Recent approaches for the prediction and mitigation of *Cochlodinium polykrikoides* blooms in Korean waters

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Major topics of this presentation

I. Introduction

II. HABs monitoring system

III. Sample collection & identifications

IV. Modelling

V. Prediction

VI. **Conclusion**

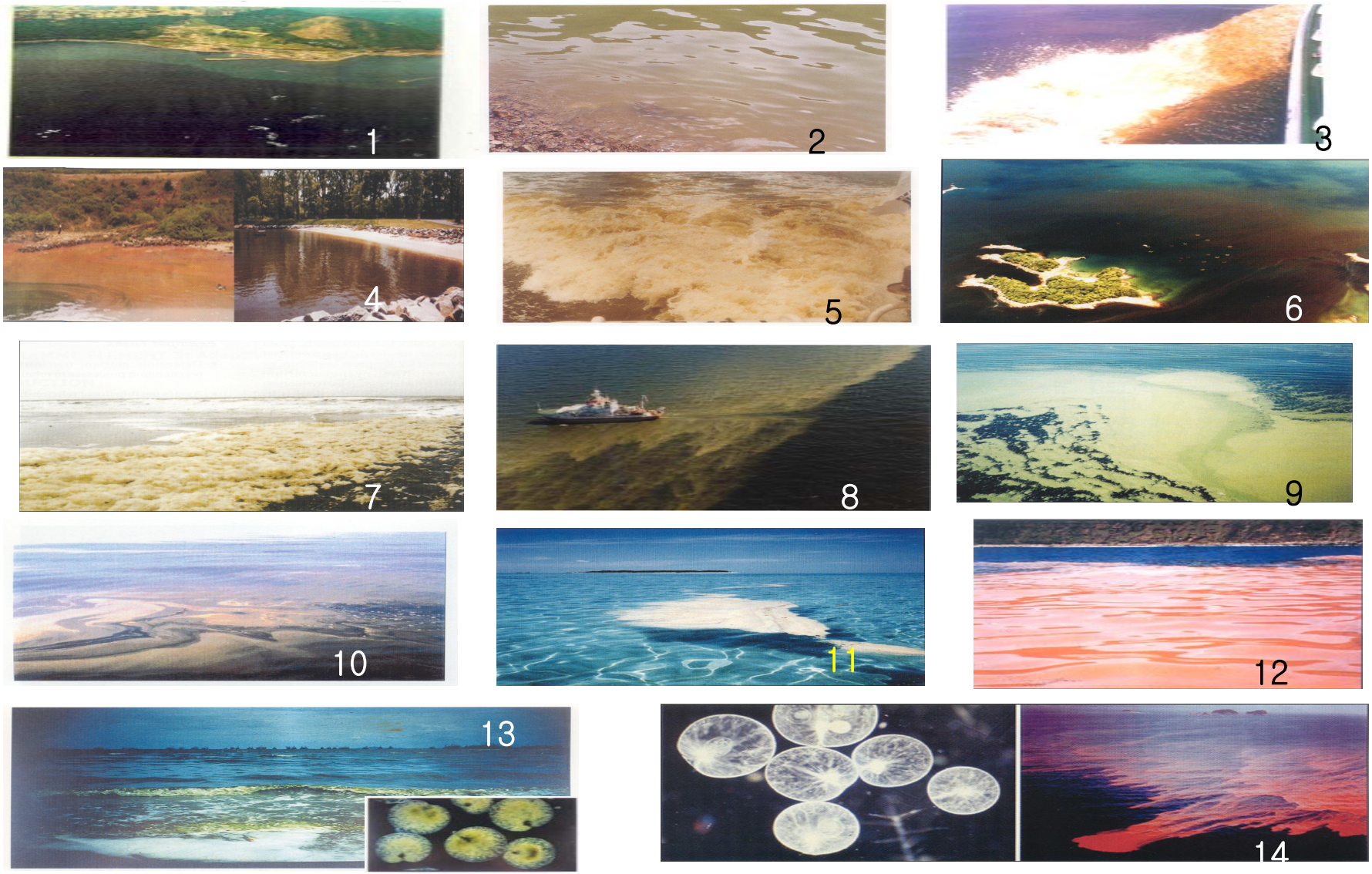


그림 II-1.세계연안의 적조 (출처 : 1. 2. 3. 5(김 등, 1993); 4. 6. 7. 8. 9. 10. 11. 12. 14(GEOHAB, 2001); 13(Okaichi, 1976); 10(Lam et al., 2003). 1.*Cochlodinium* (한국,1995), 2. *Gyrodinium* (한국,1994), 3. *Prorocentrum* (한국,1985), 4. *Prorocentrum* (홍콩.미국), 5. *K. mikimotoi* (한국,1981), 6. *K. mikimotoi* (일본), 7. *Phaeocysitis* (벨기에,1998), 8. Cyanobacteria (북해), 9. Cyanobacteria (븍헤), 10. *Tricodesmium* (베트남,1999), 11. *Tricodesmium* (호주), 12. *Noctiluca* (호주), 13. *Noctiluca* (태국), 14. *Noctiluca* (일본,1976)

Nature and history of HAB

- Historical record

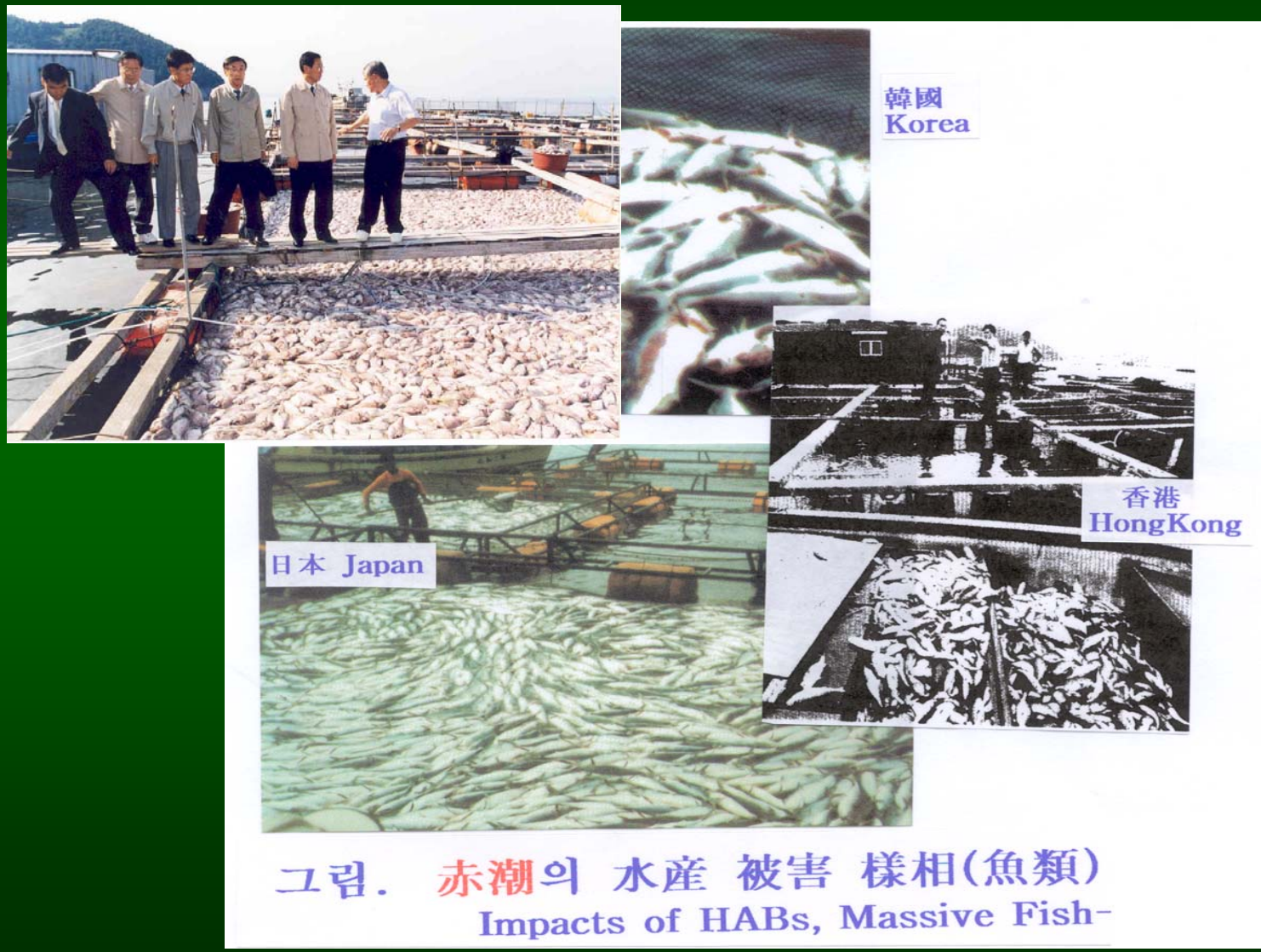
: HABs in 639 in the Silla dynasty

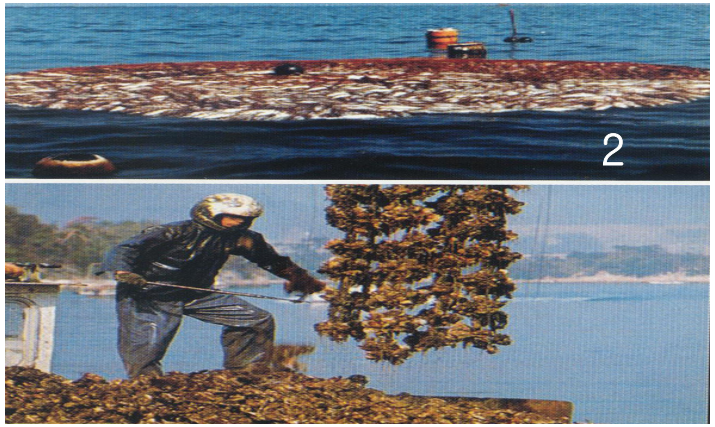
東海水赤且熱魚鼈死(三國史記卷第5號)

: The seawater, from Kijang Kaulpo in August in 1403, discolored as yellow and red, the water was viscous just as gruel and a lot of dead finfish were found in the surface.

- The first scientific report : Park & Kim; 1967

Impacts of HABs, Massive fish-kill





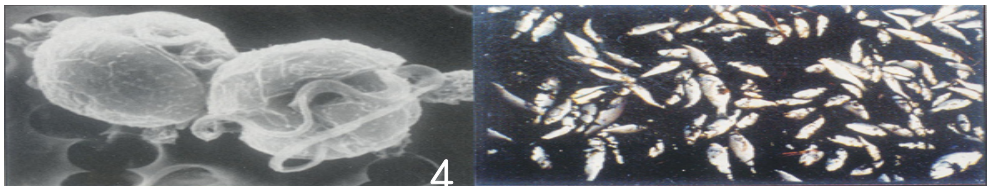


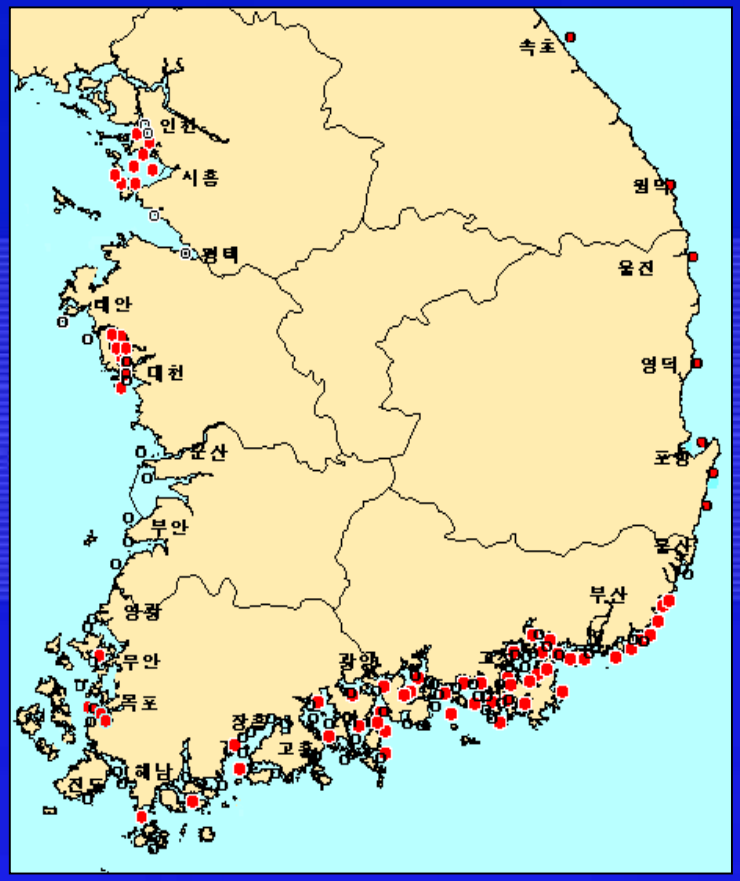
그림 VIII-1. 유해적조 피해(출처 : 1 (한국 2002); 2, 3, 4, 5(GEOHAB, 2001); 6(Anderson, 1994). 1. 어류폐사 (한국,2002), 2. 어패류폐사, 3. 어류폐사(남아프리카, 1994), 4. 어류폐사 (미국,), 5. 가축피해, 6. Humpback 고래 (미국, 1987)

Impacts of HABs on Coastal Fisheries

$$N_t = N_0 + G + R - F - M$$

- Direct effect
  - N_0 - Kill
  - G - Reduce
  - R- Decrease
  - M- Increase
- Halo Effect (3D)
  - Deteriorate habitats
  - Devaluation of Commercial fish
  - Decrease consumption

HABs Monitoring Operation in Korea



Organization	Methods	Duration	Area
NFRDI	Research Vessels	Monthly (Feb.-Nov.) Daily(HABs)	All coasts (77 st.)
Local MOMAF	On shore watch & Vessels	Weekly (Apr.-Oct.)	39 local area(92st.)
NMPA	Helicopter	Daily (HABs time)	All coasts

Constraints to be solved

- Mass production of bio-chemical samples
  – It needs to identify automatically.
- Multidisplinary analysis
  – It needs to make system analysis of climate and oceanographic dynamics.
- Wide angle view
  – It needs to make aerial and/or remotely sensed observations
- Low guaranty prediction by Fuzz model
- No practical mitigation

Present constraints and new technical approaches

- Mass production of bio-chemical samples
  – It needs to identify automatically.

