A national report on harmful algal blooms in China

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Introduction

Harmful algal blooms (HABs) have been spreading and increasing along the coast of China in the past two decades, causing damage to the marine environment and posing a threat to human health (Zou 1992; Qi *et al.* 1993; Tseng *et al.* 1993; Zhu *et al.* 1995). Because HABs are globally distributed and are integral parts of marine and brackish-water ecosystems, the central research problem can be addressed comprehensively and effectively only through international, interdisciplinary, and comparative research on important questions about the dynamics of HABs within their oceanographic and ecological systems (GEOHAB 1998). Several international organizations, including IOC (Intergovernmental Oceanographic Commission), PICES (North Pacific Marine Science Organization), APEC (Asian-Pacific Economic Cooperation) have set up programs or workshops on HABs. To foster international cooperative research on HABs, it is important for marine and health scientists and agencies to document and understand HAB occurrences in each country in order to find common issues. In this paper, we will give an overview of HAB history, causative HAB species, algal toxin distribution and poisoning events, and introduce HAB research activities and recent progress in HAB monitoring and mitigation in China.

HAB occurrence in China

The first documented HAB event in China, which was caused by *Noctiluca scintillans* and *Skeletonema costatum* in Zhejiang coast in 1933, killed marine organisms such as razor clams and other shellfish species. This event was recorded by H. Fei (Fei 1952). A summary of the early HABs in China is shown in Table 3. The Chinese government and concerned scientists started to pay greater attention to HABs after the especially devastating *Prorocentrum minimum* bloom in the Bohai Sea, in August 1977. This event covered an area of 560 km^2 and lasted 20 days, causing a mass mortality of fish, resulting in great losses to the local fishery (Hua 1989). With increased awareness of the issue and economic development along the coast of China, HAB numbers have increased dramatically each year. Figure 12 shows coastal seas in China where HABs can occur. Figure 13 demonstrates the increase in number of HAB occurrences during recent decades. It is clear that HABs have been increasing rapidly along the Chinese coast since the 1970s, and that they occur more frequently along the south coast than along the north coast. Thus, at least 322 documented HAB events have occurred from 1952-1998 in Mainland China. An average of more than 10M RMB (1.2M US$) economic loss related to HAB occurrences has been suffered each year. The main areas of HAB occurrences are the Bohai Sea, Changjiang Estuary and the South China Sea. The HAB seasons are apparently delayed from the south to the north coast, which peak in March- May in the South China Sea, June-August in the East China Sea, and July-September in Bohai Sea and Yellow Sea.

Table 4 lists 27 major and recent HAB events in China (event locations are also shown in Figure 12). These HAB events have resulted in great damage to local fisheries, the mariculture industry, and/or human health. In each of three successive years from 1998, large HAB events on the scale of several thousand square kilometers, occurred in the Bohai Sea, East China Sea or South China Sea. This increase in HAB frequency, scale and economic loss in China is drawing great attention from the government and the public.

Fig. 12 Sites of major HAB occurrences and sites of shellfish sampling for toxin analysis in the coastal seas of China. Sites are described in more detail in Table 4.

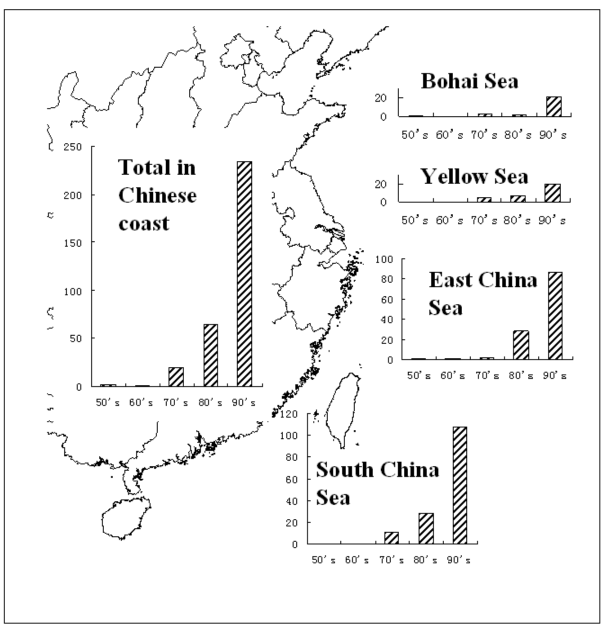

Fig. 13 HAB events reported in the coastal seas of China during each decade from 1952-1998.

As one of the areas of most frequent HAB occurrence, Hong Kong first began its reporting of HAB events in the early 1970s. In 1983, Lam and Ho (1989) pointed out that the increasing frequency of HABs and related fish-killing events in Hong Kong were thought to be correlated with increased urbanization of that region. From 1980-1997, 496 HAB events were recorded in Hong Kong waters (AFD 1997). According to the record, the area of most frequent HAB occurrence in Hong Kong was at Tolo Harbour (which experienced more than 70% of the total HAB events), Mirs Bay and Port shelter (which are all located at north-east of Hong Kong). In Hong Kong, 70% of the HABs occurred between December and May.

