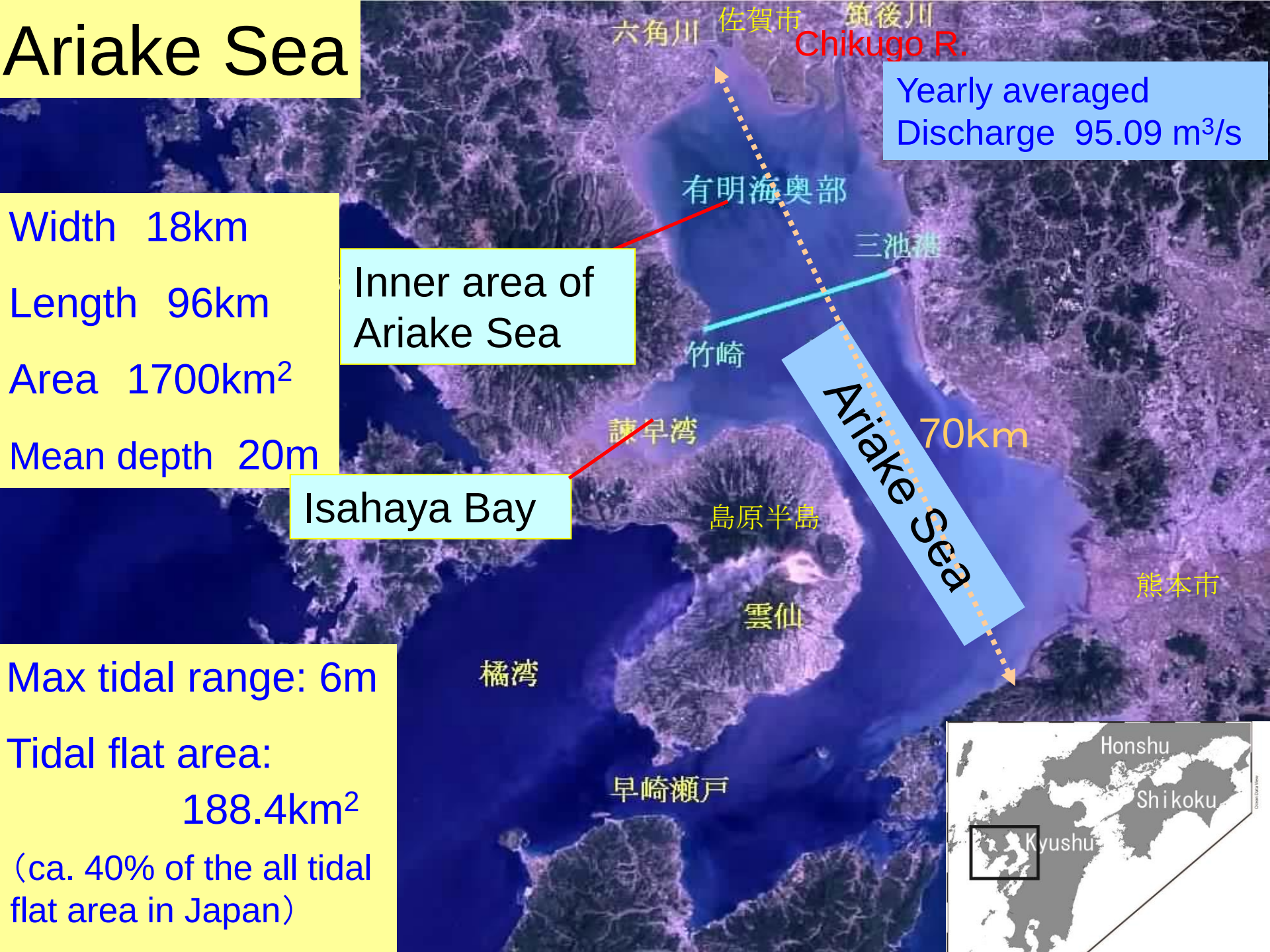
PICES 2017

Monitoring based research in Ariake Sea, Japan -To solve the environmental and fisheries problems-

Yuichi Hayami (Saga University)

Ariake Sea



Yearly averaged Discharge 95.09 m^3/s

Width 18km

Length 96km

Area 1700km^2

Mean depth 20m

Inner area of Ariake Sea

Isahaya Bay

Max tidal range: 6m

Tidal flat area: 188.4km^2

（ca. 40% of the all tidal flat area in Japan）

Ariake Sea

-especially inner area-

Extensive mud-flat

Turbid water by suspended clay

Unique biota including 23 endemic species

Inner area of Ariake Sea

Extensive mudflat

Complex topography due to tidal creeks

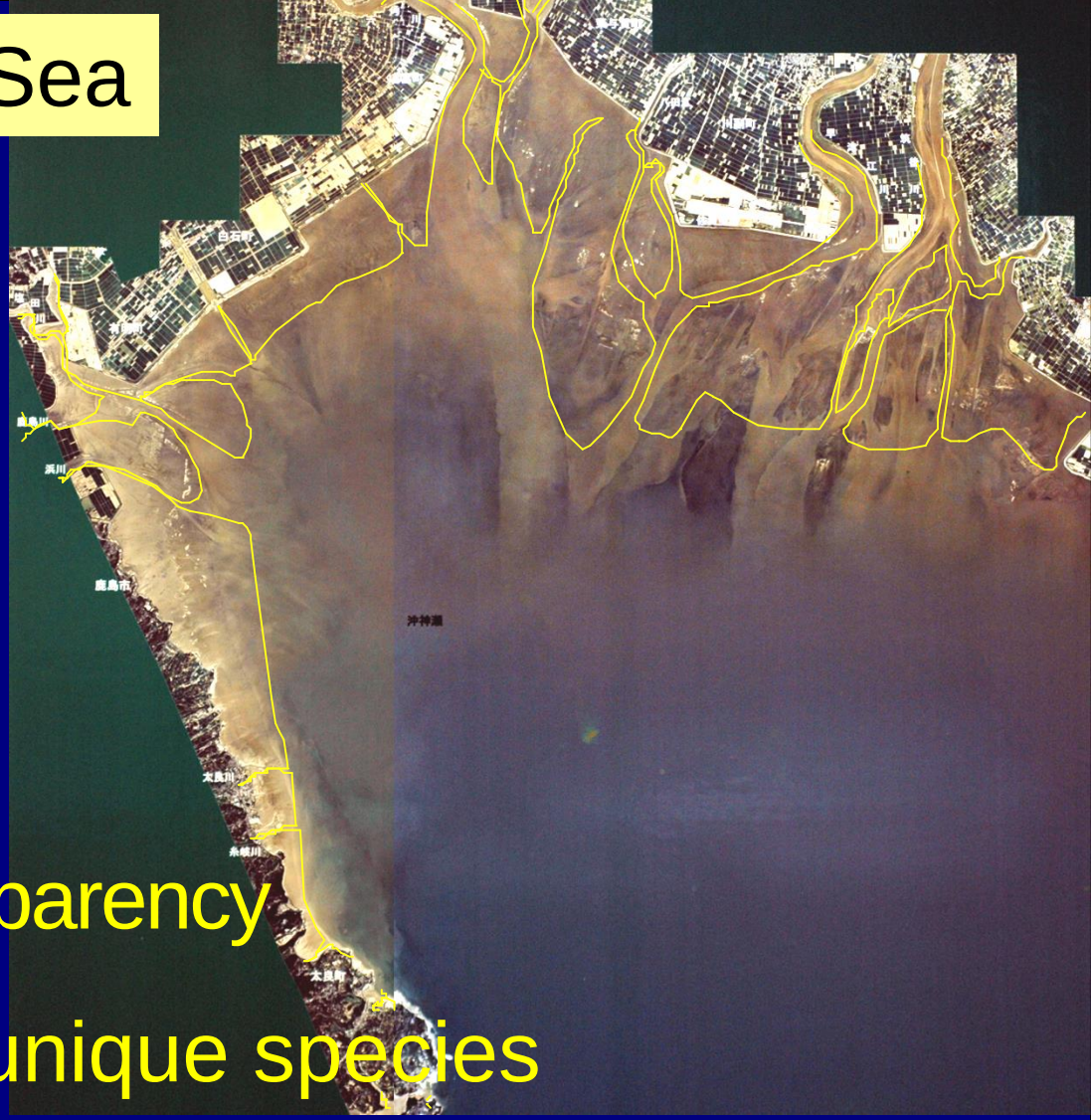
Large influence of fresh water discharge

High turbidity, low tranparency

Habitat of the many unique species

Broad area of laver culture

Serious environmental and Fisheries problems



Major environmental and fisheries problems in Ariake Sea

1) Increase of red tide

2) Occurrence of hypoxia

3) Decrease of shellfish catch

(pen shell, ark shell etc.)

