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Nutrient loading and harmful algal blooms: research advances and tools for management in Asian waters

International Council for Science

SCOR

Scientific Committee on Oceanic Research

GEOHAB

Global Ecology and Oceanography of Harmful Algal Blooms

United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

Nutrient loading and harmful algal blooms: research advances and tools for management in Asian waters

1.- What are Harmful Algal Blooms (HABs)?

2.- What causes HABs? The role of nutrient supply

3.- HABs in Asian coastal waters. Generalities.

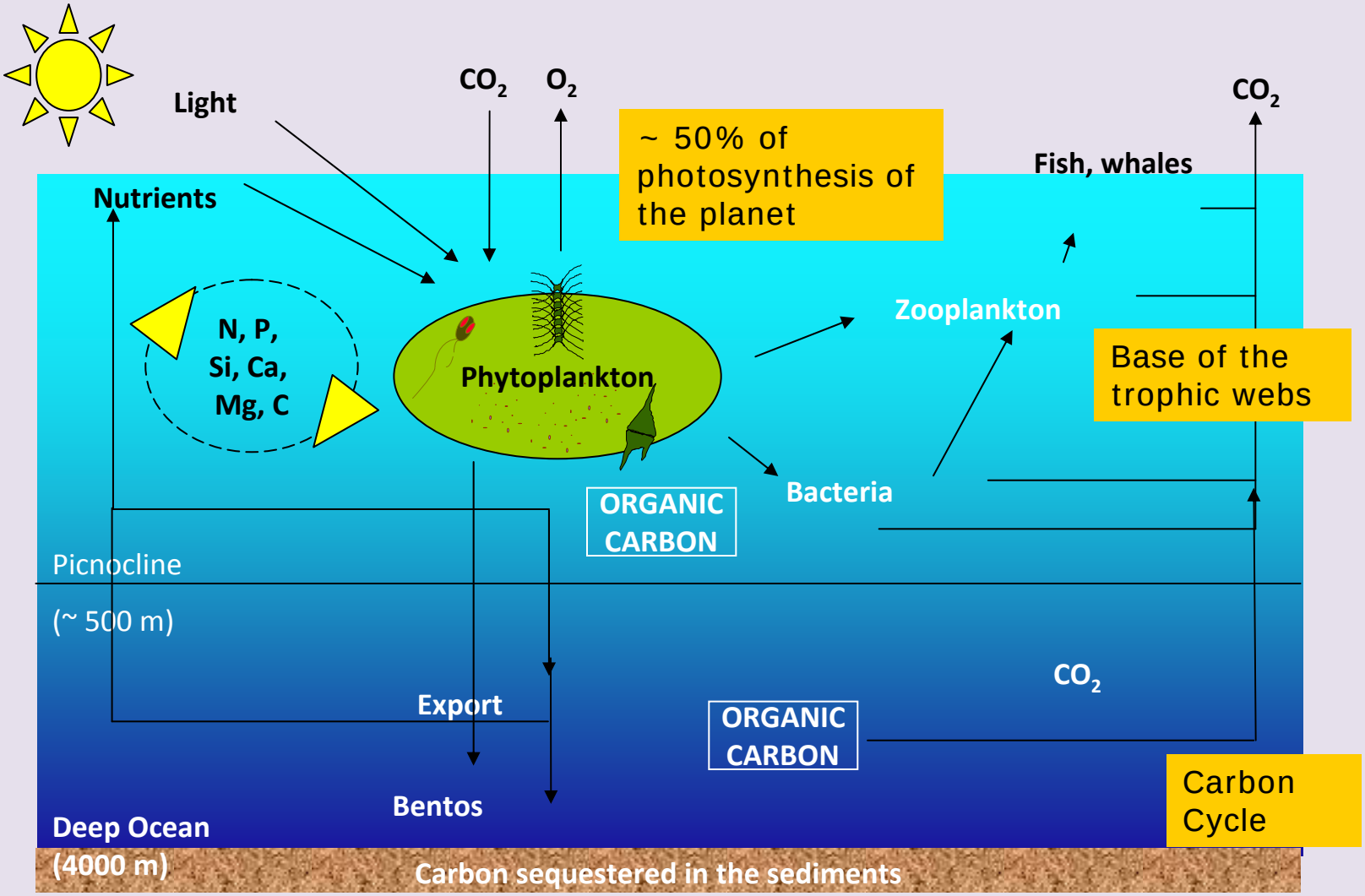
- **Case study A: HABs in Hong Kong coastal waters**
- **Case study B: HABs in the Seto Island Sea**
- **Case study C: *Phaeocystis* in southern Vietnamese coast**

4.- Available tools

1.- What are Harmful Algal Blooms (HABs)? Some concepts

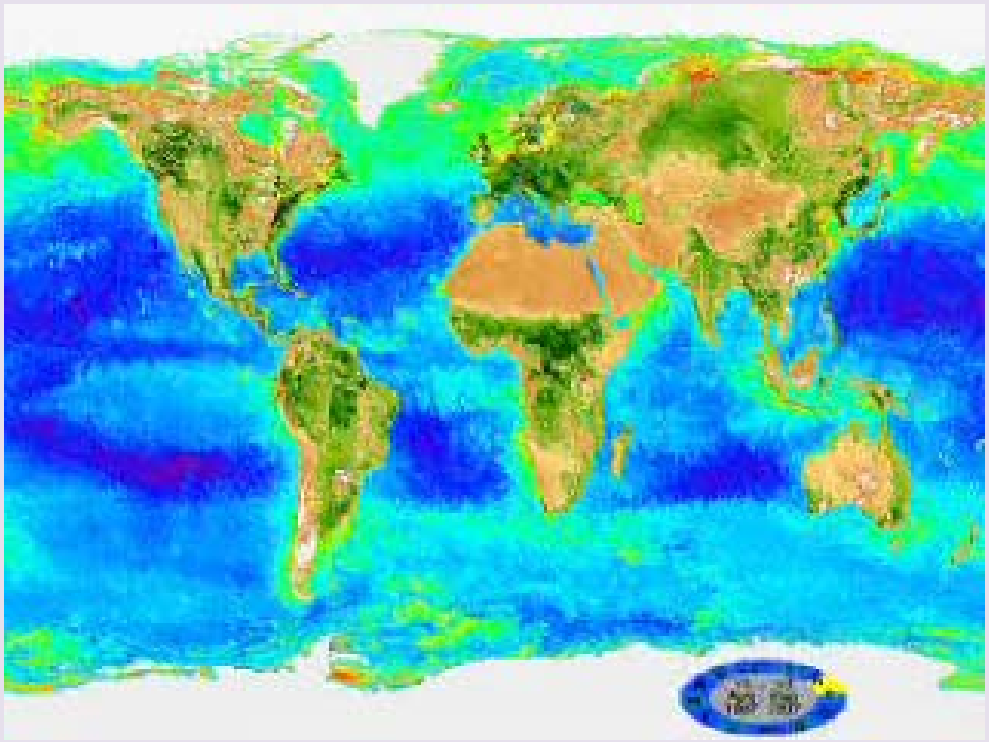
"Algae" (senso lato): - photosynthetic organisms that produce O_2, consume CO_2

- constitute the base of the food webs
- relevant role in the export of Carbon to the deep ocean



