Evolvement of HAB causative species during the past five decades in Chinese coastal waters

Douding Lu , Xinfeng Dai ,

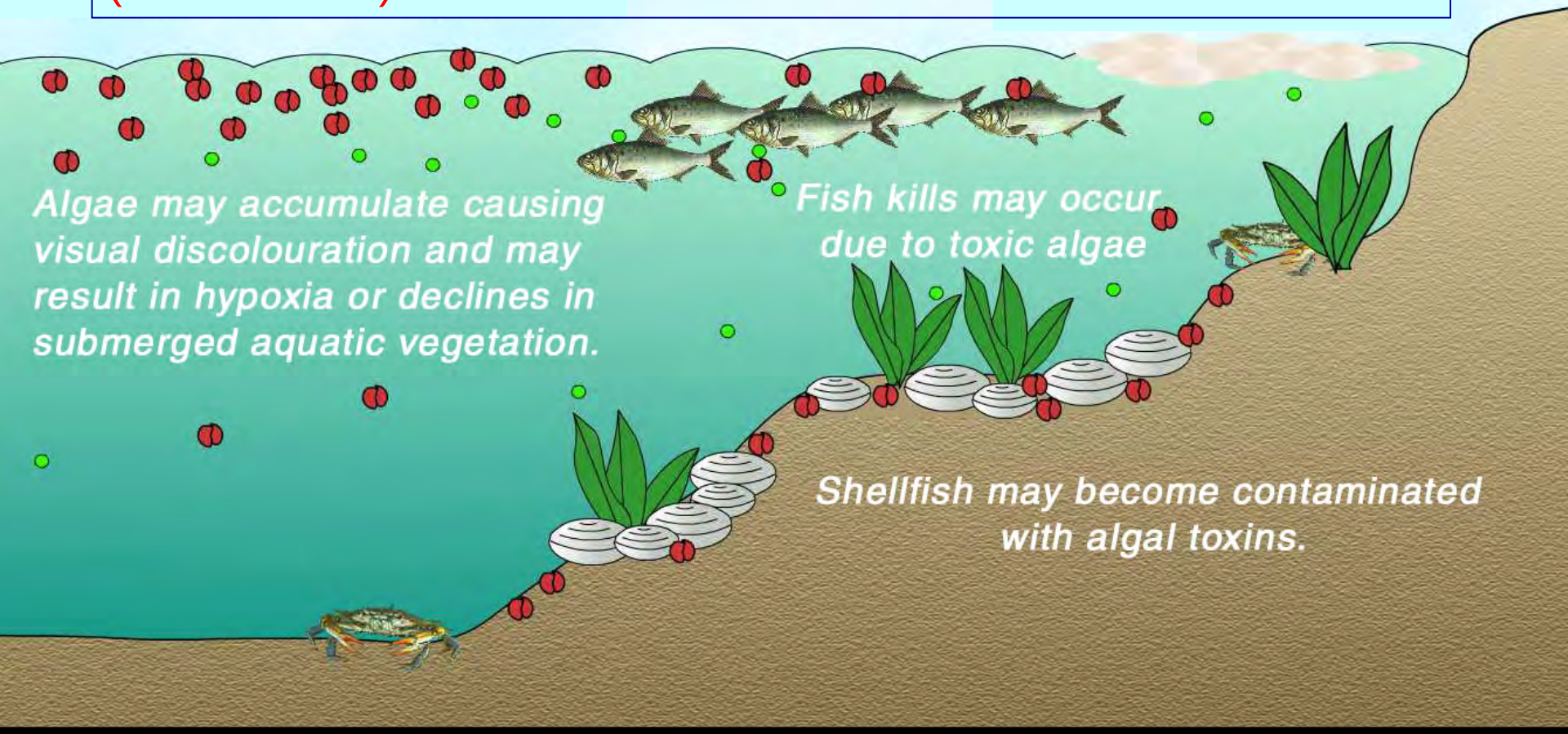
Key Laboratory of Marine Ecosystem and Biogeochemistry, Second Institute of Oceanography, SOA, Hangzhou 310012, China Email: doudinglu@sio.org.cn

FUTURE OSM 15 – 18 April, 2014

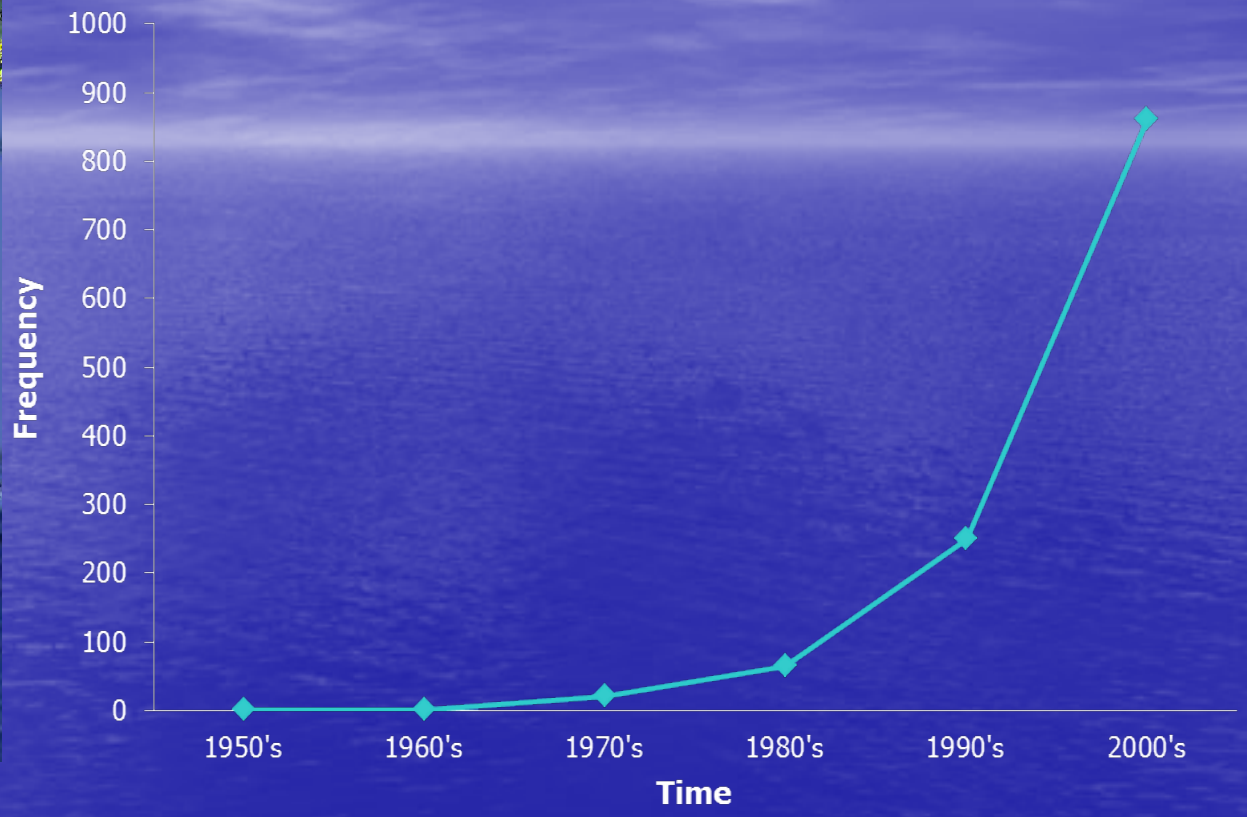
Points:

- **Apparent trend of increasing HABs**
- **Shift of causative species**
- **Possible links**

Harmful Algal Bloom: Proliferations of algae in marine or brackish waters can cause massive fish kills, contaminate seafood with toxins, and alter ecosystems in ways that humans perceive as harmful. (GEOHAB SP)



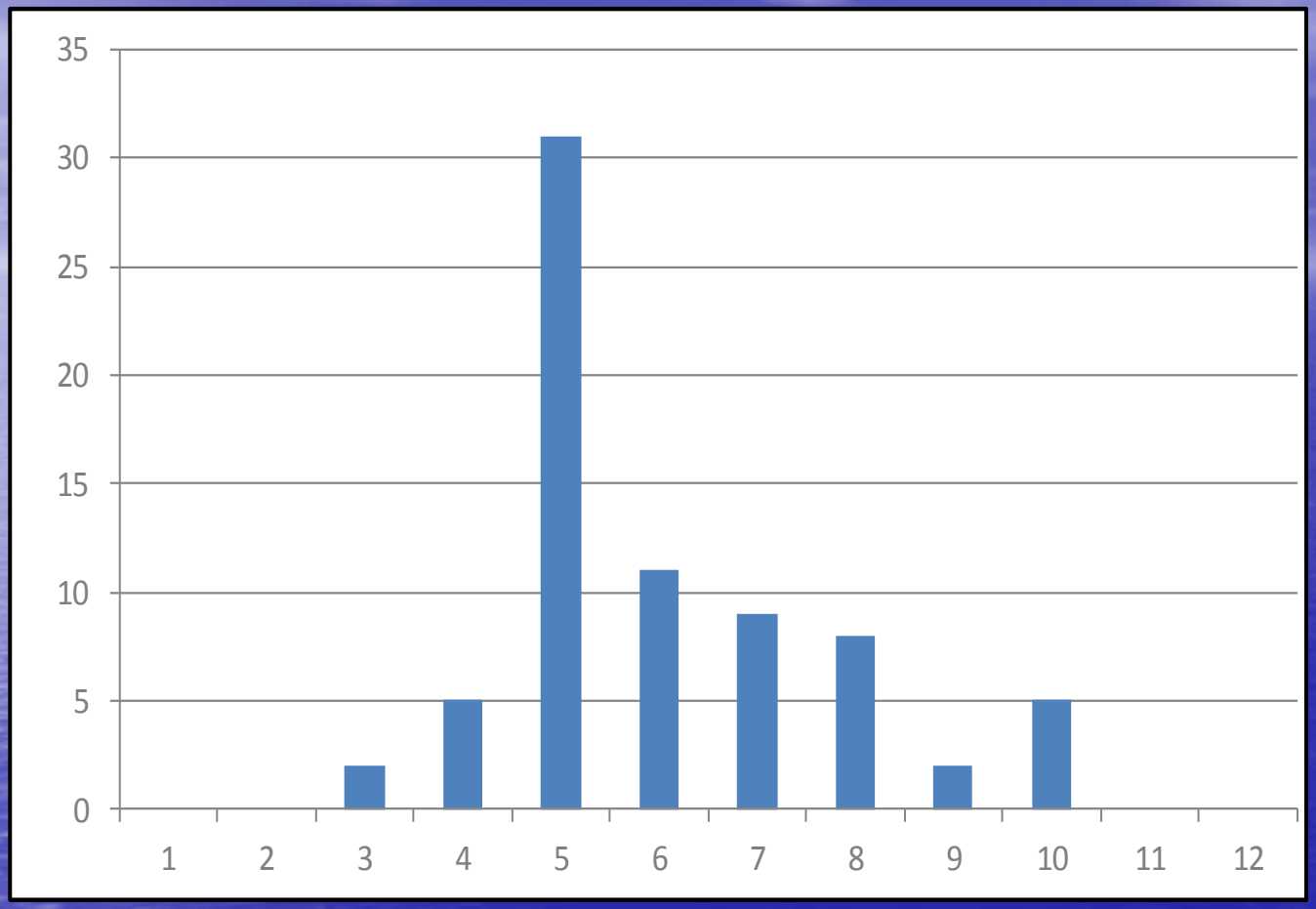
HABs may influence ecosystems in a variety of ways.



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

Occurrence of HABs in China (2012)

Location	Frequency
Bohai Sea	8
Yellow Sea	11
East China Sea	38
South China Sea	16
Total	73

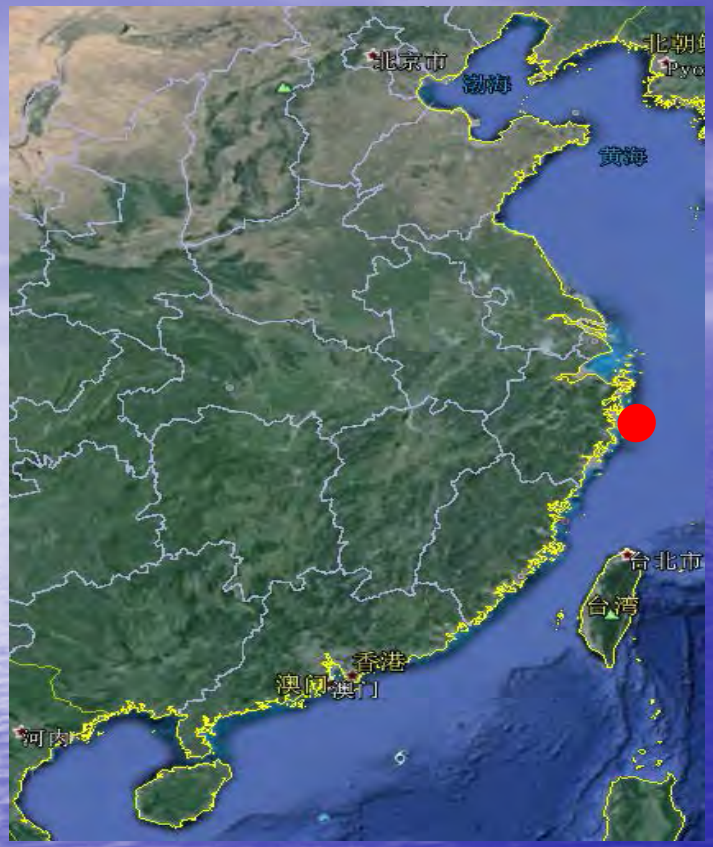


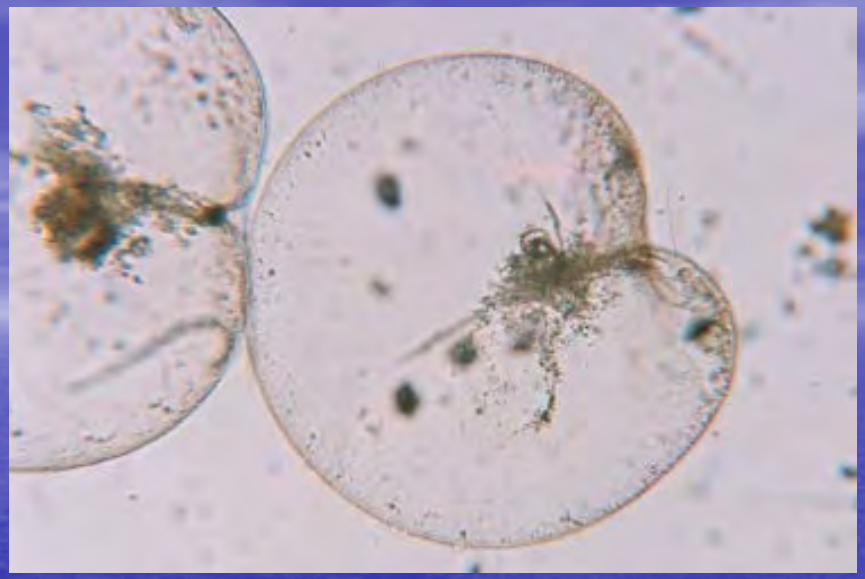
Seasonal pattern of HABs in Chinese coastal waters

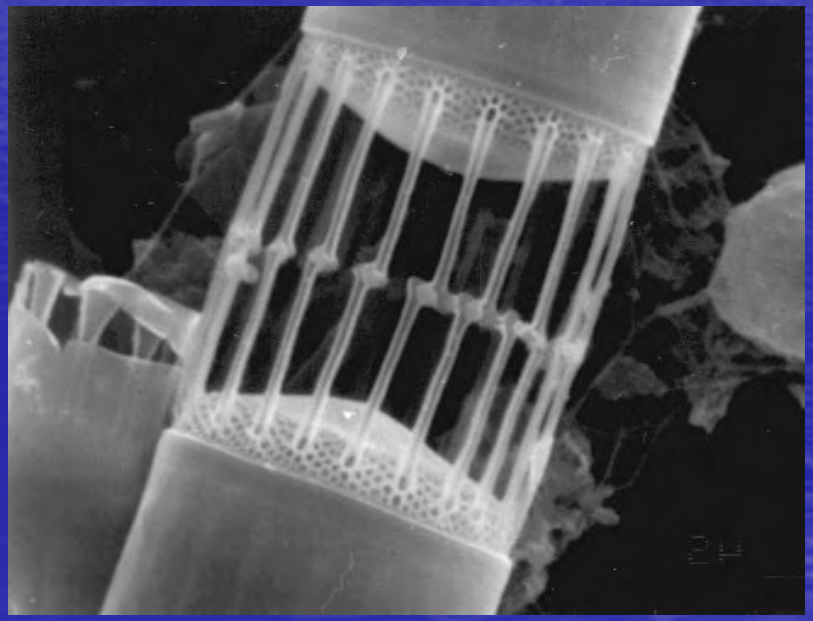
List of HAB species in Chinese coastal waters

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
Ceratium furca (Ehrenberg) Claparede et Lachmann	*Cochlodinium polykrikoides* Margalef
Ceratium 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	

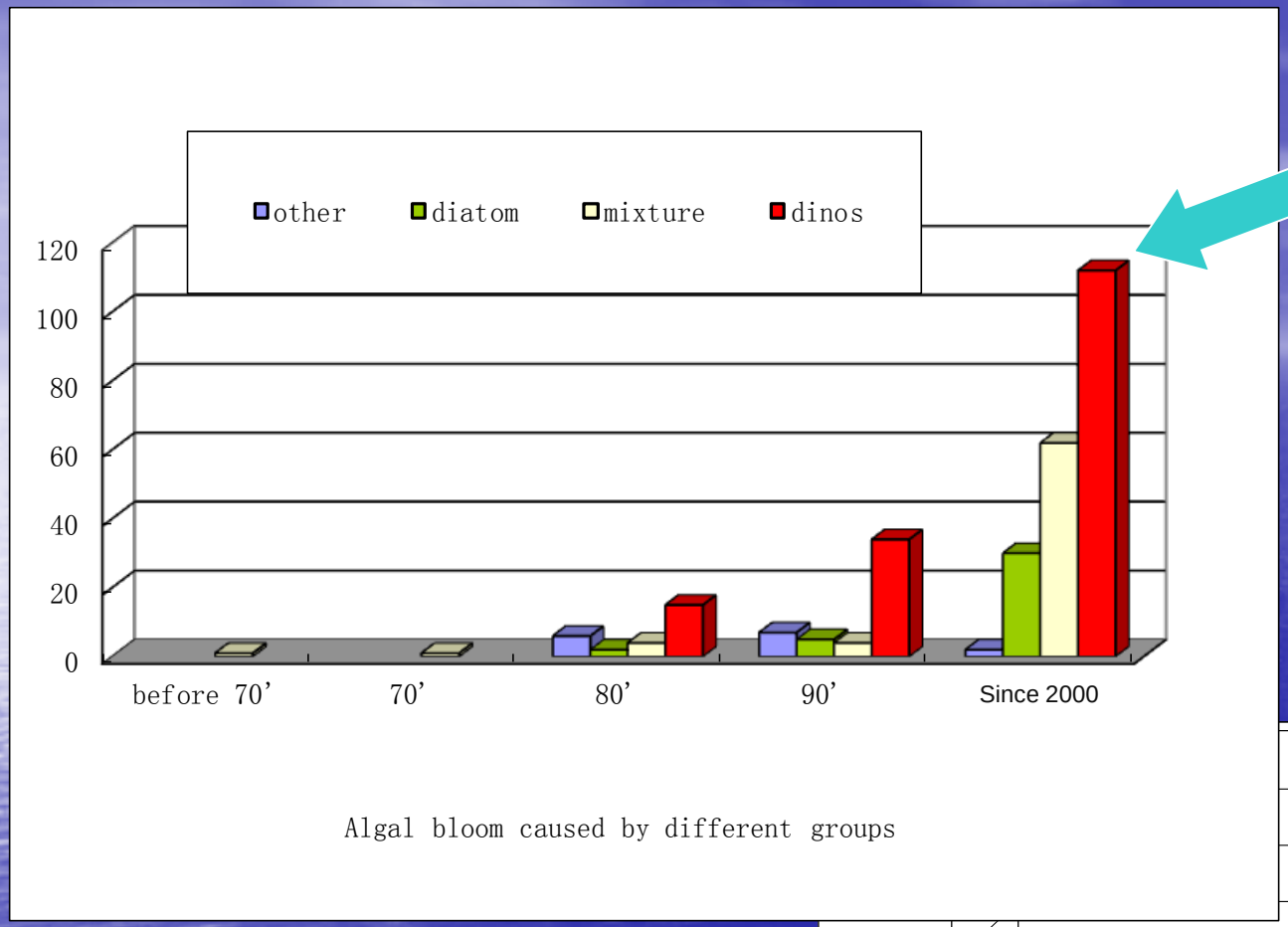
Causative species		Bloom information and impacts
Raphidophytes	*Chattonella marina* Hara et Chihara	fish kill, bloom in BS, YS and SCS
	Heterosigma akashiwo Hada	fish kill, bloom in BS, ECS and SCS
Prymnesiophytes	*Phaeocystis globosa* Scherffel	hemolytic toxins, bloom in BS, ECS and SCS
Diatom	*Pseudo-nitzschia 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



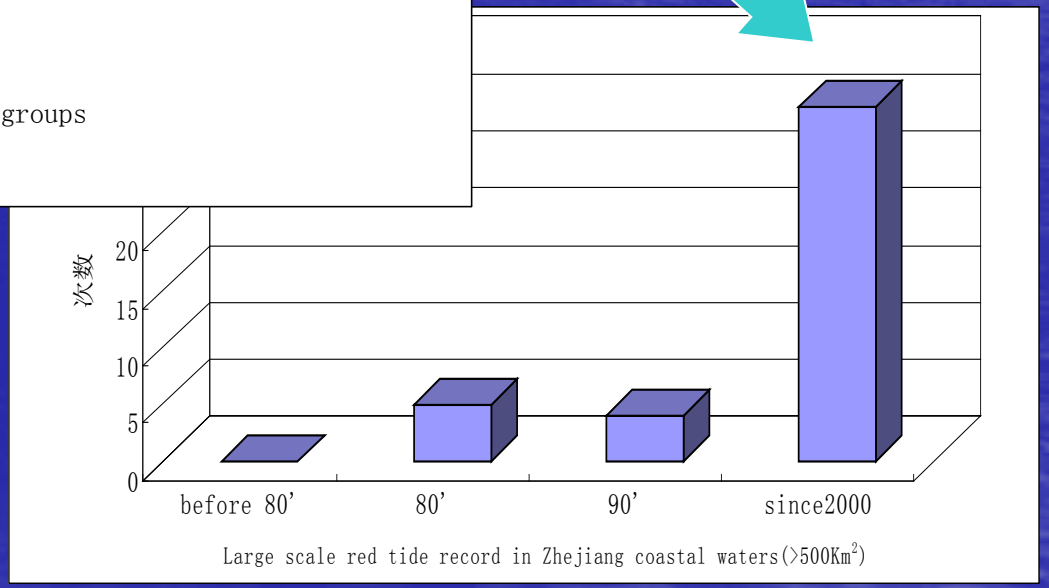




The first red tide was recorded in Zhejiang coast water in 1933. The causative species was *Noctiluca*. co-occurring species *was Skeletonema*.



