Monitoring of Harmful algal blooms
- Science for management to prevent occurrence of harm

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1. Science development in order to know nature of harmful algae; ecophysiology, toxin chemistry, biology etc.

2. Management system in order to prevent occurrence of harm; through preventing fish mass mortality, human poisoning, and economic loss.
Monitoring purpose of HAB

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   through preventing
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   human poisoning, and
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Monitoring purpose of HAB

Experience in Japan, and the Philippines

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Two types of Harmful Algae and consequences of their Blooms (HABs)

1. **Toxin-producer (toxic plankton): People killer**
   - toxin contamination in shellfish and fish, poisoning (PSP, DSP, ASP, NSP, Ciguatera)

2. **Red tide maker: Fish killer**
   - mass mortality of marine life due to anoxia and biochemical and mechanical damages,
   - unusual scenery
   - rem: 90% of Red tides (Algal Blooms) are harmless or useful (increase of fish catch, etc.)
Two types of Harmful Algae and consequences of their Blooms (HABs)

1. Toxin-producer (toxic plankton): People killer
toxin contamination in shellfish and fish, poisoning (PSP, DSP, ASP, NSP, Ciguatera)
Number of poisoning cases with fatal ones occurred after eating **shellfish** contaminated by paralytic toxins produced by microalgae.
Character of toxic algal bloom and algae

Toxic microalgae possess toxins. Toxin composition vary by microalgal species.
Five types of poisoning

Different symptoms by different toxins which are produced by different types of organisms.

- PSP
- DSP
- NSP
- ASP
- ciguatera
Toxic microalgae possess toxins. Toxin composition vary by microalgal species. Toxin amount (and composition?) vary depending on physiological condition of cell (growth stage, speed, etc.).
Life cycle of Dinoflagellates

1. Water Column
   - Vegetative Cell
   - Binary division
   - Conjugation
   - Gamete
   - Reduction division
   - Planozygote

2. Planozygotes
   - Hypnozygotes (immature stage)
   - Hypnozygotes (mature stage)
   - Fossils
   - Floating Cyst
   - Temporary Cyst

Additional terms:
- fussion of gametes
- planozygotes
- Vegetative cells
- Hypnozygotes (resting cysts)
Toxic microalgae possess toxins. Toxin composition vary by microalgal species. Toxin amount (and composition?) vary depending on

**physiological condition** of cell (growth stage, speed, etc.)

Environmental condition
temperature, salinity, nutrients, grazing pressure

Therefore toxin amount in one cell vary time by time.
Filter feeders such as bivalves and tunicates feed on microalgae and decompose them. Toxins are absorbed inside body of the bivalve and some are excreted to outside. Difference between intake and outgoing are accumulated inside the bivalve. Speed of accumulation and excretion vary by species of filter feeders. Toxin mostly stay at mid-gut gland in case of bivalves. If people eat bivalves accidentally keeping toxins more than a certain level, people become sick.
Comparison between toxic algal cell number and toxicity of mussel.
Character of toxic algal bloom and algae

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Prediction of toxin amount in shellfish (plankton feeders) cannot be calculated or predicted by number of toxic plankton cells.
Common bivalve species and ascidian species for monitoring on the PSP and DSP in Japan.

- Noble Scallop: *Chlamys nobilis*
- Short-necked clam: *Tapes philippinaris*
- Blue Mussel: *Mytilus edulis*
- Yesso Scallop: *Pinctopecten yessoensis*
- Sea squirt: *Halocynthia roretzi*
- Japanese oyster (Giant pacific oyster): *Crassostrea gigas*
- Blue Mussel: *Mytilus edulis*
- Short-necked clam: *Tapes philippinaris*
Fig. 3. Comparison of the toxicities among different species at Ofunato in 1978.

Fig. 4. Decline of the toxicities of scallop (*P. yessoensis*, a) and mussel (*M. edulis*, b) in laboratory tanks.
Character of toxic algal bloom and algae

Toxic microalgae possess toxins. Toxin composition vary by microalgal species. Toxin amount (and composition?) vary depending on physiological condition of cell (growth stage, speed, etc.).

Bloom of toxic microalgae, even in low conc. (20 cells/one L), associates harmful consequence. Toxin accumulation rate in marine organisms vary by species.
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Many PSP toxin producers possess cyst stage in life cycle.
→ simultaneous occurrence and disappearance, and expansion of blooming area
Life cycle of Dinoflagellates

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2. Conjugation
3. Fussion of gametes
4. Reduction division
5. Planozygote
6. Hypnozygote (immature stage)
7. Hypnozygote (mature stage)
8. Resting cysts
9. Sea Floor

Key terms:
- Vegetative cells
- Planozygotes
- Fussion of gametes
- Hypnozygotes (resting cysts)
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People cannot eat toxic microalgae directly, as they are too small, but people eat shellfish and fish which feed the toxic ones.
therefore we need to monitor toxicity of fish and shellfish
Management to prevent harmful consequences of toxic blooms

