Long-term Trends of Red Tides by Eutrophication and Toxic Blooms by Oligotrophication in the Seto Inland Sea of Japan

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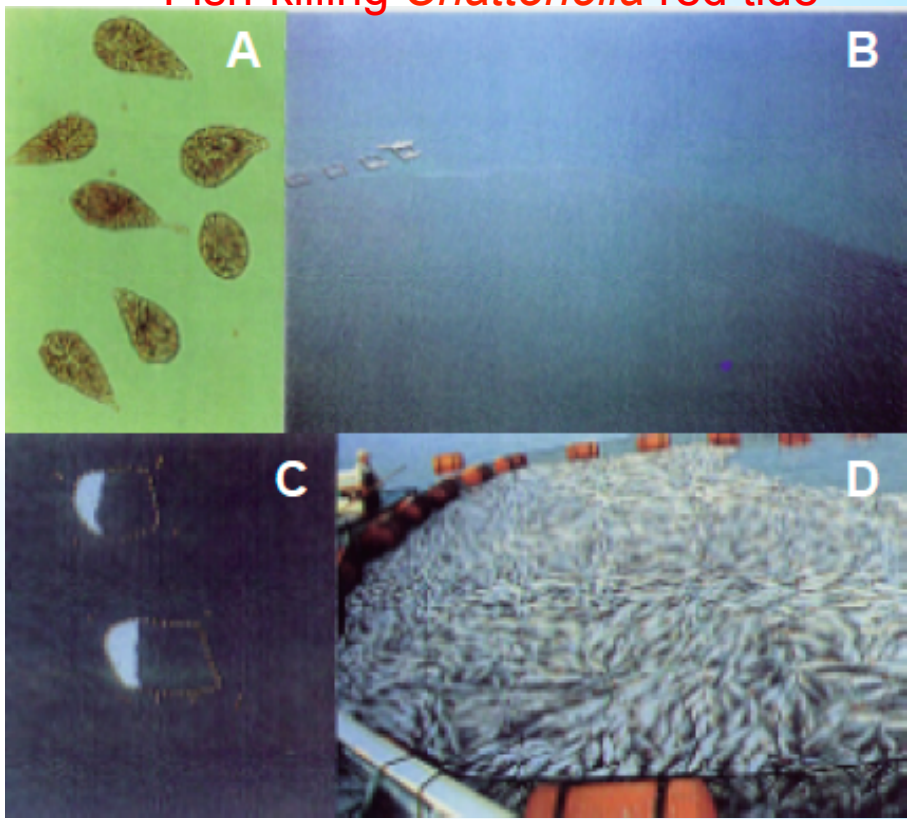
Fish-killing *Chattonella* red tide



The Seto Inland Sea has experienced extreme eutrophication during the period of high speed economic growth.

Strong human impacts were given to the Seto Inland Sea, such as large scale reclamation, heavy inputs of nutrients, etc.

Harmful algal blooms have occurred causing mass mortalities of cultured fishes and bivalves.

Atada Island,
Hiroshima Bay,
the Seto Inland Sea,
famous for fish and
oyster culture

Seto Inland Sea is currently in a trend of oligotrophication by the regulation of nutrient inputs, accompanied by frequent occurrences of toxic blooms and Bleaching problems of Nori culture.

9/10/2009

The toxic alga *Alexandrium tamarense* was introduced by human activities.

Contents

Hime-shima Island, Oita Prefecture
(famous for prawn culture)