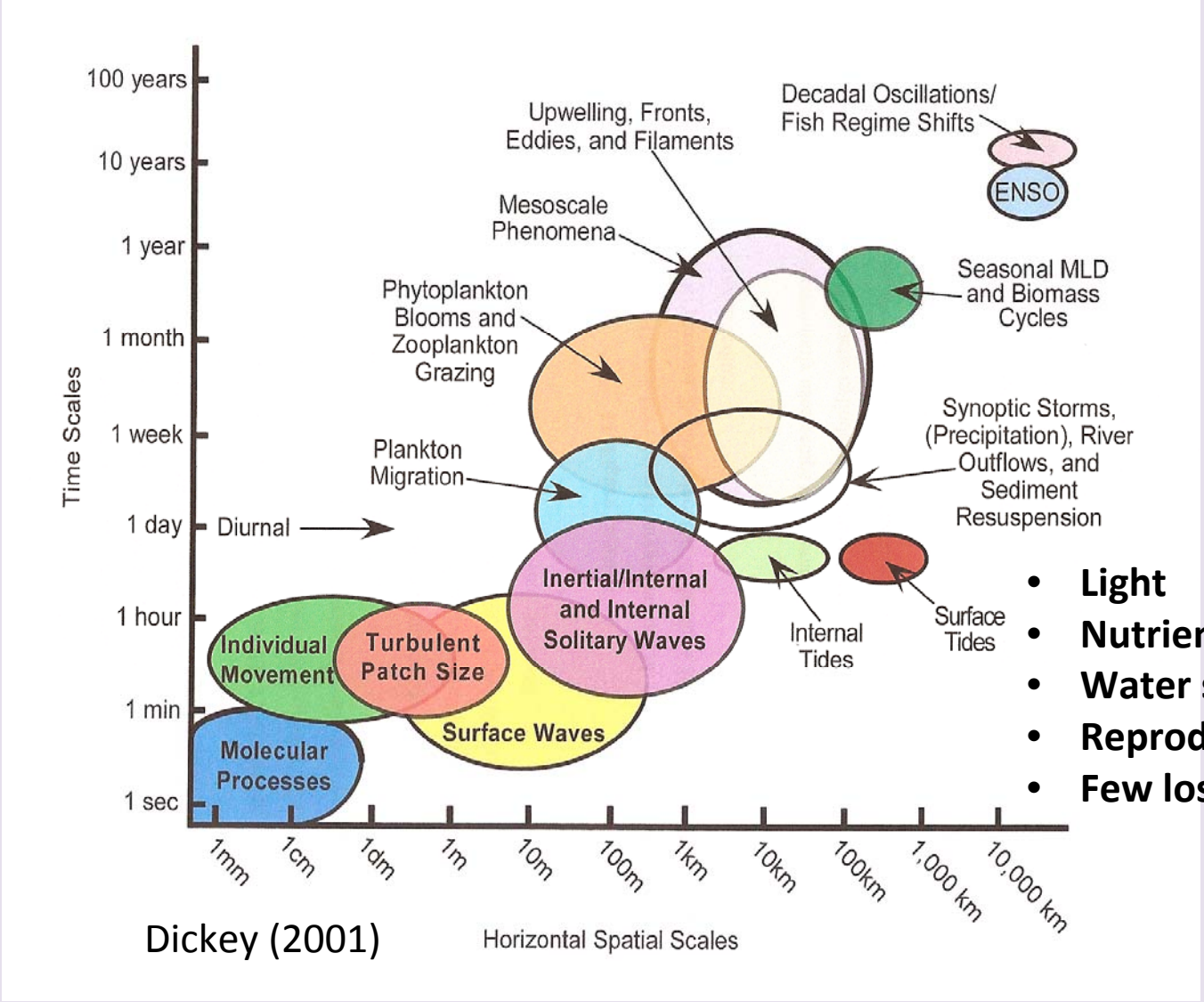
1.- What are HABs? Some concepts

The annual cycle of phytoplankton blooms in the planet seen from the NASA SeaWIFS satellite



1.- What are HABs? Some concepts

Phytoplankton blooms result from the interactions of physical, chemical, ecological and biological processes that occur at different scales.



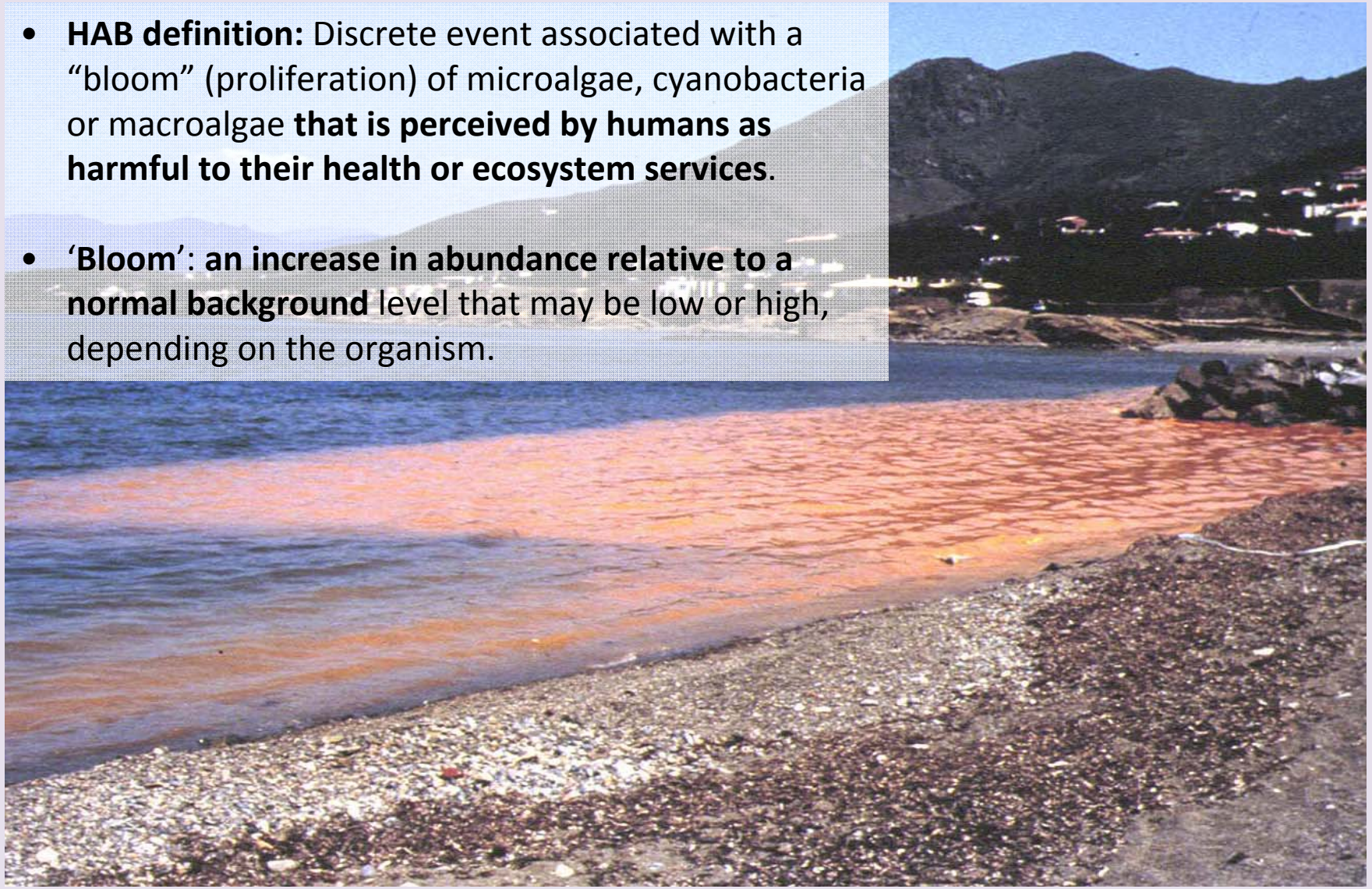
Dickey (2001)

- **Light**
- **Nutrients**
- **Water stability**
- **Reproduction capacity**
- **Few losses (death, predation)**