1. Prevention of bloom: IMPOSSIBLE
   Sometimes decrease of nutrients works favorable to the bloom
Management to prevent harmful consequences of toxic blooms

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2. Prevention of toxin contamination: IMPOSSIBLE
Management to prevent harmful consequences of toxic blooms

1. Prevention of bloom: IMPOSSIBLE
   Sometimes decrease of nutrients works favorable to the bloom

2. Prevention of toxin contamination: IMPOSSIBLE

3. Prevention of poisoning: POSSIBLE
   3-1. monitoring of toxins at appropriate system
       centralize vs. localize monitoring
       representativeness of sample (location, depth, frequency)
       authorized laboratory for toxin/plankton analysis (QA/QC)
       by internationally recognized methods
   3-2. public awareness (including enforcement)
Management to prevent harmful consequences of toxic blooms

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4. Prevention of fatal case of poisoning: POSSIBLE
   4-1. public awareness including medical doctors
   4-2. preparation of artificial respirator at hospital
Areas affected by PSP in Japan

Red color parts show prefectures having closure of harvesting of shellfish by PSP toxin contamination. (data: Japan Fisheries Agency)

Expansion of the affected area become obvious in 1990s.
Sea areas affected by Paralytic Shellfish Poisoning with exceeding the quarantine limits of 4MU/g are shown by closed circles.

Coasts of Hokkaido, Iwate, Aomori, Miyagi Prefectures are officially divided into some areas for restriction. In other prefectures, the restricted areas have been decided according to the shellfish fishery grounds.

Monitoring of shellfish toxicity and plankton occurrence is made. But only the toxicity data is used for regulation (closure of area).

- sampled, but no toxicity detected
- one time (one year)
- 2–5 times
- 6–10 times
Philippine case where expansion of area affected by PSP was so wide and quick
Experience in the Philippines with BFAR request from one poor fisherman who lost his son by poisoning

...To prevent recurrence of poisoning, we can do something...

- Effective management requires:
  1. Cost-effective monitoring system and techniques
  2. Dedicated and responsible personnel to conduct monitoring
  3. Strategies to educate/inform the people
Country background information
archipelago w/ > 7,100 islands
land area = 298,170 sq km
total territorial waters = 2.2 M sq km
coastline length = 36,289 km

Administrative division: Province = 78
cities = 61

Population = 76 million
35% below poverty line
Poverty line=monthly income
<15,000 or <400 USD
Socio-economic profile of shellfish workers/fishermen

- No fishermen cooperative/union
- Farm workers are paid daily wage of P240 or 6USD
- Shellfish are cheap source of protein for low income people
Green mussel farms in Manila Bay

Green mussels
Oyster farms in Manila Bay

Oysters
1 dies, 14 down in 'tahong' poisoning

"RED TIDE" has been pinpointed as the cause of several deaths in Batan, according to Rehman 3rd's chief director, Dr. Aurora Villacarlos.

One person, a woman and 14 others, were hosptalized at the Batan Provincial Hospital after eating mussels or "tahong." Dr. Villacarlos, however, said there are no indications that other fishes other than mussels have been affected by the red tide.

Red tide is linked to a number of natural as well as man-made ecological problems, ranging from forest destruction, soil erosion and other environmental degradations, foremost of which is deforestation.

Meanwhile, the Department of Health has sent a team to Batan to look into the situation.

Red tide menaces in Manila

Bay to last 8-9 months?

If there are no heavy rains and the present weather condition prevails, Manila Bay would be afflicted with the red tide menace for the next 8-9 months. This is the warning of a health expert.

Meanwhile, Laguna Lake Development Authority (LLDA) assured consumers that fish caught from the Laguna de Bay were safe.

Red tide may cause P60M bay area loss

The shellfish industry could lose as much as P60 million due to red tide poisoning in the areas of Parañaque and Bacoor, Cavite.

Dr. Vicente Ronquillo, consultant to the Department of Agriculture's Bureau of Fisheries and Aquatic Resources, told reporters that Bacoor contributes as much as 90% to the national shellfish production in the form of mussels.

The Manila Chronicle, Tuesday, September 13, 1988

Red tide kills boy, downs 7

A 12-year-old boy died while seven others were stricken after allegedly eating "tahong" in Manila Bay yesterday. The illness was caused by the red tide, experts said.

The Manila Times, September 12, 1988

Red tide has changed lives of small fishermen

By Dana Batnag

Hermogenes dela Cruz, 62, earns practically nothing during last year's red tide scare that lasted from August to November.

Even when he did catch a few fish, consumers rejected his products, he said.

