Can large scale of *Karenia* blooms in China coastal waters be linked to climate (weather) signals?

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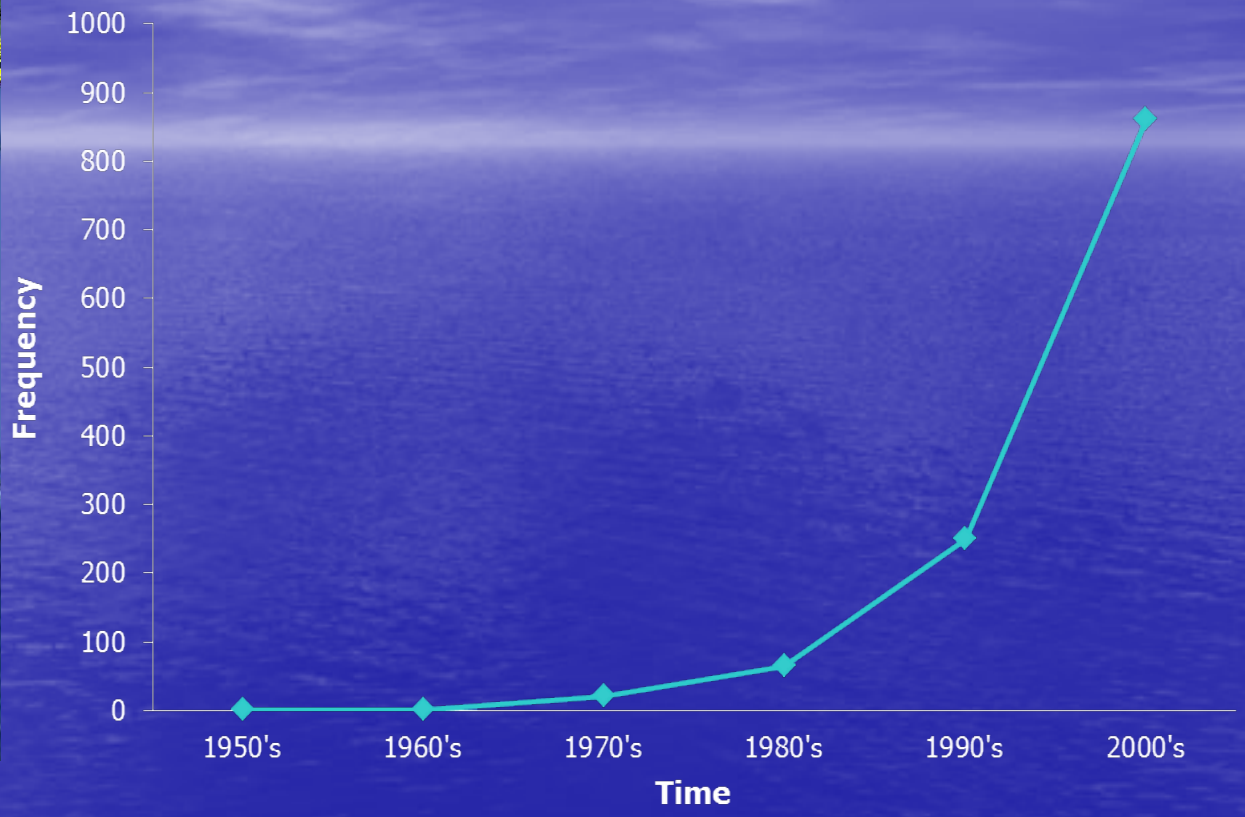
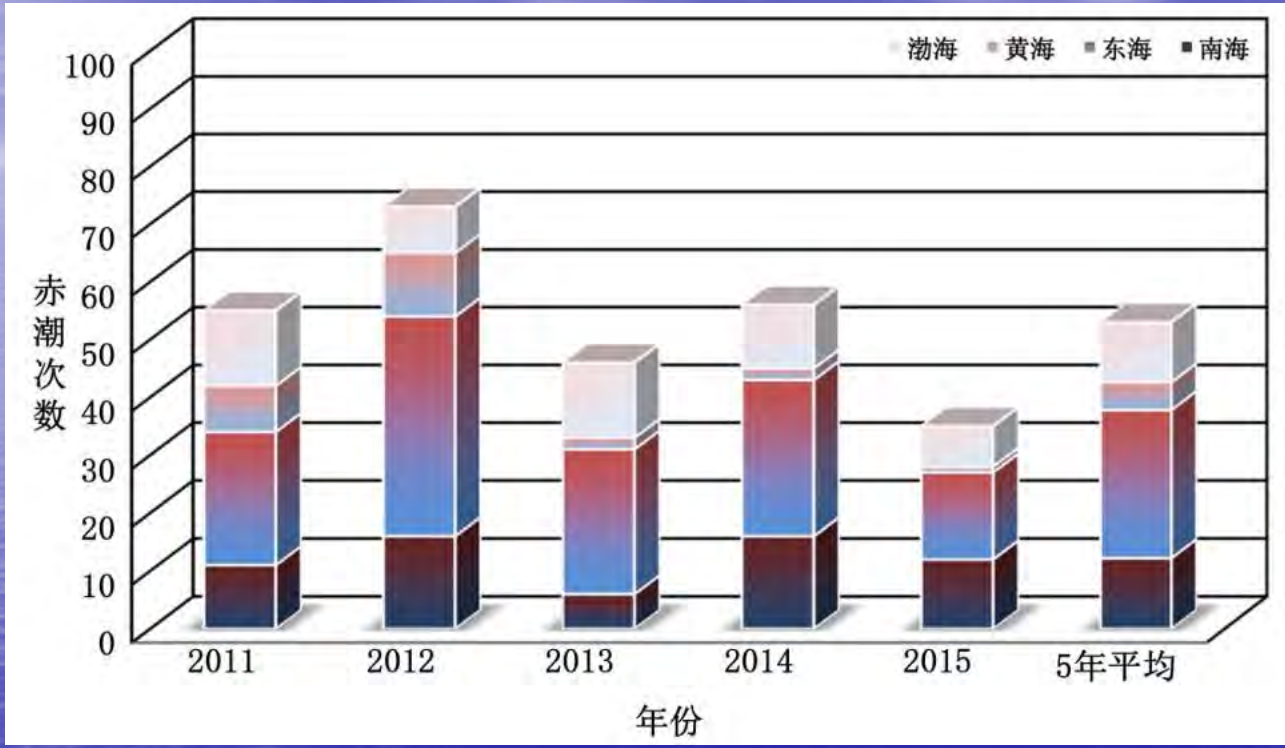
Points:

- **General Apparent trend of HABs in China**
- **Shift of causative species**
- **Large scale of Karenia blooms events**
- **Possible links**
- **Summary**

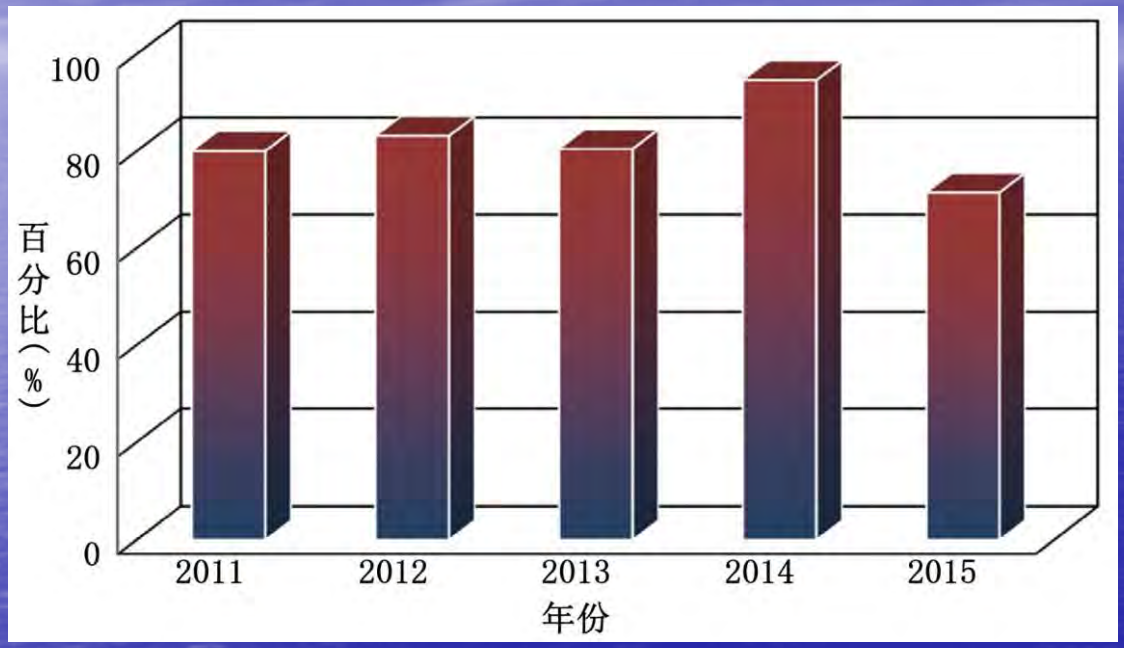


Frequency of HAB incidences in the last decades in Chinese coastal waters

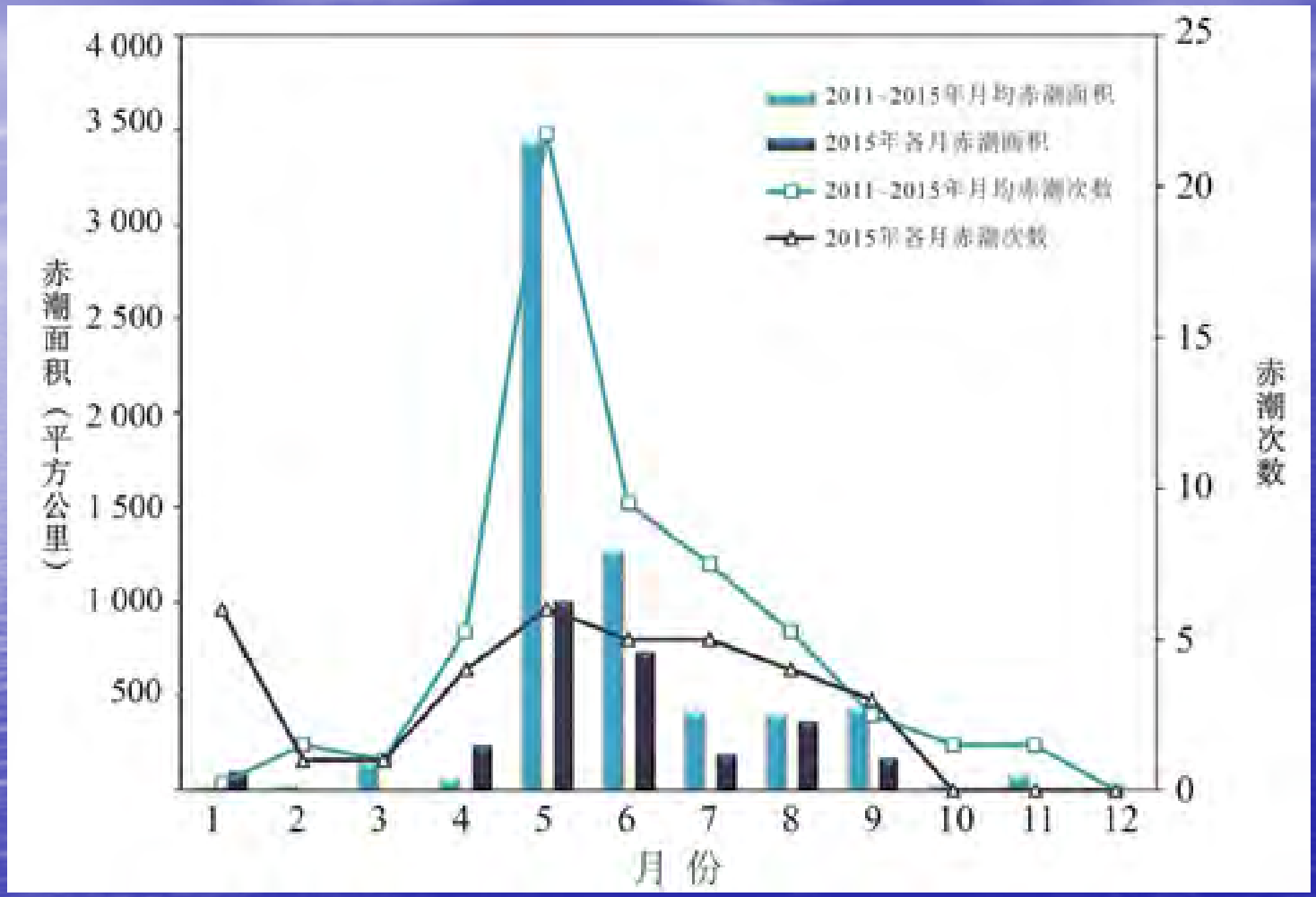
Lu et al. 2014. Algological studies



Bloom frequency in the coastal waters of China
2011~2015



Bloom proportion of dinos and other flagellates 2011~2015



Seasonal pattern of HABs frequency and coverage (km^2) from 2011~2015 in CHINA

Occurrence of HABs in China (2016)

2016年我国各海域发现赤潮情况统计见表10。

表10　2016年我国各海域发现赤潮情况统计

发现海域	发现赤潮次数	累计面积（平方千米）
渤海海域	10	740
黄海海域	4	62
东海海域	37	5 714
南海海域	17	968
合计	68	7 484

（http://www.soa.gov.cn/）

List of HAB species in Chinese coastal waters

Dinoflagellates	
Alexandrium catenella (Whedon et Kofoid) Balech	*Karlodinium veneficum* (D. Ballantine) J. Larsen
A. tamarense (Lebour) Balech	*Karenia brevis* (Davis) G. Hansen et Moestrup
A. minutum Halim	***Karenia mikimotoi* (Miyake et Kominami ex Oda) G. Hansen et Moestrup**
Amphidinium carterae Hulburt	*Karenia digitata* Yang et Takayama
Scrippsiella trochoidea Blaech et Loeblich III	*Karenia longicanalis* Yang & Hodgkiss
Akashiwo sanguinea (Hirasaki) G. Hansen & Moestrup	*Noctiluca scintillans* (Macartney) Kofoid et Swezy
Azadinium poporum Tillmann & Elbrachter	*Cochlodinium geminatum*(Schütt)Schütt
Tripos furca (Ehrenberg) Claparede et Lachmann	*Cochlodinium polykrikoides* Margalef
Tripos fusus (Ehrenberg) Dujardin	***Prorocentrum donghaiense* Lu**
Dinophysis acuminata Claparede&Lachmann	*Prorocentrum lima* (Ehrenberg) Dodge
Dinophysis fortii Pavillard	*Prorocentrum micans* Ehrenberg
Gonyaulax polygramma Stein	*Prorocentrum minimum* (Pavillard) Schiller
Gonyaulax spinifera (Claparede et Lachmann) Diesing	*Prorocentrum sigmoides* Böhm
Gymnodinium catenatum Graham	*Prorocentrum triestinum* Schiller
Gyrodinium instriatum Freudenthal et Lee	Lu et al. 2014. Algological studies

Causative species		Bloom information and impacts
Raphidophytes	*Chattonella marina* Hara et Chihara	fish kill, bloom in BS, YS and SCS
	Heterosigma akashiwo Hada	fish kill, bloom in BS, ECS and SCS
Prymnesiophytes	***Phaeocystis globosa* Scherffel**	**hemolytic toxins, bloom in BS, ECS and SCS**
Diatom	*Pseudo-nitzschia pseudodelicatissima* (Hasle) Hasle	ASP, bloom in ECS and SCS
	Pseudo-nitzschia pungens (Grunow ex P.T.Cleve) Hasle	bloom in YS, ECS and SCS
	Pseudo-nitzschia seriata (Cleve) H. Peragallo	bloom in ECS and SCS
Cyanobacteria	*Microcystis aeruginosa* Kützing	bloom in SCS
	Trichodesmium erythraeum Ehrenberg et Gomont	bloom in SCS, ECS
	Trichodesmium thiebautii Gomont	bloom in ECS
	Trichodesmium hildebrandtii Gomont	bloom in SCS, ECS
Pelagophyte	***Aureococcus anophagefferens* Hargraves et Sieburth**	**bloom in BS**

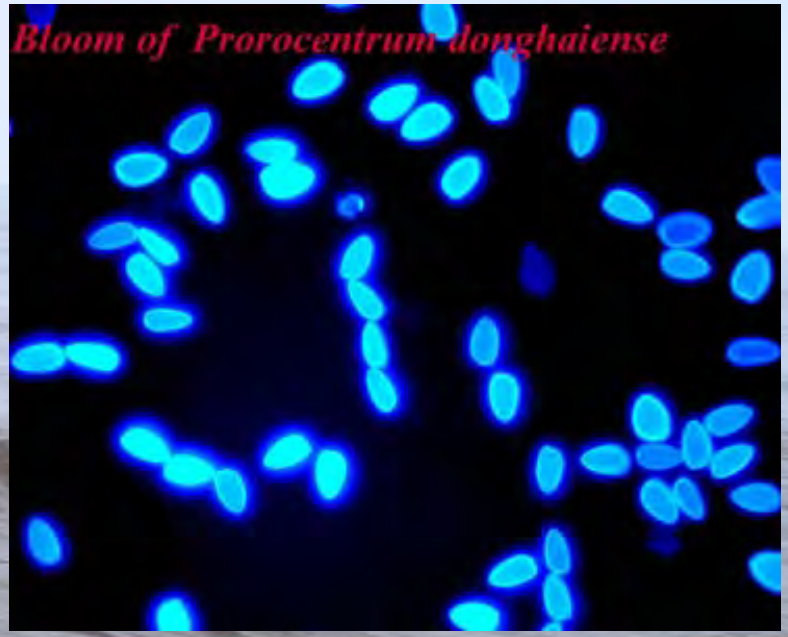
Lu et al. 2014. Algological studies

Occurrence of HABs in China (2015)

Location	Frequency	Accumulative area（Km²）
Bohai Sea	7	1522
Yellow Sea	1	48
East China Sea	15	**1098**
South China Sea	12	141
Total	35	**2809**