New techniques in developement

- ❑ Identification of target species
  - o Fluorescent lectin probe (Alexandrium)
  - o Molecular probe (LSU-rRNA)
- ❑ Quick and automatic identification
  - o Self-identification microscope
  - o Automation of chemical analysis

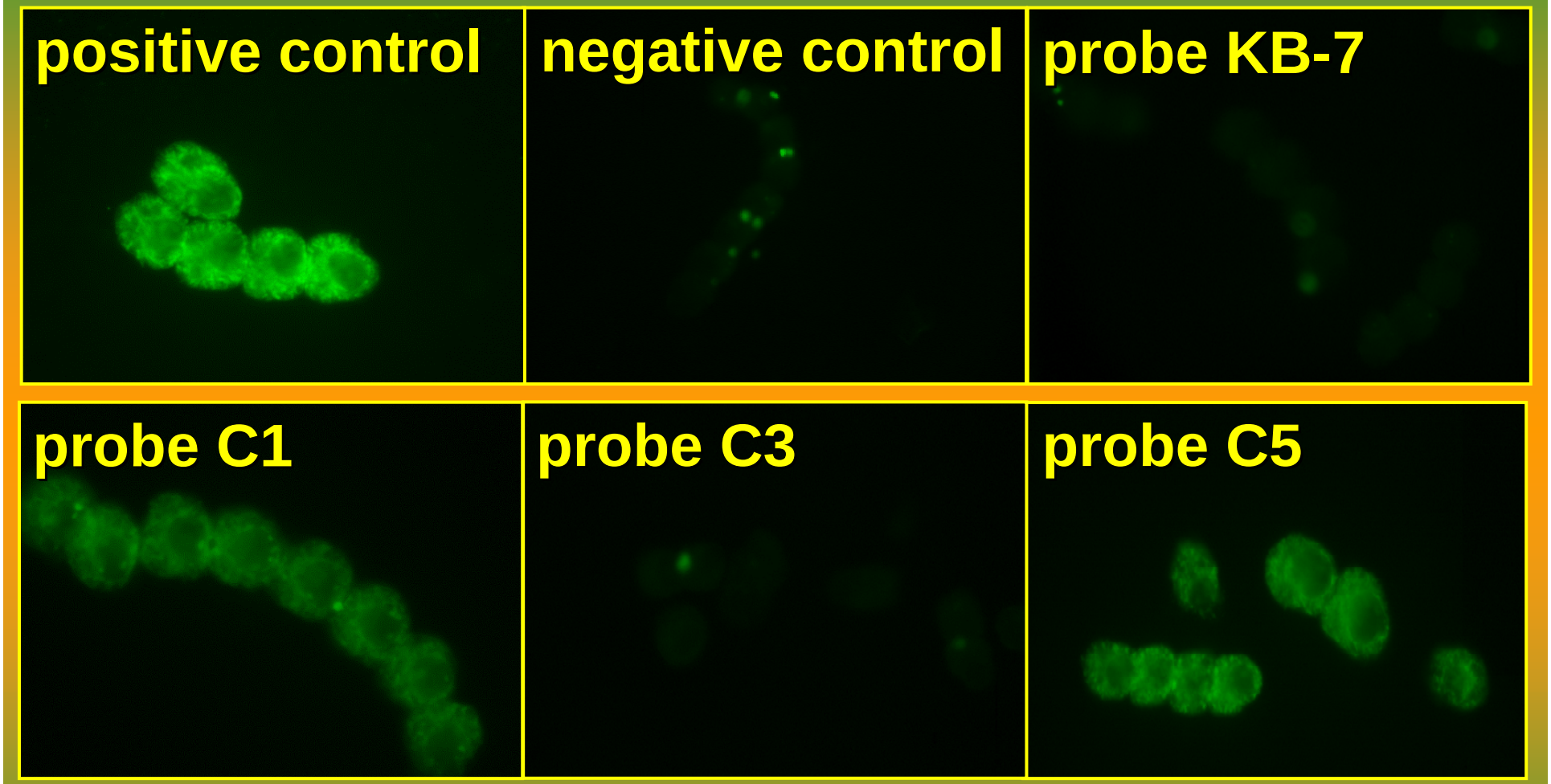

Recent approaches for the prediction and mitigation of
Cochlodinium polykrikoedes blooms in Korean waters
SBE
ON
OFF


Recent approaches for the prediction and mitigation of
Cochlodinium polykrikoedes blooms in Korean waters
PHYTO-PAM
WALZ

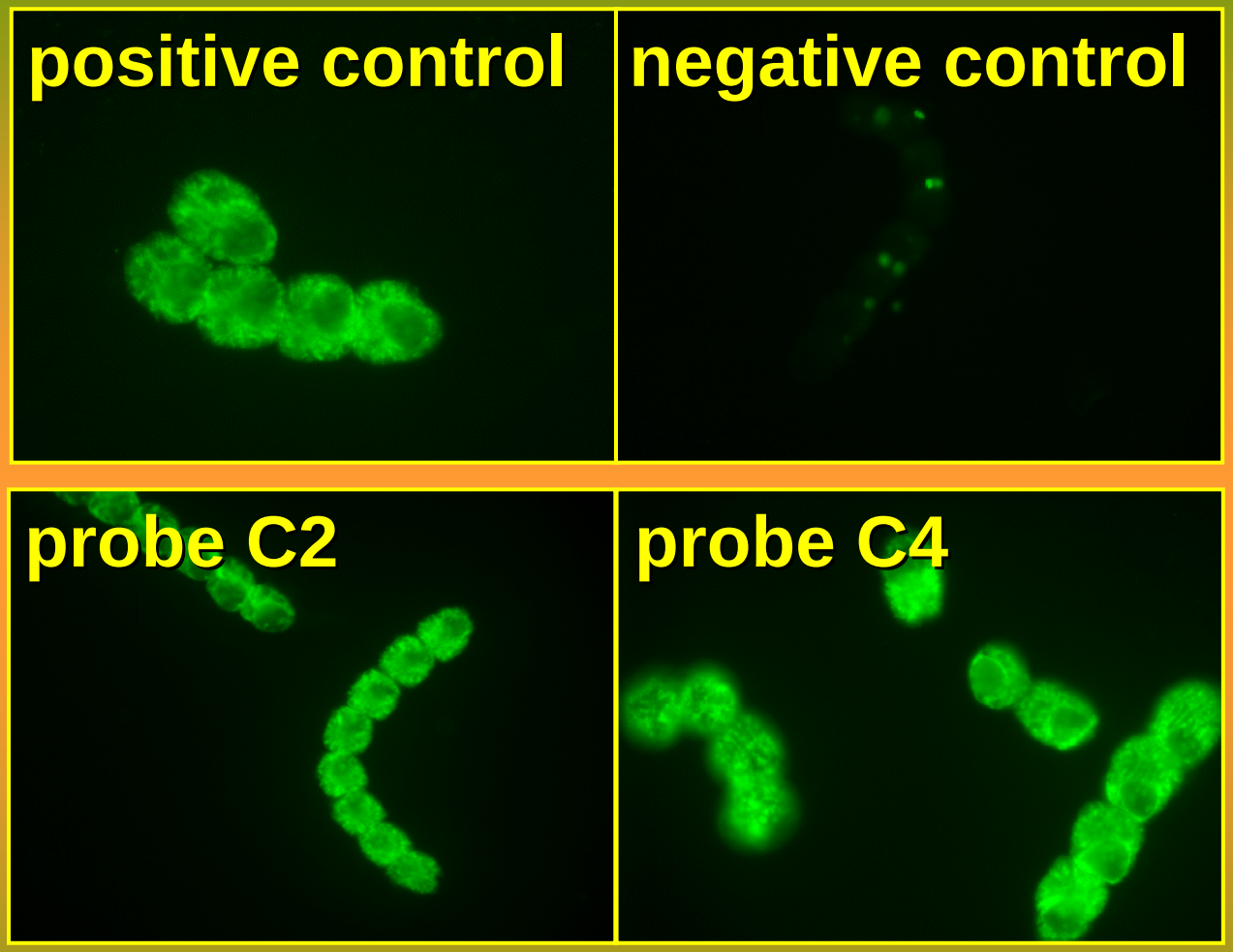

6600
DURACELL
DURACELL

Present identification of biological samples

Whole Cell Epifluorescence micrographs



Korean *C. polykrikoides* isolate (PP-3)



Korean *C. polykrikoides* isolate (PP-3)

Renovation in species identification

Present

- Eye microscopy
- Taxonomic key
- LM
- SEM

Future

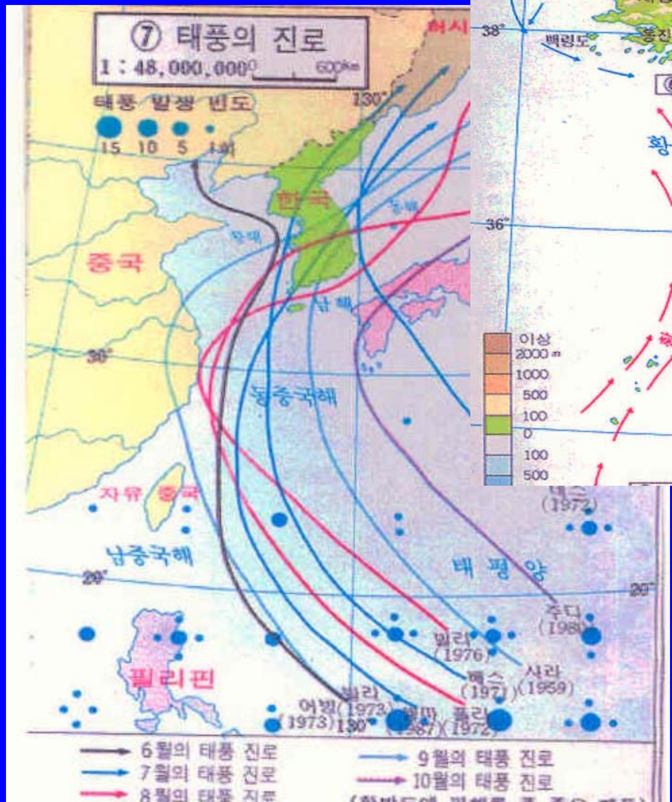
- Self microscopy
- LM
- Eye microscopy
- Taxonomic key
- SEM
- Lectin probe

Present constraints and new technical approaches

- Multidisplinary analysis
  – It needs to make system analysis of climate and oceanographic dynamics.