1.- What are HABs? Some concepts

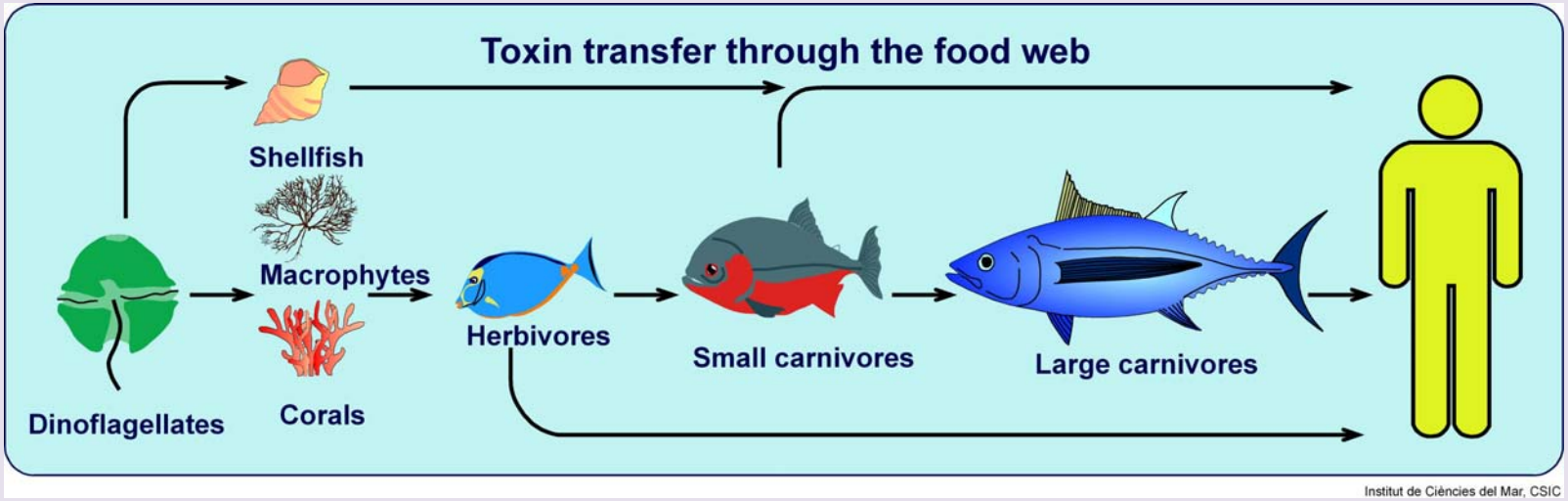
- **HAB definition:** Discrete event associated with a "bloom" (proliferation) of microalgae, cyanobacteria or macroalgae **that is perceived by humans as harmful to their health or ecosystem services**.

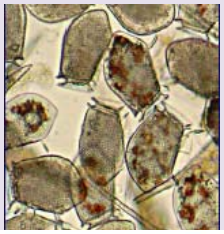
- '**Bloom**': **an increase in abundance relative to a normal background** level that may be low or high, depending on the organism.



1.- What are HABs? Some concepts

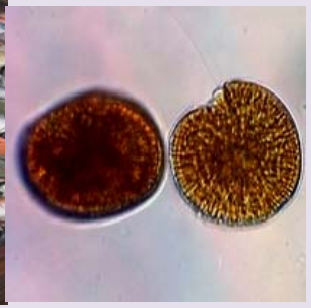
Some microalgae produce toxic substances to humans and aquatic organisms





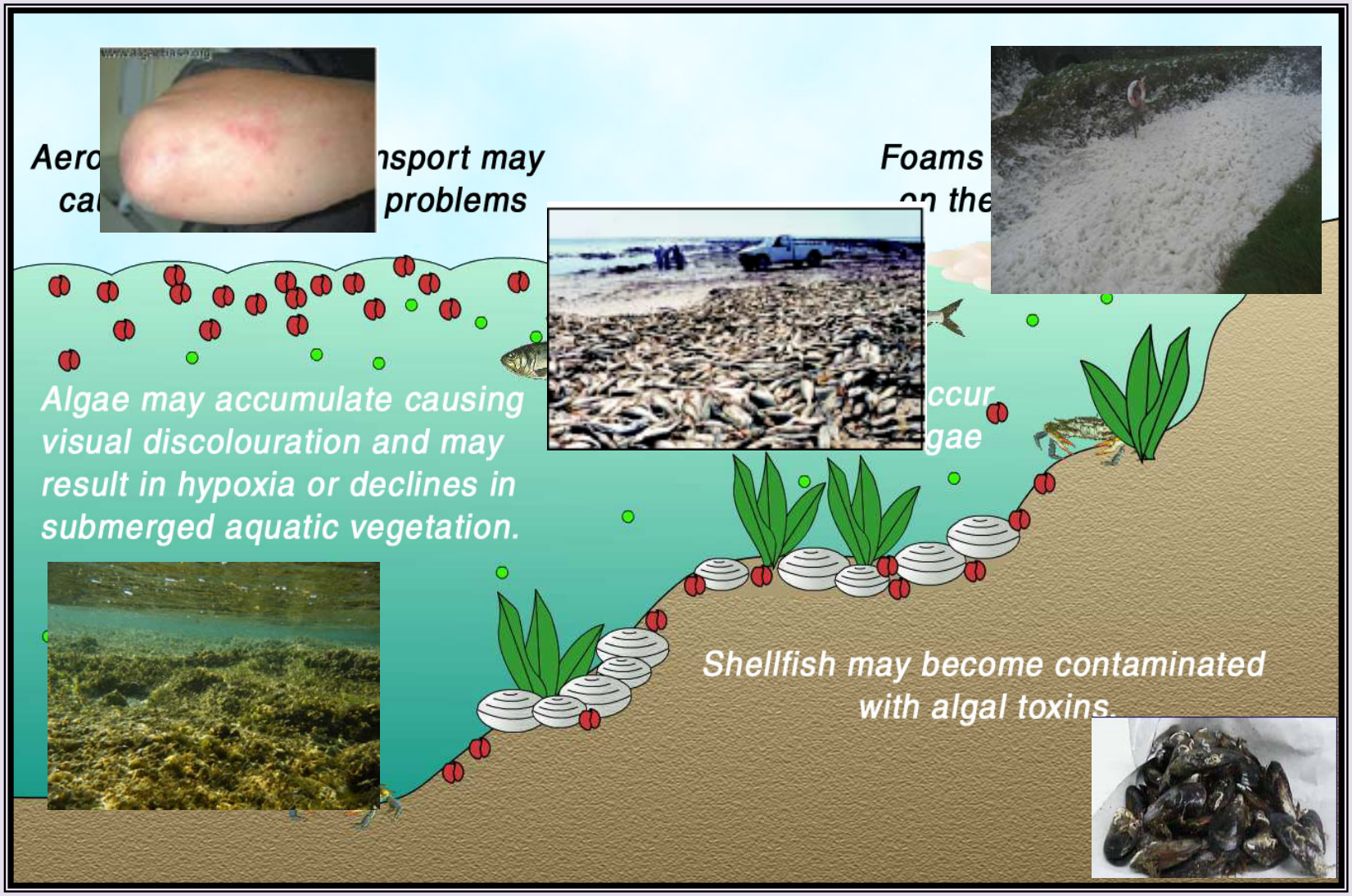
Dinophysis,
Diarrheic Shellfish Poisoning,
Closure of shellfish harvesting

Gambierdiscus,
Ciguatera fish poisoning
Endemic in the tropics



1.- What are HABs? Some concepts

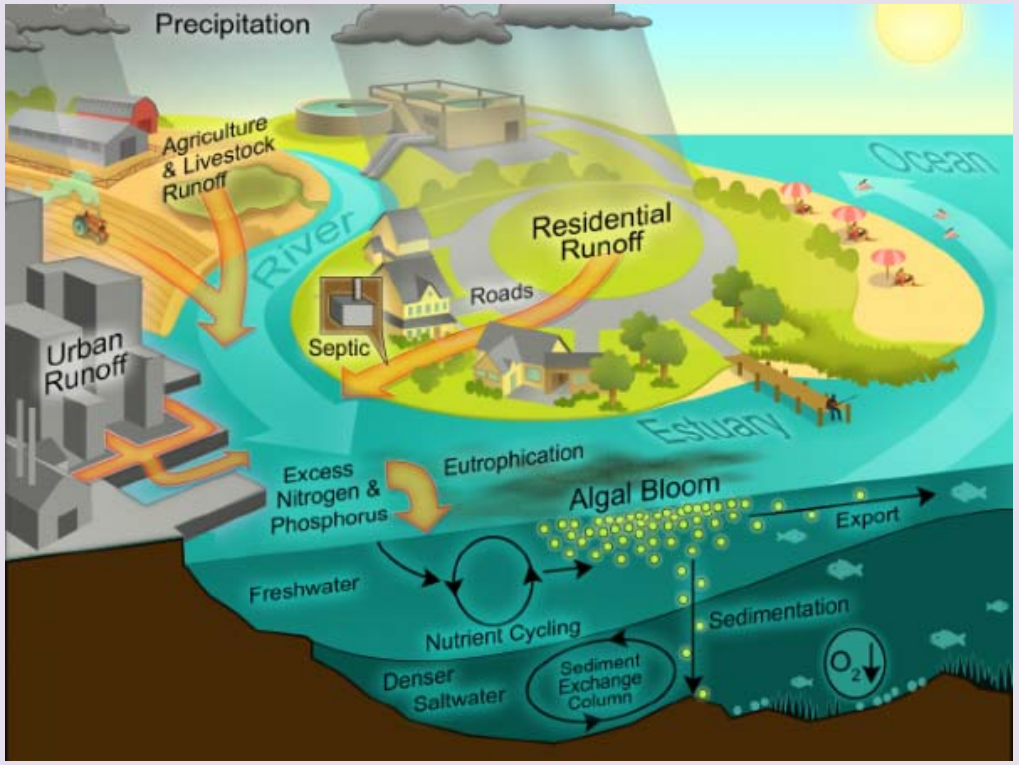
HABs events have different impacts on human health and wellbeing



2.- What causes HABs?

