History of eutrophication and harmful algal bloom (HAB) events in the Seto Inland Sea of Japan and a proposal for prevention strategies for HABs using seaweed- and seagrass-beds.

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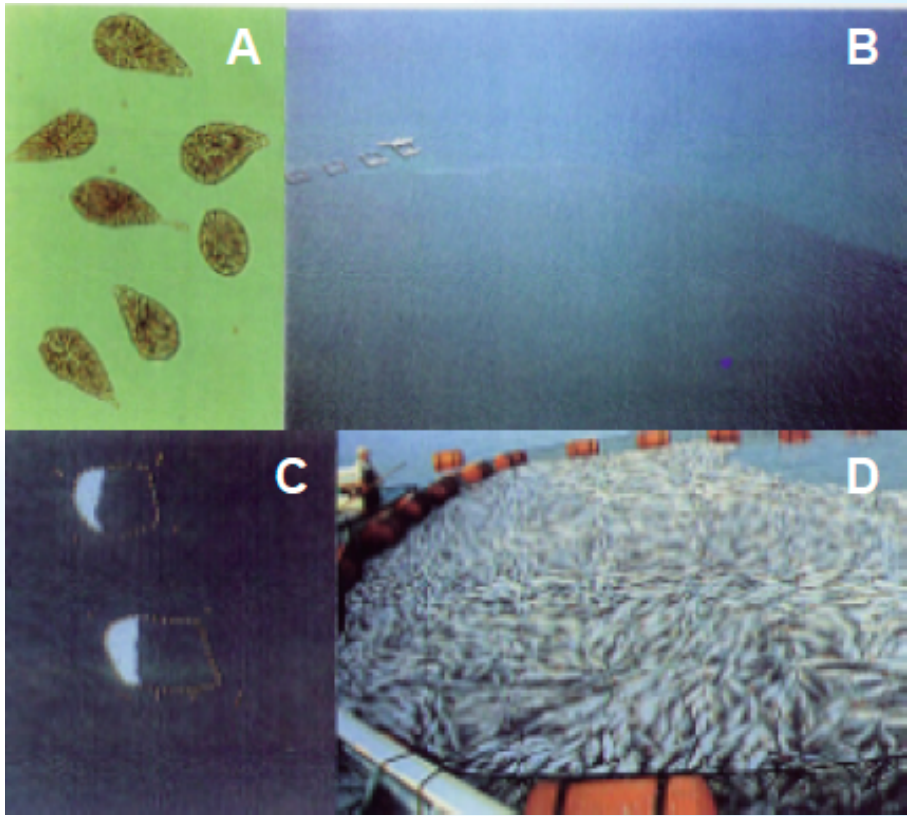


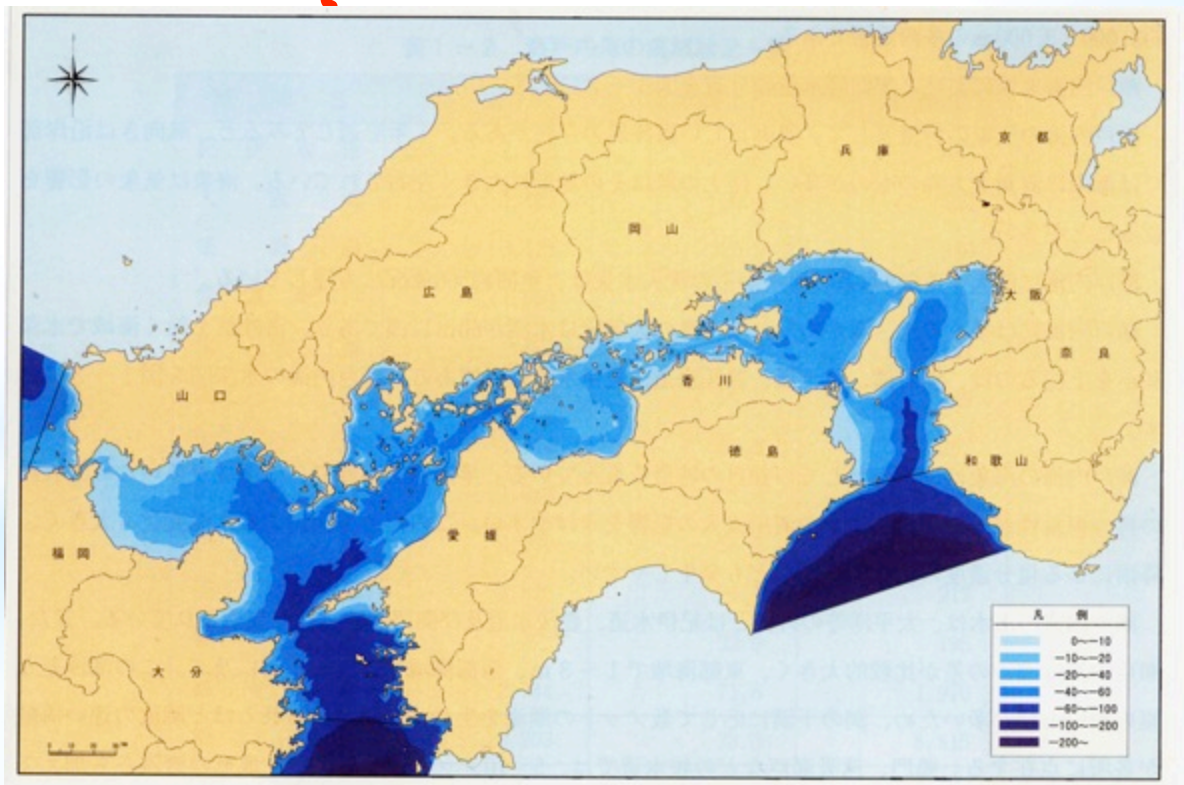
The Seto Inland Sea has experienced extreme eutrophication during the period of high speed economic growth.

