Two decadal changes of *Heterosigam akashiwo* blooms in Korean coastal waters

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Historical record of red tides

- Historical record

■ HABs in 639 in the Silla dynasty
東海水赤且熱魚鼈死(三國史記卷第5號)

■ The coastal seawater in the East Sea was discolored as red with high temperature, and some turtle and finfish were found in dead.

Now we are dispersing clay !!

Aerial view of clay dispersion in South Sea

Major topics of this presentation

I. Introduction & data acquisition

II. Brief ecology of Korean *H. akashiwo*

III. Two decadal changes of *H. akashiwo* blooms

IV. *H. akashiwo* in species succession in HABs

V. Eutrophication and *H. akashiwo* blooms

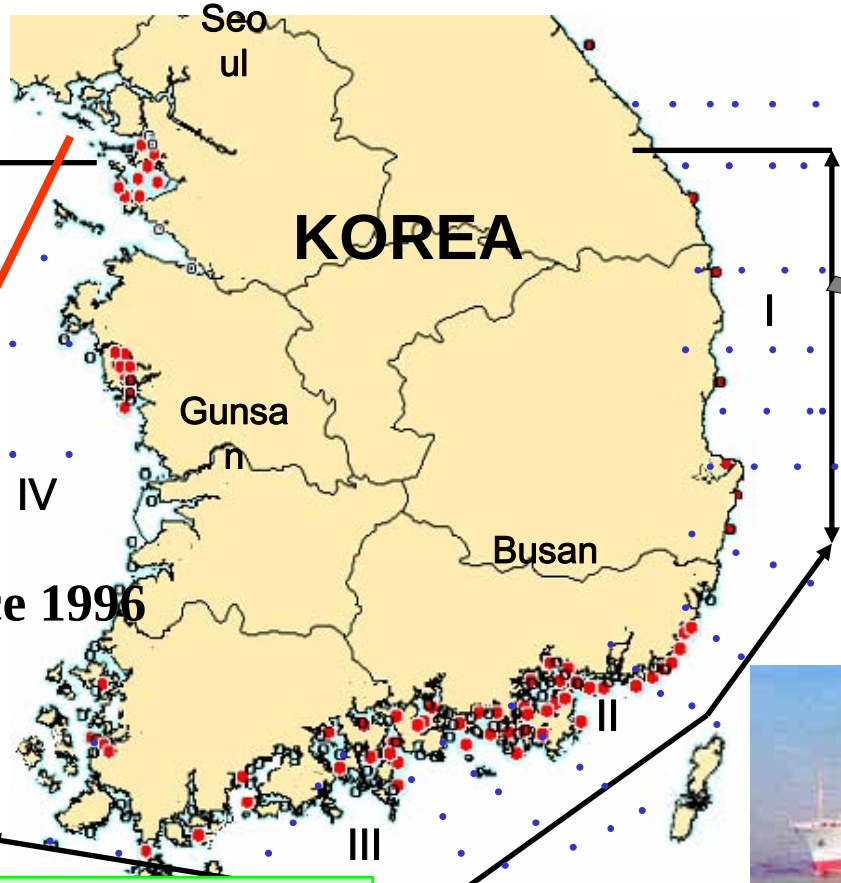
VI. Conclusions

I. Introduction & data acquisition

The Monitoring of Marine Environment and HABs

Before 1995

Since 1996



Oceanographic observation 300 points (since 1921)
Environmental observation 300 points (since 1972)
HABs observation (●) 160 points (since 1967)

Monitor components for Korean marine environment

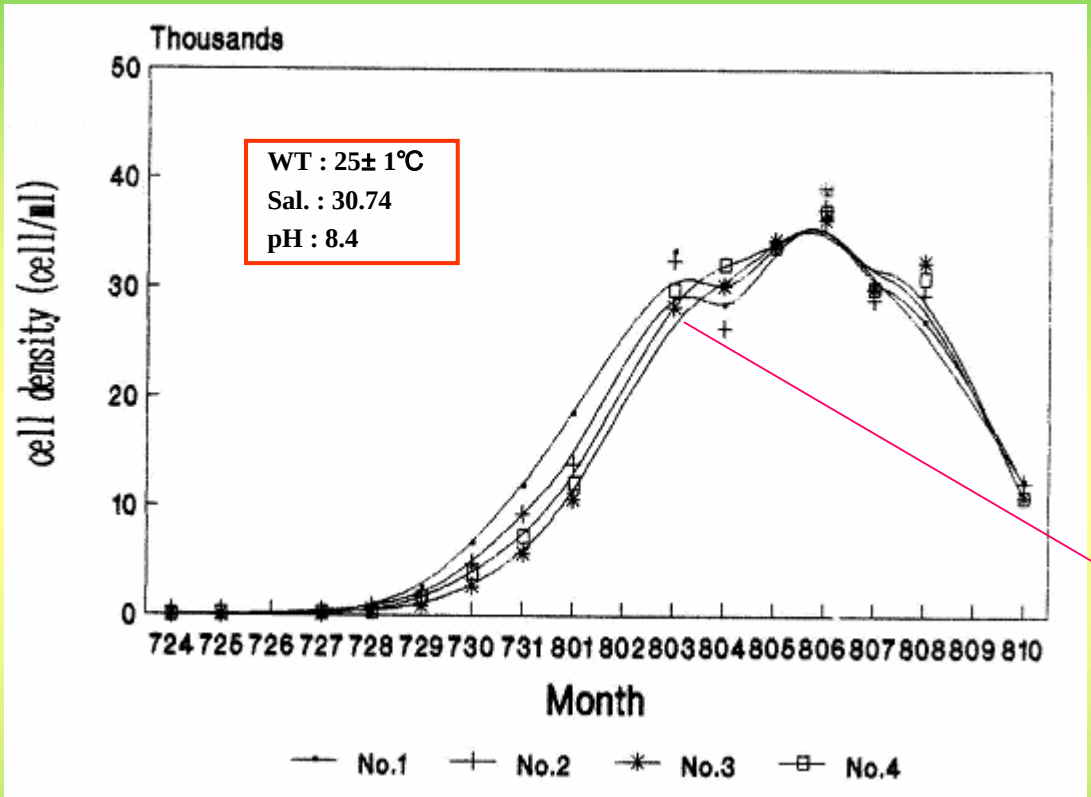
Monitoring requirement		Required monitoring components
SEAWATER (21factors)	General items	SST, Salinity, pH, DO, COD, TN, TP, NO2 - N, NO3 - N, NH4 - N, PO4 - P, SS, Oil & Grease, Clearness
	Trace metal	Cu, Pb, Zn, Cd, Cr^{+6}, total Hg, As, CN
	Organic contaminants	PCBs, TBT
SEDIMENT (12factors)	General items	Particle size, IL, AVS, COD
	Trace metal	Cu, Pb, Zn, Cd, Cr^{+6}, total Hg, As, CN
	Organic contaminants	PCBs, TBT, Pesticides, PAHs, PCDDs/DFs
ORGANISM (15factors)	General items	Chl *a*
	Trace metal	Cu, Pb, Zn, Cd, Cr^{+6}, total Hg, As, CN
	Organic contaminants	PCBs, TBT, Pesticides, PAHs, PCDDs/DFs


II. Brief ecology of Korean *H. akashiwo*
2007/10/20

Biometrics of *H. akashiwo*

- **Cell size and volume of single cell**
  - **Cell length 8-25μm, width 6-15μm**
  - **Average cell volume :1,031μm^3**
  - **Average carbon contents : 141pg/cell**
- **Cell volume and carbon contents in the monospecific blooms**
  - **Bloom density : 1,300-112,360 cells/㎖**
  - **Cell volume (x$10^6 \mu m^3$) : 1.3 - 115.8**
  - **Carbon contents (μgC/㎖) : 0.07 -3.33**

Source :Kim et al., 1993



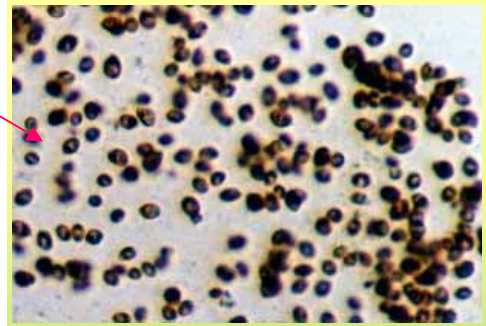


Fig. The growth curve of *H. akashiwo* in SW-II media.

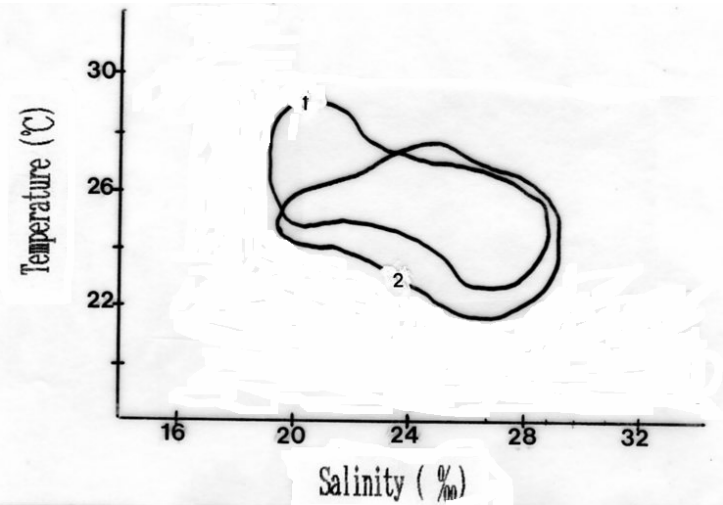


Fig. 12. The trails of water temperature and salinity in the outbreaks of red tides caused by *Heterosigma akashiwo*. 1. Chinhae Bay, 2. Onsan Bay.

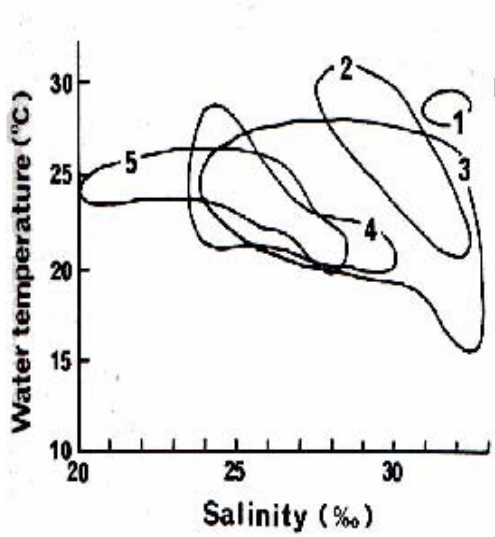


FIG. 2: The ranges of *in situ* water temperature and salinity during *H. akashiwo* red tides: 1. Nagasaki Bay, 2. Hakata Bay, 3. Seto Inland Sea, 4. Mikawa Bay, 5. Narragansett Bay.