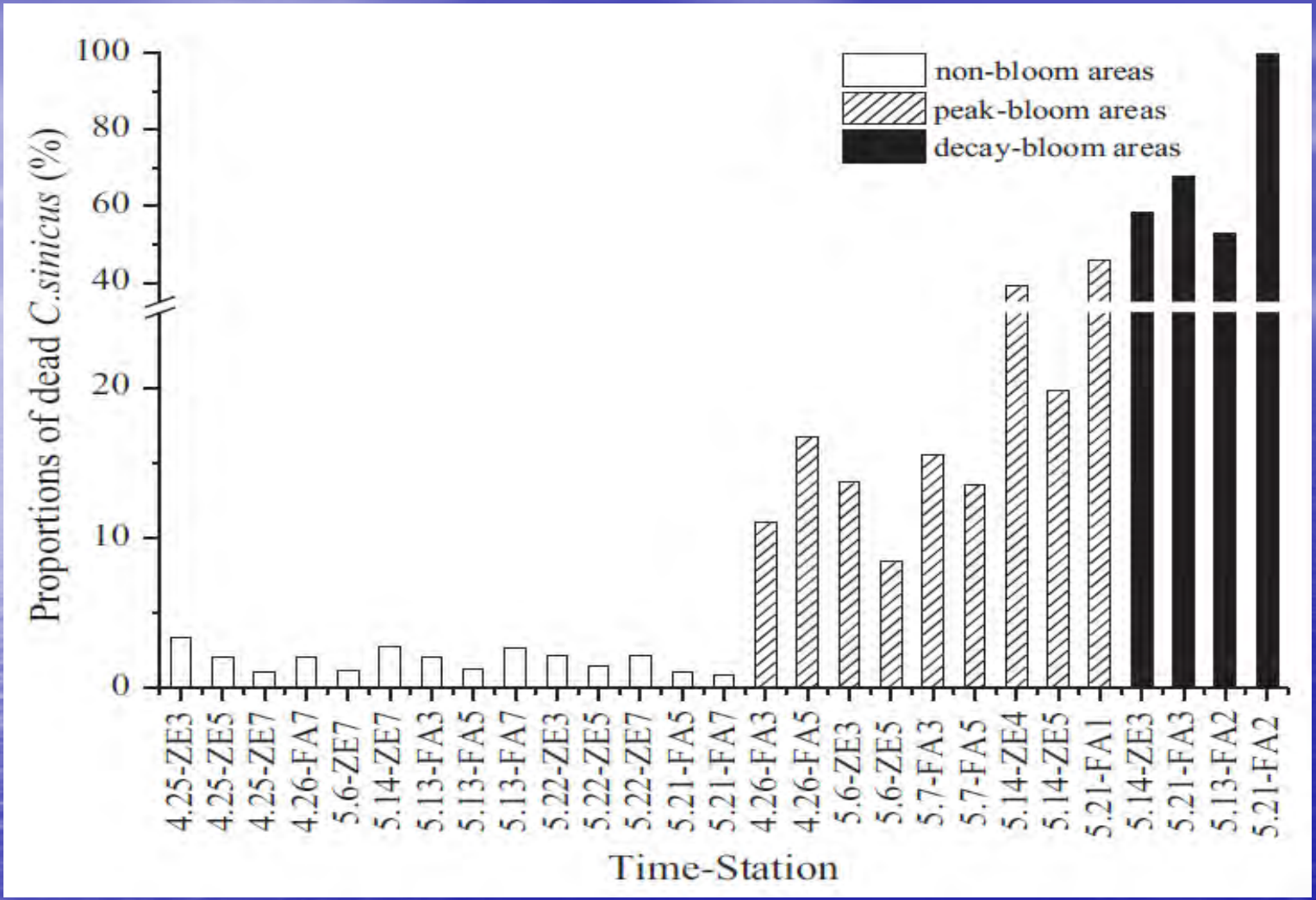
Main causative : ***Aureococcus anophagefferens***, ***Prorocentrum donghaiense***, ***Cochlodinium polykrikoides***, ***Noctiluca scintillans*** , ***Karenia mikimotoi*** , *Gonyaulax polygramma*, Other important species *Heterosigma akashiwo*, ***Phaeocystis globosa*** , *Fibrocapsa japonica etc.*

Bullitin of China Marine Environmental Desasters



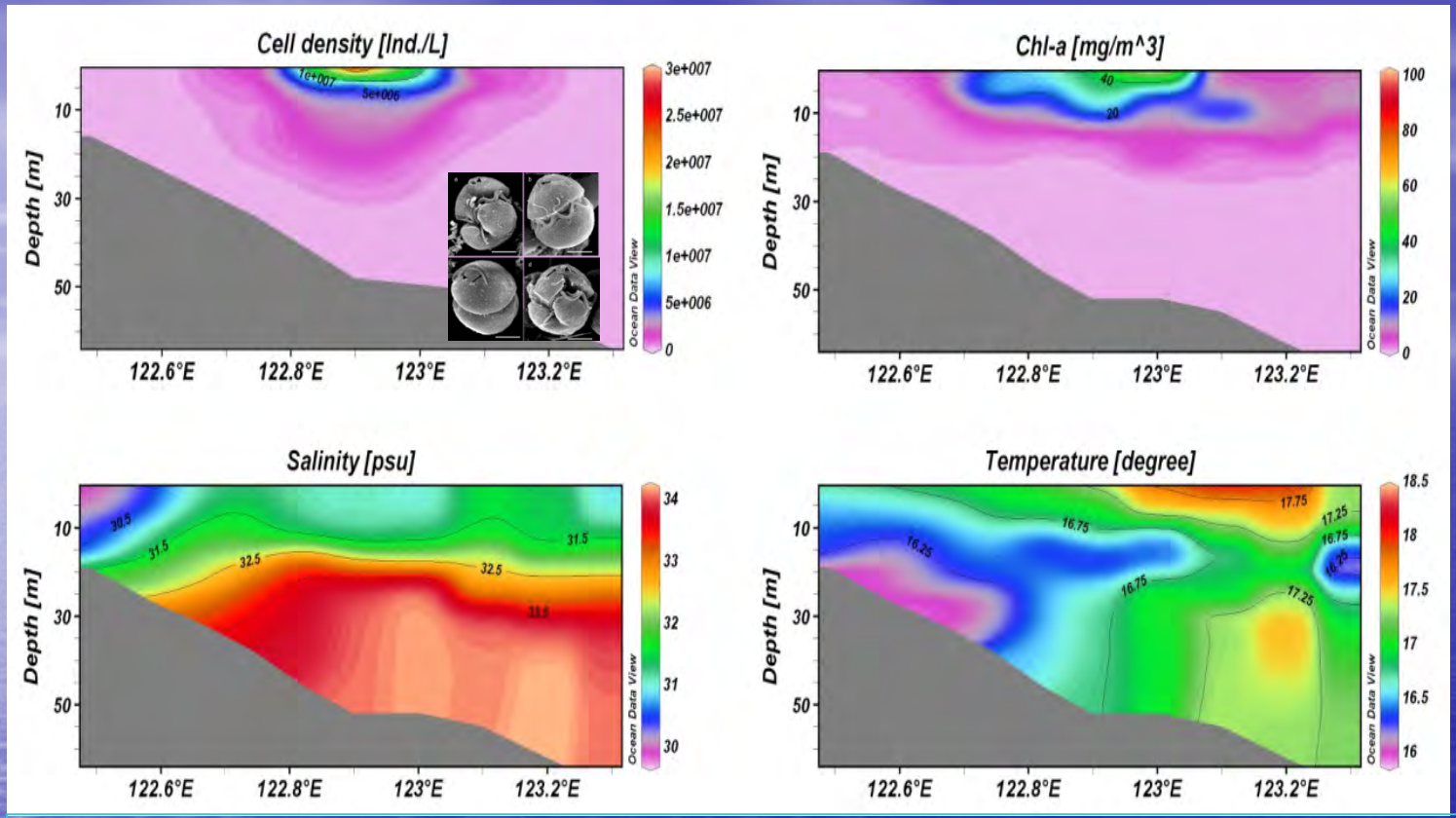
Recurrent bloom of *Prorocentrum* in the ECS

- **Initiation: beginning of April in the subsurface**
- **Occurrence：end of April——beginning of June**
- **Large scale：up to 10000km^2**
- **Highly dominant： one species >90%.**
- **High biomass：>10^{7}cells/L**
- **Long persisting time ： about one month.**



Harmful impacts of *Prorocentrum donghaiense* bloom on the mortality of *Calanus sinicus* (also cause lower egg production rates)

(Lin et al., 2014)



Vertical profiles of *K. veneficum* cell density, Chl-a, salinity and temperature on transect Rb on May 13, 2011.

The strain of *K. veneficum* isolated from the East China Sea shows strong *karlotoxins.*This species is co-occurring bloom species with *Prorocentrum donghaiense* blooms in spring 2011. The bloom pattern is supposed to be closely related to the water column stratification in the East China Sea

Deep-Sea Research II 101 (2014) 237–243

Contents lists available at ScienceDirect

Deep-Sea Research II

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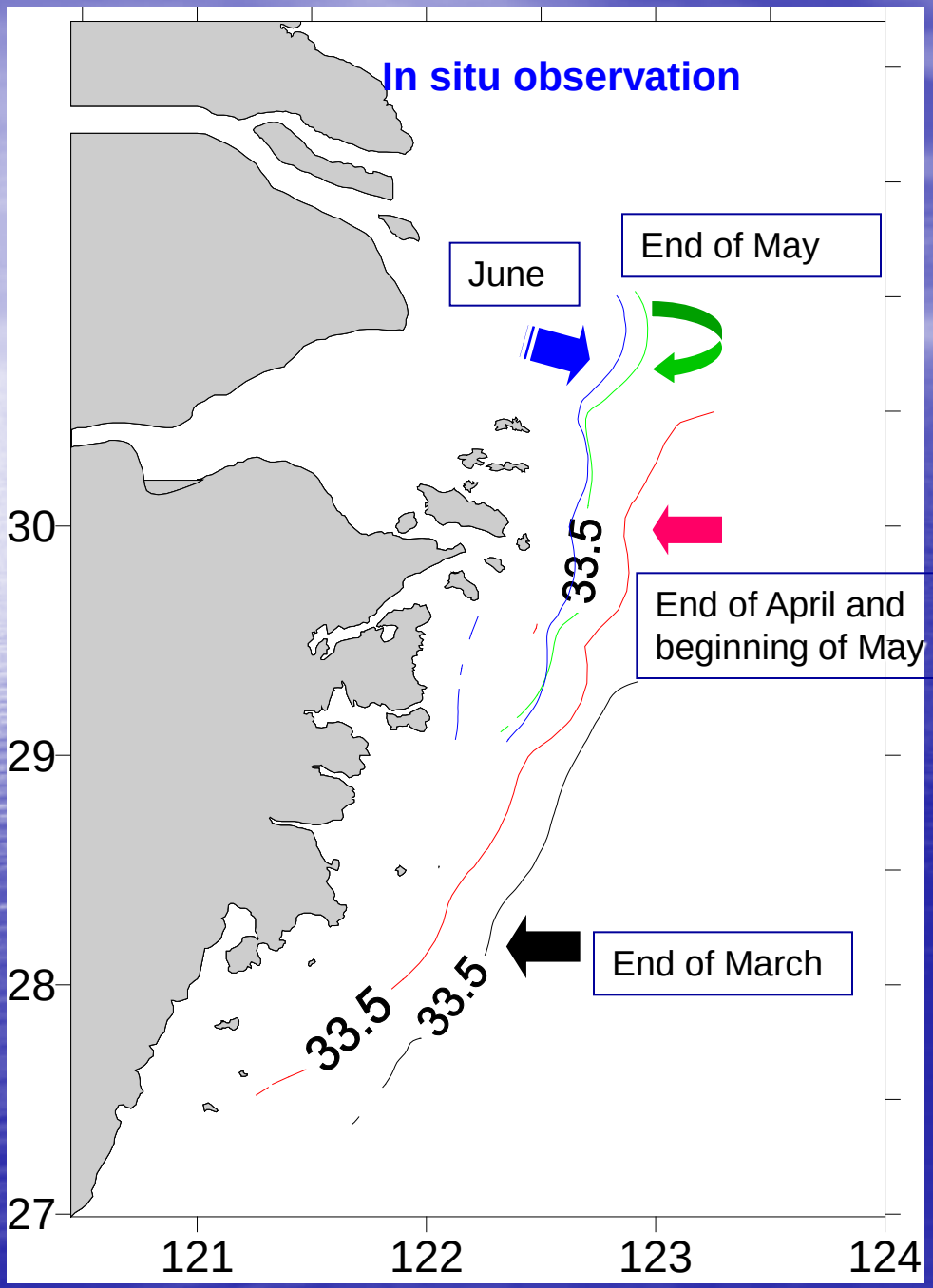
Newly recorded *Karlodinium veneficum* dinoflagellate blooms in stratified water of the East China Sea

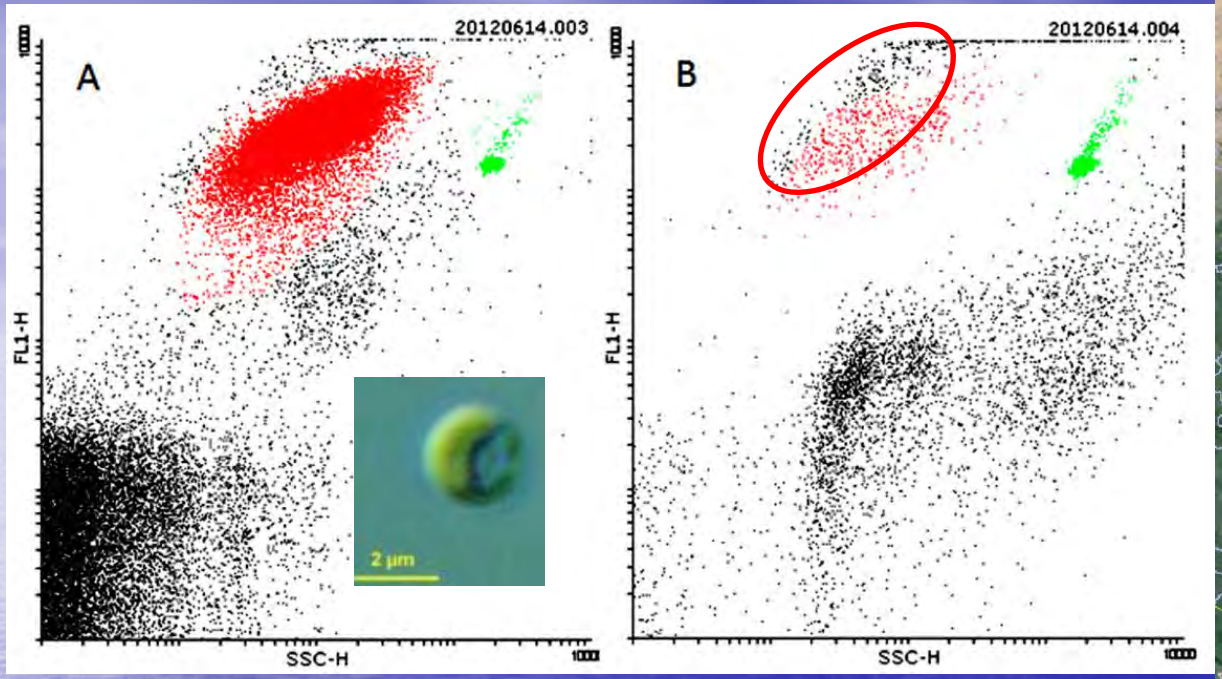
Xinfeng Dai [a], Douding Lu [a,*], Weibing Guan [a], Hongxia Wang [a], Piaoxia He [a], Ping Xia [a], Huajie Yang [b]

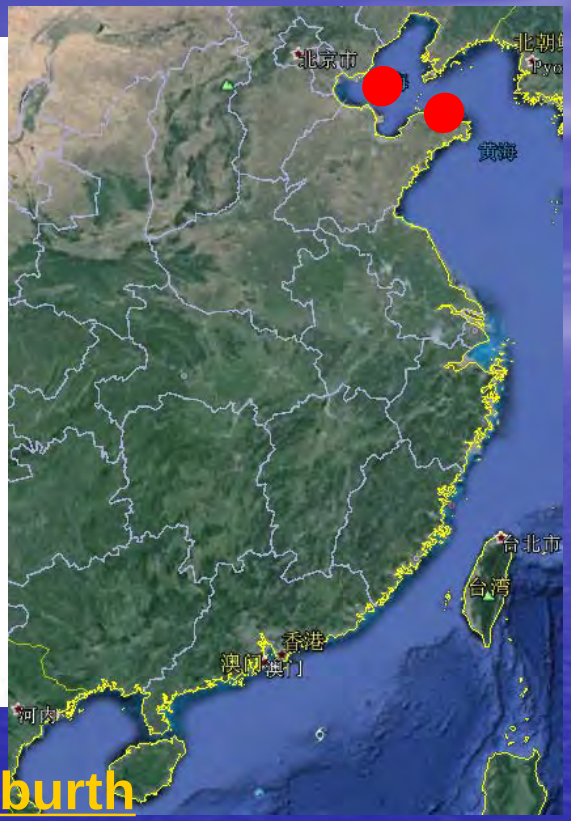
[a] State Key Laboratory of Satellite Ocean Environment Dynamics, The Second Institute of Oceanography, SOA, Hangzhou 310012, China
[b] Zhejiang University, Hangzhou 310012, China



In spring, inshore area was invaded by high salinity water, indicating more influence of TWC.

Massive blooms of PD are much related with physical process.