HABs are natural phenomena, controlled by the same factors than phytoplankton blooms.

However, some human activities can favor them:
-Eutrophication: anthropogenic nutrient enrichment leading to excess phytoplankton production that can result in undesirable disturbance to water quality and the balance of organisms.
-Alteration of water circulation patters by harbors (retention areas)
-Spread of harmful organisms through ballast waters or transport of cultured organisms



Alexandrium catenella
Images: M. Delgado/ M. Vila / JM Fortuño (ICM-CSIC)

3.- HABs in Asian waters. Main HAB taxa

Ichtyotoxic, high biomas

Cochlodinium polykrikoides

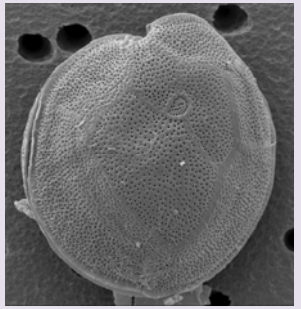
Karenia mikimotoi

Heterocapsa circularisquama

Diarrheic Shellfish Poisoning (DSP)

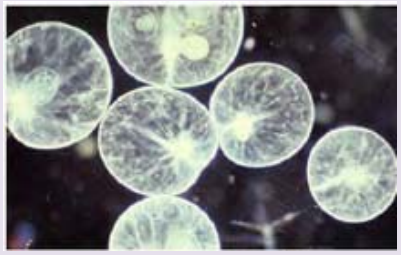
Dinophysis spp.

Ciguatera Fish Poisoning (CFP)



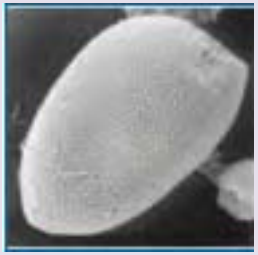
Gambierdiscus

High biomass, hypoxia, non toxic



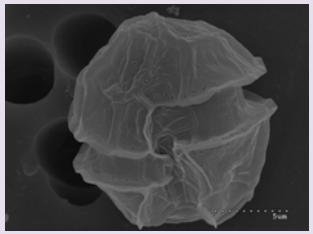
Noctiluca scintillans

Scrippsiella trochoidea

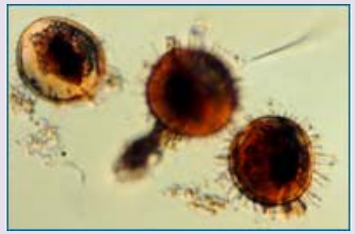


Prorocentrum donghaiense

Paralytic Shellfish Poisoning (PSP)



Alexandrium minutum



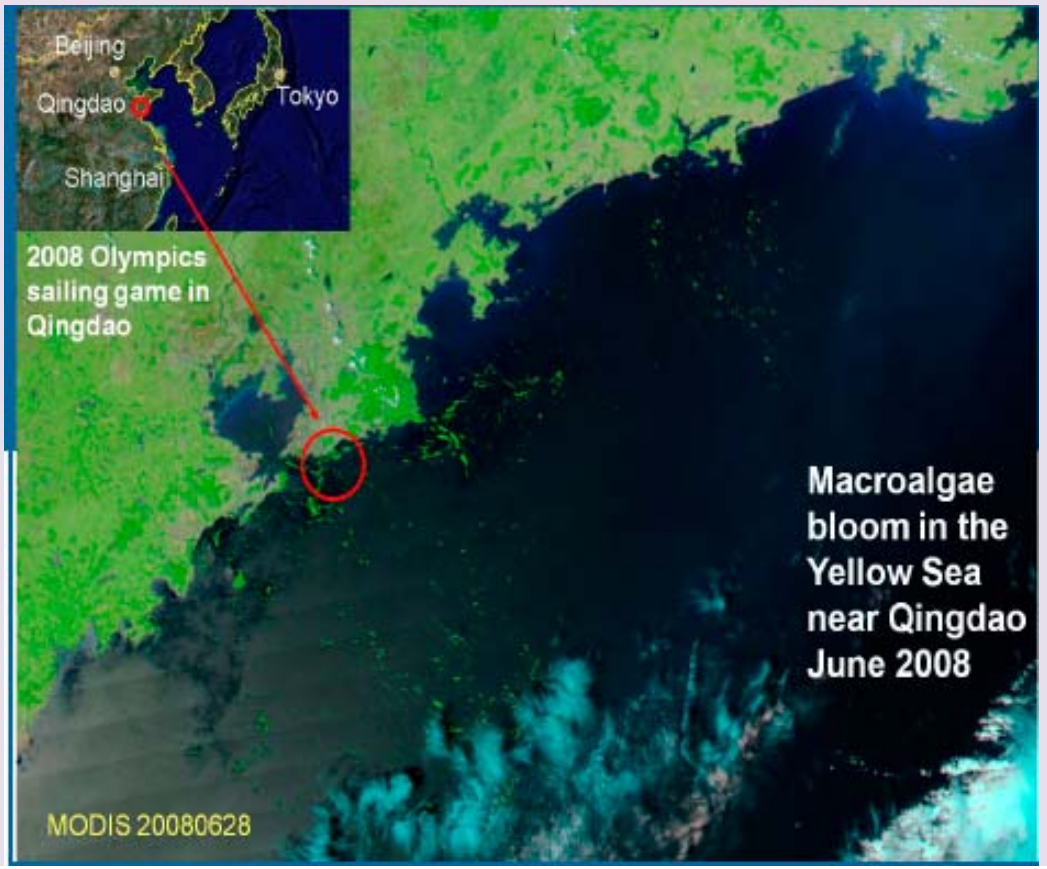
Pyrodinium bahamense v. *compressum*

3.- HABs in Asian waters. General view

In Asia, HABs have important **impacts on**:

1)Human health: a high diversity of harmful syndromes and causative organisms occur;
2)Economy: the highest production of aquaculture fish and shellfish in the globe; thus, economic impacts are high;
3)Ecosystems: regional anthropogenic eutrophication favor high biomass HAB events that result in hypoxia in the water column and alters the food webs composition.

Tiger shrimp, *Penaeus monodon*, extensively cultured on the coast of Cam Ranh Bay, Vietnam. (Y. Fukuyo).