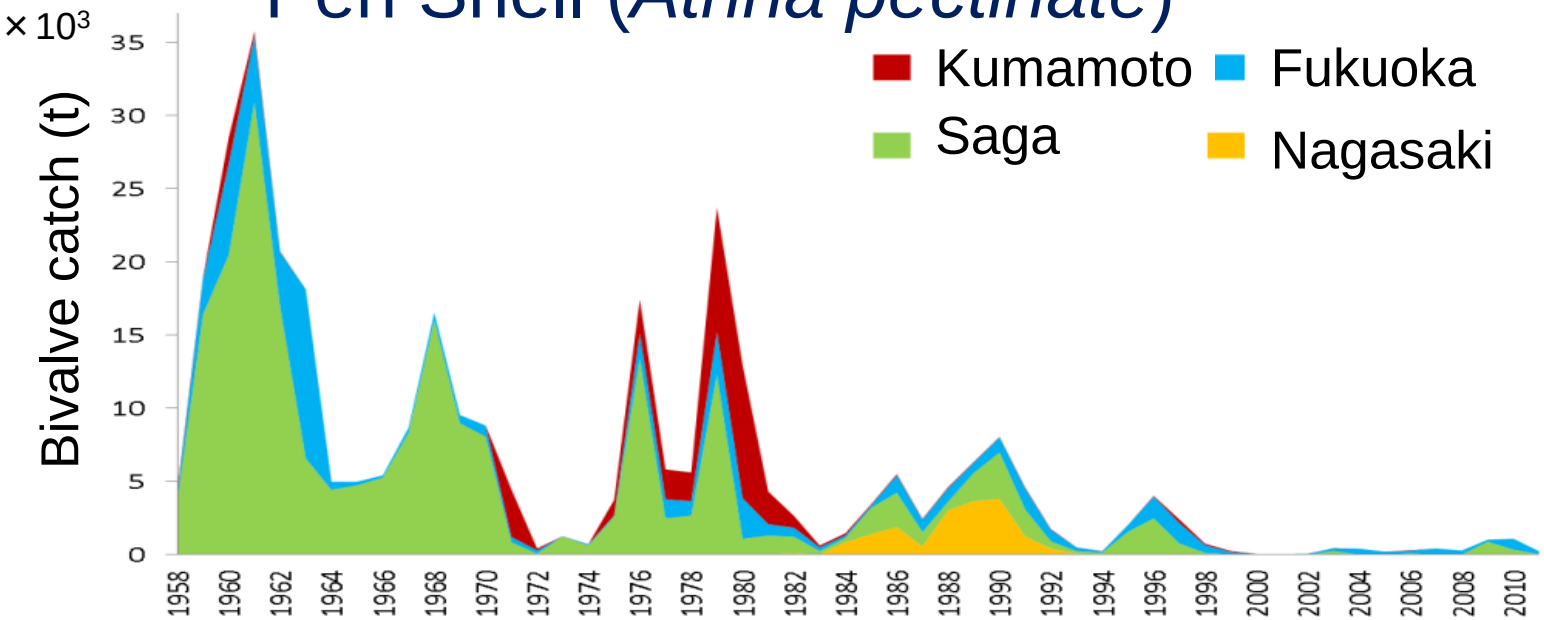
4) Decrease in other macro-benthos

5) Decrease in fish catch especially demersal fish

etc

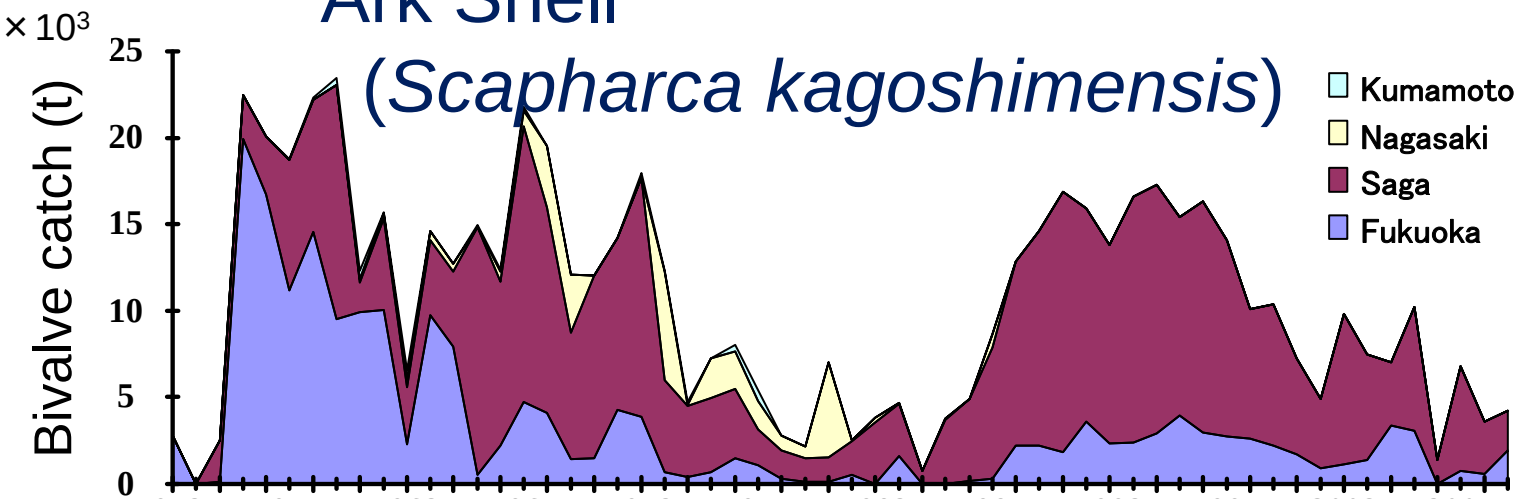
Decrease in bivalve catch

Pen Shell (*Atrina pectinate*)



1958 — 2010

Ark Shell (*Scapharca kagoshimensis*)

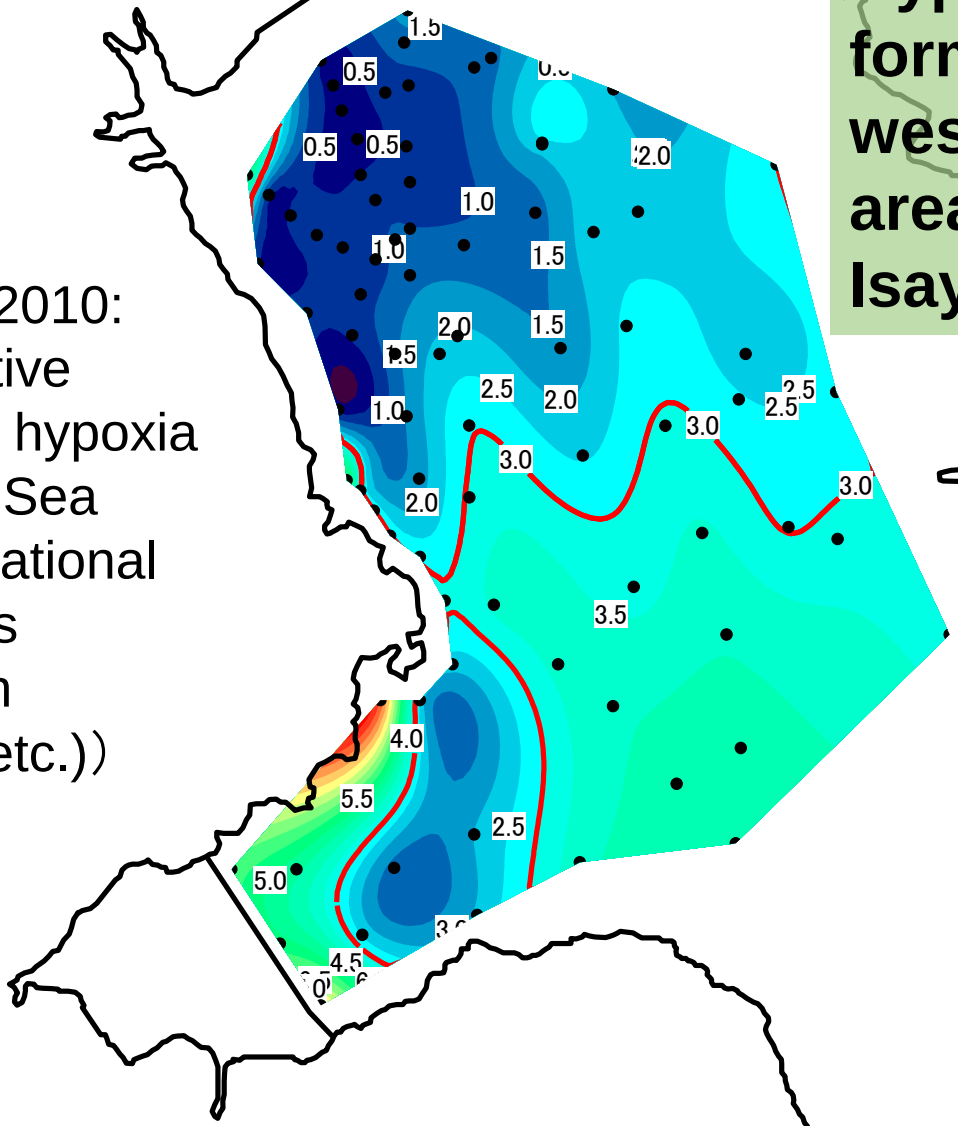


1952 — 2009

Occurrence of hypoxia

Bottom layer DO（mg/L）

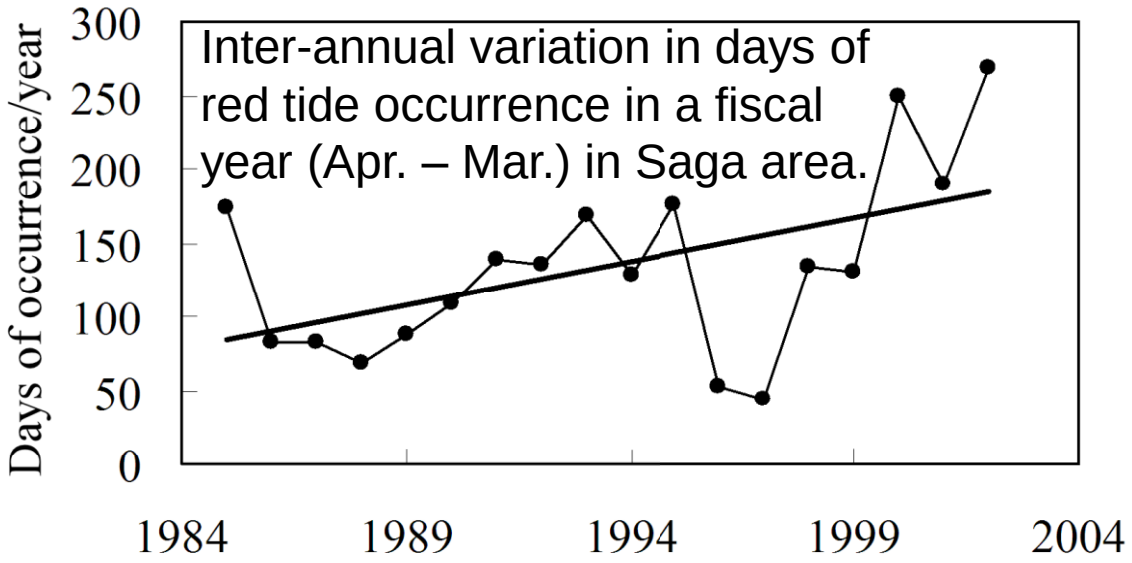
Hypoxic water mass was formed in the north-western part of the inner area of Ariake Sea and Isayaha Bay, respectively