The Manila Chronicle, Tuesday, March 21, 1989
Occurrence and Distribution of PSP in the Philippines

**Pyrodinium bahamense**

Most of shellfish aquaculture sites are far from Manila where PSP toxin can be measured.
Public health impact of HABs in the Philippines

![Chart showing PSP cases and deaths from 1983 to 2000. Peaks in PSP cases are observed in 1986, 1987, and 1992, with corresponding deaths in red.](chart.png)
Manila Bay weekly monitoring

Toxin analysis is done in central laboratory in Manila

In other local areas monthly monitoring: not enough
List of Acronyms:
IACEH - Inter-Agency Committee on Environmental Health
NRTTF - National Red Tide Task Force
DOH - Department of Health
DILG - Department of Interior and Local Government
PIA - Philippine Information Agency
BFAR - Bureau of Fisheries and Aquatic Resources
EMB - Environment and Management Bureau
DOST - Department of Science and Technology
PCG - Philippine Coast Guard
Limitations/constraints of management

1. Lack of technical capability
   - trained manpower
   - laboratory facilities and equipment
2. Lack of mechanism to disseminate accurate and timely information
3. Multi-sectoral agencies involved cause delays in implementation of regulatory action
Vision of HAB Management in the Philippines

1. Shift from centralized to decentralized management regime
How to decentralized Management???

1. Consultation/dialogue
2. Understanding/recognition of problems
3. Needs assessment
4. Capability building
5. Transfer and acceptance of responsibility/authority
6. Empowerment of LGUs
JICA’s assistance to enhance monitoring capability
Future Plans/Activities:

Establishment of Local Red Tide Testing Center

- Areas where PSP incidents have been reported
- Areas where *Pyrodinium* blooms (toxic red tide) have been observed

Dagupan City, Pangasinan (OPA)
Metro Manila and Suburbs, Bataan RT Testing Center, Cavite RT Testing Center
Sorsogon City (OPA)
Catbalogan, W. Samar (OPA)
Tacloban City, Leyte (OPA)
Surigao del Sur (OPA)
Mati, Davao Oriental (OPA)
Roxas City, Capiz (OPA)
Bacolod City, Negros Occidental (OPA)
Pagadian City (OPA), Zamboanga del Sur
Vision of HAB Management in the Philippines

1. Shift from centralized to decentralized management regime

2. Cost effective and efficient system:
   - Country-wide plan
   - Empowerment of LGUs in management decisions (regulatory actions)
1. Shift from centralized to decentralized management regime

2. Cost effective and efficient system:
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   - Empowerment of LGUs in management decisions (regulatory actions)

3. Prevent and reduce impact of HAB on public health and economy
   - Information campaign to educate fishermen and the public
   - Dissemination of timely and accurate information
People died in the Philippines

Still problem remains

People are saved in Canada

HARMFUL ALGAE NEWS
An IOC Newsletter on toxic algae and algal blooms
No. 3

Eight die in Philippines from red-tide molluscs

A state of emergency has been declared in the Philippines after eight people died and 150 were hospitalised after eating products contaminated with a microorganism.

The red tide covered about 90% of Manila Bay along the coasts of Batan, Papanga, Bulacan and Cavite.

The authorities state that fishermen in the zones where the consumption of molluscs is prohibited are undergoing hardship due to a sudden fall in fish sales. The declaration of a state of emergency allows increased government aid to those affected.

Translated from Voz de Galicia (a Spanish newspaper) of 5 July 1992. Source EFE (news service), Manila.

Artificial respiration saves two from fatal PSP in Canada

In April, a party of seven were at Kingcome Inlet, British Columbia, an approximately 250 km (155 miles) round trip. On 19 April butter clams (Clinocardium nuttallii) and giant clams (Tubulina gigantea) were harvested from Moore Bay for an evening feast the following day. On the morning of the 20th a 54-year-old man decided to have some for breakfast. He threw them on hot coals just long enough to see (eyelids closed), total paralysis only coming later for the other (fifteen minutes into the flight). Throughout the whole episode both men were able to hear, including discussions among their friends as to whether there was any point in continuing artificial respiration.

Resuscitation was begun when it was noticed that they were turning blue, although showing no struggle for life. Both had already been examined by doctors on the spot, and both were in a coma and not breathing. The lack of any medical knowledge could not have been improved, although some medical personnel were called in.

The press release notes that the men were saved by the fact that they were eating the clams, which had been killed by the red tide, and were still alive. The red tide was caused by a dinoflagellate, Pyrodinium bahamense, which has caused paralytic poisoning in Papua New Guinea, Brunei Darussalam, Sabah, and Guam. As well as in the Philippines, most of the seafood is commonly eaten in shellfish but also via plankton-eating fish. Cases of PSP elsewhere in the western Pacific may be due to the same species. Jay Maclean of ICLARM has pointed out that the coincidence of major toxic red tides in the western Pacific between 1977 and 1987 with ENSO (El Nino-Southern Oscillation) events.

Pyrodinium red tides were the topic of a management and training workshop held in Brunei Darussalam in May 1989. The proceedings are published as ICLARM contribution N° 585(1).


Now available...
People died in the Philippines

Still need raising more concern from public, especially fishery folks, medical doctors, and mass media.