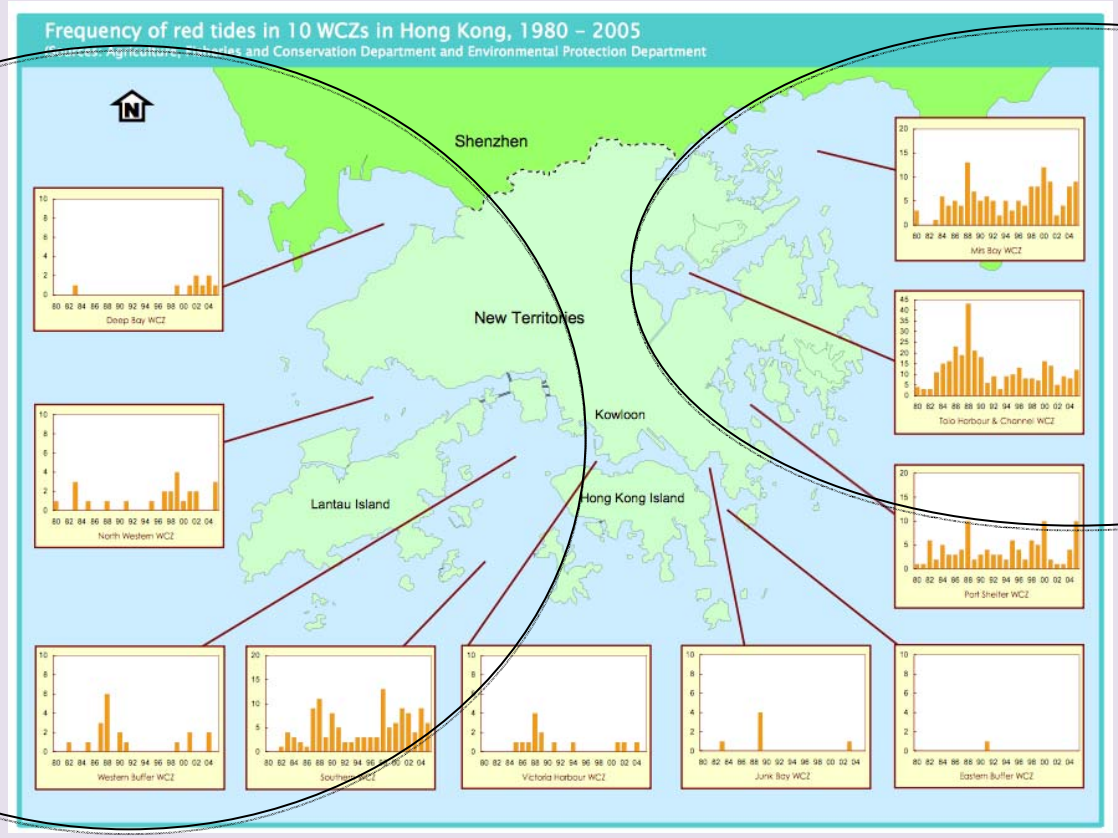


3.- HABs in Asian waters. Case A. Hong Kong coastal waters

Time series showed marked changes in the occurrence of HABs depending on the areas and periods. (Wang et al. 2008. *Hydrobiologia* 596, 79.)

Which is the role of anthropogenic nutrient enrichment on HABs occurrence?

More oligotrophic areas

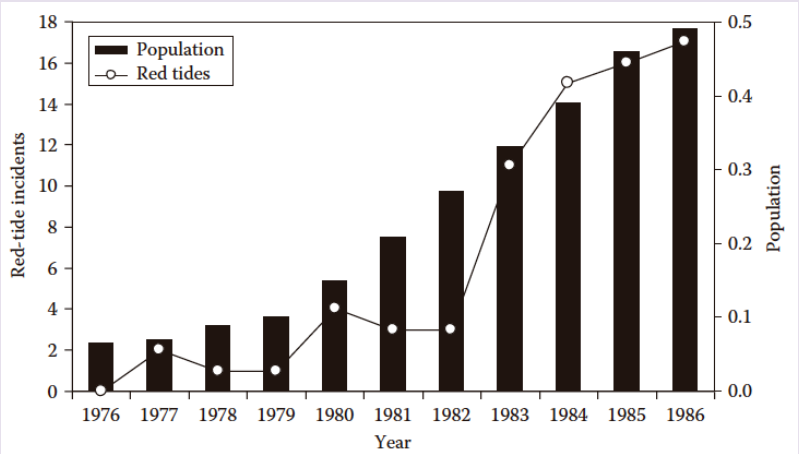


More nutrient enrichment

Source: ***20 years of marine Water Quality Monitoring in Hong Kong.***
http://www.epd.gov.hk/epd/misc/marine_quality/1986-2005/eng/13_appendices_menu.htm

3.- HABs in Asian waters. Case A. Hong Kong coastal waters

Noctiluca scintillans bloom in Tolo Harbor.
Heterotrophic dinoflagellate. Feeds on microalgae

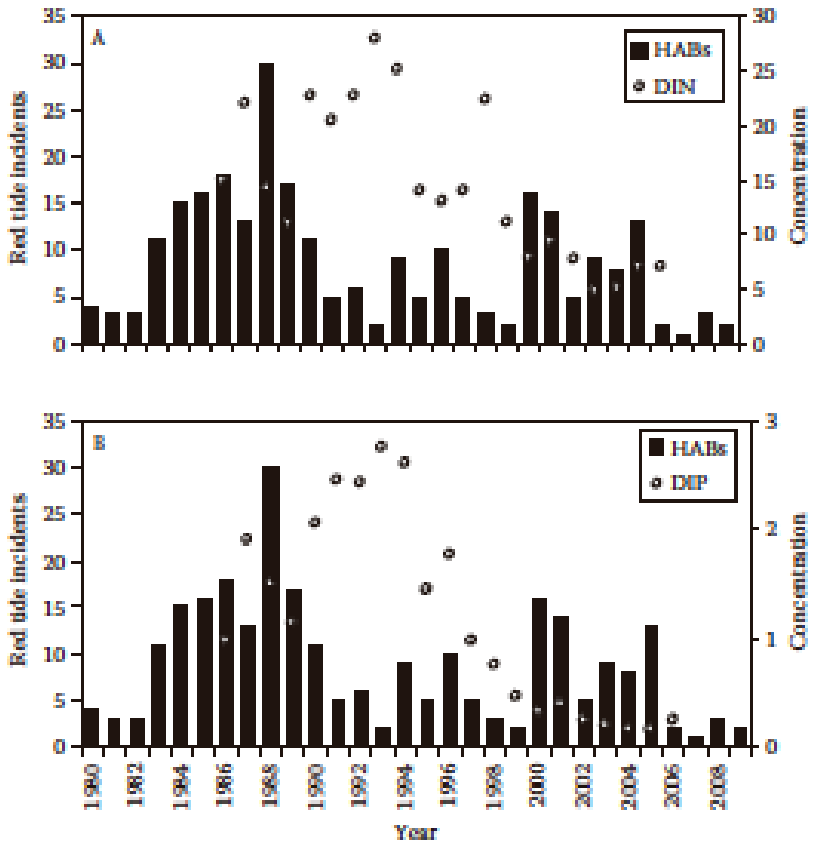


Tolo Harbor. Lam & Ho 1989 (In Okaichi et al. (eds)

1980s – 1990s: HABs events increased with population related sewage

Most events: high biomass, no toxic, hypoxia

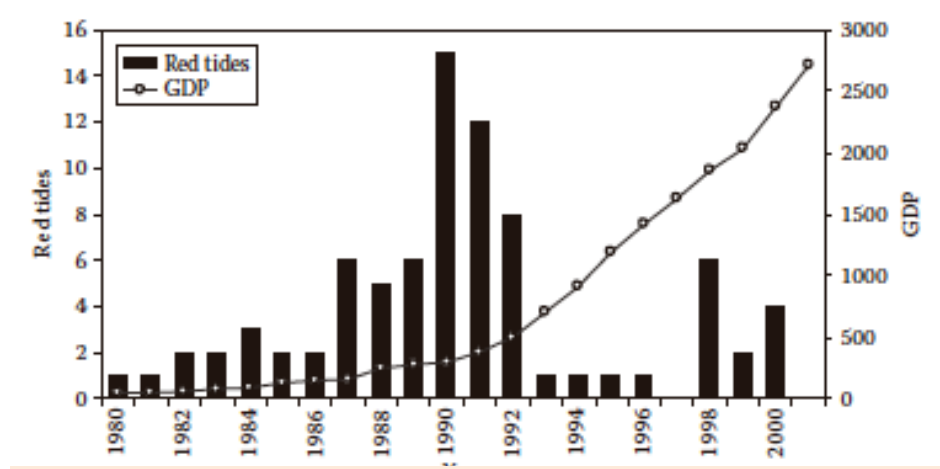
1996 – 1998: Large sewage diversion



Tolo Harbor. From Gowen et al. 2012.