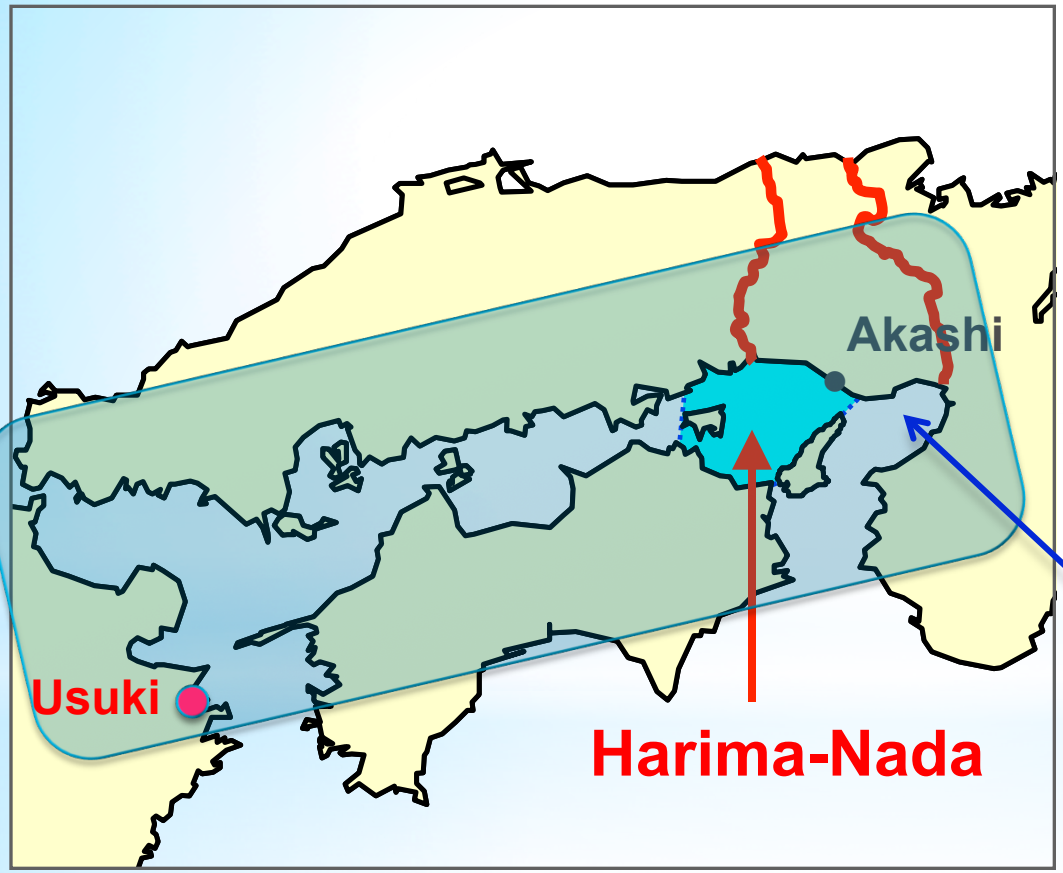
1) General trends

2) Changes in water quality

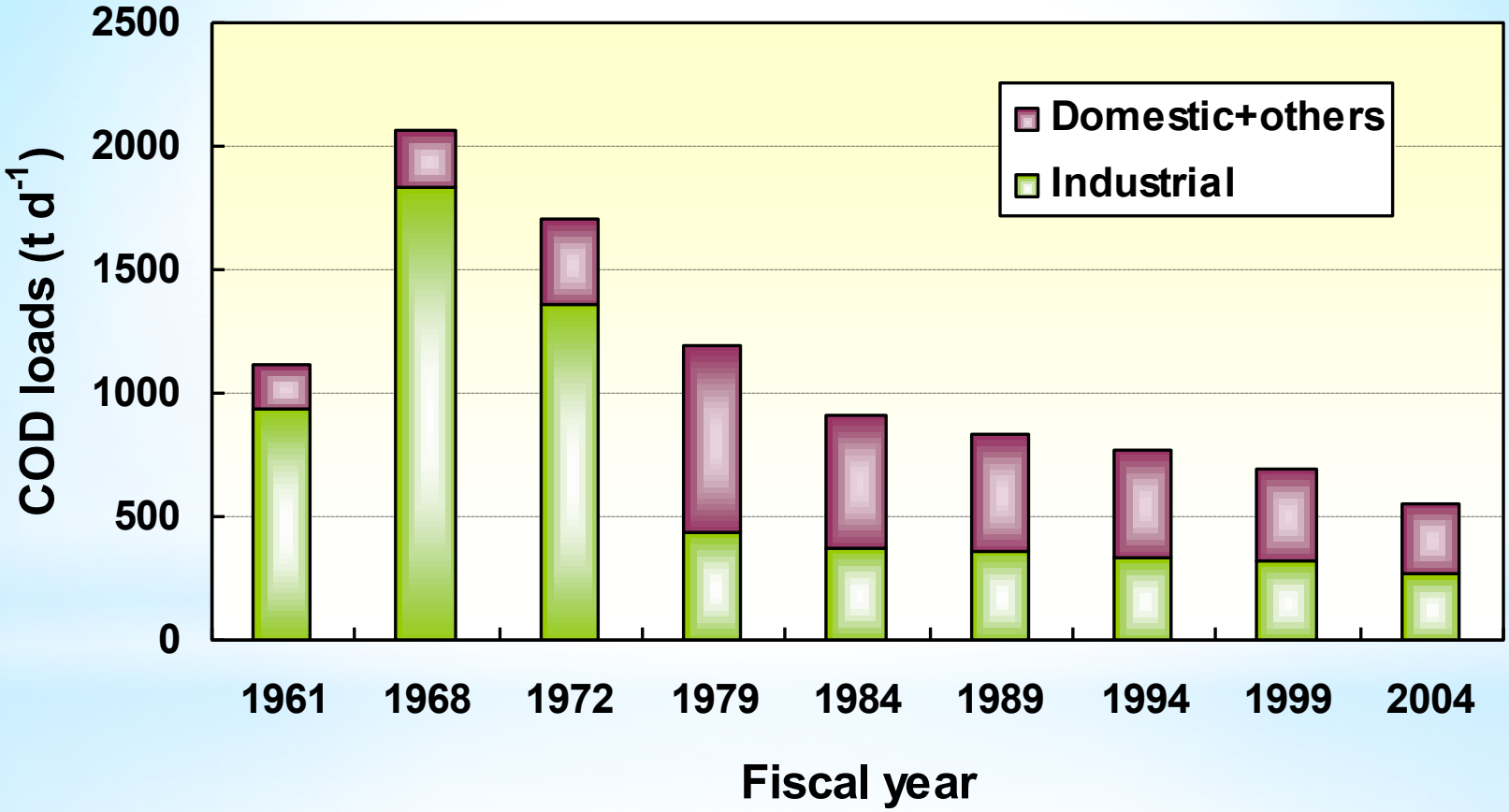
3) Red tides and toxic blooms

9/10/2009

Seto Inland Sea, Harima-Nada and Osaka Bay

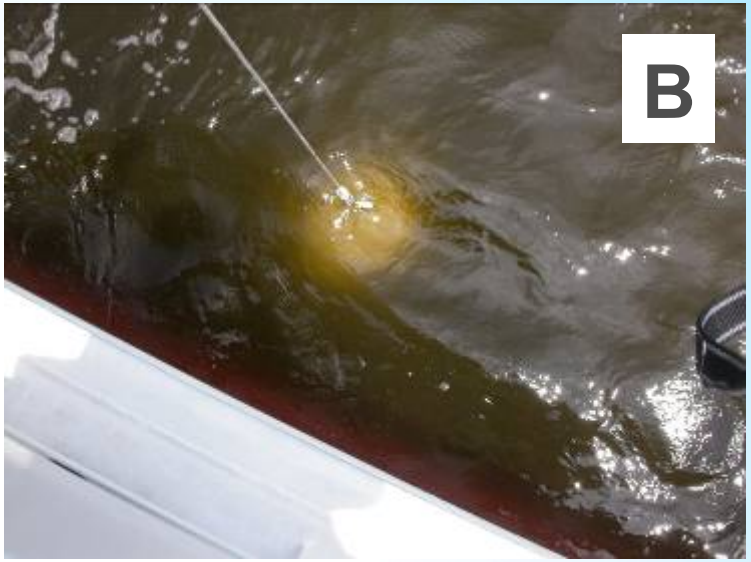


Changes in total COD loading in the Seto Inland Sea



from the Ministry of the Environment Government of Japan &
the Association for the Environmental Conservation of Seto Inland Sea

Serious eutrophication of the Seto Inland Sea



A: Red tide (Noctiluca)
B: Bloom of *Skeletonema* spp.
C: Mass mortality of cultured yellowtails in pen cage by HAB

Countermeasures for eutrophication

- Special law

"Law Concerning Special Measures for Conservation of the Environment of the Seto Inland Sea" (enacted in 1973)

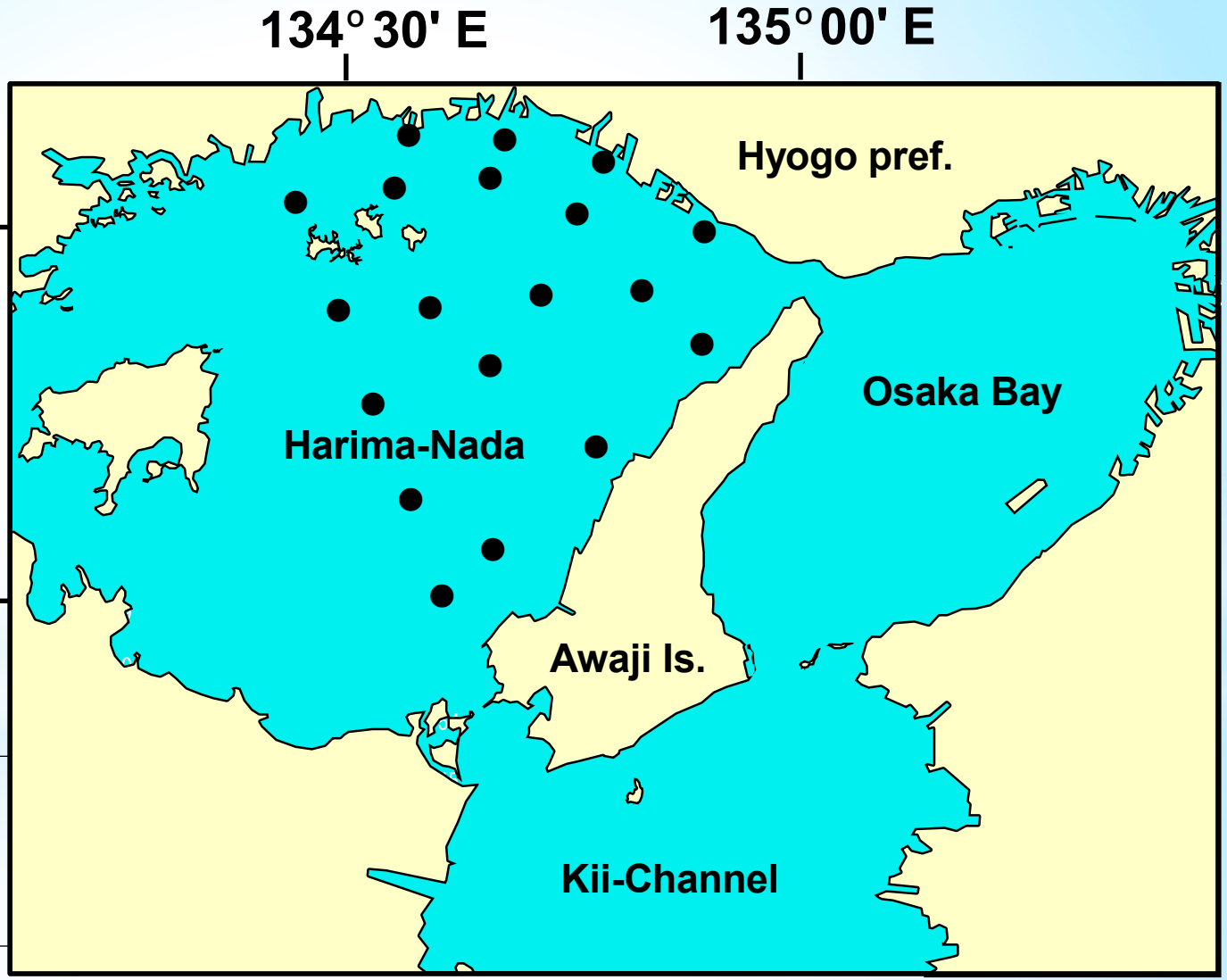
→ # Control of the total pollutant load
Reduction of the total quantity of organic pollutants in term of COD

- Control of total P inputs (from 1979)

- Control of total N inputs (from 1996)

Long-term monitoring:

Sampling stations in Harima-Nada

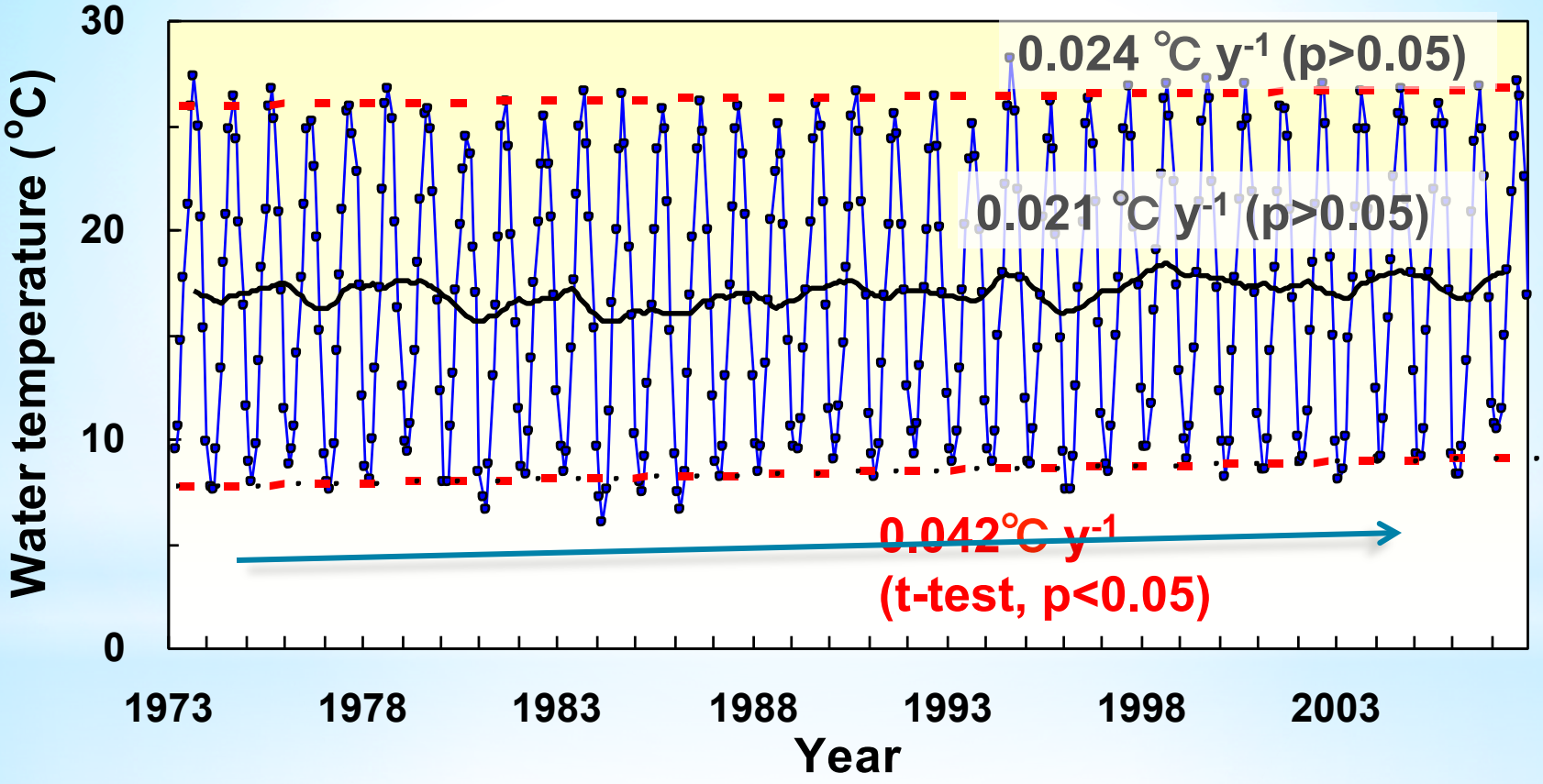


Harima-Nada

- Area: 3,400 km^2
- Mean depth: 25.9 m

Long-term variations in water temperature

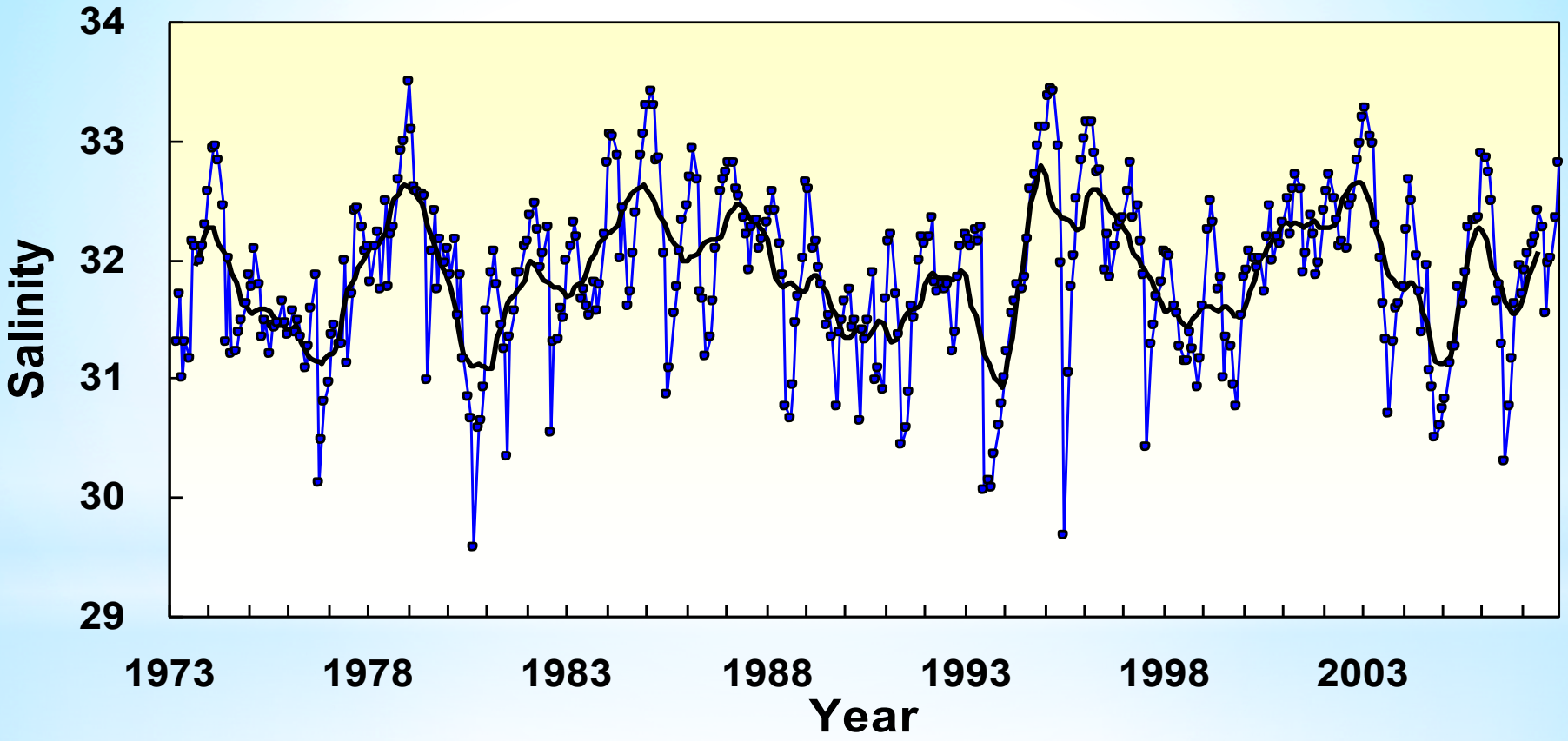
(April 1973-Dec 2007, mean of 3 depth at 19 sampling stations)



(Nishikawa et al. 2010)

Long-term variations in salinity

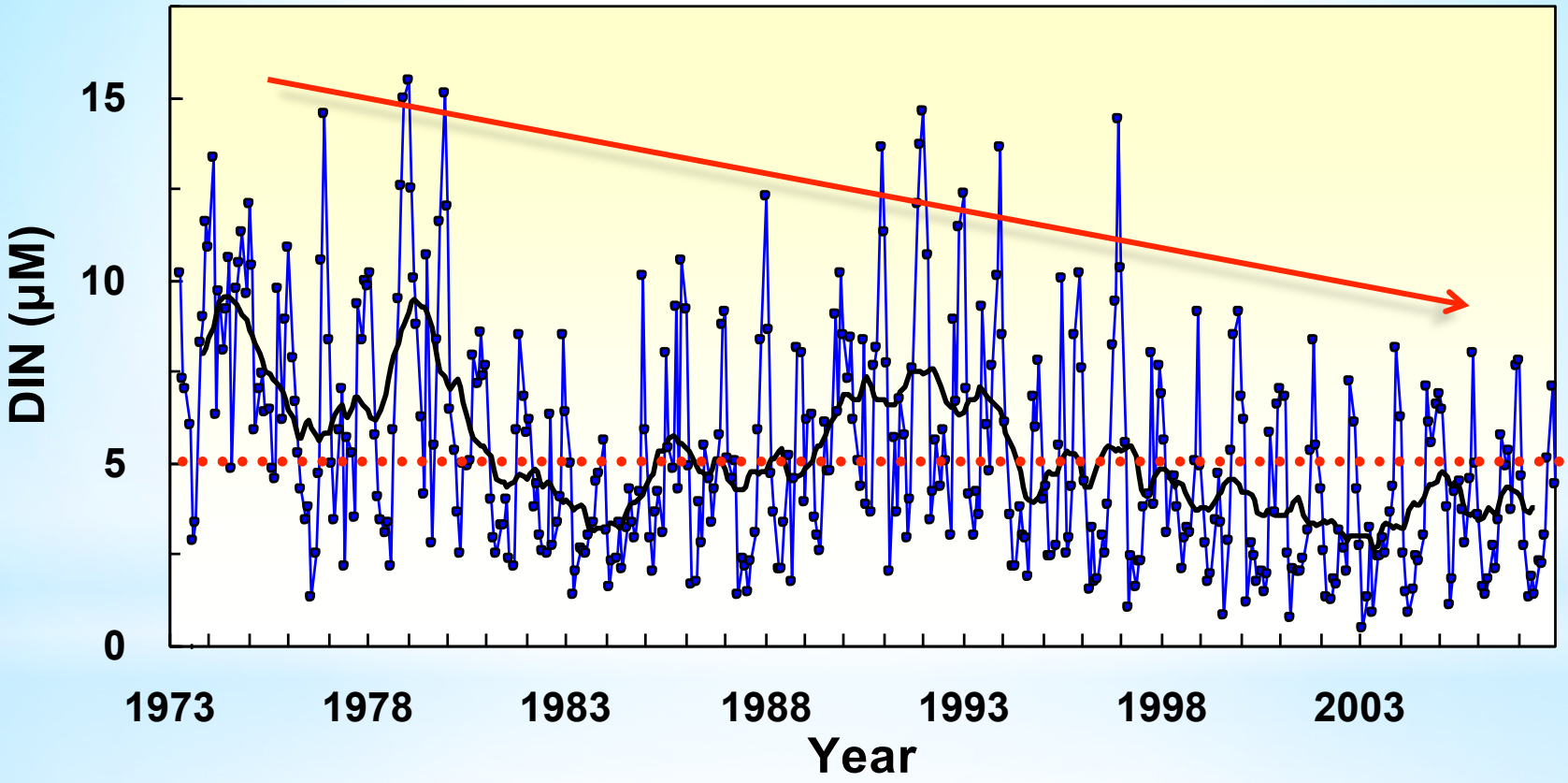
(April 1973-Dec 2007, mean of 3 depth at 19 sampling stations)