Algal bloom caused by different groups

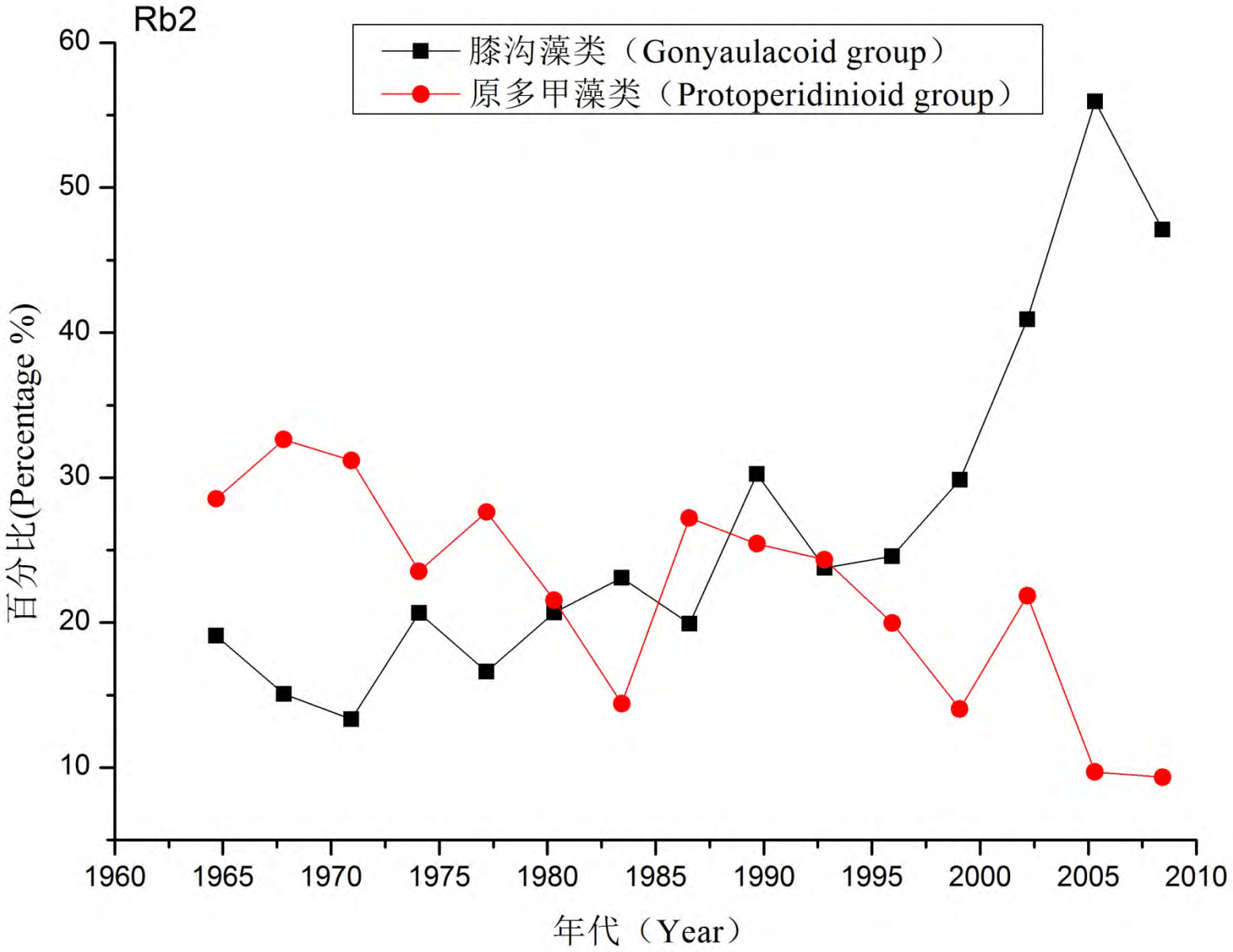


Large scale red tide record in Zhejiang coastal waters(>500Km^2)

More record of algal blooms Contributed by dinoflagellates in Zhejiang coastal waters in the last 4 decades

Main HAB species in the ECS

Species	Harmful effects	Before 70	70’	80’	90’	Since 2000
Noctiluca scientillans	High biomass	+	+	+	+	+
Skeletonema costatum	High biomass	+	+	+	+	+
Pseudo-nitzschia spp.	ASP		+	+	+	+
Dinophysis spp.	DSP			+	+	+
Trichodesmium spp.	High biomass			+	+	+
Akashiwo sanguinea	High biomass				+	+
Prorocentrum donghaiense	High biomass				+	+
**** Karenia mikimotoi***	Fish kill					+
**** Karenia brevis***	NSP					+
****Alexandrium* spp.**	PSP					+
Heterosigma akashiwo *Chattonella marina* *Chattonena ovata* *Fibrocapsa japonica*	Fish kill					+
Karlodinium venificum	Fish kill					+
Cochlodinium polykrikoides						+


Rb2
膝沟藻类（Gonyaulacoid group）
原多甲藻类（Protoperidinioid group）
百分比(Percentage %)
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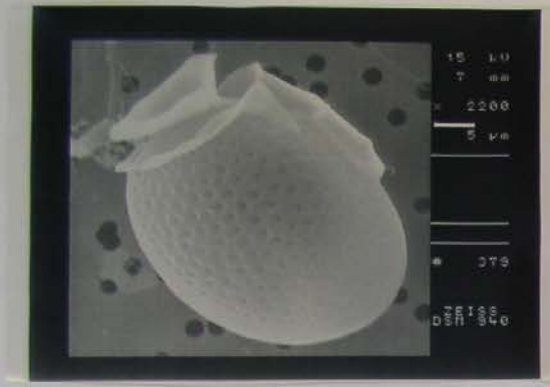
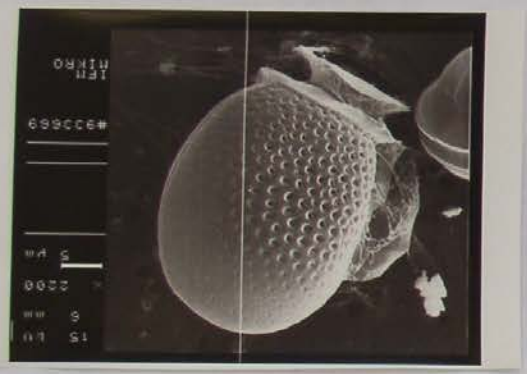
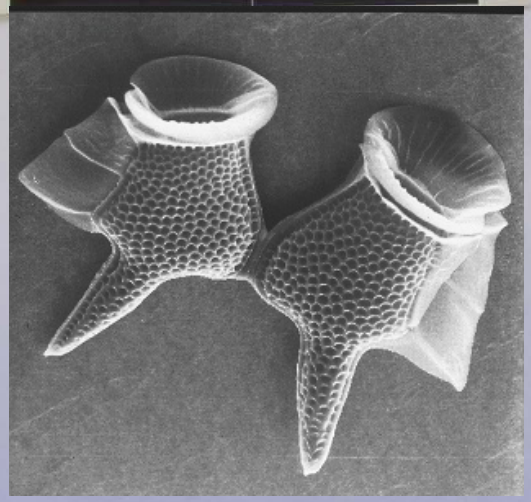
40
30
20
10
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
年代（Year）

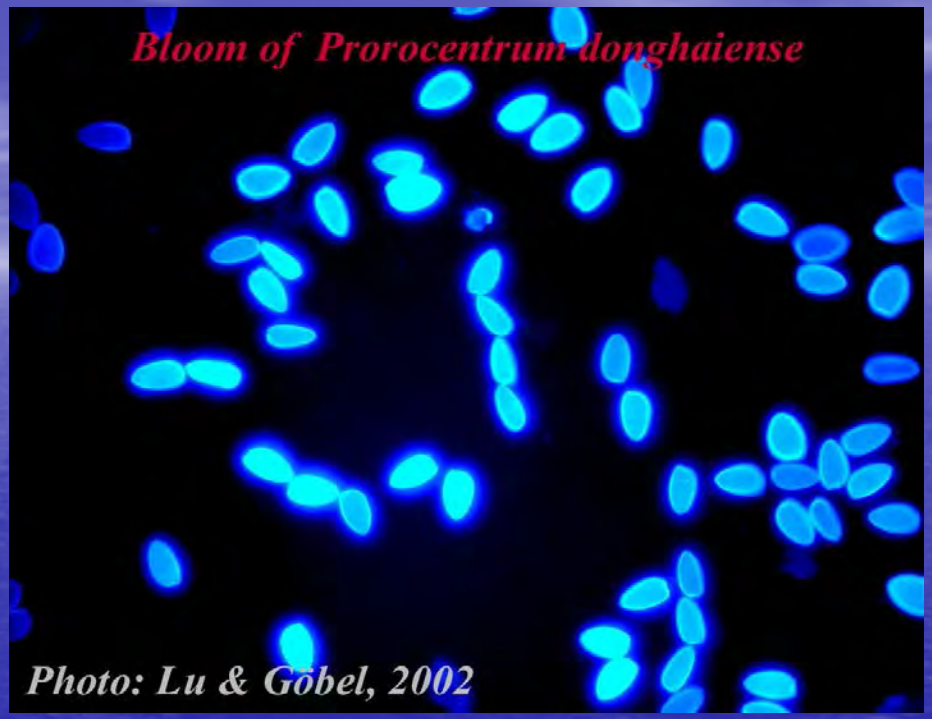






Potentially DSP producer: *Dinophysis* spp.

Prorocentrum donghaiense Lu



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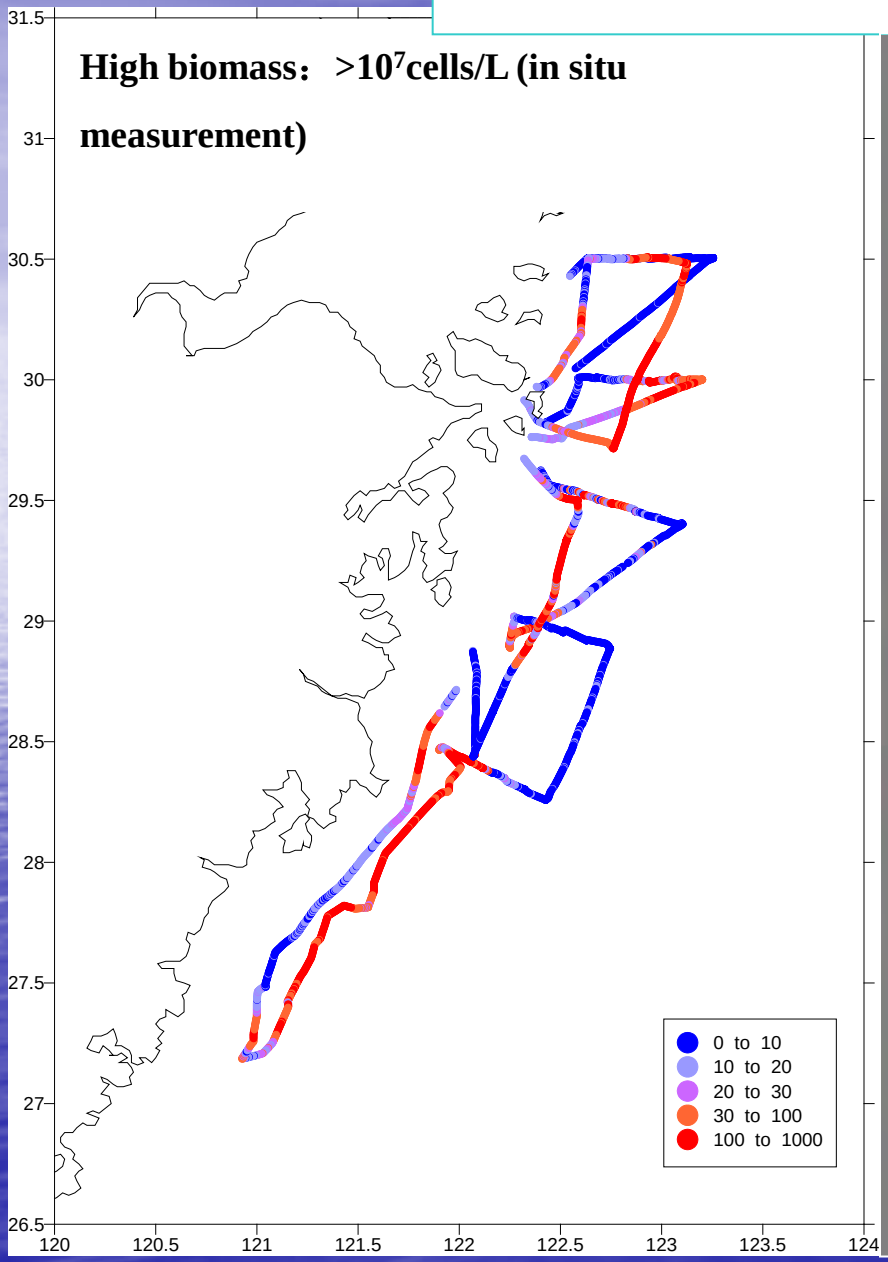
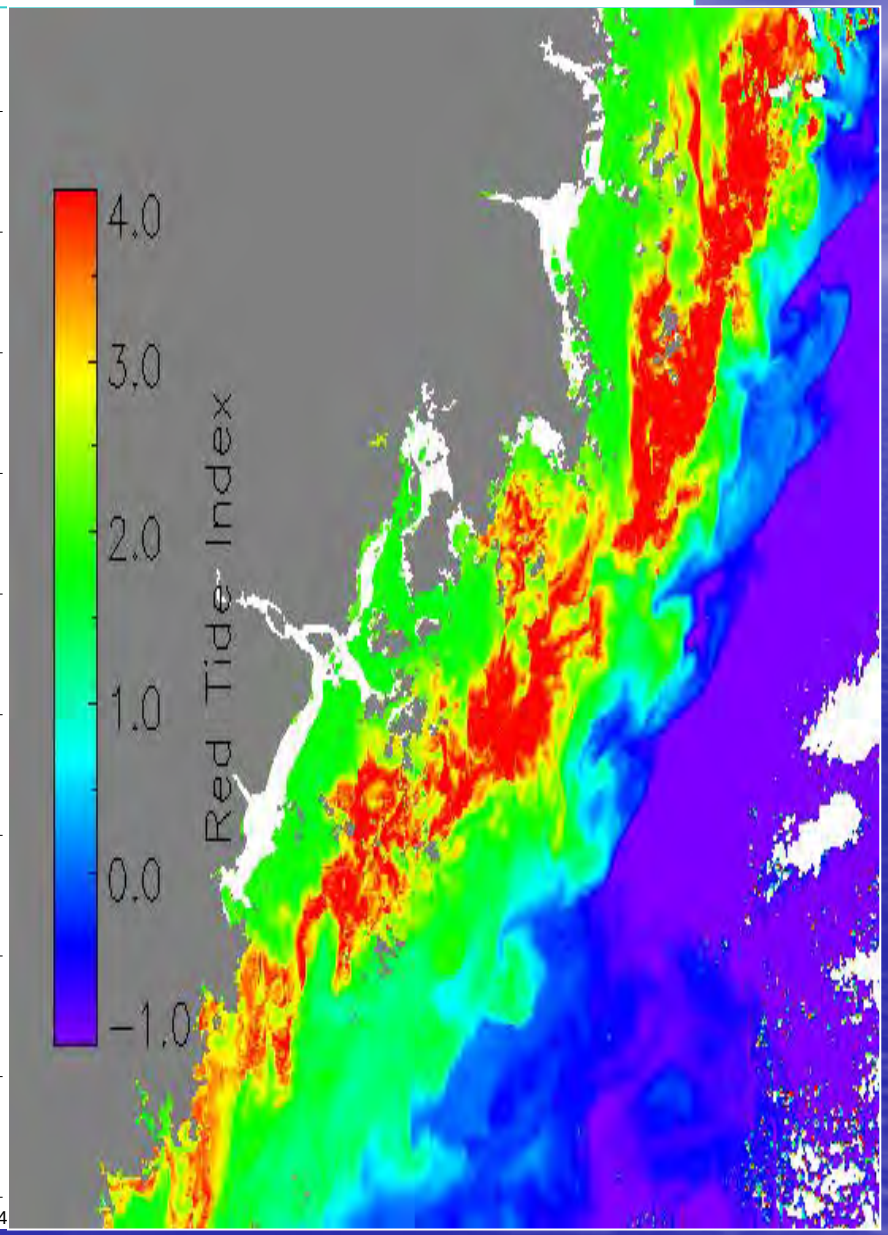
Morphological and genetic study of *Prorocentrum donghaiense* Lu from the East China Sea, and comparison with some related *Prorocentrum* species

Douding Lu[a,*], Jeanette Goebel[b], Yuzao Qi[c], Jingzhong Zou[d], Xiaotian Han[d], Yahui Gao[e], Yeguang Li[f]

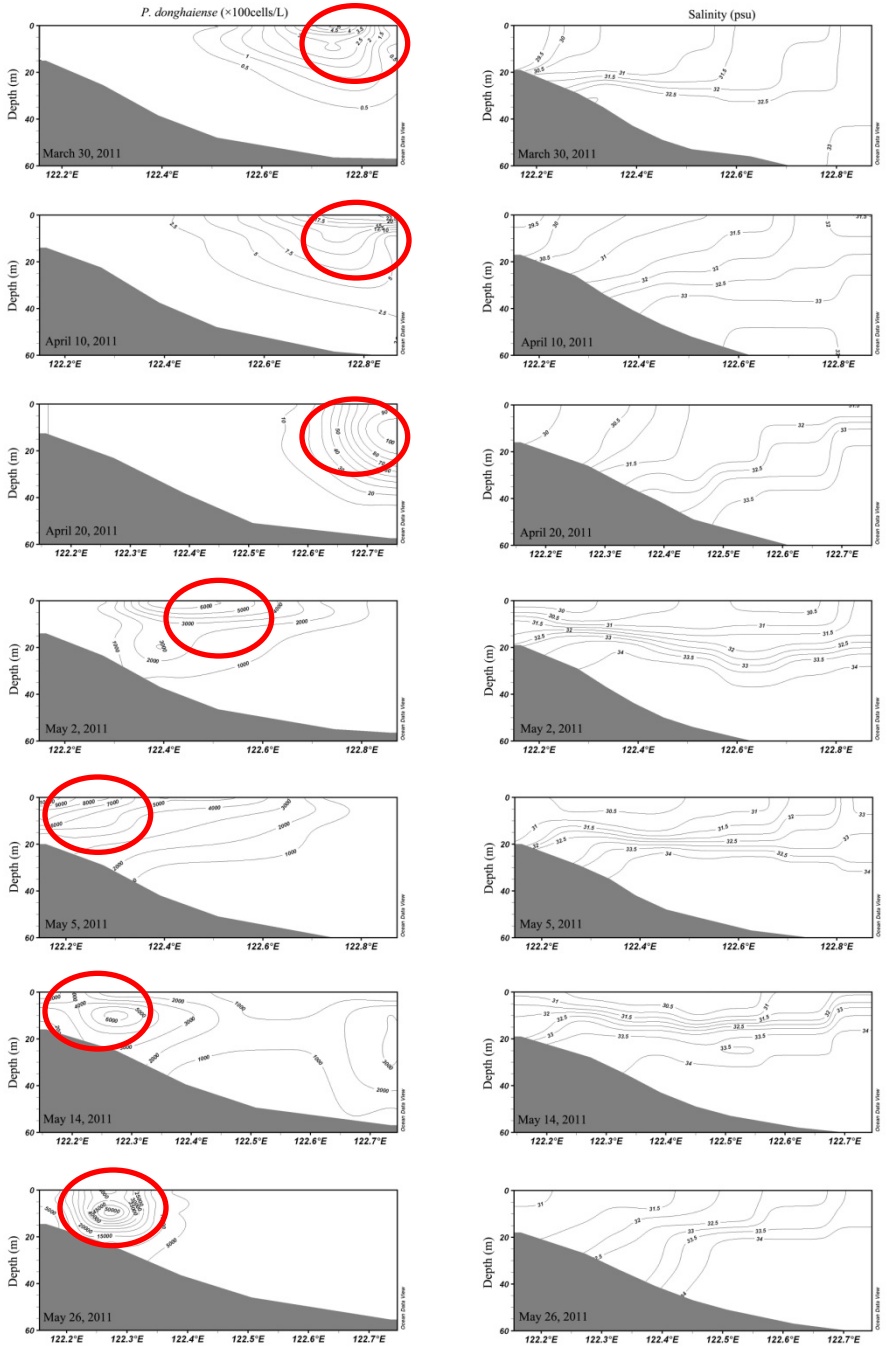
Recurrent bloom of *Prorocentrum* in the ECS





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.**



Vertical profiles of *P. donghaiense* abundance (left panels) and salinity (right panels) on the transect zb at time series in 2011

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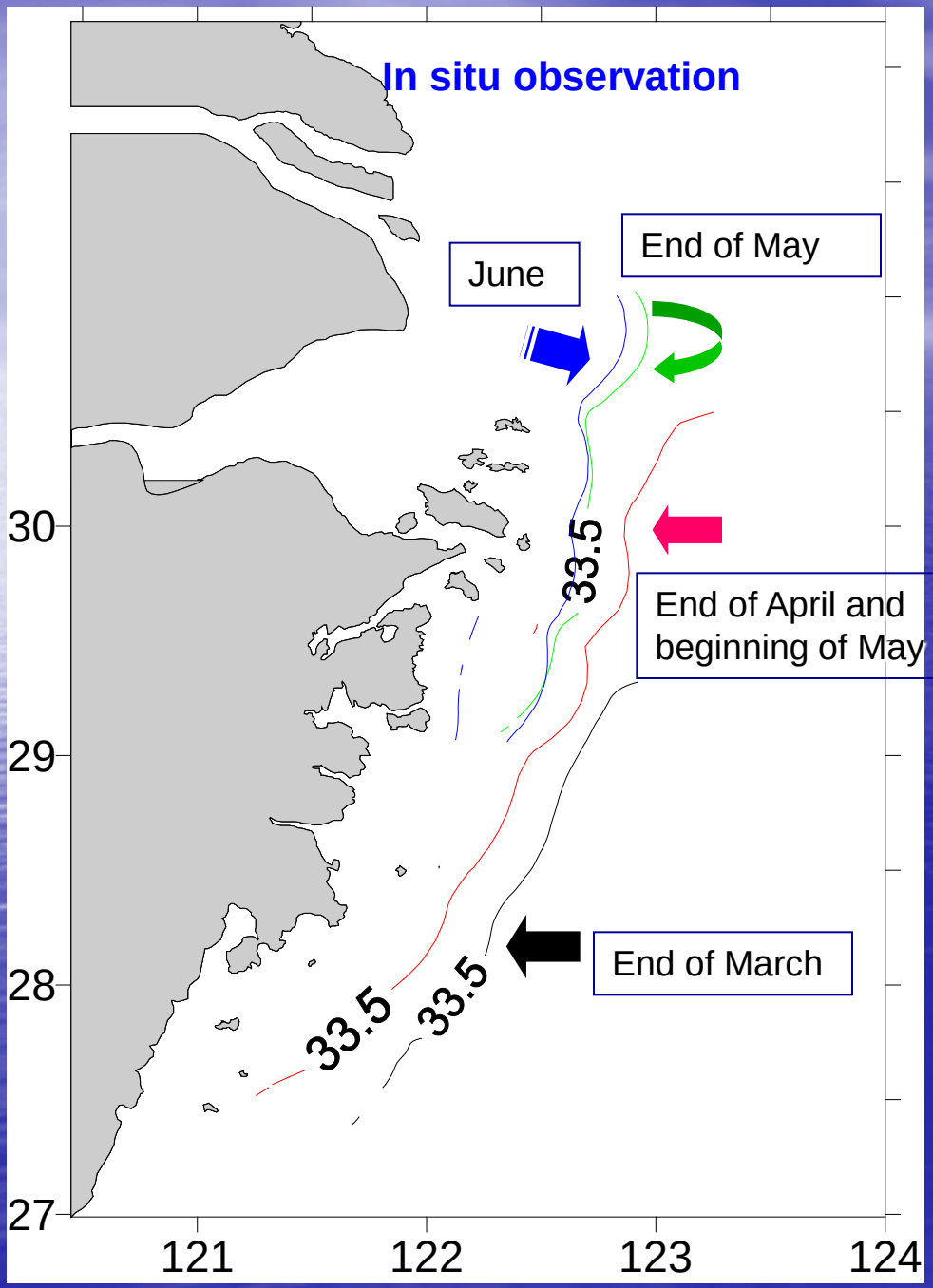
PLOS ONE

