural coastal environment. It is very difficult to determine the timing of the release and appropriate compensation.

25.3 Conclusions

The goals of management and mitigation of HABs is to secure public health and to protect aquaculture producers against economic losses. These goals can be accomplished by direct control of HABs and reducing terrestrial pollutants in order to reduce eutrophication that leads to frequent HABs.

Real-time monitoring and prediction is the first precautionary action to be implemented to minimize damage caused by HABs. In periods of high bloom risk, aircraft visual surveys, satellite remote sensing, and vessel and shore-based observations are proving to be effective tools for early warning and bloom tracking. Acknowledging that international cooperation enhances the mitigation efficiency, regional and international cooperative monitoring systems and mitigation strategies should be established for widespread HABs in the global ocean. The SEAWATCH™ system is a good example for those who want a complete operational monitoring and information system. According to the scale of the impacts and the increasing trends in incidence, HAB mitigation and control should be a prime research topic. Many chemicals and flocculants have been used as HAB mitigation agents. Clay is one of the promising agents for HAB mitigation and control, if its environmental effects are minimized.

Ballast water has long been recognized as a major vector for the introduction of non-indigenous and harmful organisms (Rosenthal 1981). Invasions of exotic HAB species are causing significant ecological and economic damage in various parts of the world. At present, restrictions on ballast water discharges should also be considered, as well as the manner in which live fish and shellfish are transported and dispersed (Hallegraeff et al. 1990).

References

Allen JC (2004) Multiparameter ecosystem models as tools for process modeling and prediction of HABs in fjords and coastal embayments. In: GEOHAB Open Sci Meeting. HABs in fjords and coastal embayments. Valparaiso, Chile. Abstracts, pp 20–21

Anderson DM, Andersen P, Bricelj VM, Cullen JJ, Rensel JE (2001) Monitoring and management strategies for harmful algal blooms in coastal waters. APEC #201-MR-01.1, Asia Pacific Economic Program, Singapore, and IOC-UNESCO, Tech Series 59, Paris, pp 174–264

Anderson DM, Kaoru Y, White AM (2000) Estimated annual economic impacts from harmful algal blooms (HABs) in the United States. Tech Rep, Woods Hole Oceanogr Inst, WHOI-200-11, Woods Hole, MA, USA, pp 3–8

Chen YQ, Gu XG (1993) An ecological study of red tides in the East China Sea. In: Smayda TJ, Shimizu Y (eds) Toxic phytoplankton blooms in the sea. Elsevier, Amsterdam, pp 217–221

Choi JK, Sun X, Lee YJ, Kim EK (2002) Synergistic effects of sophorolipid and loess combination in harmful algal blooms mitigation. In: Proc 3rd Int Symp Harmful Algal Blooms and Control, Pusan, Korea, pp 85–90

Dickman MD (2001) Hong Kong's worst red tide induced fish kill (March–April, 1998). In: Hallegraeff GM, Blackburn SI, Bolch CJ, Lewis RJ (eds) Harmful algal blooms 2000. IOC-UNESCO, Paris, pp 58–61

Doucette G (2002) Investigations of algicidal bacteria targeting the red tide dinoflagellate *Karenia brevis* in the Gulf of Mexico, USA. In: Proc 3rd Int Sym Harmful Algal Blooms and Control, Pusan, Korea, pp 57–64

Eilertsen HC, Wyatt T (1998) A model of *Alexandrium* population dynamics. In: Reguera B, Blanco J, Fernandez ML, Wyatt T (eds) Harmful algae. Xunta de Galicia and IOC-UNESCO, Grafisant, Santiago de Compostela, Spain, pp 196–199

Granéli E, Carlsson P, Legrand C (1999) The role of C, N and P in dissolved and particulate organic matter as a nutrient source for phytoplankton growth, including toxic species. Aquat Ecol 33:37–54

Hallegraeff GM, Bolch CJ, Bryan J, Koerbin B (1990) Microalgal spores in ship's ballast water: a danger to aquaculture. In: Granéli E, Sundström B, Edler L, Anderson DM (eds) Toxic marine phytoplankton. Elsevier, New York, pp 475–480

Honjo T (1992) Harmful red tides of *Heterosigma akashiwo*. NOAA Tech Rep NMFS, 111:27–32