People are saved in Canada
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Character of red tide and red tide algae

Red tide is a discoloration of surface or subsurface water by microalgae.
Red Tide caused by *Noctiluca scintillans* occurred in Seto Inland Sea, Japan  (May 6, 1976)
Subsurface red tide by *Chattonella antiqua* detected by change of color made by propeller of fishing boats running at red tide area.
Character of red tide and red tide algae

Red tide is a discoloration of surface or subsurface water by microalgae. Color of red tide is various, depending on causative organism.
Pink and green red tides

Japan, *Noctiluca*

Thailand, *Noctiluca*

Australia, *Noctiluca*
Brown and grey red tides

Germany, *Nodularia*

Japan, *Karenia*
White red tide

Australia, *Gephyrocapsa*
The color varies depending on growth stage algae.
*Noctiluca* bloom at night (shinning white)
Green tide: bloom of macroalgae *Ulva* and *Enteromorpha*
Character of red tide and red tide algae

Red tide is a discoloration of surface or subsurface water by microalgae. Color of red tide is various, depending on causative organism. Species number of red tides are 1 or 2.
One drop of discolored water by *Cochlodinium polykrikoides* in the Gulf of Thailand
Normal condition
Usually more than 50 different species can be found

Red Tide
1-2 species are dominant.

Cochlodinium polykrikoides
Pyrodinium bahamense
Number of causative species of red tides

Among 140 cases of red tides in 1964-1970

- Dominance (>95%) by one species: 97 cases (69%)
- Two species
  - One species 95-75%, the other 25-1%: 25 cases
  - Each species occupied 75-25%: 18 cases

(Adachi 1972)

Among 1020 cases of red tides in 1992-2000

- Dominance by one species: 803 cases (79%)
- Dominance by two species: 165 cases (16%)
- Dominance by three species: 52 cases (5%)

(Seto Inland Sea Fisheries Coordination Office, 1993-2001)

One species forms red tides in most of cases, but plural species sometimes form them.
Character of red tide and red tide algae

Red tide is a discoloration of surface or subsurface water by microalgae. Color of red tide is various, depending on causative organism. Species number of red tides are 1 or 2. Number of red tide causative species is >80 in one area. (composition vary depending on area. Why?)
How many causative species can we count?

Adachi 1972: 41 species

Seto Inland Sea Coordination Office 1992-2000: 46 species

Fukuyo 1992: 48 species of dinoflagellates

Number of causative species must be more than 80.
Frequent causative organisms (genus) and red tide case number in western Japan in 1992-2000

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**Dinoflagellates**: 562/1011
Character of red tide and red tide algae

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Higher and smaller cell number (cells/ml) in a red tide water (among 762 cases)

<table>
<thead>
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<th>Higher number</th>
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**Het.a**: Heterosigma akashiwo  
**Pr.d**: Prorocentrum “dentatum”  
**Kar.m**: Karenia mikimotoi  
**Gon.ma**: Gonyaulax polygramma  

**Ak. sa**: Akashiwo sanguinea  
**Noc. s**: Noctiluca scintillans  
**C.a**: Chattonella amtiqua  
**Cos.**: Coscinodiscus sp.
Character of red tide and red tide algae

Red tide is a discoloration of surface or subsurface water by microalgae. Color of red tide is various, depending on causative organism. Species number of red tides are 1 or 2. Number of red tide causative species is >80 in one area. (composition vary depending on area. Why?) Cell number in red tide water is 10-476,700 in 1 ml.
coverage of area (km²) of red tide (among 455 cases)

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<td>C.m</td>
</tr>
<tr>
<td>Ske.c</td>
<td>640</td>
<td>Noc.s</td>
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</tbody>
</table>

>1,000 km²: 4 cases
| >800  : 3 |
| >600  : 14 | >50 : 33 |
| >400  : 18 | >10 : 64 |
| >200  : 53 | >5 : 36  |
| >100  : 43 | >1 : 104 |
< 1 : 83

A half of RTs is <10 km²

*Ske. c: Skeletonema costatum
Noc. s: Noctiluca scintillans
Lep. d: Leptocylindrus danicus
Gon. ma: Gonyaulax polygramma
Kar. m: Karenia mikimotoi
Mes. r: Mesodinium rubeum
Noc. s: Noctiluca scintillans
C. m: Chattonella marina
Per. q.: Peridinium quinquecornes
Character of red tide and red tide algae

Red tide is a discoloration of surface or subsurface water by microalgae. Color of red tide is various, depending on causative organism. Species number of red tides are 1 or 2. Number of red tide causative species is >80 in one area. (composition vary depending on area. Why?) Cell number in red tide water is 10-476,700 in 1 ml of water. Size of red tides is 0.0005-1,360 km². Average < 10 km².
### Frequency of red tide duration (among 1020 cases)

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Red tide is a discoloration of surface or subsurface water by microalgae. Color of red tide is various, depending on causative organism. Species number of red tides are 1 or 2. Number of red tide causative species is >80 in one area. (composition vary depending on area. Why?) Cell number in red tide water is 10-476,700 in 1 ml of water. Size of red tides is 0.0005-1,360 km$^2$. Average < 10 km$^2$. Duration of red tides is 1-276 days. Usually shorter than 4 days.
How many red tide number can we observe?