New techniques in development

❑ Couplication of climate, current and water quality
  o Meteological, tidal current and eutrophic analysis


⑦ 태풍의 진로
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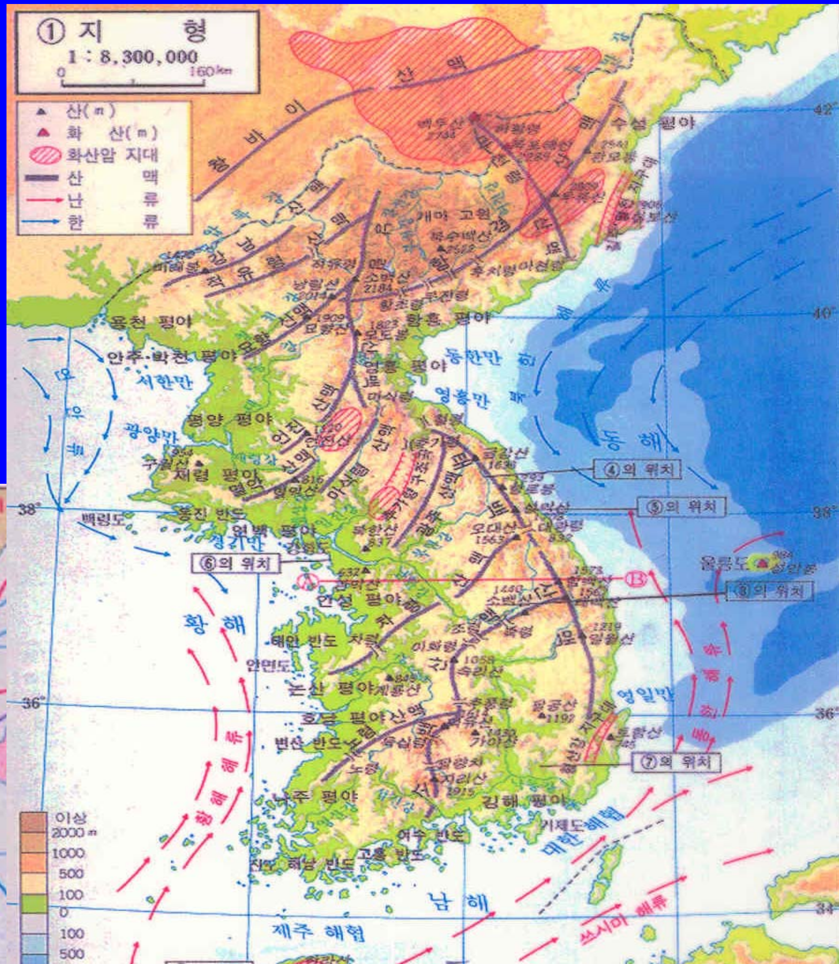
태 평 양
필리핀
6월의 태풍 진로
7월의 태풍 진로
8월의 태풍 진로
9월의 태풍 진로
10월의 태풍 진로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안주·박천 평야
서한만
평양 평야
재령 평야
옹진 반도
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호남 평야
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나주 평야
진도
해남 반도
고흥 반도
여수 반도
김해 평야
거제도
대한 해협
제주 해협
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쓰시마 해류
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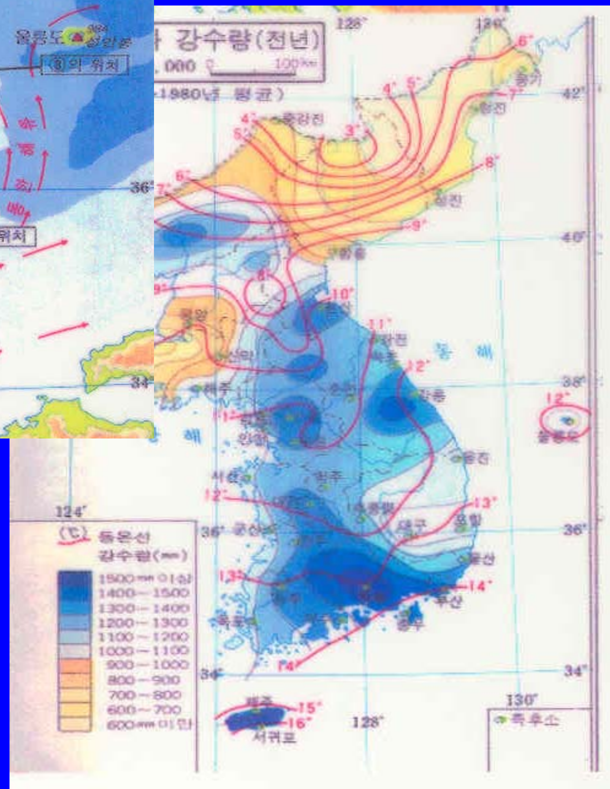
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측후소
울릉도
서귀포

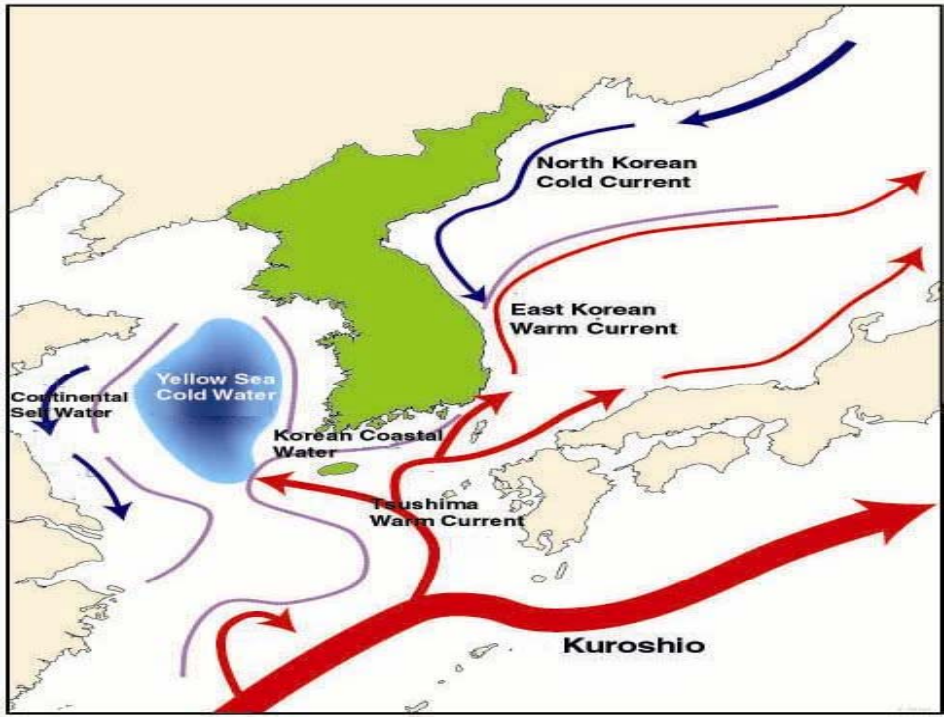
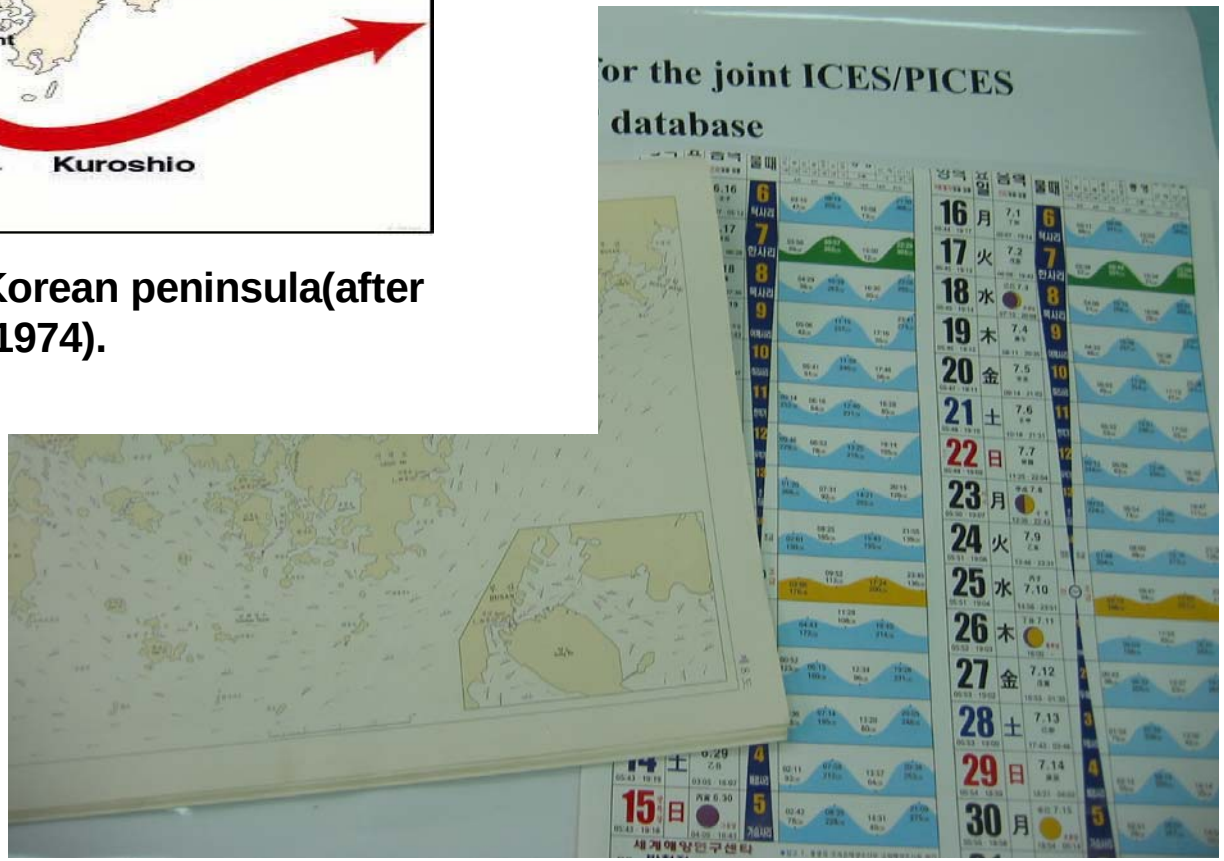
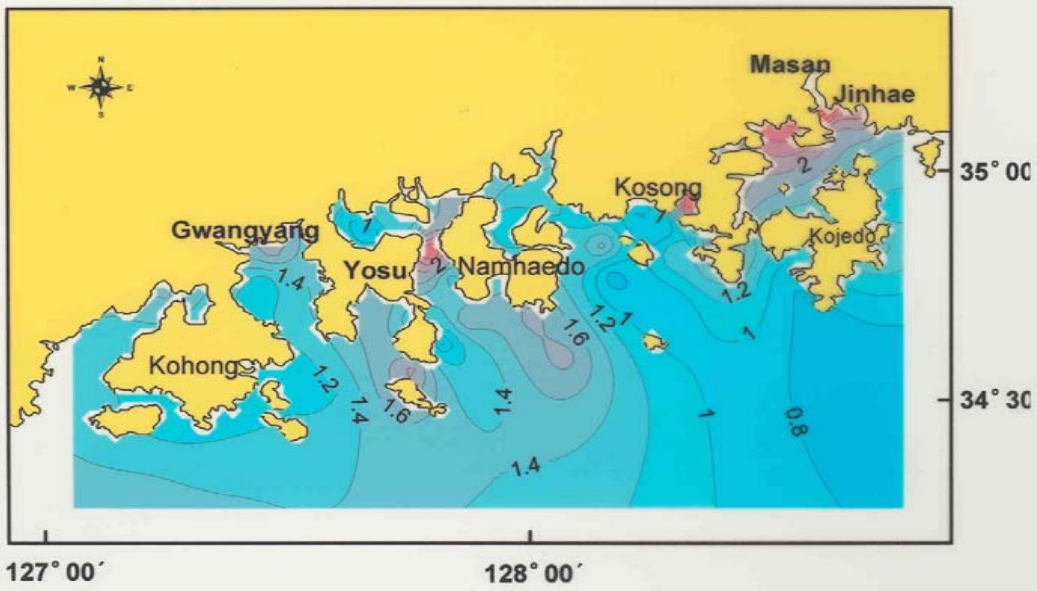


Fig. Current system around Korean peninsula(after Naganuma, 1973; Inoue, 1974).