Ichikawa S, Wakao y, Fukuyo Y (1993) Hydrogen peroxide an extermination agent against cysts of red tide and toxic dinoflagellates. In: Smayda TJ, Shimizu Y (eds) Toxic phytoplankton blooms in the sea. Elsevier, Amsterdam, pp 133–138

Iizuka S, Irie H (1966) The hydrographic conditions and the fisheries damage by the red tide that occurred in Omura Bay in summer 1965. II. Bull Fac Fish Nagasaki Univ 21:67–101

Imai I (2005) Mitigation strategies against harmful red tides by use of algicidal bacteria: application of seedweed beds as huge sources of algicidal bacteria. Proc 1st Int Work HAB Northwest Pacific region, Toyama, Japan, pp 99–105

Imai I, Kim MC, Nagasaki K, Itakura S, Ishida Y (1998) Relationship between dynamics of red tide-causing raphidophycean flagellates and algicidal microorganisms in the coastal sea of Japan. Phycol Res 46:139–146

Ingersoll E (1882) On the fish mortality in the Gulf of Mexico. Proc US Nat Mus 4:74–80

Itakura S (2002) Prevention of harmful flagellate blooms by diatoms. In: Hiroshi S, Imai I, Ishimaru T (eds) Prevention and extermination strategies of harmful algal blooms. Nippon Suisan Gakkai. Fisheries Series 134:9–18

Jenkinson IR, Arzul G (2001) Mitigation by cysteine compounds of rheotoxicity, cytotoxicity and fish mortality caused by the dinoflagellates, *Gymnodinium mikimotoi* and *G.* cf. *maguelonnense*. In: Hallegraeff GM, Blackburn SI, Bolch CJ, Lewis RJ (eds) Harmful algal blooms 2000. IOC-UNESCO, Paris, pp 461–464

Jeong HJ, Shim JH, Lee CW, Kim JS, Koh SM (1999) Growth and grazing rates of the marine planktonic ciliate *Strombidinopsis* sp. on red tide and toxic dinoflagellates. J Eukaryot Microbiol 46:69–76

JFA (1982) Clay dispersion. A manual for the mitigation of HABs impacts. Japan Fisheries Agency, 31 pp