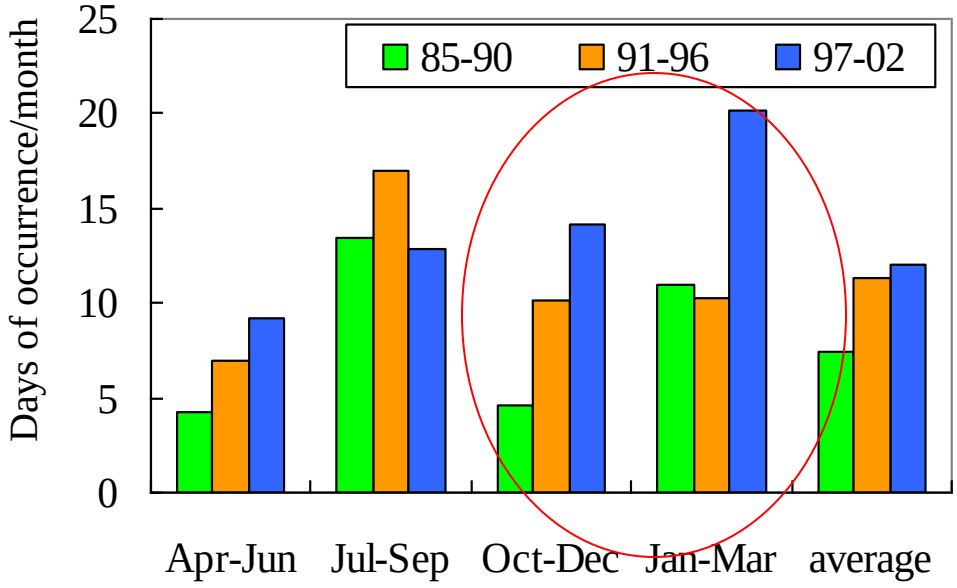


（4, Aug 2010: Cooperative survey of hypoxia in Ariake Sea (Seikai National Fesheries Research Institute etc.)）

Increase in red tide

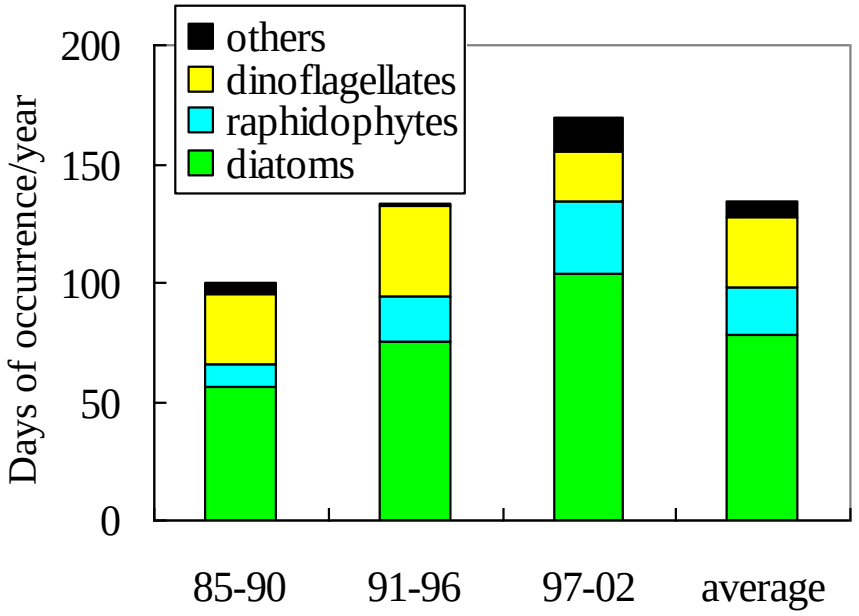
Red tide occurrence is monitored by visual survey with boat by the fisheries experiment stations of 4 prefectures.





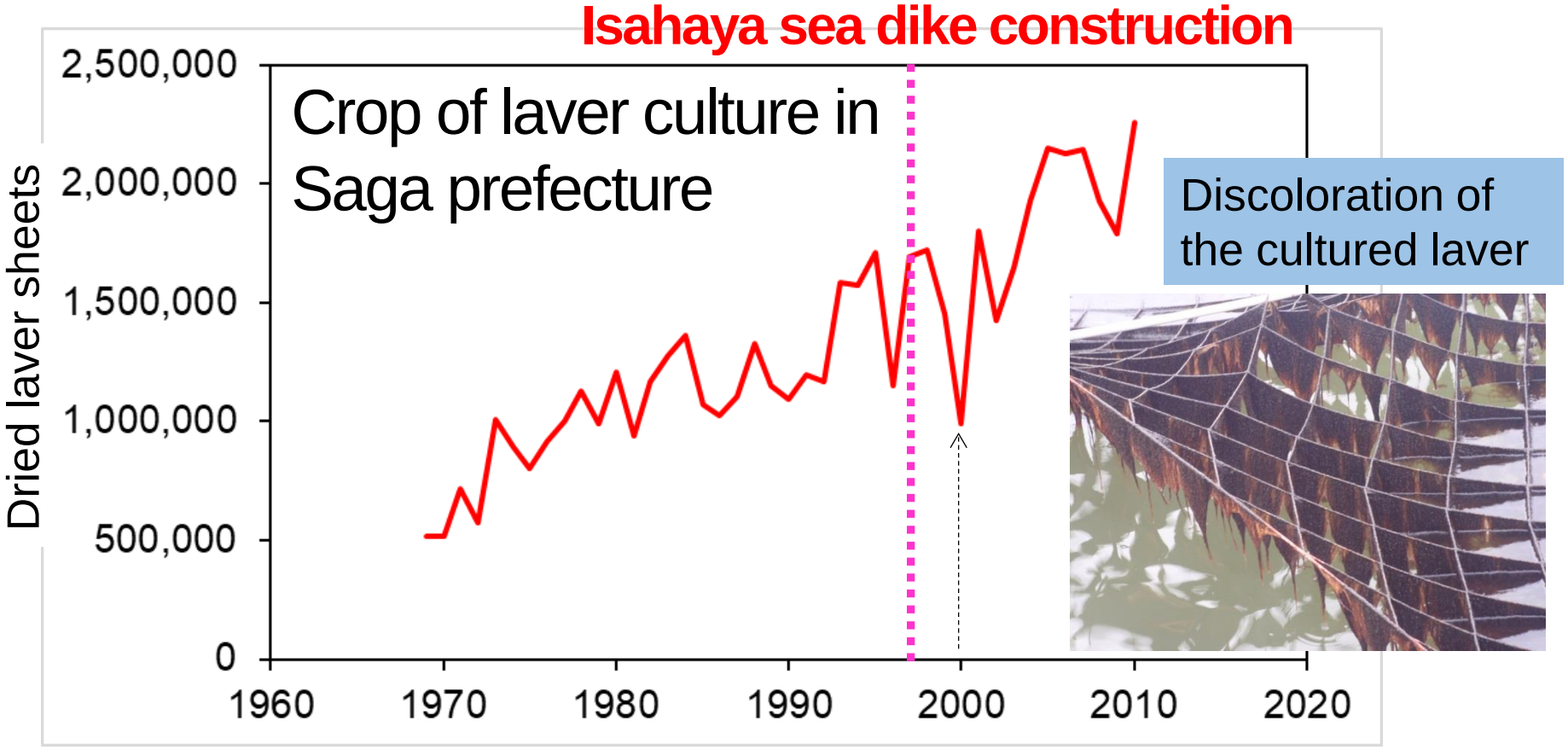
Comparison between seasons of the change in days of red tide occurrence.

Change in days of red tide occurrence per year with their composition of dominant species.



Serious low crop of laver culture in 2000

Reason for that the environmental and fisheries problems in Ariake Sea became a big social problem that had attracted attention from all over Japan

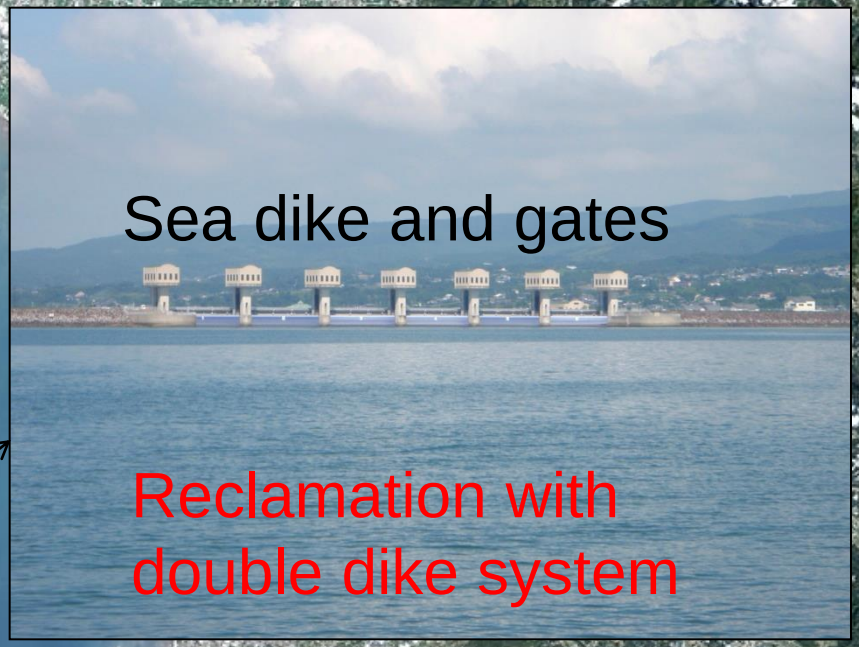


Saga City

Chikugo R.

The Isahaya Bay reclamation

Shut off by construction of the sea dike in 1997
Completed in 2008



fresh water reservoir

reclaimed land

Honmyo R.

Isahaya Bay

諫早湾

7km

Isahaya City

Reason for the environmental and fisheries problems?