Areas with intensive monitoring for red tides
In total about 200 red tide cases are observed annually in 1980-2000 in the four areas of the western Japan.
Character of red tide and red tide algae

Red tide is a discoloration of surface or subsurface water by microalgae. Color of red tide is various, depending on causative organism. Species number of red tides are 1 or 2. Number of red tide causative species is >80 in one area. (composition vary depending on area. Why?) Cell number in red tide water is 10-476,700 in 1 ml of water. Size of red tides is 0.0005-1,360 km$^2$. Average < 10 km$^2$. Duration of red tides is 1-276 days. Usually shorter than 4 days. Red tide case number varies depending on area.
Experience of Japan on red tides

Bird's-eye View of Seto Inland Sea (courtesy of Asia Air St)

east – west: 450 km, north – south: 15-55 km
area: 23,203 km², average depth: 38.0 m
shoreline: 6,868 km, 700 islands

Fish aquaculture industry became active since 1960s.
Parallel increase of red tide occurrences and yellow tail fish aquaculture industry are obvious.
Red tide is a discoloration of surface or subsurface water by microalgae. Color of red tide is various, depending on causative organism. Species number of red tides are 1 or 2. Number of red tide causative species is >80 in one area. (composition vary depending on area. Why?) Cell number in red tide water is 10-476,700 in 1 ml of water. Size of red tides is 0.0005-1,360 km². Average < 10 km². Duration of red tides is 1-276 days. Usually shorter than 4 days. Red tide case number varies depending on area. Also case number varies depending on environmental condition.
In the early stage red tides with fisheries damages occupied nearly half of the cases.

After the early stage red tides with fisheries damages occupied almost 10% of the case number.
Character of red tide and red tide algae

Red tide is a discoloration of surface or subsurface water by microalgae.
Color of red tide is various, depending on causative organism.
Species number of red tides are 1 or 2.
Number of red tide causative species is >80 in one area.
   (composition vary depending on area. Why?)
Cell number in red tide water is 10-476,700 in 1 ml of water.
Size of red tides is 0.0005-1,360 km$^2$. Average < 10 km$^2$.
Duration of red tides is 1-276 days. Usually shorter than 4 days.
Red tide case number varies depending on area.
Also case number varies depending on environmental condition.
About 10% red tide cause mass mortality of fish and shellfish.
Chattonella antiqua (Hada) Ono

Chattonella marina (Subrahmanyan) Hara et Chihara

Photomicrographs by Ichiro Imai and Sadaaki Yoshimatsu, and drawings by Yoshiaki Hara and Mitsuo Chihara
Mass mortality of yellowtail, *Seriola quinqueradiata*, cultured in cages by a red tide of raphidoflagellate *Chattonella antiqua* (Seto Inland Sea, Aug. 1977)
Mass mortality of yellowtail, *Seriola quinqueradiata*, cultured in cages by a red tide of rahydoflagellate *Chattonella antiqua* (Seto Inland Sea, Aug. 1977)
Karenia mikimotoi

Gymnodinium mikimotoi Miyake et Kominami ex Oda

Photomicrographs by Sadaaki Yoshimatsu and Haruyoshi Takayama
Heterocapsa circularisquama

In 1988-1998
26 cases red tides.
Among the 26 cases, 15 cases with mass mortality of bivalves (oyster, pearl oyster, short necked clam, mussel)
Economic loss equivalent to ca. 100M US$
(from Matsuyama 1999)
Mass mortality of shellfish
Mechanisms of fish mortality 1: daytime

**Red tide plankton**
- Free fatty acid production

**O₂ production by photosynthesis**

**O₂ in water**
- Low
- High

**Normal gill**
- Gill covered by mucus
- Difficulty in respiration
- Faster swimming to get more O₂

**Lactic acid in muscle**

**Blood carry less O₂**
- Low blood pH
- Death

**Recovery (live)**

Fish
Mechanisms of fish mortality 2: night time

- Red tide plankton
- Free fatty acid production
- O₂ consumption by respiration
- O₂ in water: low, high
- Recovery (live)
- Death

Fish

- Normal gill
- Gill covered by mucus
- Difficulty in respiration
- Faster swimming to get more O₂
- Lactic acid in muscle
- Low blood pH
- Blood carry less O₂
Mechanisms of fish mortality 3: night time and high temp.