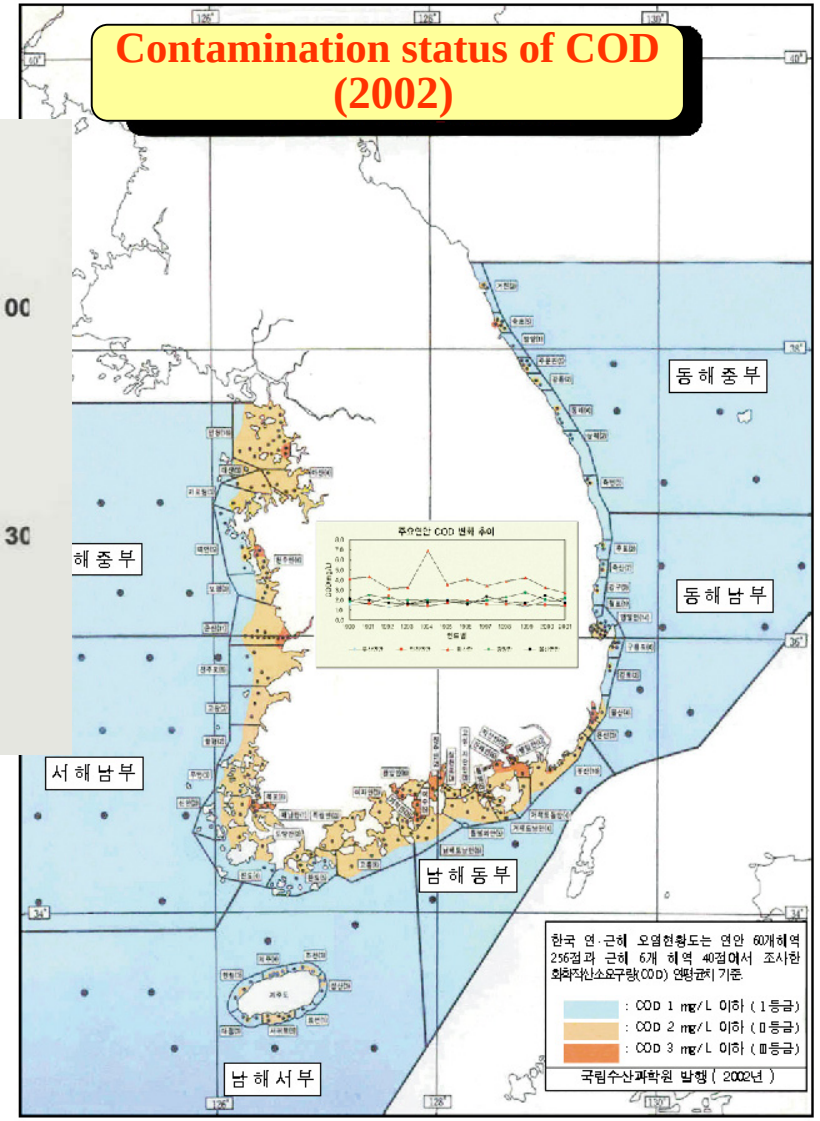


Monitoring results

- Sampling station number : 296 stations
  - Offshore : 40, coastal area : 256

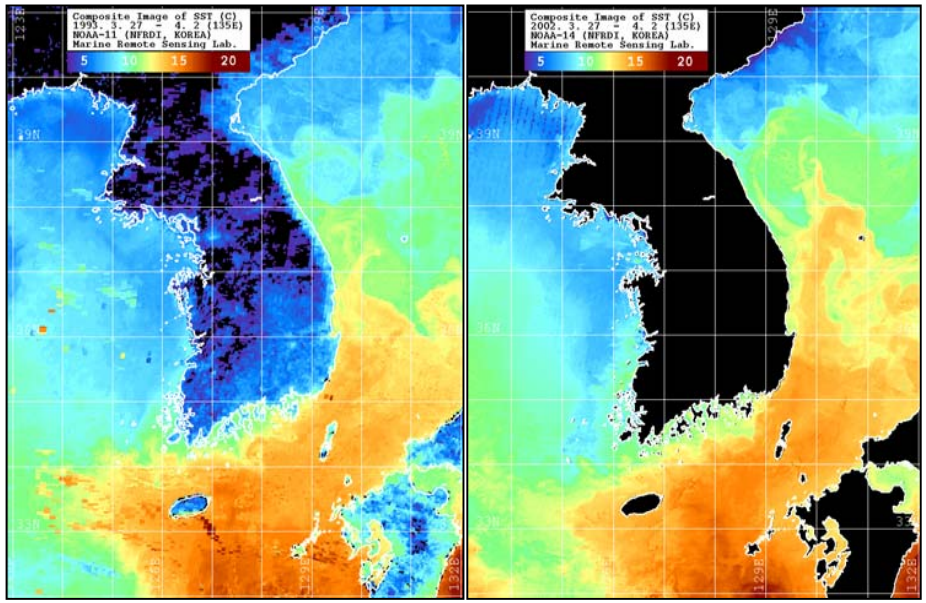


조사월	정점	표층	저층	표층	저층	표층	저층	표층	저층	표층	저층	표층	저층	표층	저층	표층	저층	표층	저층	표층	저층
02	01	9.6												008	0.009	0.045	0.032	0.217	0.175	0.014	0.020	4.0	1.480	0.000
	02	9.5												009	0.006	0.048	0.036	0.233	0.138	0.023	0.016	2.1	1.030	0.000
	03	10.3												003	0.004	0.031	0.028	0.090	0.039	0.012	0.012	1.0	0.150	0.000
	04	10.												004	0.003	0.027	0.028	0.055	0.036	0.011	0.012	0.7	0.090	0.000
	05	10.2												003	0.003	0.028	0.029	0.033	0.039	0.012	0.013	1.6	0.150	0.000
	06	10.3	10.2	33.89	33.48	8.15	8.16	5.36	5.44	1.41	1.22	0.030	0.011	0.004	0.004	0.031	0.033	0.064	0.048	0.012	0.010	2.2	0.140	0.000
05	01	14.0	13.7	34.76	34.40	8.04	8.06	8.15	8.32	0.30	0.84	0.092	0.121	0.012	0.007	0.024	0.030	0.128	0.158	0.041	0.037	7.2	7.280	0.000
	02	14.4	10.0	35.12	34.75	8.22	8.11	10.14	9.71	1.16	0.13	0.020	0.002	0.007	0.003	0.002	0.012	0.029	0.017	0.009	0.014	0.9	1.960	0.000
	03	15.1	13.6	34.70	34.00	8.07	8.23	9.33	10.12	0.40	0.86	0.119	0.025	0.008	0.005	0.021	0.017	0.148	0.047	0.042	0.022	5.6	3.820	0.000
	04	14.3	6.6	34.80	34.77	8.22	7.97	10.01	9.67	0.13	0.01	0.001	0.001	0.002	0.004	0.006	0.015	0.009	0.021	0.013	0.008	1.6	1.630	0.000
	05	14.4	6.5	34.90	34.36	8.20	7.98	10.01	9.38	0.58	0.49	0.000	0.000	0.002	0.003	0.006	0.005	0.009	0.008	0.008	0.008	1.2	1.660	0.000
	06	14.1	9.0	34.78	34.35	8.20	8.01	9.85	9.40	0.01	0.69	0.001	0.001	0.003	0.005	0.006	0.016	0.011	0.022	0.007	0.015	1.9	0.910	0.000
	01	24.1	23.7	31.70	32.02	7.92	8.04	7.93	6.09	1.32	1.50	0.170	0.120	0.008	0.009	0.089	0.051	0.267	0.180	0.041	0.043	3.9	1.440	0.000
	02	24.7	24.0	32.05	32.14	8.27	8.27	7.84	7.99	0.80	1.06	0.001	0.002	0.001	0.001	0.011	0.030	0.014	0.033	0.018	0.022	1.7	0.450	0.000

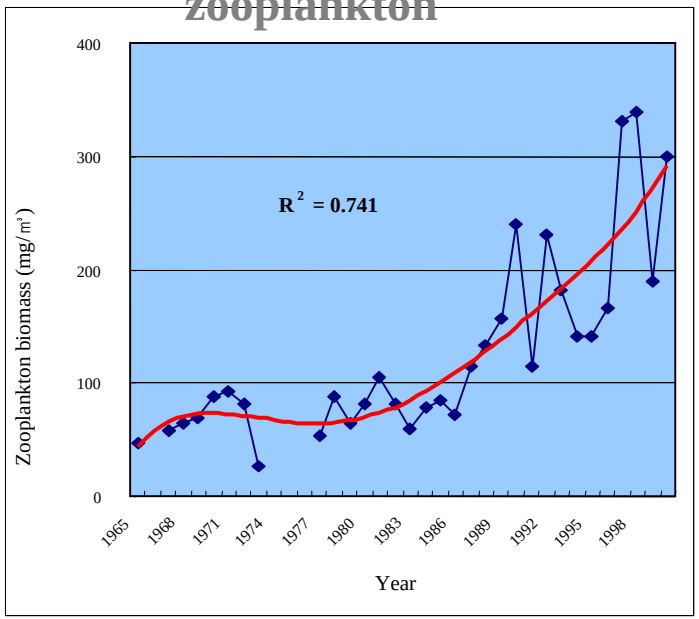


The impact of climate changes on marine ecosystem

- increase of temperature(1℃/36yrs) & zooplankton biomass



temperature



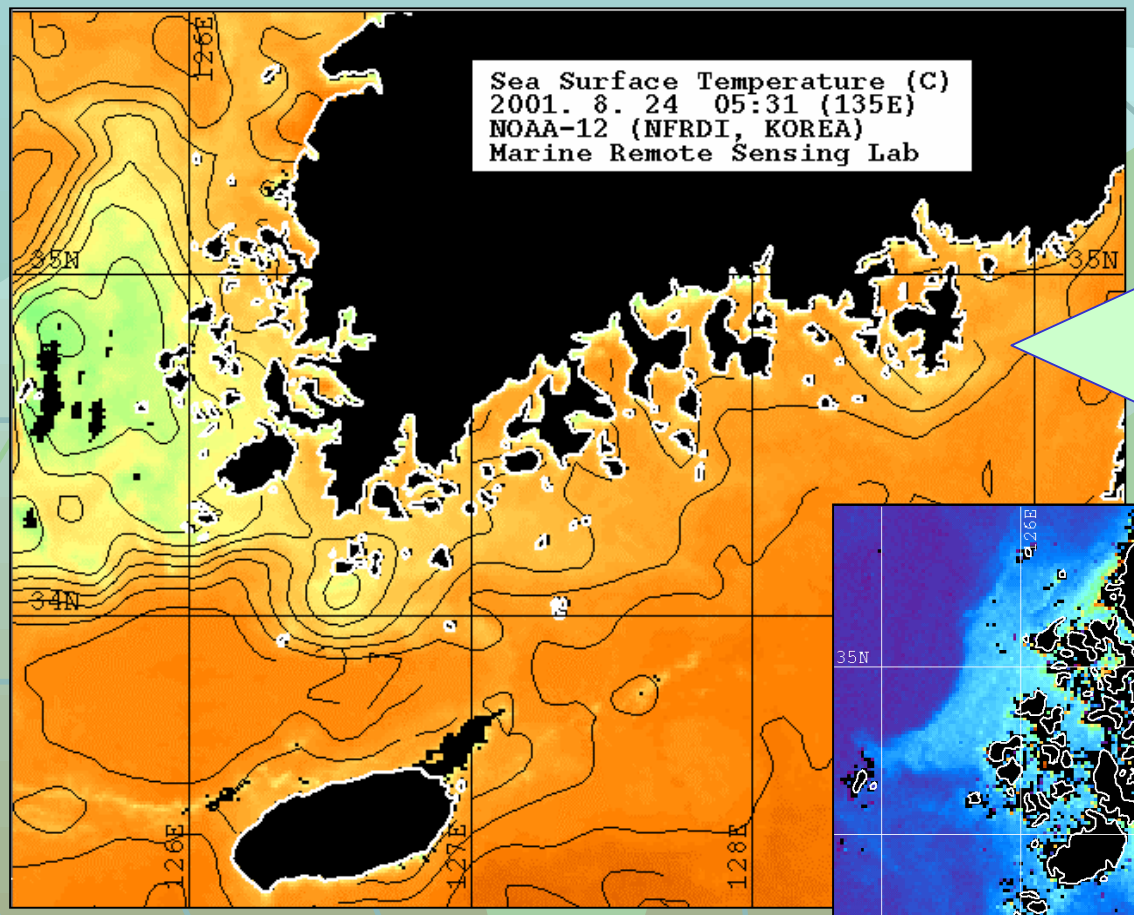
Present constraints and new technical approaches

- Wide angle view
  – It needs to make aerial and/or remotely sensed observations