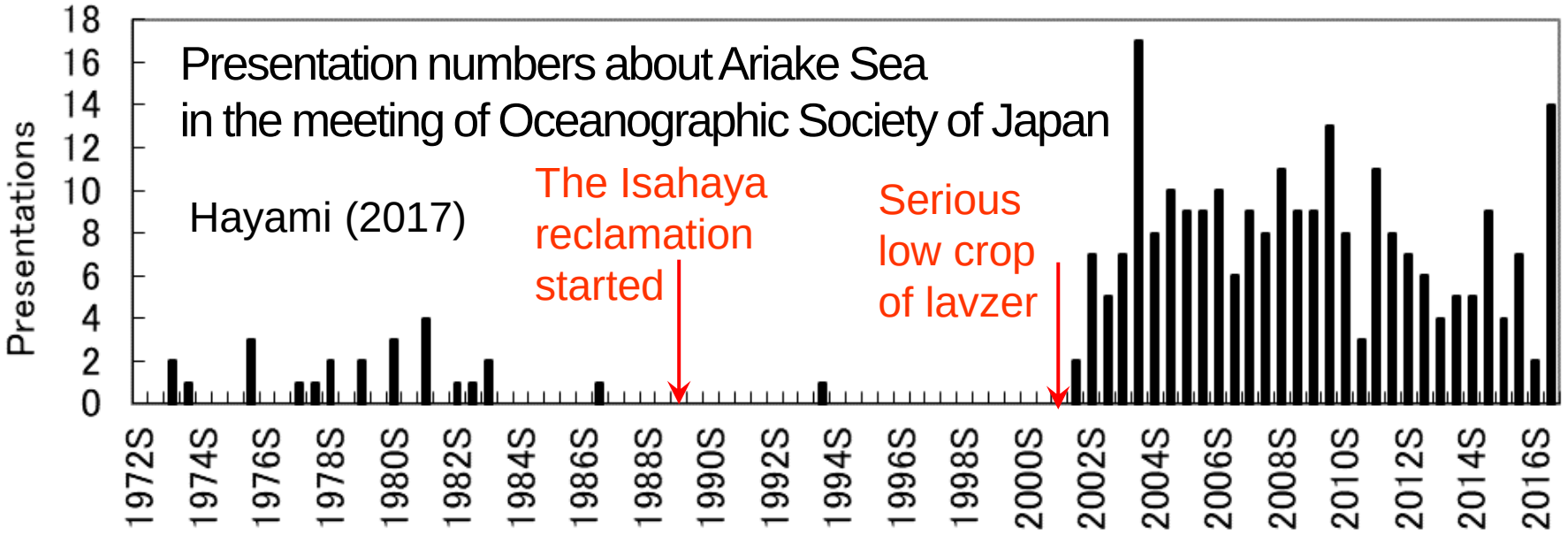
The purpose of monitoring?

1) Early warning for problems

2) Catch of the long term change

3) Elucidation of the mechanism of the environmental change

Research and observation data were very limited in Ariake Sea before 2000

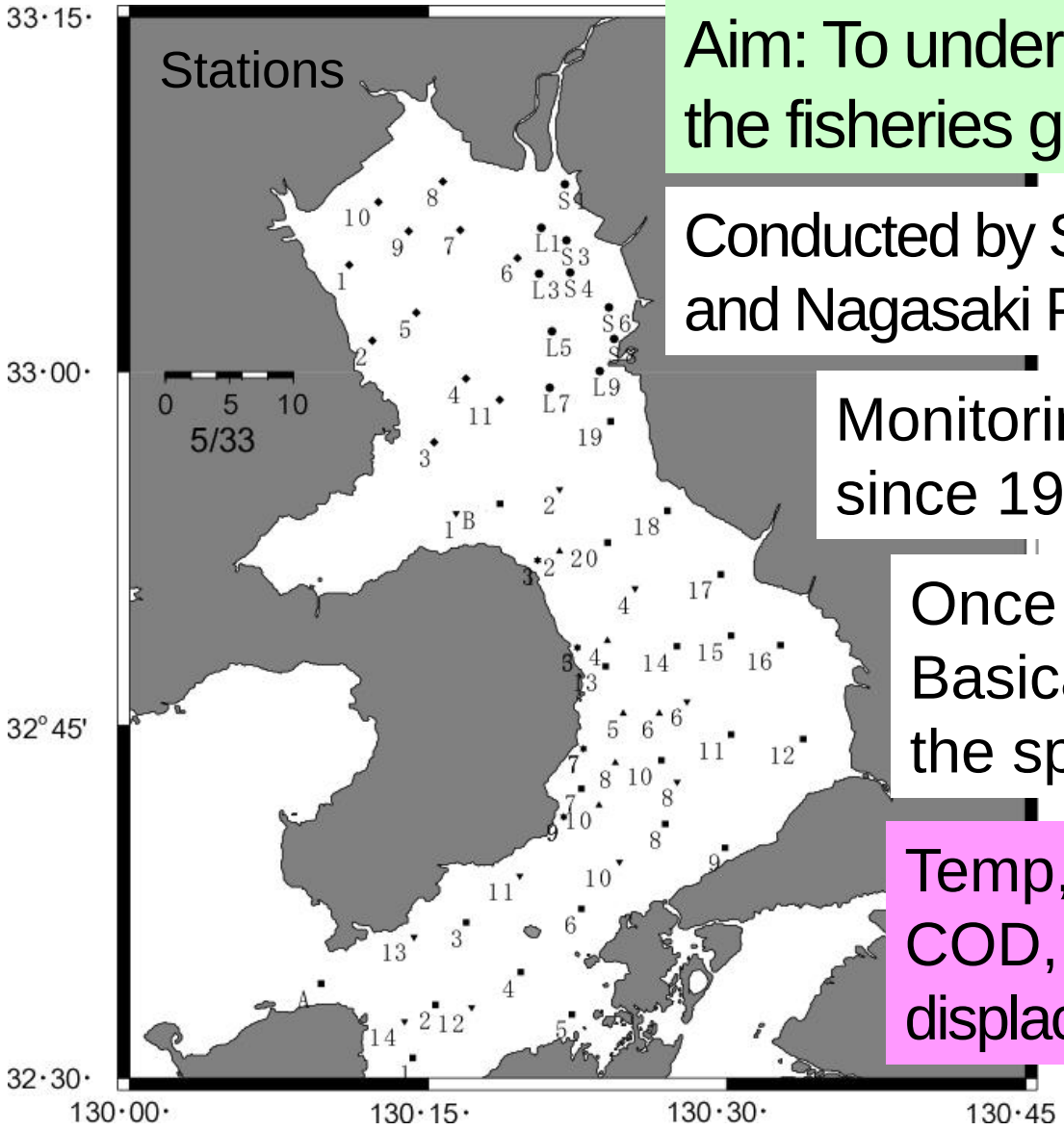


Until 2000 when the serious low crop of laver became a big social problem, the research and monitoring activity in Ariake Sea were very limited

Only the monthly oceanographic monitoring by the fisheries experimental stations of the 4 coastal prefectures was conducted

One of the principal reasons why the answer to solve the Ariake Sea problem was not obtained, though a lot of research efforts in this 15 years

Monthly oceanographic monitoring conducted by the prefectural fisheries experimental stations



Aim: To understand the environment of the fisheries ground and its variation

Conducted by Saga, Fukuoka, Kumamoto and Nagasaki Prefectures

Monitoring has been continued since 1972

Once a month
Basically during the high tide of the spring tide

Temp, Sal, Secchi depth, DO, COD, pH, Nutrients, Plankton displacement volume, etc

First report of the hypoxic water mass in Ariake Sea

Ariake Sea: Large tidal range and tidal current

↓

Active vertical mixing

↓

massive hypoxia would not occur

(but, no data in neap tide when tidal current diminished)

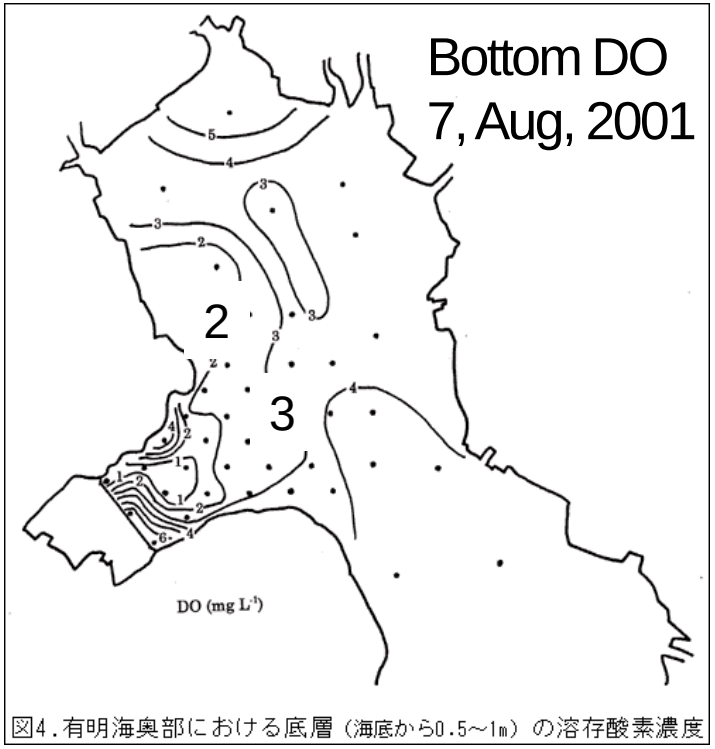


図4．有明海奥部における底層（海底から0.5～1m）の溶存酸素濃度

Murakami et al, 2001
(http://www.nacsj.or.jp/archive/2001/08/232/)

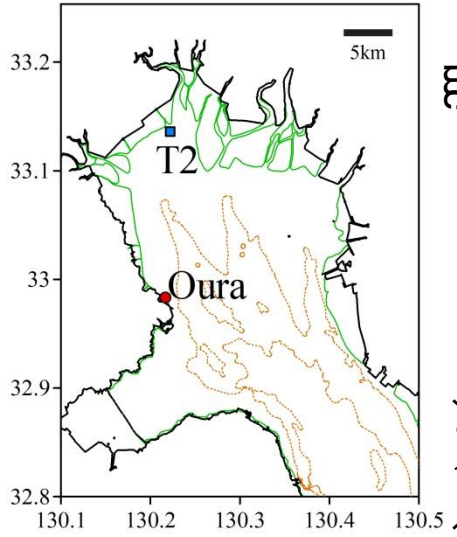
The first report of the massive hypoxic water mass