In Taiwan, *Alexandrium minutum* has been a main causative HAB species. Blooms of this species were first recorded in a crab culture pond in Pintoung County in November 1986. Since the late 1980s, blooms of this species have caused mass mortality of cultured fish and grass prawn and PSP contamination of shellfish, as well as frequent intoxication of humans in Taiwan (Zhou 1999; Su *et al.* 1993). The species was classified as *Gonyaulax tamarensis*, also known as *A. tamarense* in the early literature (Zhou 1999).

Toxin distribution and poisoning events in China

Several studies on PSP (Paralytic Shellfish Poisoning) toxins in shellfish and its causative organisms have been focused in Guangdong, Hong Kong, Taiwan, and in southern coast regions of China (Lam *et al.* 1989b; Lin *et al.* 1994; Anderson *et al.* 1996; Zhou 1999; Jiang *et al.* 2000). In Hong Kong, PSP toxins were first detected in shellfish samples in Tolo Harbour in 1985 (Lam *et al.* 1989b). PSP toxins in marine products from Hong Kong showed two peaks with the main peak occurring in the spring and the other in fall (Chan and Young 1999). However, not until a recent investigation of PSP and DSP (Diarrhetic Shellfish Poisoning) toxins along the Chinese coast (sample sites are shown in Figure 12), was it found that these toxins were distributed widely along both the northern and southern coasts of China (Zhou *et al.* 1999). This investigation also indicated that DSP toxins were more frequently detected than PSP toxins. The frequency of occurrence and levels of PSP toxins along the southern coast were higher than those along the northern coast. In March 1990, extremely high PSP toxicity (>20,000 MU/kg) was detected in shellfish samples collected in Tai Tam Bay, southeast of Hong Kong, due to a bloom of *A. catenella* (Ho and Hodgkiss 1993). The highest level of DSP (10 μg/g) in China was found in blue mussel collected on October 2, 1998, in Liaodong Bay (Juhua Island) during a bloom of *Ceratium furca* and *Dinophysis fortii* (Zhao 2000). The distribution of PSP and DSP toxins along the Chinese coast is shown in Table 5.

Table 3 Early record of HAB events in China.

Year	Site	Species	Reference
1933	Zhenhai to Taizhou-Shipu along Zhejiang Coast	*Noctiluca scintillans* *Skeletonema costatum*	Fei, 1952
1952	Yellow River Estuary, 1460 km^2	*Noctiluca scintillans*	Fei, 1952
1962	Pingtan Island sea area along Fujian Coast	*Trichodesmium* sp.	Zhou, 1962
1971	Hong Kong coast	*Noctiluca scintillans*	Morton & Twentyman, 1971
1972	Exterior sea area of Changjiang Estuary	*Trichodesmium* sp.	Chen, 1972

Table 4 Main HAB events in the last 20 years in China. The number in parentheses under Area indicates its location in Figure 12.

Sea	Area	Time	Extent	Species	Damage/ Loss
Bohai Sea	(1) Huanghua coast, Hebei	Aug.-Sept., 1989	1300 km^2	*Gymnodinium* sp.	Economic loss was about 200M RMB (25M US$)
	(2) Bohai Sea	Sept.-Oct., 1998	5000 km^2	*Ceratium furca*	Economic loss 500M RMB
	(2) Sishili Bay, Yantai	Aug.-Sept., 1998	100 km^2	*Gymnodinium sanguineum*	large amount of marine organisms, 30M RMB loss
	(2) Bohai Sea	July, 1999	6300 km^2	*Noctiluca scintillans*	
	(3) Liaodong Bay	July, 2000	350-850 km^2		About 100M Jellyfish died
	(4) Liaoning Coast	Aug., 2000	1000 km^2		
East China Sea	(5) Exterior sea area of Changjiang Estuary	June–July, 1987	1000 km^2	*Skeletonema costatum*	Marine ecosystem was affected seriously
		June, 1988	1400 km^2	*Noctiluca scintillans*	Marine ecosystem was damaged seriously
		July, 1989	1700 km^2	*Noctiluca scintillans*	Marine ecosystem was damaged seriously
	(6) Gouqi sea area of Zhejiang	Aug., 1987	large area	*Noctiluca scintillans*	A large amount of bay scallop and abalone, also mussels died
	(7) East coast of Zhejiang	May, 1990	7000 km^2		fish, shrimp, and shellfish affected
	(8) Weitou Bay to Quanzhou Bay in Fujian	mid June, 1990		*Cochlodinium* sp.	Large amount of fish and clams died. 600M RMB
	(9) Changjiang Estuary and Hangzhou Bay	1998	Large area		