(Nishikawa et al. 2010)

Long-term variations in DIN

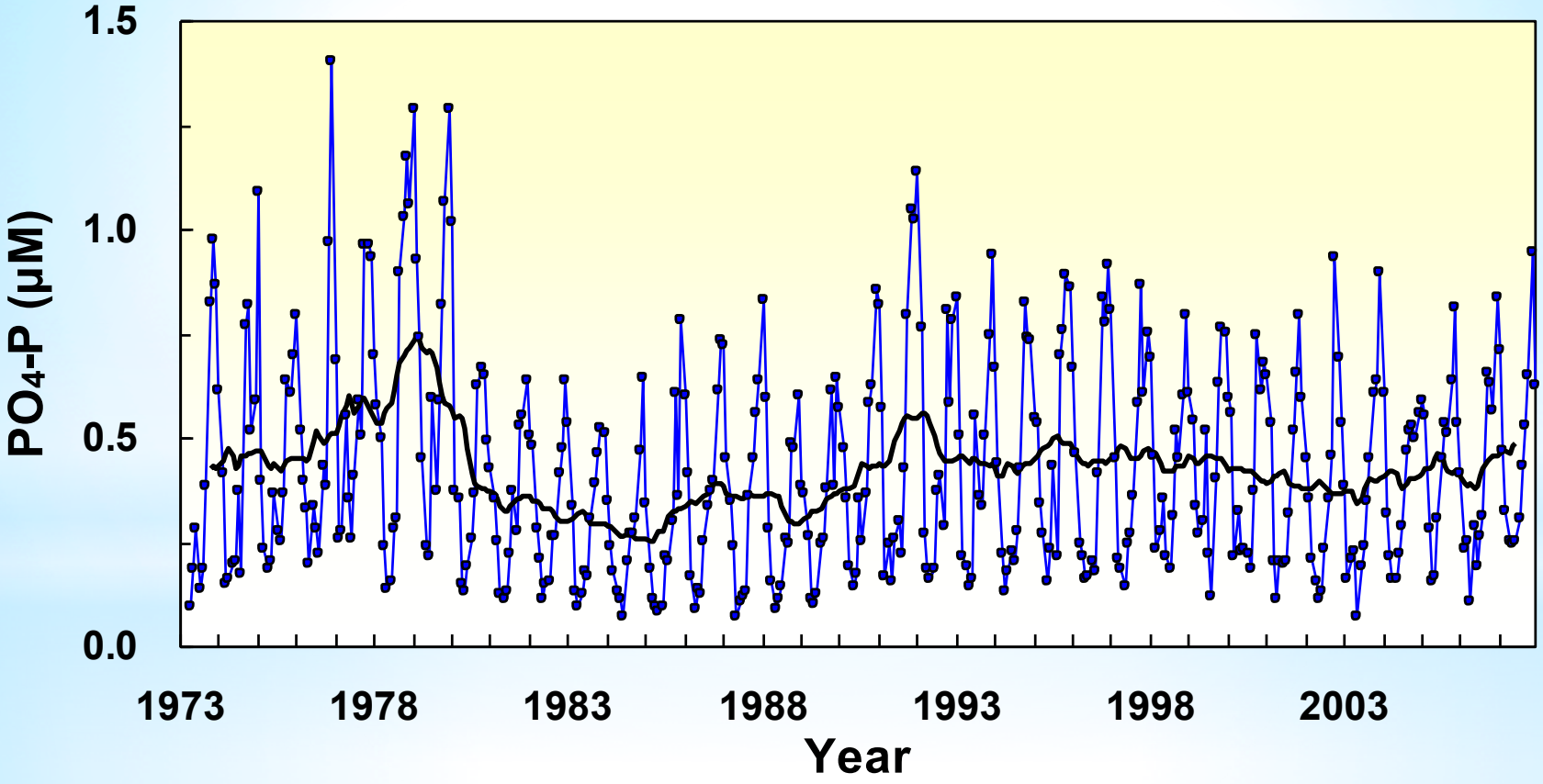
(April 1973-Dec 2007, mean of 3 depth at 19 sampling stations)



(Nishikawa et al. 2010)

Long-term variations in phosphate

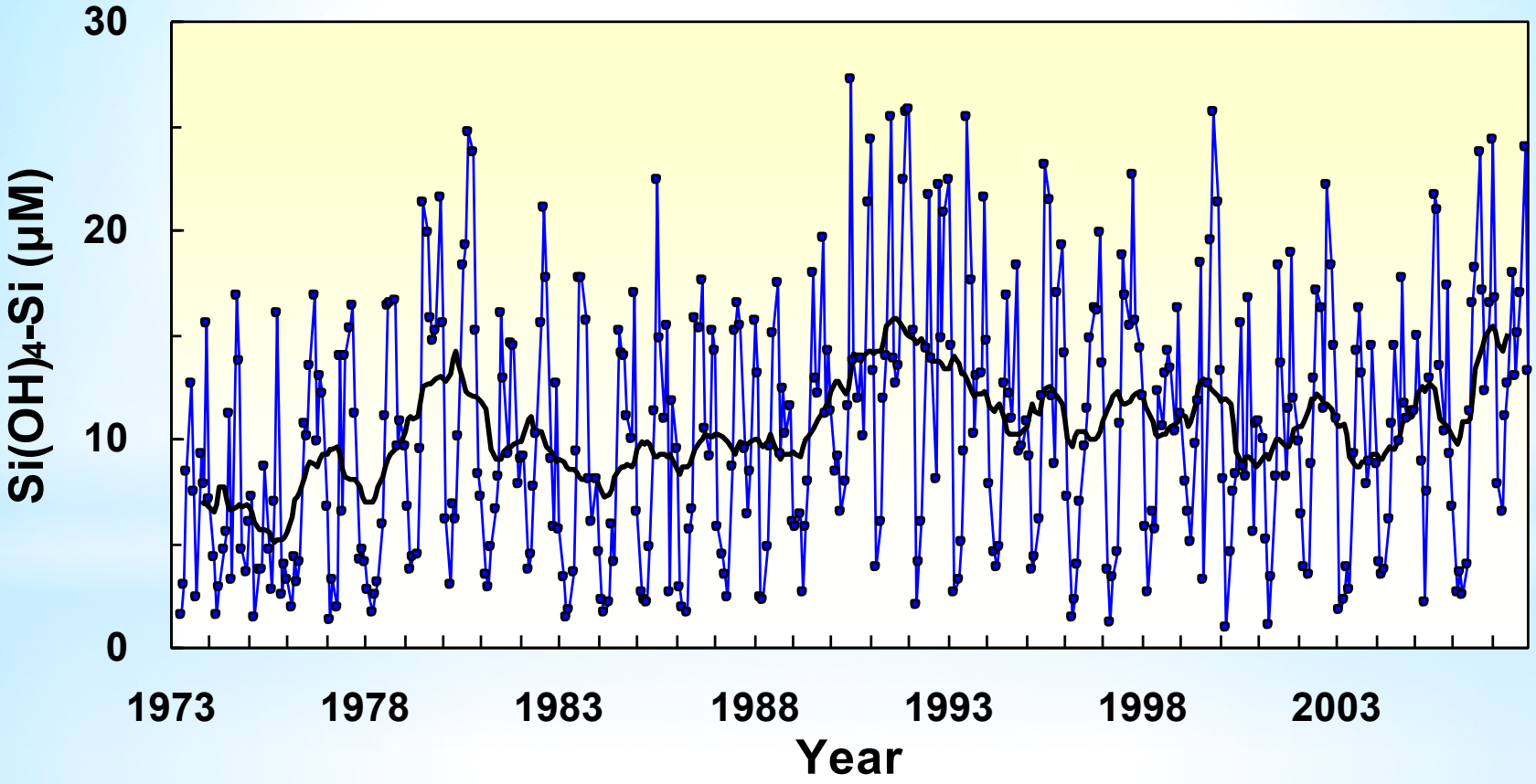
(April 1973-Dec 2007, mean of 3 depth at 19 sampling stations)



(Nishikawa et al. 2010)

Long-term variations in silicic acid

(April 1973-Dec 2007, mean of 3 depth at 19 sampling stations)



Summary of water quality changes

Significant long-term changes:

1) Rise in winter water temperature (0.042℃ y^{-1}).