- red tide plankton
- free fatty acid production
- O₂ consumption by respiration
- O₂ in water
- low
- high
- recovery (live)
- death

fish

- normal gill
- gill covered by mucus
- difficulty in respiration
- faster swimming to get more O₂
- lactic acid in muscle
- low blood pH
- blood carry less O₂

high temperature
Economic loss caused by red tides in the four areas

Number of red tides causing fisheries damages in the four areas

Economic loss caused by red tides
Character of red tide and red tide algae

Red tide is a discoloration of surface or subsurface water by microalgae. Color of red tide is various, depending on causative organism. Species number of red tides are 1 or 2. Number of red tide causative species is >80 in one area. (composition vary depending on area. Why?) Cell number in red tide water is 10-476,700 in 1 ml of water. Size of red tides is 0.0005-1,360 km$^2$. Average < 10 km$^2$. Duration of red tides is 1-276 days. Usually shorter than 4 days. Red tide case number varies depending on area. Also case number varies depending on environmental condition. About 10 % red tide cause mass mortality of fish and shellfish. Economic loss by harmful red tides is sometimes >50M USD mostly by fish in aquaculture farms.
Character of red tide and red tide algae

Red tide is a discoloration of surface or subsurface water by microalgae. Color of red tide is various, depending on causative organism. Species number of red tides are 1 or 2. Number of red tide causative species is >80 in one area. (composition vary depending on area. Why?) Cell number in red tide water is 10-476,700 in 1 ml of water. Size of red tides is 0.0005-1,360 km². Average < 10 km². Duration of red tides is 1-276 days. Usually shorter than 4 days. Red tide case number varies depending on area. Also case number varies depending on environmental condition. About 10 % red tide cause mass mortality of fish and shellfish. Economic loss by harmful red tides is sometimes >50M USD mostly by fish in aquaculture farms.

Is it possible to prevent red tides by science and management ????
Fisheries production is still growing in the western Pacific, although those from other regions might reach the maximum plateau.

Comparing to the increase of the catch, that of the aquaculture production is much bigger.

re: observe the difference of unit of vertical axis

Aquaculture becomes important more and more.
Fish cage culture
Fish cage culture in Batam, Indonesia
Small scale hatchery (Backyard Hatchery) in Indonesia

Difficult in controlling quality of their wastewater
Shrimp culture ponds in Cam Ranh, Khanh Hoa, Vietnam
River mouth areas along Thailand coast

Shrimp culture farms in mangrove along the coast of the Gulf of Thailand

Photo by Dr. Thaithaworn Lirdwitayaprasit of the Department of Fisheries of Thailand

IOC-WESTPAC HAB R0006
Mega Scale Shrimp Culture Farm (18,000 ponds) in Indonesia
Shrimp farms in Sumatra, Indonesia

Mega scale aquaculture farm
Mechanism: factors related to red tide blooming

- sunshine
- rainfall
- wind
- sewage
- industries
- temperature
- salinity
- nutrients
- vitamins

It is important to establish aquaculture techniques to prevent damages.

Long time use of area for aquaculture induces bottom sediment to contain much amount of organic substances originated from feces and remaining diet.

Organic substances accumulated in sediment are decomposed by bacteria and changed to various substances promoting growth of red tide plankton.

We need various factors optimum to become a red tide.

(Revised from Japan Fisheries Resource Conservation Association)
Mass mortality of milkfish, associating with red tide of *Prorocentrum minimum* in the Philippines, late January to early February 2002.
Fish Mass Mortality associated with a Red Tide

by *Cochlodinium* in Korea

by *Chattonella* in Japan

by *Karenia* in Hong Kong
Mechanism: factors related to red tide blooming

It is important to establish aquaculture techniques to prevent damages.

Long time use of area for aquaculture induces bottom sediment to contain much amount of organic substances originated from feces and remaining diet.

Organic substances accumulated in sediment are decomposed by bacteria and changed to various substances promoting growth of red tide plankton.

We need various factors optimum to become a red tide.

Growth Factors
- Temperature
- Salinity
- Nutrients
- Vitamins

Growth Promoters
- Heavy Metals
- Organic Substance

Sediment with Much Organic Materials

Deterioration of sediment

Sewage from industries

Sewage

Weather and Ocean condition

Sunshine

Rainfall

Wind

Dissolution
Countermeasures (management) for elimination of red tide occurrences and harmful consequences

Indirect: 1. Water and sediment quality improvement through regulations
  2. Water and sediment quality improvement by projects of rehabilitation
  3. Improvement of aquaculture technology
  4. Management and info. exc. net work

Direct: 1. Spray of clay
  2. Filtration
  3. Chemicals etc.
Countermeasures (management) for elimination of red tide occurrences and harmful consequences

Indirect: 1. Water and sediment quality improvement through regulations
          2. Water and sediment quality improvement by projects of rehabilitation
          3. Improvement of aquaculture technology
          4. Management and info. exc. net work

Direct: 1. Spray of clay
        2. Filtration
        3. Chemicals etc.
Parallel increase of red tide occurrences and yellow tail fish aquaculture industry are obvious.

Setting various regulation

No data on red tide case
Table 14. Important laws on conservation of environment in Seto Inland Sea.