Sea	Area	Time	Extent	Species	Damage/ Loss
	(11) Zhoushan Area, Zhejiang	May, 2000	7000 km^2	*Prorocentrum* sp.	
South China Sea	(12) Inland bay of Zhanjiang Harbour, Guangdong	May 1980		*Guinardia flaccida*	fish died, resulting in reduction of fish mariculture output
	(13) Tolo Harbour in Hong Kong	Sept., 1980			Resulted in the death of fish and invertebrates, and also affected tourism in this area
	(14) Sansha sea area of Mindong, Fujian	Sept., 1981		*Noctiluca scintillans*	Cultured oysters and kelp were influenced
	(15) Dapeng Bay and Daya Bay, Guangdong	April, 1983		*Rhizosolenia Alata* f. *Gracillima*	A large loss of fish, shrimp, and shellfish. In one county alone, Gaoyang, 75 tons fish died.
	(13) Hong Kong sea area	summer, 1987		*A. polygramma*	Large sea area, dead fish reached 120 tons and economical loss was 24 thousands Pounds
	(13) Hong Kong sea area	March, 1989		*A. catenella*	Market sales of shellfish were suspended for two weeks
	(16) Tainan county, Taiwan	June, 1989		*A. minutum*	Mass mortality of grass prawn
	(17) Chiayi county, Taiwan	Feb., 1991		*A. minutum*	136 human poisonings, 2 deaths
	(15) Yantian Sea area of Dapeng Bay	March 20, 1991		*Chattonella marina*	Large amount of fish and fish fry were killed
	(14) + (15) Quanzhou Bay in Fujian to Shanwei in Guangdong	Nov.-Dec., 1997	some thousand km^2	*Phaeocystis pouchetii*	180M RMB
	(13)+(15) Hong Kong and Guangdong Waters	March-April, 1998	Large area	*Gymnodinium* sp.	Fish fry and cultured fish affected, economic loss reached 100M HK$
	(15) Daya Bay, Guangdong	August, 2000	20 km^2	*Scrippsiella trochoidea Peridinium quinquecorne*	Fish death, economic loss About 1M RMB.

Table 5 PSP and DSP distribution along the Chinese coast. Sampling sites are indicated in Figure 12.

Sampling site	PSP	DSP	Sampling site	PSP	DPS
Tianjin (TJ)	-	+	Zhoushan(ZS)	+	+
Yantai (YT)	+	+	Shengzhen(SZ)	-	+
Qingdao (QD)	-	+	Guangdong	+	
Rizhao (RZ)	-	-	Hong Kong	+	+
Lianyungang (LYG)	+	+	Taiwan	+	

\+ detected - not detected

Table 6 summarizes records of shellfish poisoning events in China, in which more than 1,800 people were affected and 31 people died (Zhou, M. *et al.* 1999; Zhou, H. *et al.* 1999). Several illnesses are suspected to have been due to the consumption of DSP toxin-contaminated marine products in 1995 (Qian and Liang 1995). Ciguatera Fish Poisoning (CFP) is also a frequent algal toxin problem in the Hong Kong area. More than 200 documented CFP poisoning events have occurred in Hong Kong since 1989, resulting in more than 1,000 people being intoxicated. Although most of these CFP incidents were due to the consumption of imported coral reef fish, the causative HAB species *Gambierdiscus toxicus* has also been found recently in local waters (Lu and Hodgkiss 1999). Similar to Hong Kong, PSP and CFP toxins are the most frequently measured algal toxins in shellfish in Taiwan (Zhou, H. *et al.* 1999). A summary of PSP, DSP, CFP events, animal and plant mortalities over the past decade (1990-2000) appears in Appendix CH.

Causative HAB organisms

Table 7 summarizes 148 HAB species that have been found in China thus far, of which 44 have caused HAB events. Among these 44 species, 28 are known to be toxic (Qi *et al.* 1993; Zou 1992; Zhu *et al.* 1997). The most common species include *Noctiluca scintillans, Prorocentrum minimum, P. mians, Alexandrium tamarense, Gonyaulax polyedra, Skeletonema costatum, Mesodinium rubrum, Trichodesmium* sp., and *Chattonella marina*. Twenty two species of dinoflagellate cysts have been found in samples collected from the East and South China Seas, including cysts from *A. tamarense*, *Cochlodinium sp.*, *Diplopelta parva*, *Gonyaulax grindleyi*, *G. spinifera*, *G. scrippsae*, *Gymnodinium calenatum*, *Gymnodinium sp.*, *Lingulodinium polyedra*, *Pheopolykrikos hartmanii*, *Polykikos kofoidii*, *P. schwartzii*, *Protoperidinium americanum*, *P. cf. avellana*, *P. claudicans*, *P. conicum*, *P. conicoides*, *P. oblongum*, *P. subinerme*, *Pyrophacus steinü*, *Scrippsiella precaria* and *S. trochoidea* (Qi *et al.* 1996). Table 7 shows that more dinoflagellates are distributed along the southern than the northern coast, while harmful diatoms are distributed evenly in both southern and northern coastal waters.