III. Two decadal changes of *H. akashiwo* blooms

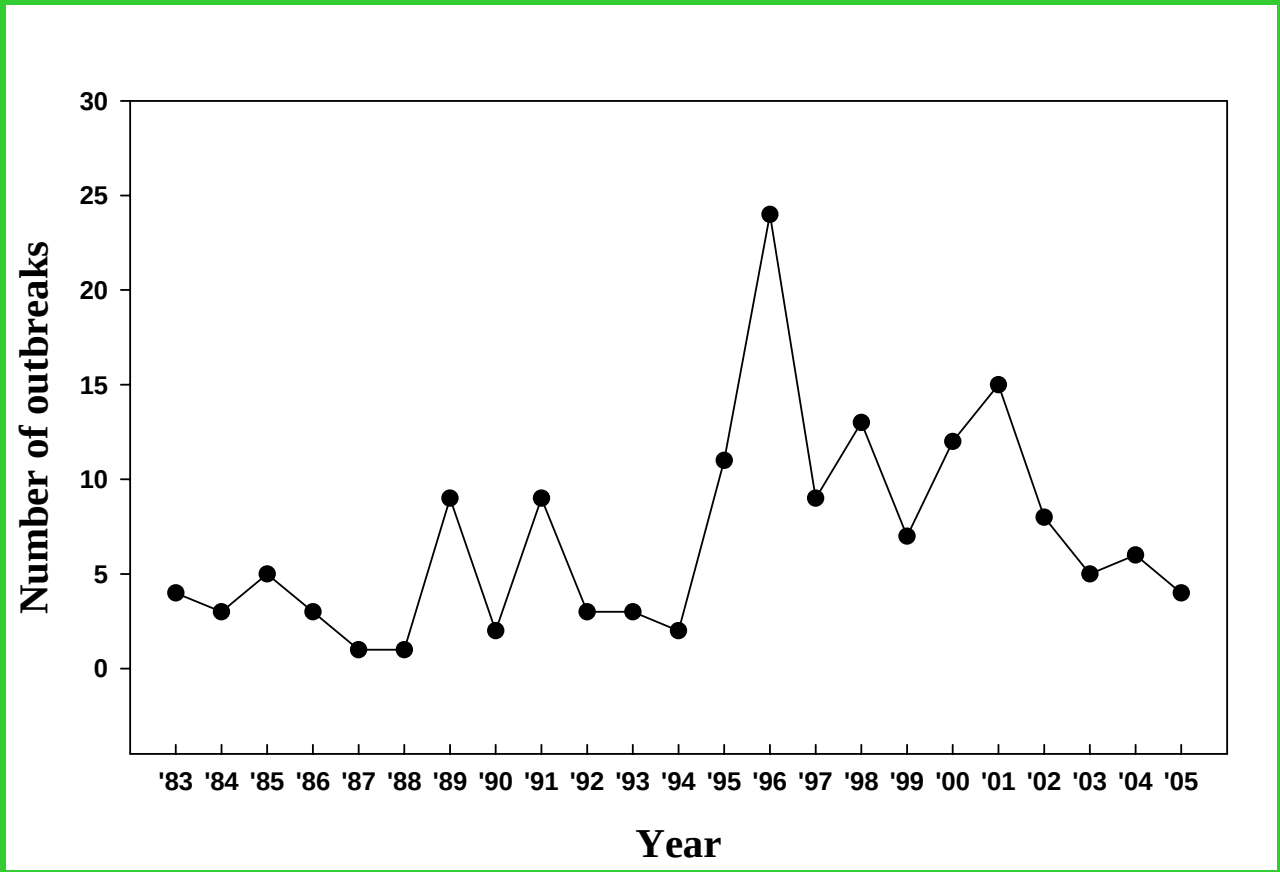


Fig. Annual changes in the number of outbreaks of *H. akashiwo* blooms along the south coast in 1983-2005 period.

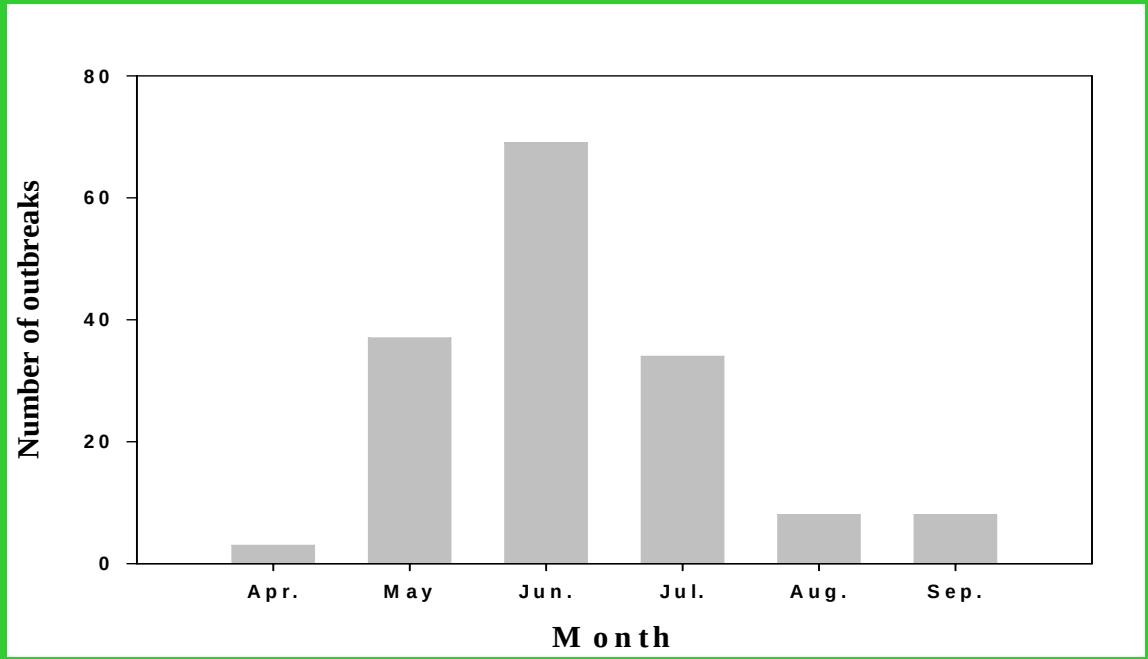


Fig. Monthly distribution of the number of outbreaks of *H. akashiwo* blooms along the south coast in 1983-2005 period.

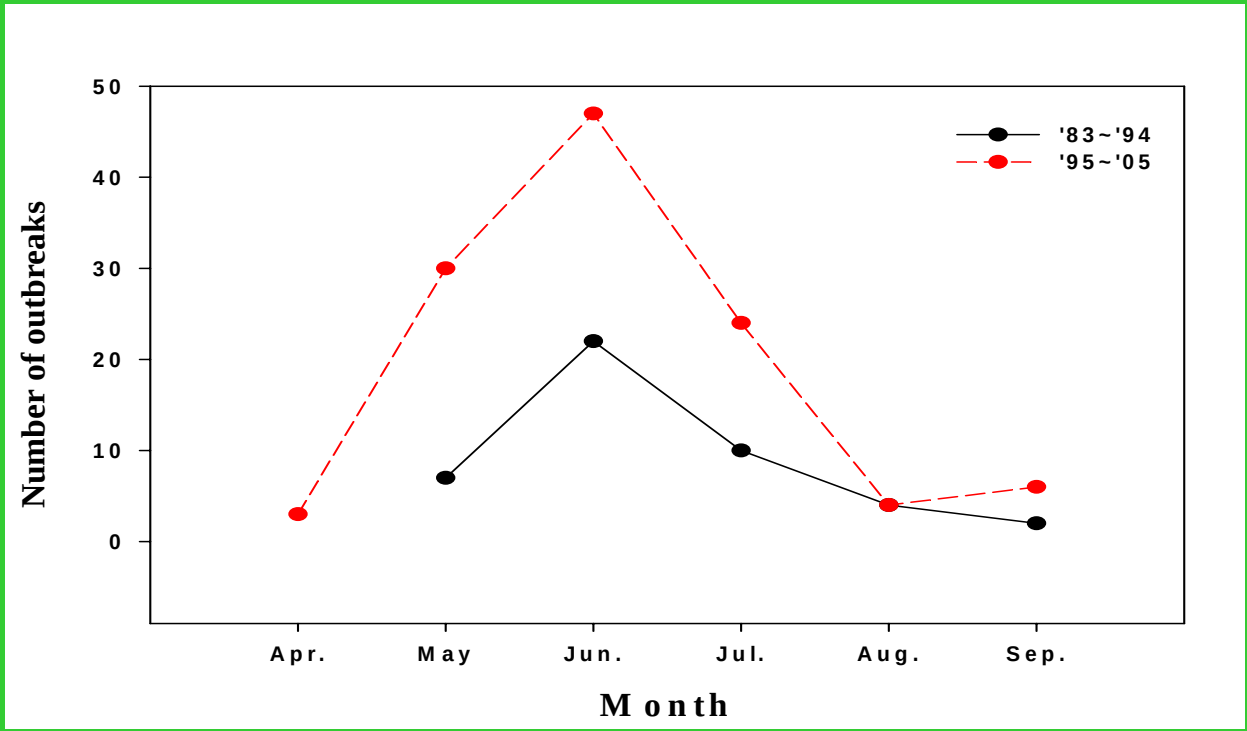


Fig. Monthly distribution in the number of outbreaks of *H. akashiwo* blooms along the south coast in the first decade of 1983-1994 and that of the second decade 1995-2005.

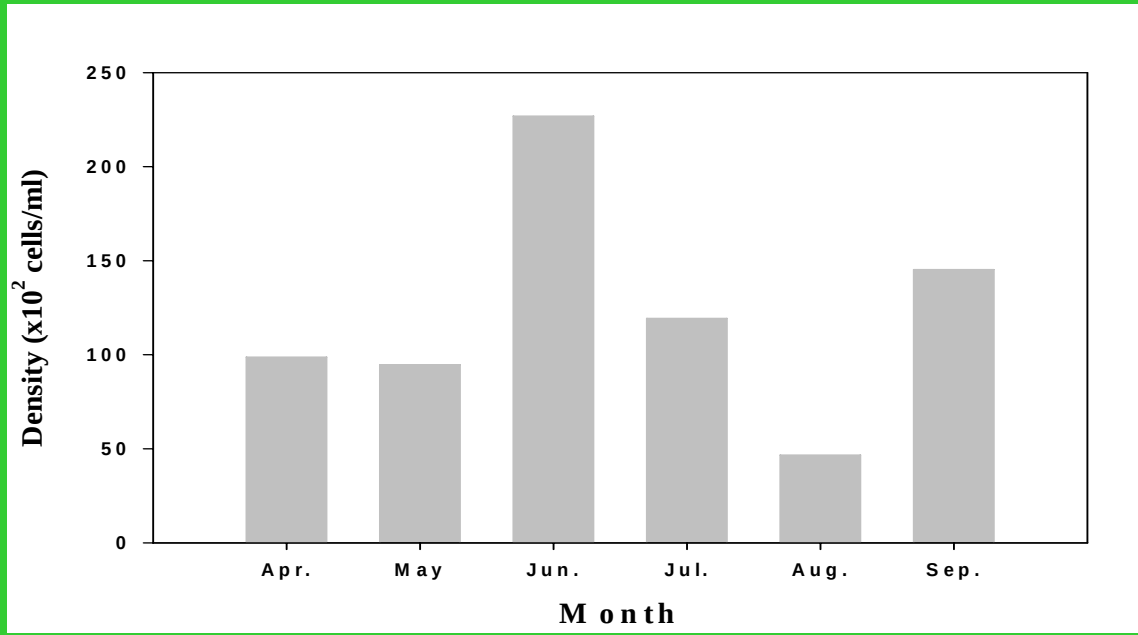


Fig. The distribution of the average density in *H. akashiwo* blooms along the south coast in 1983-2005 period.