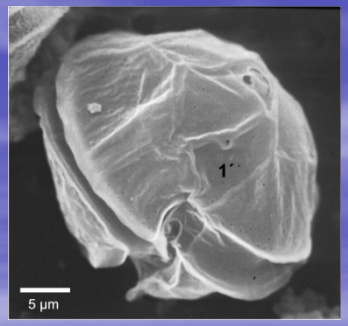
The Correlation between *Prorocentrum donghaiense* Blooms and the Taiwan Warm Current in the East China Sea - Evidence for the "Pelagic Seed Bank" Hypothesis

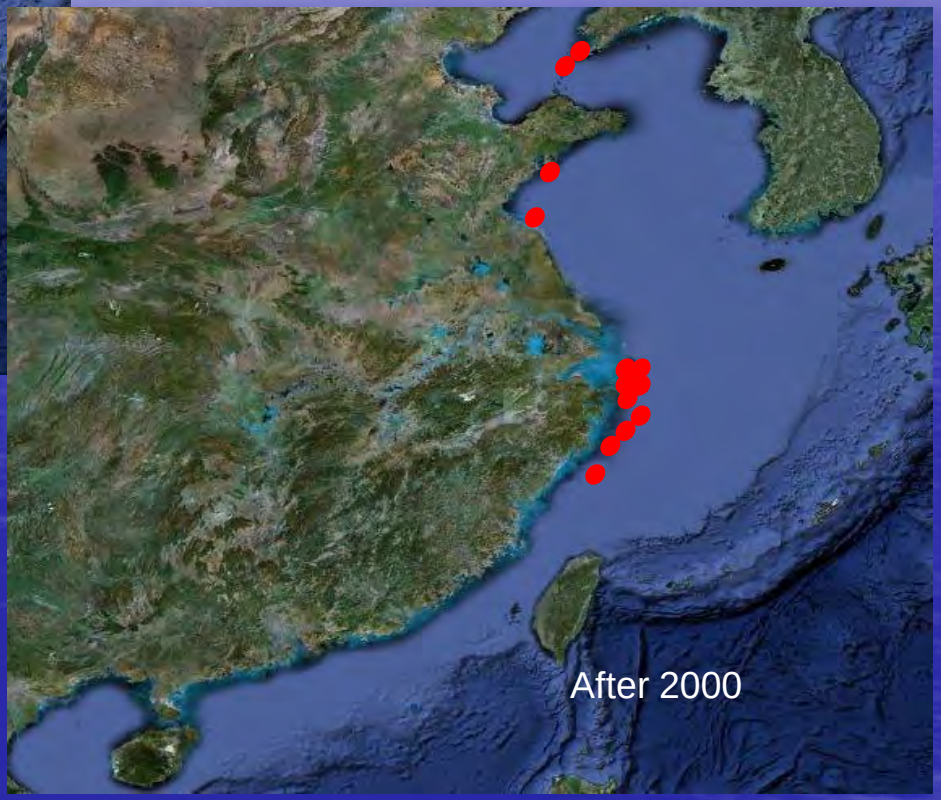
Xinfeng Dai, Douding Lu*, Weibing Guan, Ping Xia, Hongxia Wang, Piaoxia He, Dongsheng Zhang

State Key Laboratory of Satellite Ocean Environment Dynamics, The Second Institute of Oceanography, SOA, Hangzhou, China

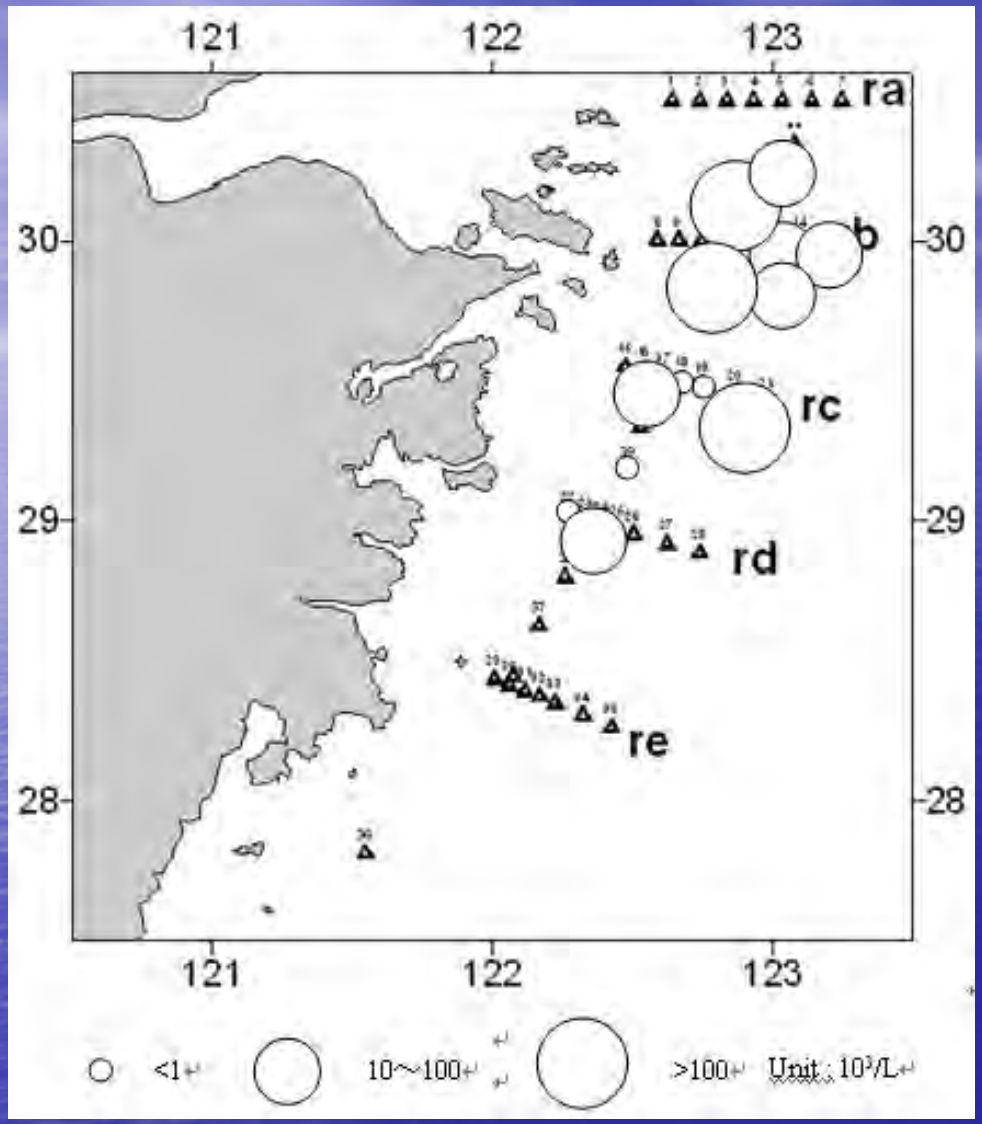


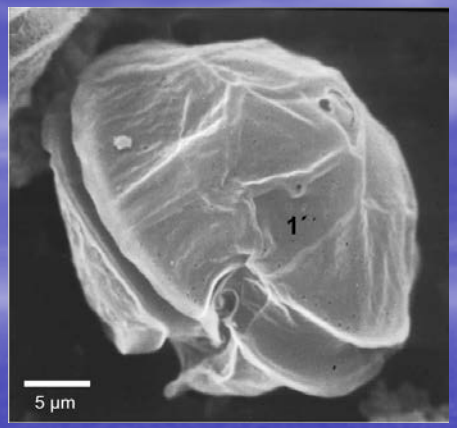
In spring, inshore area was invaded by high salinity water, indicating more influence of TWC





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.





Alexandrium bloom:

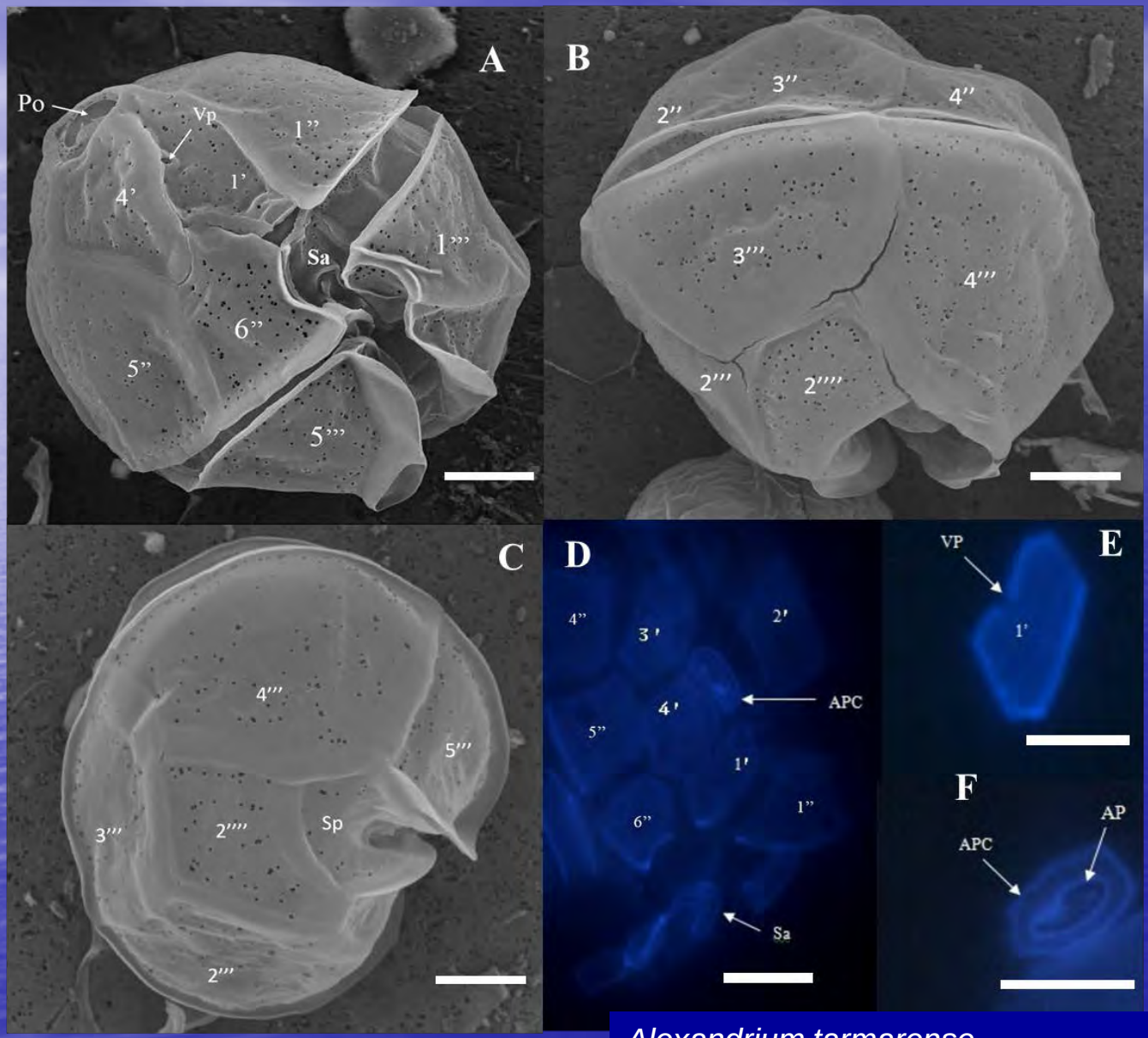
May 2002;

Nov. 2003

(highest cell concentration: 10^6 cells/L);

May 2004, 2013

Blooms caused by *Alexandriun tamrense/catenella*



Alexandrium tarmarense

基于5.8S rDNA及ITS序列系统发育树：

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

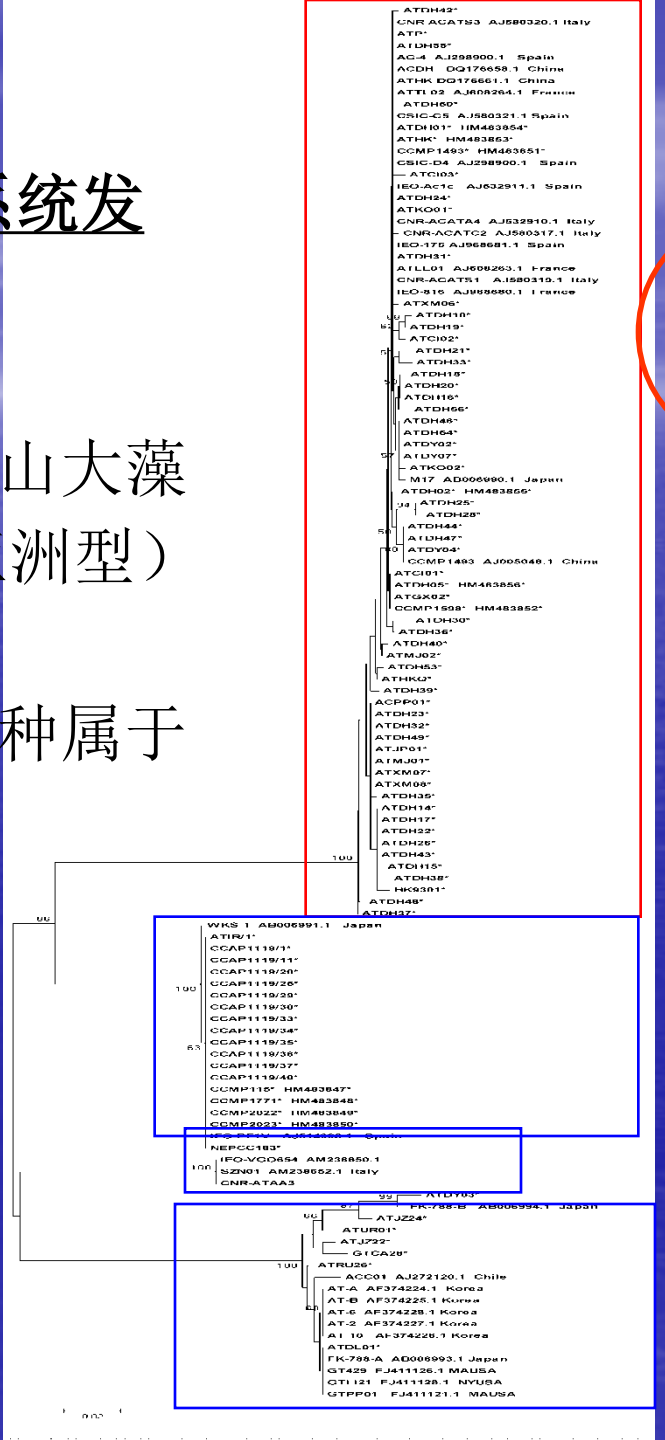
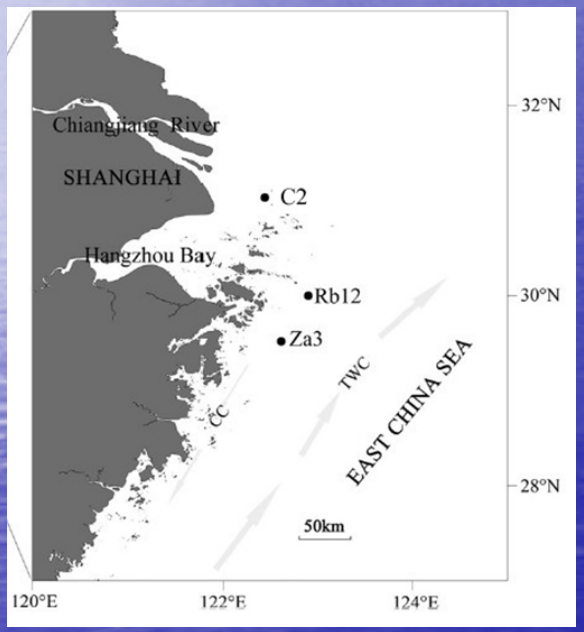


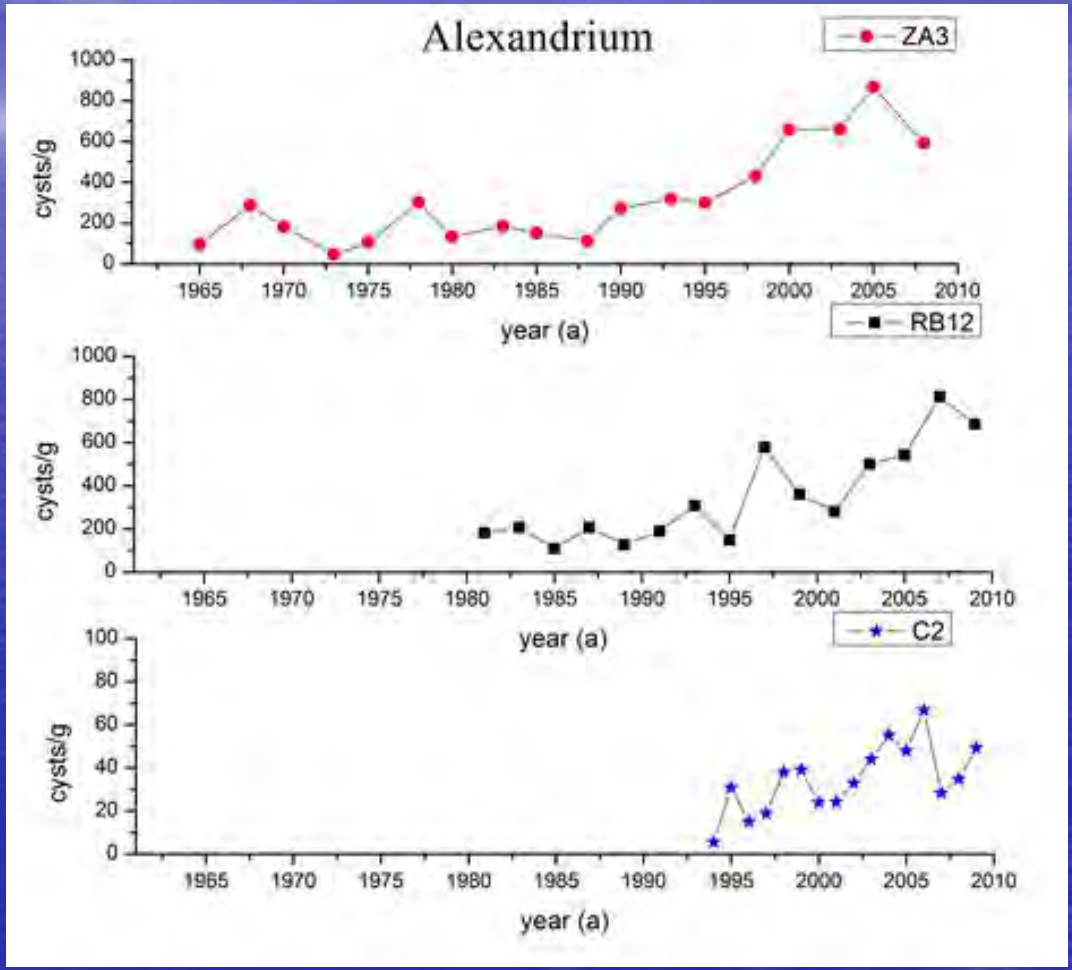
图 塔玛亚历山大藻基于5.8S rDNA及ITS序列系统发育树

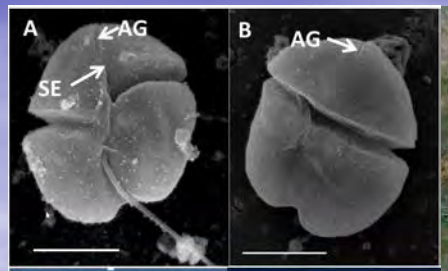
据杨卫东

Cysts concentration



Cysts concentration in core Rb12 , Za3 and C2.

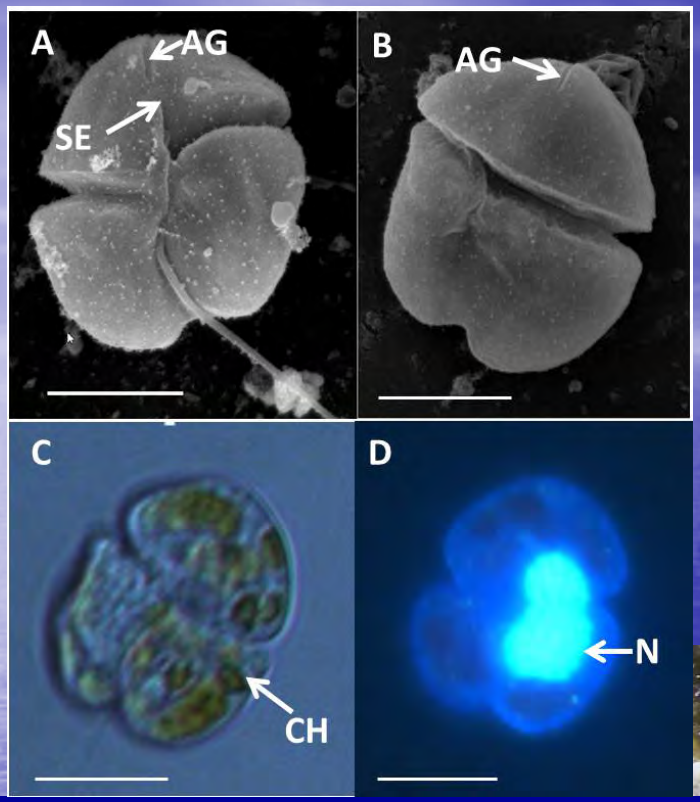


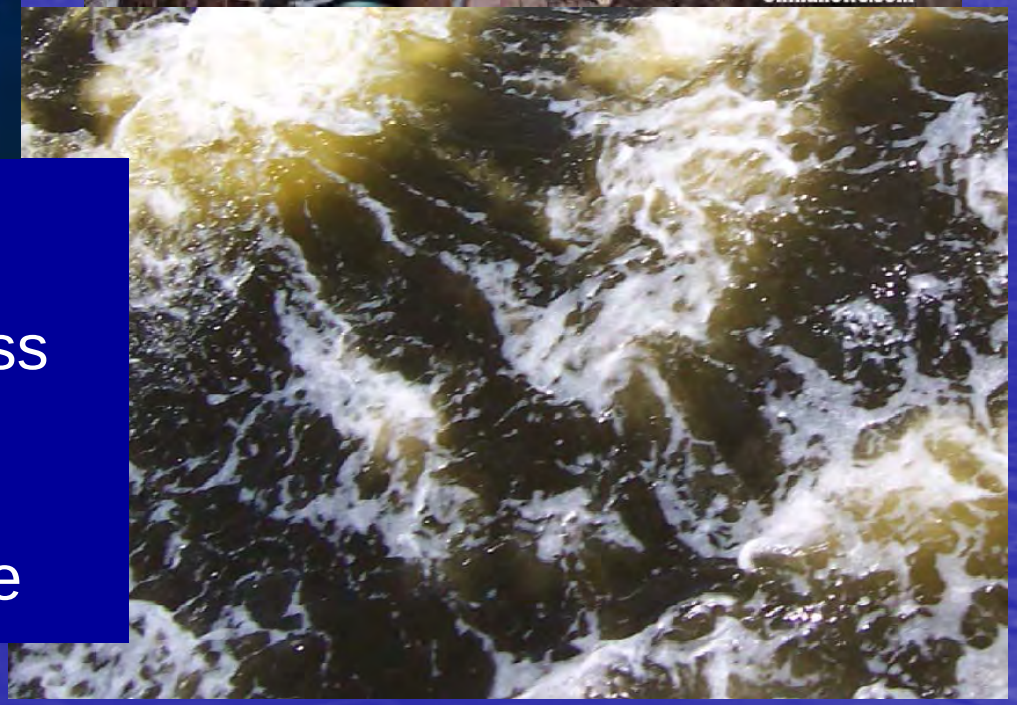


Before 2000

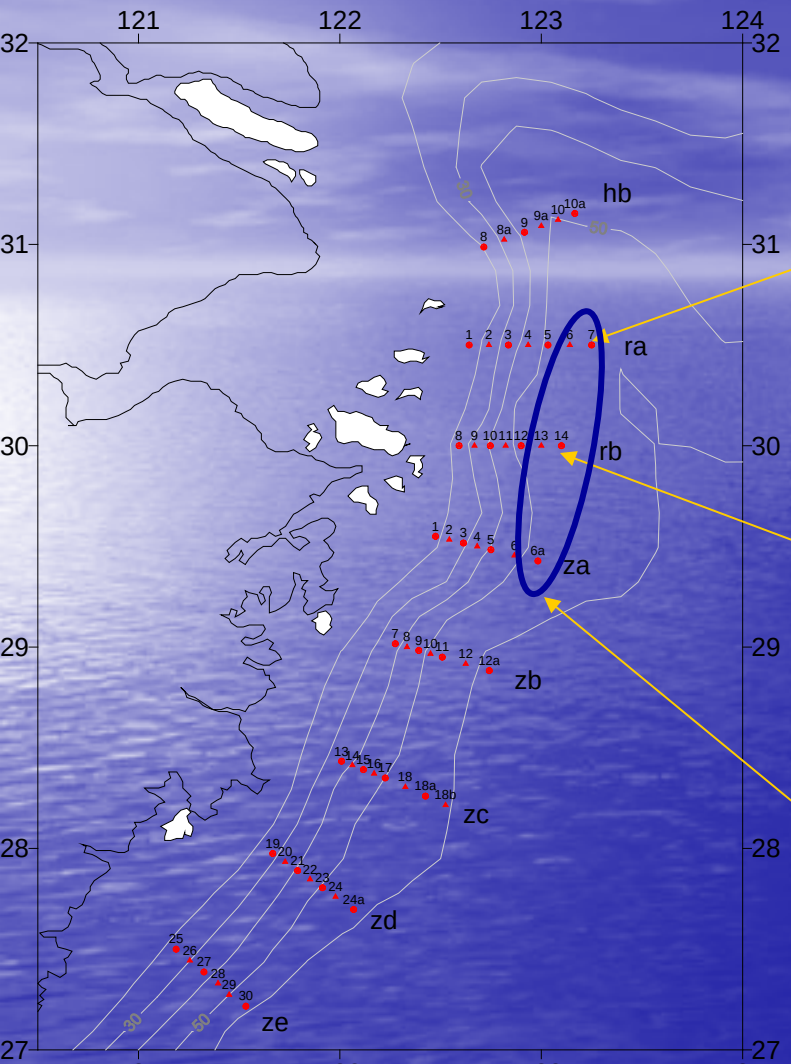
After 2000

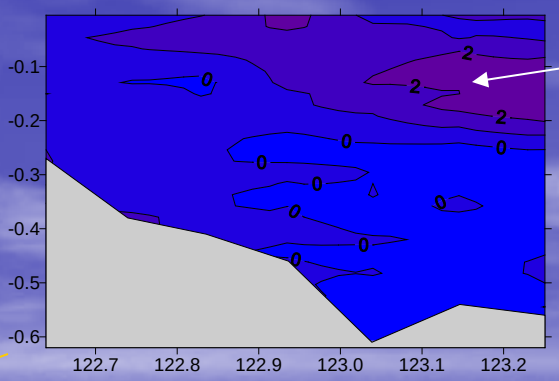
Since 1998, nearly 90 blooms caused by this species occurred in China. The massive bloom of *Karenia mikimotoi* in South China Sea in 1998 and in the East China Sea in 2005, 2012 resulted in the heavy loss of fish farming (http://www.soa.gov.cn).