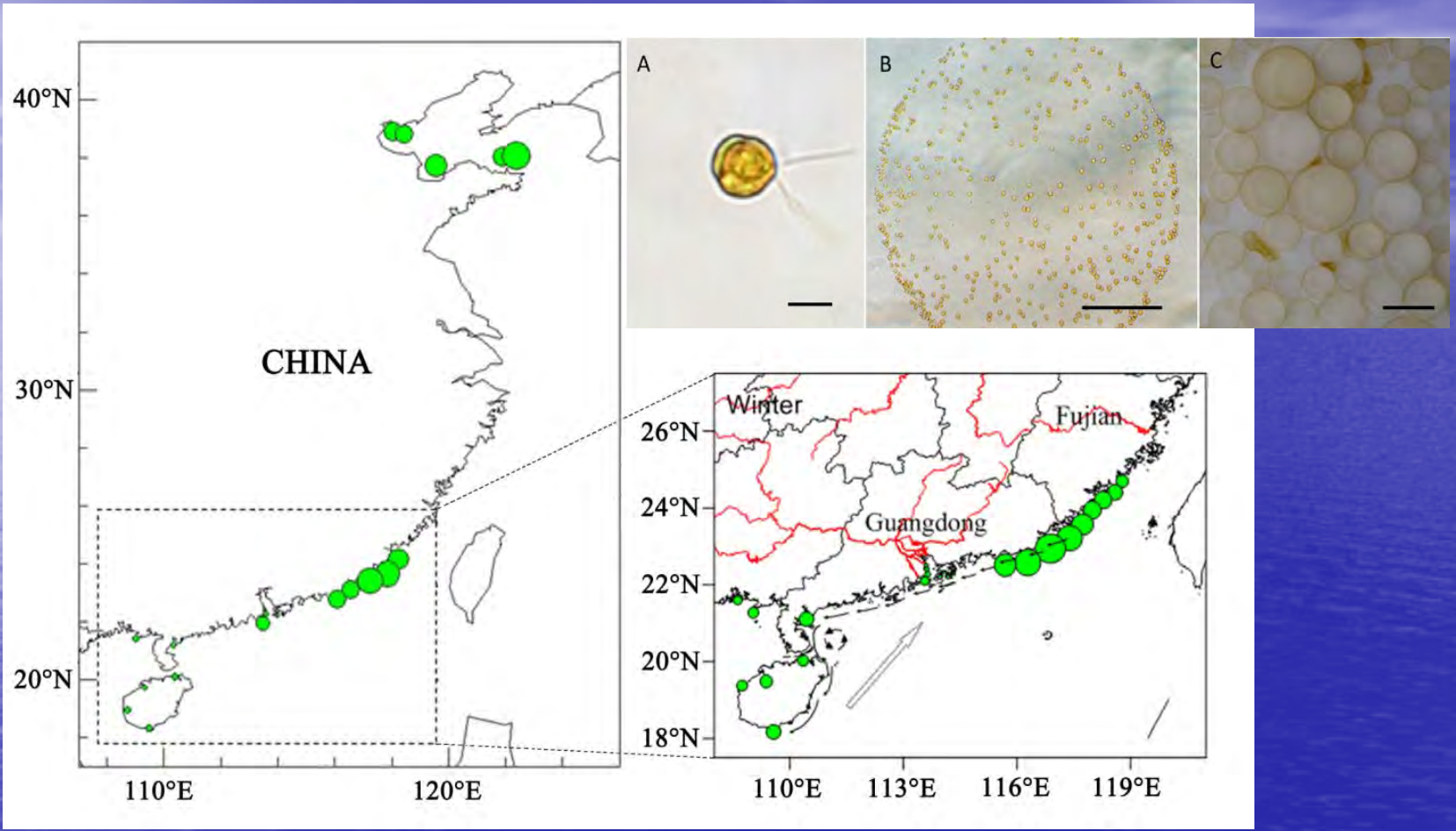


Aureococcus anophagefferens Hargraves & Sieburth

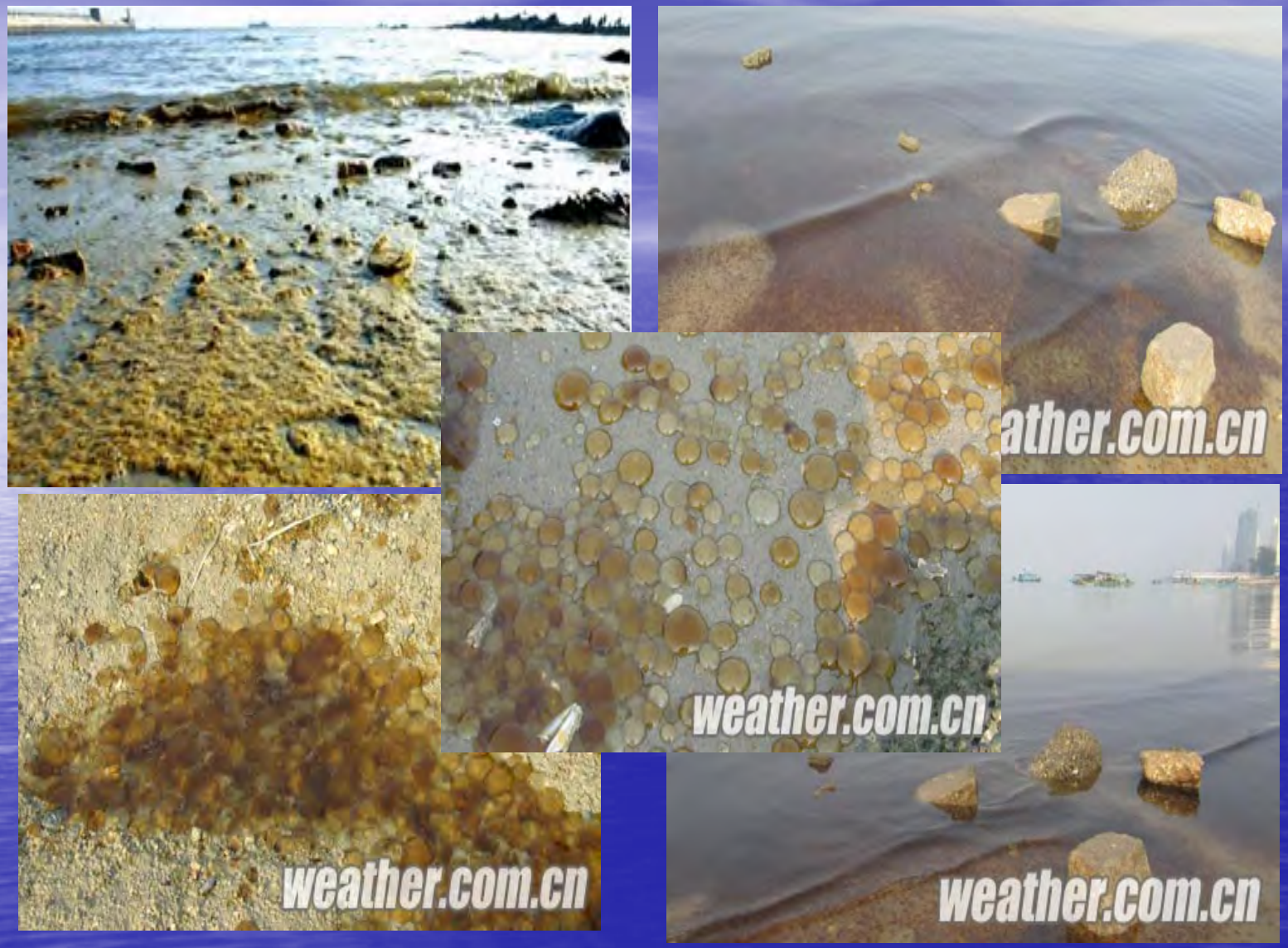
Reactivity of FITC-MAb with *A. anophagefferens* cells. A: the positive culture control using *A. anophagefferens* CCMP1984 cultured in the laboratory; B: the field sample sampled from the coastal waters of Qinghuangdao in the Bohai Sea in 10th June 2012. The red dots meaning *A. anophagefferens*cells, and the green dots meaning fluorescent beads adding in the samples

The blooms occurred recurrently in this region for at least 8 years from 2009–2016. Brown tides in the Bohai Sea generally initiated during the late May, and sustained till the August. It was recorded as largest HABs in recent years in CHINA.

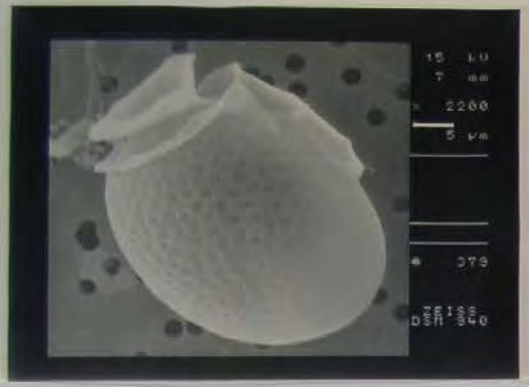
Algological studies, 2014

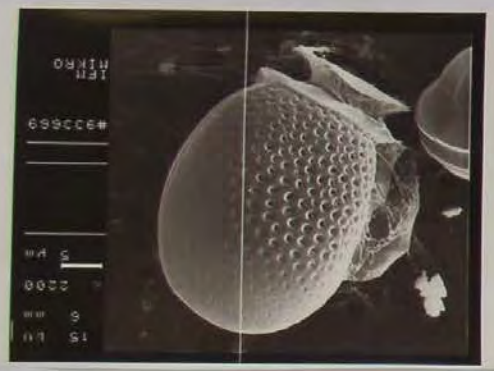


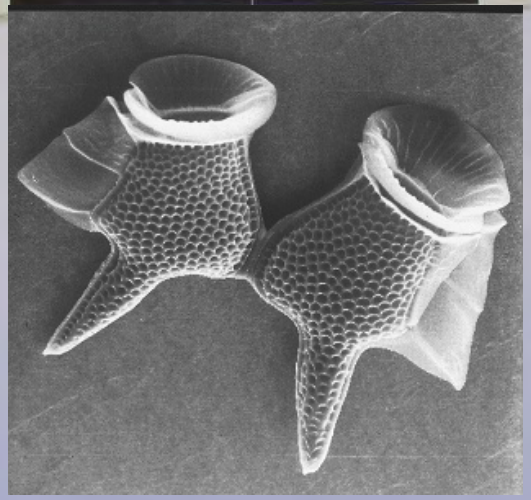
Records of *Phaeocystis globosa* blooms along the coasts of China.Maps showing the spread of the *Phaeocystis globosa* blooms from the Bohai Sea to the South China Sea (left), with special reference to the coastal currents of the South China Sea in winter (right)



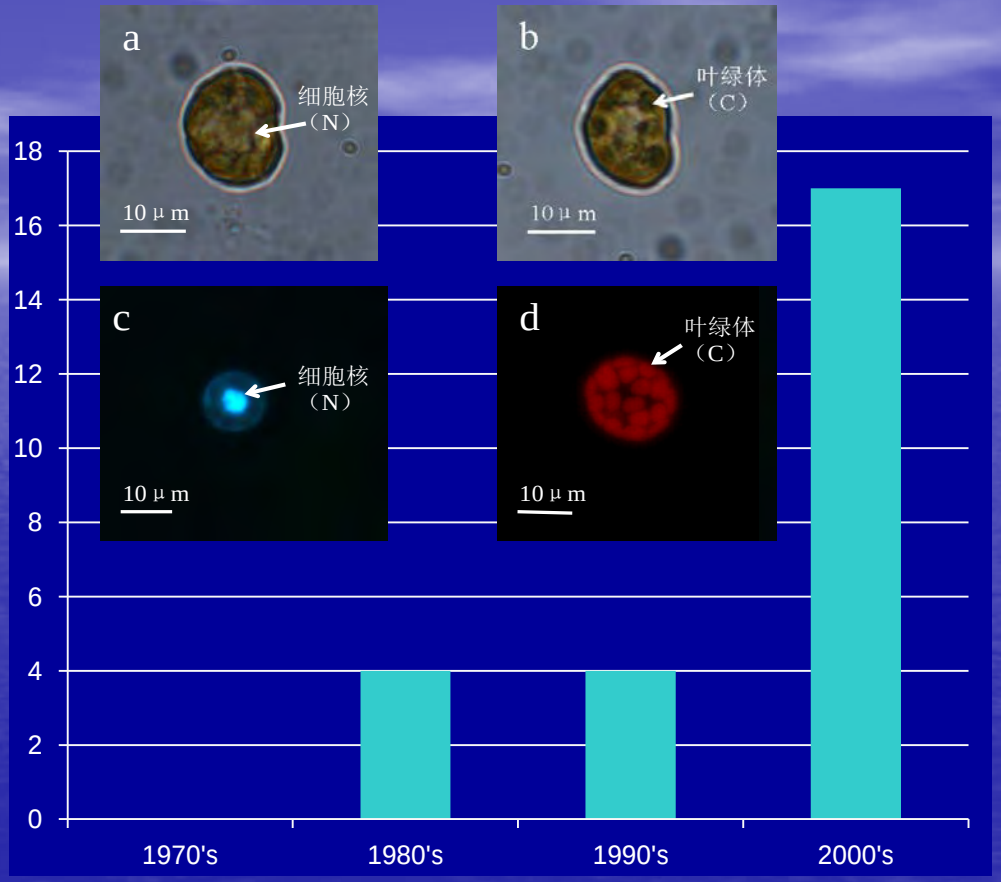
Phaeocystis globosa blooms along the coasts of Guangxi between December 2014 and Feb of 2015 causing clog of water tube for cooling power plant.



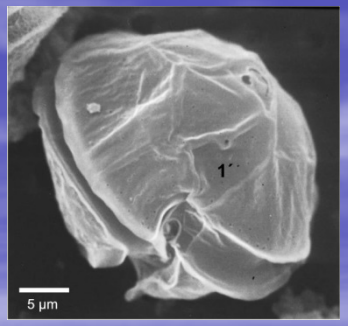


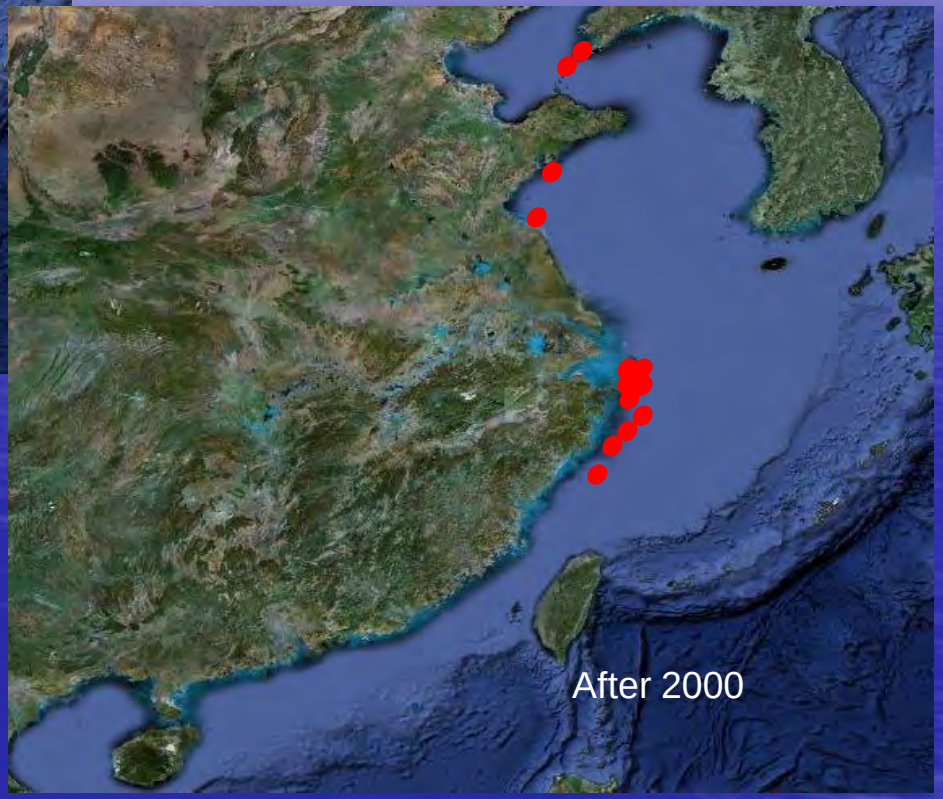


Potentially DSP producer: *Dinophysis* spp.



about thirty bloom events of *Heterosigma akashiwo* have been registered and bloom frequency has increased along China coastal waters. This species has mainly formed blooms in the Bohai Sea and the Yellow Sea and recently expanded to other China coastal waters.

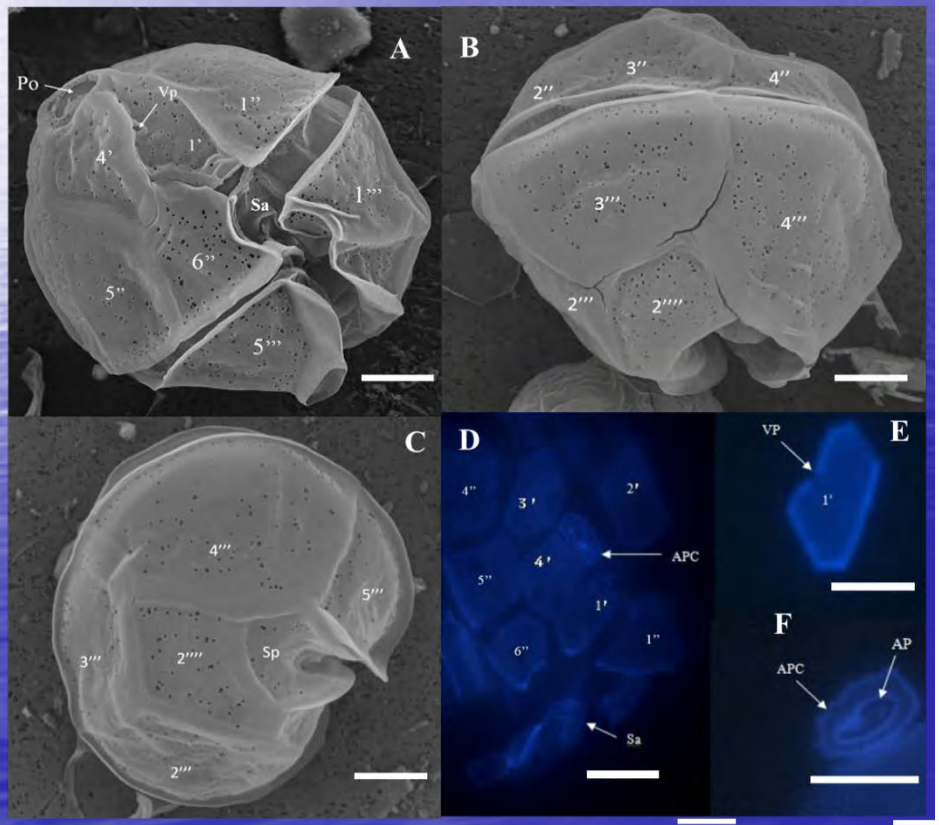


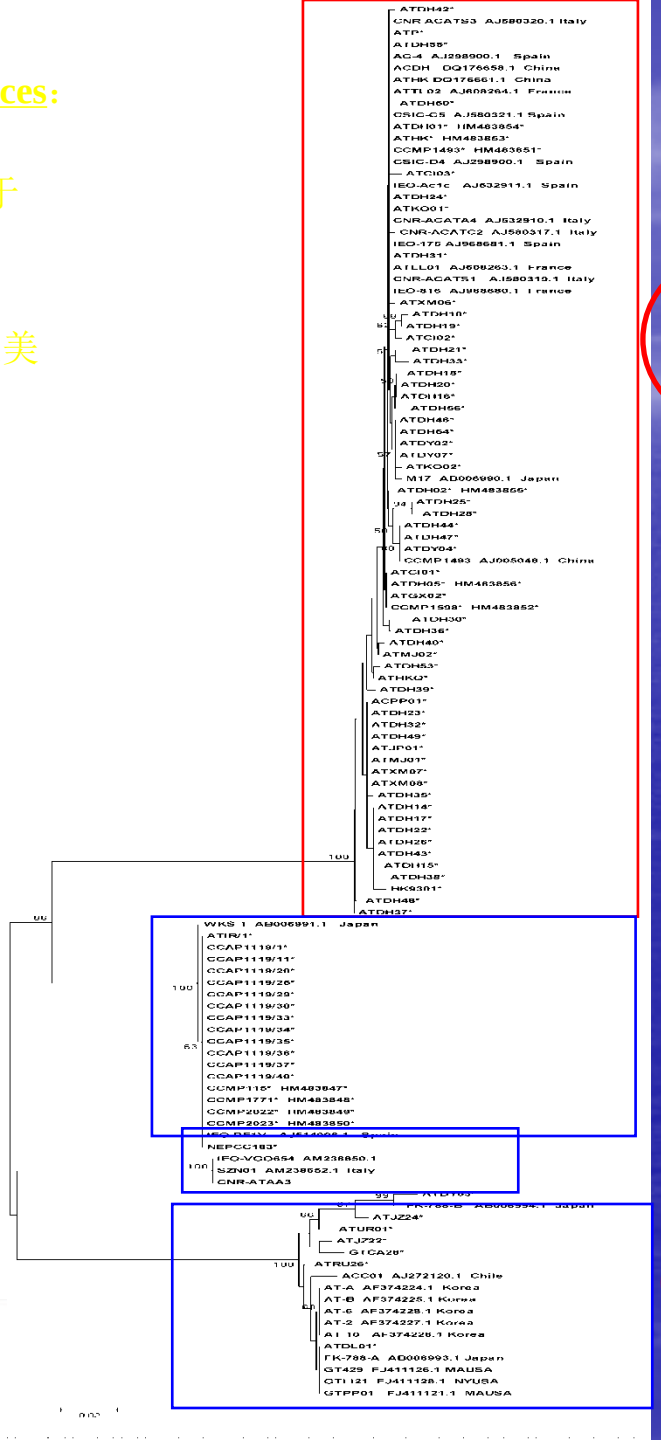


before the year 2000, there were virtually no recorded cases of *Aexandrium* bloom in China. After the year 2002, over 10 bloom events were documented in Chinese coastal waters.