At least 58 HAB species are found in Hong Kong. Here, the main HAB species are *N. scintillans*, *S. costatum*, *G. polygramma*, *P. triestinum*, *P. minimum*, *C. furca*, *M. rubrum*, *G. splendens*, *P. sigmoidens, P. triquetra,* and *L. minimus* (AFD 1997). Hong Kong is also considered to be a vulnerable area for importation of foreign HAB species because it is such an internationally important marine transportation center. Several species of dinoflagellate cysts were found in ballast waters arriving from Aukland and California (Zhang and Dickman 1999).

HAB research, management and collaboration in China

HAB research in China covers the following areas: biology and taxonomy; nutrient dynamics and physio-ecological characteristics; life history; toxicity; dynamics of occurrence and disappearance processes; statistical models, and HAB prevention and treatment (Lin 1997; Zhang 1994; Zhu and Li 1995). About 30 projects on HAB and algal toxins have been sponsored by various national or local concerned government bodies in Mainland China since 1978. It is clear that the efforts on HAB research by government agencies and concerned scientists are steadily increasing.

A National Project of HAB in China called CEOHAB (Ecology and Oceanology of HAB in China), was approved in October 2001. The project is called the "973 key project" and has funding of 28 MRMB (3.5 million US$) for the five years, beginning in April 2002. Integrated and multidisciplinary biological, chemical and physical oceanographic research will be initiated in order to understand the mechanism of large-scale HAB events in coastal areas, to provide scientific basis for "prevention, control and treatment of HABs", and to allow the sustainable development of the marine economy in China.

Table 6 Shellfish poisoning events in China.

Time	Province	Toxin	Poisoned	Died	Shellfish	Algae
1956	Taiwan			1?	Oyster	ND
1967-1979	Zhejiang	PSP	423	23	*Nussarius succinstus*	ND
1986	Taiwan	PSP	50	2	*Soletellina diphos*	*A. minutum*
1986.11	Fujian	PSP?	136	1	*Ruditapes phillipenensis*	*Gymnodinium* sp (?)
1989.2	Guangdong	PSP	5	--	*Pinna pectinata*	ND
1989.11	Fujiang	PSP?	4	1	*Nussarius succinstus*	ND
1991.2	Taiwan	PSP	8	--	*Soletellina diphos*	*A. minutum*
1991.3	Guangdong	PSP?	4	2	*Perna viridis*	ND
1994.6	Zhejiang	PSP?	5	1	*Nussarius succinstus*	ND
1989-1999	Hong Kong	CFP	1000		Coral reef fish	ND
1992	Hong Kong	?	Several		Shellfish from Mirs Bay	ND
1995	Hong Kong	DSP?	Several		Marine products	ND

ND: not detected

Table 7 HAB organisms of coastal China.

Have Formed HAB	Toxic	Species	Distribution: Yellow & Bohai Sea	Distribution: East China Sea	Distribution: South China Sea
		Dinophyceae			
	■	*Amphidinium carterae* Hulburt			+
	■	*A. operculatum* Claparede & Lachmann =*A. klebsii* Kofoid & Swezy	+		+
■		*Alexandrium affine* (Inoue & Fukuyo) Balech		+	+
■	■	*A. catenella* (Whedon & Kofoid) Balech			+
		A. cohorticula (Balech) Balech			+
		A. fraterculus (Balech)Balech			+
		A. leei (Balech) Balech			+
■	■	*A. minutum* Halim			+
		A. tropicale Balech=*A. excavata* (Braarud)			+
■	■	*A. tamarense* (Lebour) Balech	+	+	+
		Ceratium breve (Ost. & Schm.) Schroder			+
		C. deflexum (Kofoid) Jorg.			+
		C. furca (Ehrenberg) Claparede & Lachmann	+	+	+
		C. fusus (Ehrenberg) Dujardin	+		+
		C. humile Jorg			+
		C. massiliense (Gourret) Jorgensen			+
		C. trichoceros (Ehrenberg) Kofoid			+
		C. tripos (O. F. Mueller) Nitzsch	+	+	+
		Cochlodinium helicoides Lebour			+
		Cochlodinium sp.			+
■	■	*C. polykrikoides* Margelef			+
	■	*Dinophysis acuminata* Claparede & Lachmann	+	+	+