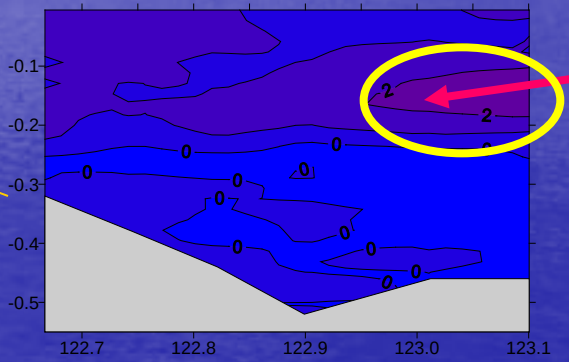


Karenia mikimotoi blooms cause severe economic loss in Fujian and Zhejiang Province(>2 billion Chinese Yuan)

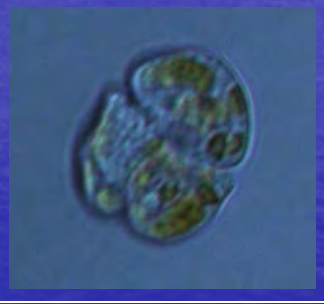


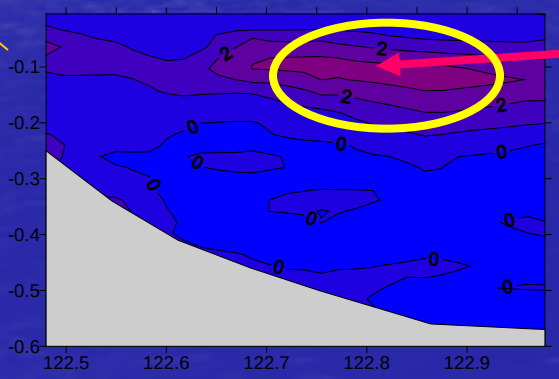


Karenia mikimotoi: 10^4 cells/L



Karenia : $2X10^4$ cells/L

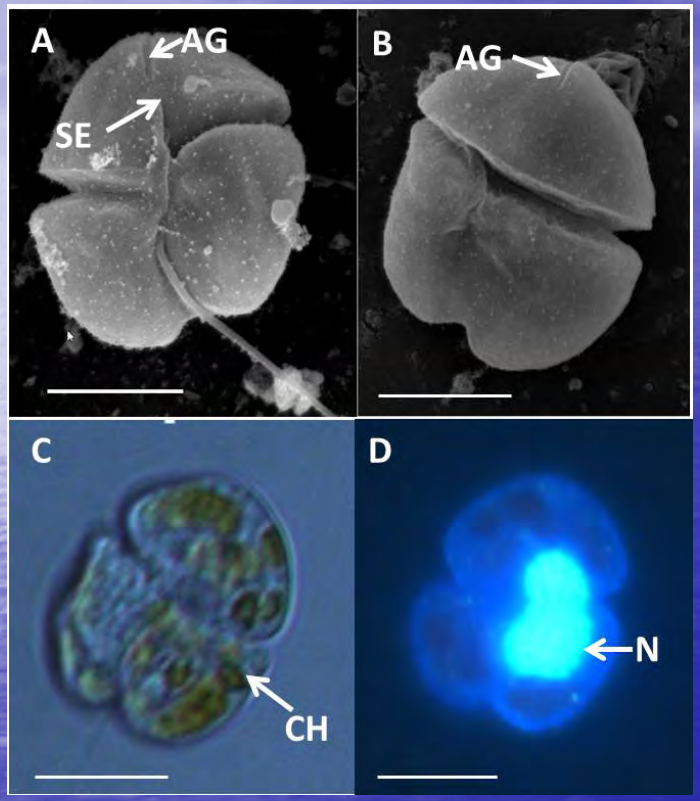


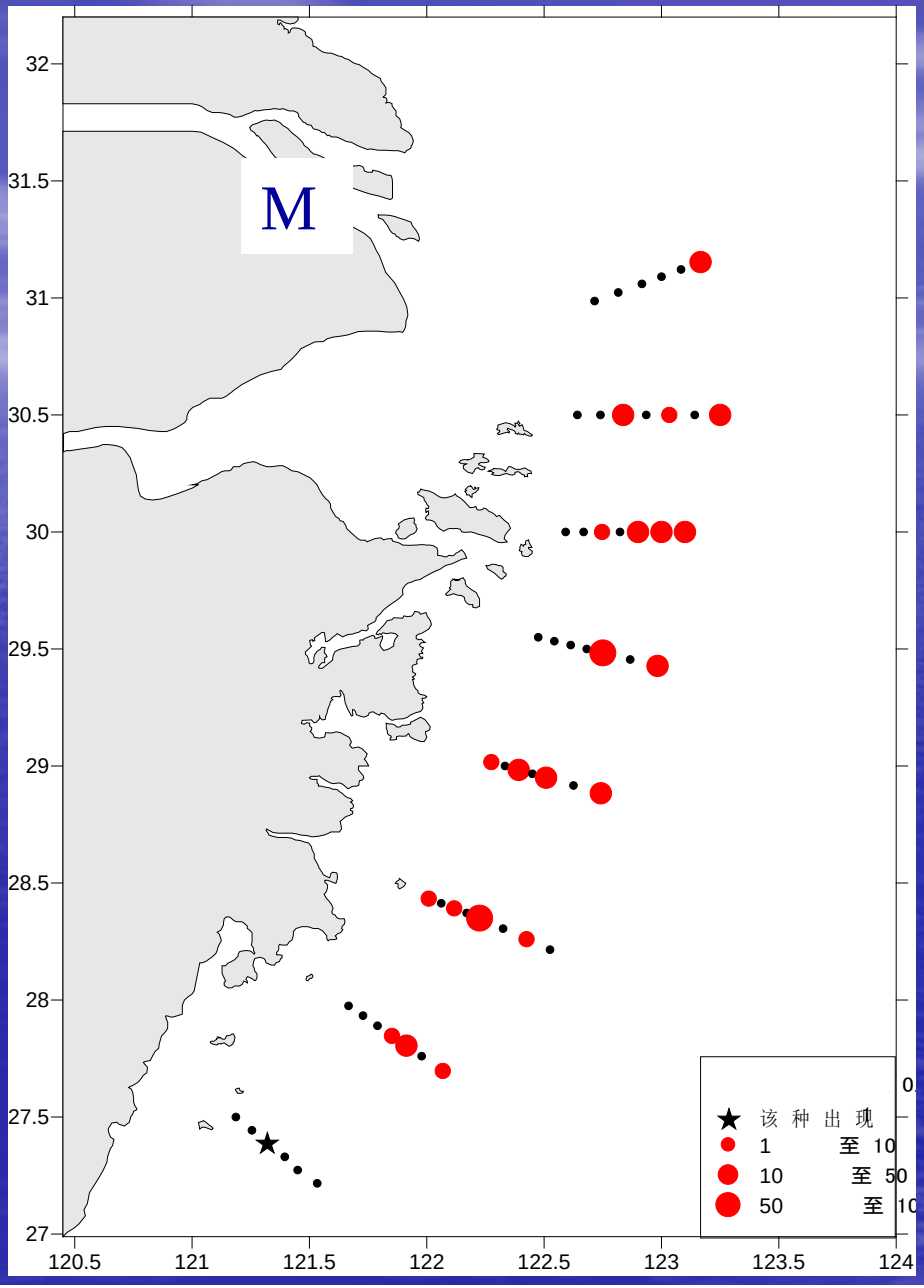


Karenia : $4X10^4$ cells/L

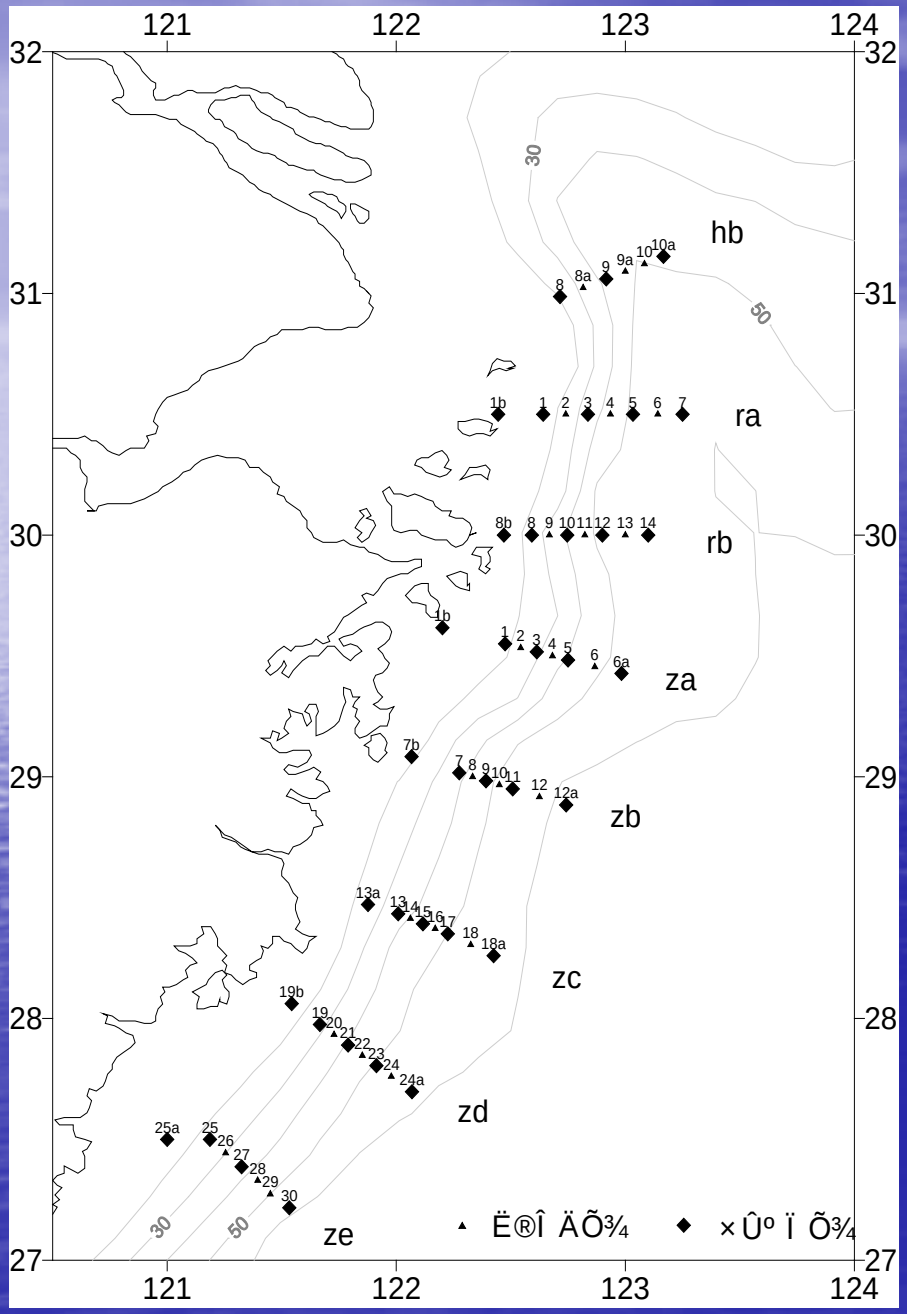
These zones are considered as incubators for subsequent massive blooms

“Pelagic seed banks”





***Karenia mikimotoi*, 3-9 May, 2005 (MC2005-3) (×10^3cells/L)**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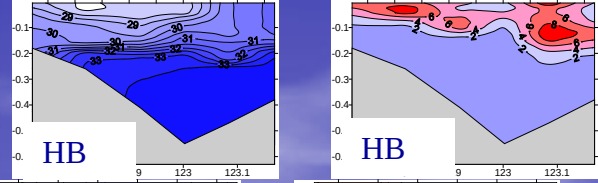
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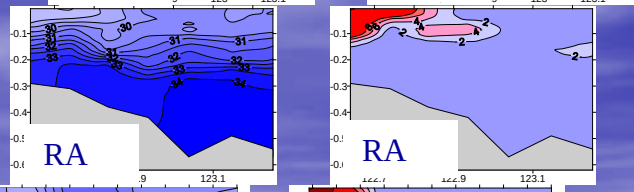
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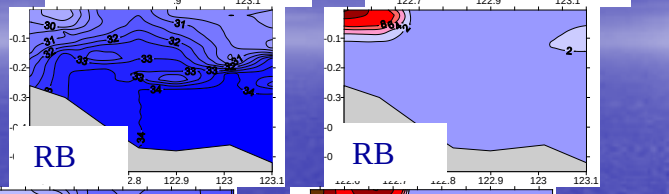
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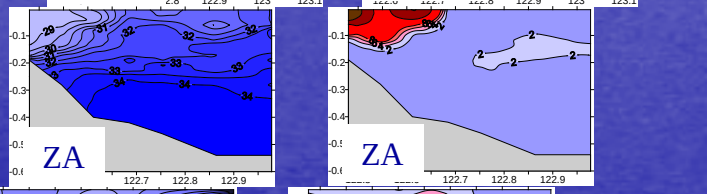
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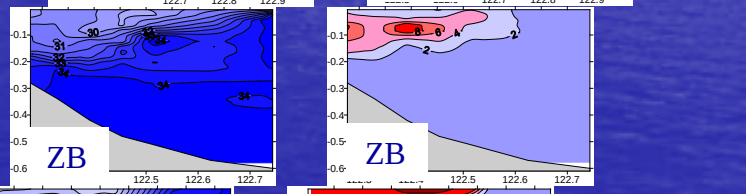
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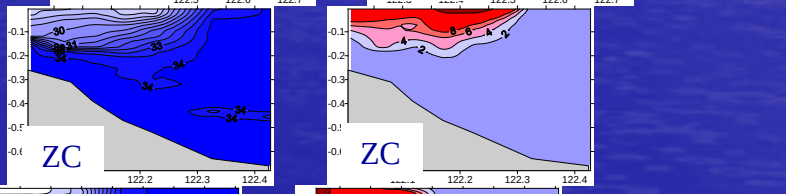
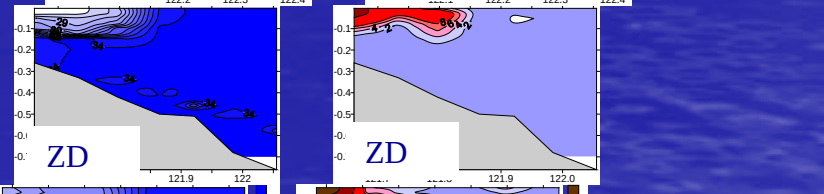

ZC
ZC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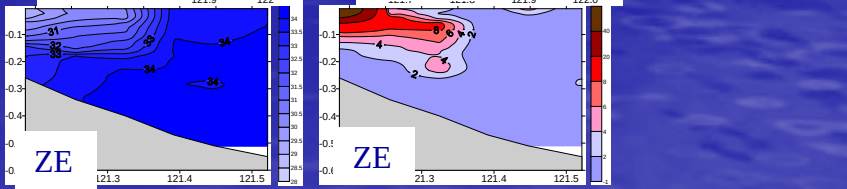
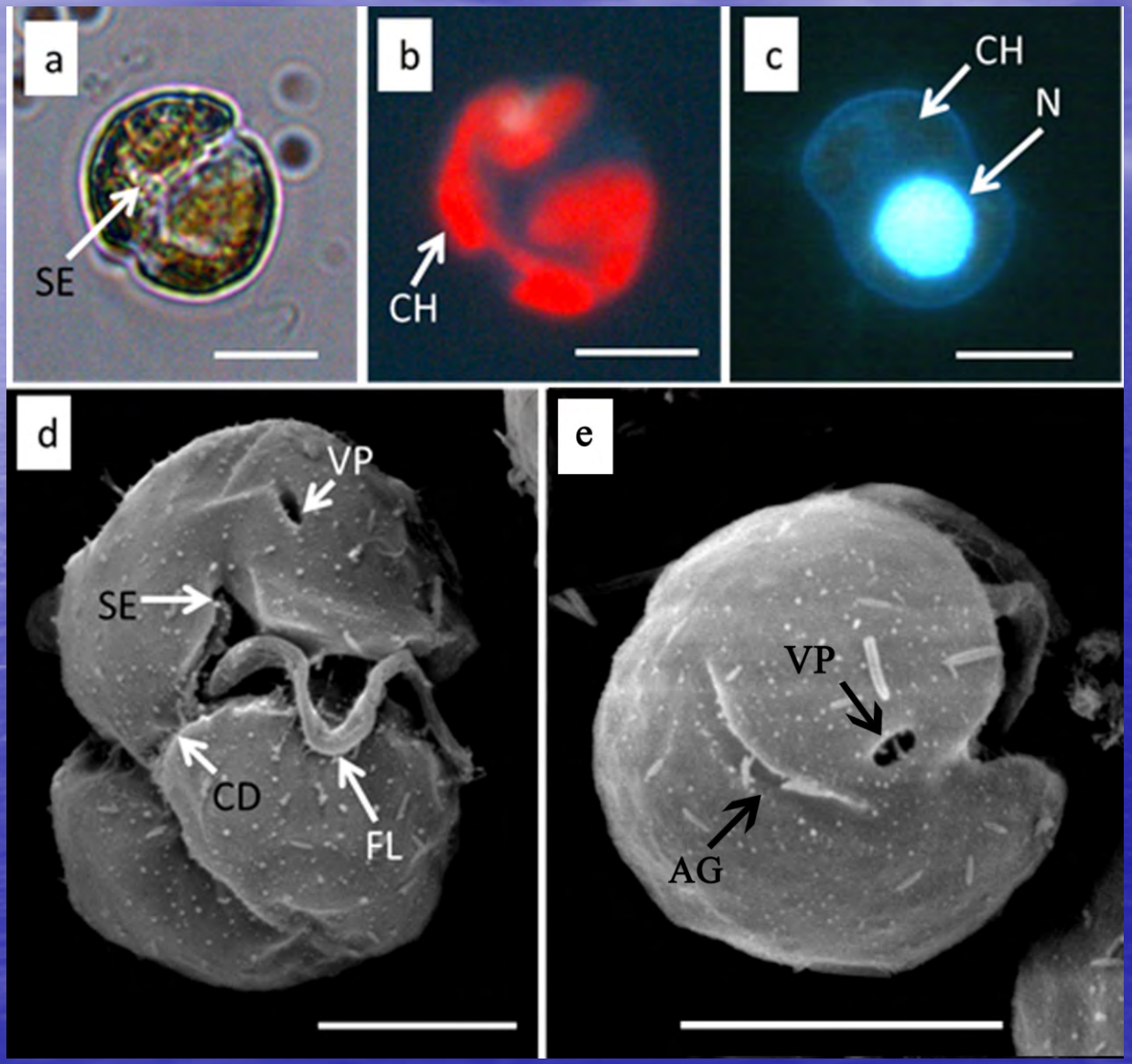

ZE
ZE

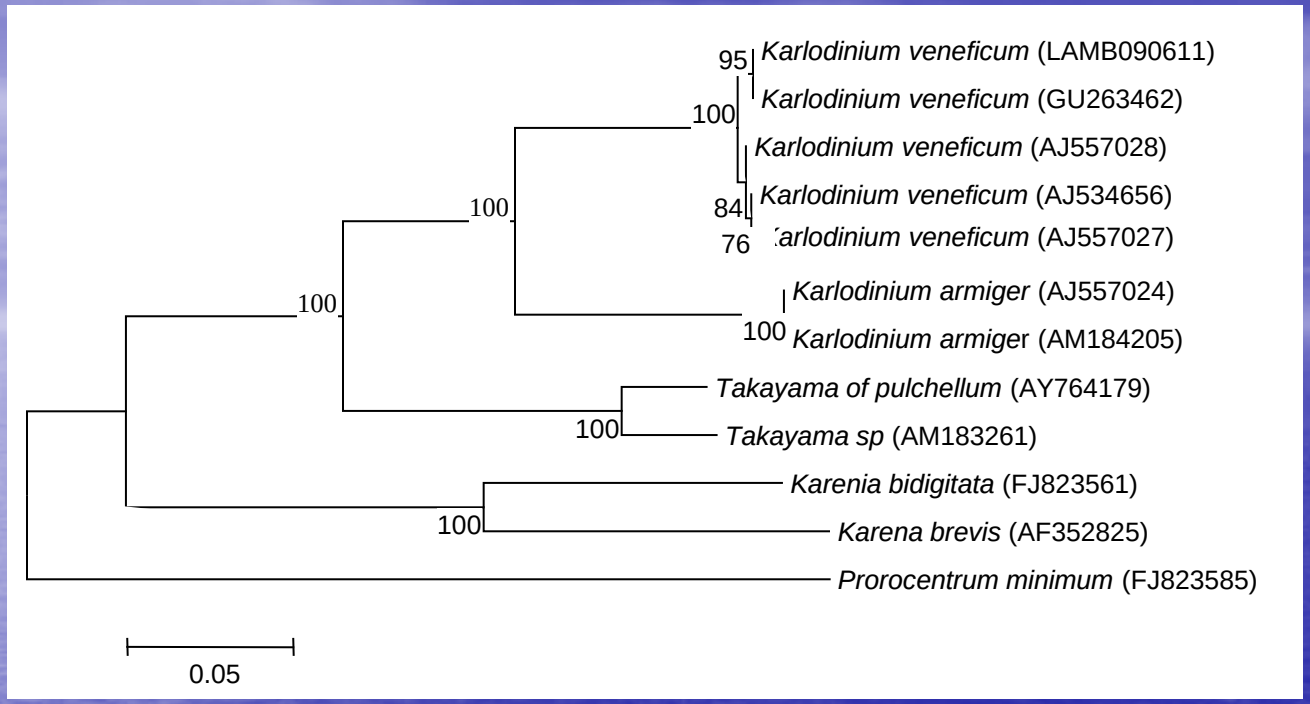
Karlodinium veneficum (ECS strain)



Cell measurements and morphological characteristics of *Karlodinium veneficum* strains

	Strain number			
	LAMB090611	LAMB010601	K-0522	Plymouth 103
Cell length/μm	11.1–18.7 (14.2±1.8, n=50)	12.7–17.9 (15.1±1.2, n=50)	8–18 (13.6±1.9, n=50)	9–18
Cell width/μm	8.2–14.7(10.8±1.5, n=50)	9.1–14.7 (11.4±1.1, n=50)	8–14(11.1±1.4, n=50)	7–14
Length-to-width ratio	1.14–1.64(1.32±0.08, n=50)	1.13–1.53(1.32±0.07, n=50)	0.97–1.49(1.23±0.1, n=50)	1.26
Cingulum displacement total cell length (%)	30–38	31–38	23–32	<20
Sulcal extension	yes	yes	yes	yes
Apical groove	straight, descending one-fifth down the dorsal epicone	straight, descending one-fifth down the dorsal epicone	straight, descending one-seventh down the dorsal epicone	
Ventral pore	pore size (0.8–1 μm). located on the left of the apical groove	pore size (0.8–1 μm). located on the left of the apical groove	elongated pore (1 μm) on the left of the apical groove	
Nucleus	large, round, located centrally at hypocone	large, round, located centrally at hypocone	large, round, located on the left side of the hypocone or centrally	median, indistinct except prior to cell division
Chloroplasts	2 or 4, with equal number in epi-and hypocone	2 or 4, with equal number in epi-and hypocone	2 to 4, with equal number in epi-and hypocone, orange-brown in color	2 to 8(usually four), irregular in shape, golden brown in color

Wang et al, 2011



Phylogenetic trees of the family Kareniaceae based on the ITS–5.8S rDNA sequences. (0.05 is the nucleotide substitution).