Phylogenetic trees based on **5.8S rDNA and ITS sequences**:

- 中国东海(ECS)和南海(SCS)塔玛亚历山大藻复合种属于Group IV(温带亚洲型）
- 渤海(Bohai Sea)塔玛亚历山大藻复合种属于Group I (北美型）





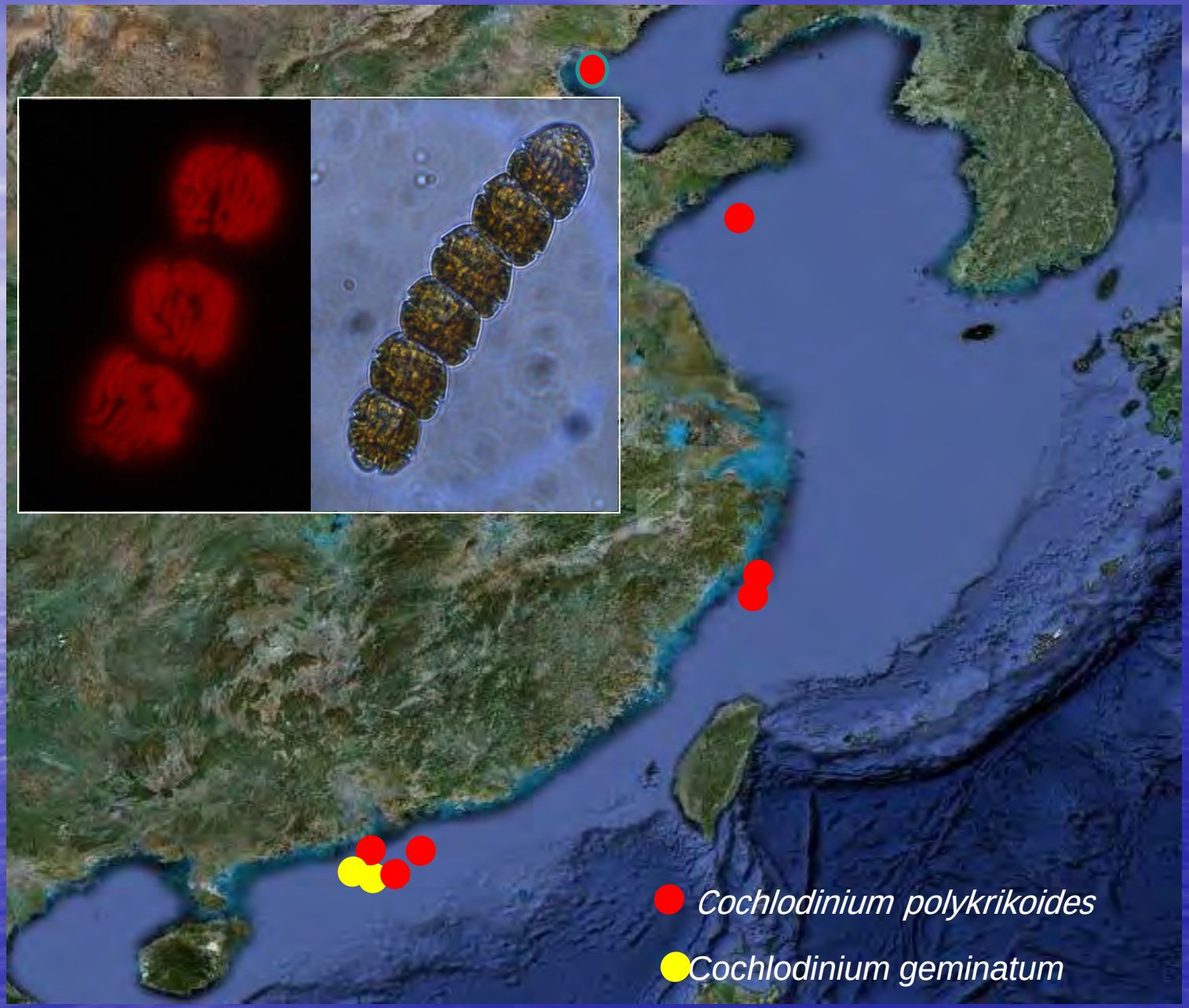
温带亚洲型
Group IV

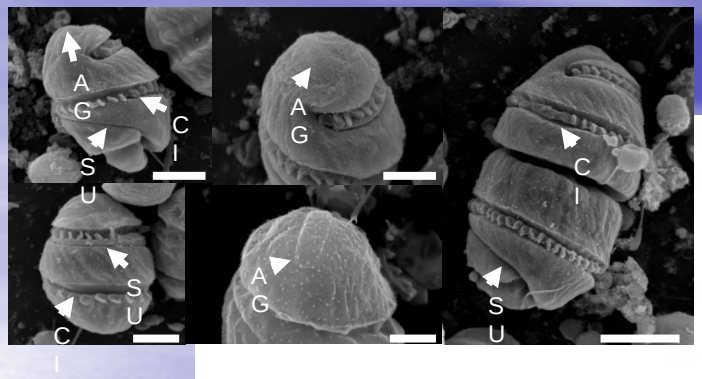
西欧型
GroupIII

地中海型
Group II

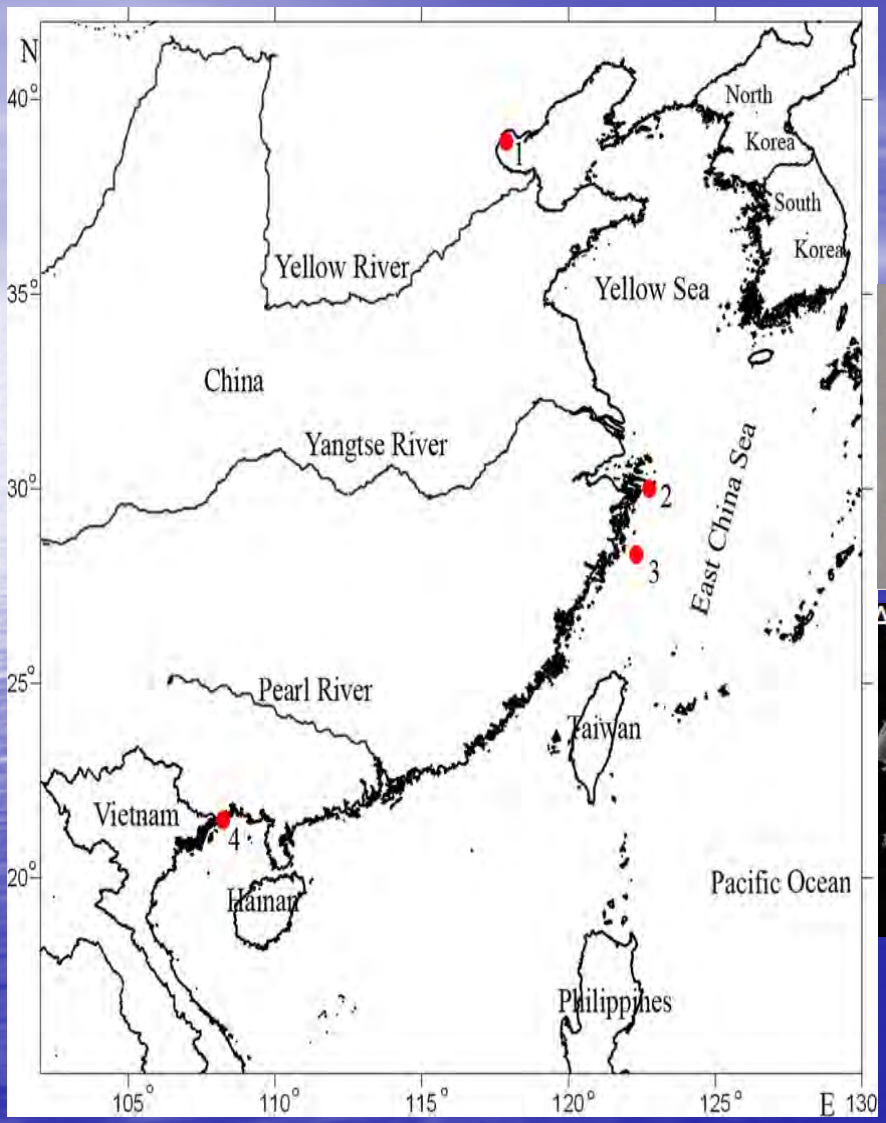
北美型
Group I

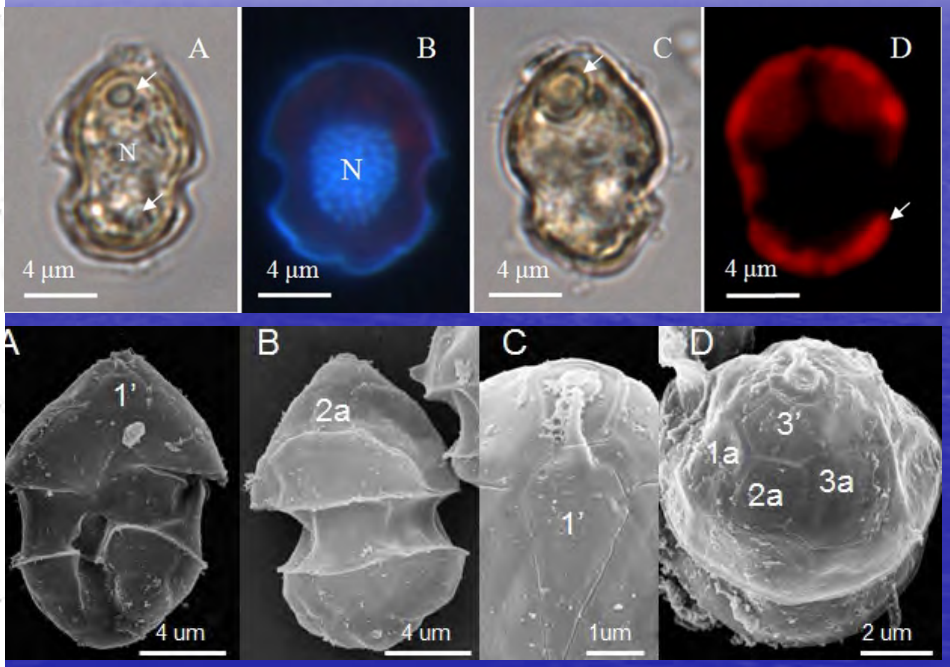
(After Yang)


Cochlodinium polykrikoides
Cochlodinium geminatum

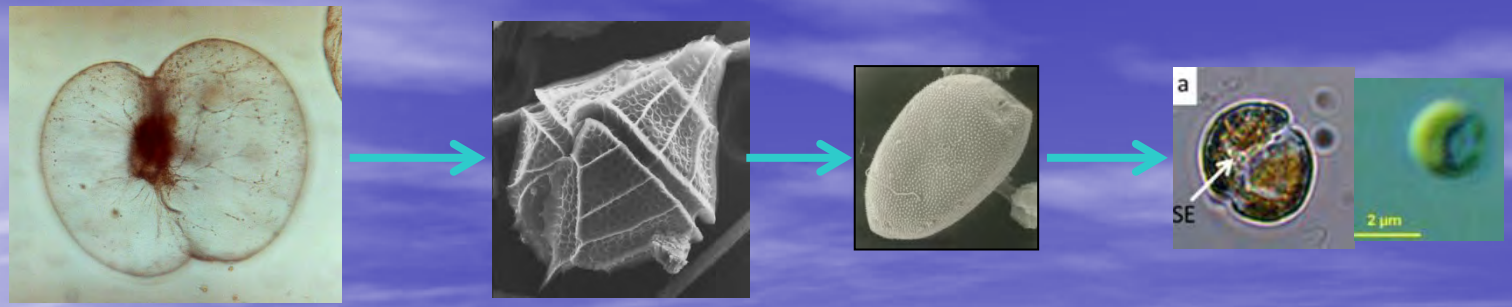


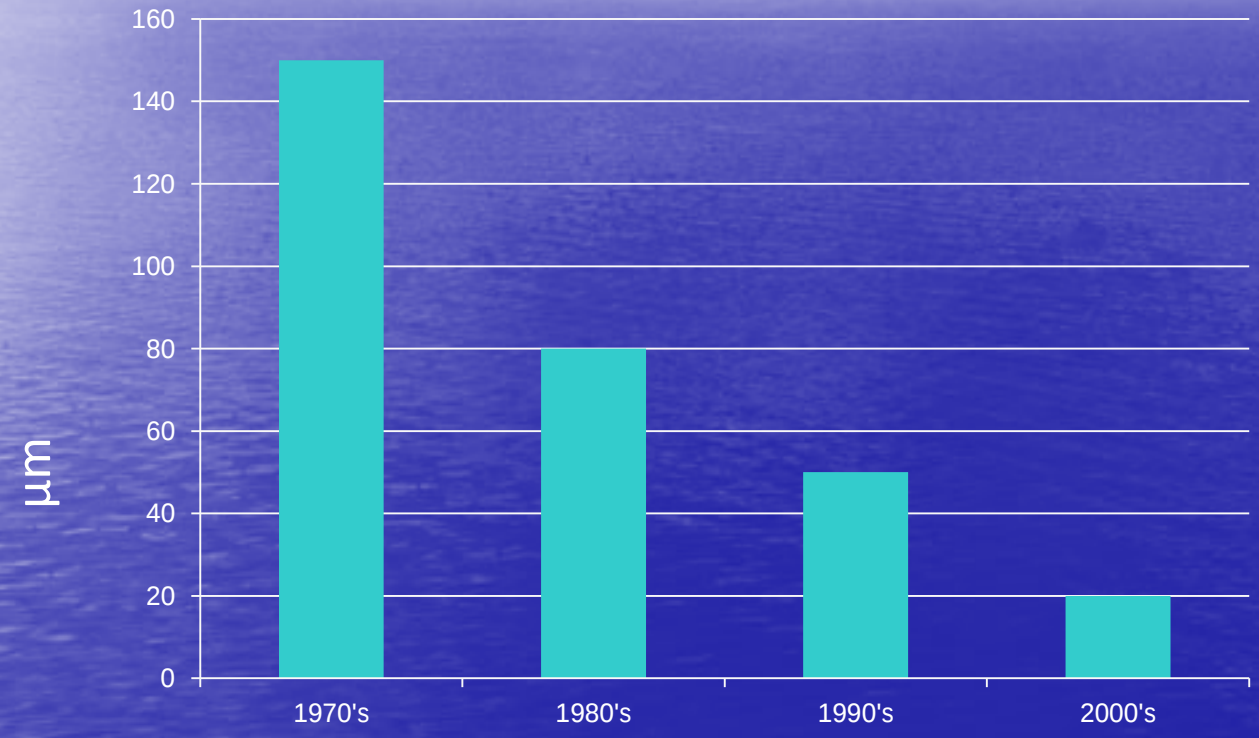
Phylogenetic trees of the *Cochlodinium polykrikoides* based on the LSU rDNA (D1-D3) sequences





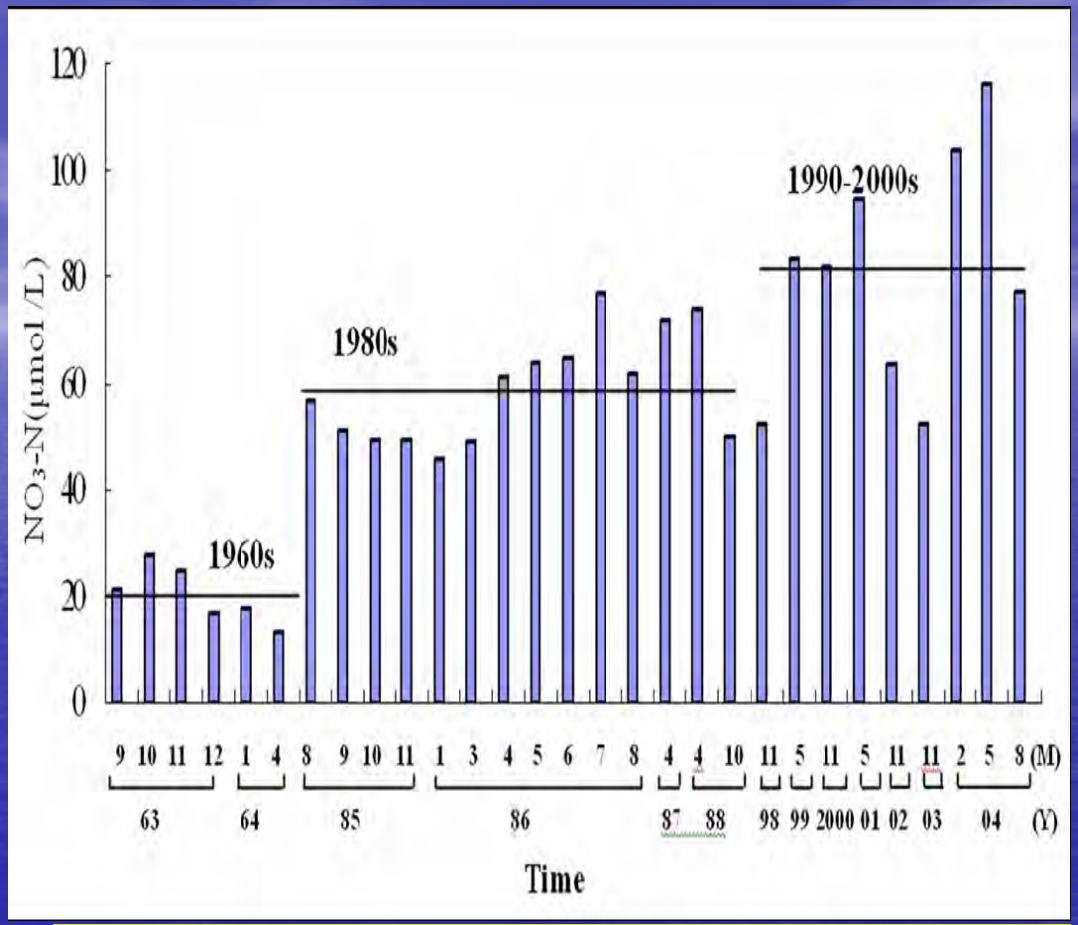
Azadinium poporum
Gu， 2013





Size spectrum of bloom species in China

Possible links :