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.

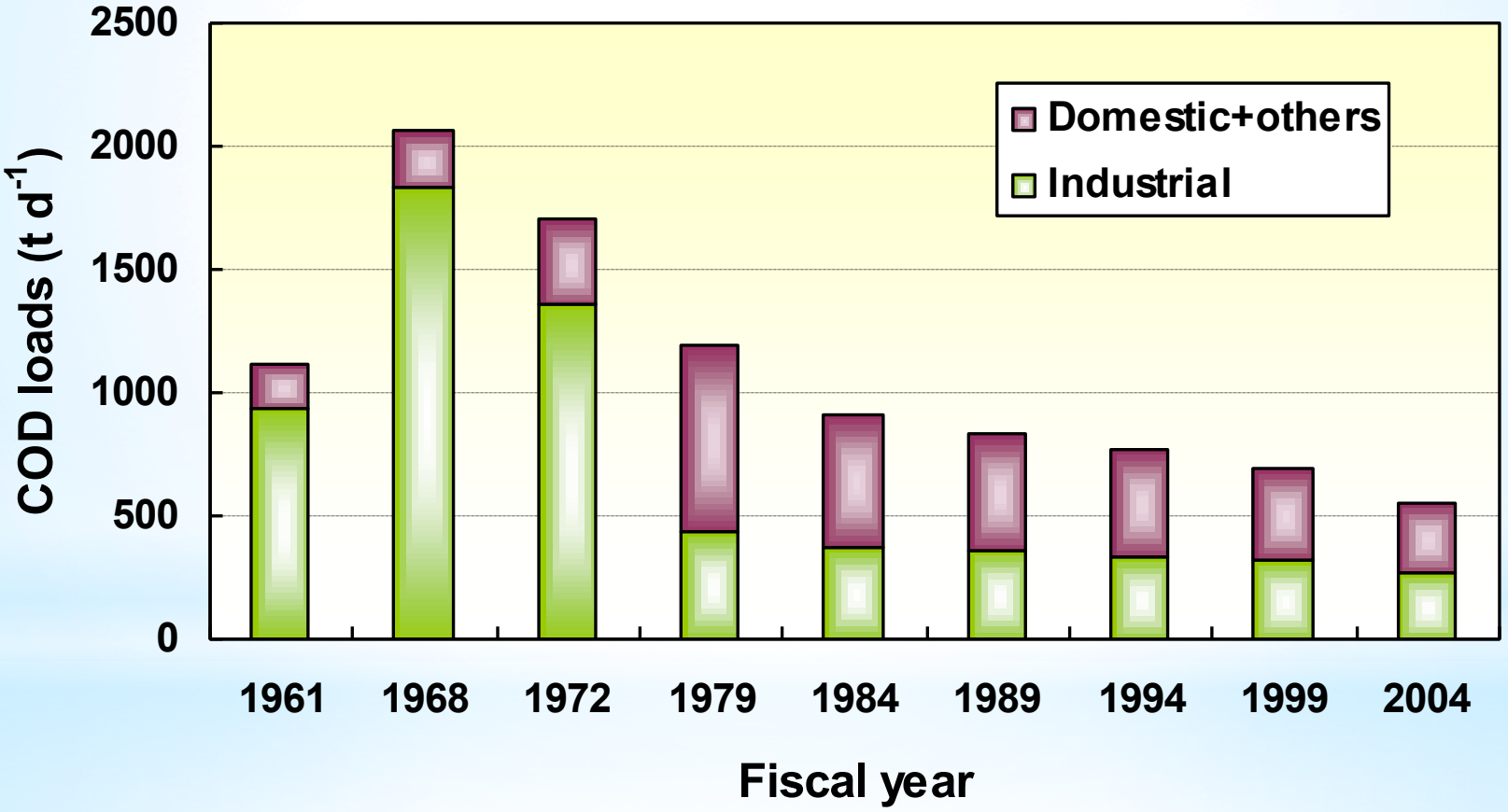
<Seto Inland Sea>

Area	23 203 km^2
Mean depth	38 m
Population	3.0 x 10^7
Fishery production	6 x 10^5 ton /yr
Aquaculture production	3 x 10^5 ton /yr



The Seto Inland Sea

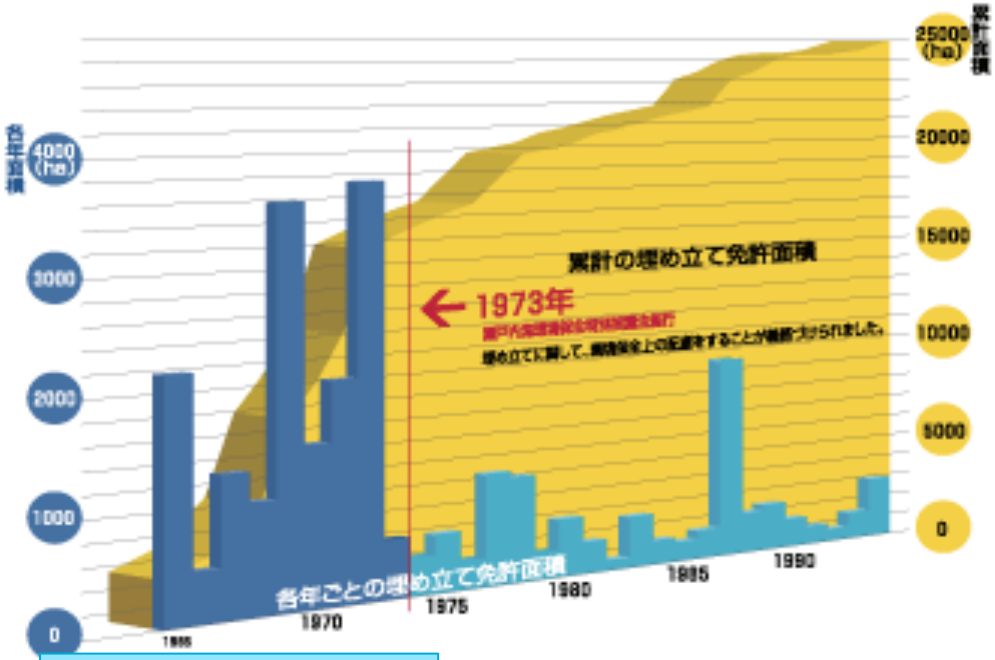
Changes in total amount of COD load in the Seto Inland Sea