1990s – 2000s:
HABs decrease before sewage diversion

3.- HABs in Asian waters. Case A. Hong Kong coastal waters



In contrast, no direct link in the Guangdong Province

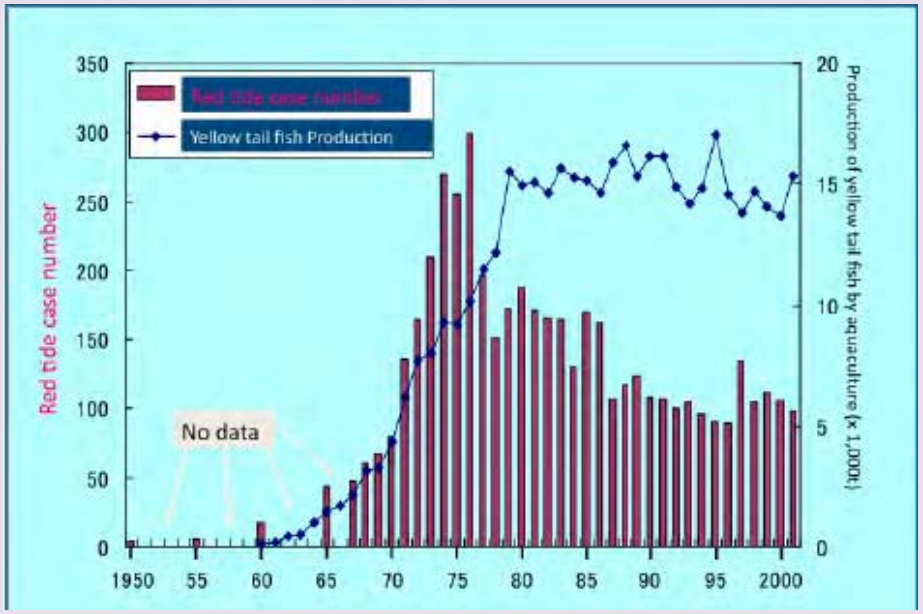
Karenia mikimotoi **exceptional bloom in 1998, coinciding with the most intense El Niño** in the 20th century. It was advected from offshore coastal water. Associated to massive fish fills.

Other factors interacting with nutrient availability in Tolo Harbor:
hydrodynamics & physical factors

-Long flushing time: 15 days – 1 month
-Small dimension: 50 km^2
-Narrow sea inlet, shallow (max 12 m depth)
-Water column stratified during most part of the year
-Unbalanced Silicate supply: less diatoms, more flagellates
-1988: max HABs probably related to small short-lived typhoons (wind speed ca. 2 m/s)
-1993: min HABs, probably related to 9 long-lived active typhoons (wind speed >3 m/s)
-Monsoon dynamics and Pearl River plume influence

3.- HABs in Asian waters. Case B. Seto Island Sea

Fish cage culture of yellow tail (*Seriora quinqueradiata*) in the Seto Inland Sea, Japan. Photo by Suisan Aviation. *Chattonellla antiqua* caused major fish kills in the 1970s, before waste-water treatments were applied.

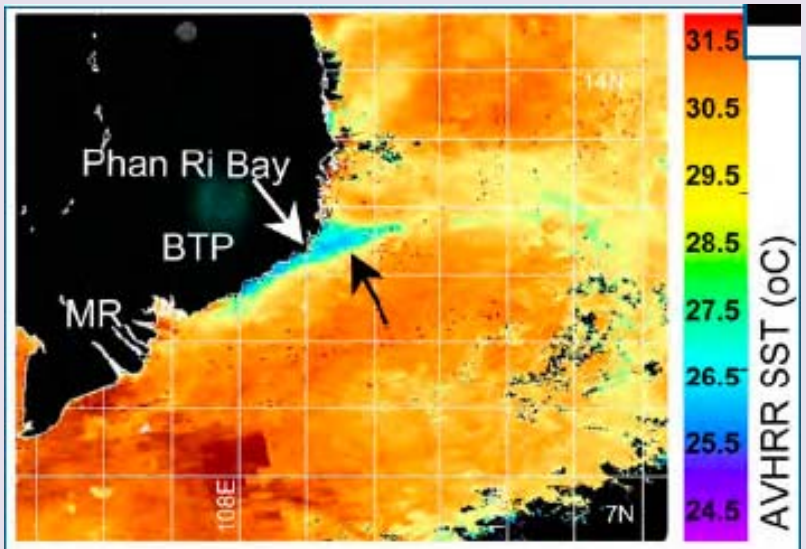


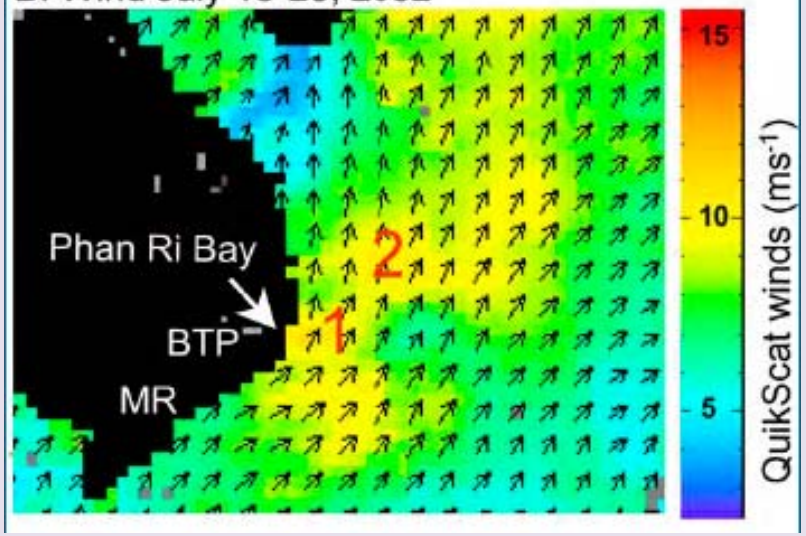
Parallel increase of red tide occurrences and yellowtail fish aquaculture industry in Seto Inland Sea, Japan. (Y. Fukuyo.)

- Anthropogenic nutrients (fish cages, industry, sewage): important factor promoting HABs
- A highly productive area due, in part, to hydrodynamic conditions:
  - seasonal stratification, frontal boundaries
  - Semi-enclosed, residence time 1.2 years
  - 600 small islands, small bays, narrow channeles
  - Weak estuarine circulation in most areas (low freshwater input in general)
- **Hydrodynamics favor high productivity and HABs**
- 1996: **Legislation** to control effluent (total N, reduce N & P): improved water quality

3.- HABs in Asian waters. Case C. *Phaeocystis*

Phaeocystis globosa dense bloom, sea surface waters are often covered by thick foam. South Vietnamese coast. (N.N. Lam; Y.Z. Qi).