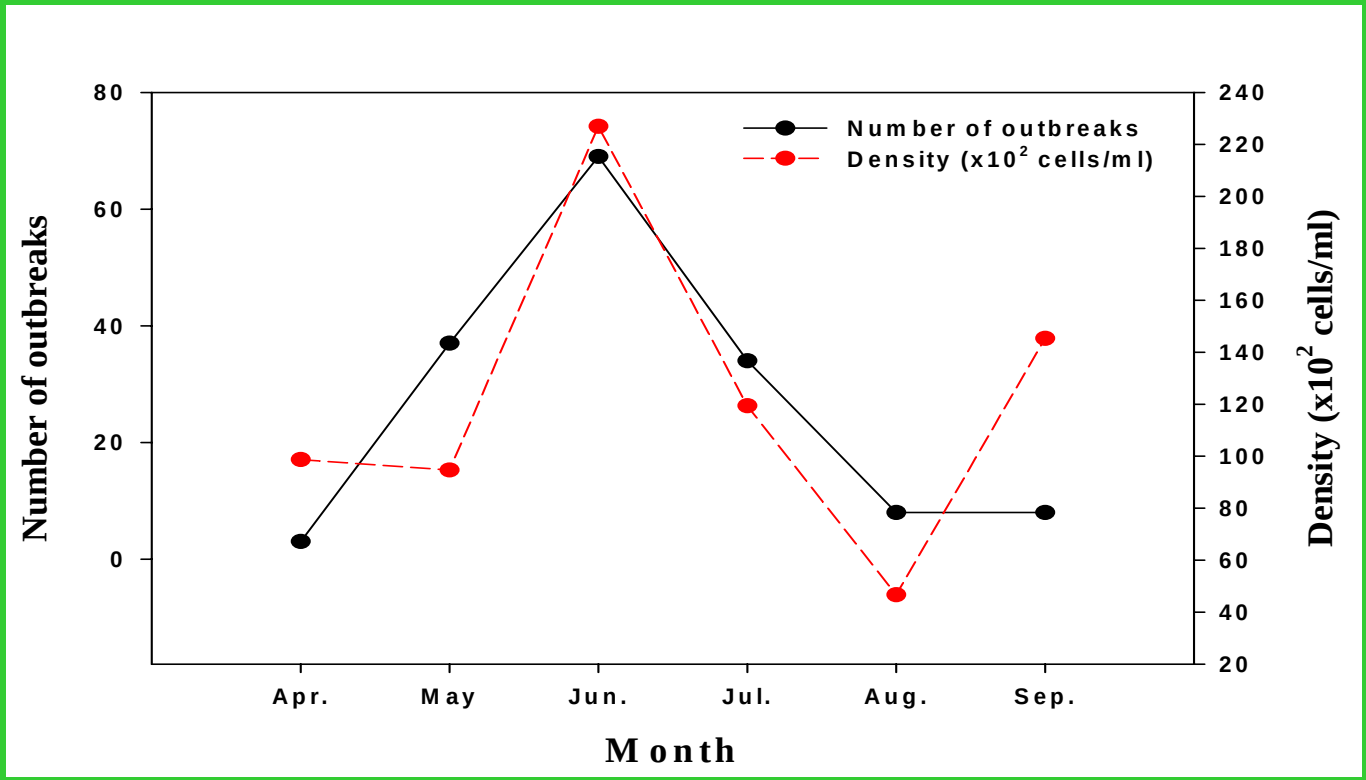


Fig. The number of outbreaks and their density of *H. akashiwo* blooms along the south coast in 1983-2005 period.

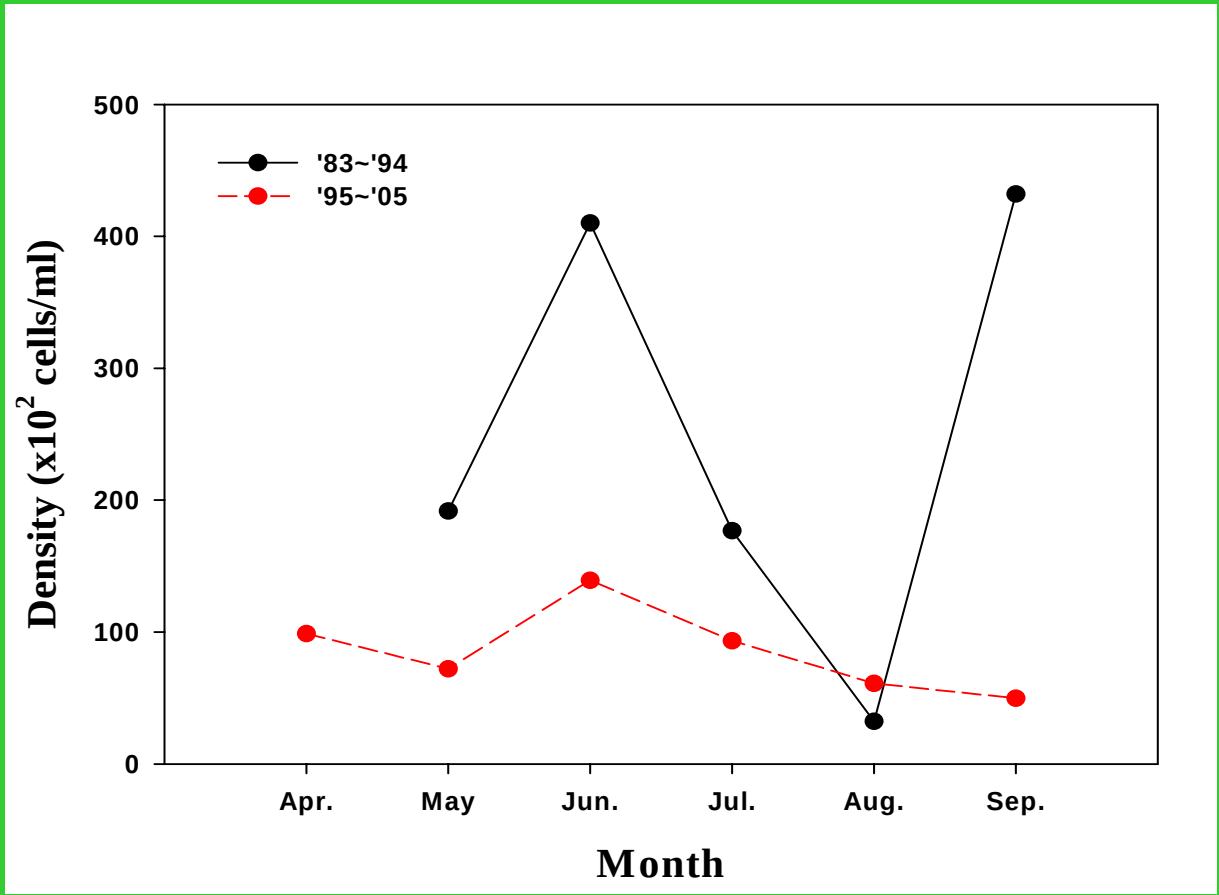


Fig. The average density of *H. akashiwo* blooms along the south coast in the first decade of 1983-1994 and that of the second decade 1995-2005.

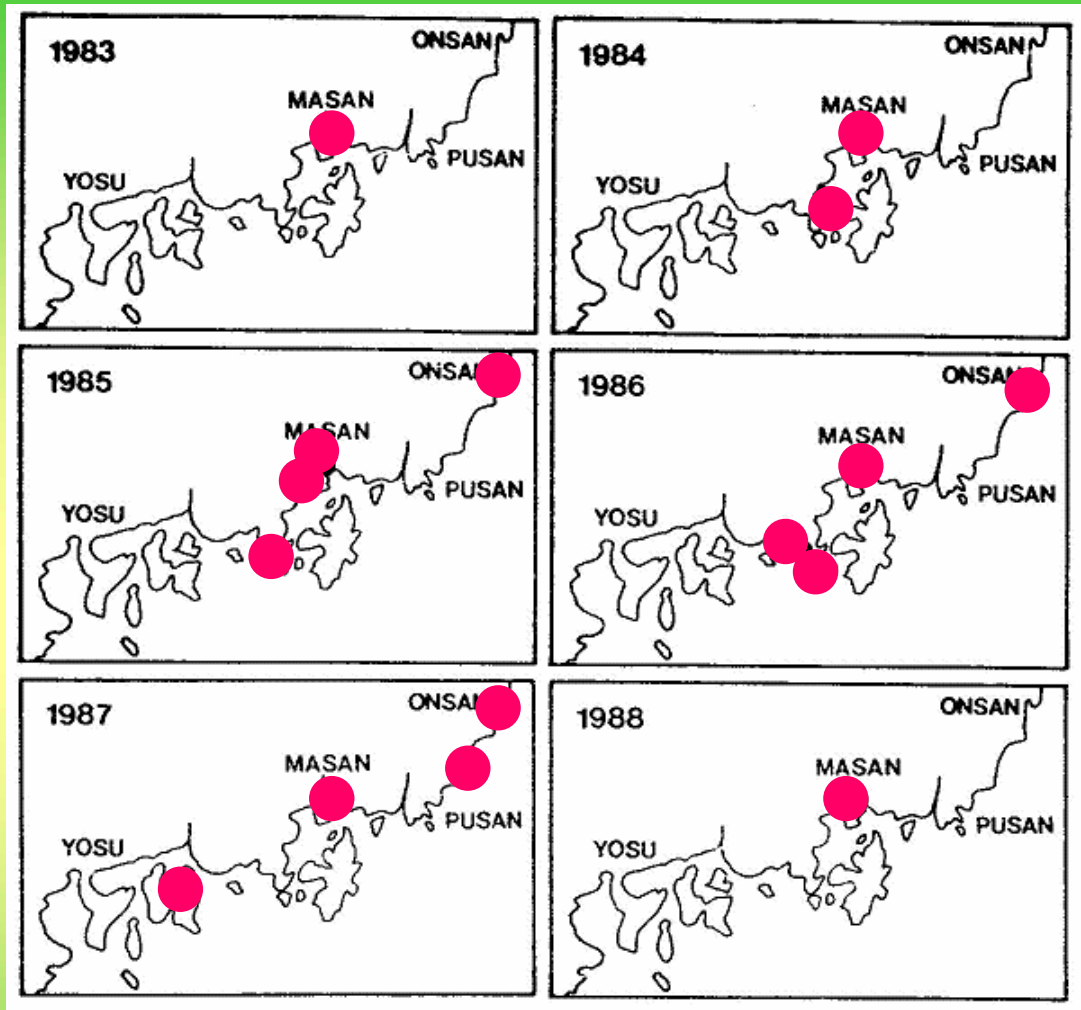


Fig. The geographical spreading of *H. akashiwo* blooms along the south coast in 1983-1988 period.

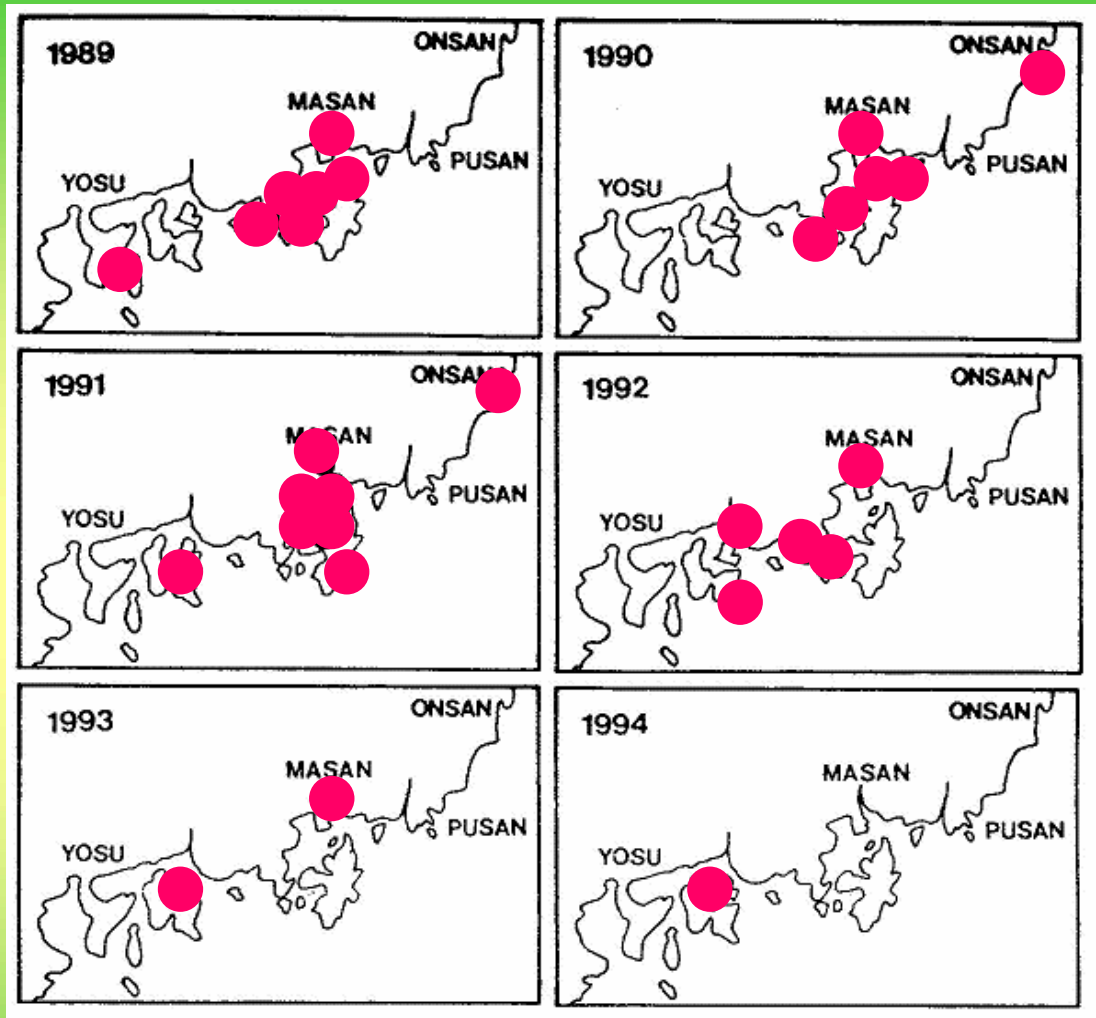


Fig. The geographical spreading of *H. akashiwo* blooms along the south coast in 1989-1994 period.