Acta Oceanol. Sin., 2011, Vol. 30, No. 6, P. 112-121
DOI: 10.1007/s13131-011-0168-6
http://www.hyxb.org.cn
E-mail: hyxbe@263.net

First observation of *Karlodinium veneficum* from the East China Sea and the coastal waters of Germany

WANG Hongxia[1], LU Douding[1*], HUANG Haiyan[1], GÖBEL Jeanette[2], DAI Xinfeng[1], XIA Ping[1]

Station RB 10

Skeletonema： 8 x10 ^{5} cells/L

Other diatoms： 10 ^{5} cells/L

***Karlodinium*: 3x10 ^{5} cells/L**

Karenia ： 2.5X10 ^{5} cells/L

Gyrodinium: 10 ^{5} cells/L

Prorocentrum:7.5x10^{4}cells/L

Station RB12

Karenia： 2X10^6 cells/L

Prorocentrum :10^{6}cells/L

***Karlodinium*: 2.1x10^{6}cells/L**

Station RB13

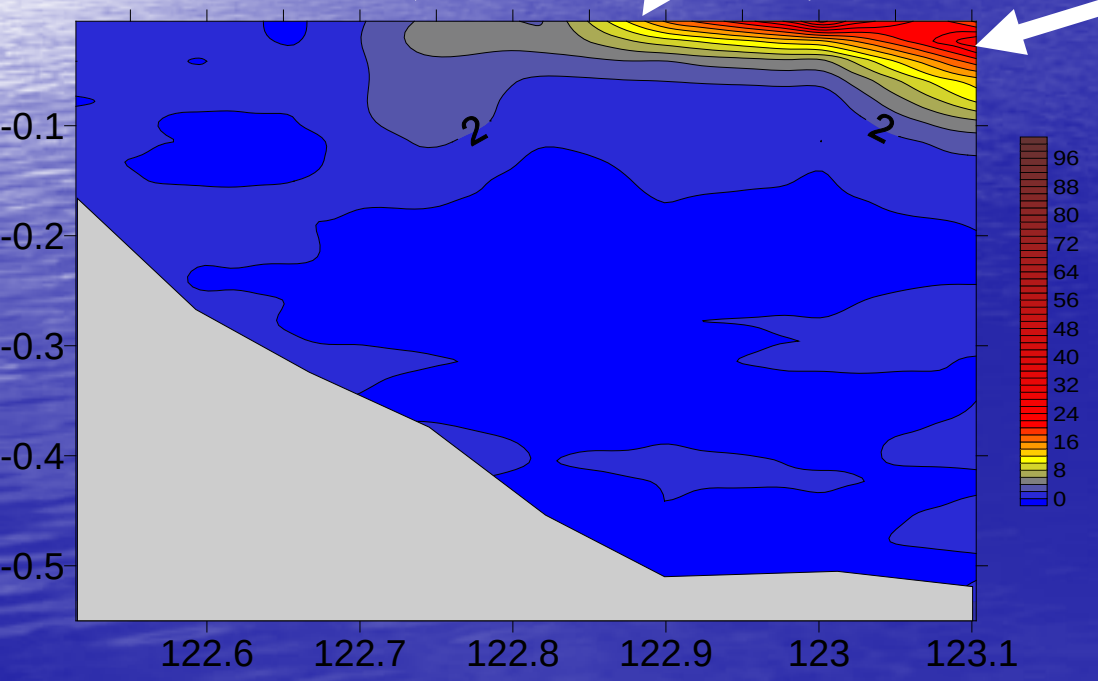
Karenia ： 1.7X10^6 cells/L

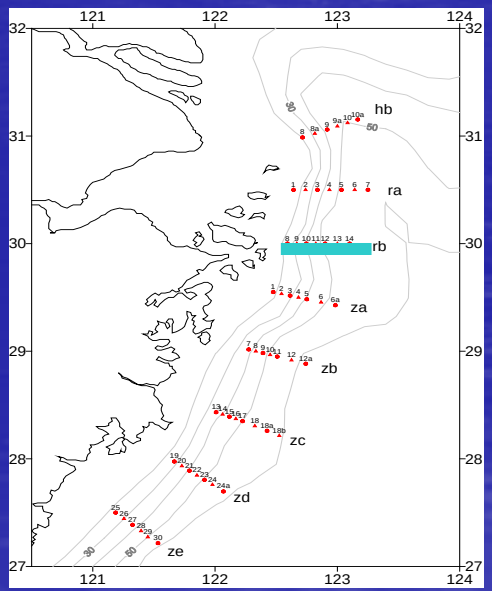
***Karlodinium*: 5x10^{6}cells/L**

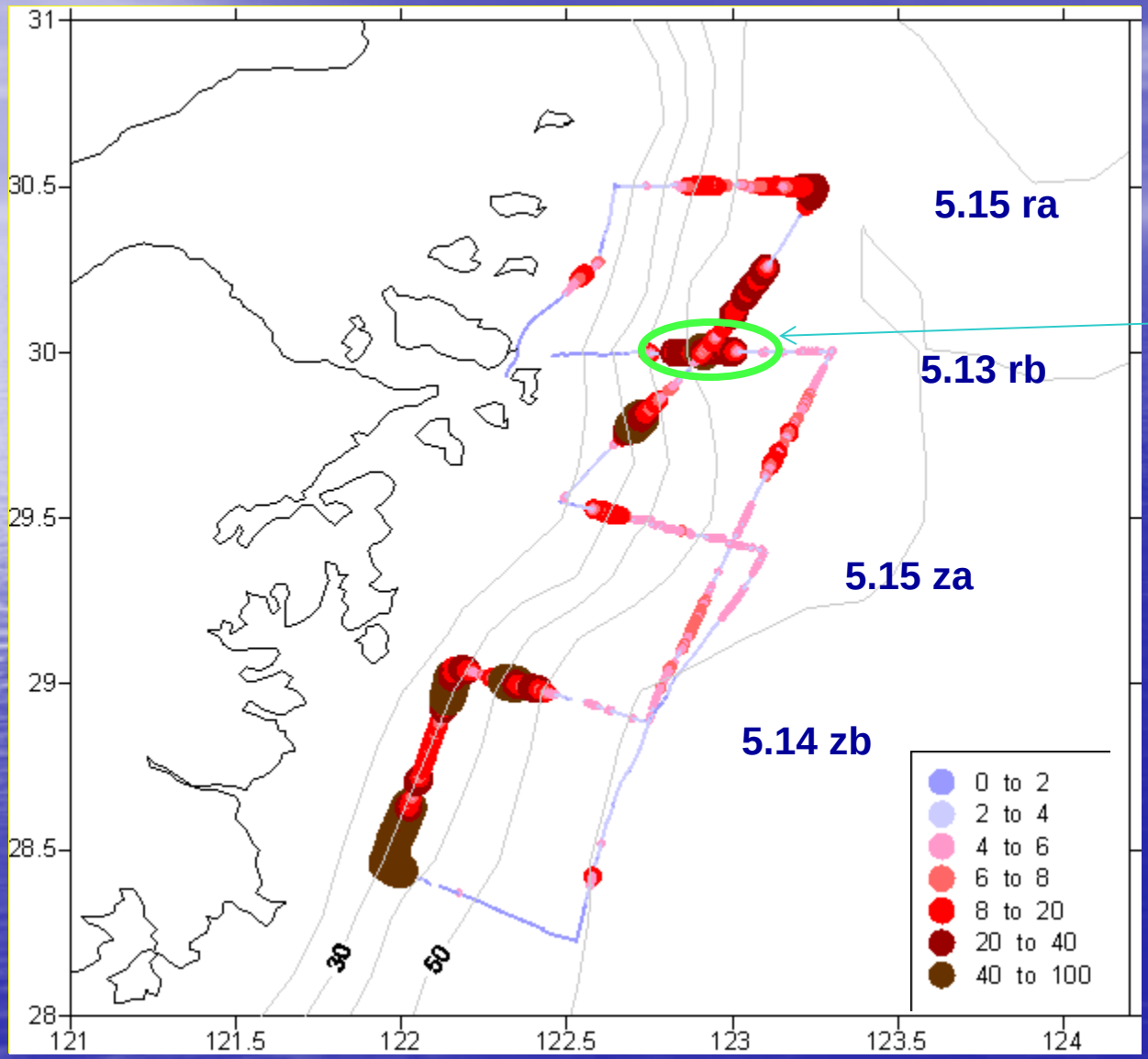
Station RB14

Karenia ： 1.9X10^6 cells/L

***Karlodinium*: 5x10^{5}cells/L**

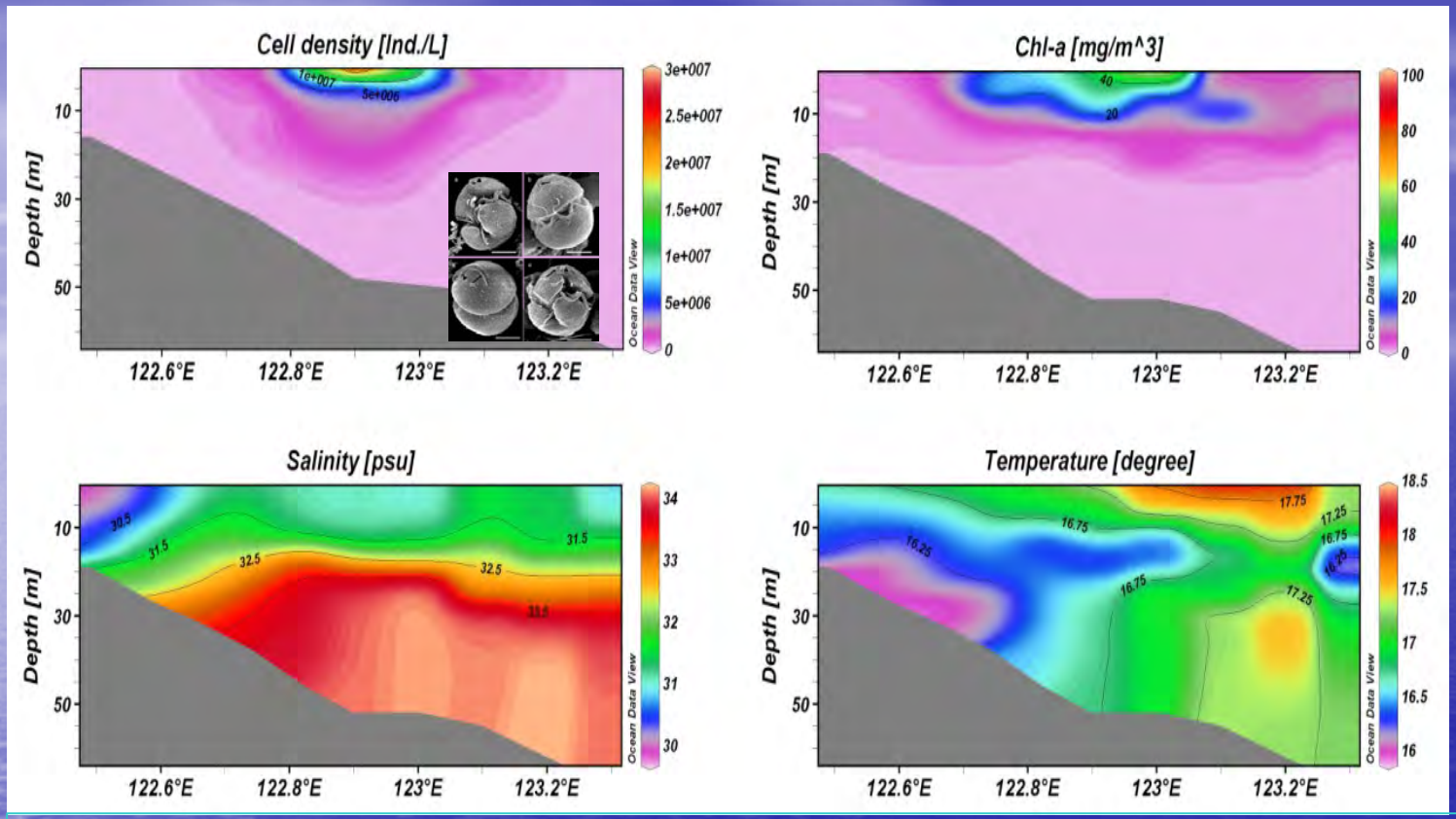






Prorocentrum

Karlodinium /
Prorocentrum



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

Contents lists available at SciVerse ScienceDirect

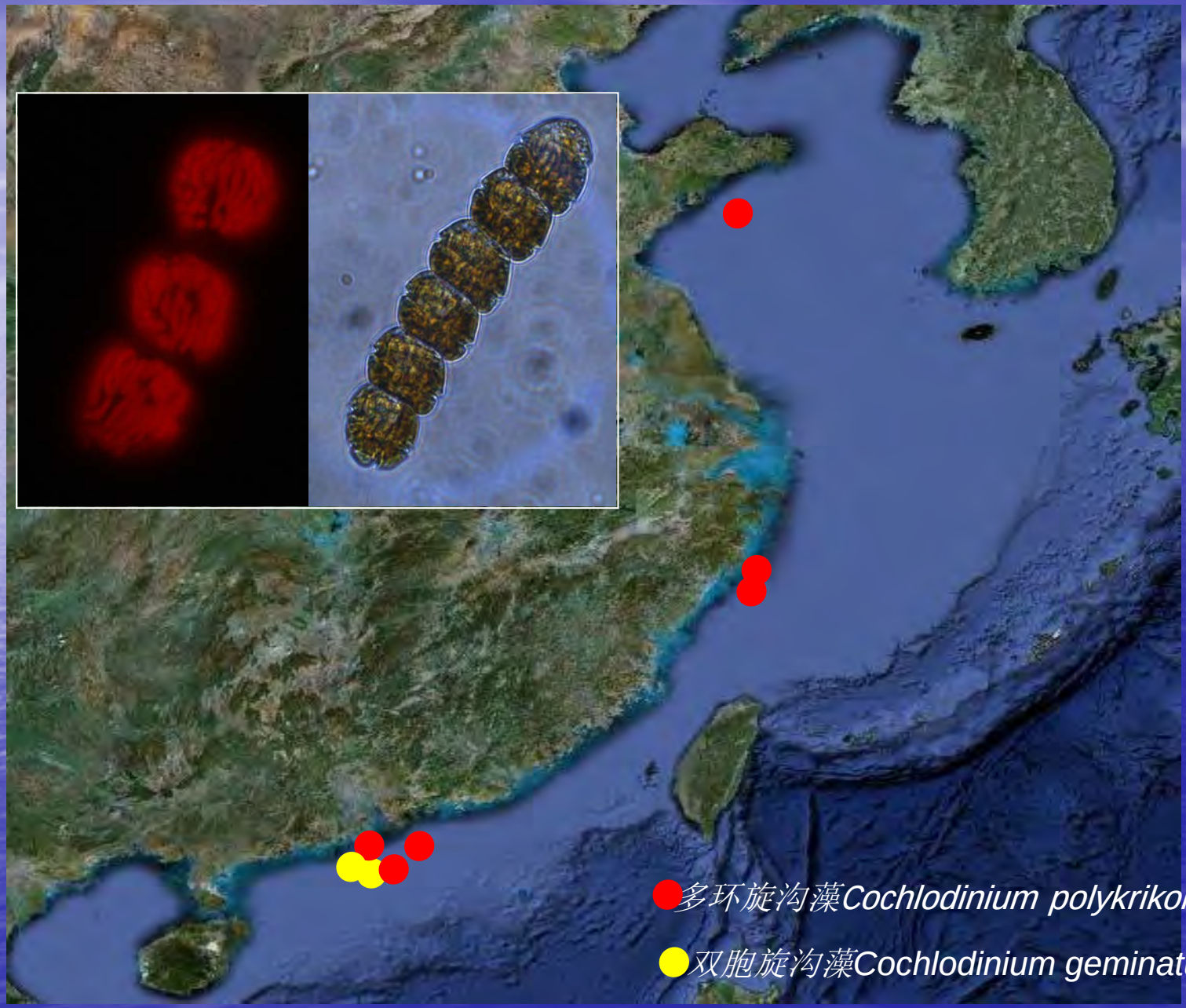
Deep-Sea Research II

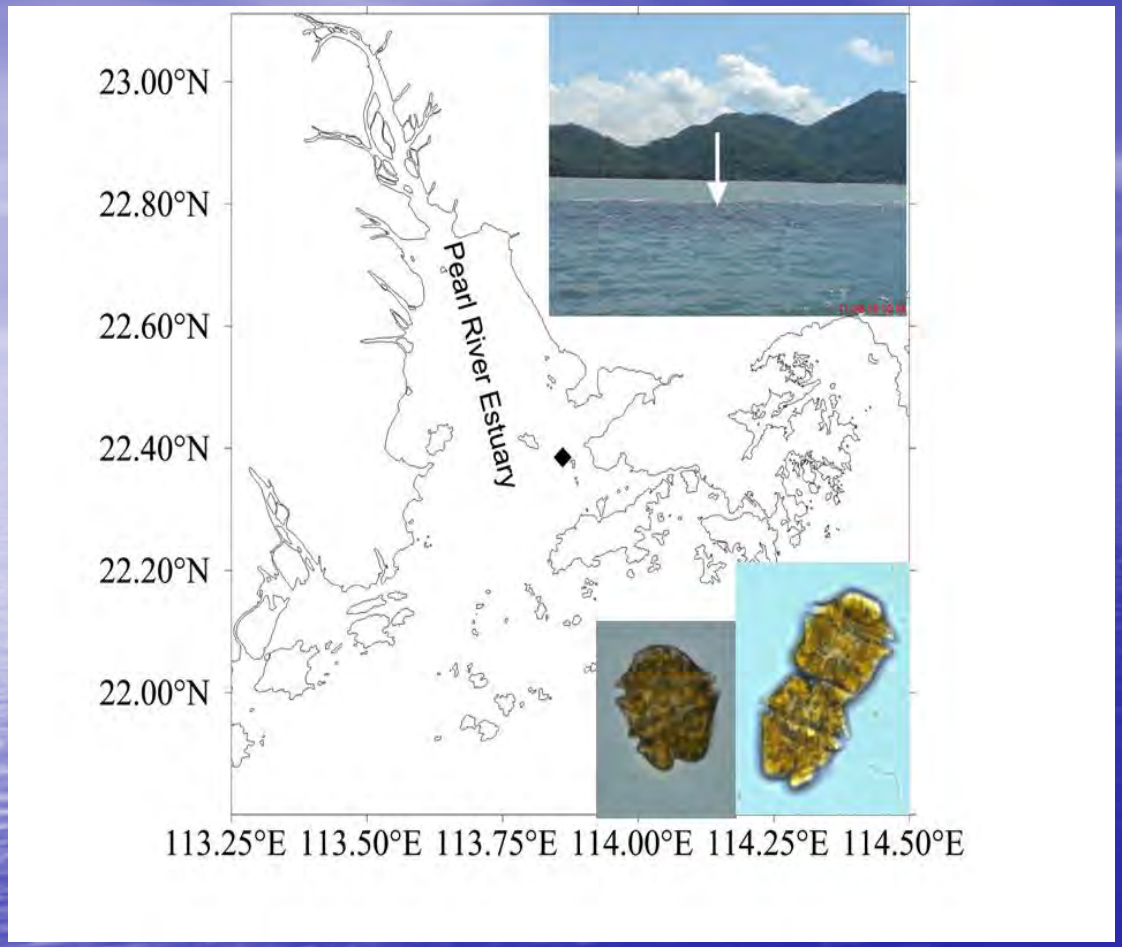
journal homepage: www.elsevier.com/locate/dsr2

Newly recorded *Karlodinium veneficum* 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] The Second Institute of Oceanography, SOA, Hangzhou 310012, China
[b] Zhejiang University, Hangzhou 310012, China


多环旋沟藻Cochlodinium polykrikoides
双胞旋沟藻Cochlodinium geminatum



Bloom events of （*Cochlodinium geminatum*） in the Pearl River Estuary in August 2005，2009，and 2012