2) Increase in nutrients in 1960s and 1970s.

3) Decrease in dissolved inorganic nitrogen (DIN) (10 μM in the 1970s to ～5μM in the 1990s and thereafter).

*Mass mortality of yellowtail by a *Chattonella* red tide

Mass mortality of yellowtail, *Seriola quinqueradiata*, cultured in cages by a red tide of raphidoflagellate *Chattonella antiqua* (Seto Inland Sea, Aug.1977)

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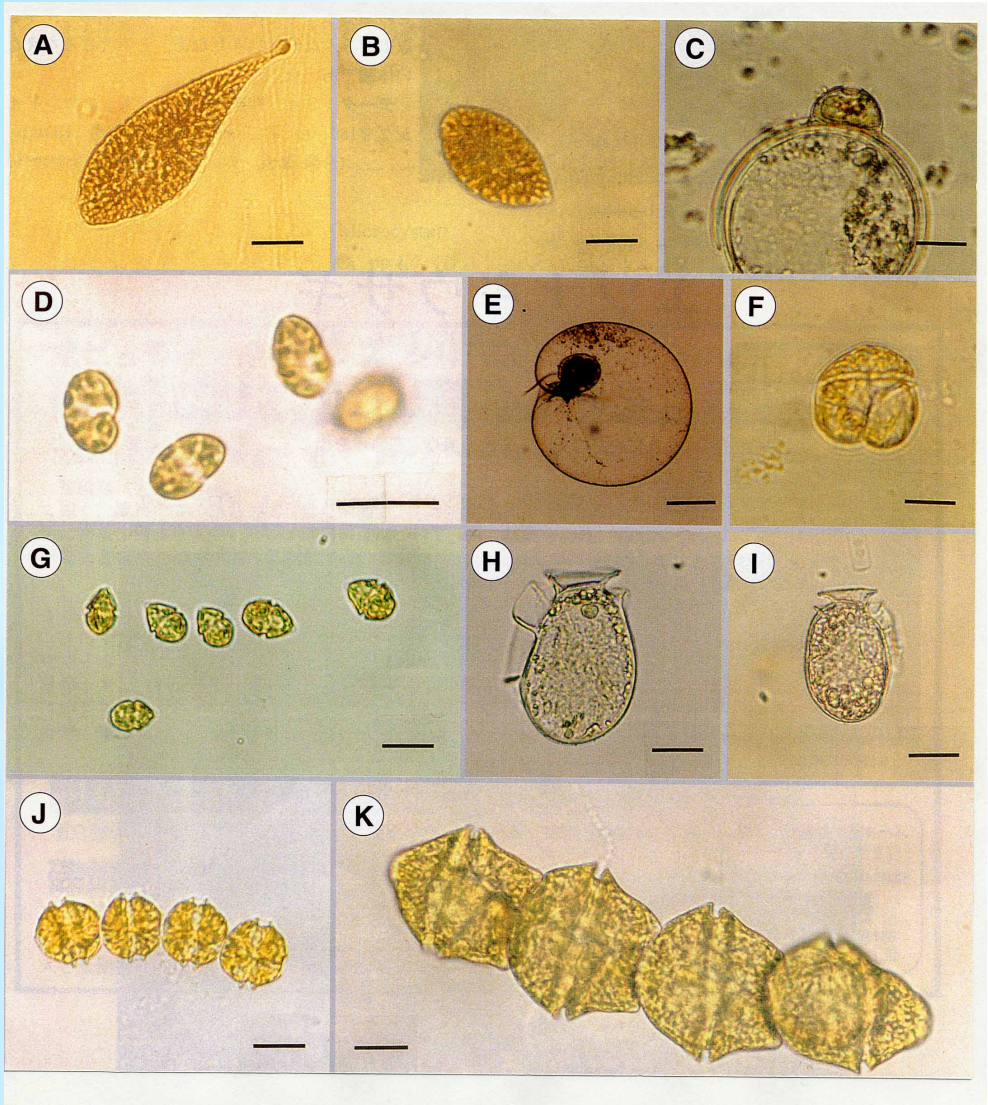
Harmful algae in the Seto Inland Sea

(Imai et al. 2006)