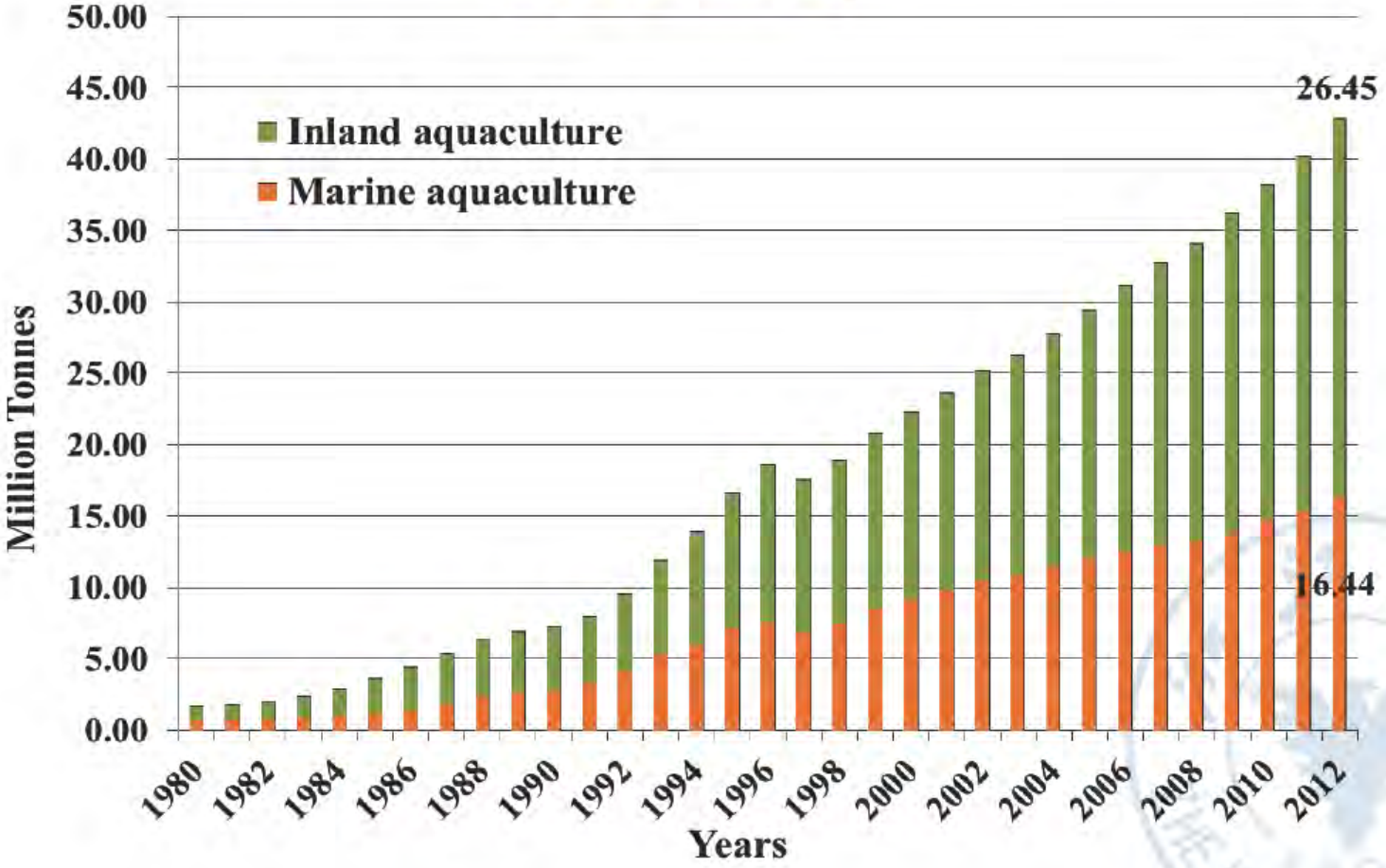


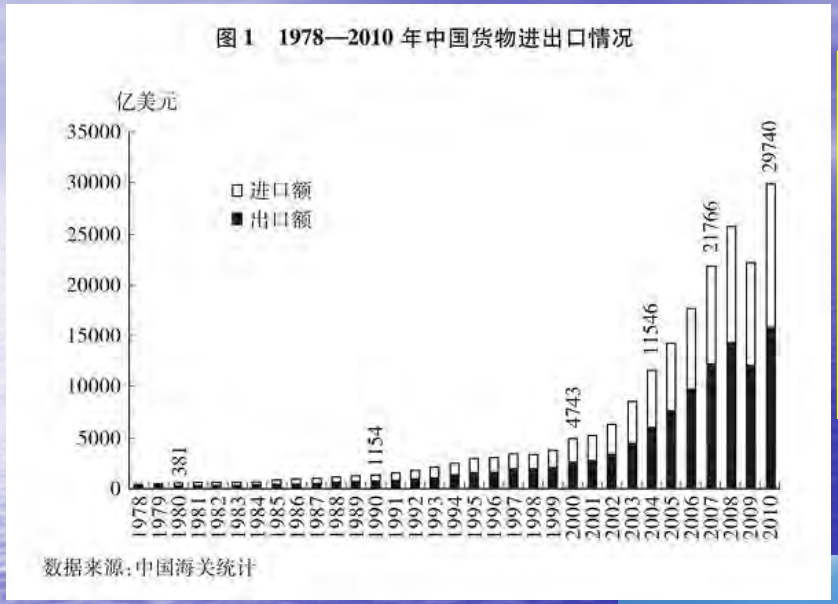
Status of pollution in Chinese coastal waters, 2008 (http://www.soa.gov.cn)

Nutrient enrichment of coastal waters leading to the selection for, and proliferation of, harmful algae

(Zhou et al. 2008)

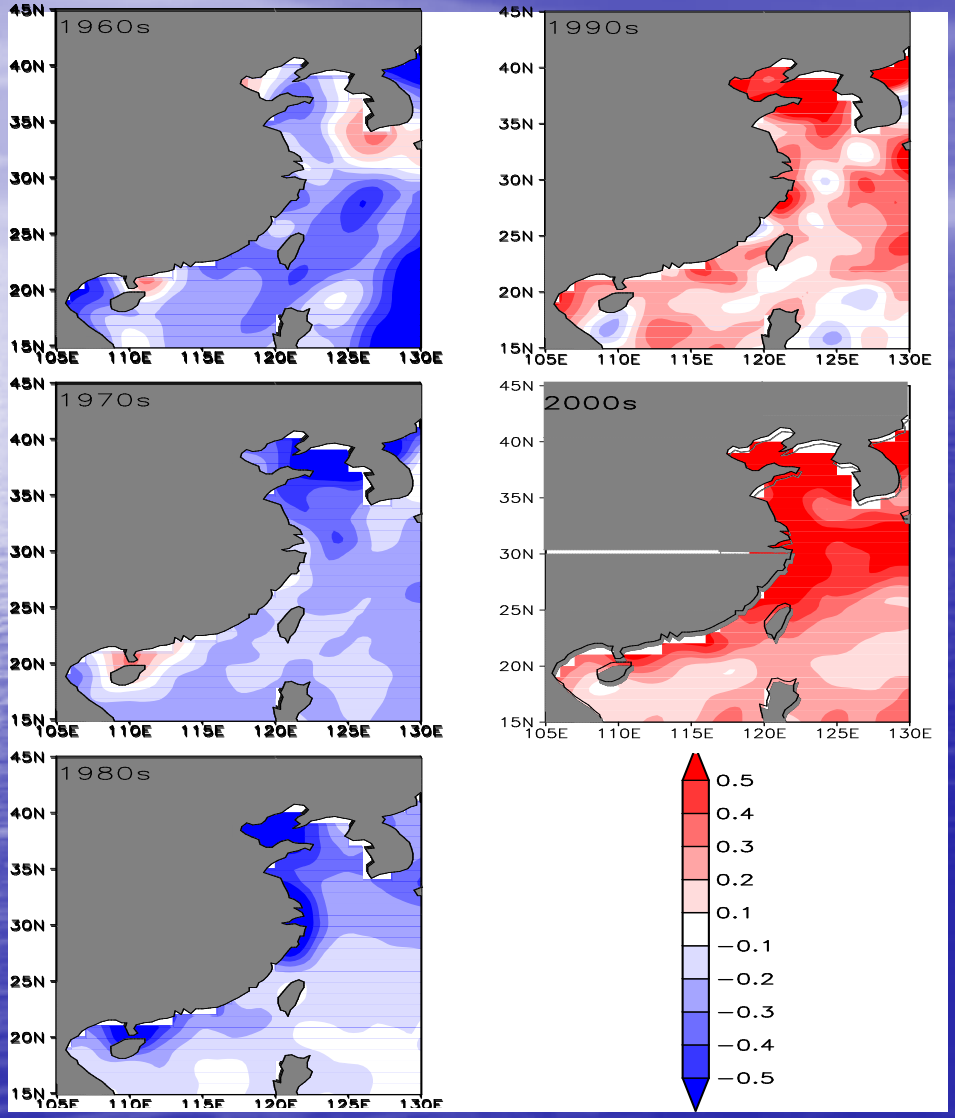
Marine and inland aquaculture in China (1980-2012)

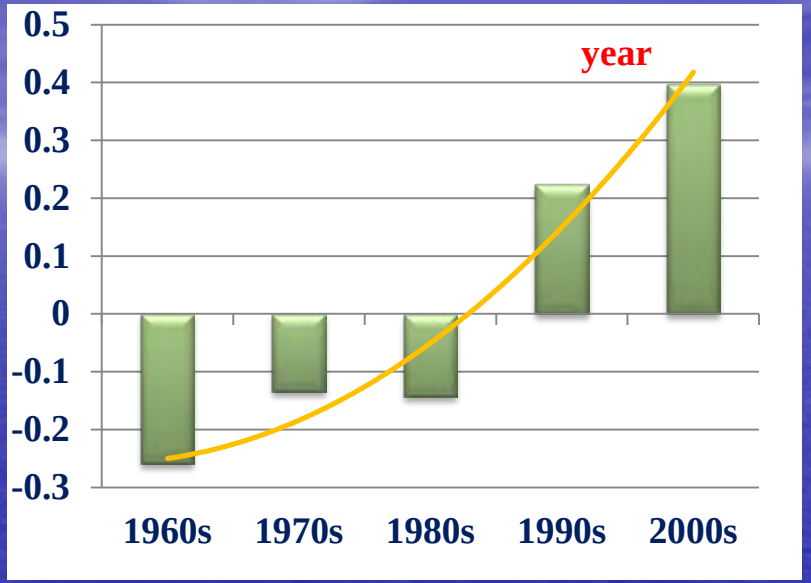




HAB species may transported and dispersed by ballast water

Water temperature in China Seas





Li, unpublished data

The SST anomalies of decadal average (℃) in 1960s, 1970s, 1980s, 1990s and 2000s

Sea level change

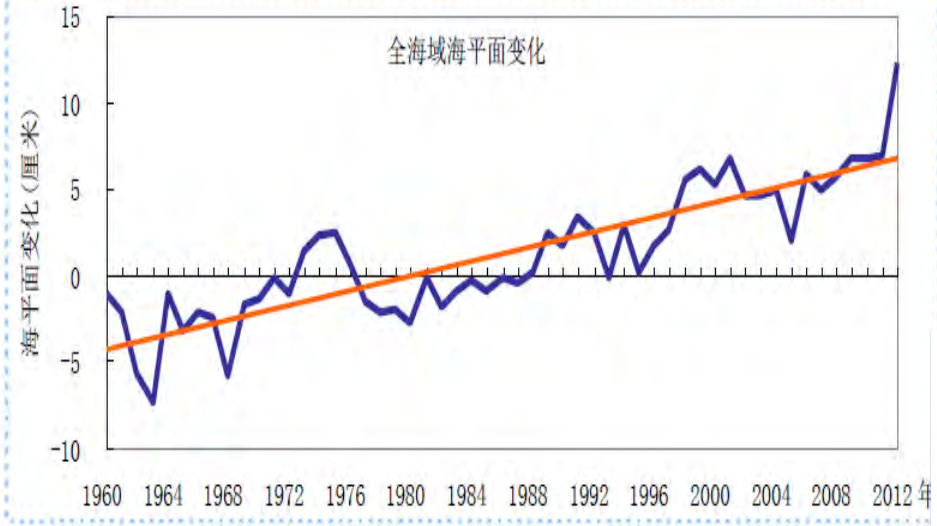


图 2.93 1960-2012 年中国沿海年平均海平面变化(图例)

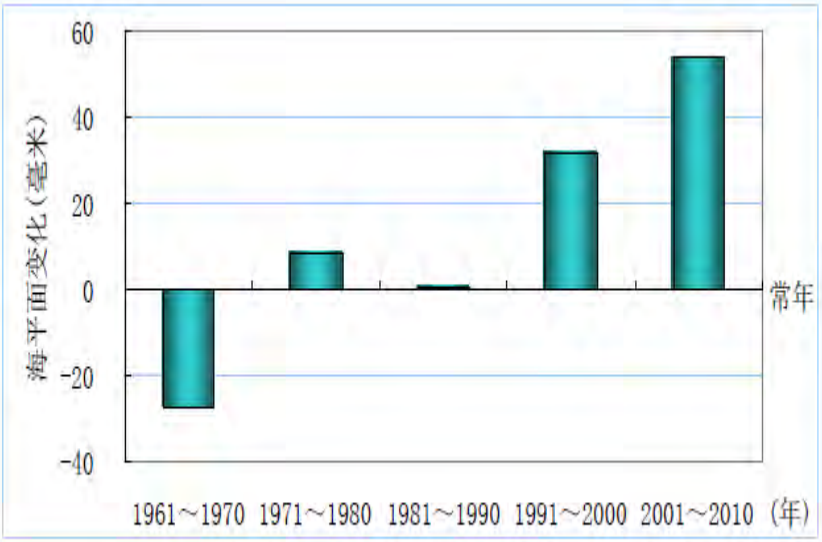
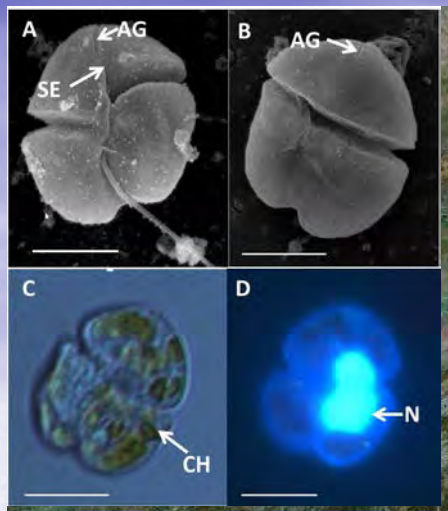


图 2.101 1960～2010 年中国沿海十年平均海平面变化*

Li, unpublished data

Climatic changes may favor the HAB species



Before 2000

After 2000

Since 1998, over 120 blooms caused by this species occurred in China (http://www.soa.gov.cn).

1998

2005

2012

2016

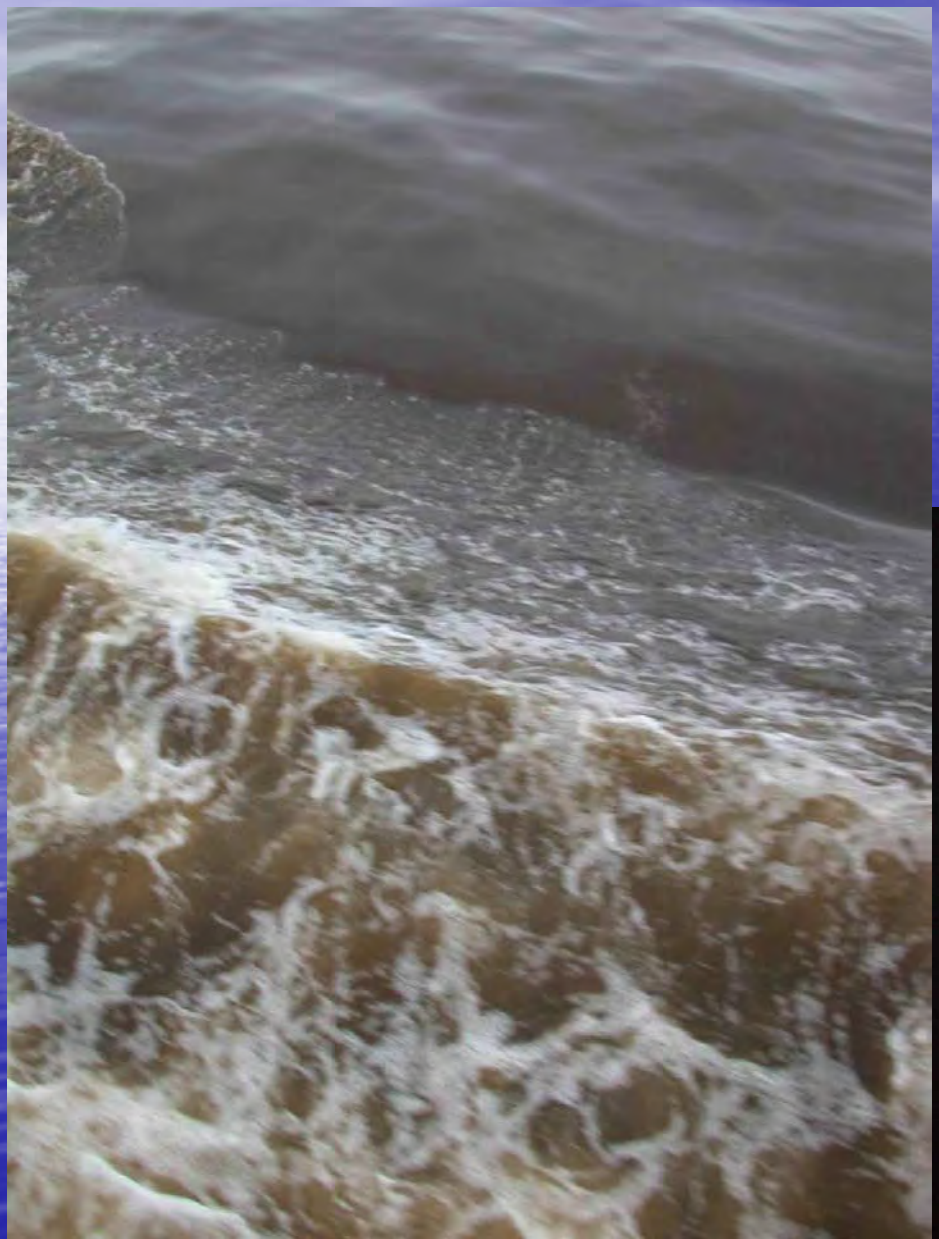
表 2 国内米氏凯伦藻引发赤潮(中国海洋环境质量公报;中国海洋灾害公报)

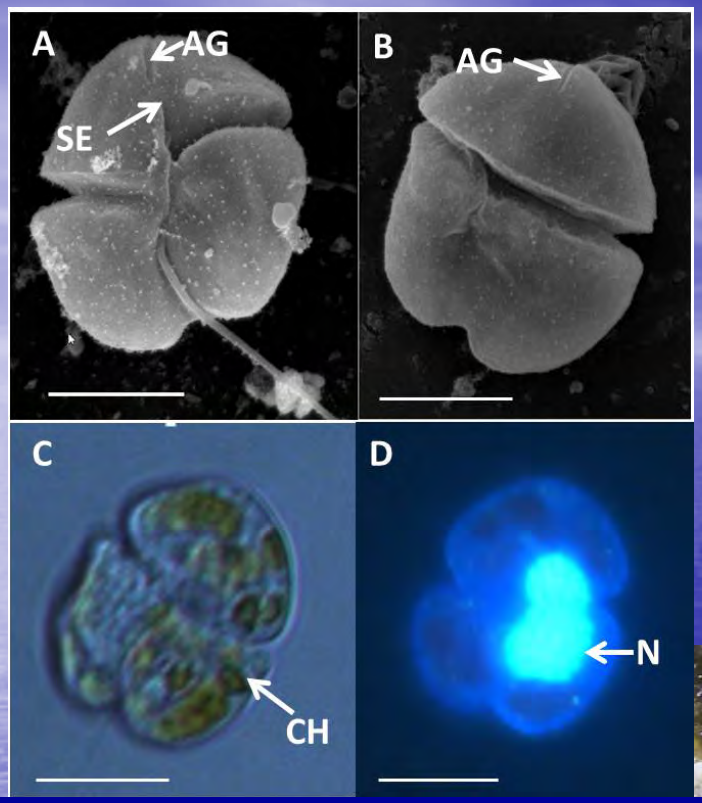
时间	省份	发生海域	损失
1998.3	广东	珠江口、桂山岛、大鹏湾、深圳湾	3.5 亿
1998.5	广东	大亚湾	
2002.5.4	福建	福鼎和霞浦东部海域	
2002.5.16	福建	福鼎和霞浦东部海域	
2002.6.3	福建	连江近岸海域	
2003.5.10	福建	福宁湾及福鼎沿海	
2003.5.18	福建	霞浦长春海域	
2003.5.20	福建	霞浦福宁湾	
2003.5.21	福建	福鼎、霞浦沿海	
2003.5.24	福建	连江近岸海域	
2003.5.28	福建	四霜列岛海域	
2004.5.22–6.13	浙江	南麂海域	
2004.6	天津	塘沽、渤海中东部	
2005.6.21–22	天津、山东	渤海湾	
2005.5.24–6.19	浙江	虾峙岛东部、舟山海域、桃花水道	
2005.5.30–6.17	上海、浙江	花鸟山、嵊山、嵊泗、壁六横岛等海域	2000 万
2005.6.2–6.10	浙江	南麂列岛附近海域	
2005.6.8–6.13	浙江	桃花岛、虾峙岛－韭山列岛、三门近岸海域	
2005.6.18–6.20	浙江	南麂岛新码头至温州市、瓯江近海海域	
2005.7.23–7.24	浙江	南麂大沙岙海域	
2006.5.14–7.24	长江口外		
2006.5.20–5.27	浙江	渔山列岛附近海域	
2006.6.12–6.14	浙江	洞头岛至北麂列岛	
2006.6.15–6.21	浙江	渔山列岛、象山附近海域	
2006.6.24–6.27	浙江	中部渔山列岛至韭山列岛海域	
2007.6.11–6.13	福建	平潭东澳一级渔港西面海域及龙王头海域	500 万
2008.5.1–5.5	浙江	苍南县大渔湾	
2009.7	江苏	海州湾	
2010.6.13–16	福建	泉州深沪湾海域	4 万
2012.5.23–6.8	浙江	温州南麂列岛附近海域	280 万
2012.5.24–6.3	浙江	温州洞头岛附近海域	57.7 万
2012.6.3–6.7	浙江	舟山嵊泗海域	67.3 万
2012.5.18–6.7	福建	霞浦、福鼎海域	30 万
2012.5.27–6.8	福建	连江黄岐海域	10539.0 万
2012.5.30–6.8	福建	福清东翰海域	11996.1 万
2012.6.5–6.8	福建	罗源碧里乡吉壁－新沃海域	1170 万
2012.5.26–6.7	福建	平潭	63151.2 万
2012.5.25–27	福建	湄洲岛洋屿海域	1050
2012.5.30–6.3	福建	东岙、坑口、石城、湄洲岛洋屿海域	14549.5 万
2012.5.25–26	福建	泉州惠安海域	80 万
2012.5.30–6.7	福建	泉州惠安海域	3700