		D. acuta Ehrenberg	+		
Have Formed HAB	Toxic	Species	Distribution		
			Yellow & Bohai Sea	East China Sea	South China Sea
		D. caudata Saville-Kent	+		+
		D. fortii Pavillard	+		+
		D. miatra (Schutt) Abe			+
		D. ratrndatum Claparede & Lachmann			+
		Exuviaella Baltice Lachmann			+
		Gambierdiscus toxicus Adachi & Fukuyo			+
		Gonyaulax digitale (Pouchet) Kofoid	+	+	+
		G. polygramma Stein	+		+
		G. spinifera (Claparede & Lachmann) Diesing	+	+	+
		G. verior Sournia			+
		Gymnodinium breve Davis		+	+
		G. catenatum Graham		+	+
		G. mikimoloi Miyake & Kominami ex Oda =*G. Nagasakiense* Takayama & Adachi		+	+
		G. sanguineum Hirasaka=*G. splendens* Lebour	+	+	+
		G. simplex (Lohmann) Kofoid & Swezy			+
		Gymnodinium sp.	+	+	+
		Gyrodinium aureolum Hulburt			+
		G. dominans Hulburt			+
		G. falcatum Kofold & Swezy			+
		G. fissum (Levander) Kofoid & Swezy	+	+	+
		G. resplendens Hulburt			+
		G. spirale (Bergh) Kofoid & Swezy		+	+
		G. instriatum Freudenthal & Lee			+
		Lingulodinium polyedrum (Stein) Dodge =*Gonyaulax polyedra* Stein		+	+
		Noctiluca scintillans (Macartney) Kofoid & Swezy	+	+	+
		Ostreopsis siamensis Schmidt			+
		Oxyrrhis marina Dujardin			+
		Polykrikos schwartzii Buetschli			+
		Prorocentrum balticum (Lohmann) Locblich , Sherley&Schmidt			+
		P. dentatum Stein	+		+
		P. gracile Schutt			+
		P. lima Dodge		+	+
		P. mexicanum Tafall =*P. rhathymum* Loeblich			+
		P. micans Ehrenberg	+	+	+
		P. minimum (Pavillard) Schiller	+		+
		P. sigmoides Boehm			+
		P. triestinum Schiller	+	+	+
		P. conicum (Gran) Balech	+	+	+
		P. divergens (Ehernberg) Balech	+	+	+
		Protoperidinium depressum (Bailey) Balech	+	+	+
		P. pellucidum Bergh			+
		P. quinquecorne Abe			+
		P. triquetrum Ehrenberg			+
		Pyrodinium bahamense var. *Compressum* (Boehm) Steidinger			+
		Pyrophacus horologium Stein			+
		Pyrophacus horologium v. Steinii Schiller			+
		Pyrocystis fusiiformis Murray			+

		Scrippsiella trochoidea (Stein) Loeblich	+	+	+

Have Formed HAB	Toxic	Species	Distribution		
			Yellow & Bohai Sea	East China Sea	South China Sea
Bacillariphyta					
		Asterionella glacialis (Castracane) F. E. Round	+	+	+
		A. kariana (Grunow) Round	+		
		Bacillaria paxillifera (O. F. Muller) Hendey	+		
		=*Nitzschia paradoxa* (J. F. Gmelin) Grunow in Cleve & Grunow	+	+	+
		Bellerochea malleus (Brightwell) Van Heurck emend. Von Stosch		+	+
		Cerataulina pelagica (Cleve) Hendy =*Cerataulina bergonii* (H. Peragallo) Schuett			+
		Chaetoceros affinis Lauder	+	+	+
		C. atlanticus Cleve			+
		C. compressus Lauder	+	+	
		C. curvisetus Cleve	+	+	+
		C. danicus Cleve	+	+	+
		C. dentiuelus Lauder			+
		C. debilis Cleve	+	+	+
		C. diadema (Ehernberg) Gran	+	+	
		C. didymus Ehrenberg	+	+	+
		C. laciniosus Schutt	+	+	+
		C. lorenzianus Grunow	+	+	+
		C. peruvianus Brightwell	+	+	+
		C. pseudocurvisetus Mangin	+	+	+
		C. siamense Ostenfeld	+	+	
		C. socialis Lauder	+		+
		Coscinodiscus asteromphalus Ehrenberg	+	+	
		C. centralis Ehrenberg	+		
		C. gigas Ehrenberg			+
		C. granii Gough	+	+	+
		C. jonesianus (Greville) Ostenfeld	+		+
		C. radiatus Ehrenberg	+		
		C. wailesii Gran & Angst	+		+
		Cyclotella cryptica Reimann, Lewin & Guillard			+
		Cylindrotheca closterium (Ehrenberg) Lewin& Reimann	+	+	
		C. striata (Kuetzing) Grunow in Cleve & Grunow	+	+	
		Cyclotella sp.	+	+	+
		Ditylum brightwellii (West) Grunow & Van Heurck	+	+	+
		Eucampia zodiacus Ehrenberg	+	+	+
		Guinardia flaccida (Castracane) Peragallo	+	+	+
		Lauderia annulata Cleve=*Lauderia borealis* Gran	+	+	+
		Leptocylindrus danicus Cleve	+	+	+
		L. minimus Gran			+
		Lithodesmium variabile Takano			+
		Melosira nummuloides C. A. Agardh			+
		Nitzschia longissima (Brebisson, in Kuetzing) Ralfs in Pritchard	+	+	+
		Odontella aurita (Lyngbye) C. A. Agardh	+	+	
		O. mobiliensis (Bailey) Grunow	+	+	
		O. sicensis (Greville) Grunow	+	+	
		Paralia sulcata (Ehrenberg) Cleve =*Melosira sulcata* (Ehrenberg) Kuetzing	+	+	+