Bars=20μm, E=100μm

A-G: Red tide algae

A: *Chattonella antiqua*

B: *Chattonella marina*

C: A cyst of *Chattonella*

D: *Heterosigma akashiwo*

E: *Noctiluca scintillans*

F: *Karenia mikimotoi*

G: *Heterocapsa circularisquama*

H-K: Toxic algae

H: *Dinophysis fortii*

I: *Dinophysis acuminata*

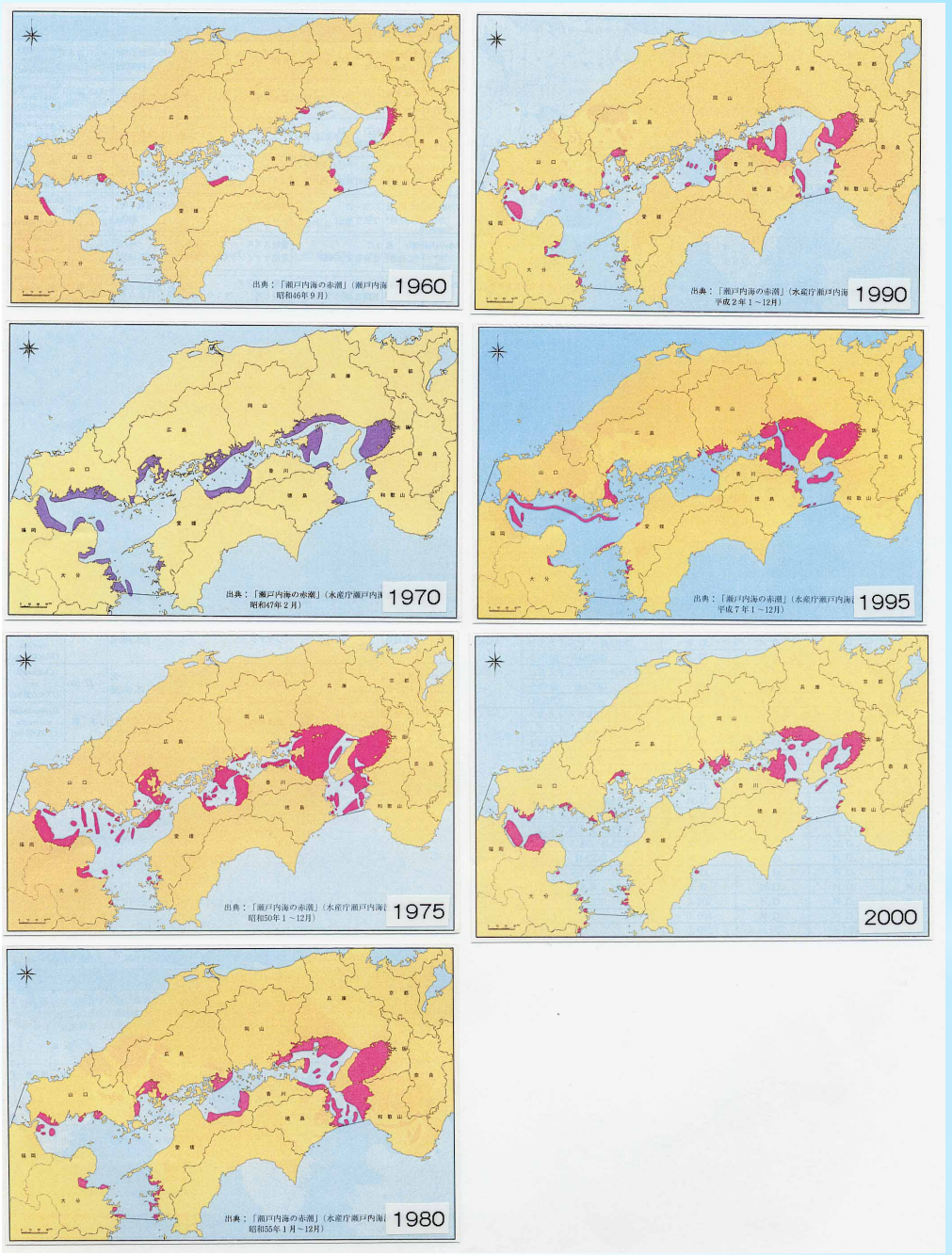
J: *Alexandrium catenella*

K: *Gymnodinium catenatum*

*Changes in the red tide areas

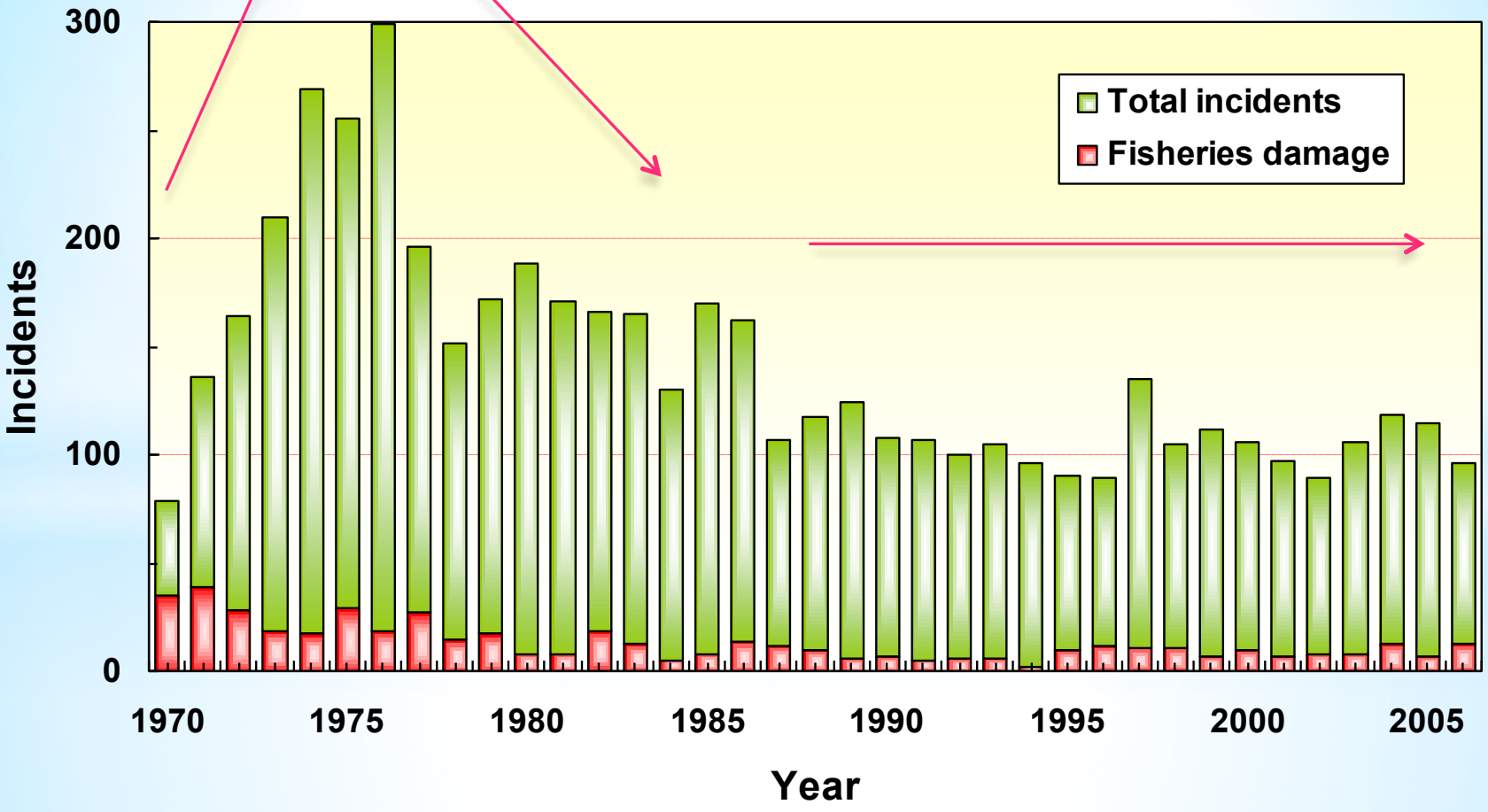
*Large scale red tides had been frequent in 1970’ s and 1980

(Fisheries Agency, 2009)

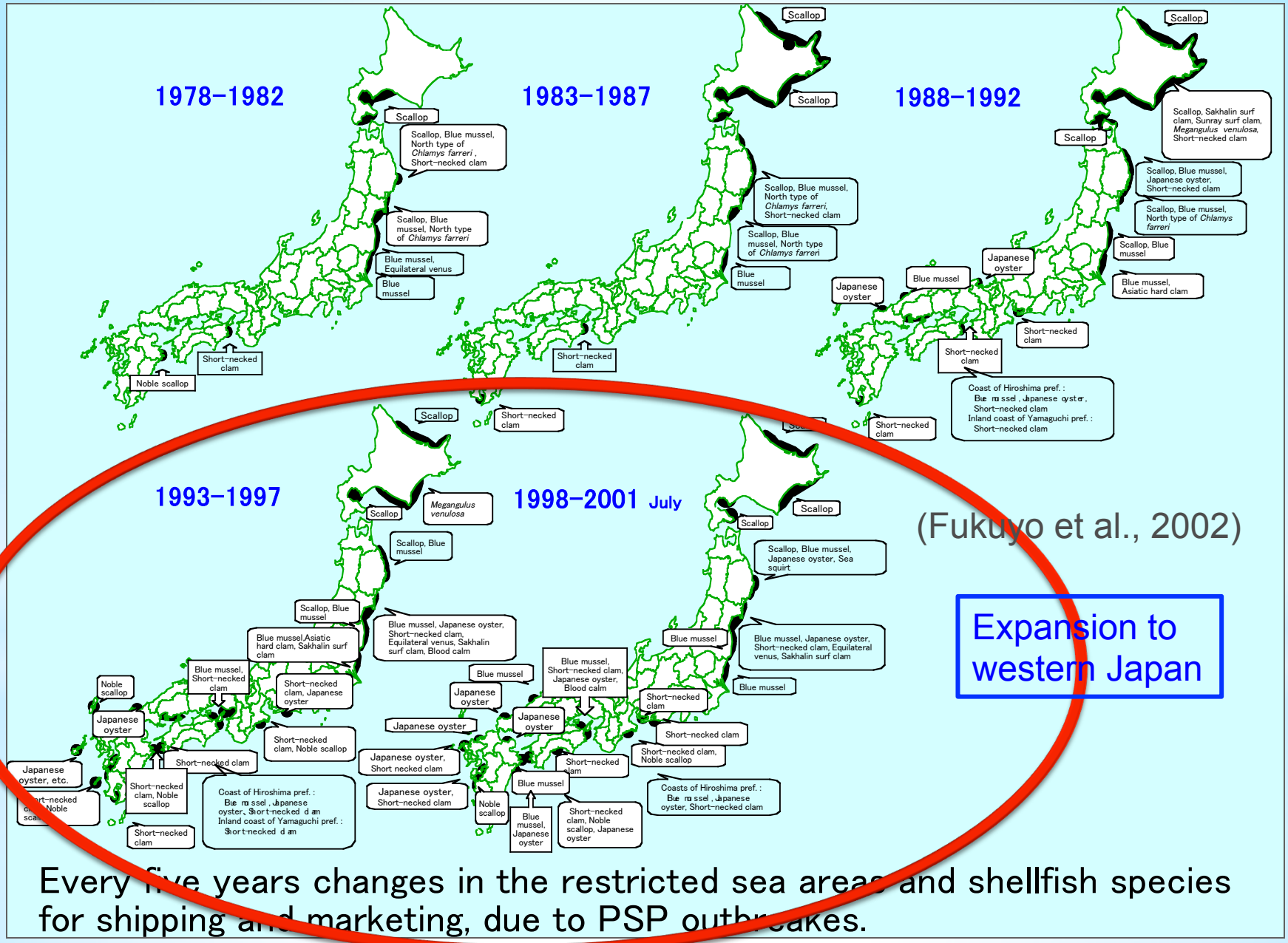


Occurrences of red tides in the Seto Inland Sea from 1970 to 2006

(Fisheries Agency, Japan, 2007)