Kakizawa H, Asari F, Kusumi T, Toma T, Sakurai T, Oohusa T, Hara Y, Chihara M (1988) An allelopathic fatty acid from the brown alga *Chadosiphon okamuransus*. Phytochemistry 27:731–735
Kim CS, Lee SG, Kim HG, Jung J (1999) Reactive oxygen species as causative agents in the ichthyotoxicity of the red tide dinoflagellate, *Cochlodinium polykrikoides*. J Plankton Res 21:2105–2115
Kim CS, Bae HM, Cho YC (2001) Control of harmful algal blooms by clay via photochemical reactions. J Korea Soc Phycol, Algae 16:67–73
Kim HG (1987) Ecological study of dinoflagellates responsible for red tide. 1. The population growth and control of *Prorocentrum triestinum* Schiller. Bulletin NFRDI 39:1–6
Kim HG (1998) *Cochlodinium polykirkoides* blooms in Korean waters and their mitigation. In: Reguera B, Blanco J, Fernandez ML, Wyatt T (eds) Harmful algae. Xunta de Galicia and IOC-UNESCO, Grafisant, Santiago de Compostela, Spain, pp 227–228
Kim HG (2005) Harmful algal blooms in the sea. Dasom Publ Co. 467 pp (in Korean)
Kim HG, Jeong HJ, Hahn SD et al (1999) Management and mitigation techniques to minimize the impacts of harmful algal blooms. Korean Ministry of Maritime Affairs and Fisheries, special rep 527 pp
Kim HR, Kim KI, Kim DS, Park KS, Hong TH, Jeong HJ (2000) Developing a method of controlling the outbreak and maintenance of red tides using NaOCl produced by electrolysis of natural seawater. In: 9th Int Conf Harmful Algal Blooms, Hobart, Australia, 2000. (Abstract), p 28
Landsberg JH (2002) The effects of harmful algal blooms on aquatic organisms. Reviews Fish Sci 10:113–390
Maeda H, Sasaki H, Nishino H, Taoka Y, Dung N, Hidaka M (2005) Suppression of red tide by magnesium hydroxide. In: Proc 1st Int Workshop on HAB Northwest Pacific region, Toyama, Japan, pp 95–98
Marvin KT, Proctor RR Jr (1964) Preliminary results of the systematic screening of 4,306 compounds as „red-tide“ toxicants. USFWS Bureau of Commercial Fisheries report, Galveston, Texas. Contribution no 184, 85 pp
Matsuyama Y, Nagai K, Mizuguchi T, Fujiwara M, Ishimula M, Yamaguchi M, Uchida T, Honjo T (1995) Ecological features and mass mortality of pearl oysters during the red tide of *Heterocapsa* sp in Ago Bay in 1992. Nippon Suisan Gakkaishi 61:35–41 (In Japanese)
McCoy JLF, Martin DF (1977) The influence of *Gomphosphaeria aponina* on the growth of *Gymnodinium breve* and the effects of aponin on the ichthyotoxicity of *Gymnodinium breve*. Chem Biol Interactions 17:17–24
Nagasaki T, Tomaru Y, Shirai Y, Mizumoto H, Nishida K, Takao Y (2005) Possible use of viruses as a microbiological agent to control HAB. Proc 1st Int Workshop on HAB Northwest Pacific region, Toyama, Japan, pp 106–108
NFRDI (1999) The clay and HABs. Korean Nat Fish Res Dev Inst Tech Rep 19 pp
Okaichi T (1997) Red tides in the Seto Inland Sea. In: Okaichi T, Yanagi Y (eds) Sustainable development in the Seto Inland Sea – from the viewpoint of fisheries. Tera Sci Publ Co, Tokyo, Japan, pp 251–304
Oshima Y (1982) Occurrence of paralytic shellfish poison in Japan and tropical areas. In: Toxic phytoplankton-occurrence, mode of action and toxins. Nippon Suisan Gakkai, Fish Series 42:73–87
Rosenthal H (1981) Ozonation and sterilization. In: World symposium on new developments in the utilization of heated effluents and recirculation systems. Stavanger, Norway, 511 pp
Rounsefell GA, Evans JE (1958) Large-scale experimental test of copper sulfate as a control for the Florida red tide. US Fish Wildlife Serv Spec Sci Rep, 270 pp

SCOR/GEOHAB (1998) The global ecology and oceanography of harmful algal blooms. A plan for co-ordinated scientific research and co-operation to develop international capabilities for assessment, prediction and mitigation, Joint SCOR-IOC Workshop Rep. Havreholm, Denmark 13–17 Oct 1998, 22 pp

Sengco MR, Li A, Henry MS, Petersen B, Anderson DM, Pierce R (2000) Preliminary mesocosm studies of clay dispersal in Sarasota Bay, Florida (USA). In: Proc 1st Interstate Symp: The evaluation on the mitigation capability of clay and yellow loess at the HABs and their impacts on marine ecosystem, Pusan, Korea, pp 53–59

Shirota A (1989) Red tide problem and countermeasures. Int J Aquat Fish Technol 1:195–293

Shirota A, Adachi M (1976) Abst Annual Meeting of Japan Oceanogr Soc, p 15

Smayda T, Borkman D (2005) Multidecadal changes in the diatom: flagellate ratio and Si:N and Si:P ratios in Narragansett Bay, and influence of Si:N supply ratios on diatom species competition. In: GEOHAB Open Sci Meeting HABs and Eutrophication, Baltimore, Maryland USA, (abstract), p 56

Sundström B, Edler L, Granéli E (1990) The global distribution of harmful effects of phytoplankton. In: Granéli E, Sundström B, Edler L, Anderson DM (eds) Toxic marine phytoplankton. Elsevier, New York, pp 537–541

Taylor FJR (1968) Parasitism of the toxin-producing dinoflagellate *Gonyaulax catenella* by the endoparasitic dinoflagellate *Amoebophrya ceratii*. J Fish Res Board Can 25:2241–2245

Yasumoto T (1982) Occurrence and chemistry of diarrhetic shellfish poison. In: Toxic phytoplankton-occurrence, mode of action and toxins. Nippon Suisan Gakkai, Fisheries Series 42:102–111

Yu ZM, Zou JZ, Ma X (1994) Application of clays to removal of red tide organisms 1. Coagulation of red tide organisms with clays. Chin J Oceanol Limnol 12:193–200