New techniques in development

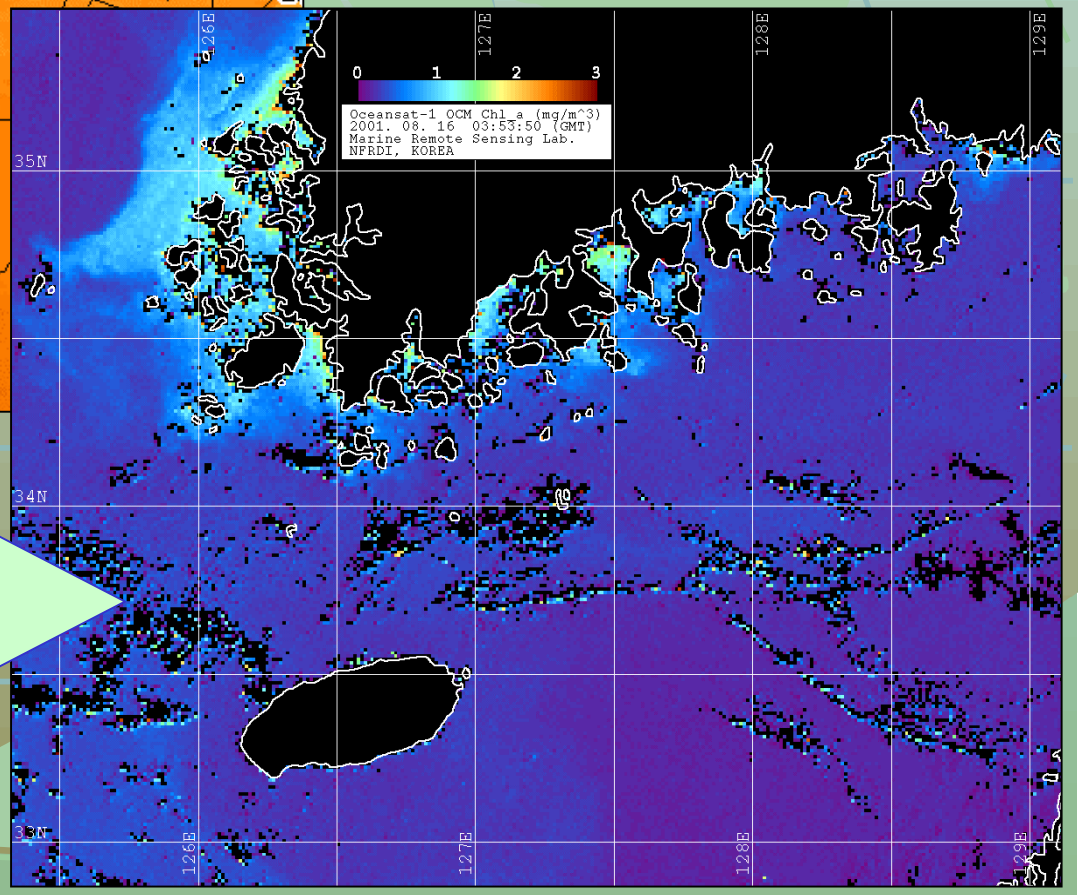
- Develop high resolution for clean image
  - o remotely sensed observation
  - o change naked aerial view into bio-optic map

Real-time Satellite Oceanographic Information



NOAA

Sea Surface Temperature



OCM

Chl. a concentration

98. 9월)
sing aircraft.
, Sept. 1998

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ial monitoring.
Sept. 1998

1995년도 적조

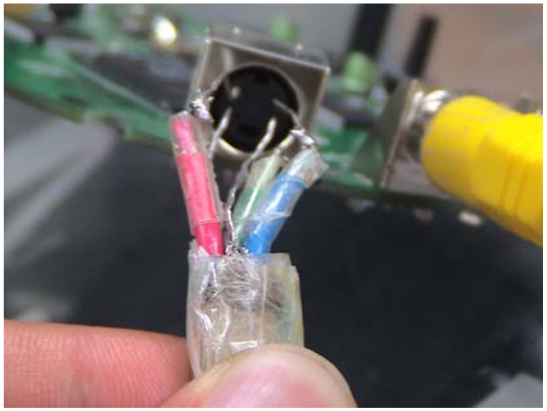
Cochlodinium polykrikoides blooms

미역양식장 뒤덮은 적조대 적조와 기름으로 바다가 신음하고 있는 가운데 29일 부산 靑砂浦 앞바다에 검붉은 적조대가 미역양식장을 뒤덮고 있다。<부산시 소방본부헬기=朴熙萬기자>

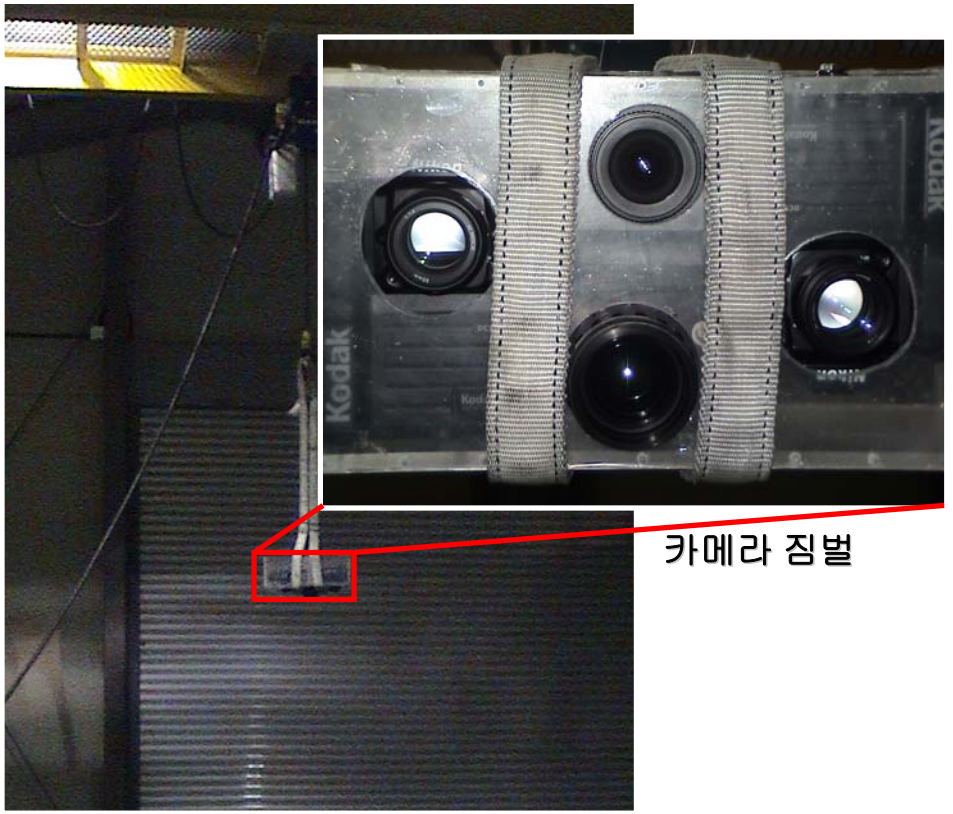
▪ PKNU 3호 시스템 개발

- 촬영시스템 설계 제작 및 실내 실험

카메라 짐벌 방진 제작



케이블 방진 제작



기초성능 실내 실험

▪ Sensor 검보정

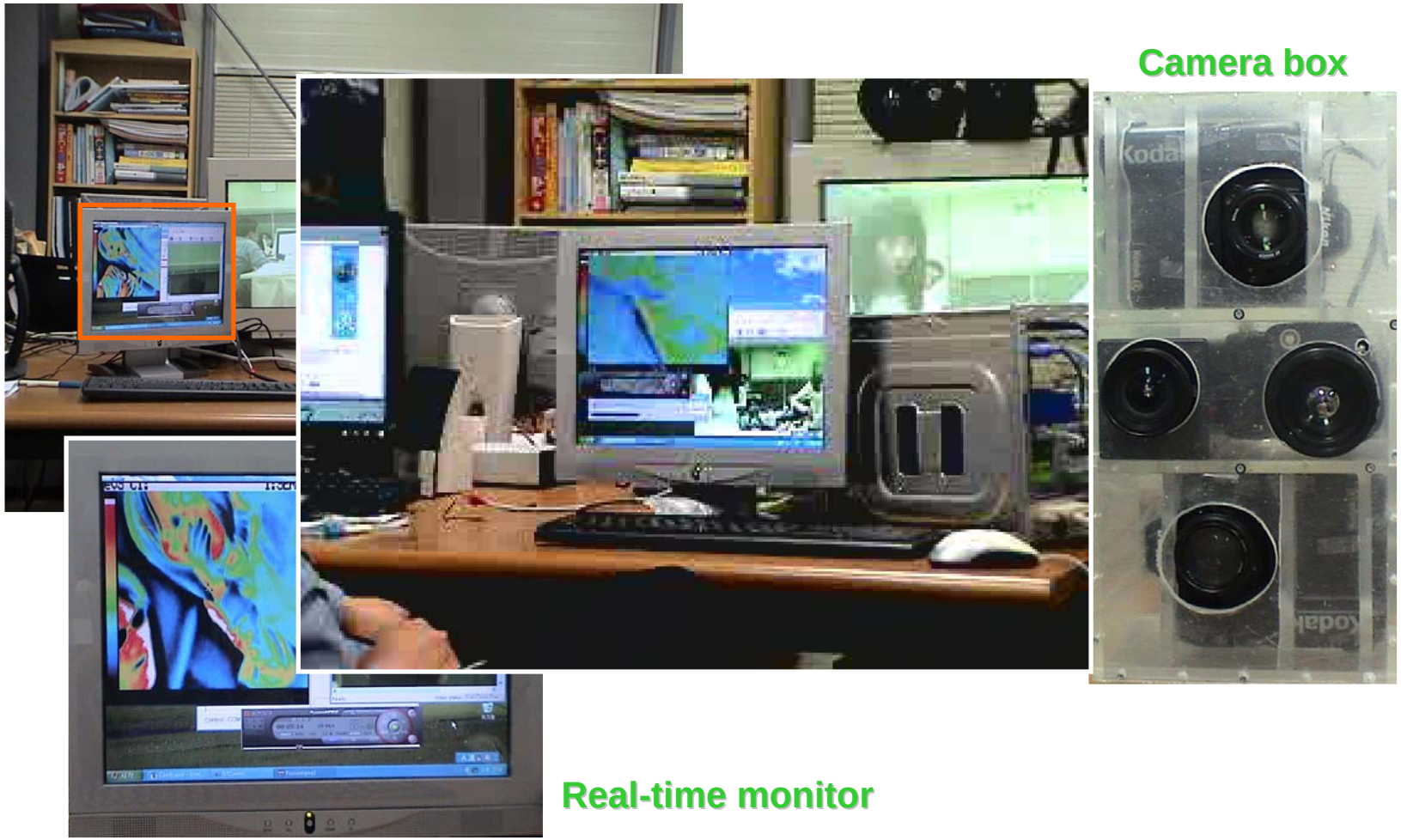
- 온도보정(현장사진)

콘크리트 지상센서

지상 온도 습도 센서

잔디 지상센서

- **PKNU 3호 시스템 개발**
  - 기초촬영가능성 실험



Camera box

Real-time monitor

- **PKNU 3호 시스템 개발**
  - 탑재가능성 현장조사

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	3,700 m
	5,000 m
	300
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	3 + 1
Operat	

Present constraints and new technical approaches

- Forecasting from the initiation
  – It needs to collect all data for initiation and subsequent movement.

New techniques in development

- Clarify the initiation mechanisms
  - o NOWPAP/CEARAC-CCG project
  - o collect all data driving the movement

Present Korean HABs Monitoring System - Focused on *Cochlodinium* blooms

- **Precautionary Monitoring : Less than 300cells/ml**
  - **5 susceptible areas initiating the first bloom**
  - **To begin in June till the first bloom at the density of more than 300cells/ml**
- **Regular Monitoring (over 300cells/ml)**
  - **Regular Cruise : weekly, biweekly at 70 stations from Mar. to Nov.**
  - **Emergent Cruise : daily observation in *Cochlodinium* blooms area**

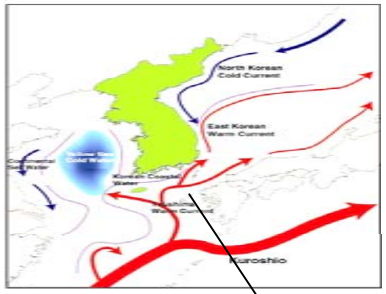
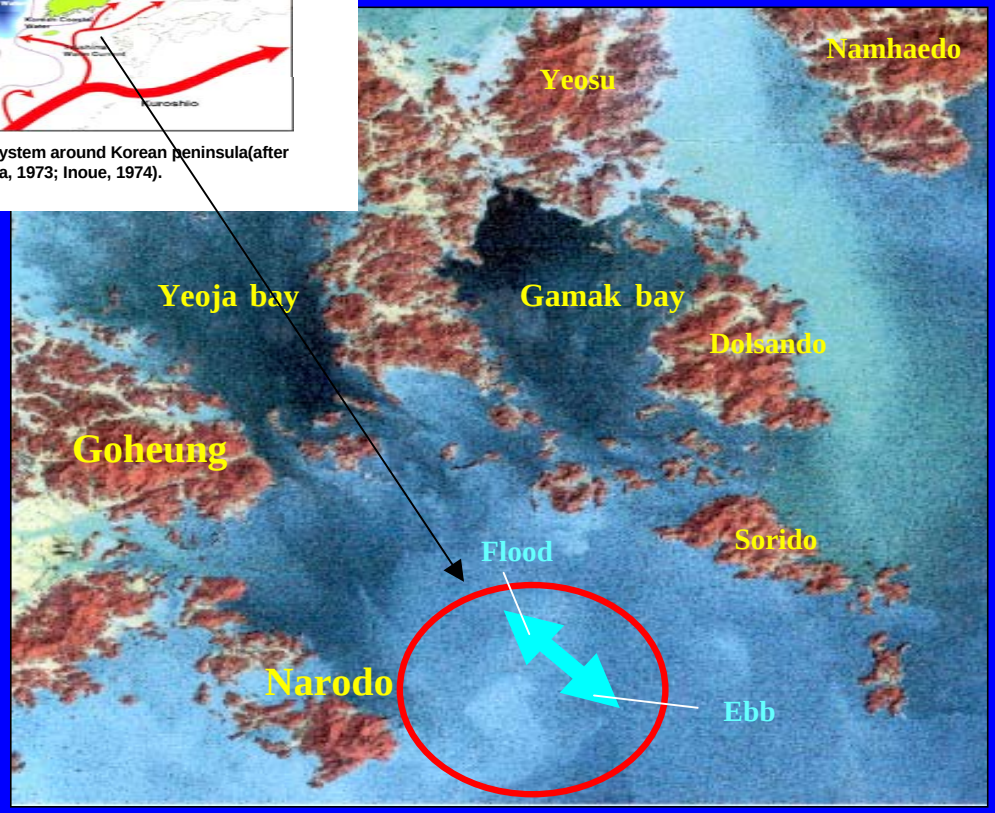


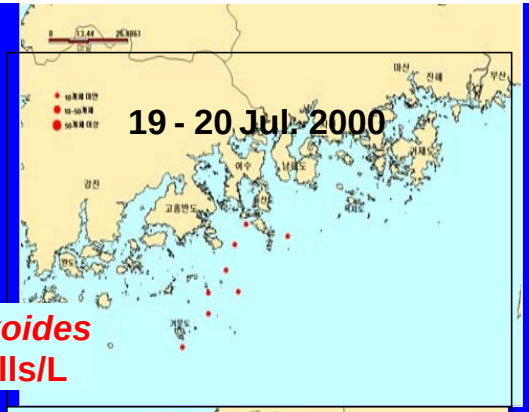
Fig. Current system around Korean peninsula(after Naganuma, 1973; Inoue, 1974).