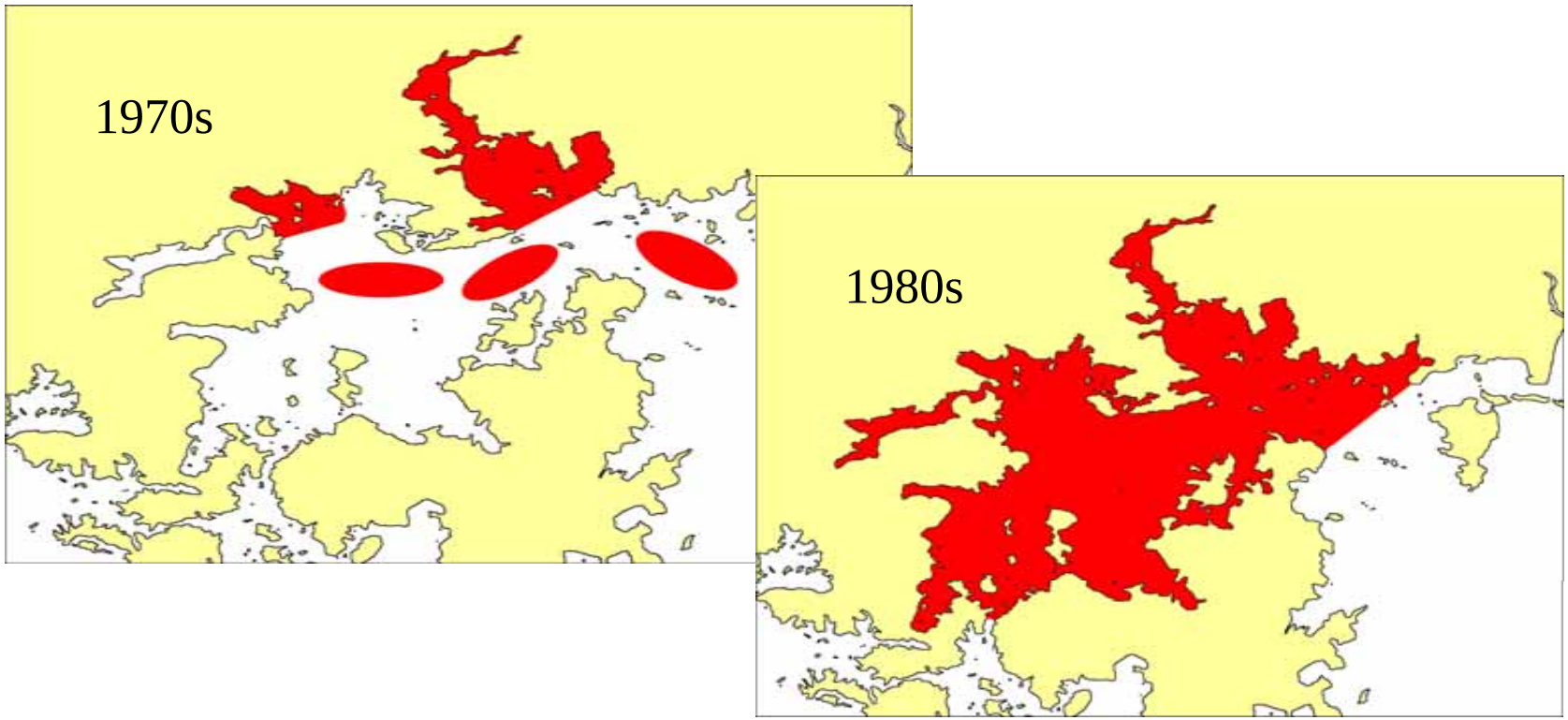


Fig. The areas affected by *H. akashiwo* blooms in Jinhae By in the 19970s and 1980s

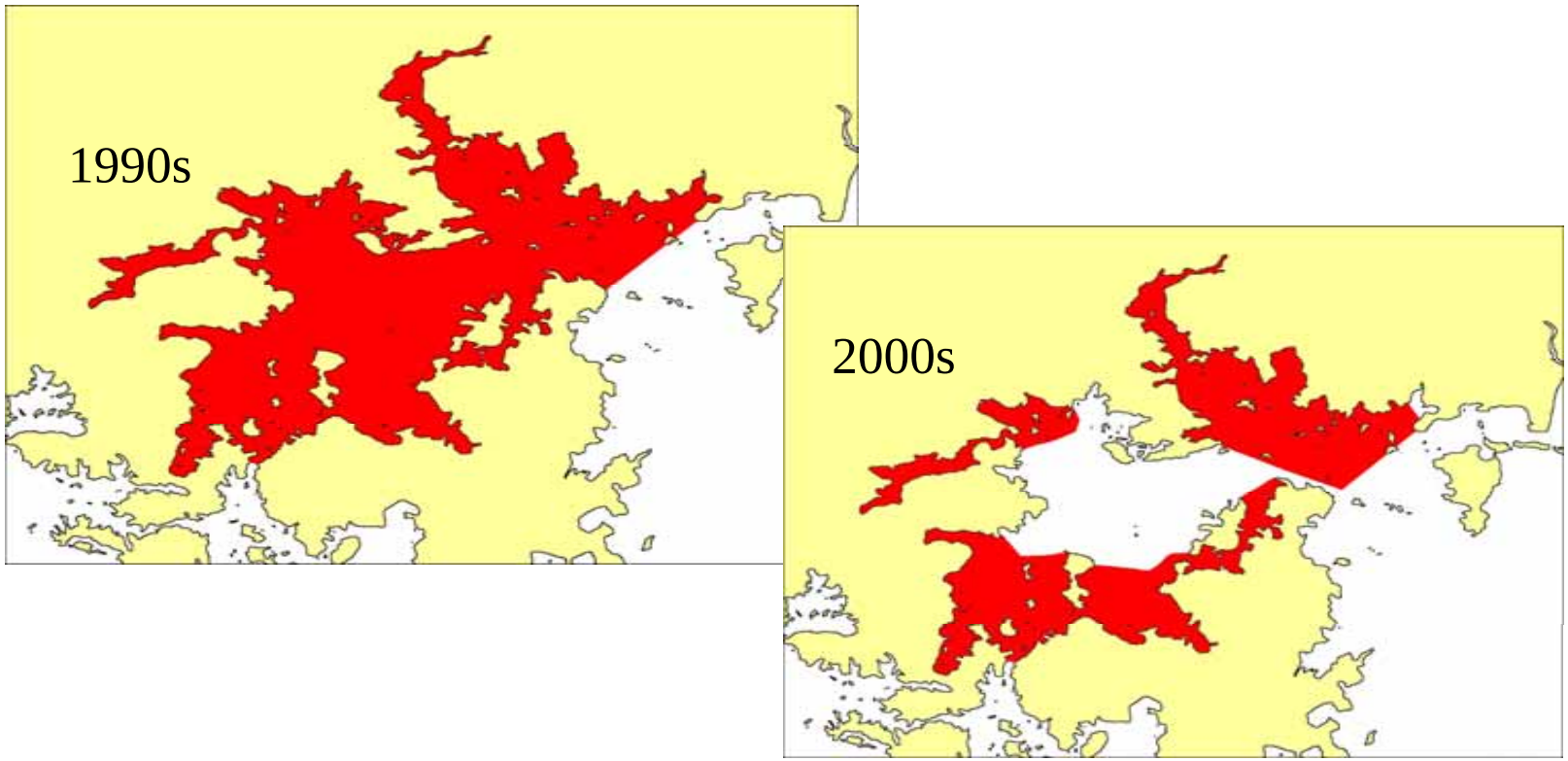


Fig. The areas affected by *H. akashiwo* blooms in Jinhae By in the 1990s and 2000s

Summary 1

- **The *H. akashiwo* blooms were in the peak in the 1995-2001 periods in Korean waters.**
- **The haunting season of this blooms is early summer(May-July) with peak in June.**
- **The high density blooms have been appeared in June.**

IV. *H. akashiwo* in species succession in HABs

Regional comparison of eutrophic level

- Select 3 stations for regional comparison of species succession
  - Masan : haunting area of HABs
  - Tongyoung : mariculture bed
  - Yeosu : bordering offshore waters

Eutrophic level in three representing regions

Recent eutrophic state in Masan Bay and Yosu coastal area

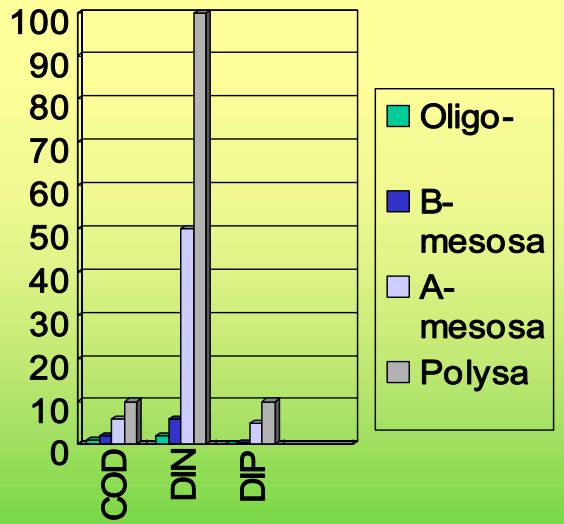
Terms	Yeosu	Masan Bay
COD(mg/l)	1~2	2~4
DIN(uM)	0.4~0.8	0.8~4.5
DIP(uM)	0.01~0.50	0.01~1.50
DO (mg/l)		
-hot season	4~6	0~4
-cold season	5~6	4~5
HABs	Multispecies	Monospecies

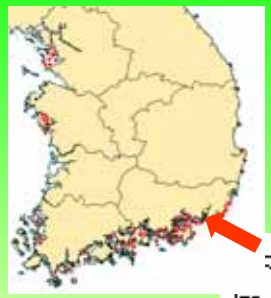
◆ Assessment by Liebman's saprobien system

Yeosu : β - mesosaprobic state

Masan : α - mesosaprobic state

- **Based on COD (ppm)**
  - **Oligotrophic : below 1**
  - **B-mesosaprobic : 1-3**
  - **a-mesosaprobic : 3-10**
  - **Polysaprobic : more than 10**



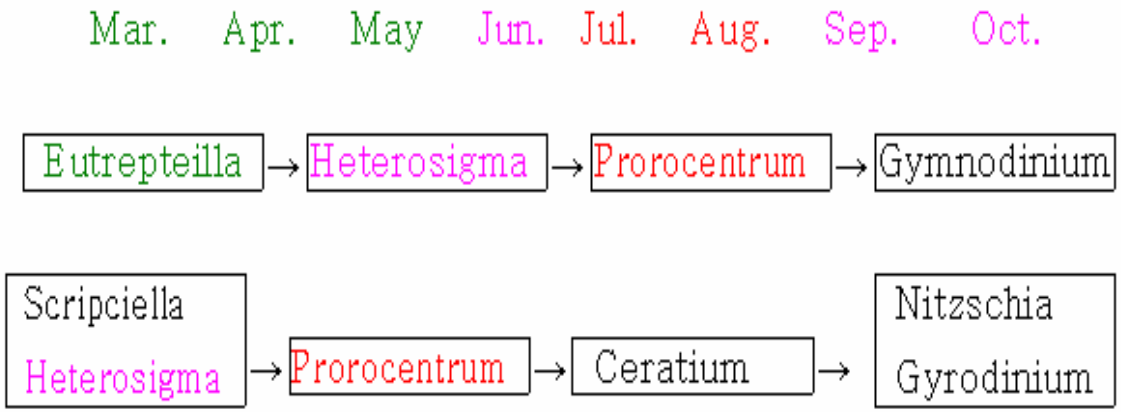


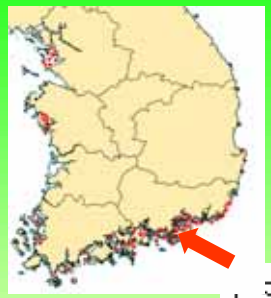
Year \ Month	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.
1980~1988			Skele.	Thala.	Skele. Hetero Proro.	Proro.		
1989~1992	Skele. Hetero.		Entrep. Proro.	Hetero. Proro.	Hetero Proro.	Chaeto. Proro.	Skele.	Gym.
1993~1997		Entrep.	Entrep. Hetero Proro.	Entrep. Hetero Proro.	Others. Hetero Proro.	Others. Hetero Proro.	Cera.	
1998~2001	 Hetero capsa 	Entrep Hetero Proro	Hetero Hetero Gym	Cera Hetero Proro	Cera Proro Proro	Proro Gym Skele	Skele	