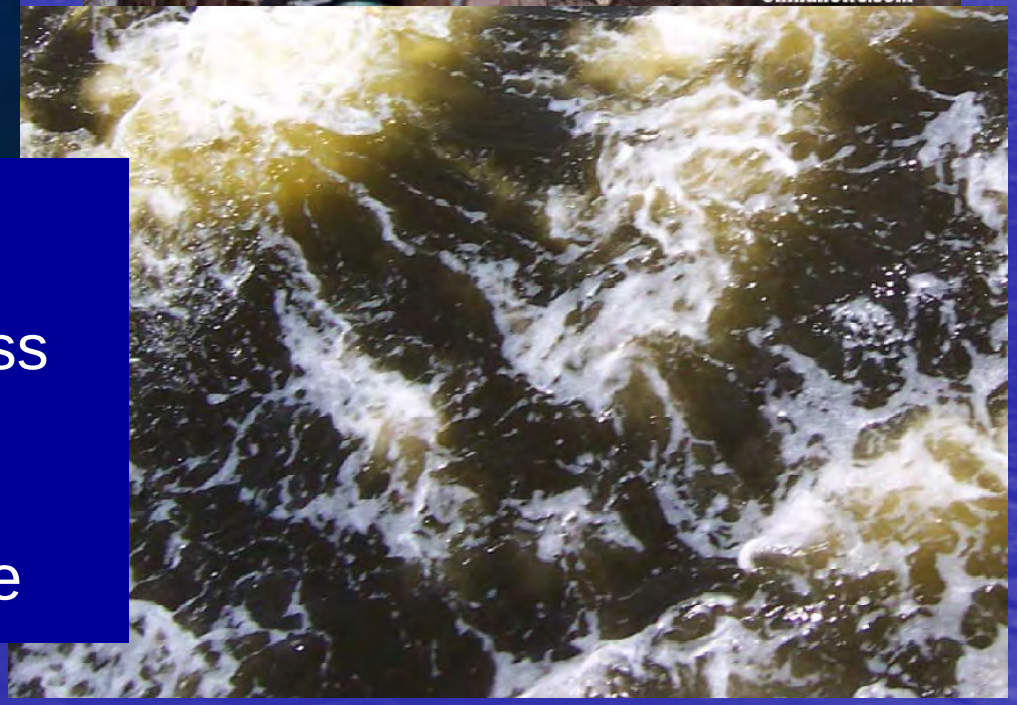
Marine Environmental Bulletin，
（http://www.soa.gov.cn/）

2016.1-2 Hongkong

Fish kill caused by Karenia bloom, late spring 2005







Karenia mikimotoi blooms cause severe economic loss in Fujian and Zhejiang Province(>2 billion Chinese Yuan)

Harmful Algal Blooms in Hong Kong

Karenia mikimotoi

死魚潮時序

	首宗魚類死亡報告日期	魚類養殖區	海魚養殖業牌照數目
1	2015年12月23日	鹽田仔	120
2	2015年12月30日	鹽田仔(東)	81
3	2015年12月31日	榕樹凹	101
4	2015年12月31日	老虎笏	3
5	2016年1月2日	深灣	39
6	2016年1月21日	塔門	30
7	2016年1月21日	較流灣	6
8	2016年1月30日	澳背塘	20

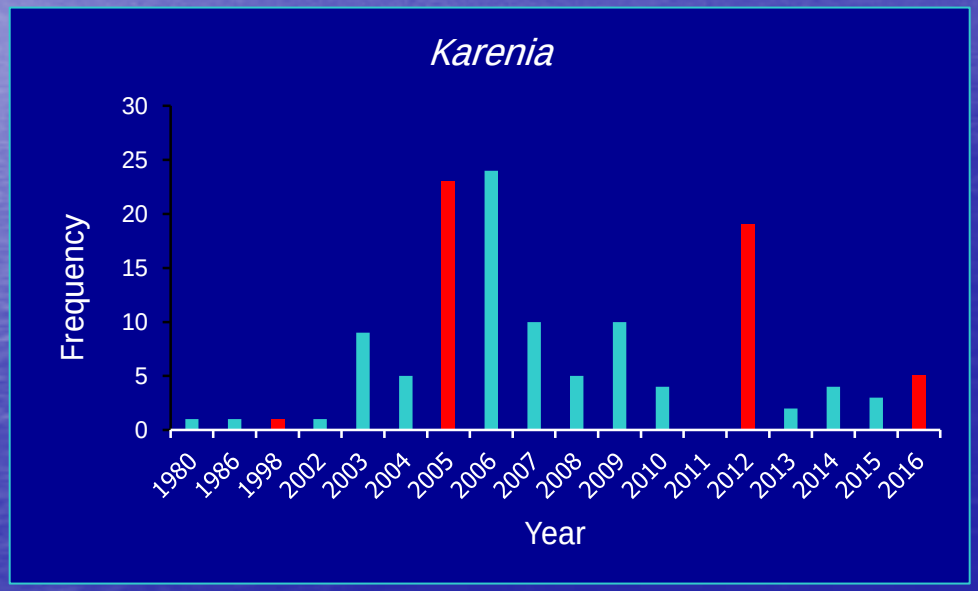
資料來源：漁農自然護理署

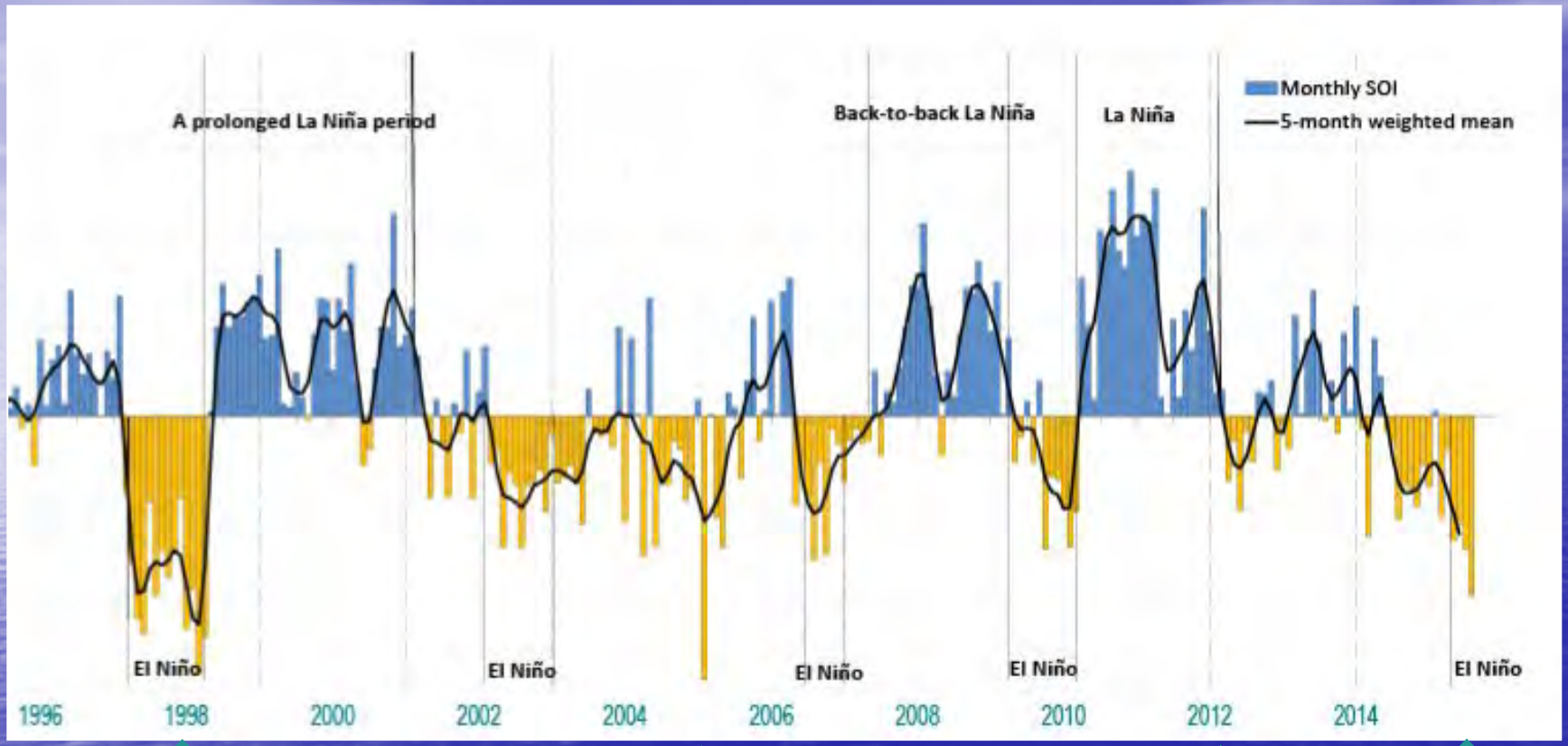
米氏凱倫藻

外地影響　日本水域主要有害紅潮藻類，曾在日本、澳洲、新西蘭、福建及浙江令養殖魚類死亡

資料來源：漁農自然護理署

Can these large scale of Karenia blooms in China coastal waters be linked to climate (weather) signals?



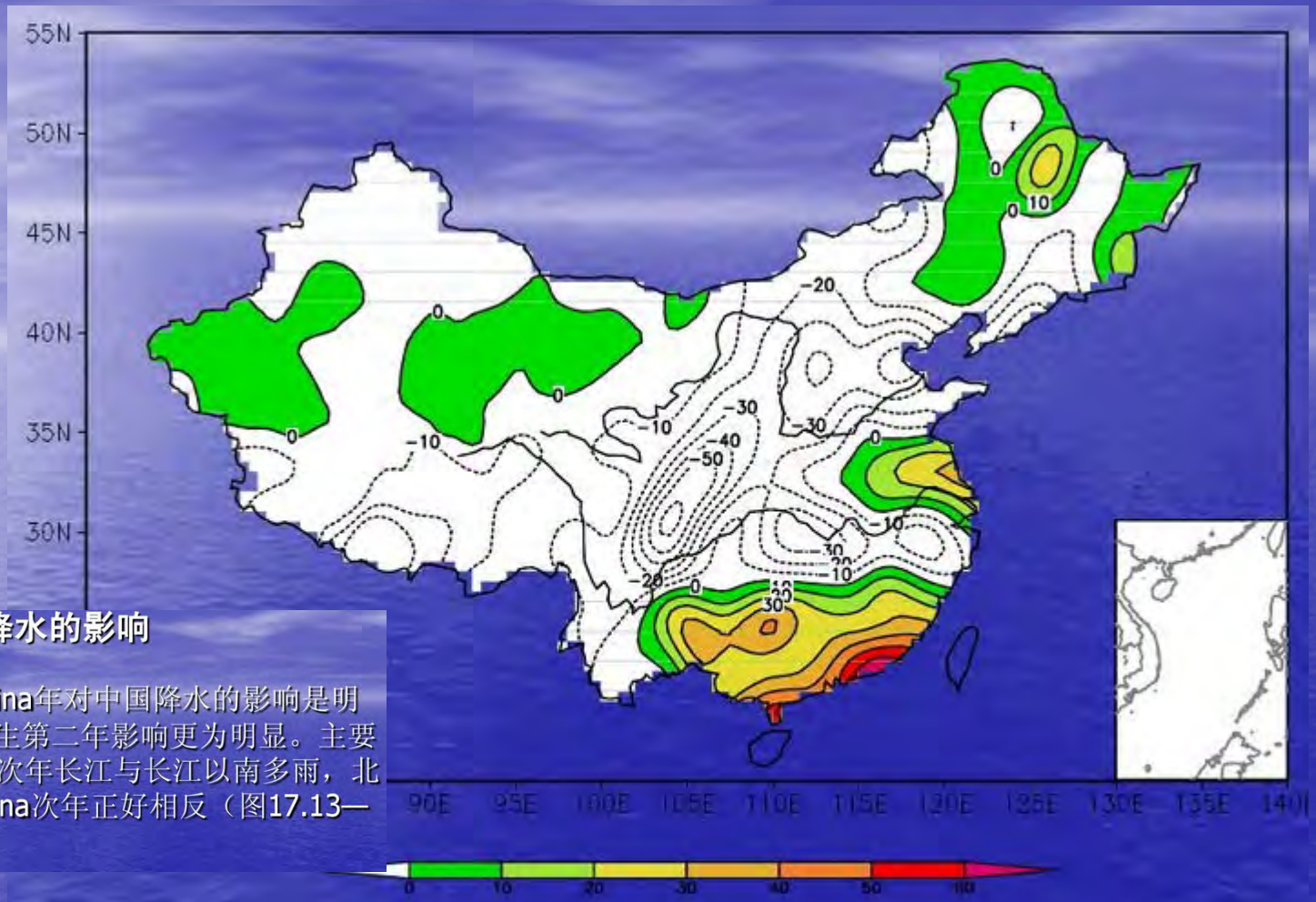


:Large scale blooms of *Karenia*

http://www.bom.gov.au/climate/influences/timeline/

ENSO事件对中国降水的影响

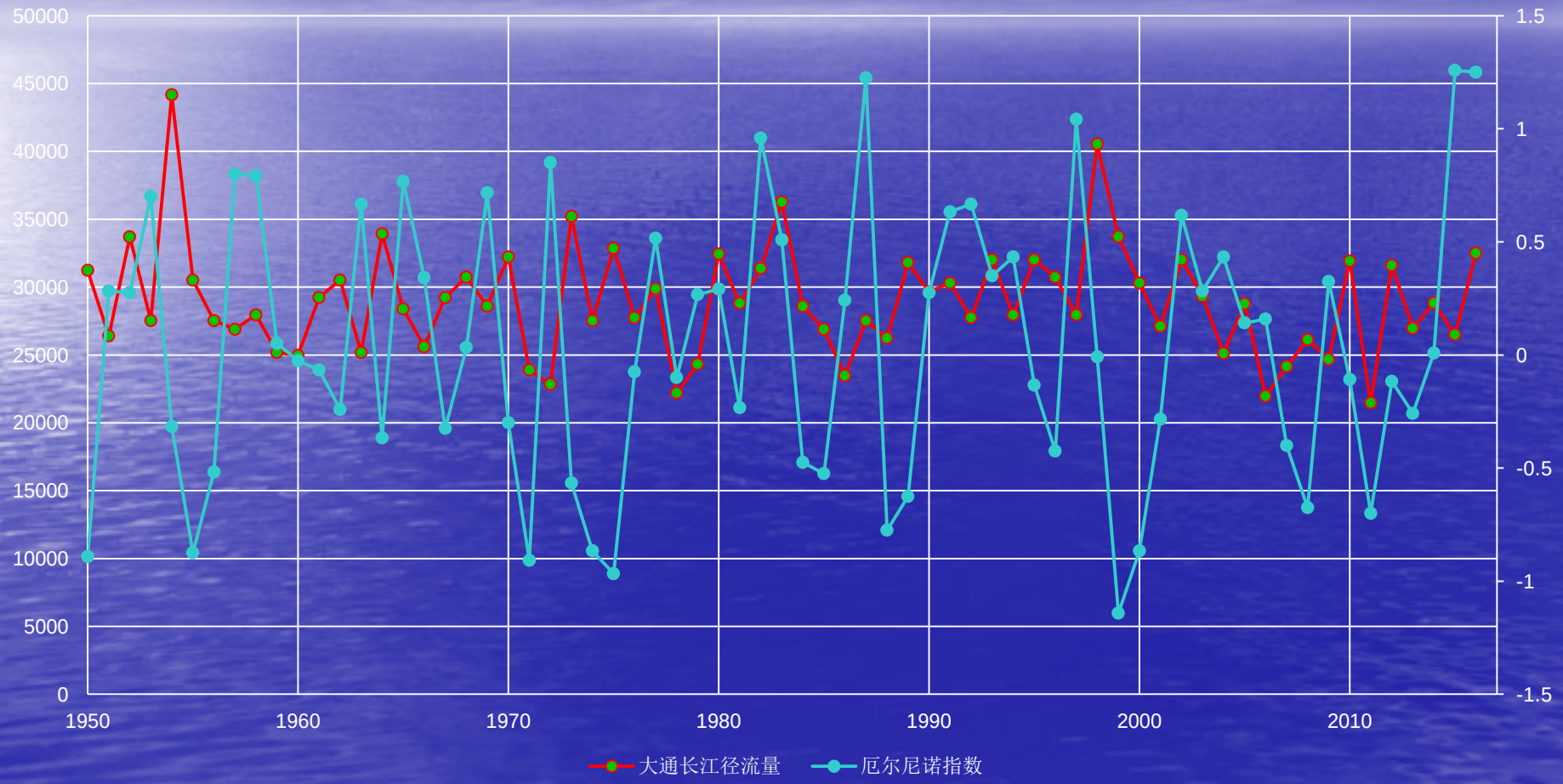
El Nino年与La Nina年对中国降水的影响是明显的，尤其是发生第二年影响更为明显。主要特征是El Nino年次年长江与长江以南多雨，北方少雨，而La Nina次年正好相反（图17.13—图17.16）。