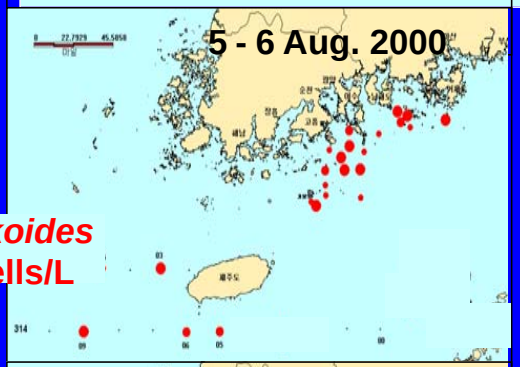
Environmental Features

- mean SST in Aug.: 24-25℃,
- eastern boundary of tidal mixing area
- coastal front between coastal waters and warm current
- plentiful nutrients input
- tidal curr. : flood(northwestward) ebb(southeastward)

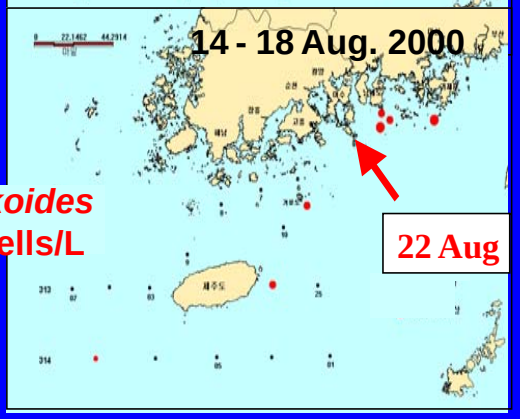
Fig. Landsat image around first outbreak area (red circle) of *C. polykrikoides*



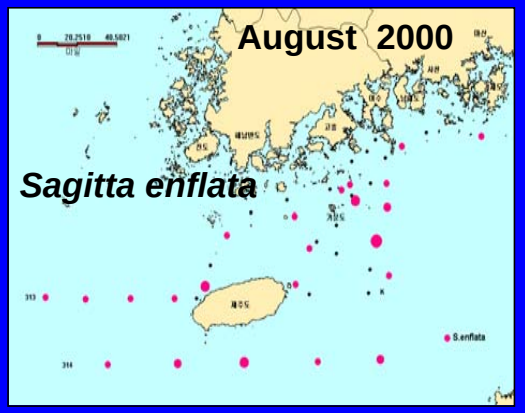
C. polykrikoides
10 - 30 cells/L



C. polykrikoides
10 - 50 cells/L



C. polykrikoides
10 - 100 cells/L



- Advance observation before the HAB to detect the swimming cells

It is estimated that the origin of the *C. Polykrikoides* blooms is the coastal approaching warm current from offshore area

Fig. The cells distribution of *C. polykrikoides* And *S. enflata* before HABs in summer 2000.

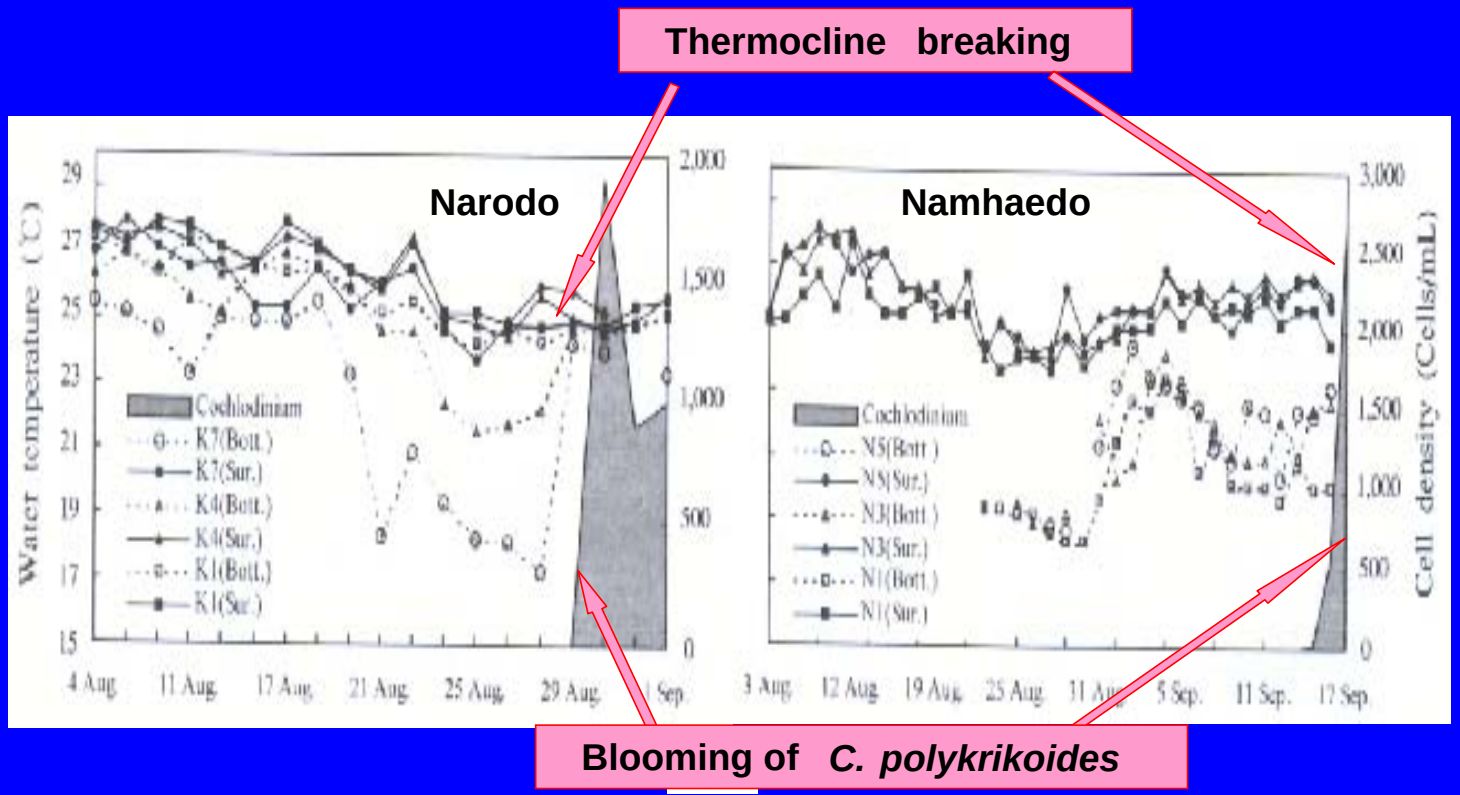
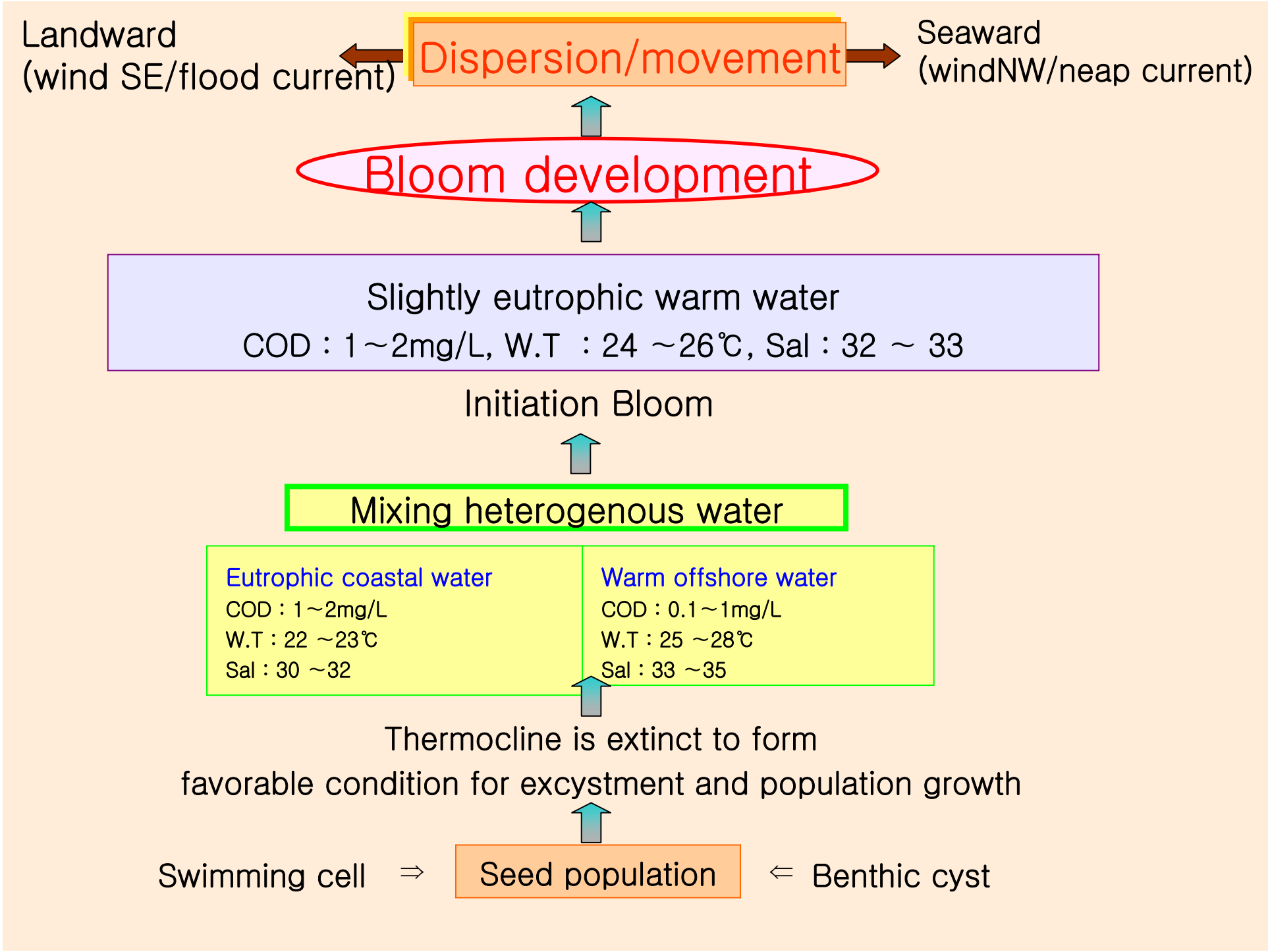


Fig. the relationship between the bloom of C. polykrikoides and Thermocline breaking in August 2000


Landward
(wind SE/flood current)
Dispersion/movement
Seaward
(windNW/neap current)
Bloom development
Slightly eutrophic warm water
COD : 1~2mg/L, W.T : 24 ~26℃, Sal : 32 ~ 33
Initiation Bloom
Mixing heterogenous water
Eutrophic coastal water
COD : 1~2mg/L
W.T : 22 ~23℃
Sal : 30 ~32
Warm offshore water
COD : 0.1~1mg/L
W.T : 25 ~28℃
Sal : 33 ~35
Thermocline is extinct to form
favorable condition for excystment and population growth
Swimming cell ⇒ Seed population ⇐ Benthic cyst

When HABs initiate the bloom ?