Have Formed HAB	Toxic	Species	Distribution: Yellow & Bohai Sea	East China Sea	South China Sea
■		*Pseudo-nitzschia pungens* (Grunow ex Cleve) Hasle =*Nitzschia pungens* Grunow ex Cleve	+	+	+
		P. delicatissima (Cleve) Heiden in Heiden & Kolbe	+	+	
		P. seriata (Cleve) H. Peragallo in H. & M. Peragallo f. Seriata		+	+
		Proboscia alata (Brightwell) Sundstrom =*Rhizosolenia alata* Brightwell	+	+	+
		Pseudosolenia calcar avis (Schultze) Sundstroem =*Rhizosolenia calcar-avis* Schultze	+	+	+
■		*Guinardia delicatula* (Cleve) Hasle =*Rhizosolenia delicatula* Cleve	+	+	+
■		*Guinardia striata* (stolterfoth) Hasle =*Eucampia striata* Stolterfoth =*R. stolterfoth* H. Peragallo	+	+	+
■		*Dactyliosolen fragilissimus* (Bergon) Hasle =*Rhizosolenia fragilissima* Bergon	+	+	+
■		*Rhizosolenia alata* f. Grocillima Cleve	+	+	+
		R. alata f. indica (Peragallo) Ostenfeld	+	+	
		R. hebetata f. semispina (Hensen) Gran	+		+
		R. setigera Brightwell	+	+	+
		R. styliformis Brightwell	+	+	+
■		*Skeletonema costatum* (Greville) Cleve	+	+	+
		Stephanopyxis palmeriana (Greville) Grunow	+	+	+
		Thalassionema nitzschioides (Grunow) Mereschkowsky	+	+	+
■		*Thalassiosira mala* Takano	+	+	+
		T. nordenskioeldii Cleve	+	+	+
		T. pacifica Gran & Angst		+	
		T. rotula Meunier		+	+
		T. subtilis (Ostenfeld) Gran	+	+	+
		Thalassiothrix frauenfeldii (Grunow) Hallegraeff	+		+
		Cyanobacteria			
■		*Trichodesmium erythraeum* Ehrenberg	+	+	+
		T. thiebautii Gomont		+	+
		Chrysophyceae			
■		*Dictyocha fibula* Ehrenberg	+	+	+
■		*Distephanus speculum* (Ehrenberg) Haeckel		+	+
		Ebria tripartita (Schumann) Lemmermann			+
■	■	*Phaeocystis poucheti* (Hariot) Lagerheim			+
		Raphidophytes			
■	■	*Chattonella marina* (Subrahmanyan) Hara & Chihara			+
		Chattonella sp.			+
■	■	*Heterosigma carterae* (Hulburt) Taylor	+	+	+
		Cryptomonadaceae			
■		*Cryptomonas* sp.	+		+
		Chlorophyceae			
		Nephroselmis sp.			+
		Carteria sp.			+
		Protozoa`			
■		*Mesodinium rubrum* Lohmann	+	+	+

In terms of HAB management, environmental monitoring systems were establihsed in China by the State Oceanic Administration and Ministry of Agriculture and Fisheries in 1984 and 1990.

A specific program for HAB monitoring along the Chinese coast, sponsored by the State Oceanic Administration, was initiated in 2001. To address the issue of treatment and mitigation of HABs, a method using modified clay to coagulate HAB organisms has been developed. Development of this process started in the early 1990s, and primarily involves: coagulation of clays with HAB organisms, studies of clay surface modification and preparation methods; kinetic studies of clay particles coagulating HAB organisms, and assessment of environmental impacts of clays on marine ecosystems (Yu *et al.* 1998).

Recently, a China Harmful Algal Bloom WebPage was set up at http://www.china-hab.ac.cn. This C-HAB WebPage contains various sub-areas including FAQ (Frequently Asked Questions), Occurrences, Species, Research, Coordination, Reporting and Links. It is designed to provide basic knowledge to the public, to summarize the main HAB occurrences in China, to describe the main HAB species involved, to introduce research activities in China, and to provide links to related international web sites and projects. Recent HAB occurrences in China will be reported in a timely manner via this web site. The "C-HAB" WebPage has both Chinese and English versions.