1) 1973: Revision of provisions in "Public water body reclamation law" is promulgated
   - Consideration for preservation of environment is clearly described regarding permission criterion for reclamation.

2) 1973: "Seto Inland Sea conservation law" are put into force (1973).
   - Fundamental policy to preserve the environment in Seto Inland Sea is to be established.
   As an temporary measure prior to the fundamental policy,
   1) The pollution discharge (indicated by COD) shall reduce to a half of 1972 within 3 years.
   2) Permission regarding installation/modification of special equipment specified by Government.
   3) Special consideration for reclamation of foreshore
   - Establishment of council for preservation of environments in Seto Inland Sea.

3) 1976: Revision of provisions in Seto Inland Sea conservation law.

4) 1976: "Marine pollution prevention law" is revised into and damage due to shipwreck.

5) 1978: Revision of provisions both in "Seto Inland Sea conservation law and Water pollution control law" are promulgated (In 1979 it is changed into special measure: regulation on preservation of environment in Seto Inland Sea.
   - Prefectural policy based on the fundamental policy.
   - Regulation on total emission (amount).
   - Prohibition to use phosphorus in order to prevent the damage due to eutrophication.
   - Conservation of natural beach by designation of "natural beach conservation area."
   - Prevention of oil leakage in case of shipwreck.
   - Research project on mechanism of red tide occurrence.

6) 1984: Special measure on conservation water quality in lakes and marshes is promulgated (It is put into force 1985).

7) 1996: Revision of provisions in "water pollution control law" is promulgated.
Change of load to Seto Inland Sea
(from International EMECS Center 2008)
Rem: duration of the upper and lower figures are different.
Parallel increase of red tide occurrences and yellow tail fish aquaculture industry are obvious.

Setting various regulation

No data on red tide case
Figure 2-6 Trends in fishery production in the Seto Inland Sea

Note: Source: Ministry of Agriculture, Forestry and Fisheries

Figure 2-4 Fish-species and the composition of fishery production

Note: Source: Ministry of Agriculture, Forestry and Fisheries

Figure 2-5 Fish-species composition of aquaculture production

Note: Source: Ministry of Agriculture, Forestry and Fisheries
Reduction of N and P may have relation to decrease of fishery production.

If so, how to prevent eutrophication (degradation) without having reduction of fisheries production???
Decoloration of culturing Nori (*Porphyra* sp.) seaweed
Countermeasures (management) for elimination of red tide occurrences

Indirect: 1. Water and sediment quality improvement through regulations
2. Water and sediment quality improvement by projects of rehabilitation
3. Improvement of aquaculture technology
4. Management and info. exc. net work

Direct: 1. Spray of clay
2. Filtration
3. Chemicals etc.
Mitigation: Prevention of harmful red tides by *Chattonella* by prolongation of diatom red tide.

*Diatom red tide* itides useful, as they are foods for marine lives and keep environment clear.

*Chattonella* cannot bloom during diatom red tide.
Countermeasures (management) for elimination of red tide occurrences and harmful consequences

Indirect: 1. Water and sediment quality improvement through regulations
2. Water and sediment quality improvement by projects of rehabilitation
3. Improvement of aquaculture technology
4. Management and info. exc. net work

Direct: 1. Spray of clay
2. Filtration
3. Chemicals etc.
赤潮

ウォー

キャー
赤潮だ
このままだと
死んじゃうよ

こわいよう

底に近いと
酸素が足りない
こともあるから
あまり下げすぎないでね

あれ？どこに
いったのかな？

あー！助かった

石灰散布

海底で
硫化水素が
発生しにくく
なります

底泥と酸素の
接触をはかります

耕うん

きれいな海砂で
底泥を覆い
栄養塩の溶出を
抑えます

ばっ気

底泥に
酸素を
供給します

覆砂
Mitigation using algicidal bacteria

Seaweeds have many bacteria on the surface which excrete substances killing microalgae.

Culture of seaweed at surface of fish cages.
Countermeasures (management) for elimination of red tide occurrences

Indirect: 1. Water and sediment quality improvement through regulations
2. Water and sediment quality improvement by projects of rehabilitation
3. Improvement of aquaculture technology
4. Management and info. exc. net work

Direct: 1. Spray of clay
2. Filtration
3. Chemicals etc.
Structure for Exchange of Red Tide Information

Fishermen
- We've to send this information ASAP.
- Look, red tide!
- We found a red tide outbreak.
- I am monitoring seawater everyday to protect fishes in our cages.

Fisherman Cooperative Union
- Chattonella!
- It's very harmful.
- Pl. come ASAP.

Seto Inland Sea Fisheries Coordinating Office
- I'll send detailed information of the red tide.

Fisheries Division of Local Government
- Stop feeding now!
- It's really harmful species.
- It needs to observe in details.

Prefectural Fisheries Experimental Station
- OK! We come in hours.