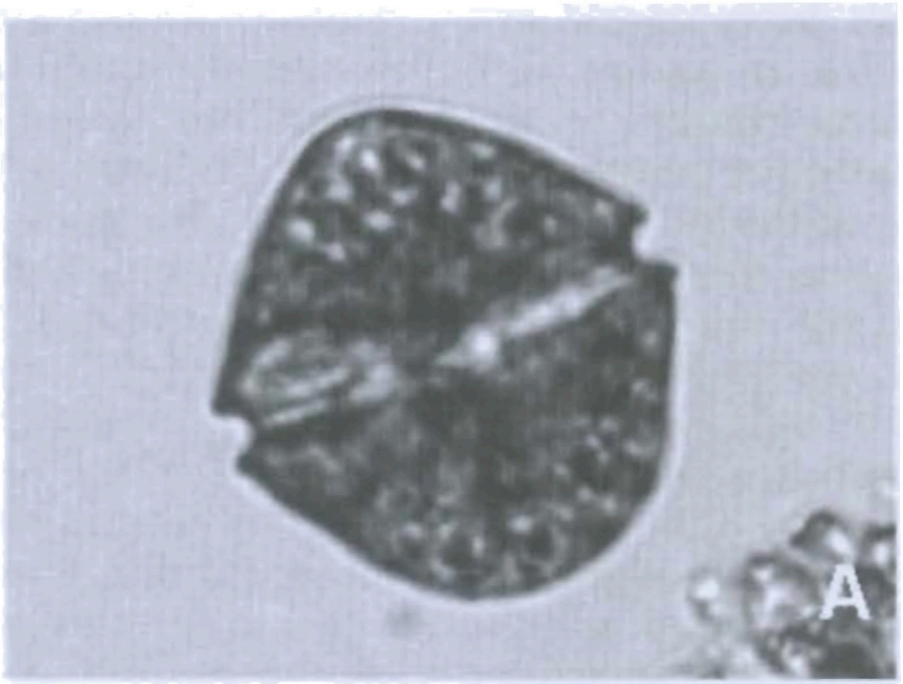
* Expansion of PSP affected areas

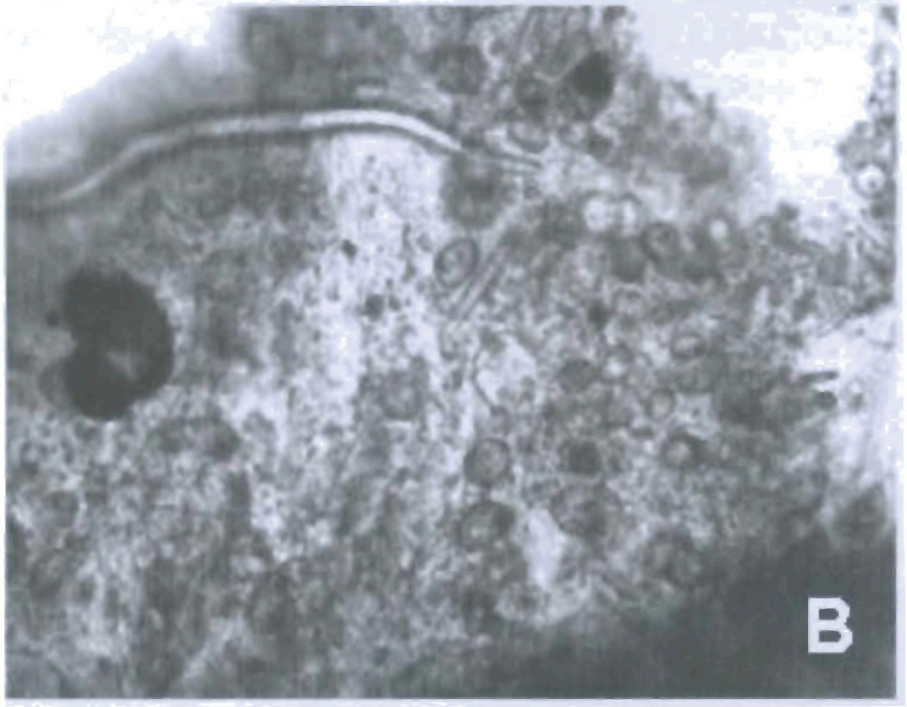


(Fukuyo et al., 2002)

Expansion to western Japan

Every five years changes in the restricted sea areas and shellfish species for shipping and marketing, due to PSP outbreakes.





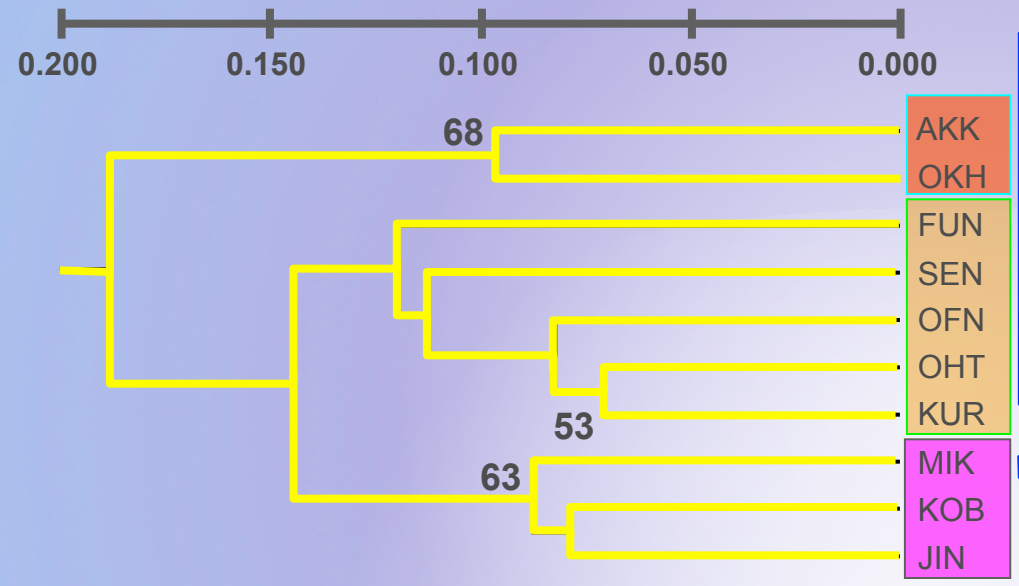
Identified cells of the toxic dinoflagellate *Alexandrium tamarense* from the transplanting oyster spats from north to the Seto Inland Sea. <Matsuyama et al. 2008>

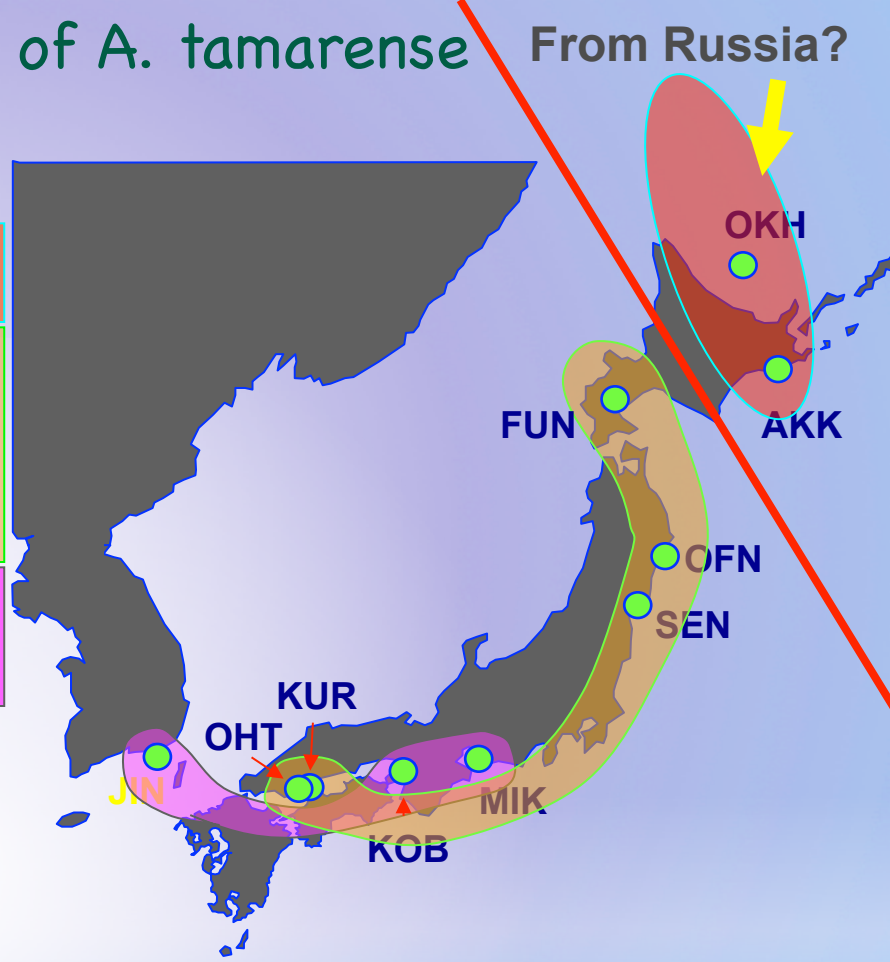
A: Vegetative cell

B: Many temporary cysts including *A. tamarense* observed in ejected feces from transplanting oyster spats.

(Matsuyama et al., 2010)

Distribution of population genetics of A. tamarense





UPGMA dendrogram constructed using Nei's genetic distance among the ten localities of *A. tamarense* samples.