Chinese scientists are active in many collaborative international HAB programs, such as IOC (Intergovernmental Oceanographic Commission) Harmful Algal Bloom Program and the APEC (Asian-Pacific Economic Cooperation) Red Tide/Toxic Algae Management project. In addition, the China SCOR (Scientific Committee on Oceanic Research)-IOC HAB workshop was convened in 1992. China is also participating in programs such as GEOHAB (Global Ecology of Harmful Algal Blooms) and PICES Working Group 15 (Ecology of harmful algal blooms in the North Pacific).

Discussion

The seas around China cover a large area of about 3,000,000 km^2. At the present time, however, Mainland China, Hong Kong and Taiwan each utilize different systems for monitoring HABs. Therefore, in the greater China region, there are differences in monitoring methods and frequency as well as in defining HAB events. Such variations might help to explain the big difference in reports of HAB frequency between Mainland China and Hong Kong, in which the number of HABs in Mainland China was 322 from 1952-1998, whereas Hong Kong reported 496 HABs from 1980-1997. During 1980-1998, 67 HAB events were reported from the South China Sea. Among them, 24 took place in both Guangdong and Hong Kong, including the serious "Hong Kong'98" (Hodgkiss *et al.* 2000). Because Hong Kong shares much of the same coastline, e.g., Mirs Bay (Dapeng Bay), with Guangdong Province, and Taiwan likewise shares the Taiwan Strait with Fujian Province, it is crucial for all areas to coordinate their various regional HAB studies. This will allow scientists in the greater China region to better understand HAB mechanisms and to further develop and set up common and efficient HAB alarm systems. It is heartening to see Hong Kong and Mainland China progressing so quickly toward cooperation in this area, through symposia and similar joint projects. China also shares common sea areas with Korea, Japan, Vietnam, Philippines etc. Therefore, international coordination should be strengthened for better understanding of this oceanographic and ecological problem.

For the future study of HABs, China will link its programs more closely with GEOHAB. On the other hand, because China has the largest mariculture operation in the world, we recommend future research efforts on the relationship between mariculture activity and HAB occurrences in key coastal areas, in order to better foster and maintain the sustainable development of both mariculture operations and healthy marine ecosystems along the Chinese coast.

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Appendix CH

SUMMARY SHEET 1

Country Name: **P.R. China**

Country Information:

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CFP Events from 1990 to 2000

Location Name	Section No.	Latitude	Longitude	ASP	DSP	PSP	NSP	Ciguatera	Animal/ Plant Mortalities	Comments
Hong Kong	9	114°	22°10'							More than 200 CFP events happened in HK resulted 1,000 people poisoned.(Lv, 1999), Mostly caused by imported fish.

SUMMARY SHEET 2

Country Name: P.R. China

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DSP events from 1990 to 2000

Location Name	Section No.	Latitude	Longitude	ASP	DSP	PSP	NSP	Ciguatera	Animal/Plant Mortalities	Comments
										DSP unit: micro g /100g wt,
East coast of Liaodong Bay	1	120°40'-121°50'	40°-41°		max1000					1998. 9.29-10.2, bivalves (Zhao 2000)
Tianjin	2	117°30'	39°		30.43					1996.9.5, scallop *Chlamys fareri*
Qingdao	4	120°20'	36°		54.29					1997.3.25, *Venerupis philippinarum*
Zhoushan	5	122°	30°		29.71					1996.8.5, scallop *Chlamys farreri* and *Mytilus edulis*
Shenzhen	9	114°	22°40'		22.14					1997.7.3, *Mytilus edulis*
Shenzhen	9	114°	22°40'		84.57					1997.8.3, *Mytilus edulis*
Hong Kong	9	114°	22°10'							1992, several illness from eating shellfishh from Mirs Bay
Hong Kong	9	114°	22°10'							1995, several illness from marine products

SUMMARY SHEET 3

Country Name: **P.R. China**

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Animal and Plant Mortality Events from 1990 to 2000

Location Name	Section No.	Latitude	Longitude	ASP	DSP	PSP	NSP	Ciguatera	Animal/Plant Mortalities	Comments
Liaodong Bay, Bohai Bay and Laizhou Bay	1,2,3	118-121°	37°30'-40°30'						maricultured shrimp and shellfish affacted by *Ceratium furca*	1998.9.16-10.19
and Laizhou Bay										
Tianjin and Huanghua	2	118°10'	38°21'						100 million jellyfish were killed	2000/07/20-21
Yantai	3	121°30'-122°	37°30'-40°30'						scallop, seacucumber, abalone and benthic fish killed by *Gymnodinium sanguineum*	1998.08
East coast of Zhejiang	5	122°	28°25'						fish and shellfish were killed	1990.5
Xiamen	7	118°08'	24°30'						fish killed by chae ….	1997
Weitou Bay to Quanzhou Bay	7	24°3-25°10	118°30-118°50						fish and clam died from *Cochlodinium* sp.	1990 mid June
Xiamen	7	118°08'	24°30'						shrimp killed by *Alexandrium tamarense*	1994
Quanzhou to Shanwei	7, 8	22°50'-25°10'	115°20'-118°50'						fish killed by *Phaeocystis pouchetii*	1997
Raoping	8	117°10'	23°40'						fish killed *Phaeocystis pouchetii*	1999
Dapeng Bay	9	114°10'	22°40'						fish killed by *Chattonella marina*	1991.3.2
Pearl River Estuary, HK,	9	112°-114°20'	21°30'-22°20'						fish killed by *Karenia mikimotoi*	1998.3-4
Daya Bay	9	114°40'	22°30'						fish kill by *Chaetoceros* spp.	