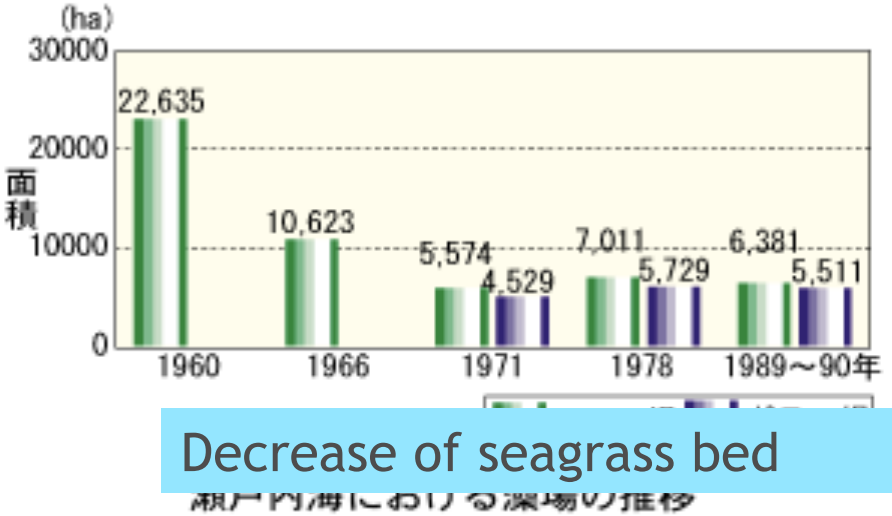
from the Ministry of the Environment Government of Japan &
the Association for the Environmental Conservation of Seto Inland Sea

*Reclamation and decrease of intertidal flats and seagrass beds in the Seto Inland Sea