Contents lists available at SciVerse ScienceDirect

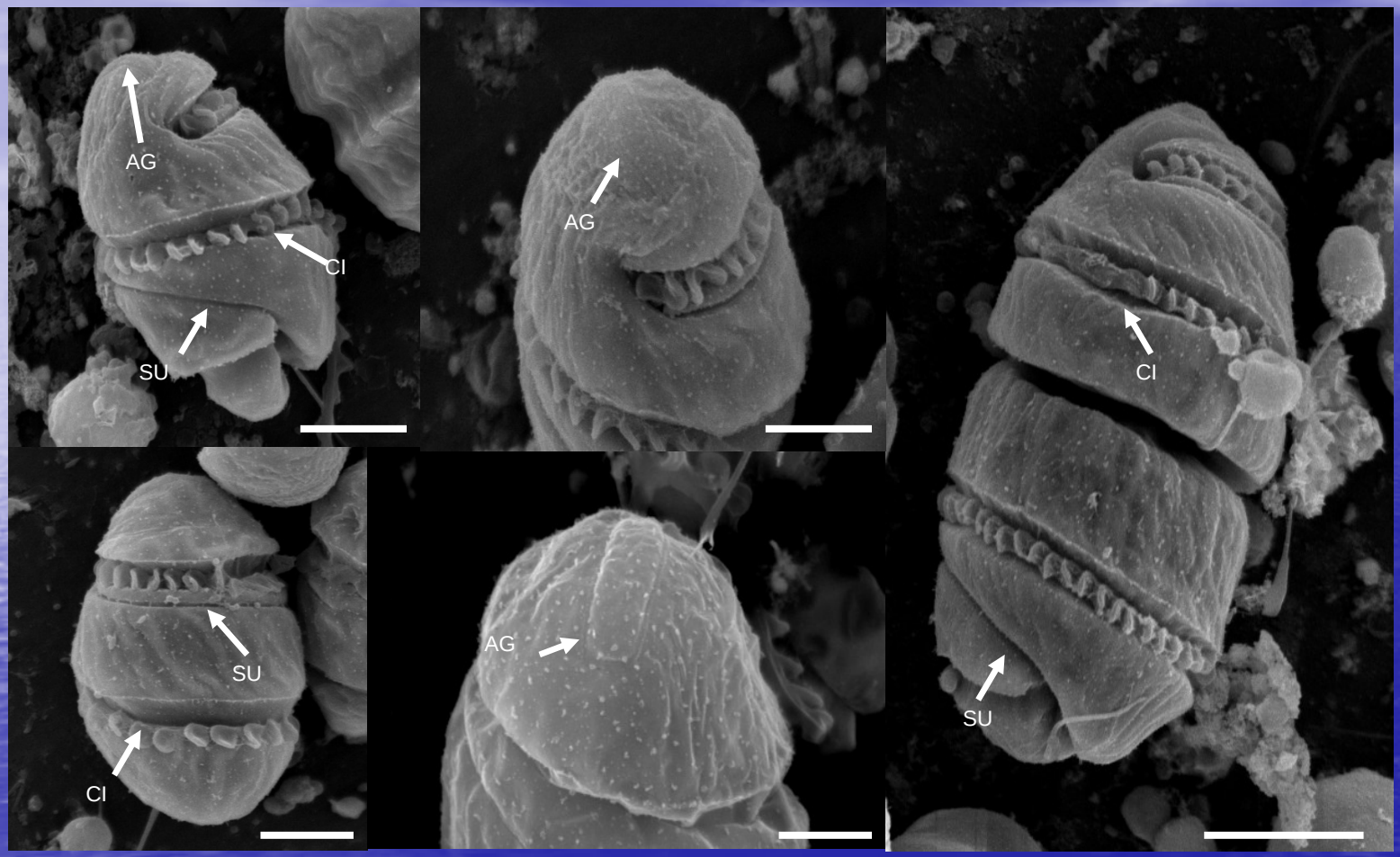
Harmful Algae

journal homepage: www.elsevier.com/locate/hal

Morphology and bloom dynamics of *Cochlodinium geminatum* (Schütt) Schütt in the Pearl River Estuary, South China Sea

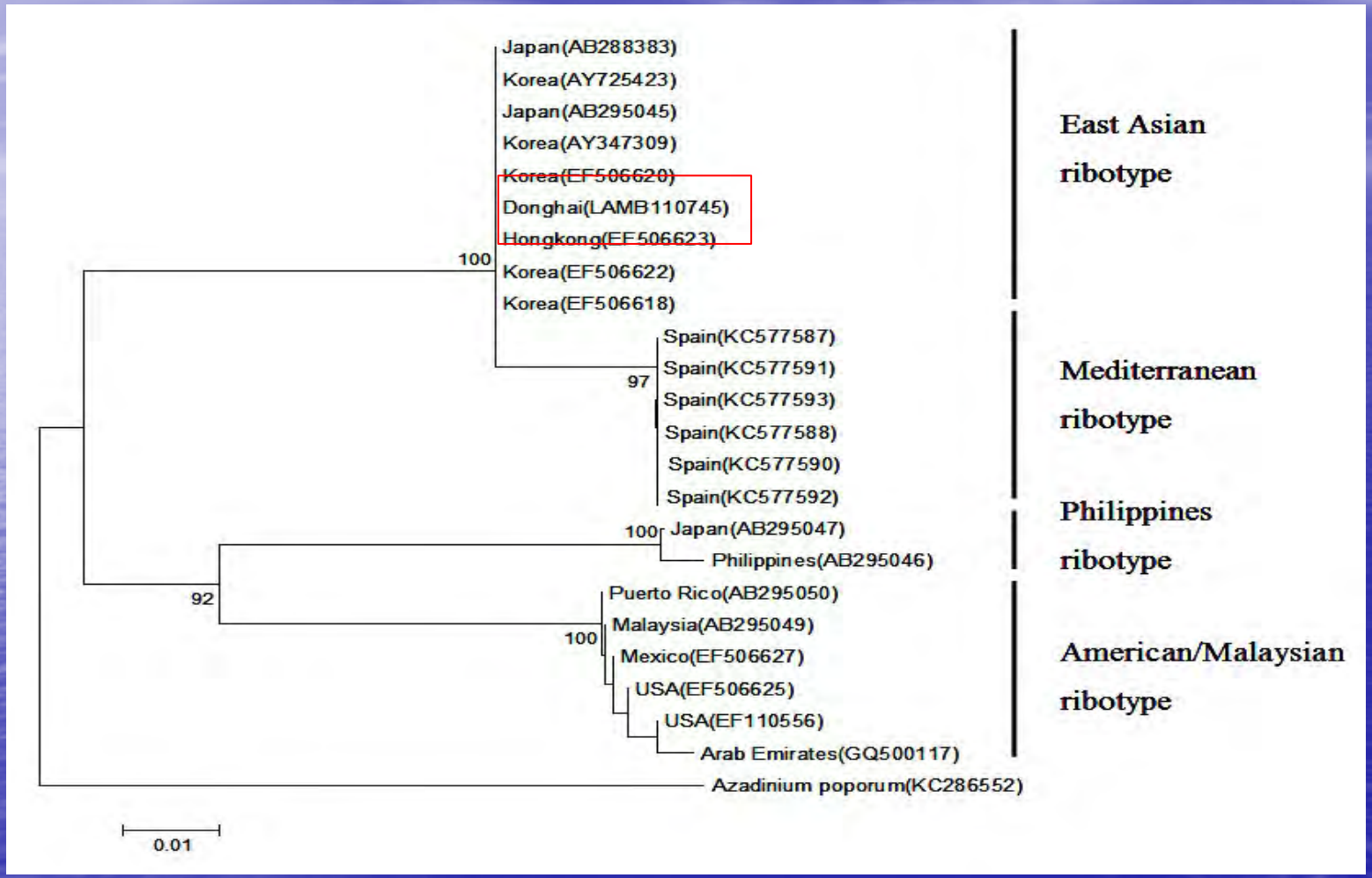
Ping-Ping Shen [a,*], Ya-Nan Li [a,b], Yu-Zao Qi [c,**], Lv-Ping Zhang [a], Ye-Hui Tan [a], Liang-Min Huang [a]

[a] Key Laboratory of Marine-Bioresources Sustainable Utilization, South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou 510301, China
[b] Graduate University of Chinese Academy of Sciences, Beijing 100049, China
[c] Research Center for Harmful Algae and Aquatic Environment, Jinan University, Guangzhou 510632, China

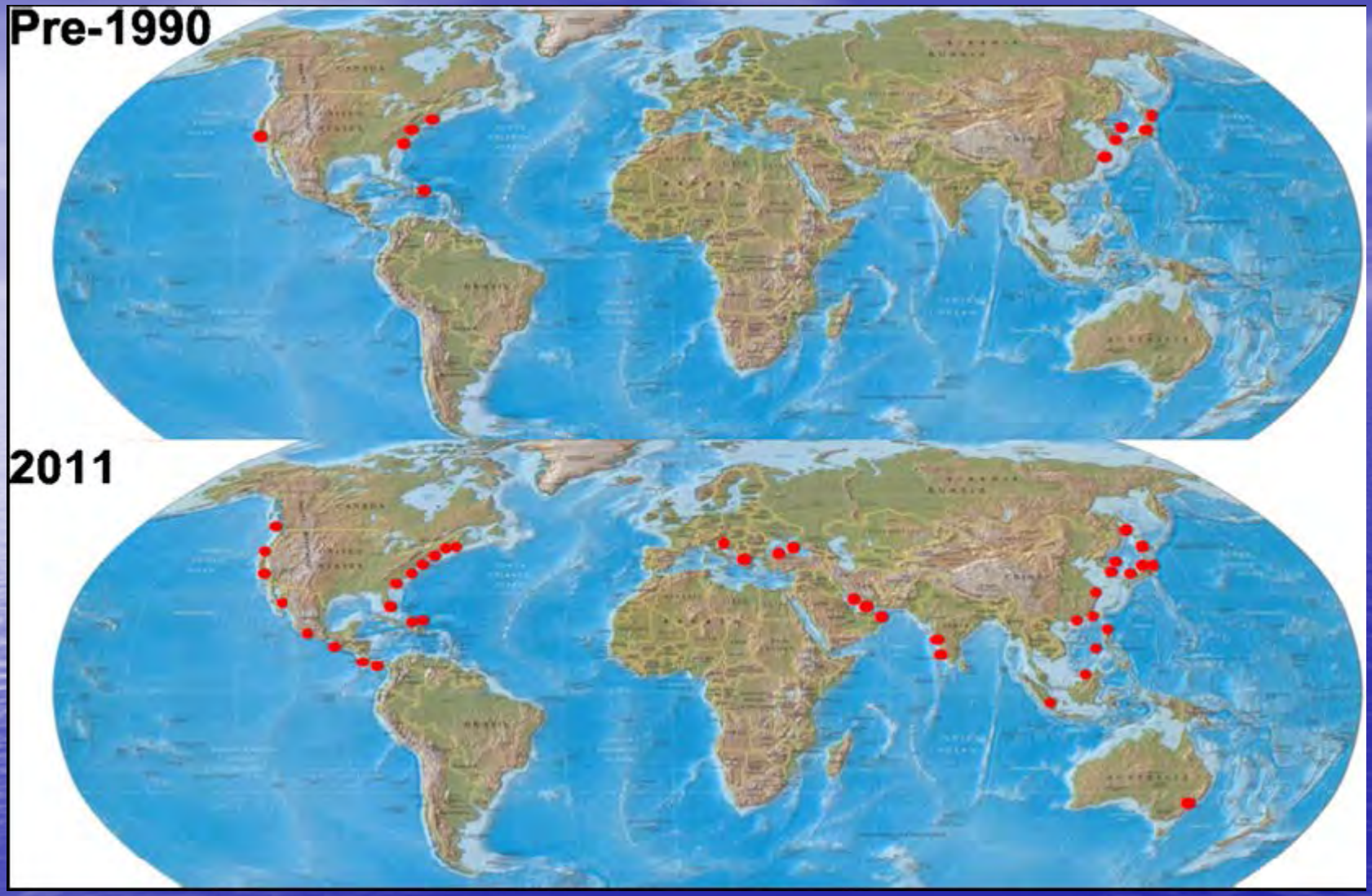


Cochlodinium polykrikoides

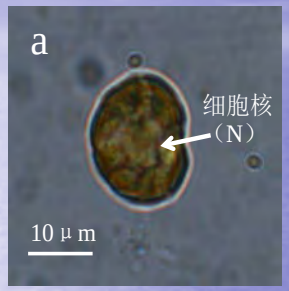
基于核糖体大亚基系统发育树

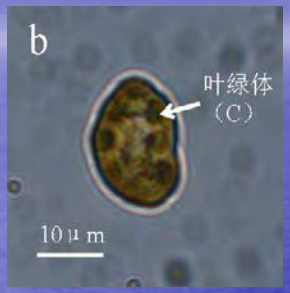


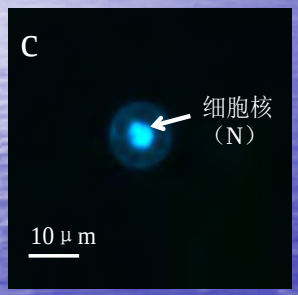
Phylogenetic trees of the *Cochlodinium polykrikoides* based on the LSU rDNA (D1-D3) sequences

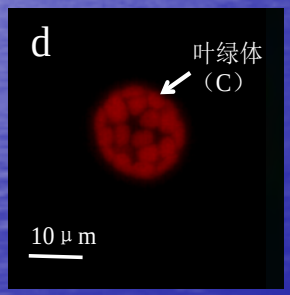


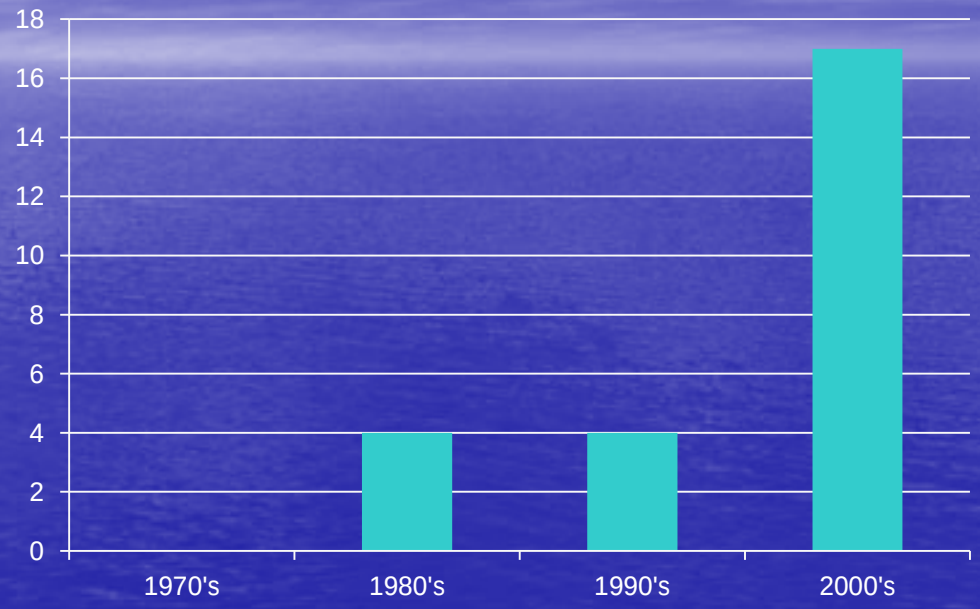
Global distribution of reported Cochlodinium events showing the apparent expansion in blooms before (top panel) and after (bottom) 1990. (Raphael , Gobler, 2012)



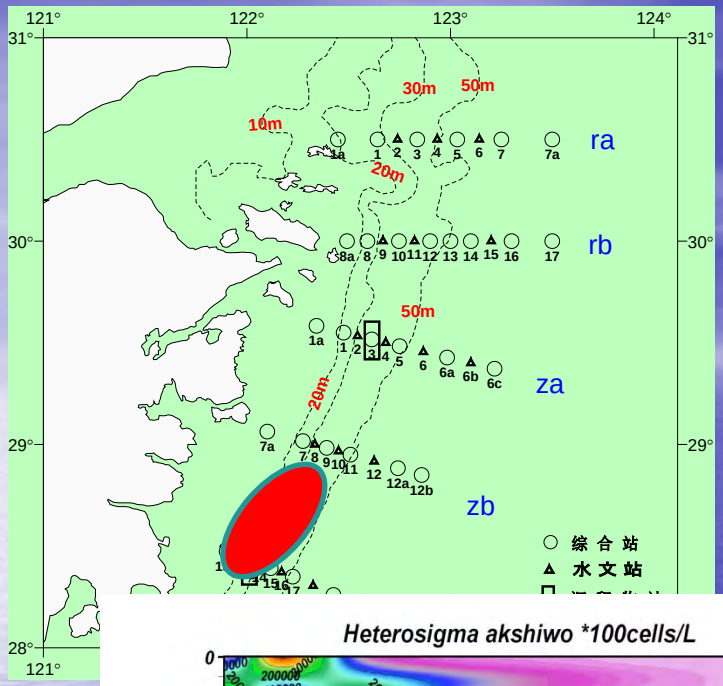




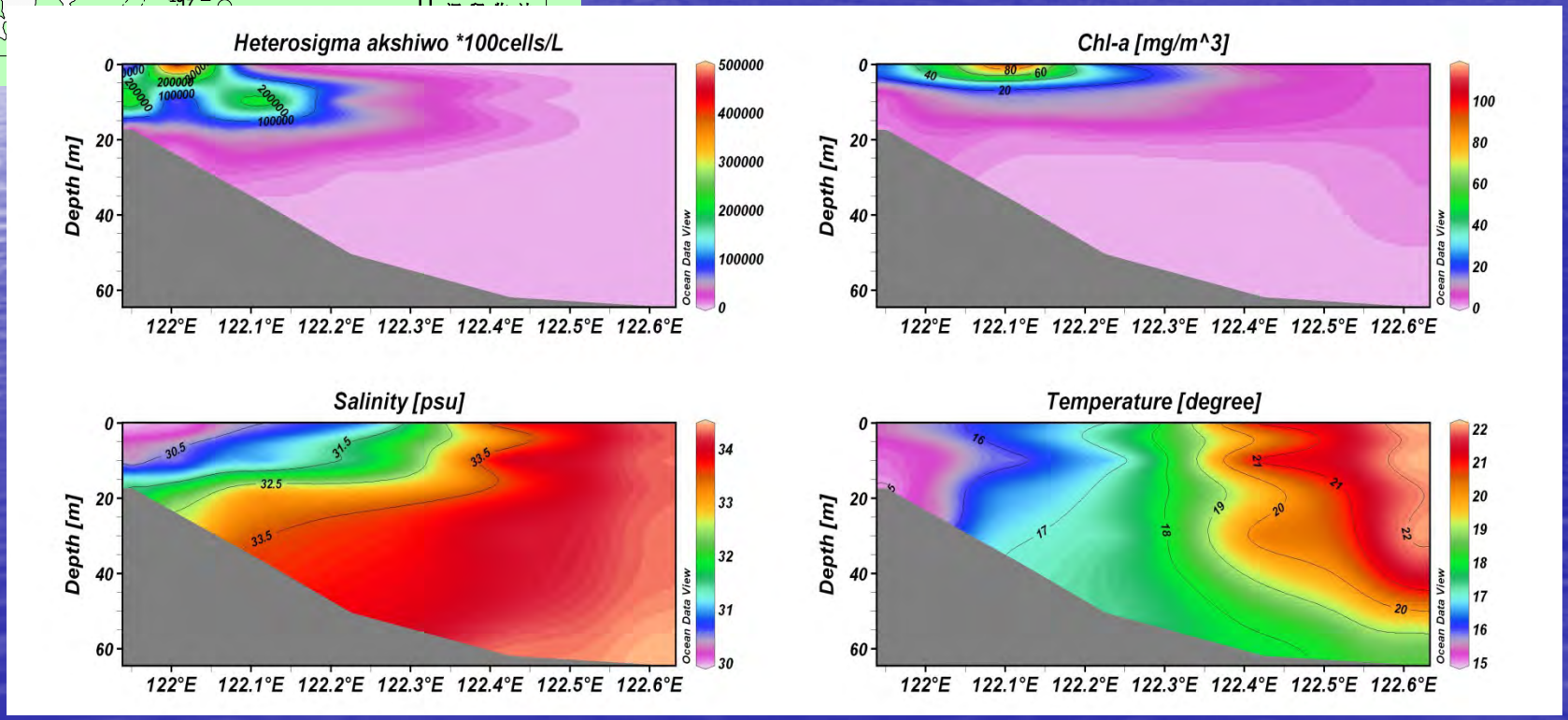


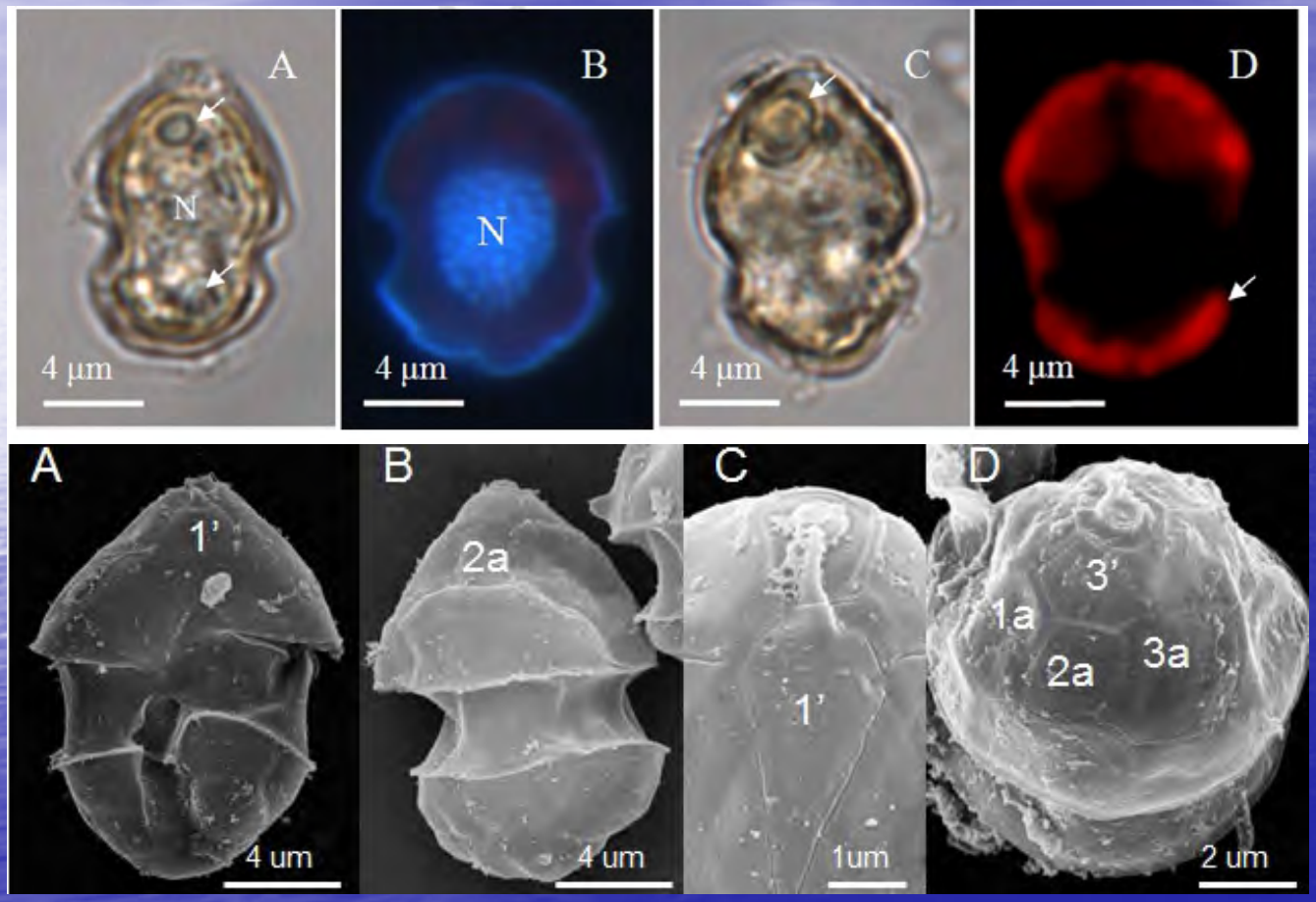


HAB records of *Heterosigma akashiwo* in the last decades in Chinese coastal waters