Skeletonema, Thalassiosira, Chaetoceros
Eutreptiella, Heterosigma, Prorocentrum
Gymnodinium, Ceratium, Alexandrium
Cochlodinium, Noctiluca, Others

Fig. Species succession in HABs in Masan Bay since 1980

Species succession of phytoplankton community in Masan Bay representing Chinhae Bay





Year \ Month	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.
1980~1988					Skele. Gym.			
1989~1992		Noctil.	Proro.	Hetero. Proro. Other	Skele. Proro. Proro.	Cochl.	Cochl. Gym. Other.	
1993~1997		Hetero. Gym.	Hetero Proro.	Gym. Proro.	Cera. Proro.	Gym. Proro.	Cochl.	Cochl. Gym
1998~2001		Noctil	Hetero Hetero Cera	Hetero Proro	Cera Proro Cochl	Skel Cochl Cochl	Gym Cochl	

Skeletonema, Thalassiosira, Chaetoceros
Rutreptiella, Heterosigma, Prorocentrum
Gymnodinium, Ceratium, Alexandrium
Cochlodinium, Noctiluca, Others

Fig. Species succession in HABs in Tongyoung Bay since 1980

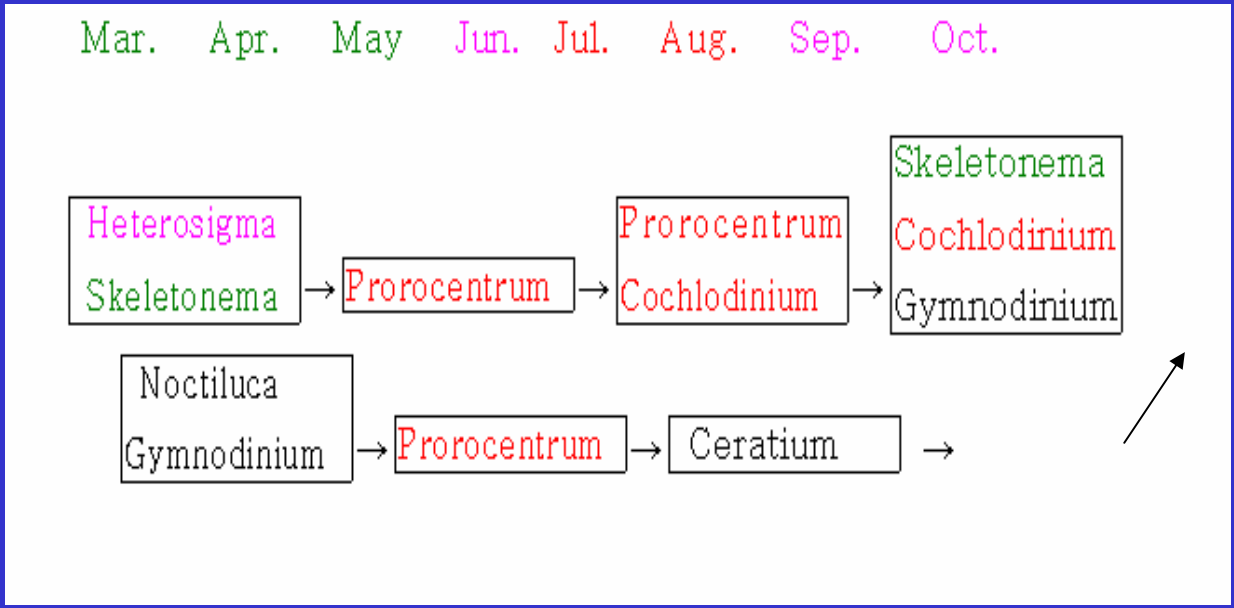
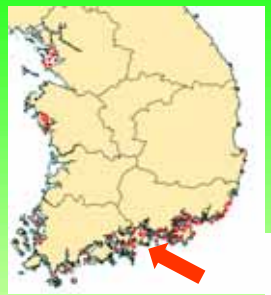


Fig. Species succession of phytoplankton community in Tongyoung areas representing culture beds



Year \ Month	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.
1980~1988					Skele. Others			
1989~1992			Hetero.	Skele.	Skele. Proro. Alex.	Gym		
1993~1997		Noctil.	Skele. Hetero Noctil.	Proro Hetero Alex.	Skele. Hetero Cera.	Skele. Hetero Cera.	Cochl.	Cochl.
1998~2001			Skele Hetero	Cera Hetero Proro	Skele Hetero Chaeto	Skele Cochl Cochl	Cochl.	

Skeletonema, Thalassiosira, Chaetoceros
Rutreptiella, Heterosigma, Prorocentrum
Gymnodinium, Cerstium, Alexandrium
Cochlodinium, Noctiluca, Others

Fig. Species succession in HABs in Yeosu Bay since 1980

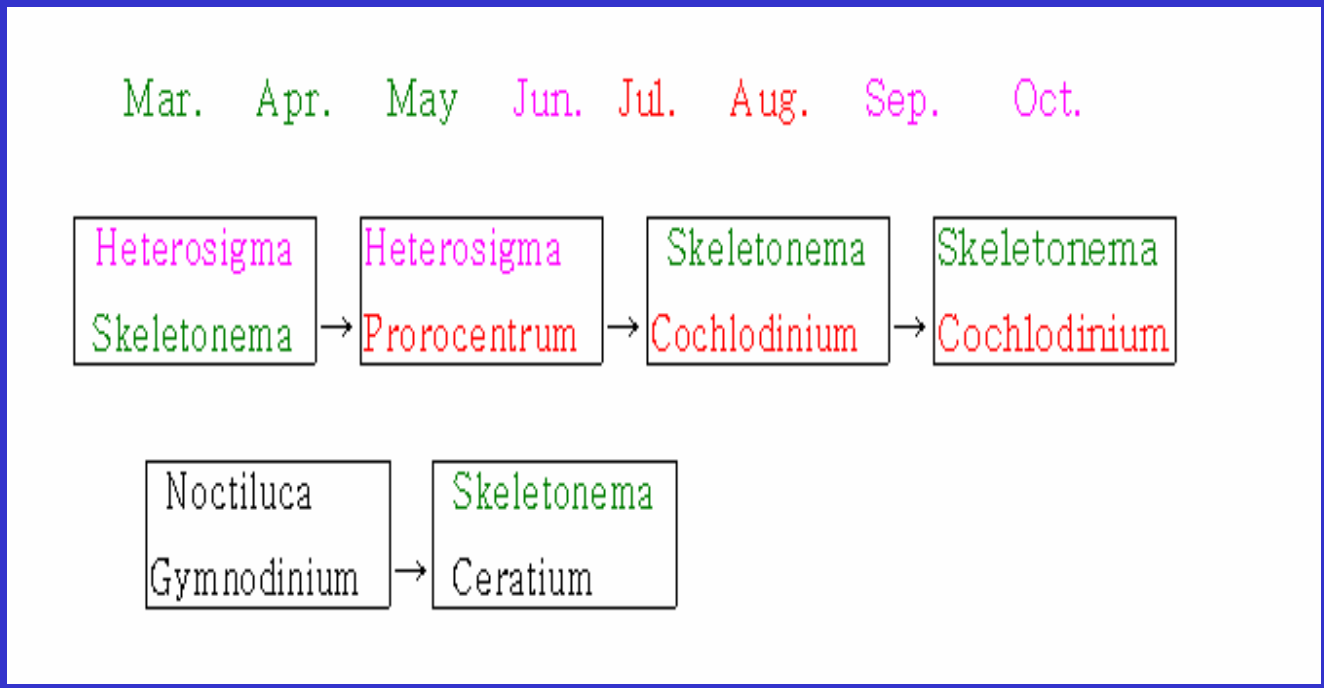
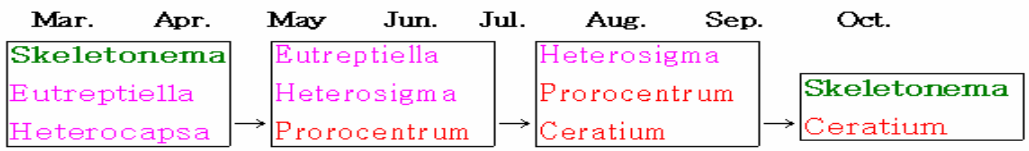
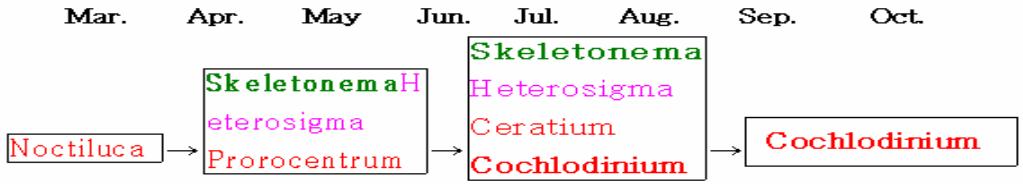


Fig. Species succession of phytoplankton community in Yeosu areas representing culture beds

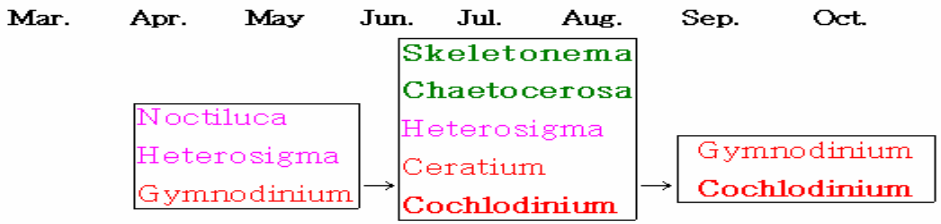
☐ Masan Bay (highly-eutrophic, COD *c.a.*, 3ppm)