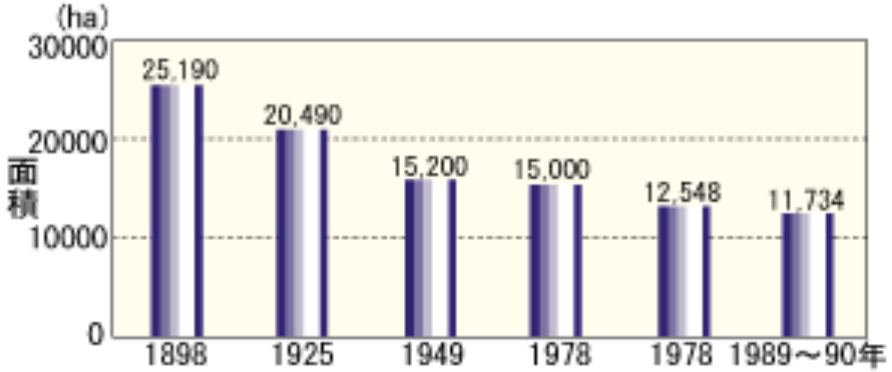
Red tide occurrences



Reclamation

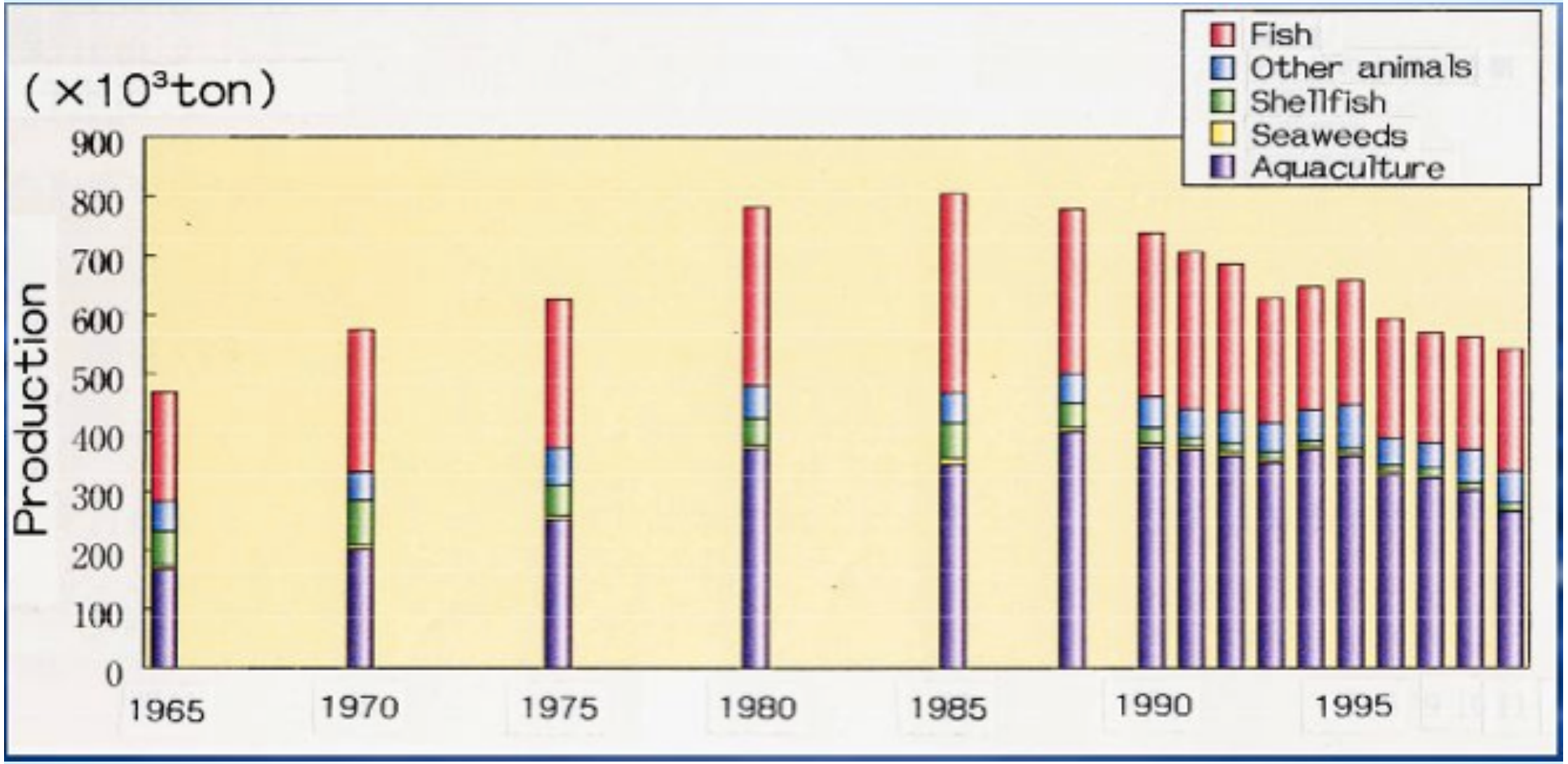


Decrease of seagrass bed



Decrease of intertidal flats

*Fisheries production in the Seto Inland Sea



Measures for eutrophication

- Special law

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

→ Total Pollutant Load Control
Reduce the total quantity of organic pollutants in term of COD

- Controls of total P (from 1979)

- Controls of total N (from 1996)

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

WESTPAC-HAB
IOC Harmful Algal Bloom Programme

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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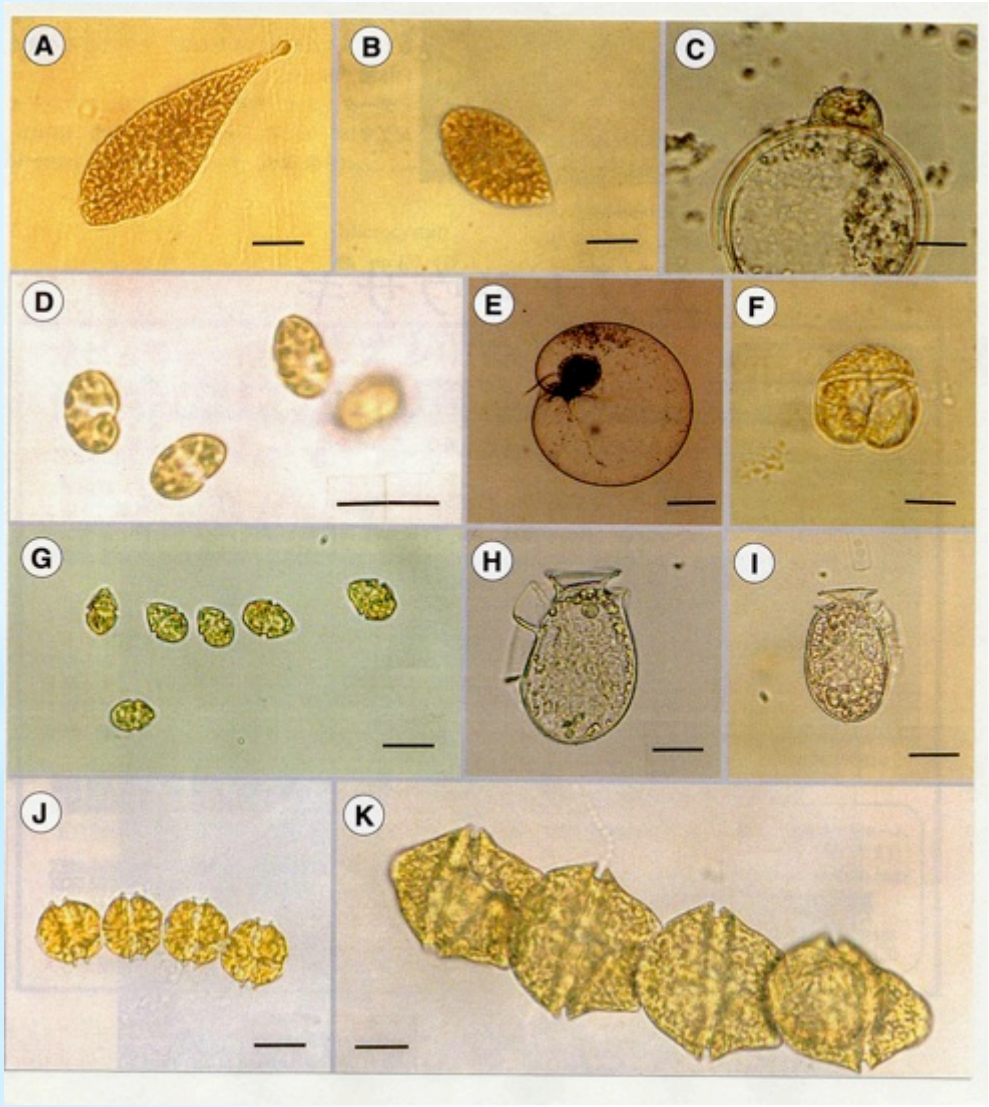
Harmful algae in the Seto Inland Sea