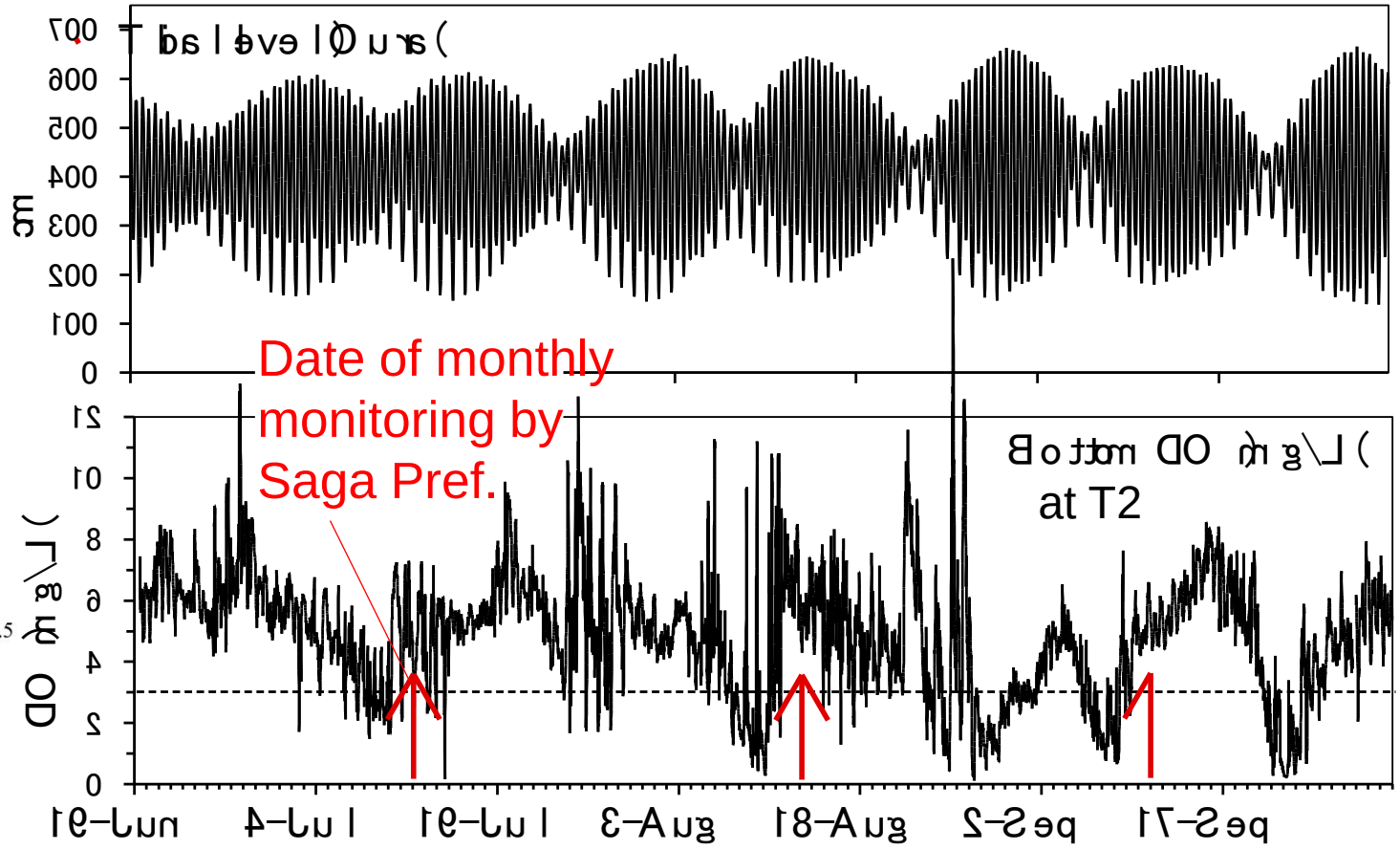
The needs for the monitoring of DO (hypoxia) became important

Hypoxia in Ariake Sea

Hypoxia has been observed every summer from 2001 in Ariake Sea
Massive kills of shellfish occurred when the hypoxia occurred (Okamura, 2010; Aramaki and Ohkuma, 2011)

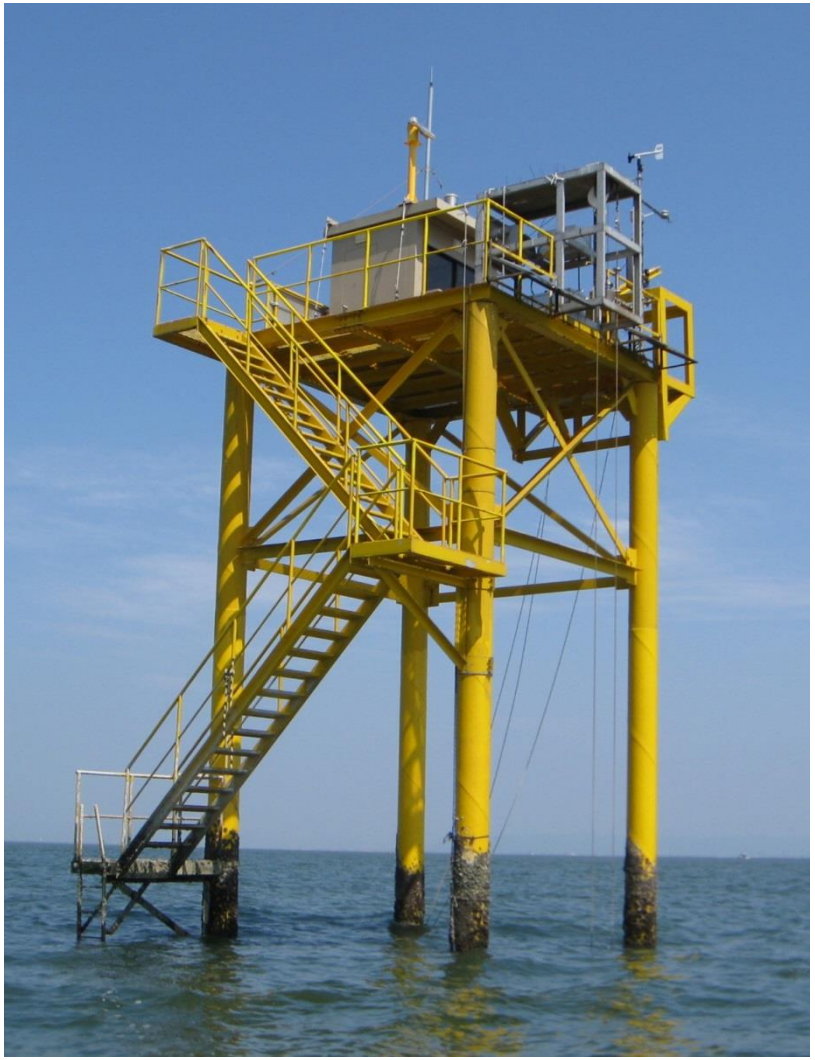
It has large short time fluctuation caused by the neap-spring tidal variation and winds





DO data from Seikai NFRI

Continuous monitoring in Ariake Sea 1



Monitoring tower of Saga University

Monitoring parametars

Profiles of water quality and current

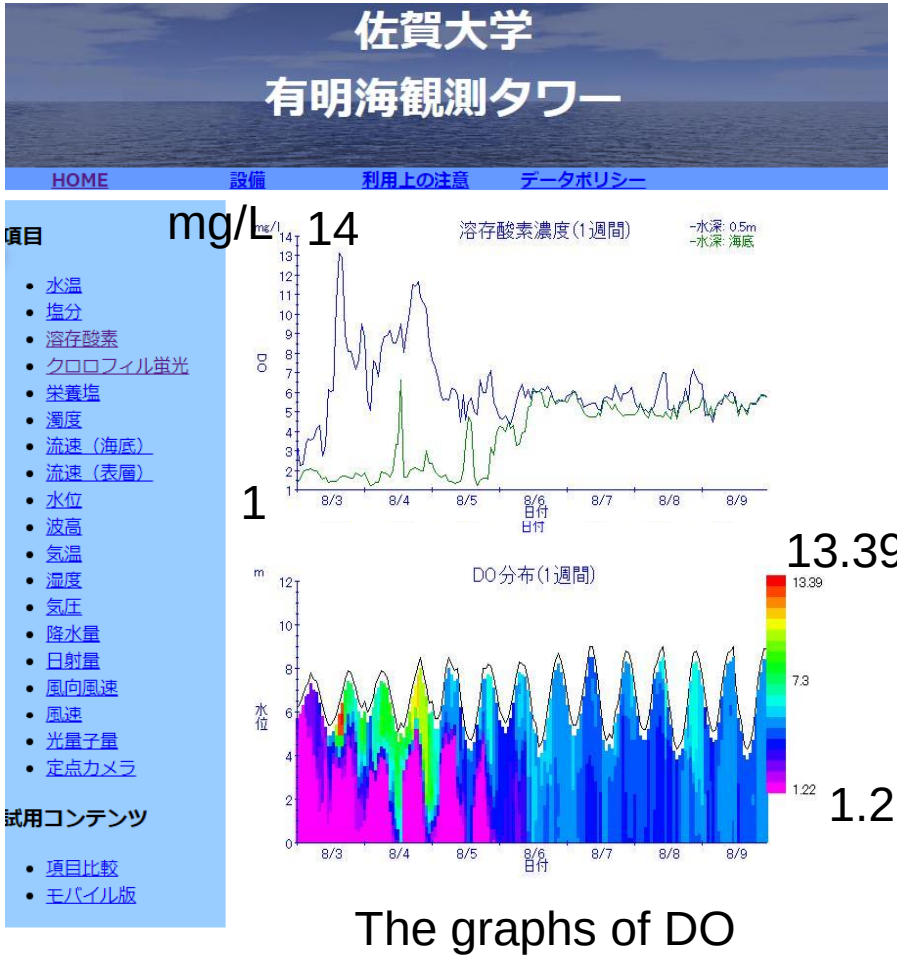
Sea level and wave

Weather

Automatic vertical profiling system of water quality

Real time information in the web sites

The data can be seen freely in real-time via Internet



The graphs of DO

Web site of the Saga University real-time monitoring system
(http://www.ilt.saga-u.ac.jp/aripro/tower/index.html)