Initiation day (Lunar)	Tide	Julian day
1995. 8.29 (8.22)	Neap tide	241-294
1996. 9. 4 (7.22)	Neap tide	248-276
1997. 8.25 (7.22)	Neap tide	237-265
1999. 8.10 (6.29)	Neap tide	221-275
2000. 8.22 (6.29)	Neap tide	235-264

Where HABs to go ?

Driving forces	Direction	Magnitude
Tidal current	Come & back	Flood-NE Ebb-SE
Winds	Surface	SE-landward NE-seaward
Migration	Vertical	Day-surface Night-deep

What is the velocity ?

Driving forces	Speed/hour	Travel in 4hrs
Tidal current	50cm(1kt)-100cm(2kt)	7-14km
Tsushima current	3-20kt/d	10-15days to cross south Sea
Winds	SE-NE	Variable
Migration depth	Surface to 20 m	Light dependent

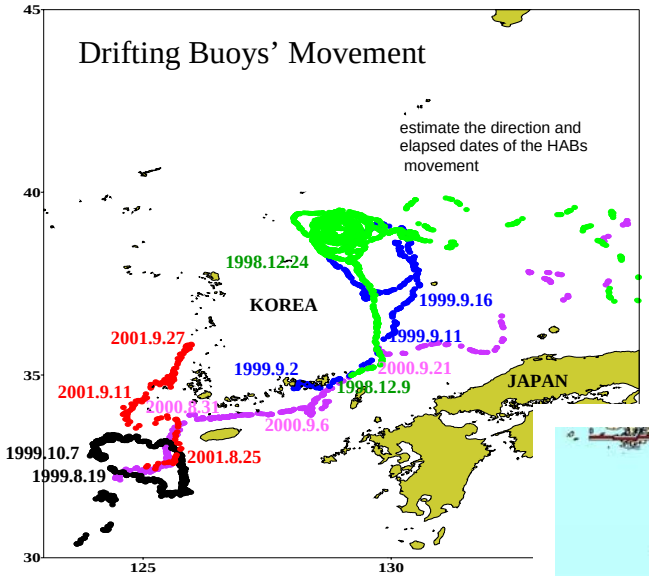


Fig. Drifting buoy trajectories in Korea

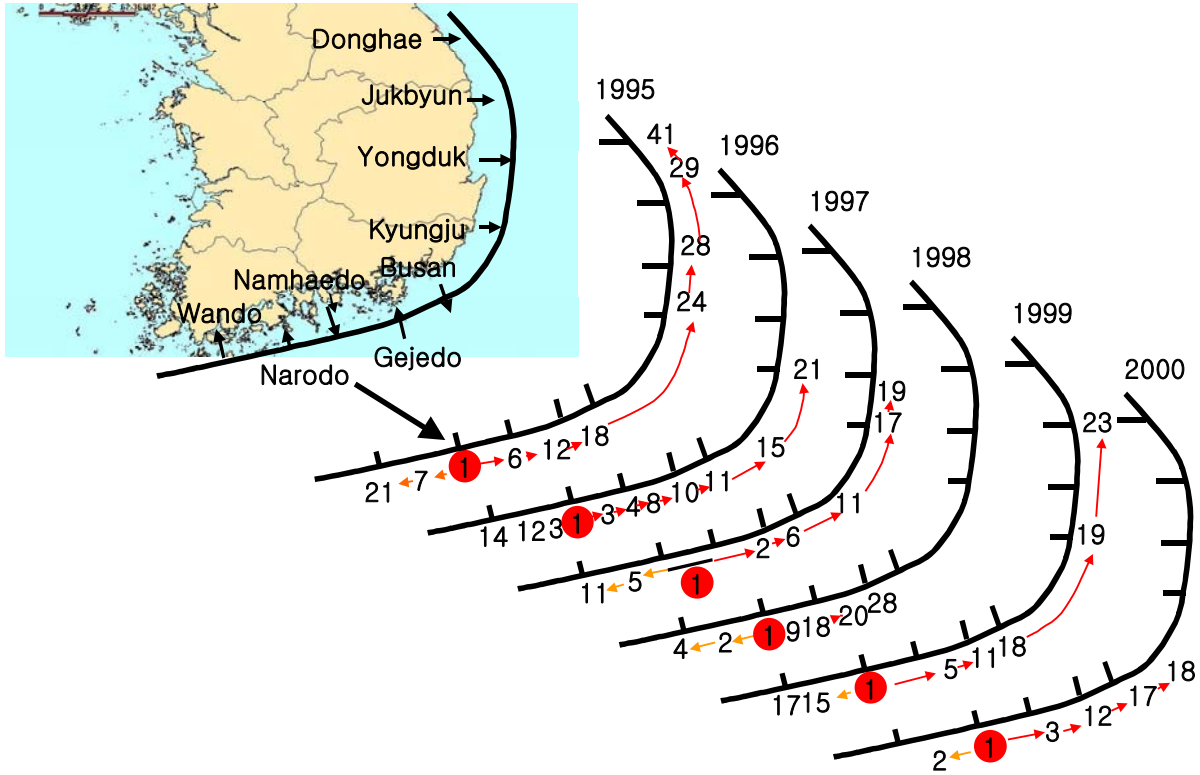


Fig. Year to year variations of the movement of HABs. Red circles and numbers denote the first outbreak area and the elapsed dates respectively.

Operational HABs Prediction System Fuzzy Model

Territories	Compilation of data and information
Oceanographic	3D-water movement pattern, T-S diagram, nutrients status, remote sensing data
Biological	Abundance and distribution, vertical migration,
Meteorological	Winds (direction & speed), Light intensity, Precipitation,
HABs inventories	All of the HABs data over the three decades

Present constraints and new technical approaches

- Early warning based on newsletter
- Clay dispersion by application ship

New techniques in development

❑ In-situ warning for direct controlling

❑Target shooting and enhance removal rate

- o dispersing gun
- o mix clay with electrolized seawater

HABs Management & Mitigation Strategies

Protect victim

- Real time monitoring network
- Early warning system & prediction
- Cage movement to avoid from HABs

Red Tide Warning System

Class	Rationale (*Cochlodinium* density and bloom size)
Cochlodinium appearance	First identification of *Cochlodinium* , the triggering point of bloom initiation
Red Tide Attention	300cells/ml, bloom area within 2-5km radius equivalent to 12 to 78㎢
Red Tide Alert	1,000cells/ml, bloom area over 5km radius equivalent to 79㎢
Warning Lift	HABs are extinct, no risk of fisheries damages

Real time HABs Service

Services	Available channels	Destinations
Easy Fax.	TV, Radio, Newspaper	Aquaculturists, fisherman, administratives, fish consumers, journalists, fisheries shareholders
ARS	12 lines since 6 May 1996	
Internet access	http://www.nfrdi.re.kr	

Punish violator

- Remove by dispersing clays
- Dilute the dinoflagellates density
- Entrapping using shield curtain

2001년 8월 30일 부산일보

Old style

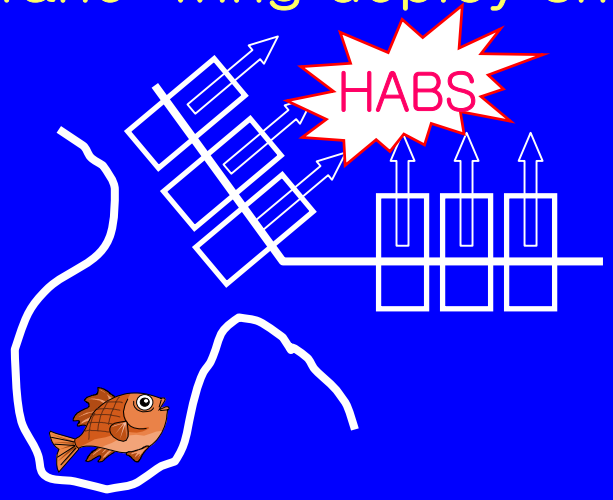
유독성 적조가 동해안까지 확산하고 있는 가운데 29일 오후 검붉게 변한 울산시 울주군 서생면 앞바다에서 바지선을 이용한 황토살포 작업이 한창이다.

김경현기자 view@

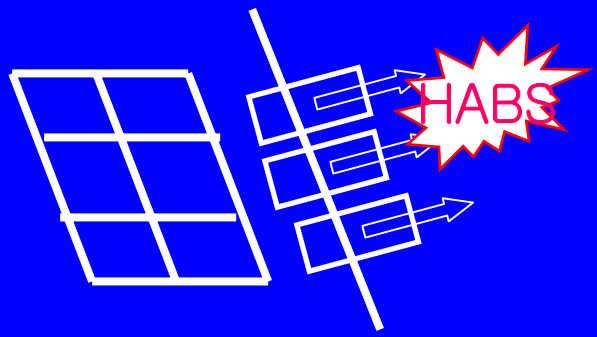
New clay dispersing ship with electrolyzed seawater