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*

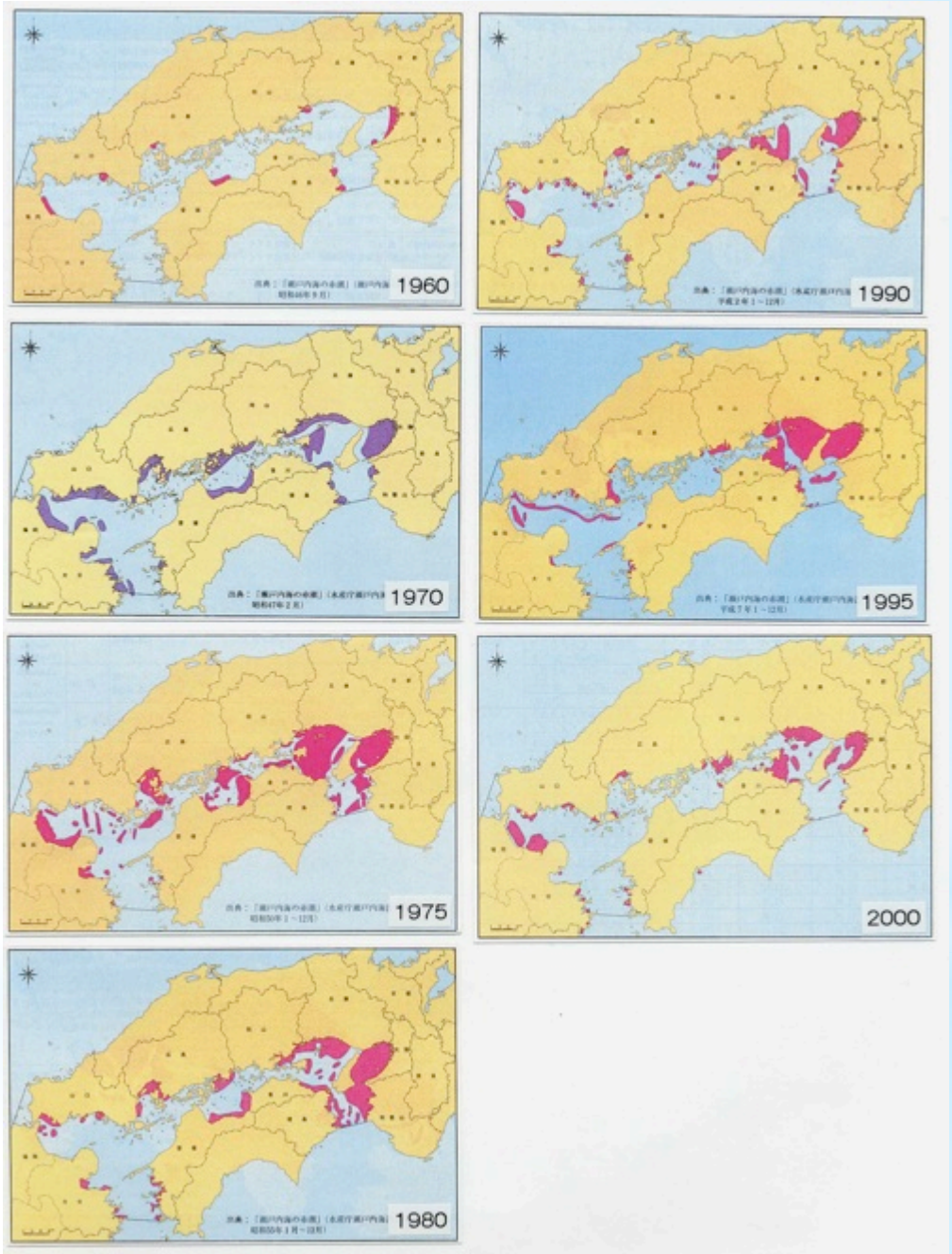
I: *Dinophysis acuminata*

J: *Alexandrium catenella*

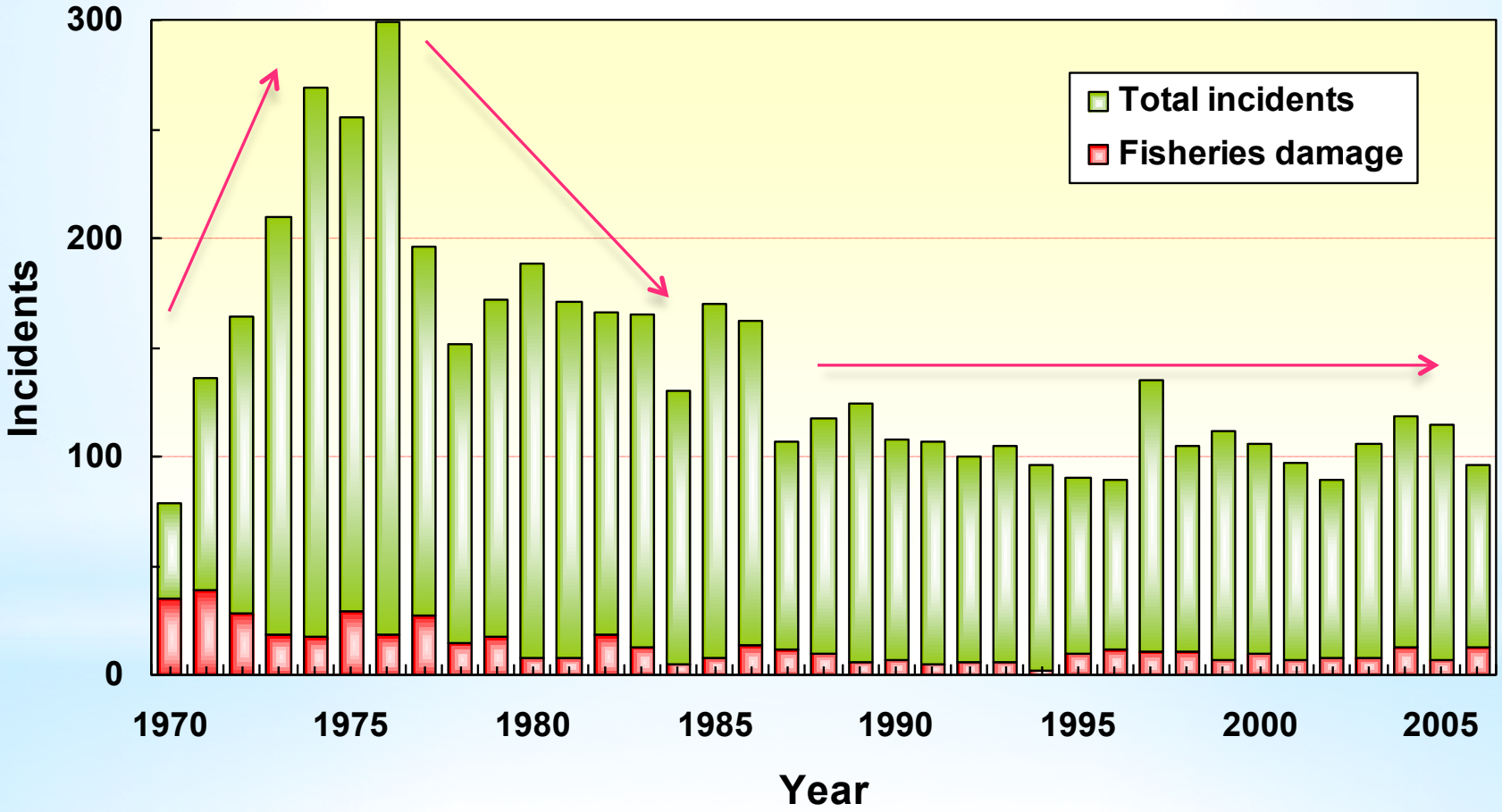
K: *Gymnodinium catenatum*

*Changes in the red tide areas

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



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

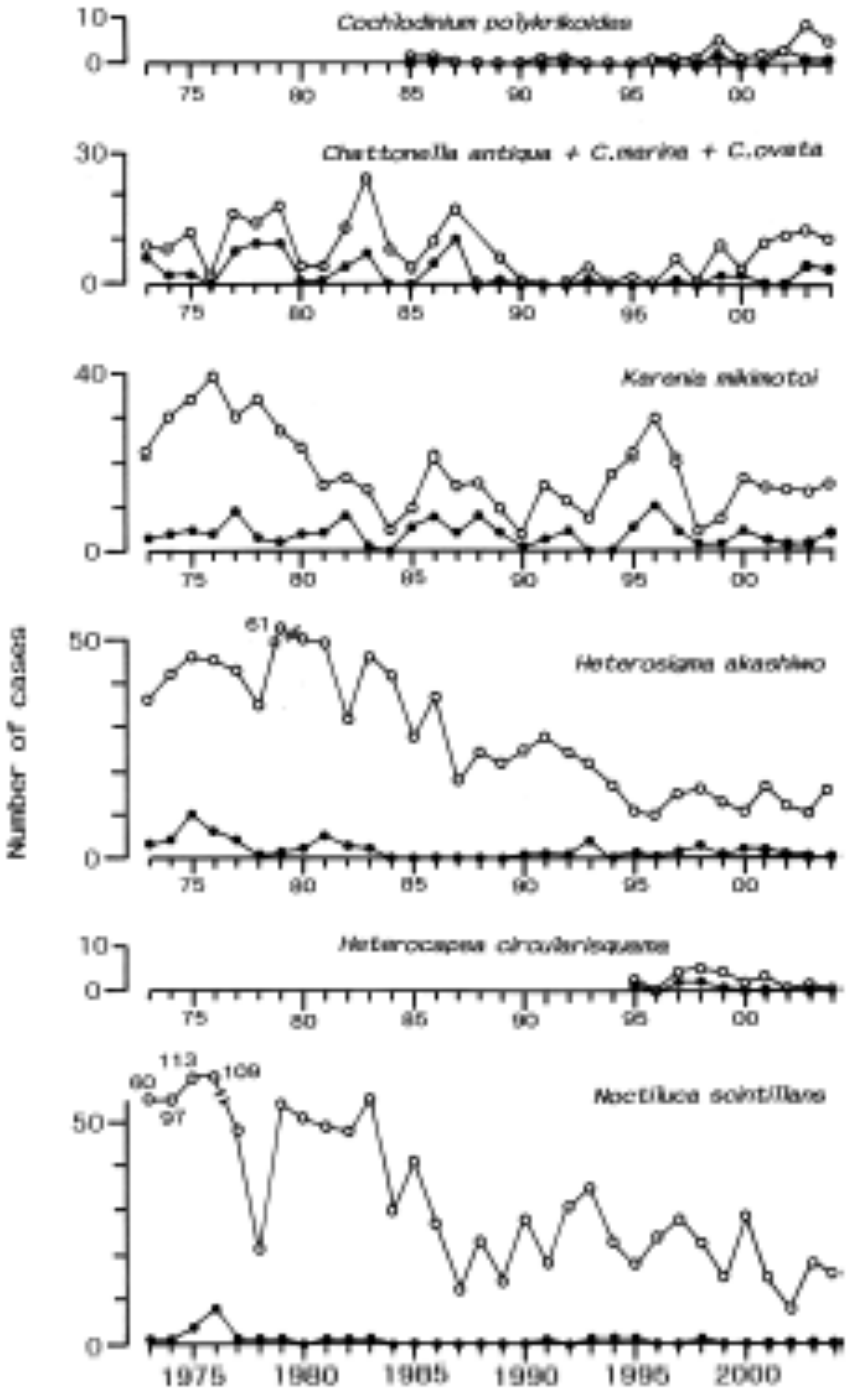