El Nino年对中国降水的影响

El Nino and precipitation in China

El Nino index and runoff of Changjiang River （m^3/s）1950-2016



Precipitation increse next year after El Nino year

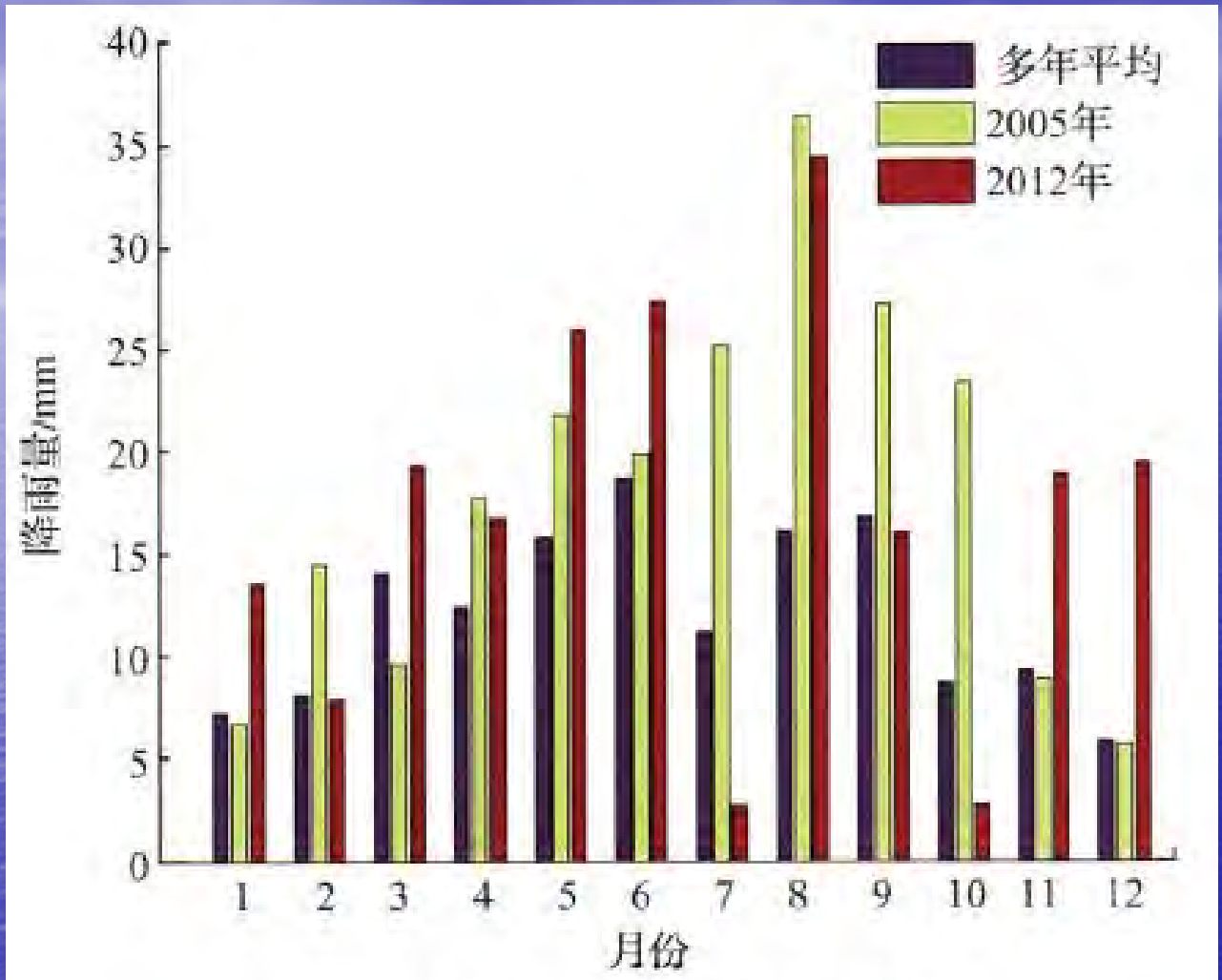
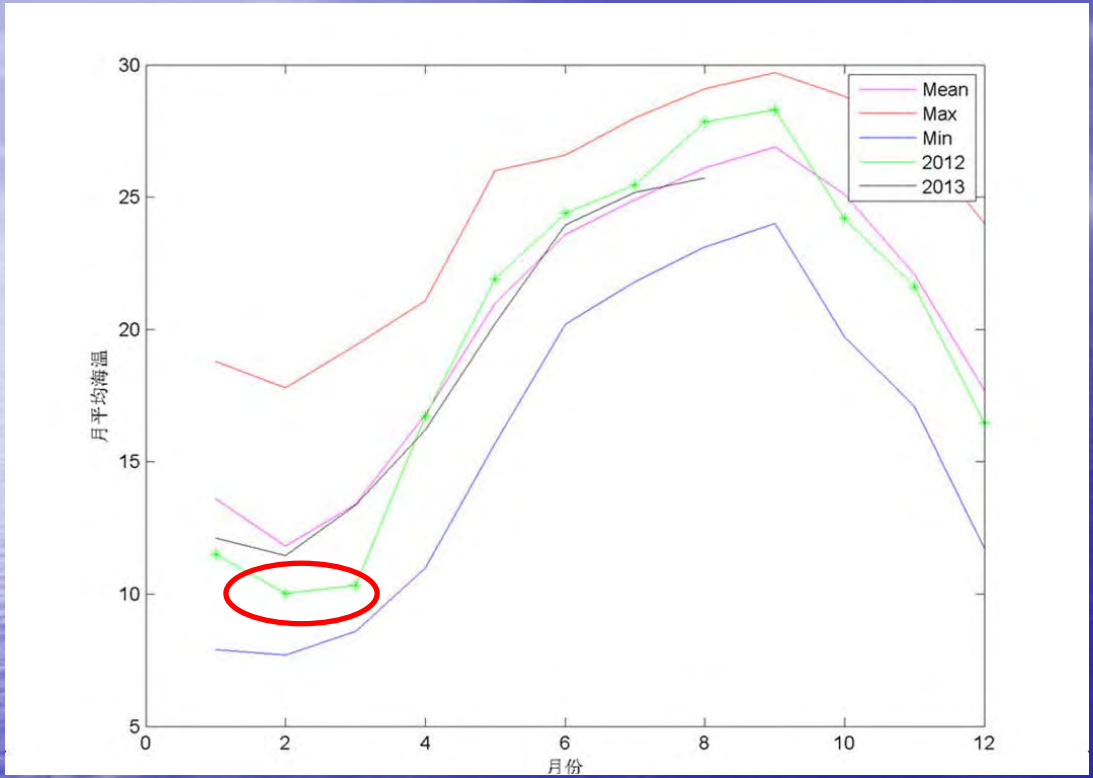
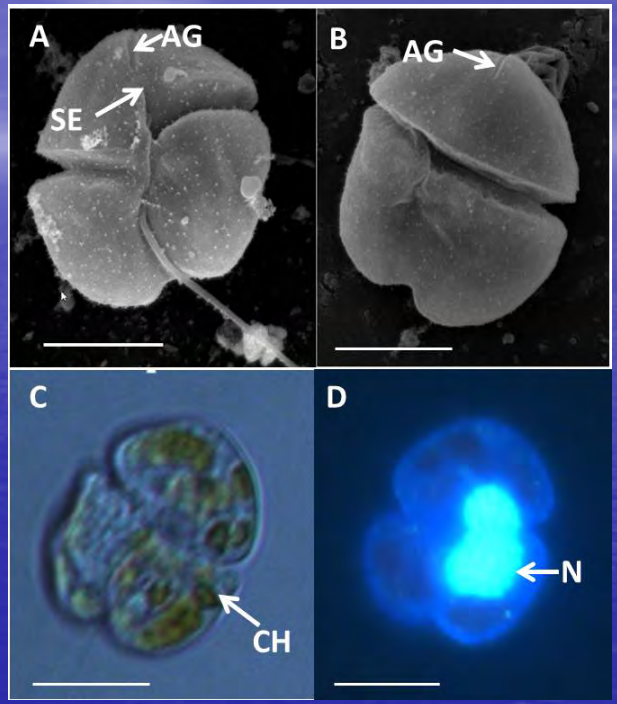


图 12　大陈岛月平均降雨量情况

Fig. 12　Monthly average rainfall in Dachen Island

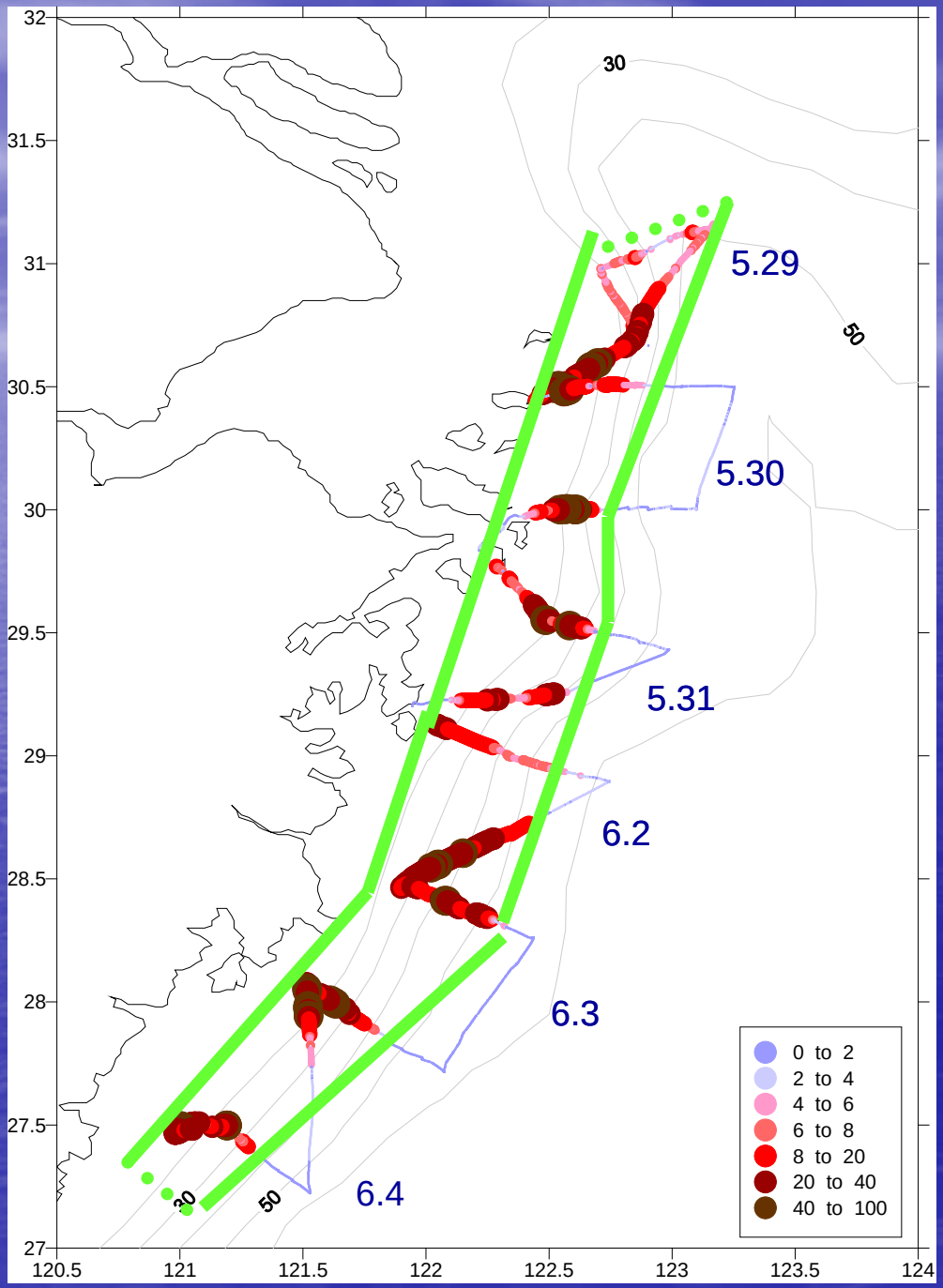




Formation of massive blooms of *Karenia* might be linked to climate signal! Relative cold in winter and rapid increase of T later on probably induced the massive blooms.

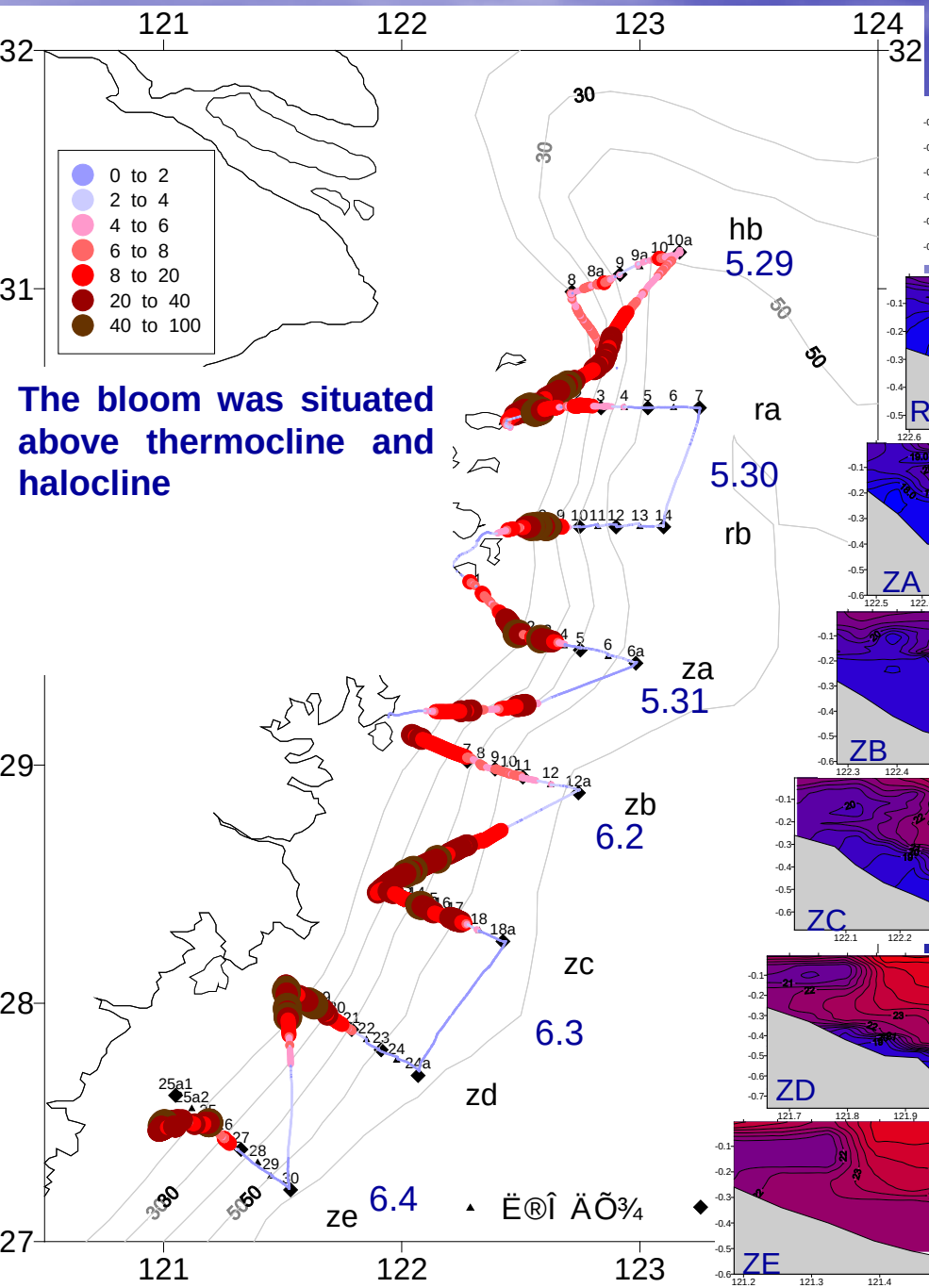
MC2005-4 Chl a

(29 May-4 June,2005)

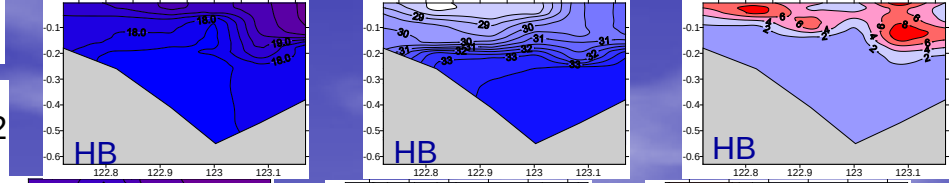


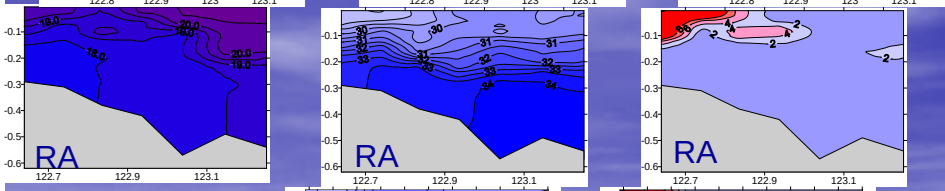
Karenia bloom occupied 15000km^2

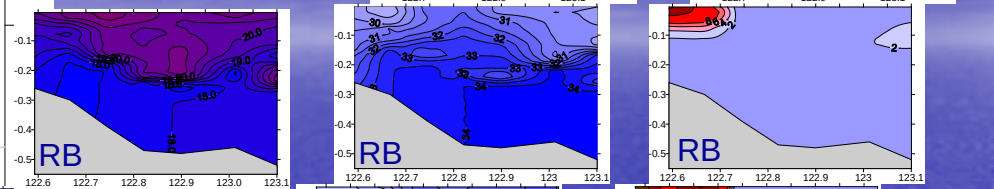
MC2005-4大面表层叶绿素和温度、盐度、叶绿素剖面图

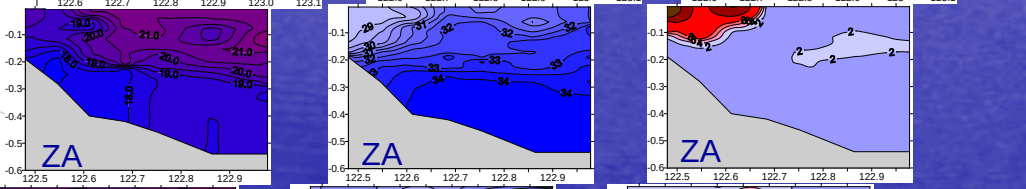


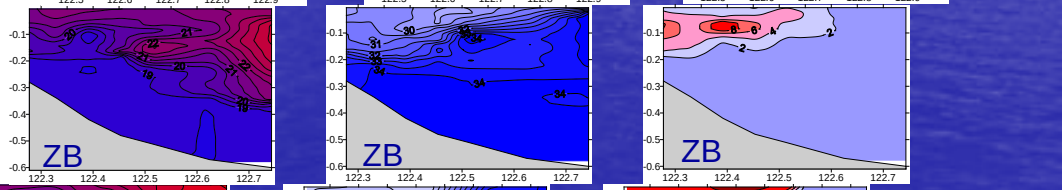
The bloom was situated above thermocline and halocline