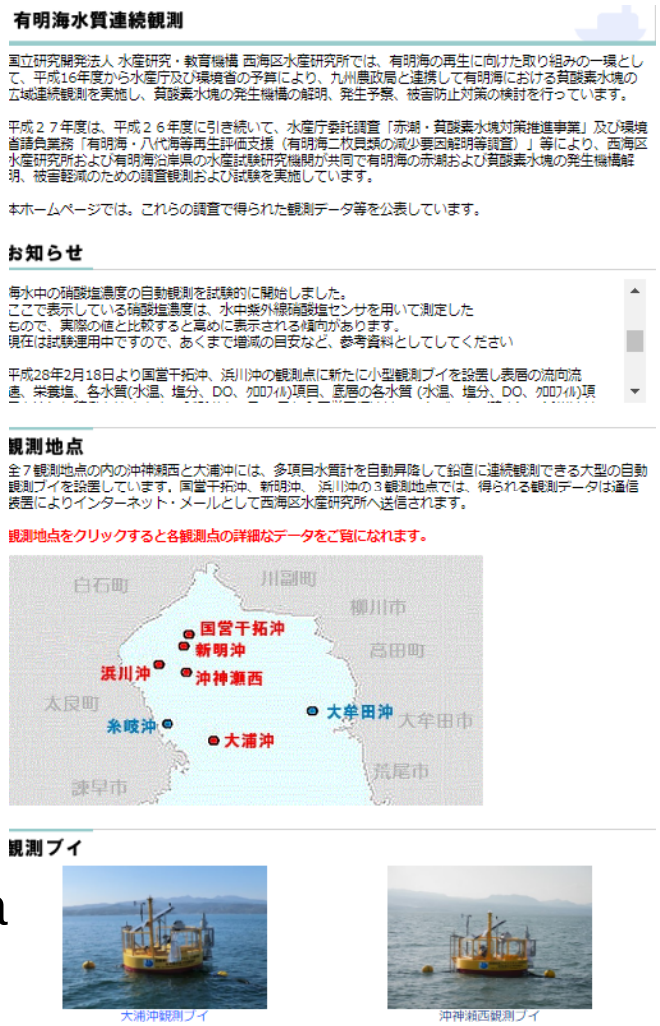
Continuous monitoring in Ariake Sea 2

Monitoring buoy of Seikai National Fesheries Research Institute

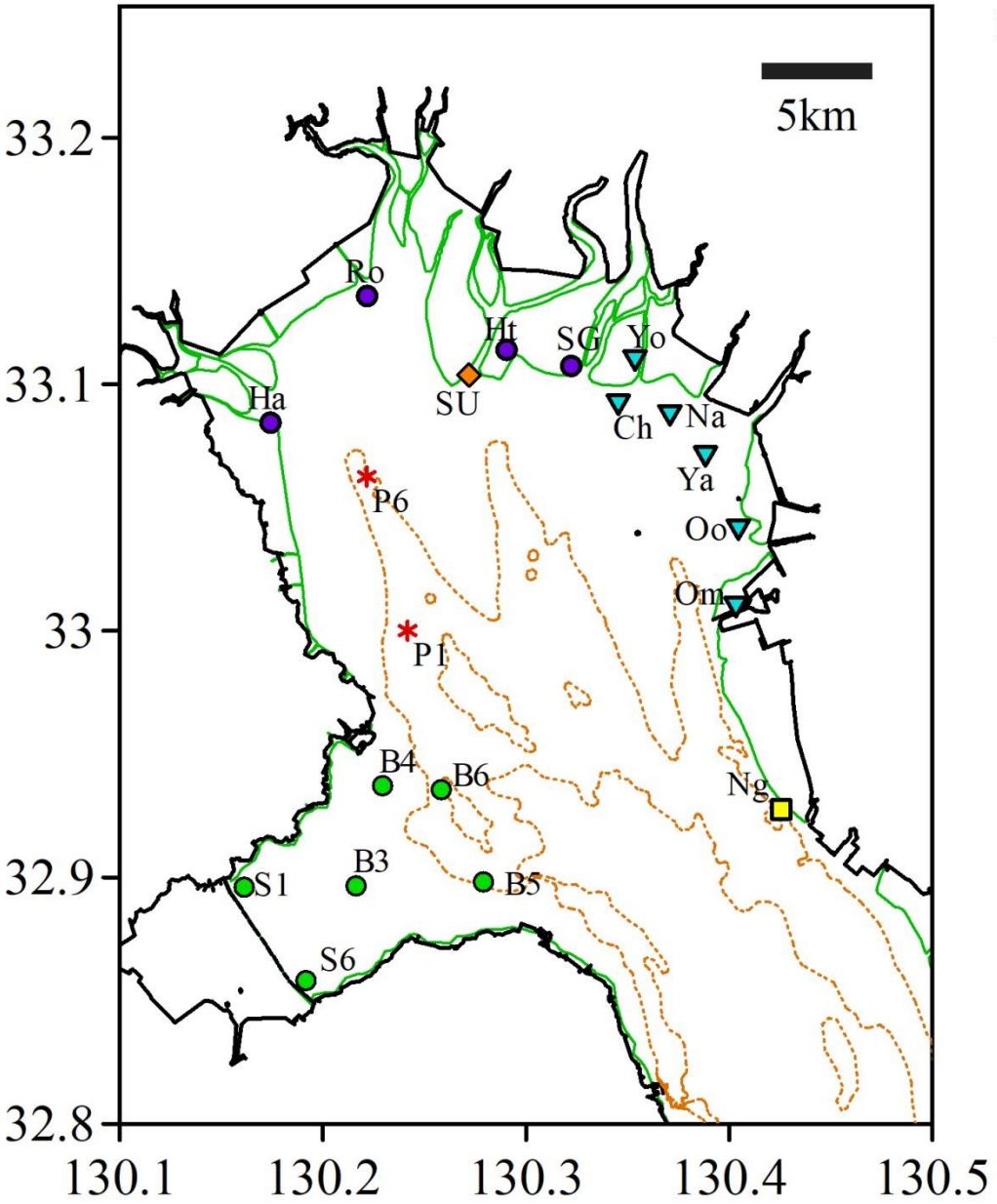
Monitoring parametars

Profiles of water quality, irradiance and current
Sea level
Wind

Web site of Seikai National Fesheries Research Institute (http://ariake-yatsushiro.jp/ariake/top2.htm)



Location of the monitoring towers and buoys



- Kumamoto (Buoy) — Prefecture
- Fukuoka (Buoy) — Prefecture and Fishermen Co-op
- Saga (Tower) — Prefecture and Fishermen Co-op
- Seikai NFRI (Buoy)
- Kyushu RAAO (Tower)
- Saga Univ. (Tower)

Monitoring vertical profiles

Kumamoto conducts monitoring only surface temp. and sal. Including other 2 stations located in the southern area

Saga and Fukuoka conduct monitoring (surface temp. and sal.) only in the laver culture season (Oct.-Apr.)

Merits of the monitoring by buoys and towers

Continuous data
Short time variation can be observed (neap-spring tidal variation, wind induced variation, etc)

Real-time data
Researchers are using to plan the field survey by boat

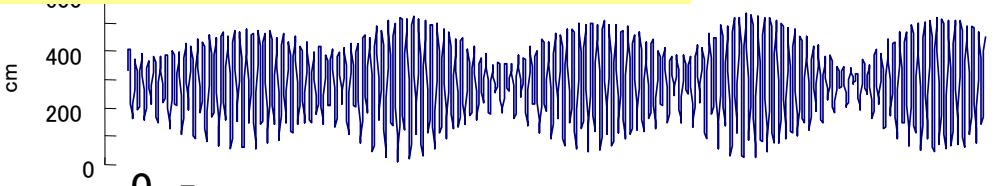
Commercial fishermen and citizens are using
(For aquaculture, fishing, etc)

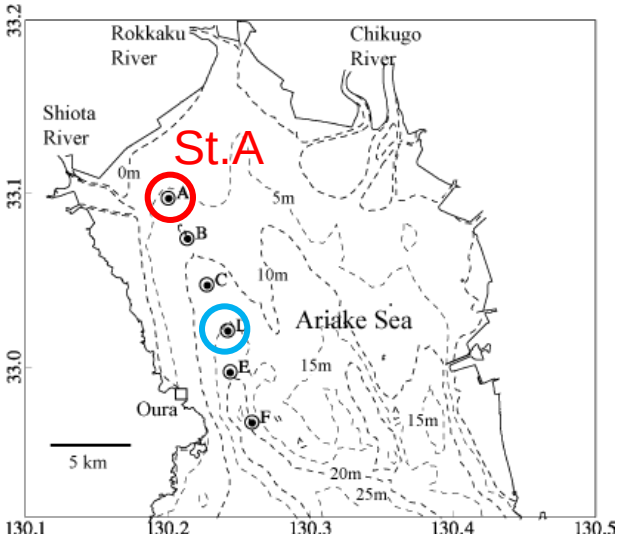
Continuous data + ship survey
Make it easy to understand the mechanisms of the environmental variation deeply

Neap-spring tidal cycle of bottom DO

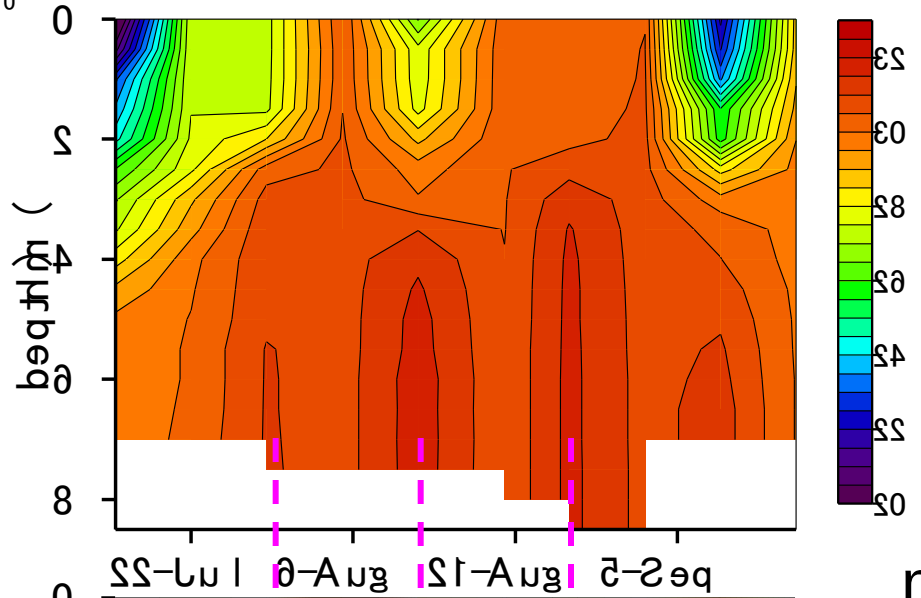
Hayami (2007)

Tide level at Oura



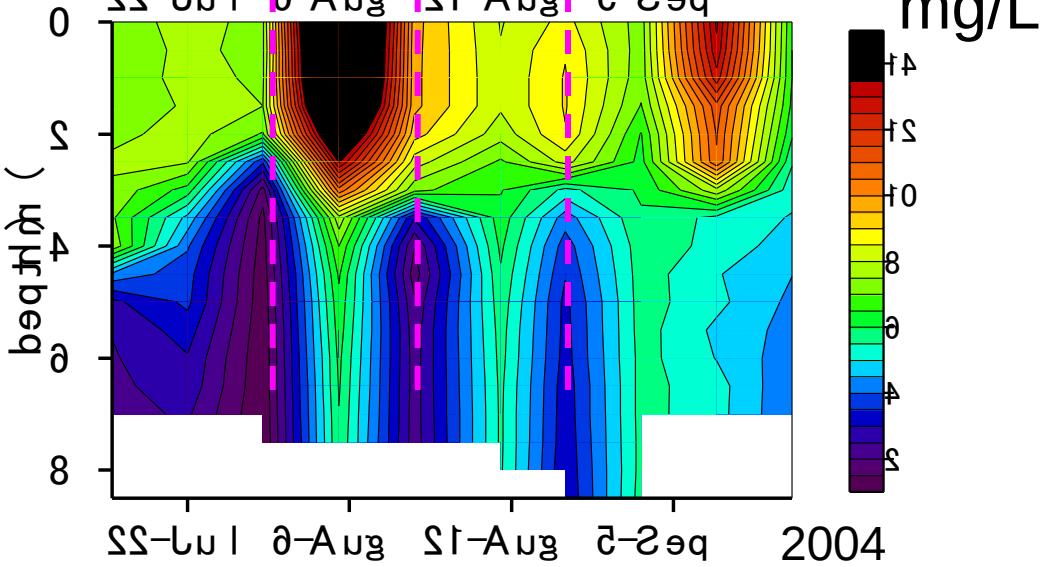


Sal.