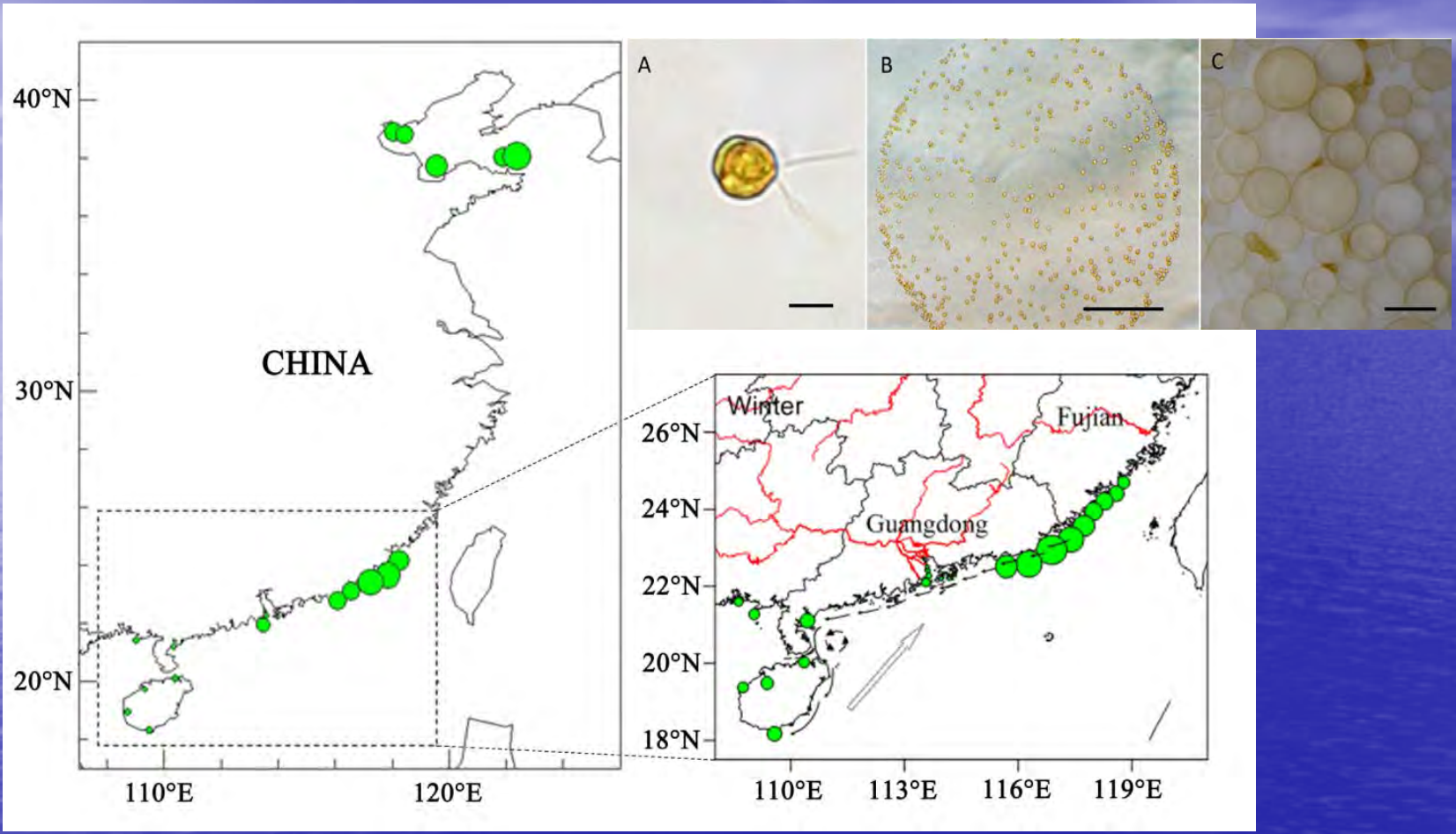
Heterosigma akashiwo bloom In May 2011)



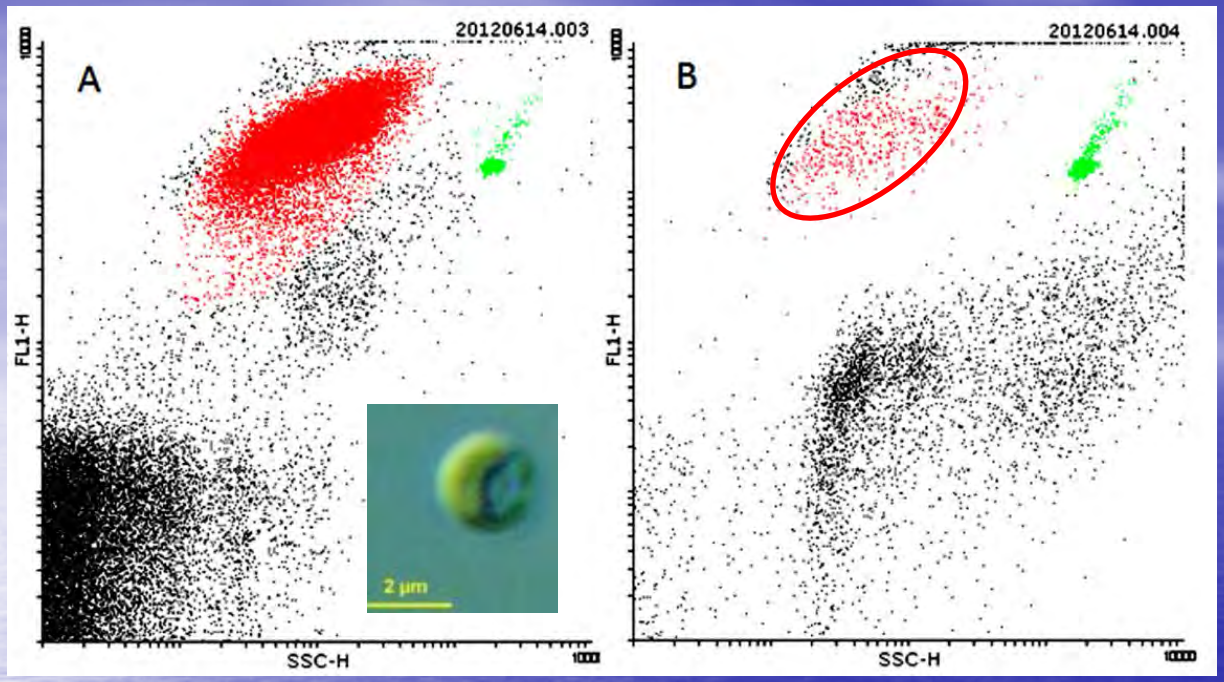


SEM of vegetative cells and cysts of *Azadinium poporum*.
(A) ventral view; (B) dorsal view; (C) detail of the the apical pore complex; (D) dorsal view showing three anterior intercalary plates.

Gu， 2013



Records of 球状棕囊藻*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)



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.

Contents lists available at SciVerse ScienceDirect

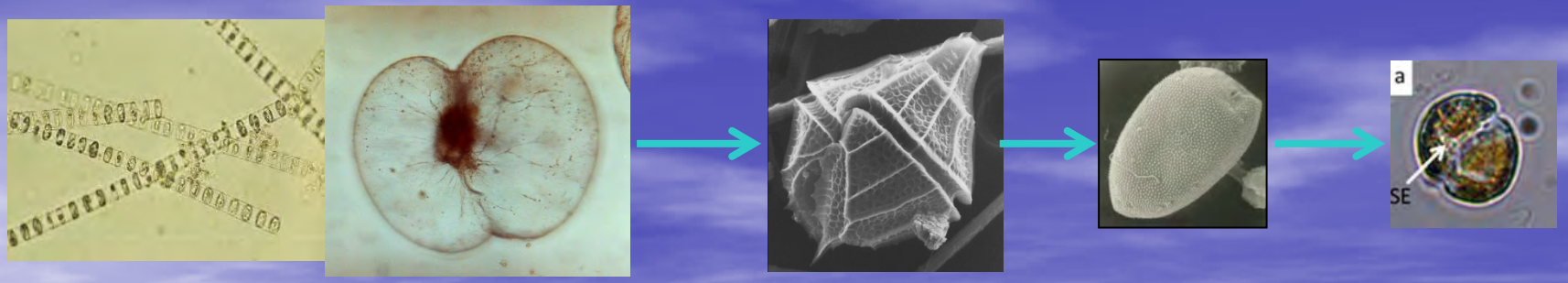
Harmful Algae

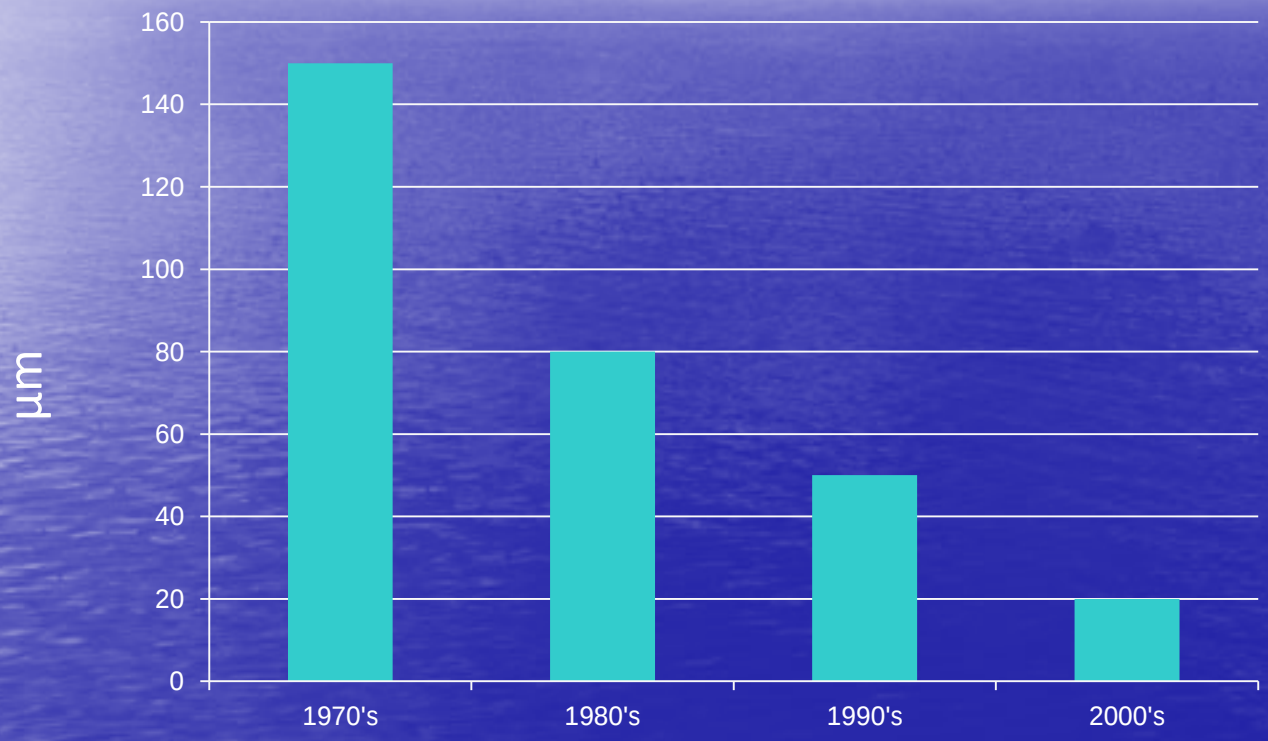
journal homepage: www.elsevier.com/locate/hal

Emergence of brown tides caused by *Aureococcus anophagefferens* Hargraves et Sieburth in China

Qing-Chun Zhang [a], Li-Mei Qiu [b,1], Ren-Cheng Yu [a,*], Fan-Zhou Kong [a], Yun-Feng Wang [a], Tian Yan [a], Christopher J. Gobler [c], Ming-Jiang Zhou [a]

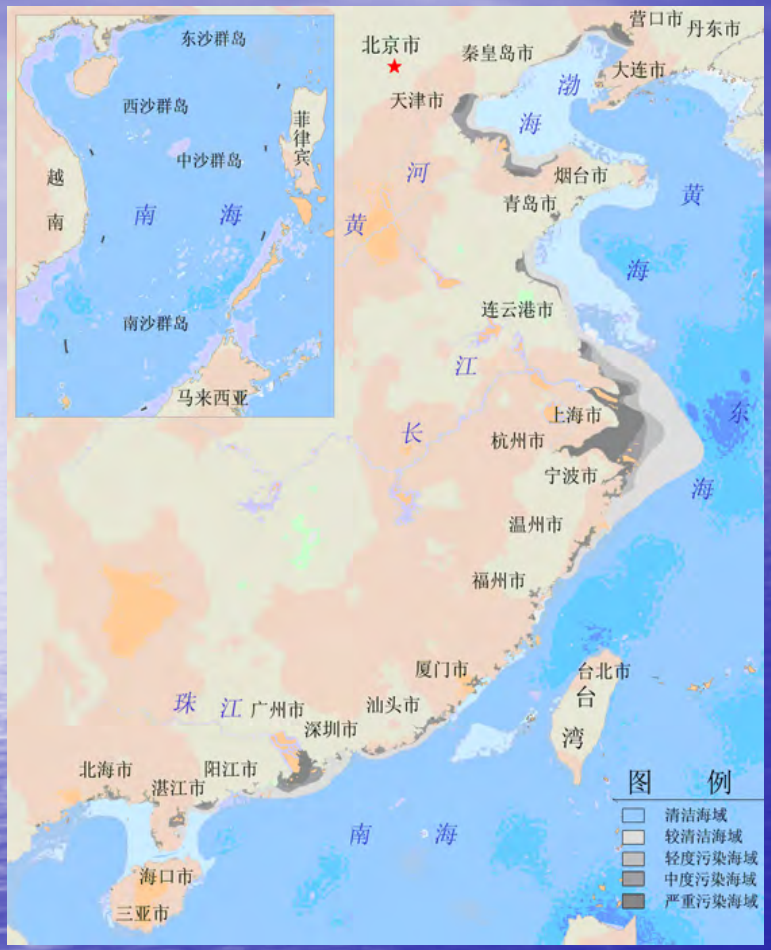
[a] Key Laboratory of Marine Ecology and Environmental Sciences, Institute of Oceanology, Chinese Academy of Sciences, Qingdao 266071, China
[b] Key Laboratory of Experimental Marine Biology, Institute of Oceanology, Chinese Academy of Sciences, Qingdao 266071, China
[c] School of Marine and Atmospheric Sciences, Stony Brook University, New York, United States



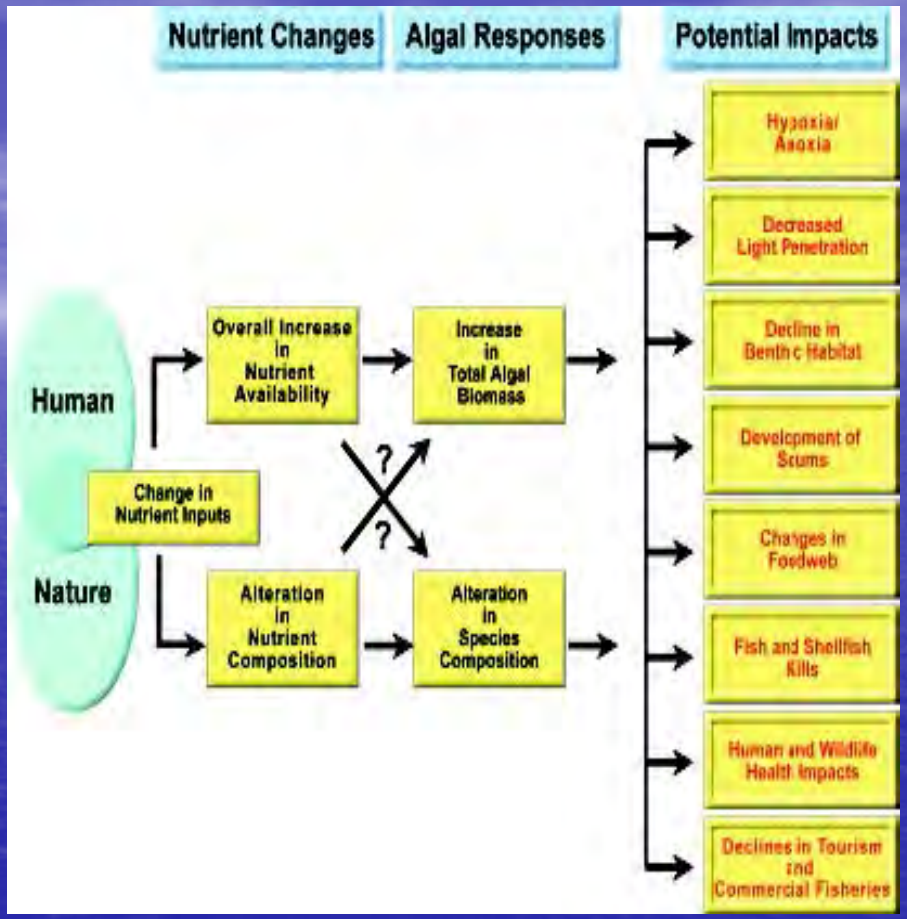


Size spectrum of bloom species in China

- **Possible links :**
- **Stronger human activities (Eutriphication, increased aquaculture, ballast water）**
- **Climatic changes**
- **Improved methodology and monitoring activities**

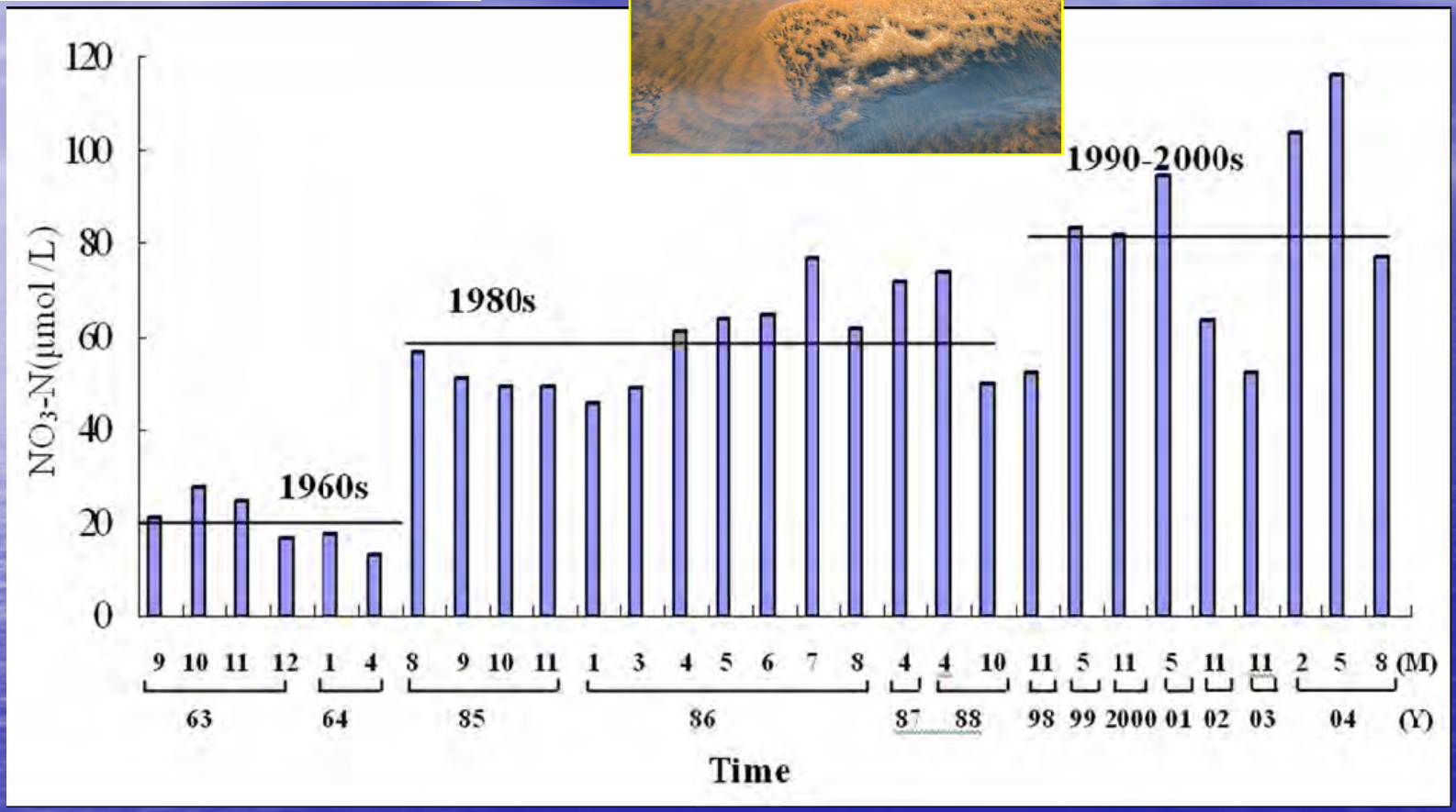


Status of pollution in Chinese coastal waters, 2008 (http://www.soa.gov.cn)



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

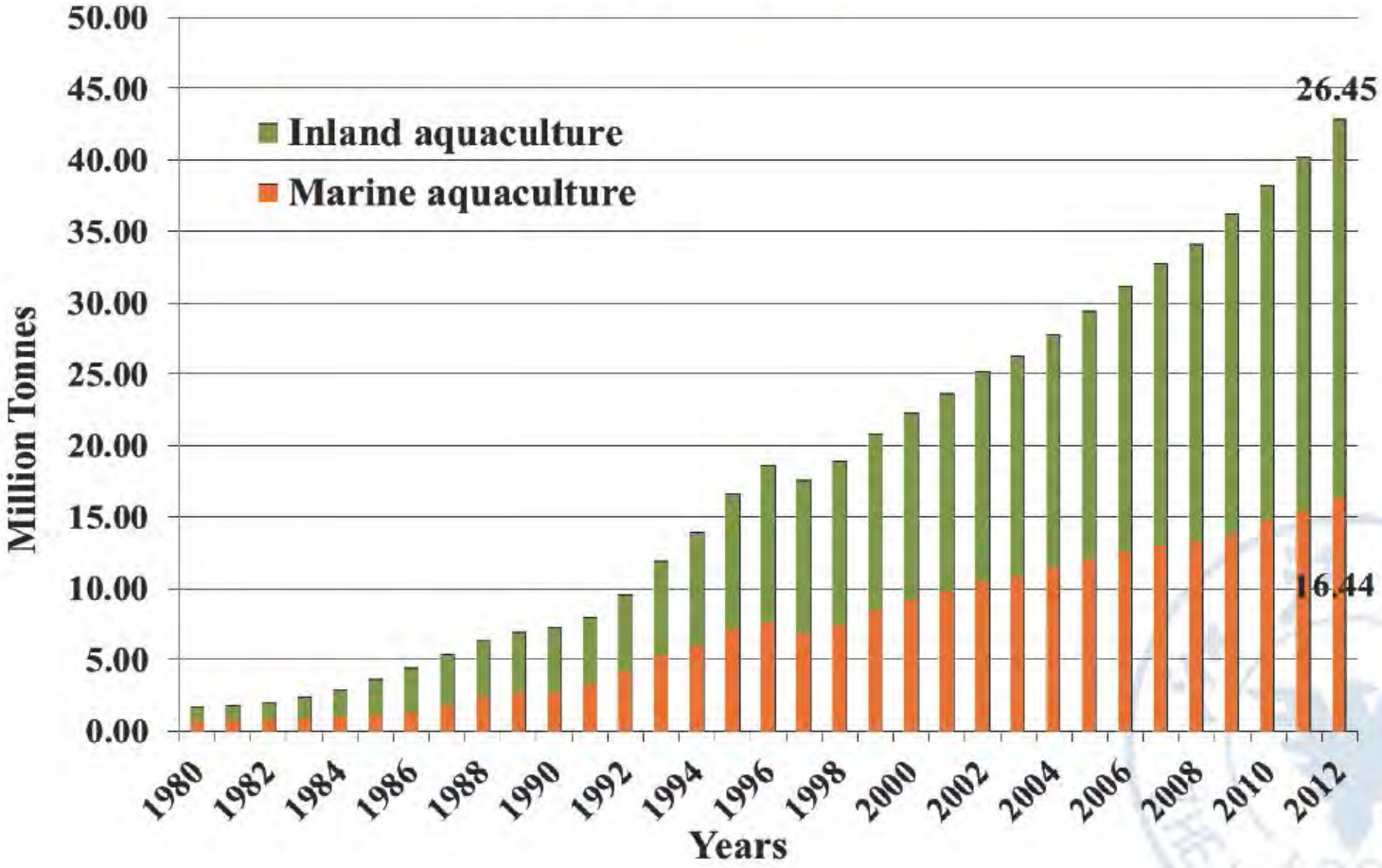
Consequence of Eutrophication



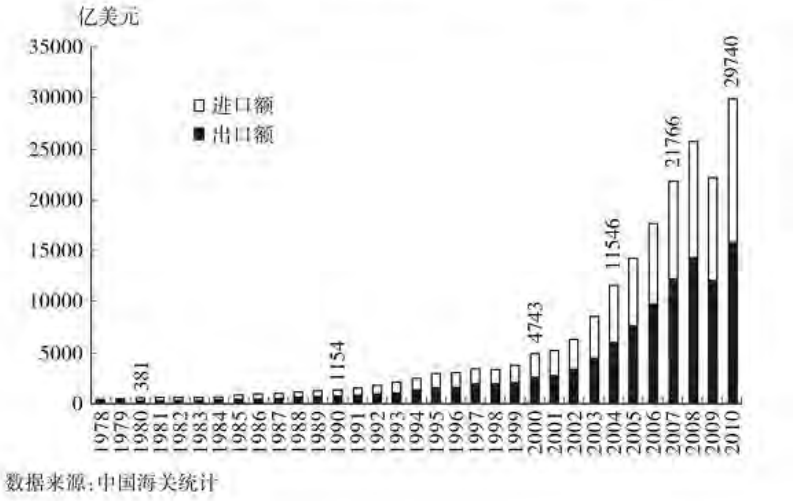
A long-term variation in nitrate concentration at the mouth of the Changjiang River shows a steady rise in riverine inputs of nutrients (Y) and (M) are the year and the month of sample collection, respectively.