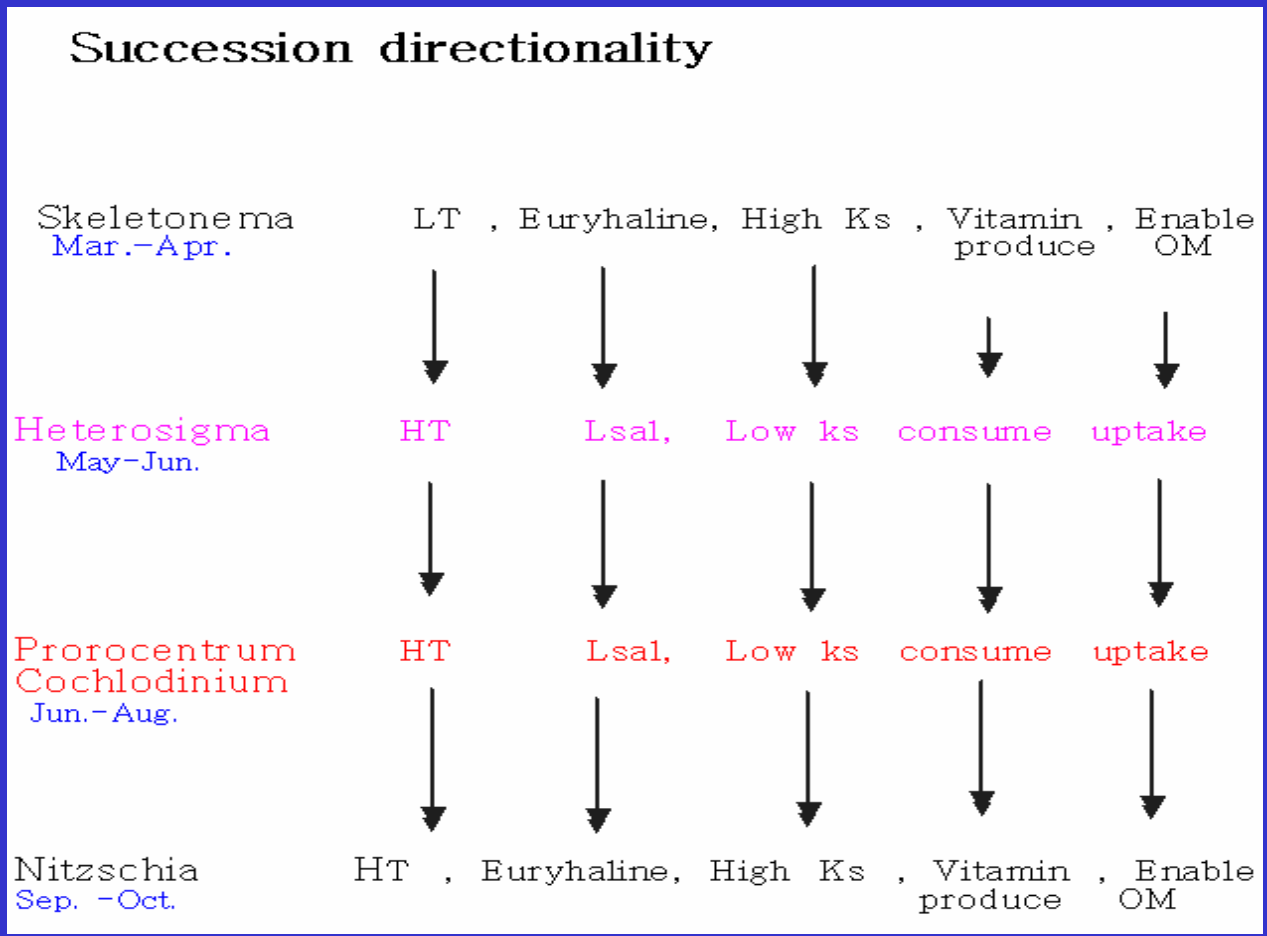
☐ Yeosu Coast (eutrophic, COD *c.a.*, 2ppm)



☐ Tongyoung Coast (eutrophic, COD *c.a.*, 1ppm)

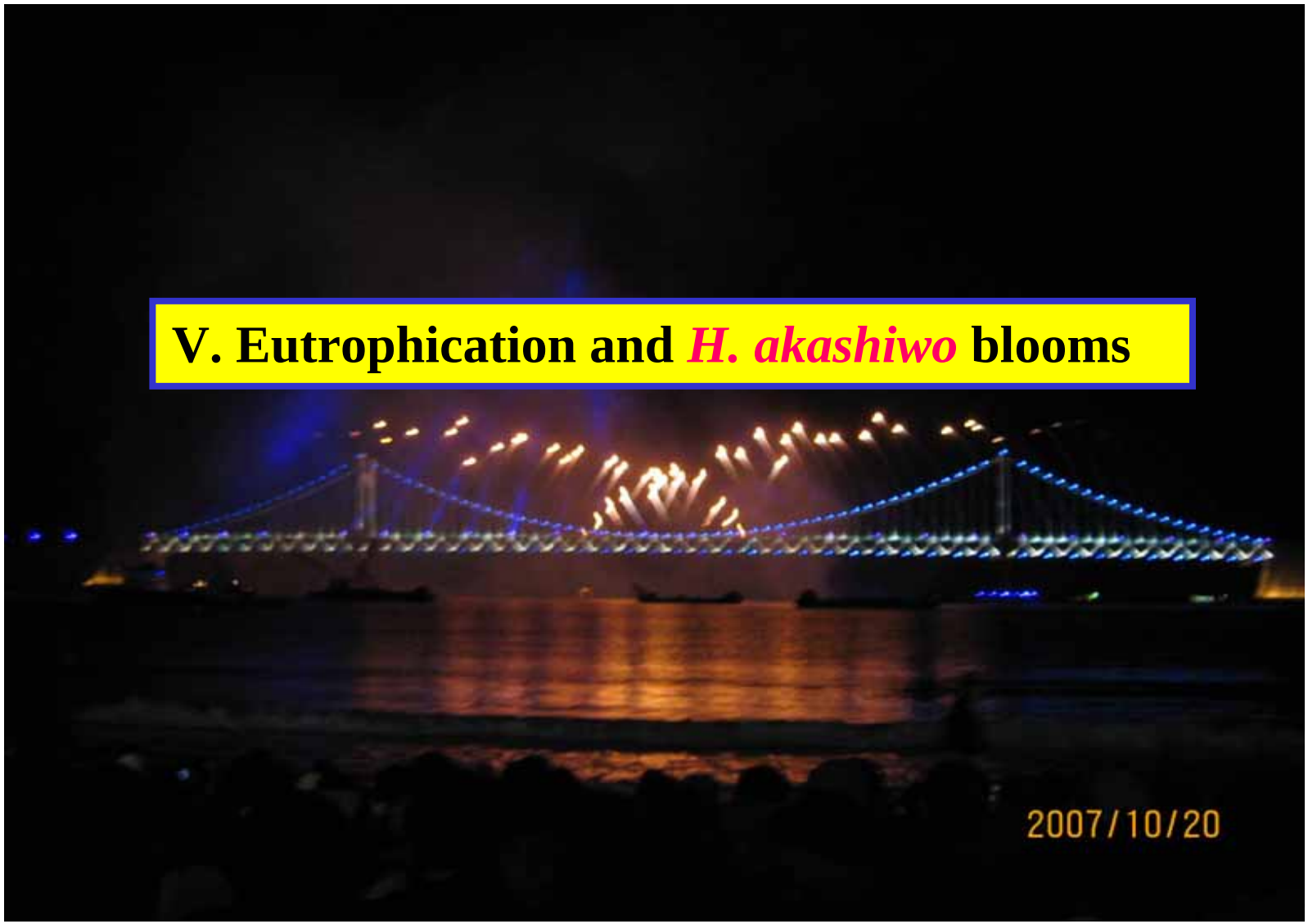


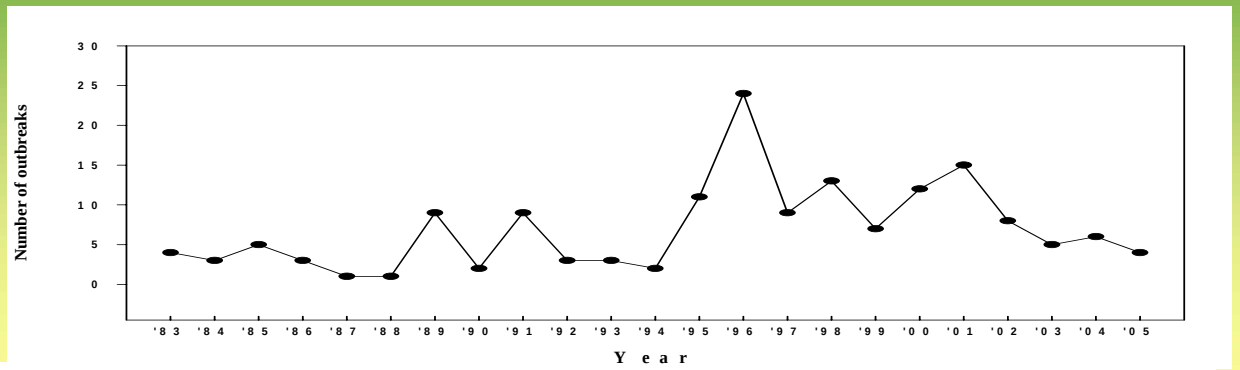
Succession directionality



Summary 2

- **There found an annual and seasonal species succession in the monospecific bloom in Korean waters.**
- ***H. akashiwo*** **has been the prevailing species in spring and early summer both in inshore and offshore waters.**
- ***H. akashiwo*** **can be dominant even in summer in the inshore waters, but it was** ***Cochlodinium polykrikoides*** **in the offshore waters since 1995.**


V. Eutrophication and H. akashiwo blooms
2007/10/20



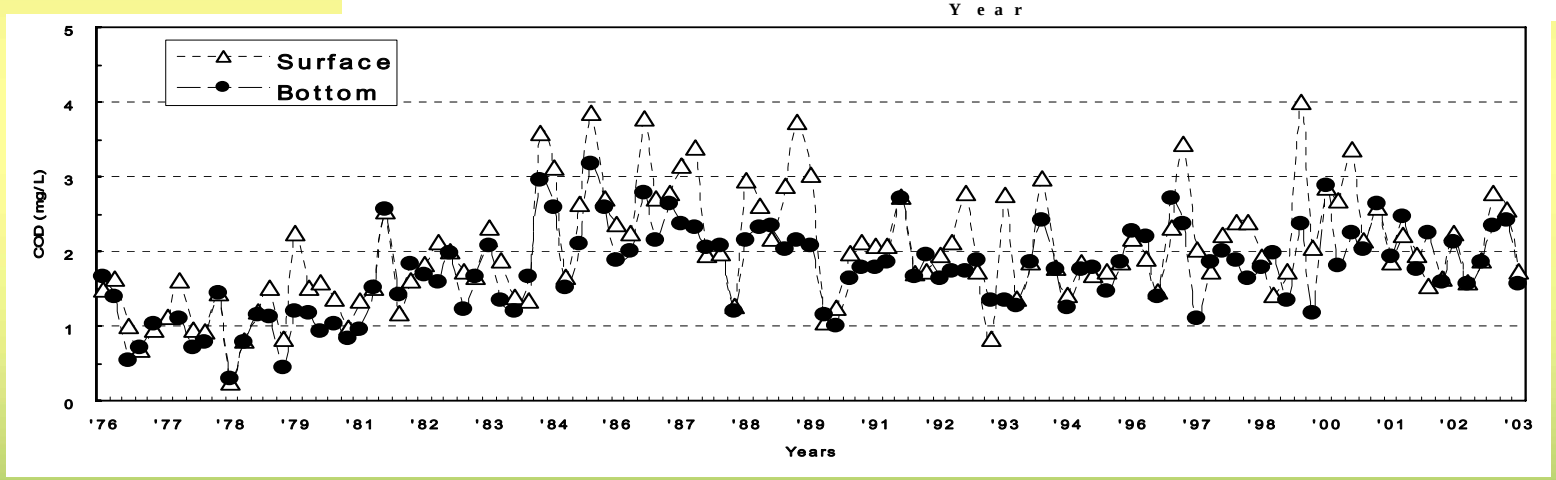
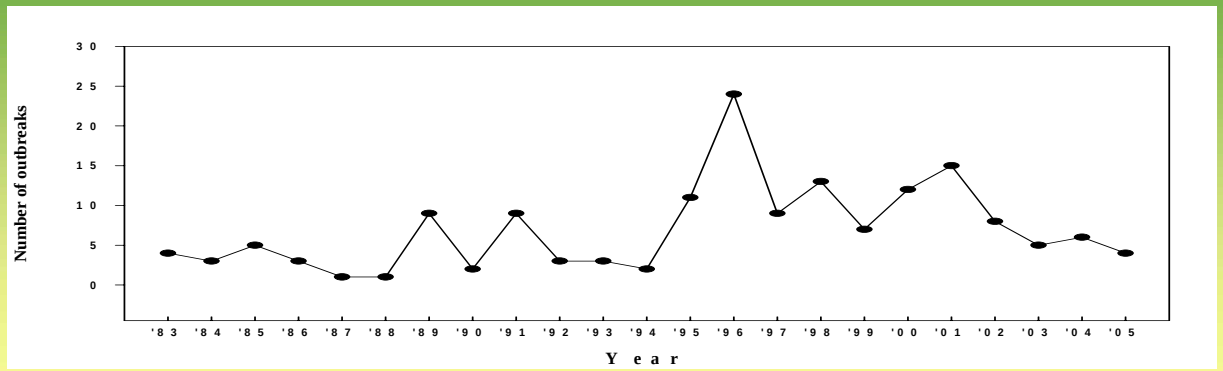