*Incidents of red tides caused by main species

*Recent increase of *Cochlodinium polykrikoides*

*Revival of *Chattonella* and increase of *C. ovata*

*Long-term decrease of *Heterosigma akashiwo* and *Noctiluca scintillans*



* Fishery damage amounts (yen) given by main red tide species in the Seto Inland Sea

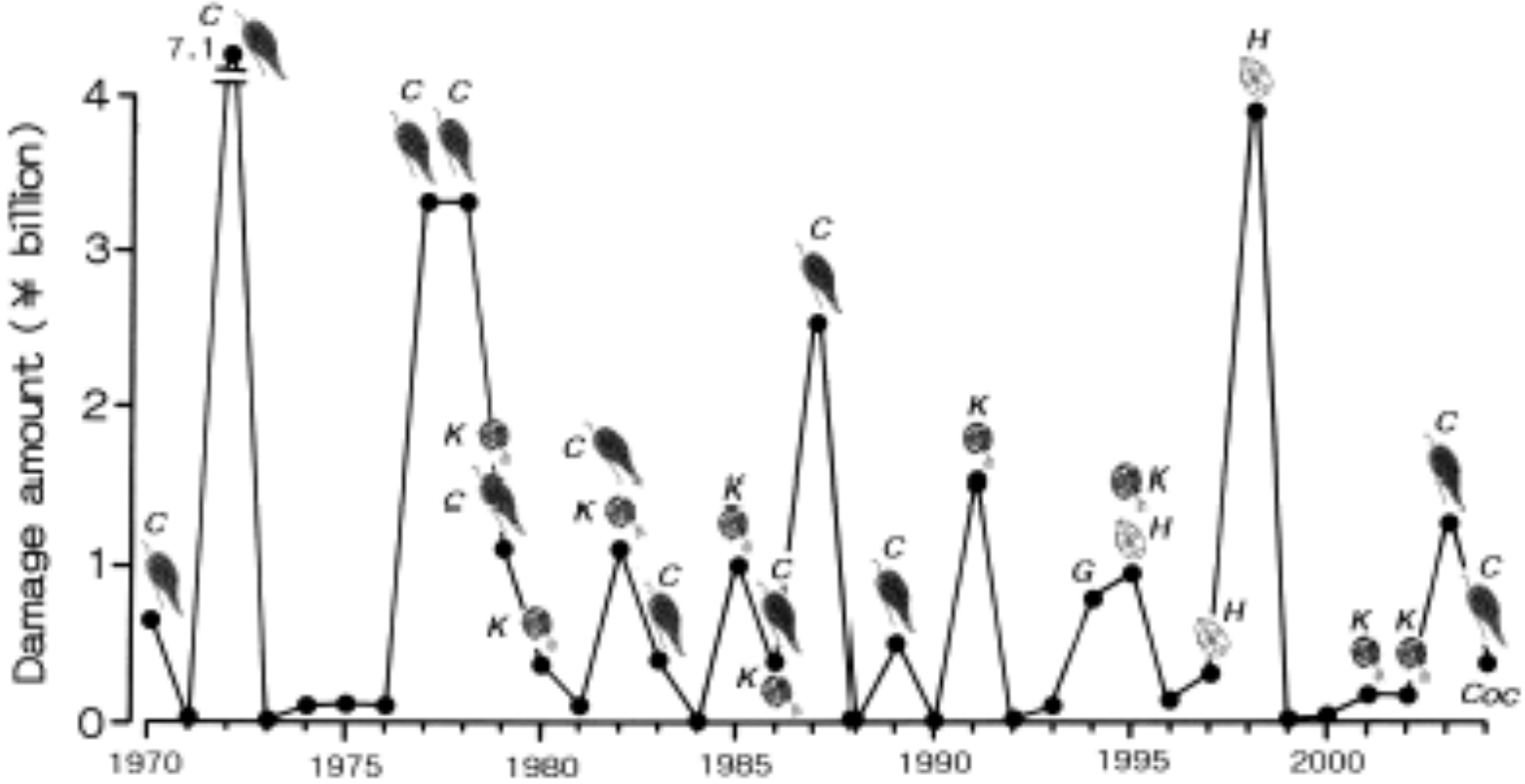


Fig. 7. Fishery damage to aquaculture caused by noxious red tides in the Seto Inland Sea from 1970 to 2004. Illustrations indicate causative microalgae responsible for >80% of total damage of each year. *C*: *Chattonella* spp. (*C. antiqua*, *C. marina* and *C. ovata*), *K*: *Karenia mikimotoi*, *H*: *Heterocapsa circularisquama*, *G*: *Gonyaulax polygramma*, *Coc*: *Cochlodinium polykrikoides*.