Location Name	Section No.	Latitude	Longitude	ASP	DSP	PSP	NSP	Ciguatera	Animal/Plant Mortalities	Comments
Daya Bay	9	114°40'	22°30'						fish kill by *G. mikimotoi*	1998.5
Shenzhen Bay	9	114°	22°40'						fish kill by *G. intriatum* and *Phaeopolykrikos harmanii*	
Shengzhen-Huiyang	9	114°40'-115°	22°20'						fish killed by *Srippsiella trochoidea*	2000.8.17-20
Daya Bay	9	114°40'	22°30'						fish killl by *Srippsiella trochoidea, Peridinium quinquecorne*	2000.9.3-6
Pingdong, Taiwan	10	120°20'	22°30'						cultured-fish were killed by *A. minutum*	1992/06
Pingdong, Taiwan	10	120°20'	22°30'						cultured-fish were killed by *A. minutum*	1992/12
Pingdong, Taiwan	10	120°20'	22°30'						cultured-fish were killed by *A. minutum*	1993/03
Pingdong, Taiwan	10	120°20'	22°30'						cultured-fish were killed by *A. minutum*	1995/03
Pingdong, Taiwan	10	120°20'	22°30'						cultured *Hiatula* sp.contain toxins	1996/06
Pingdong, Taiwan	10	120°20'	22°30'						cultured-fish were killed by *A. minutum*	1997/01
Pingdong, Taiwan	10	120°20'	22°30'						cultured-fish were killed by *A. minutum*	1997/03
Pingdong, Taiwan	10	120°20'	22°30'						cultured-fish were killed by *A. minutum*	1997/04
Pingdong, Taiwan	10	120°20'	22°30'						cultured-fish were killed by *A. minutum*	1997/02
Kaohsung, Taiwan	10	120°10'	22°30'						cultured-fish were killed by *A. minutum*	1997/05
Kaohsung, Taiwan	10	120°10'	22°30'						cultured-fish were killed by *A. minutum*	1997/04
Kaohsung, Taiwan	10	120°10'	22°30'						cultured-fish were killed by *A. minutum*	1997/05
Kaohsung, Taiwan	10	120°10'	22°30'						cultured-fish were killed by *A. minutum*	1997/12
Kaohsung, Taiwan	10	120°10'	22°30'						cultured-fish were killed by *A. minutum*	1998/01

SUMMARY SHEET 4

Country Name: **P.R.China**

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PSP Events from 1990 to 2000

Location Name	Section number	Latitude	Longitude	ASP	DSP	PSP	NSP	Ciguatera	Animal/Plant Mortalities	Comments
Yantai	3	121°10'	37°30'			133				1997.9.22, scallop *Chlamys farreri* (Zhou et al. 1999)
Zhejiang	6									1994, five poisoned and one died, *Nussarius succinstus*
TaiTam Bay, HK	9	114°20'	22°10'			max>400,000				1990.3, shellfish (Ho&Hodgkiss 1993)
Mirs Bay, HK	9	114°10'	22°40'			8000 0				1990.4, shellfish (Ho&Hodgkiss 1993)
Dapeng Bay	9	114°10'	22°40'			300				1990, spring, scallop (Lin et al. 1993)
Dapeng Bay	9	114°10'	22°40'			120				1990, autumn, scallop (Lin et al. 1993)
Dapeng Bay	9	114°10'	22°40'			120				1991, spring, scallop and mussel, four were poisoned and two were killed on March 28 (Lin et al. 1993)
Dapeng Bay	9	114°10'	22°40'			100				1991,autum, scallop (Lin et al. 1993)
Daya Bay	9	114°10'	22°30'			514				1991, spring, scallop and mussel (Lin et al. 1993)
Hong Kong	9	114°10'	22°20'			320				1996.9.17, scallop *Chlamys nobilis* (Zhou et al. 1999)
Daya Bay	9	114°10'	22°30'			2340				1999.1, visceral of scallop *Chlamys nobilis* and *Perna viridis* (Jiang et al. 2000)
Dapeng Bay	9	114°10'	22°40'			174				1999.1, visceral of scallop *Chlamys nobilis* (Jiang et al. 2000)
Taiwan	10	120°20'	22°30'			9800/visceral, 600/other tissue				1991.2, *A. minutum, Hiatula* sp., eight were poisoned