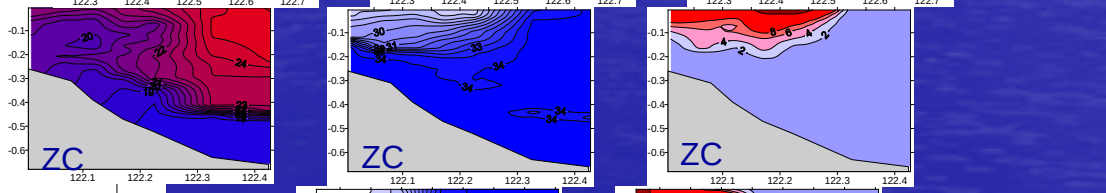


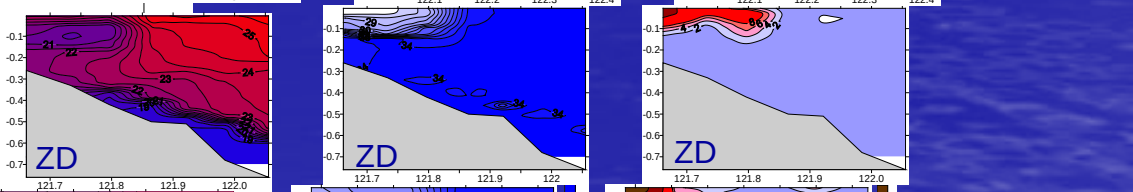


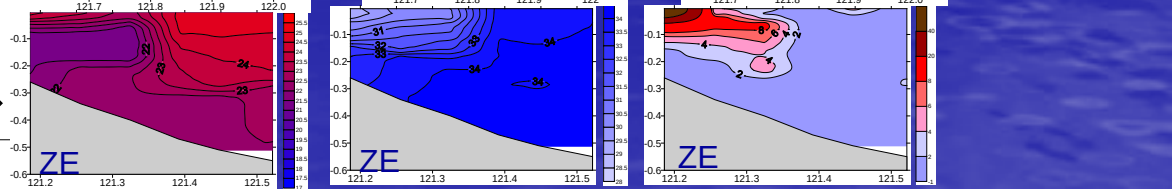




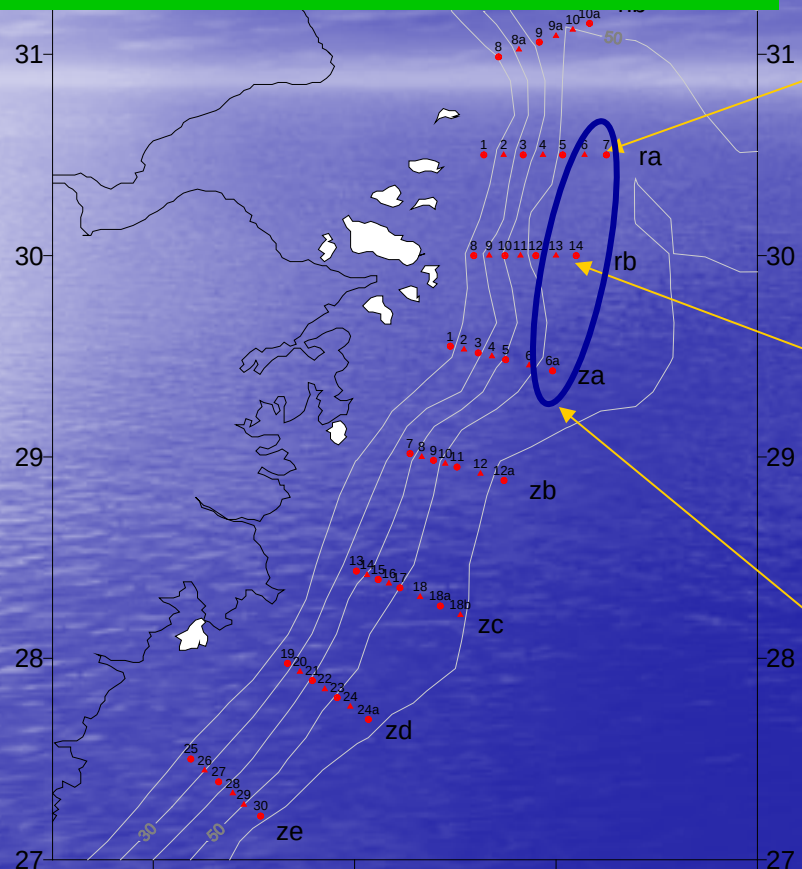


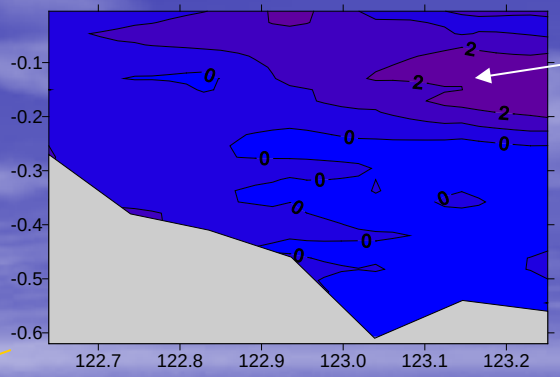


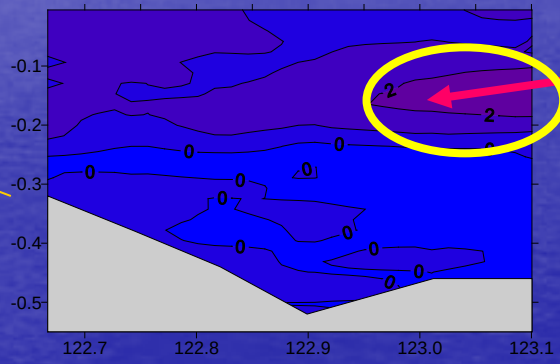


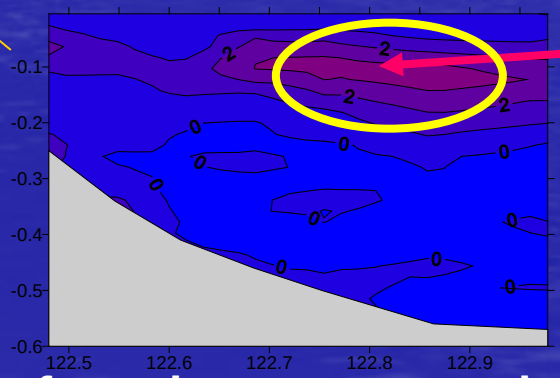


After blooms of diatom, the process of development of Prorocentrum donghaiense did not exist in the subsurface as usual. Instead, Karenia was well developed leading to outbreak of the first largest blooms of this toxic species recorded in ECS in May;





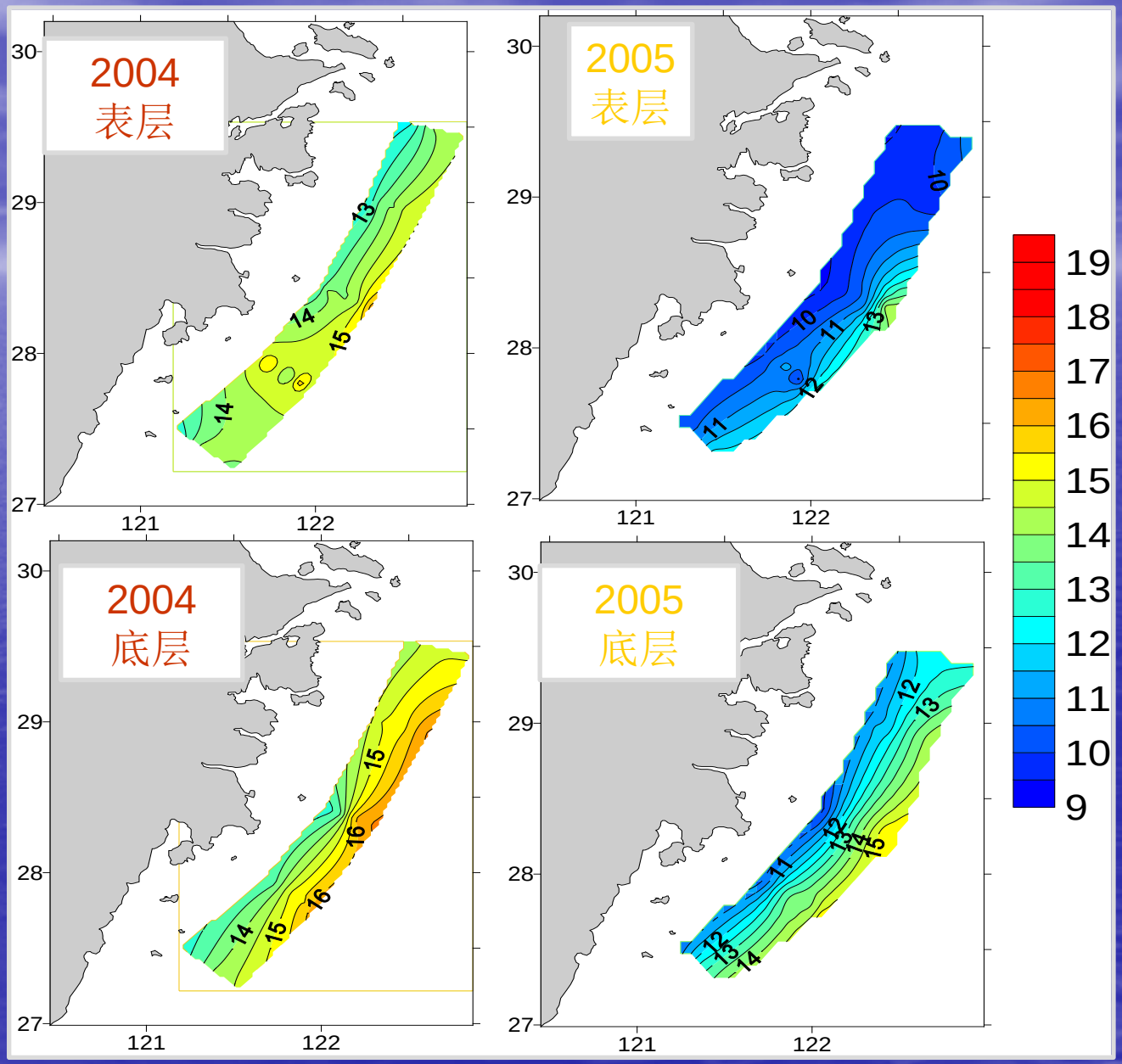




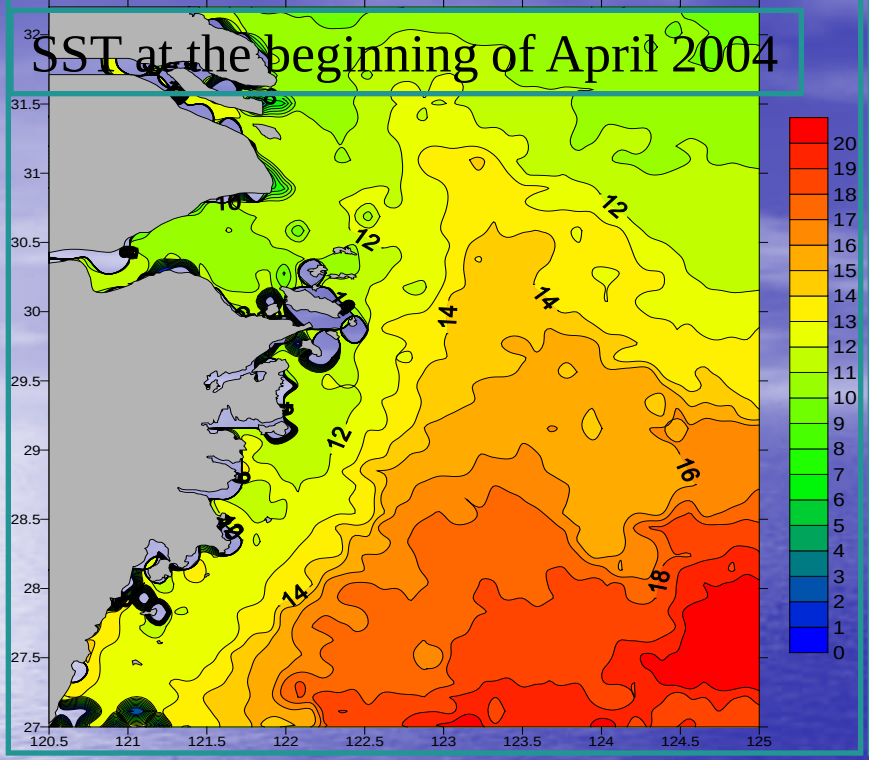
These zones are considered as incubators for subsequent massive blooms

“Pelagic seed banks”

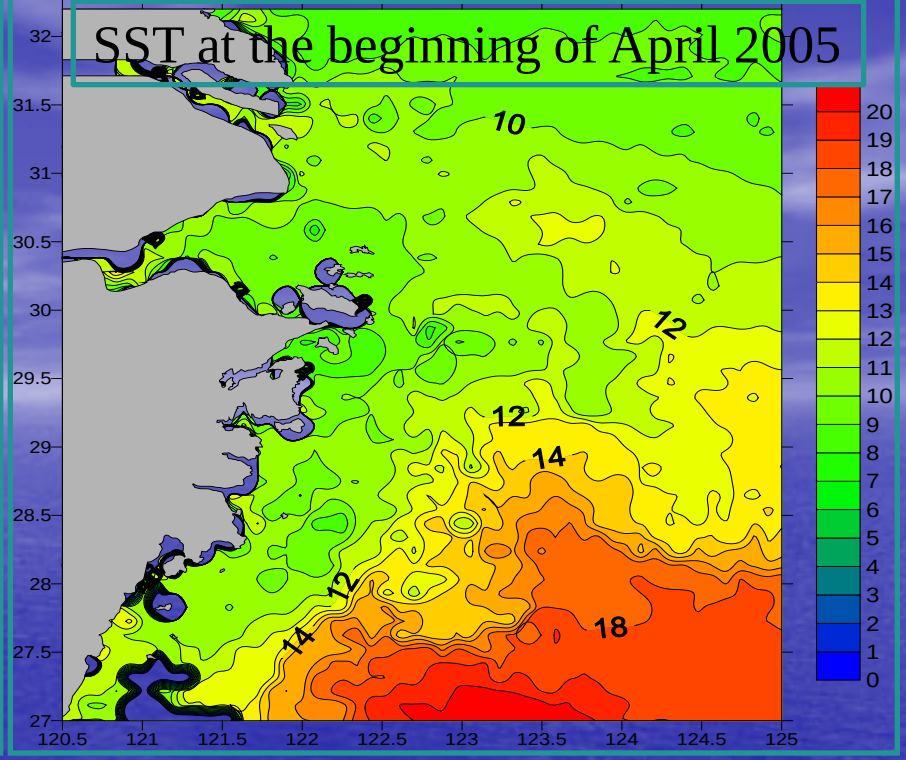
cold and rainy winter (temperature was much lower than previous years, runoff of Yangtze increased 40% in the first three month than normal). Water temperature at the first part of April in 2005 was 3^0C lower than that of 2004. Temperature increased fast in middle of April. Salinity was higher in TWC compared with last years;

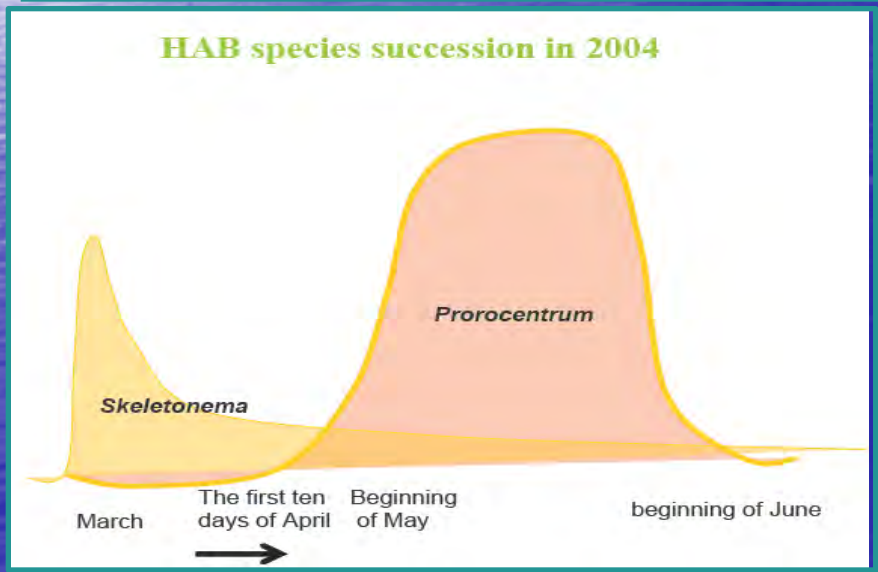


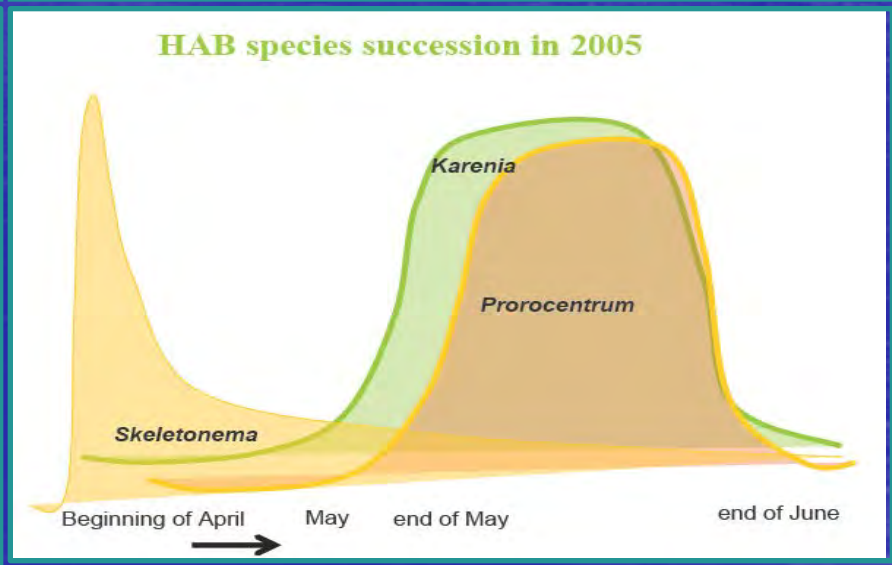
SST at the beginning of April 2004



SST at the beginning of April 2005







Short-term climate change can change the succession pattern of algae in Sea water (ECS). Toxic species may prevail due to climate variation

Summary:

Karenia mikimotoi bloom was first recorded in HongKong waters 1980 in China. The second record was probably in Xiamen Harbor, 1986. However, over 120 blooms caused by this species occurred in China coastal waters since 1998. Particularly, the massive bloom of *K. mikimotoi* in the South China Sea in 1998, 2016 and in the East China Sea in 2005, 2012 resulted in the heavy loss of fish and shellfish farming industry. These four large scale HAB events seemed corresponding to climate, El Nino, signal. Generally, there is more rainfall in the east and south coastal areas in China during El Nino years. Air and sea water temperature in winter time are lower than the mean level. Our results show that water temperature in March 2005, 2012 was obviously lower than that of normal years in Zhejiang and Fujian coastal sea especially in nearshore region of coastal waters compared to the same period of other years. Special meteorological and sea conditions (low air temperature and strong northern monsoon, more rainfall and feeblish Taiwan Warm Current) were observed from January to March. Warming rate of temperature was relatively fast in April and May. These special conditions might provide a well physical, biological and chemical environment for the growth of *K. mikimotoi* to compete with other species. In the case of 2005, *K. mikimotoi* became dominant late April in an offshore subsurface layer after a diatom bloom. This led to the development of the first large-scale bloom of *K. mikimotoi* recorded in the ECS which caused severe damage to farmed caged fish in inshore waters in late May and early June. There is a strong need to better identify long-term trends for this HAB organism in the context of climate change pressures.

Thank you