DO

mg/L



Spring to neap tide

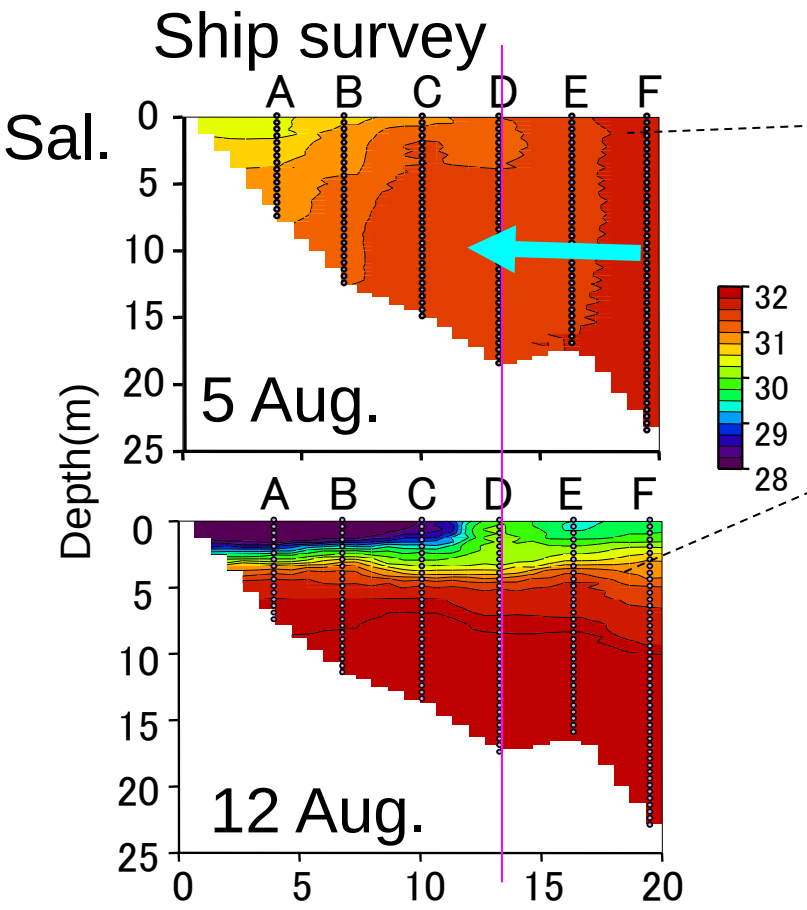
Increase in salinity
Decrease in DO

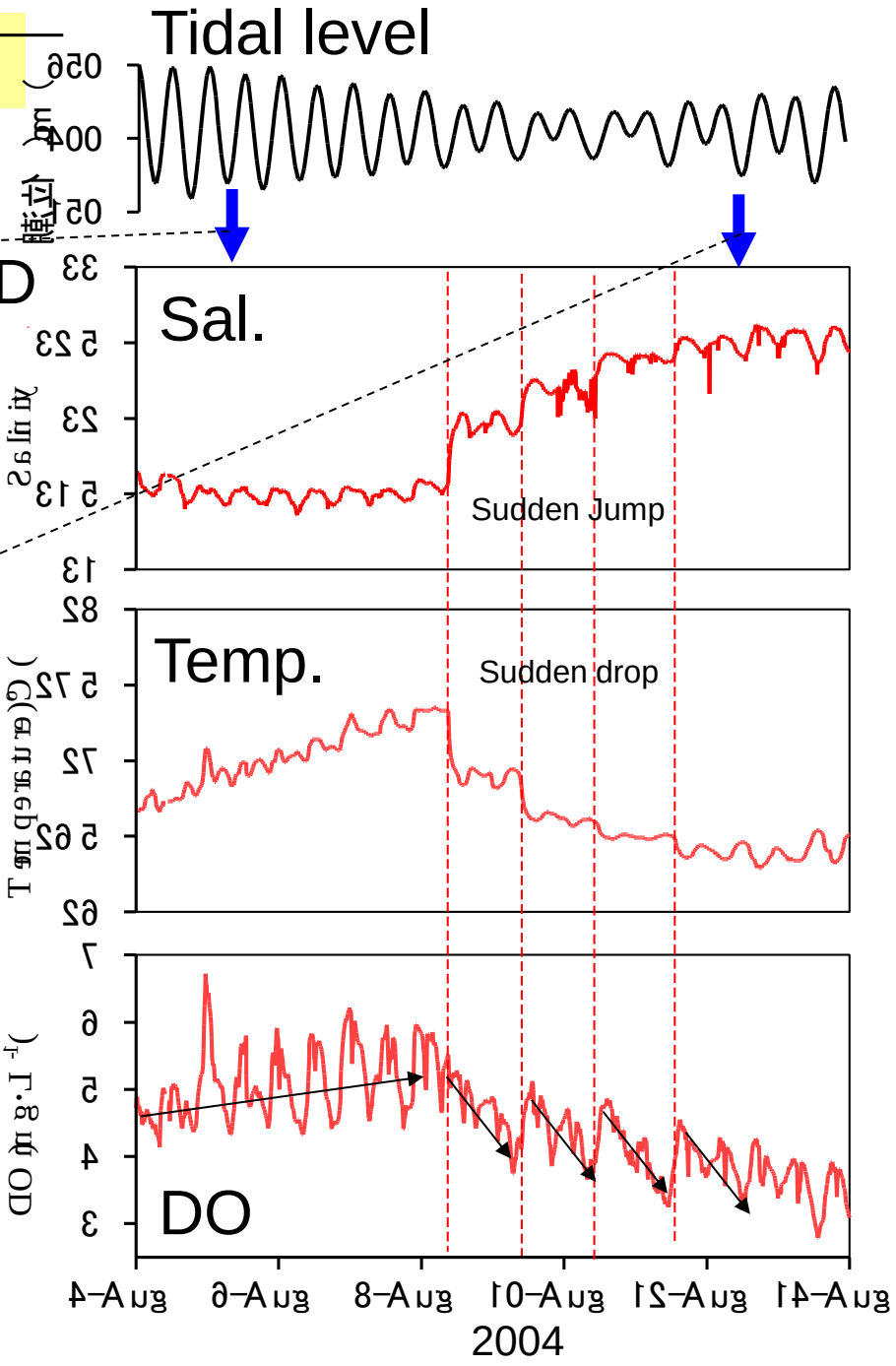
⬇

Hypoxia in neap tide

(Data from Kyusyu Regional Agricultural Administration Office)

Variation of bottom water at St.D





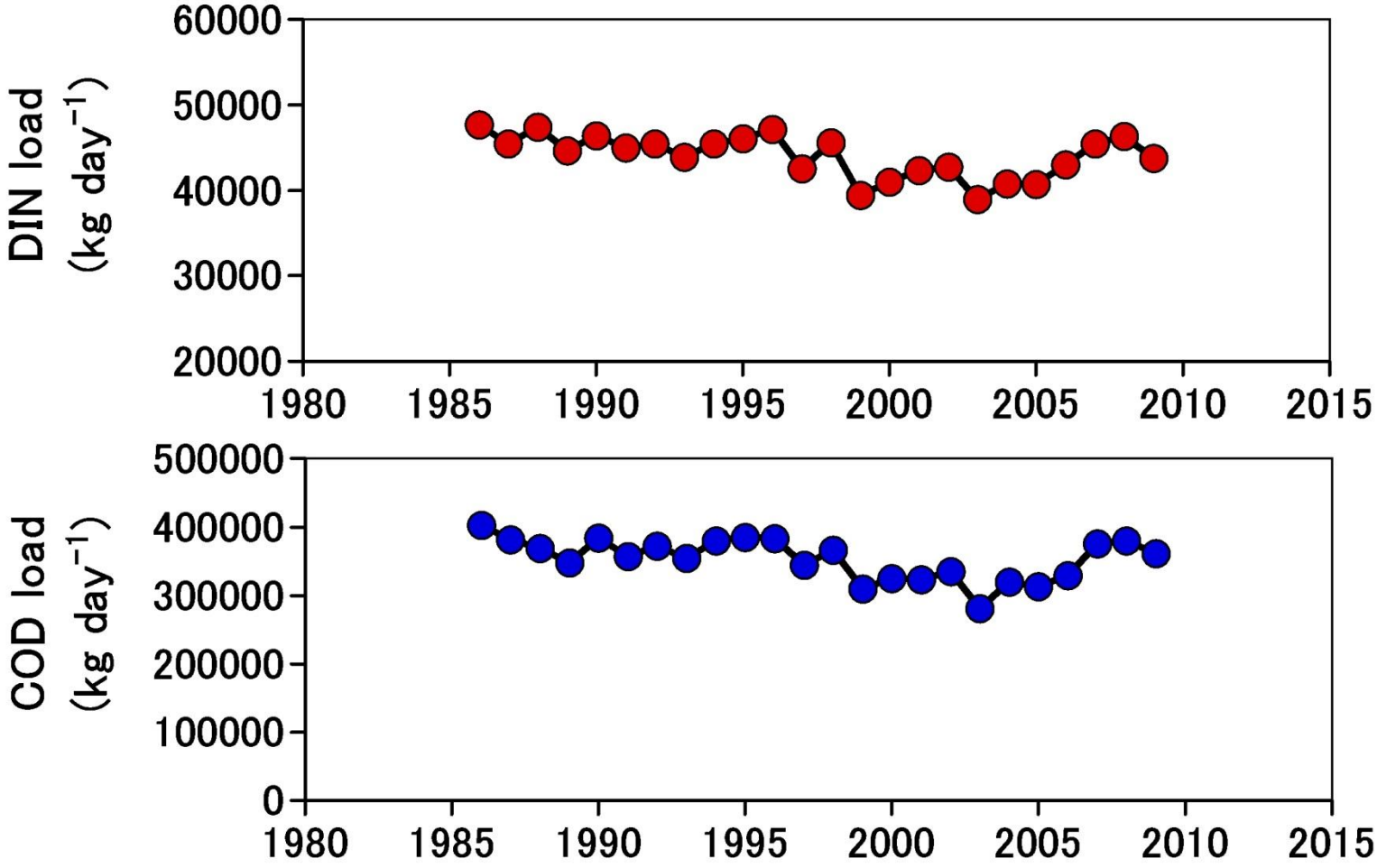
Salinity Jump in neap tide

Bottom DO decreased when the intrusion of high sal and low temp water occurred

How about the long term change?