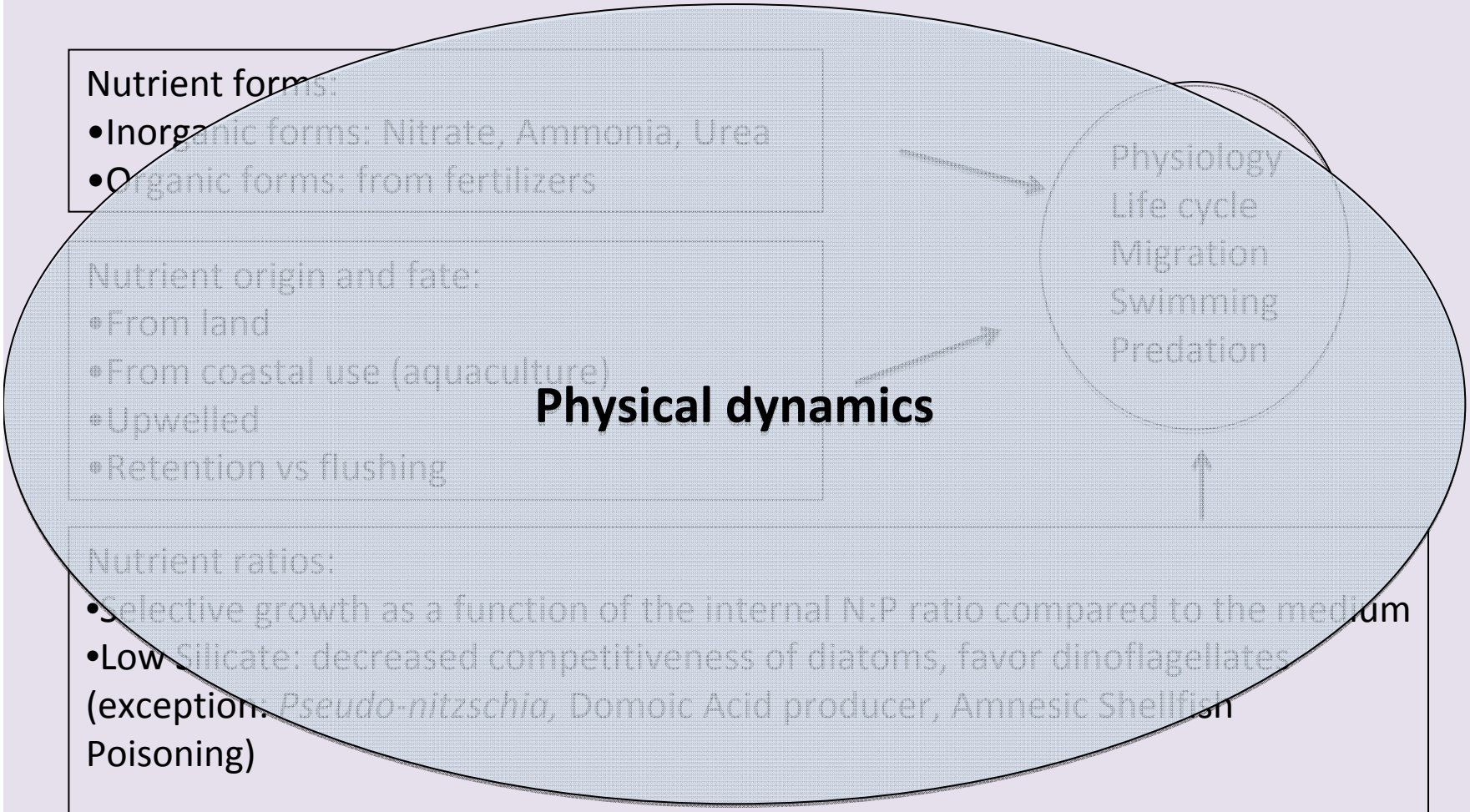


- Blooms associated with nutrients supplied by upwelling during the southwest monsoon (Tang et al. 2004).
- Ecological changes in the composition of the food web (competition)
- Changes in nutrient stoichiometry (N:P)
- Wind-forced upwelling controlled by monsoon dynamics

Blooms of *Phaeocystis*, *Prorocentrum donghaiense* and *Karenia mikimotoi* are modulated by physical forcing, no caused by anthropogenic nutrient enrichment

4.- Available tools. Fundamental research

INTEGRATED UNDERSTANDING OF THE LINKS BETWEEN NUTRIENTS, PHYSIOLOGY OF HARMFUL PHYTOPLANKTON AND PHYSICAL DYNAMICS



MULTIPARAMETER TIME SERIES (MONITORING)

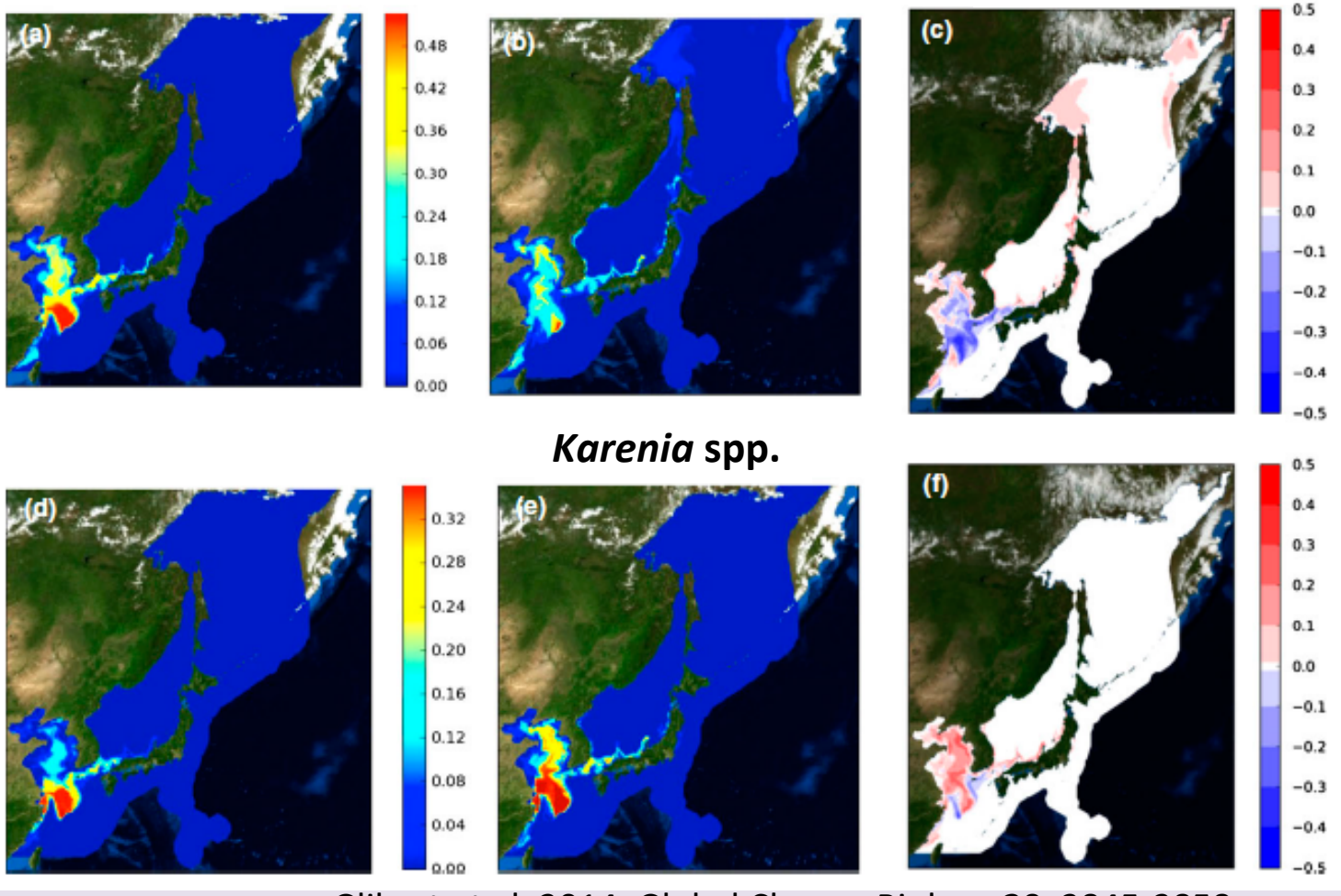
4.- Available tools. Modelling

Potential effects of nutrient loading and climate change.

Projections in NE Asia: expansion in area and/or number of months annually conducive to development of *Prorocentrum* and *Karenia*.