Field strategies for clay dispersion to control HABs

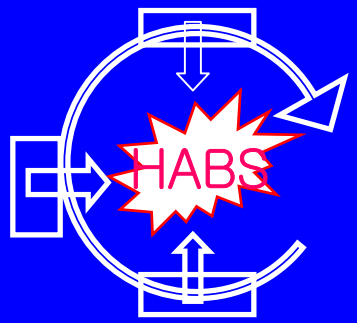
Crane-wing deploy shooting



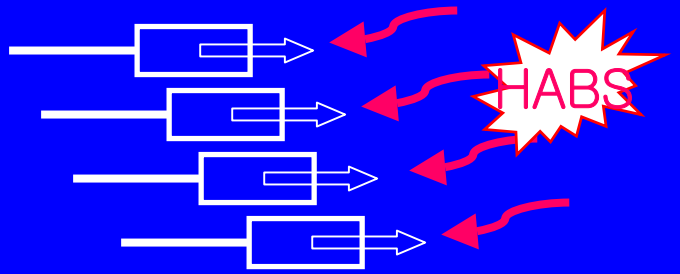
Frontal shooting



Merry-go-round shooting



Parallel shooting

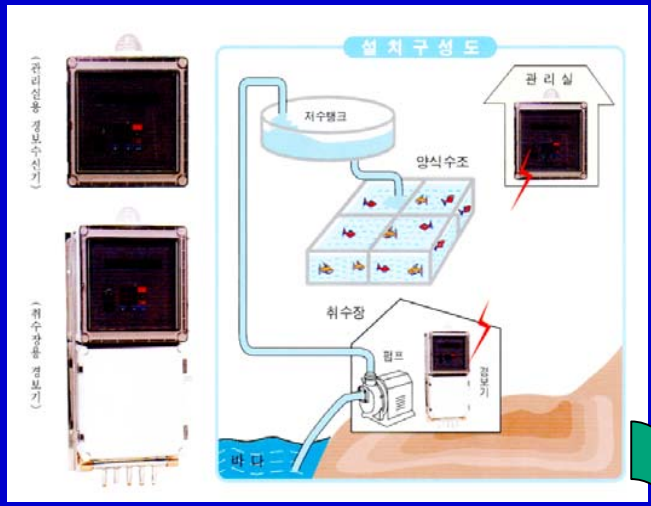


Aerial view of clay dispersion in South Sea

Aerial view of clay dispersion in South Sea

New system for the mitigation of fish

Offshore fish-cage

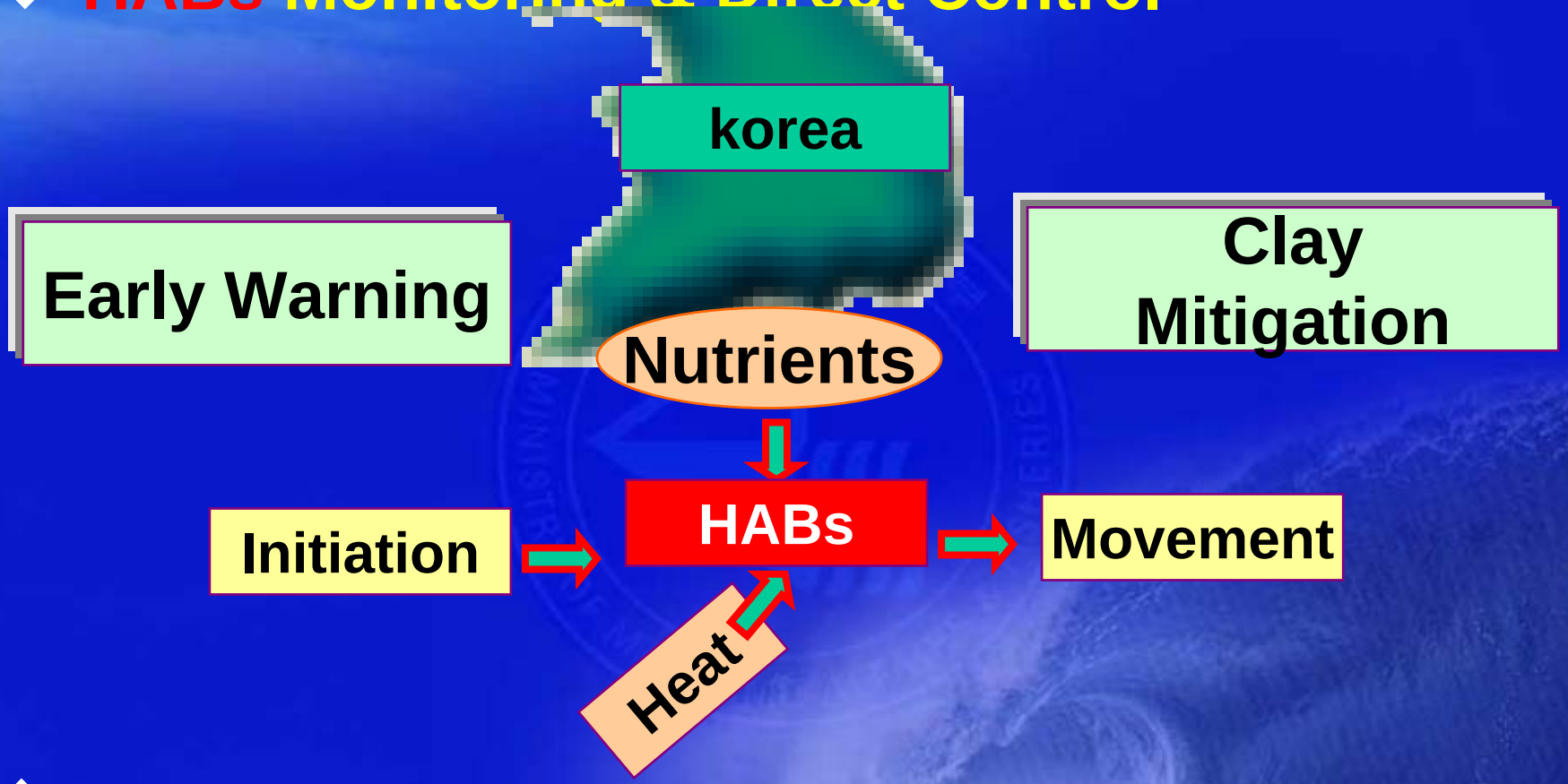


HABs warning system

New approaches

Element		Present	Destination
Monitoring	Identification	LM/SEM	DNA-probe, identification card for microscope
	Data analysis	Water and sediment quality, movement	Climate variability and current system
	Wideview	RS and aircraft by naked eye	Bio-optic aircraft monitoring
	Prediction	Initiation and movement	From the initiation
	Model	Fuzz	Ecosystem model
Mitigation	Early warning	Three grades	Four grades
	Clay dispersion	Fish boat and application ship	Specified clay dispersion ship with electrolizing system

❖ HABs Monitoring & Direct Control



❖ Coastal Environment management

- Regulate terrestrial input & sediment removal
- Aquaculture restructuring

Thank you

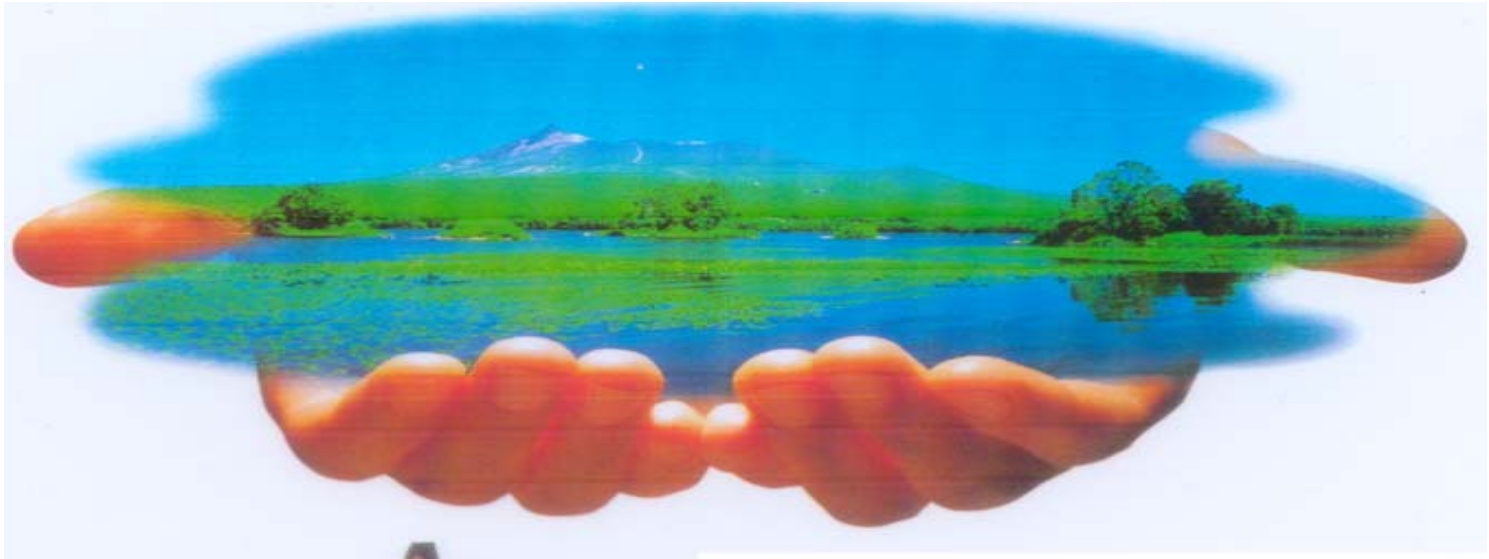
Korean Shellfish Toxin Monitoring

Governing Law or Act

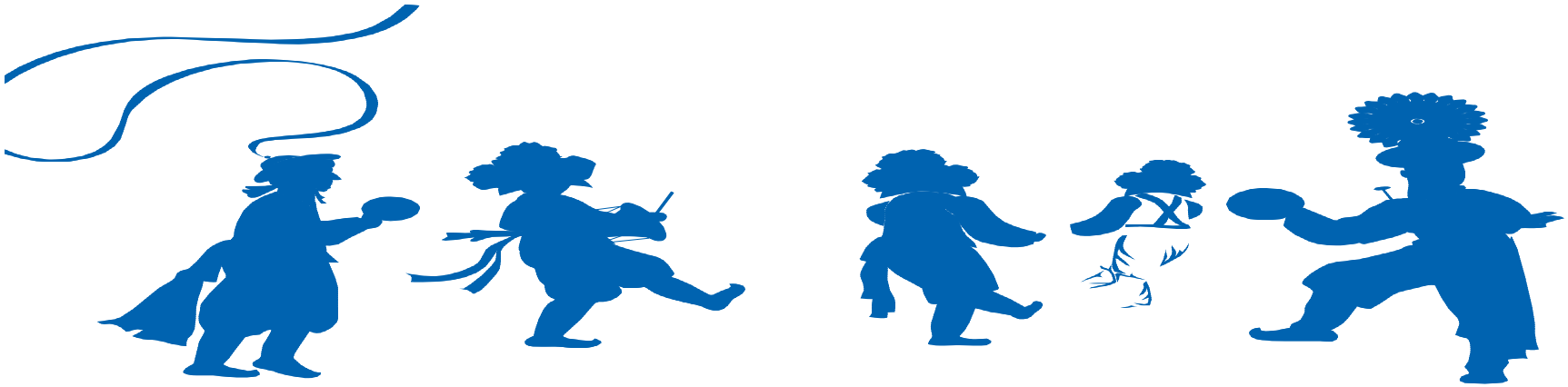
- Food Sanitation Law
- Fishery Product Quality Control Act

Governing Authority

- Ministry of Maritime Affairs and Fisheries (MOMAF) : drive national policy to secure public health
- NFRDI : run national monitoring programs
- Local Government : enforce the governing act and law such as harvesting ban



If we harm the environment, it will harm us in return



한국의 적조 KORHAB - Microsoft Internet Explorer

파일(F) 편집(E) 보기(V) 즐겨찾기(A) 도구(T) 도움말(H)

뒤로 검색 즐겨찾기 미디어

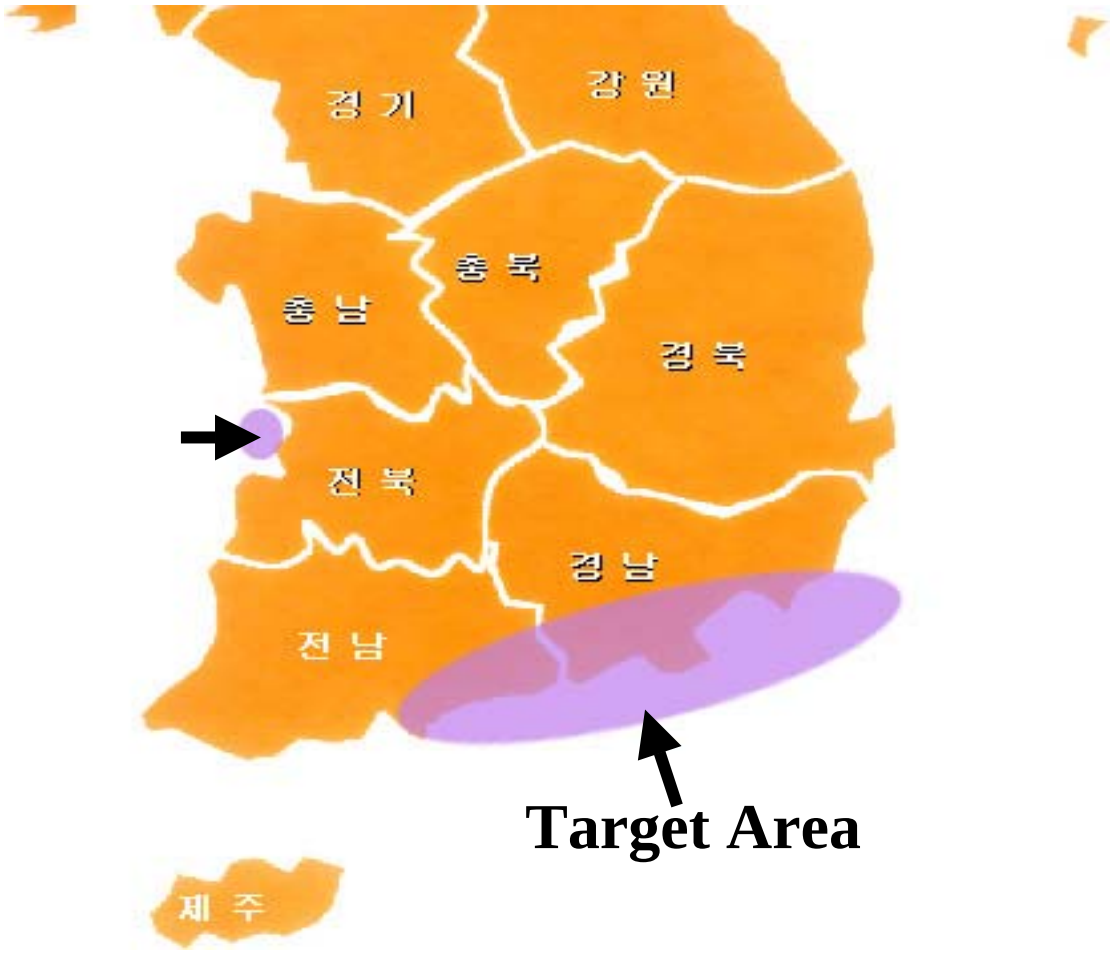
주소(D) http://www.nfrdi.re.kr/korhab/index.html 이동 연결 »

부산광역시 기장군 기장읍 시랑리 408-1번지 전화:051.720.2114, fax:051.720.2266

오늘의 my0...

인터넷

Target Area for the Monitoring of Shellfish Toxin in Korea



Current Shellfish Toxin Monitoring Portfolio in Korea

	Prevailing season	Occurring area	Starting year
PSP	From March to May	South coast (Jinhea Bay and adjacent area)	Since 1980
DSP	Sporadic	Not specified	Since 1995
ASP	Sporadic	Not specified	Since 1995

Number of Sampling Station and Monitoring Frequency

- **Number of sampling station**
  - **PSP : 55 stations**
  - **DSP : 15 stations**
  - **ASP : 40 stations**
- **Frequency of shellfish toxin**
  - **Once a month : All the year round**
  - **Every week : Toxic season (Usually Mar. to May)**
- **Monitoring target shellfish species**
  - **Blue mussel(*Mytilus edulis*), oyster (*Crassostrea gigas*), ark-shell (*Scapharca broughtonii*), short necked clam (*Ruditapes philippinarum*) and etc.**

Detection Methods for Shellfish Toxins

- **Paralytic shellfish poisoning (PSP)**
  - **Mouse bioassay**
- **Diarrhetic shellfish poisoning (DSP)**
  - **Mouse bioassay and HPLC**
- **Amnesic shellfish poisoning (ASP)**
  - **HPLC**