* Warning levels of main red tide species in Hiroshima Prefecture, Seto Inland Sea

Table 4. Warning level of cell densities of five representative red-tide organisms, minimum cell quota, and equivalent nutrient level to warning.

Species	Warning level (cells ml^{-1})	Minimum cell quota (fmol cell^{-1}) Nitrogen	Phosphorus	N (μM) equivalent to warning level	P (μM) equivalent to warning level
Chattonella antiqua	100	7800	620	0.78	0.062
Karenia mikimotoi	5000	3130	250	15.7	1.25
Heterosigma akashiwo	50000	1440	95	72.0	4.75
Heterocapsa circularisquama	500	1100	89.4	0.55	0.045+
Cochlodinium polykrikoides	500	5250	370	2.63	0.185

Chattonella antiqua, *Heterocapsa circularisquama* and *Cochlodinium polykrikoidea* are extremely dangerous red tide organisms.

Harmful algal blooms (HABs) have occurred in the Seto Inland Sea

We need environment-friendly prevention strategies for HABs

Algicidal bacteria are the hopeful candidates

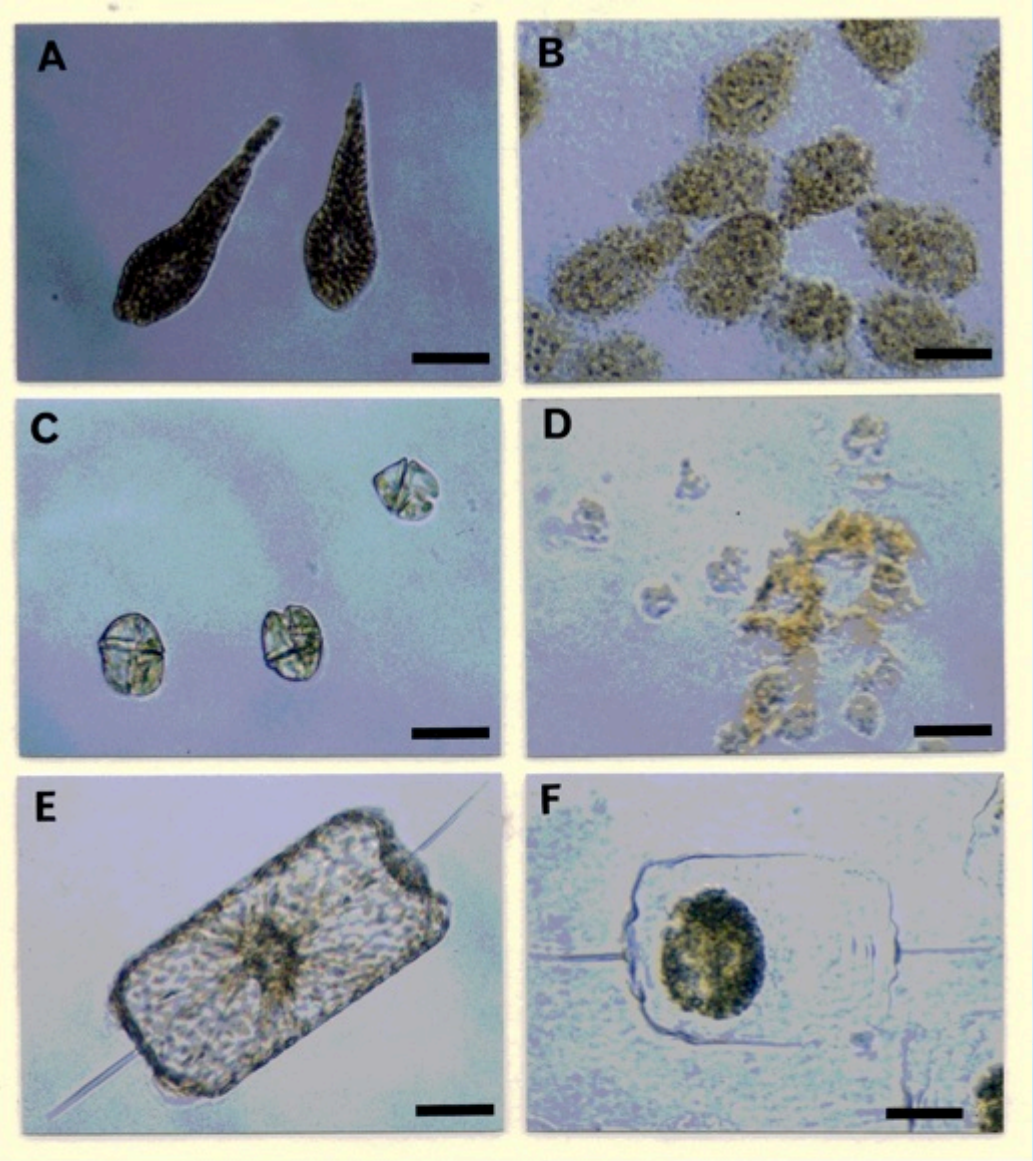
* Algicidal bacteria

Left:

Live cells

Right:

Killed cells



Slide 4. Examples of algicidal activity of algicidal bacteria. Bars, 30μm. **A:** Live cells of *Chattonella antiqua* (Raphidophyceae), **B:** Killed cells of *C. antiqua*, **C:** Live cells of *Gymnodinium mikimotoi* (Dinophyceae), **D:** Killed cells of *G. mikimotoi*, **E:** A live cell of *Dityllum brightwellii* (Bacillariophyceae), **F:** A killed cell of *D. brightwellii*

Seagrass beds ~Source of algicidal bacteria~

Algicidal bacteria which attack to HAB species are supplied from seagrass bed

⇒Prevention of red tide occurrence

Thanks for your attention !

the Seto Inland Sea