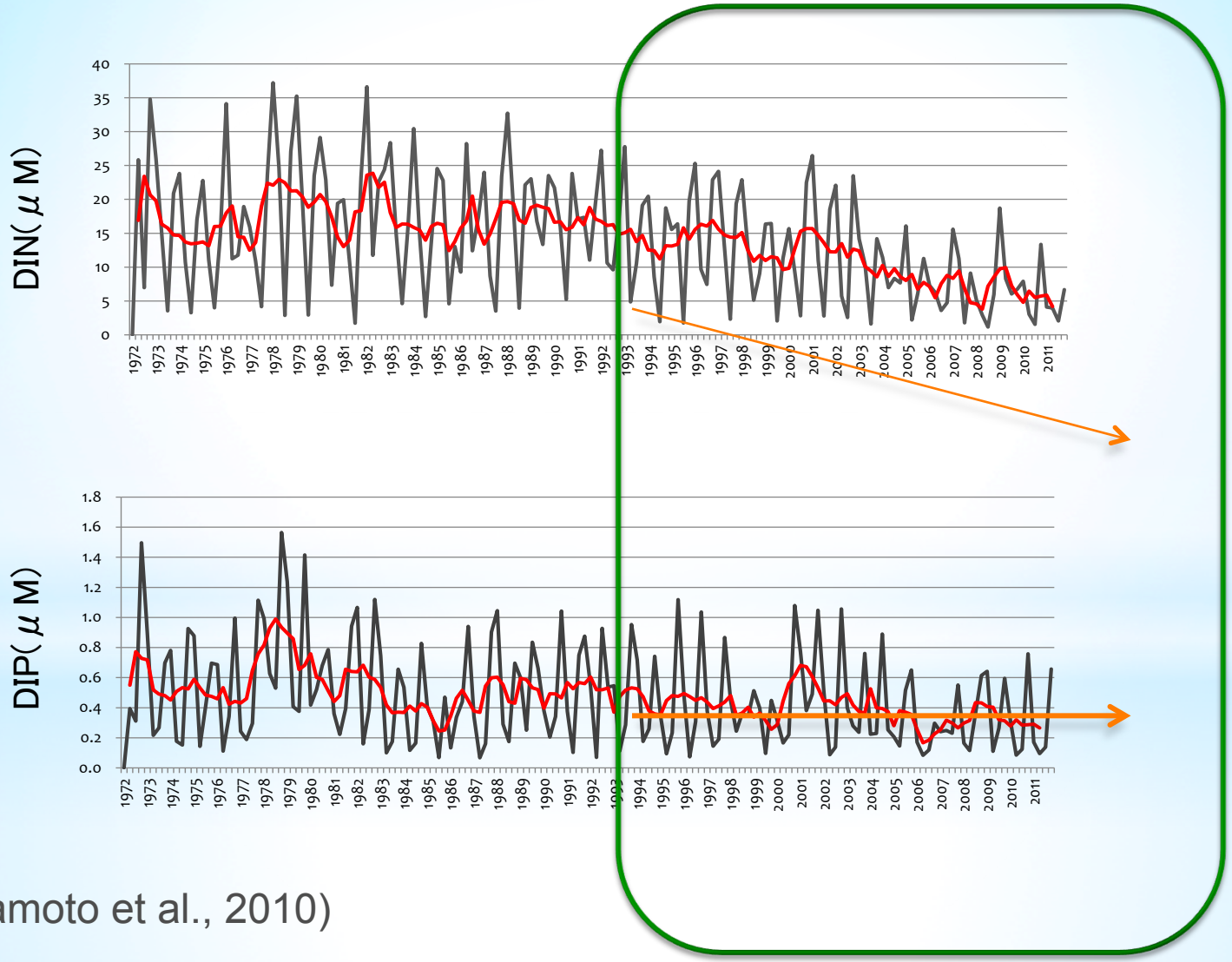
The dendrogram identified 3 clusters.

Transplantation from north to the Seto Inland Sea

(Nagai et al., 2006)

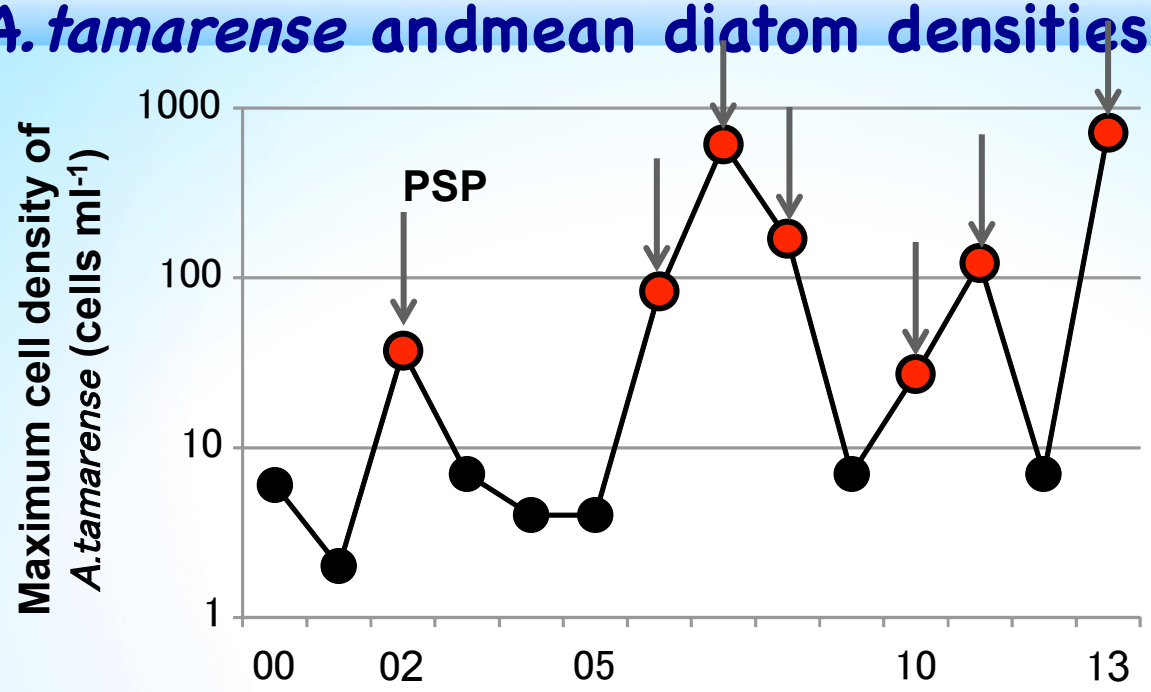
Long term trends of nutrients and *A. tamarense* cells

(Predominance of A. tamarense in oligotrophic waters)

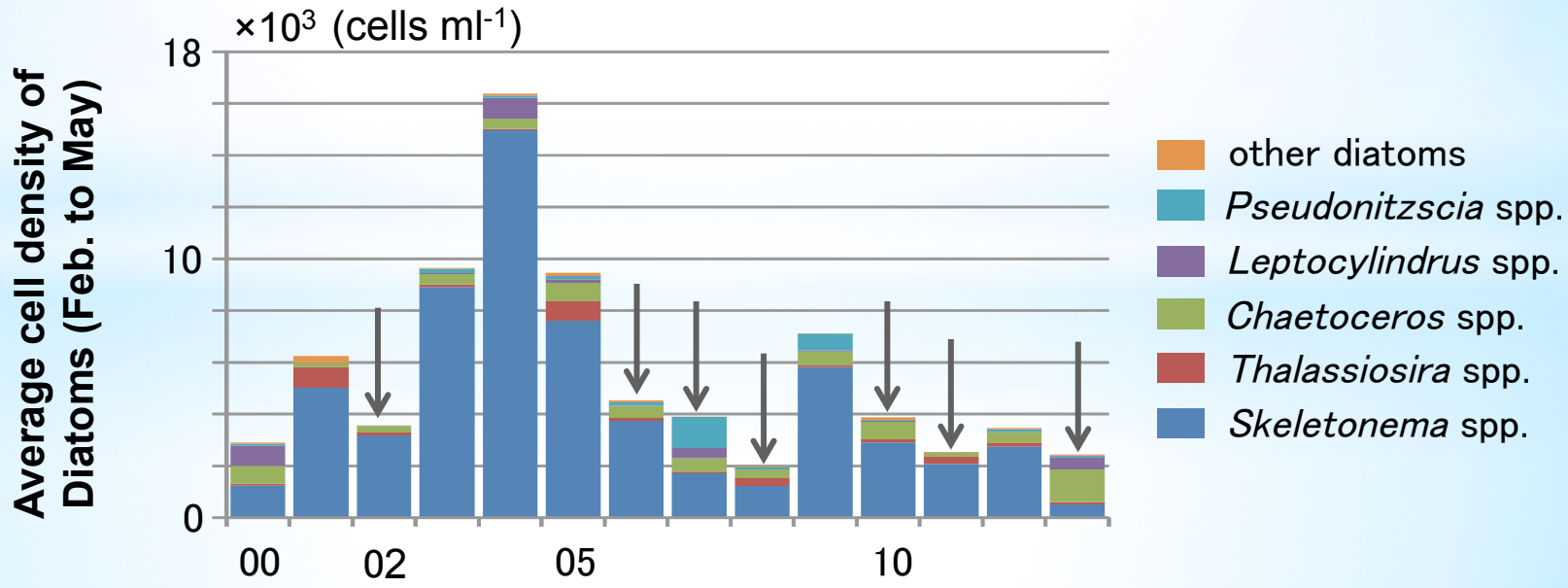


(Yamamoto et al., 2010)

Antagonistic relations between maximum densities of *A.tamarense* andmean diatom densities in 2000s



Arrows (and) indicate occurrences of Paralytoc Shellfish Poisonings (PSP) In Osaka Bay after 2002.



Summary

1 In 1960s and 1970s, red tide incidents markedly increased along with serious eutrophication in the Seto Inland Sea.

2 Regulation by law and technical development contributed to decrease nutrient inputs into the Seto Inland Sea.

3 The toxic dinoflagellate *Alexandrium tamarense* was newly transplanted into the Seto Inland Sea from northern area by human activities of oyster aquaculture industry.

4 PSP problems started in the Seto Inland Sea by *A. tamarense* from about 1990 and completely established.

Thanks for your attention !

My native beach, Usuki Bay, the Seto Inland Sea