Fig. Annual changes of COD in the seawater collected from Jinhae Bay



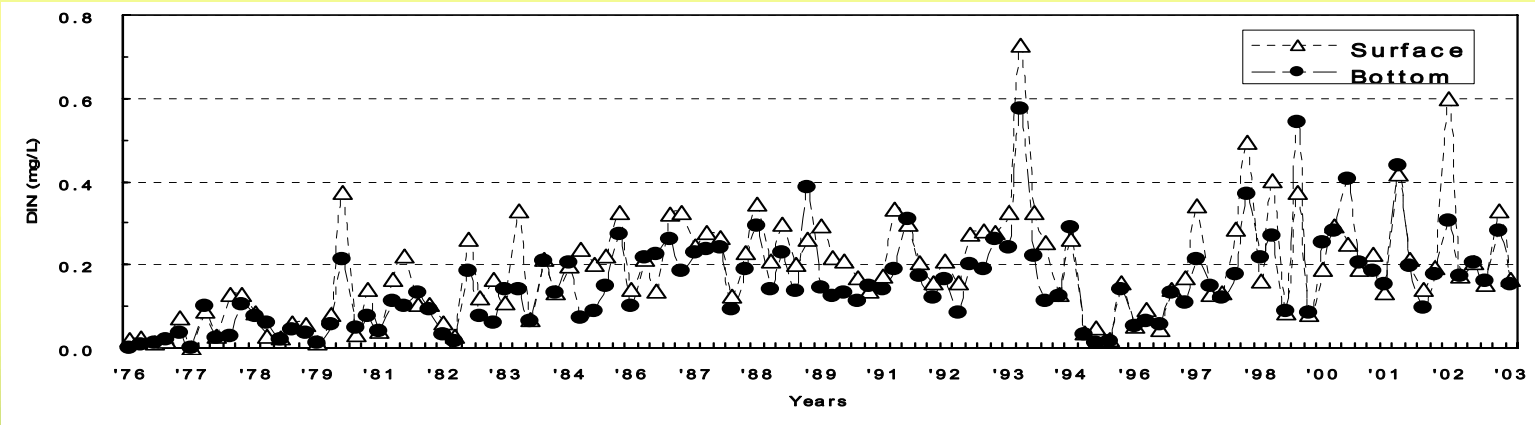
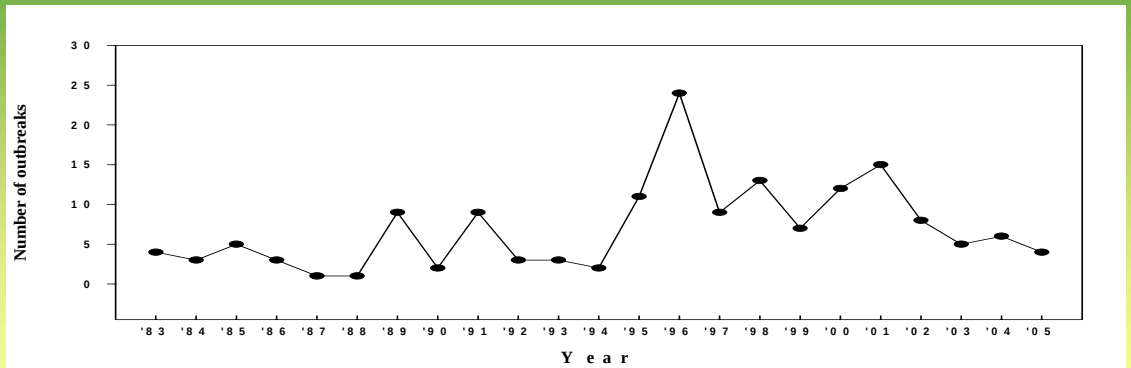


Fig. Annual changes of DIN in the seawater collected from Jinhae Bay



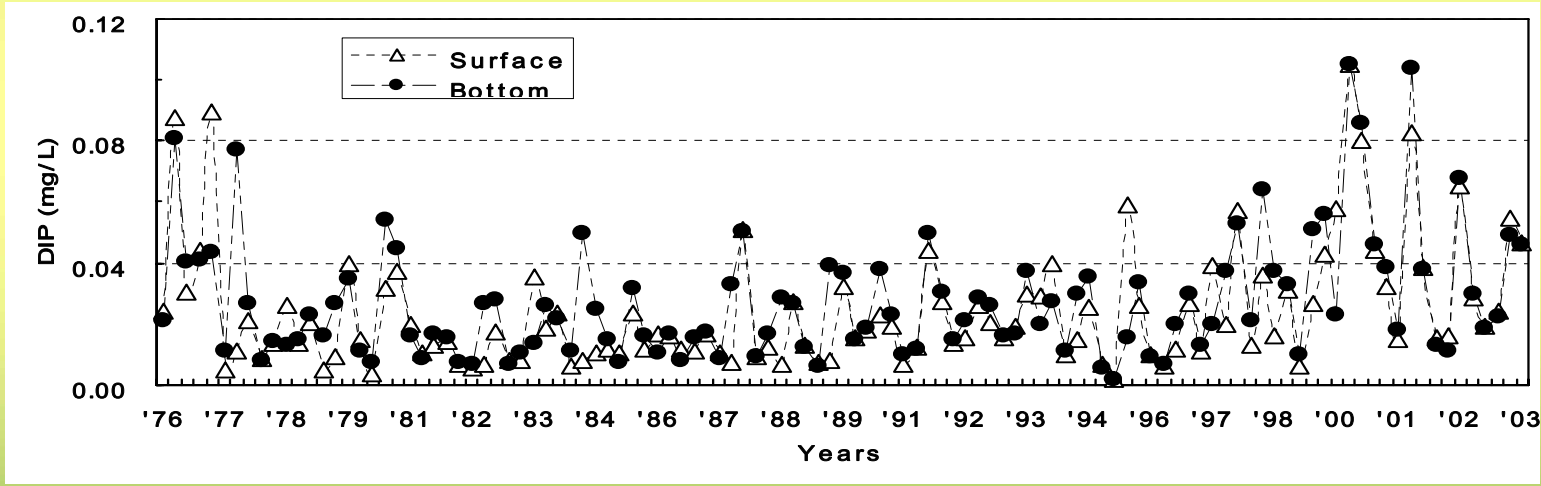
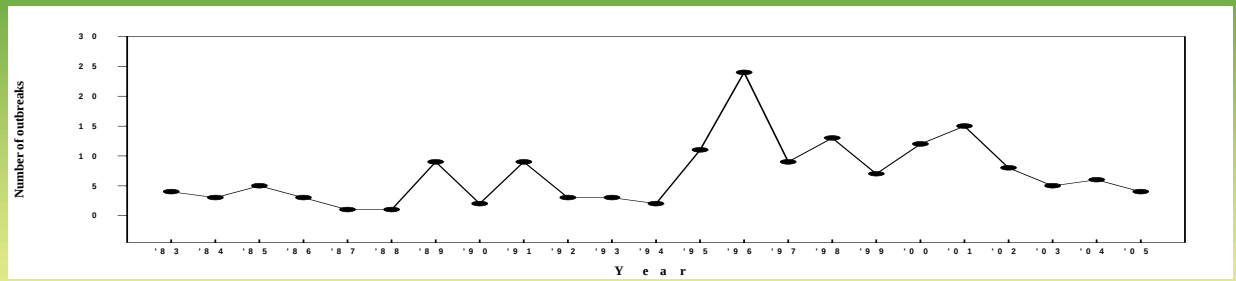


Fig. Annual changes of DIP in the seawater collected from Jinhae Bay



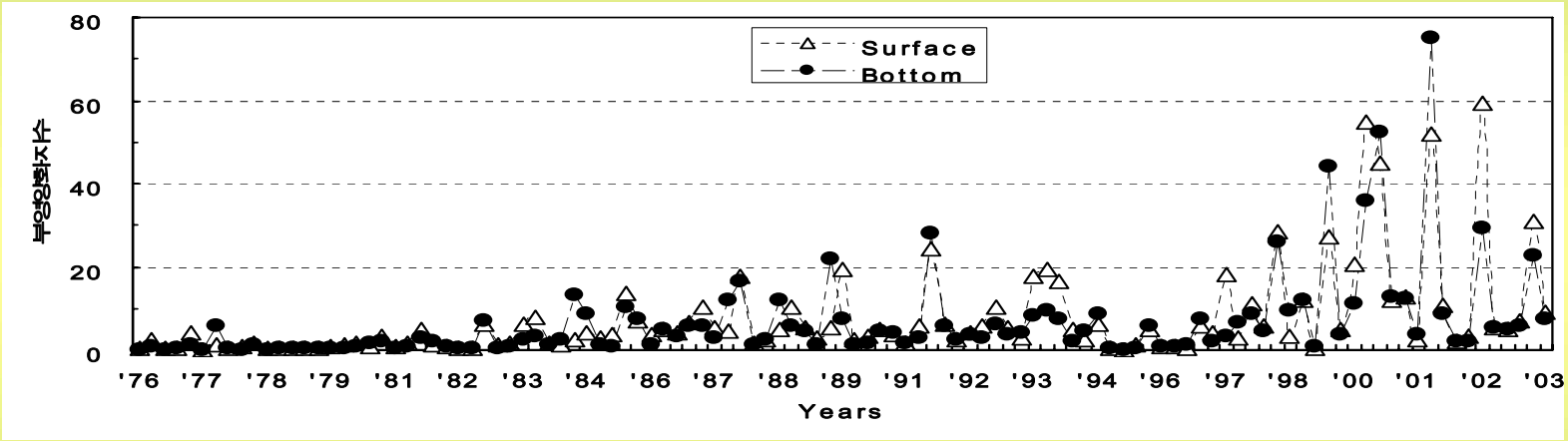
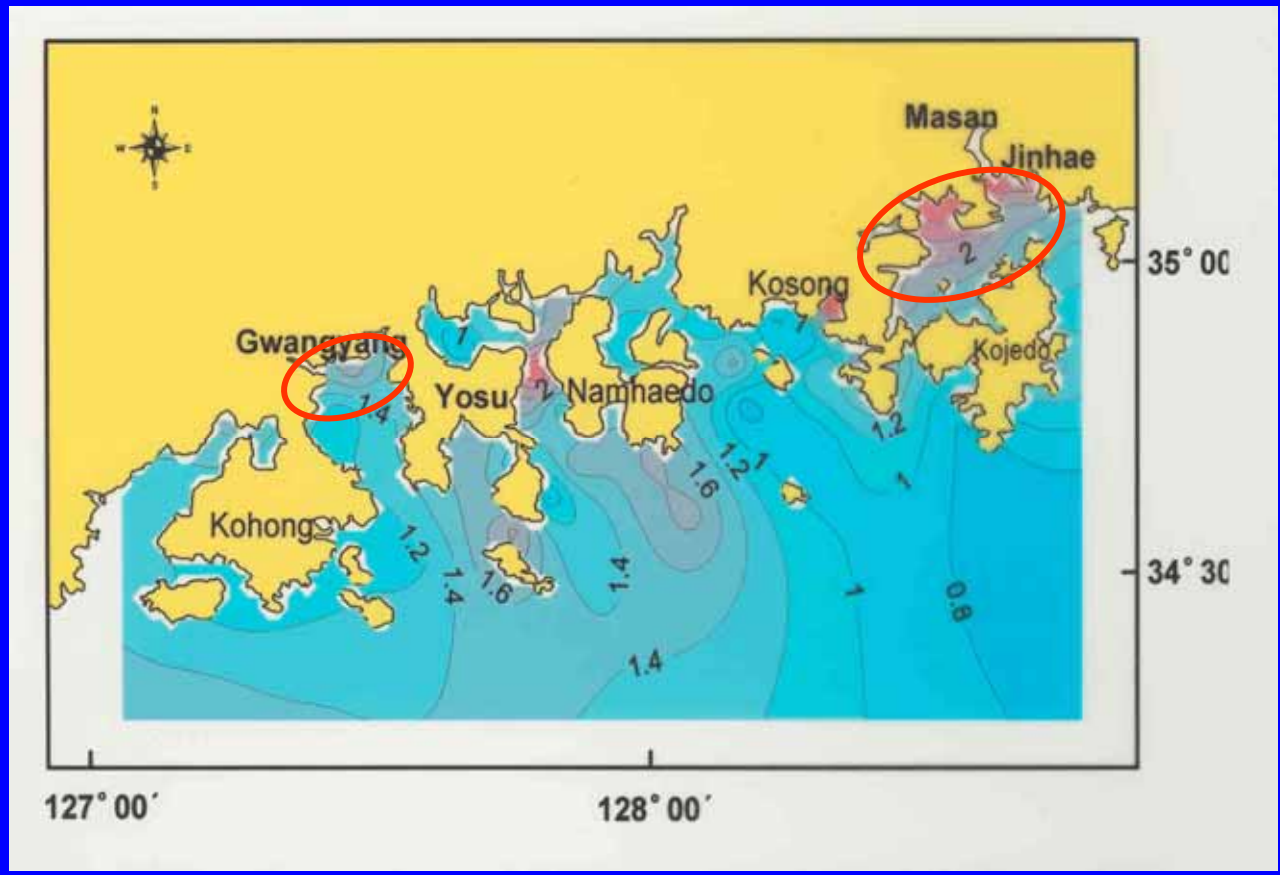