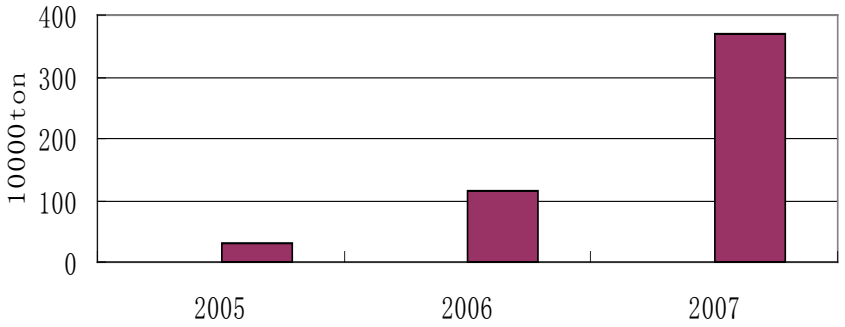
(Zhou et al. 2008)

Marine and inland aquaculture in China (1980-2012)



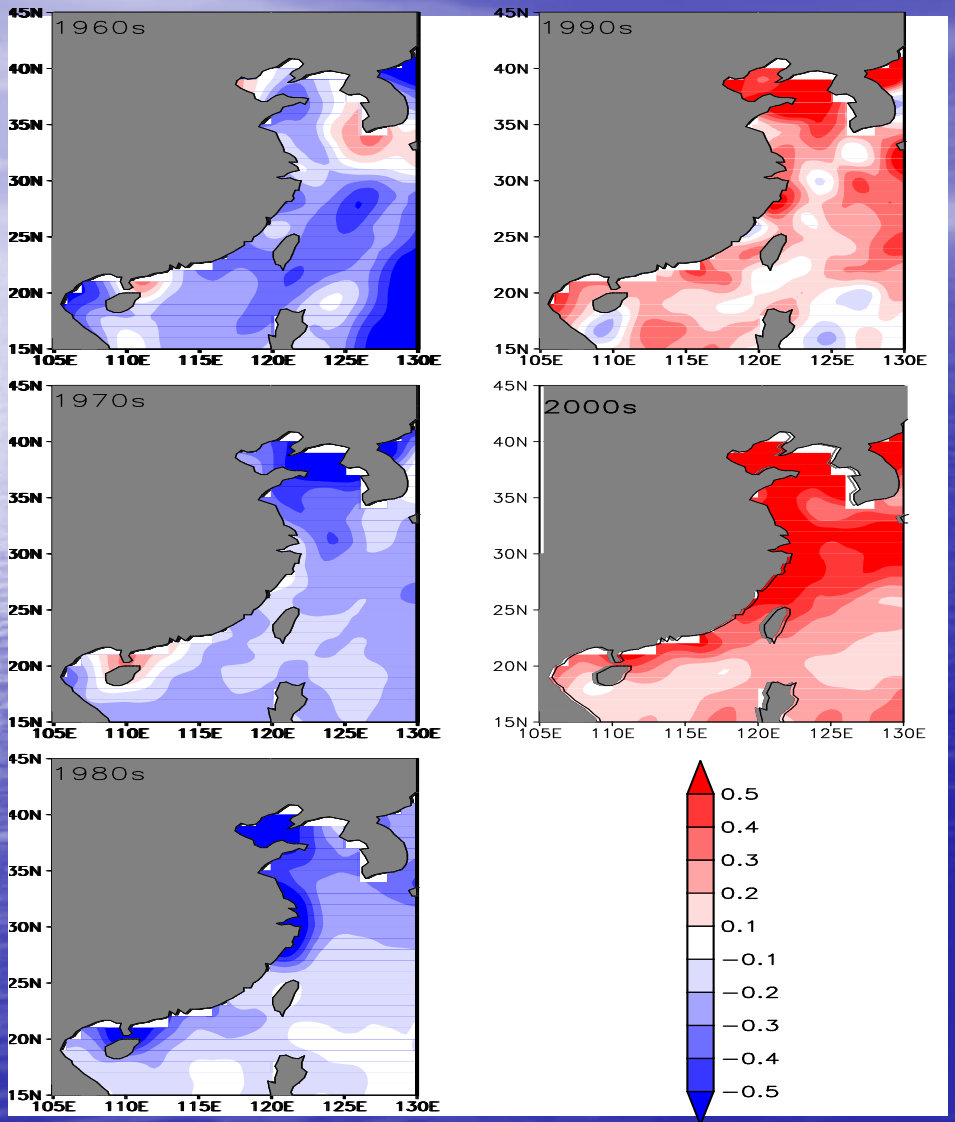
HAB species may transported and dispersed by ballast water

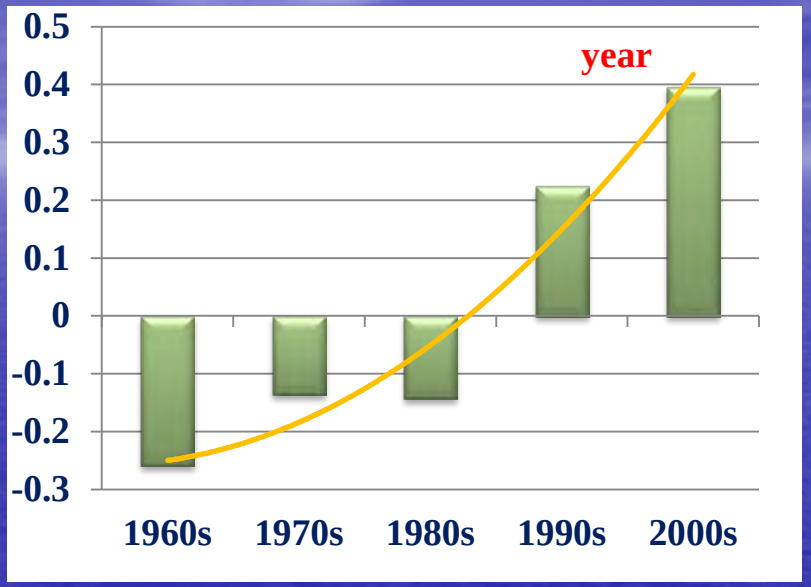




Ballast water released by repaired vessels in Zhoushan

Water temperature in China Seas





Li, unpublished data

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

Sea level change

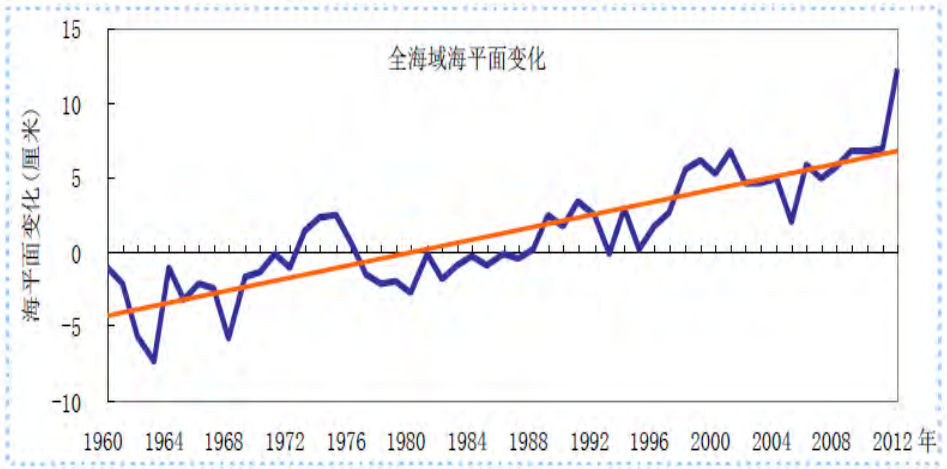


图 2.93　1960-2012 年中国沿海年平均海平面变化(图例)

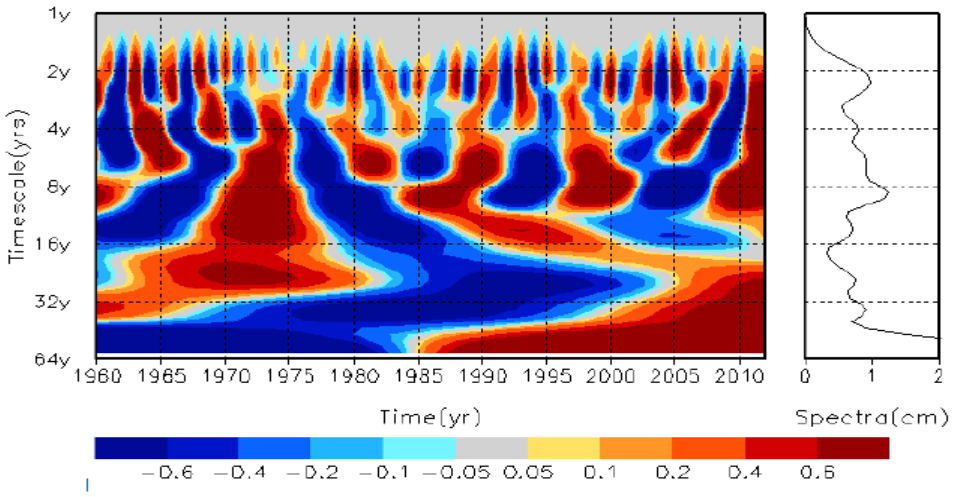


图 2.94　中国沿海海平面小波变换分析结果
（左部为小波谱的实部(cm)；右部为小波谱的振幅(cm)

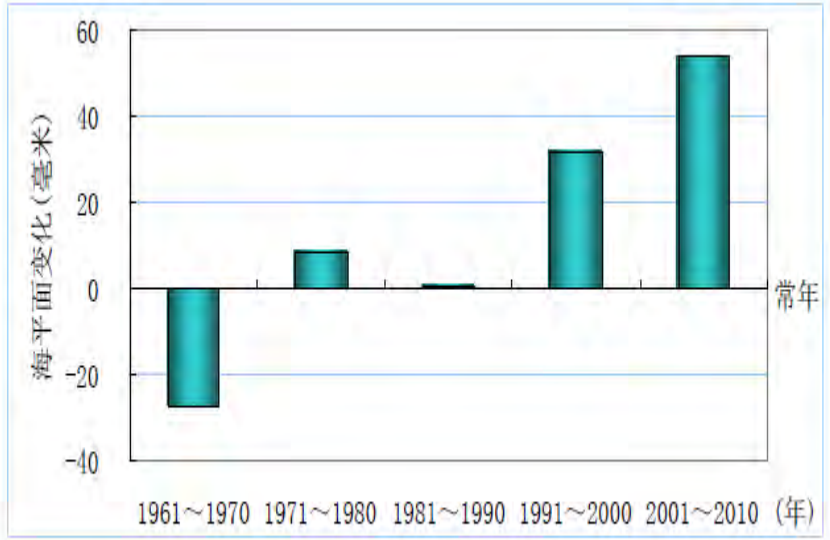
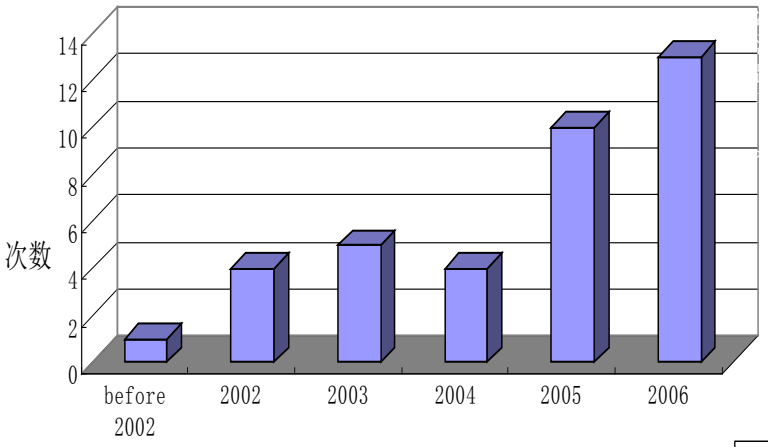
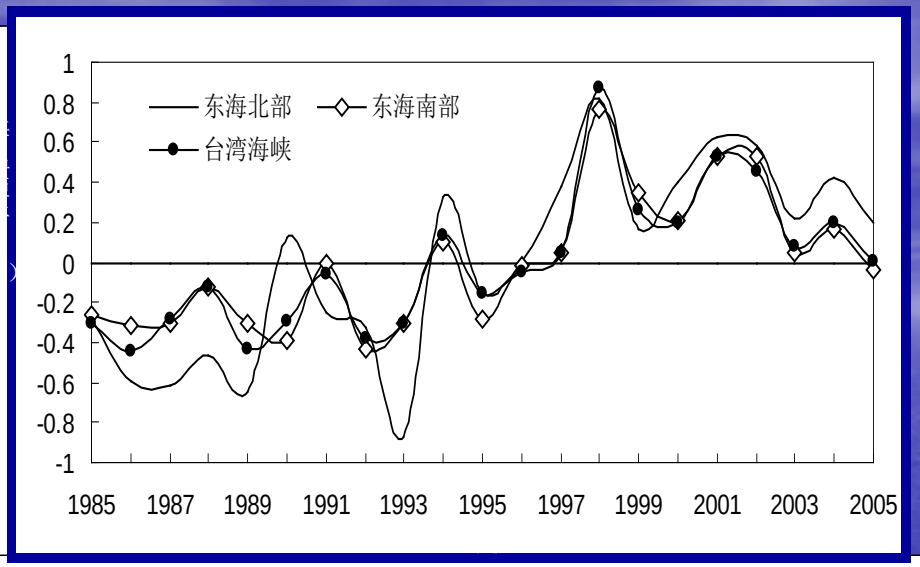


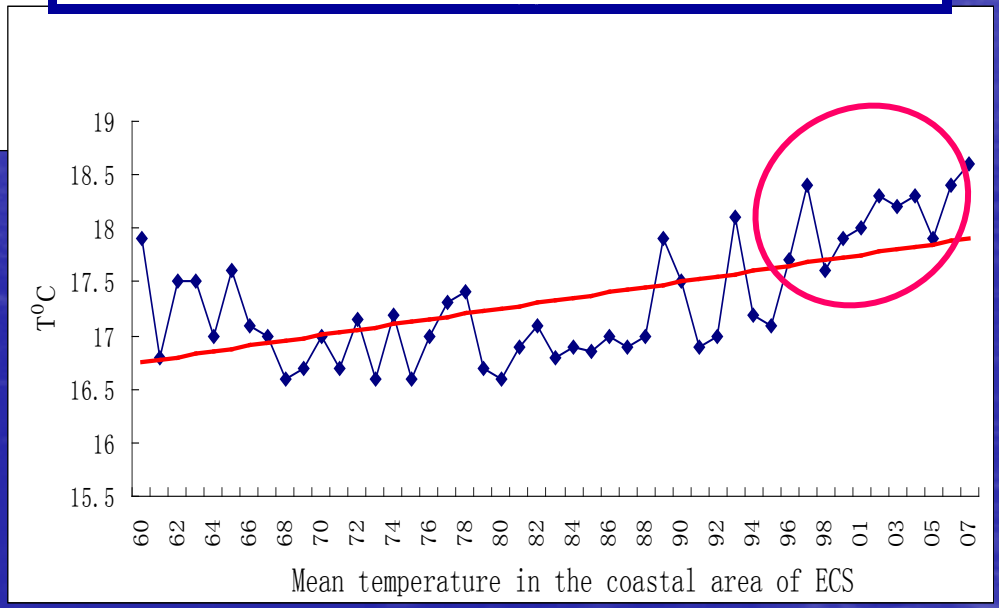
图 2.101 1960～2010 年中国沿海十年平均海平面变化*

Li, unpublished data



Record of toxic RT in Zhejiang coastal waters

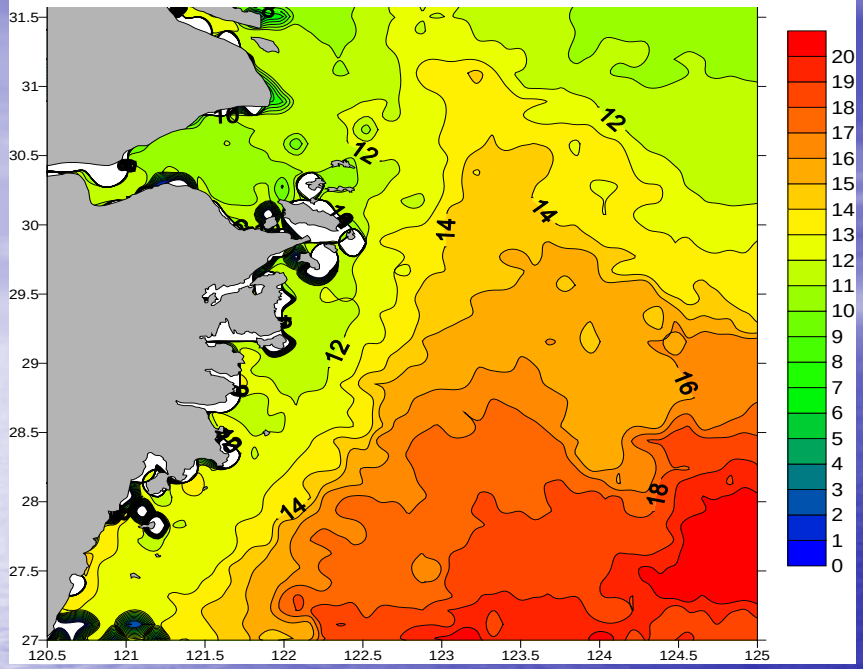




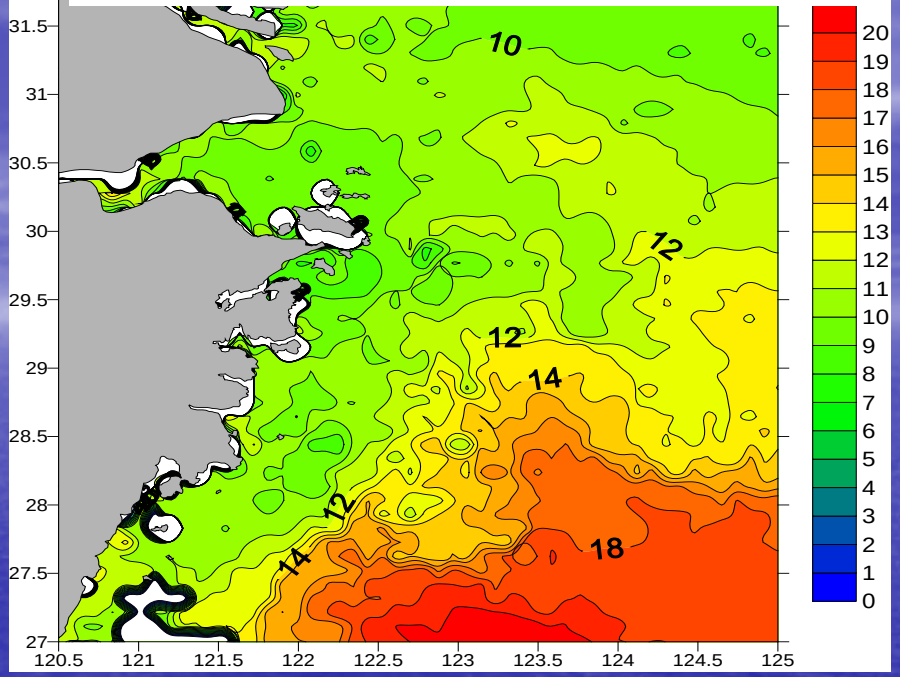
Mean temperature in the coastal area of ECS

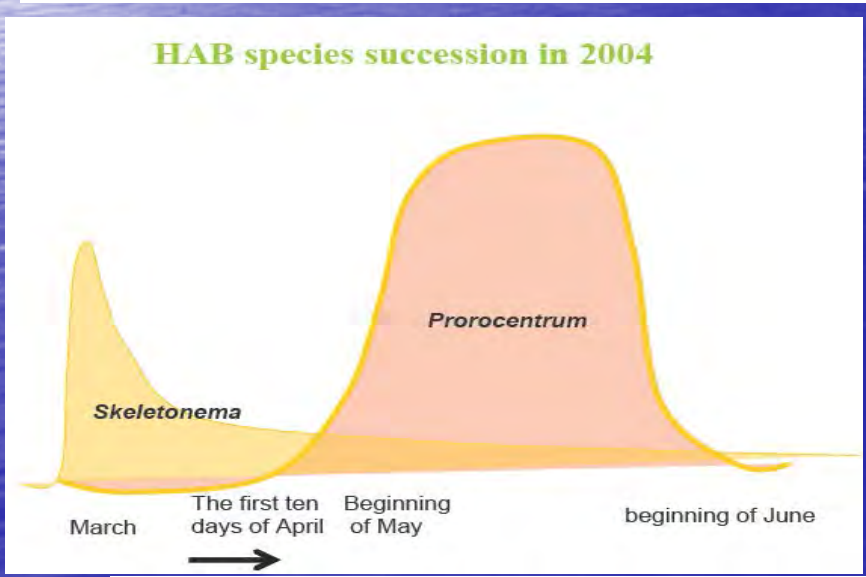
Climatic changes may favor the HAB species

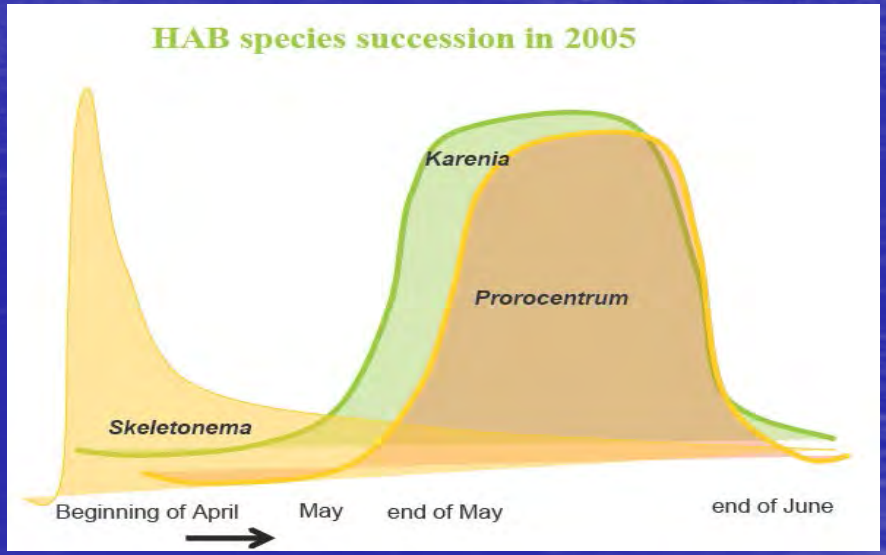
SST at the beginning of April 2004



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 environmental change

Thank you