National Research Institute of Fisheries and Environment of Inland Sea

Fisheries Agency
- Let us make suggestions and recommendations to prefectures concerned.
Countermeasures (management) for elimination of red tide occurrences

Indirect: 1. Water and sediment quality improvement through regulations
2. Water and sediment quality improvement by projects of rehabilitation
3. Improvement of aquaculture technology
4. Management and info. exc. net work

Direct: 1. Spray of clay
2. Filtration
3. Chemicals etc.
ホルネリア赤潮に対する粘土散布
Occurrences of *C. polykrikoides* in Japan and Korea

Red tides of *C. polykrikoides* have continuously occurred along coastal waters, does this imply that the Japanese and Korean population are identical?

- Miyahara et al. 2005
- Matsuoka & Iwataki 2004
- Jun-Aug 2002
- Sep. 2003
Red tide occurred in Malaysian and Philippine waters (from Azanza 2005)

How to confirm safety of fishes?

Cochlodinium polykrikoides
Thank you for your patience
HABs occurrence mechanism 1

expansion of utilization of costal area

change of water quality

optimum for the growth of certain phytoplankton

green: toxin producing species
red: red tide causing species

- toxin accumulation in marine organisms
- people poisoning
- closure of market
- red tide
- mass mortality of marine organisms
HABs occurrence mechanism and countermeasure

- Expansion of utilization of coastal area
- Change of water quality
  - Optimum for the growth of certain phytoplankton
    - Toxin producing species
      - Toxin accumulation in marine organisms
        - People poisoning
        - Closure of market
    - Red tide causing species
      - Red tide
        - Mass mortality of marine organisms

Management for conservation of coastal environment
HABs occurrence mechanism 2

- Expansion of utilization of coastal area
  - Increase of population (resident, tourist)
    - Increase of chance to eat marine products having contaminated toxins
      - People poisoning
      - Closure of market
  - Increase of aquaculture and its products (fish, shellfish)
    - Increase of chance to accumulate toxins
    - Increase of chance to meet red tide
      - Mass mortality of marine organisms
HABs occurrence mechanism and countermeasures 2

- Expansion of utilization of costal area
  - Increase of population (resident, tourist)
    - Increase of chance to eat marine products having contaminated toxins
      - People poisoning
    - Increase of chance to accumulate toxins
      - Closure of market
        - Management for monitoring toxins in marine products
  - Increase of aquaculture and its products (fish, shellfish)
    - Increase of chance to meet red tide
      - Mass mortality of marine organisms
    - Improvement of aquaculture technology
きれいな海と望ましい環境

どのような海と環境を望み、創り、守るのか？

あってほしいと考える「海」は人によって異なる。そのため、期待する海を創造していく方法も異なる。今まで、我々は多くの試行錯誤を繰り返してきたので、それを「赤潮、富栄養化」を例に考えてみたい。

「きれいな海」と「豊かな海」を両立させるためには、何をどのように考えていかなけりはならないか？
きれいな海と望ましい環境
どのような海と環境を望み、創り、守るのか？

あってほしいと考える「海」は人によって異なる。そのため、期待する海を創造していく方法も異なる。今まで、我々は多くの試行錯誤を繰り返してきたので、それを「赤潮、富栄養化」を例に考えてみたい。

きれいな海」と「望ましい環境」を両立させるためには、何をどのように考えていかなければならないか？
とても一筋縄ではいかない。でも将来のために
漁業の現状

世界の漁獲量はすでに頭打ちの状態。今後人口はより増える。だから賢い養殖が必要。
世界の養殖漁業

中国以外のアジア

中国

FAO 2008
養殖量の多いトップ15の内、11カ国はアジア、そのうち東南アジアと東アジアがそれぞれ5,4カ国となっている。

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注：藻類を含む。
魚貝類が死ぬ原因はいくつかあり、単純ではない

赤潮プランクトンの分泌する毒物質

酸素欠乏
  鰓つまり（粘液分泌量増加、赤潮プランクトン付着）
  鰓表皮細胞の機械的損壊
  血液のpH低下

酸欠水
  赤潮プランクトンの腐敗

赤潮が起こっても魚が死なない養殖をする。
すべての赤潮が魚貝類被害を伴うわけではない。瀬戸内海では発生した赤潮の10%程度が問題となっている。この割合は養殖技術の向上などにより以前より低くなっている。
瀬戸内海における赤潮発生件数と漁業被害件数の推移

赤潮発生件数
収穫量(10,000 t)
ブリ類養殖収穫量(10,000 t)

魚類斃死は発生した赤潮の10%程度でみられる
魚類の斃死機構

図 5.1 ハマチ Hb の酸素解離曲線における pH の影響
Hb 濃度、約 0.2%：緩衝液、0.1M Tris・HCl (pH 8.0 〜 7.0), 0.1M Bis Tris・HCl (pH 6.8 〜 5.0) : 20°C

図 5.3 赤潮による養殖魚の罸死機構。