***Prorocentrum* spp.**

Present day **Future projection** **Difference**

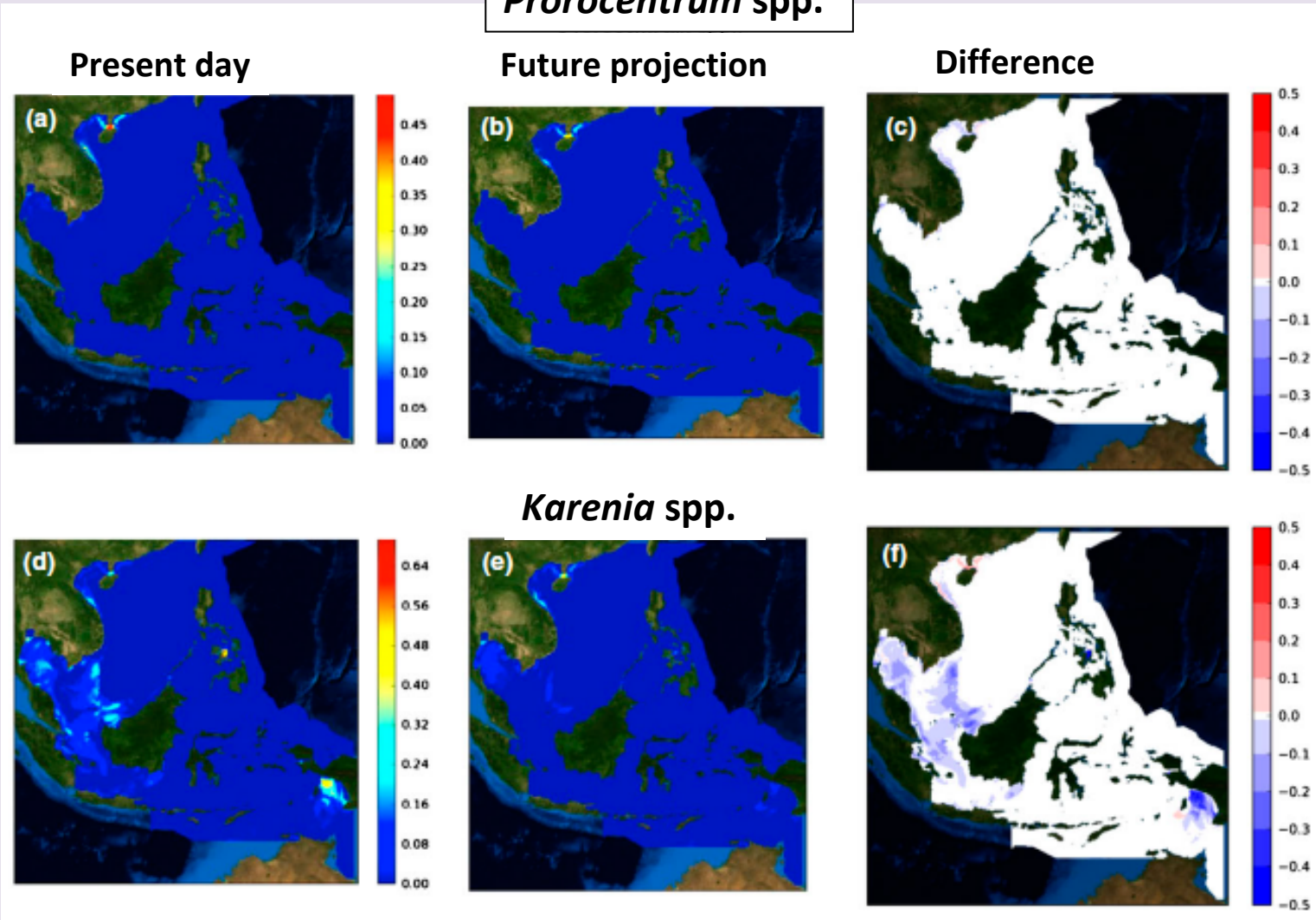


Glibert et al. 2014. Global Change Biology **20**, 3845-3858

4.- Available tools. Modelling

Potential effects of nutrient loading and climate change.

Projections in SE Asia: no expansion of *Prorocentrum* spp., contraction in area and months conducive for blooms of *Karenia* spp.

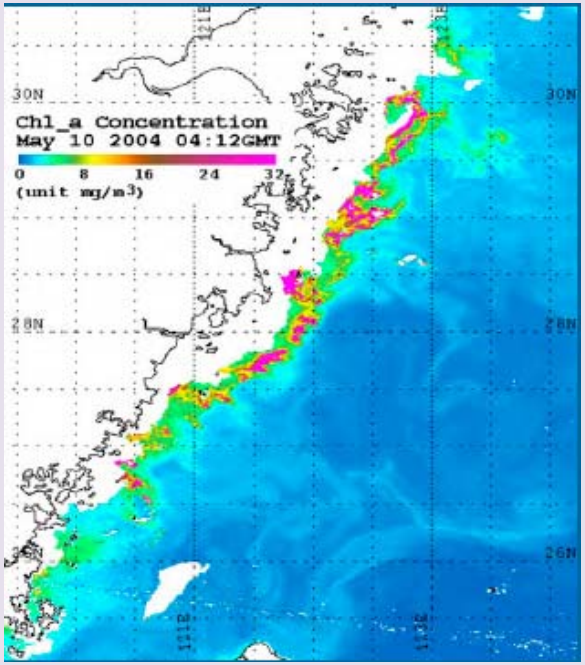


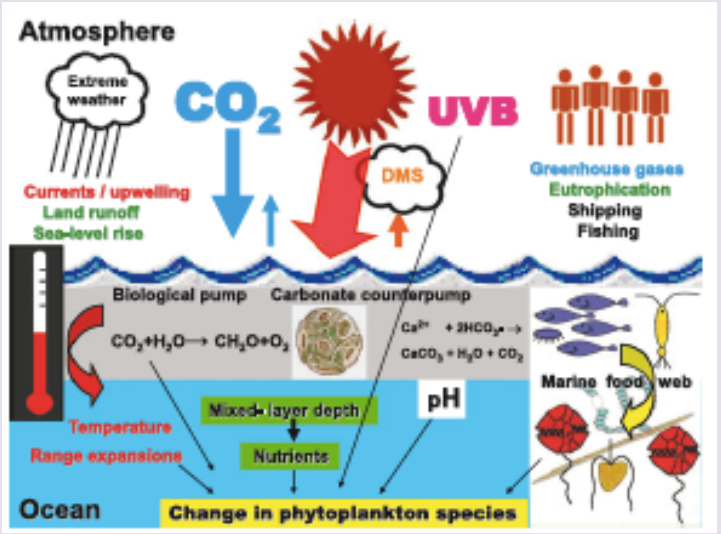
Glibert et al. 2014. Global Change Biology **20**, 3845-3858

4.- Available tools. Monitoring

- **Monitoring the causative species and/or the presence of biotoxin in seafood** in real time to prevent contaminated shellfish reaching the markets, currently the only effective **way to protect human health.**

- **Multidisciplinary monitoring**: including nutrients and physical and meteorological variables can help ascertain the effects of nutrient enrichment and climate and other environmental changes on HAB occurrences and their impacts. **Most data series are not long enough to draw clear conclusions.**

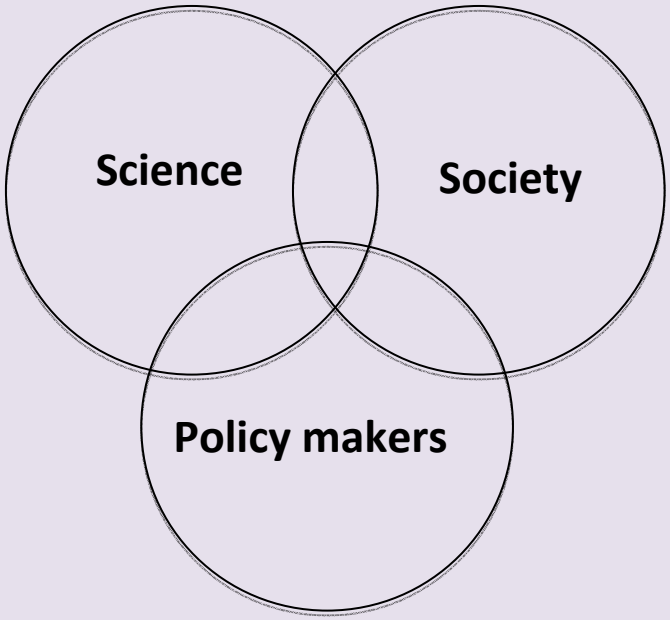




- Satellites help tracking high-biomass blooms. *P. donghaiense*, East China Sea. CCAR/HKUST.

4.- Available tools. Management

There is a need to maintain and reinforc initiatives and local and international **policies** to reduce human pressures on the marine environment that may increase the occurrence of HABs and the severity of associated events.



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