Fig. Annual changes of eutrophic index in the seawater collected from Jinhae Bay. Okaichi Eutrophic index = $(COD_{(mg/l)} x DIN_{(ug\text{-}at/l)} x PO_4\text{-}P_{(ug\text{-}at/l)})/3.43$

Configuration of COD in seawater in Aug. 2001 and *H. akashiwo* haunting areas



Coastal eutrophication and HABs

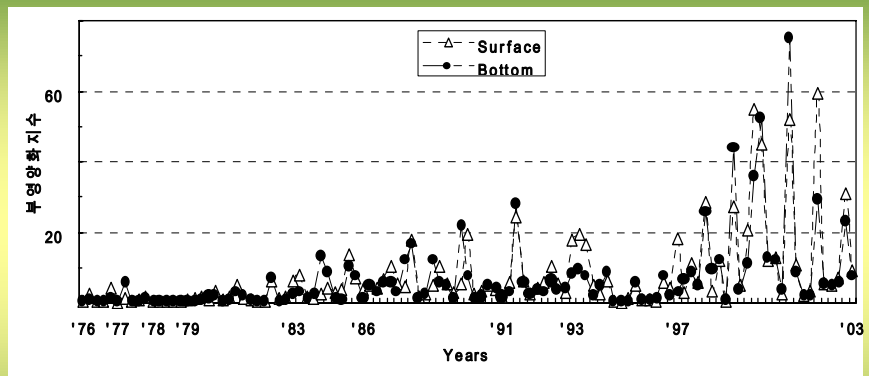
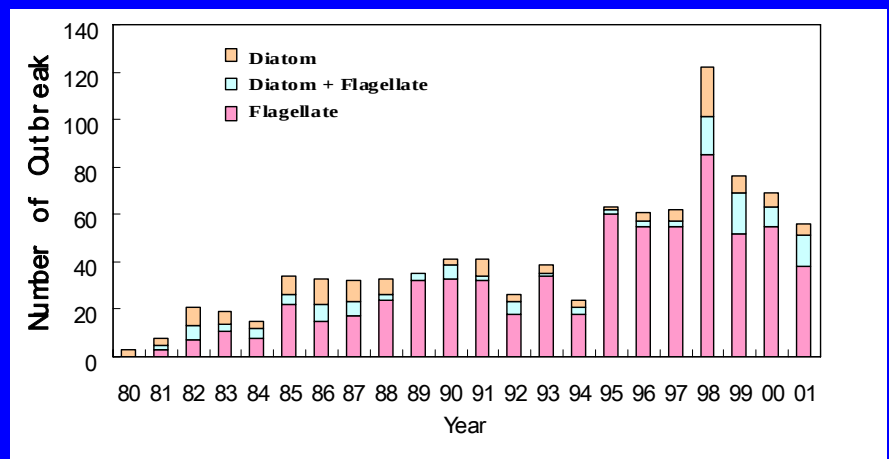
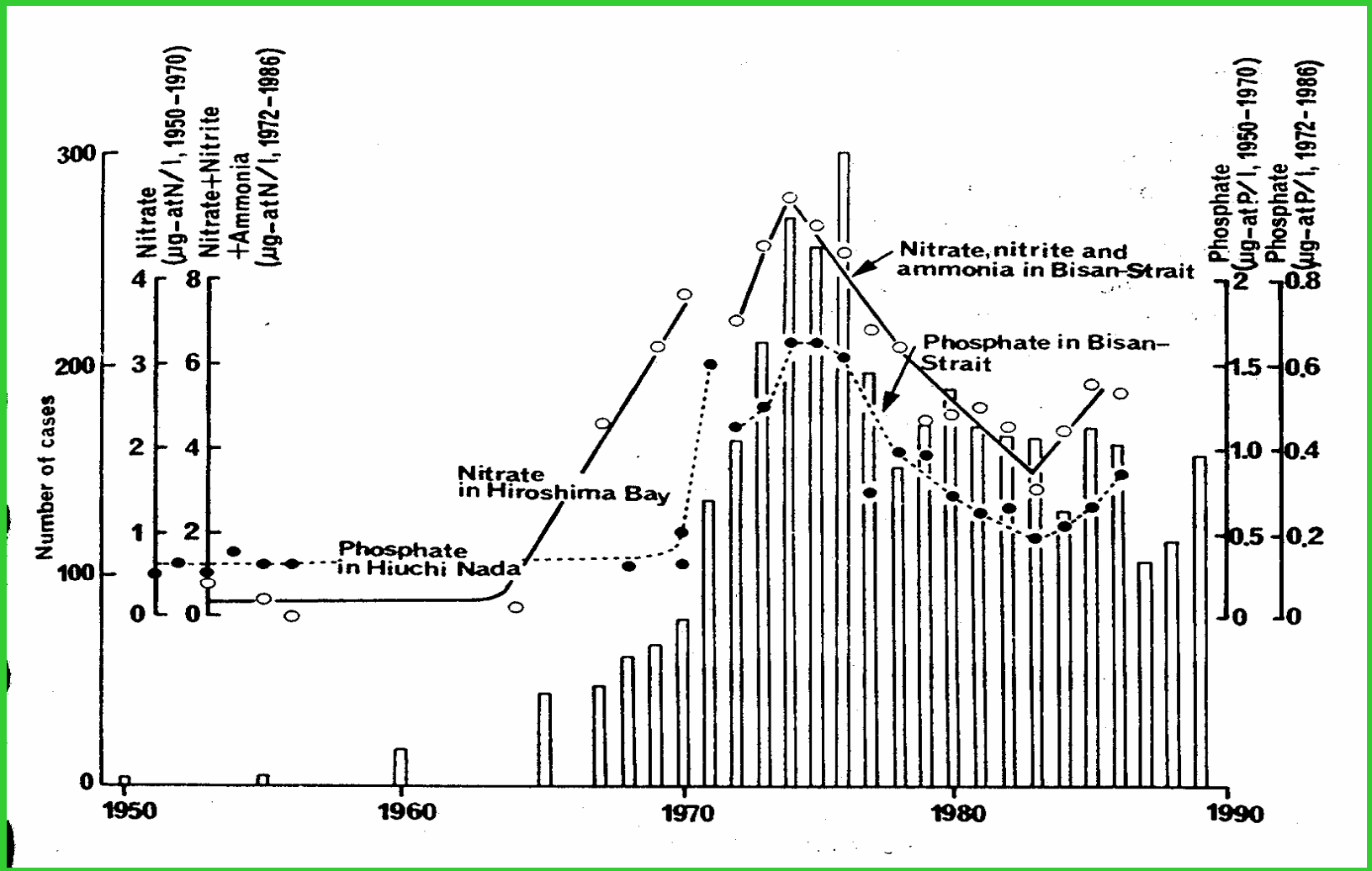


Fig. Annual changes of eutrophic index in the seawater

Okaichi Eutrophic index = ($COD_{(mg/l)}$x$DIN_{(ug\text{-}at/l)}$

Yearly distribution of the number of Red tides since 1981

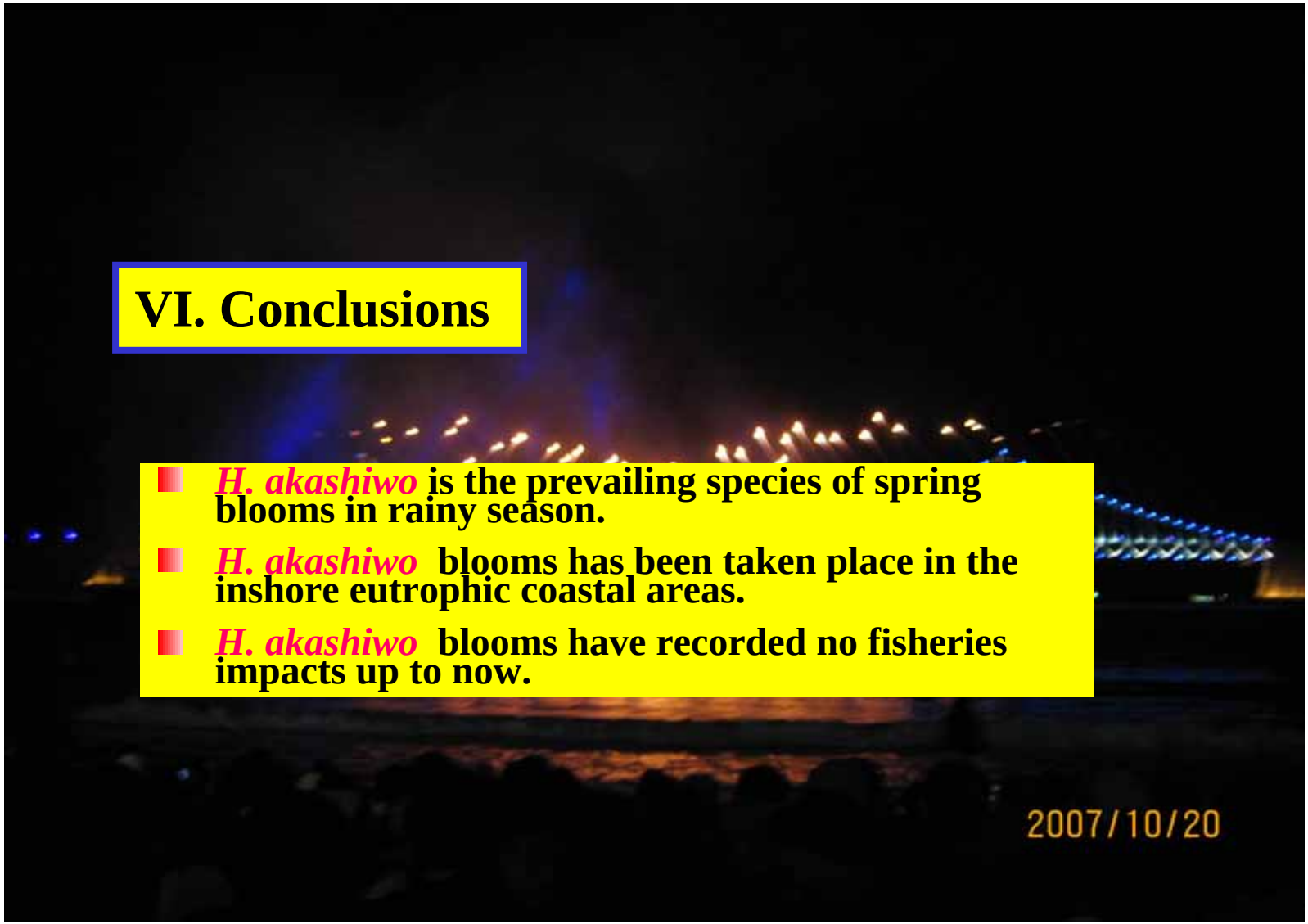




Total number of red tides, concentration of N and P in the Seto Inland sea (Honjo, 1993, in Toxic Phytoplankton Blooms in the Sea)

Summary 3

- **There found a significant relation between eutrophic state and the number of the outbreaks of *H. akashiwo* blooms.**
- **The high intensity of *H. akashiwo* blooms are coincident with the rainy season.**
- **B-mesosaprobic state would be the favorable condition for *H. akashiwo* bloom.**



VI. Conclusions

- ***H. akashiwo*** **is the prevailing species of spring blooms in rainy season.**
- ***H. akashiwo*** **blooms has been taken place in the inshore eutrophic coastal areas.**
- ***H. akashiwo*** **blooms have recorded no fisheries impacts up to now.**

Thank you

For your attention