What can we find from the limited monitoring data?

Riverine loads of COD and DIN into the inner area of Ariake Sea in July and August (11 years running mean)

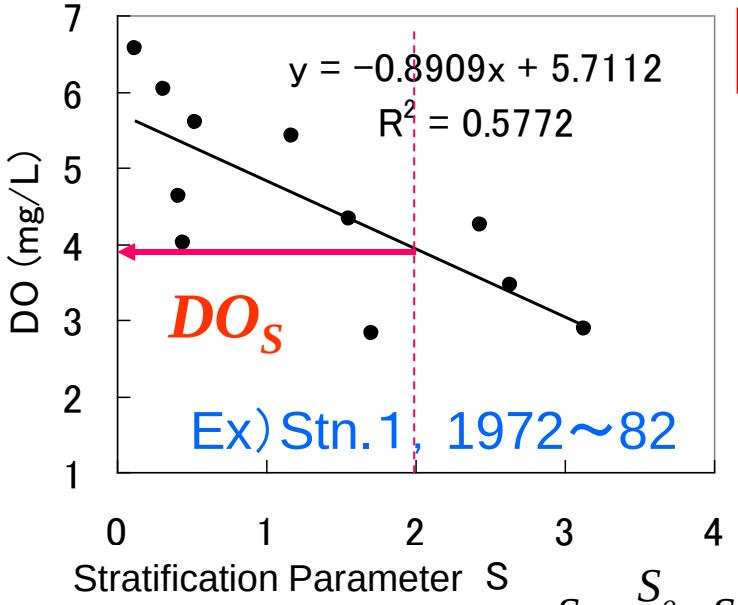


(Hayami and Fujii, accepted)

No increase in terrestrial loads, but red tide and hypoxia became problem

Long term change in bottom DO

Analysis of monthly data of Saga Prefecture



DO_s in July decreased from 1970s to early 90s

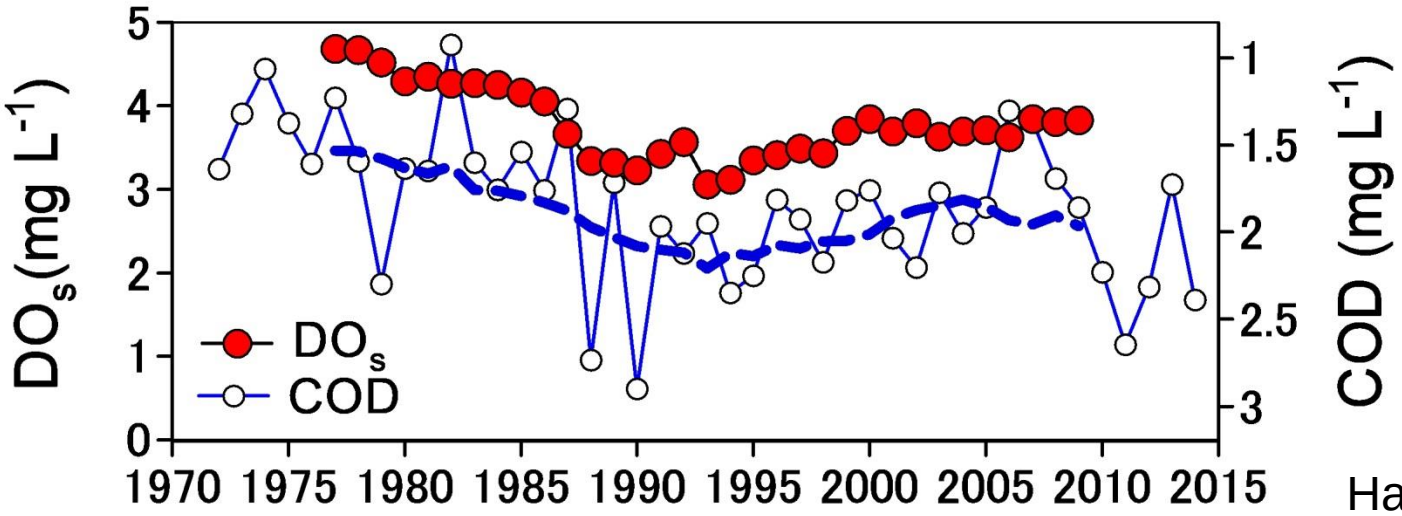
DO decrease when the variation in stratification was removed

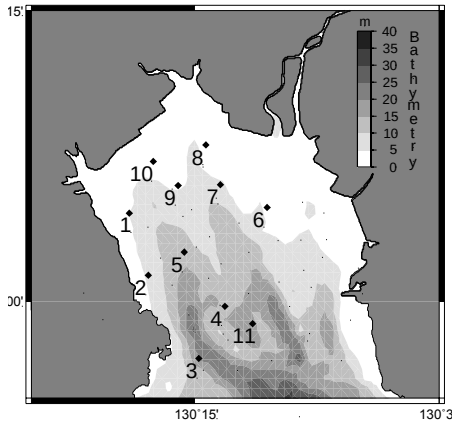
It suggests the increase of oxygen demand

Increase in organic matter??

$$S = \frac{S_o}{S_m}, S_o = \frac{(\rho_0 - \rho_{b-1m})}{h}$$

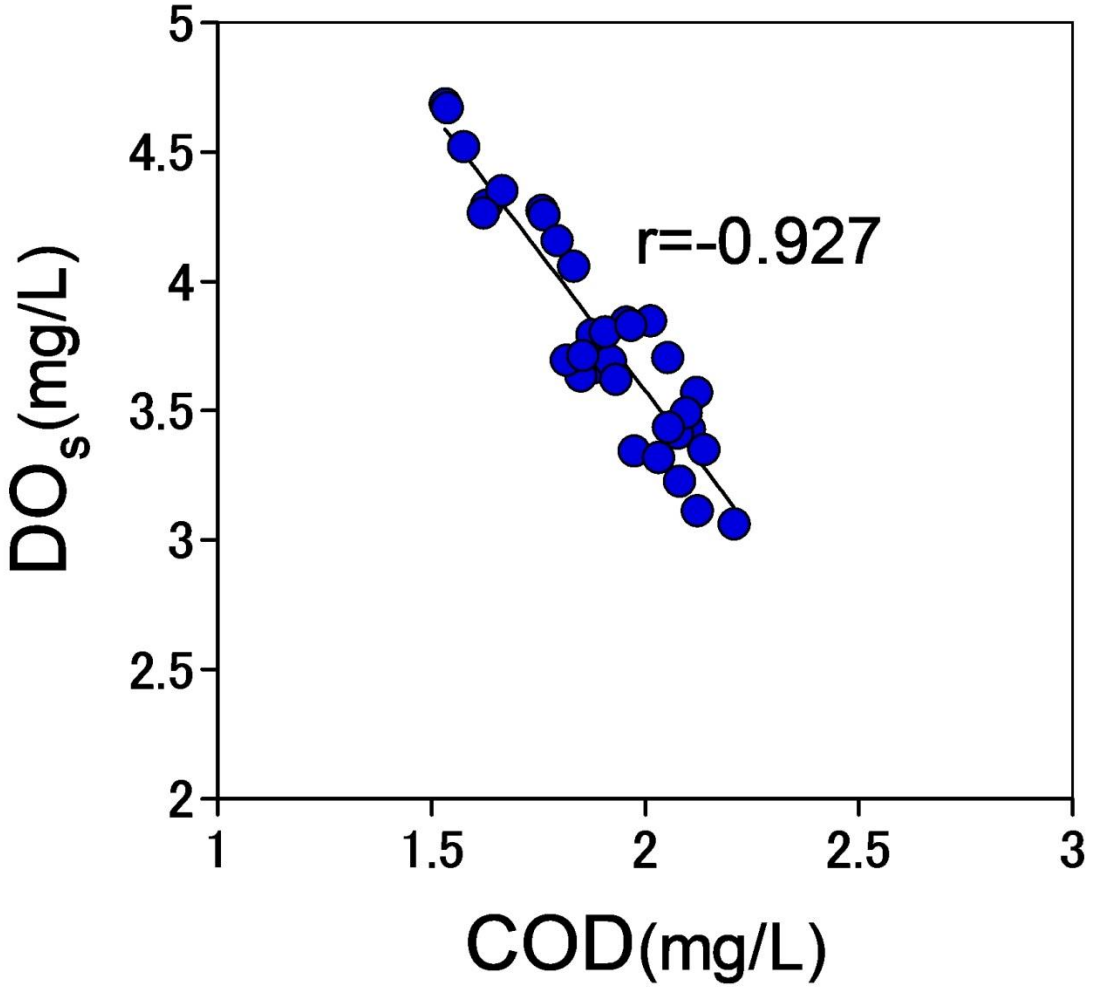
S_m: average in all the data period





Hayami (2007) modified

Relationship between DO_s and COD in July (11 years running mean)



It suggests that the progress in hypoxia was induced by the increase in organic matter

Why the COD increased from 1970s to early 90s?

Box model analysis

Analysis of monthly data of Saga and Fukuoka Prefectures

Data

Monthly monitoring data by Saga and Fukuoka Prefectures from June to August

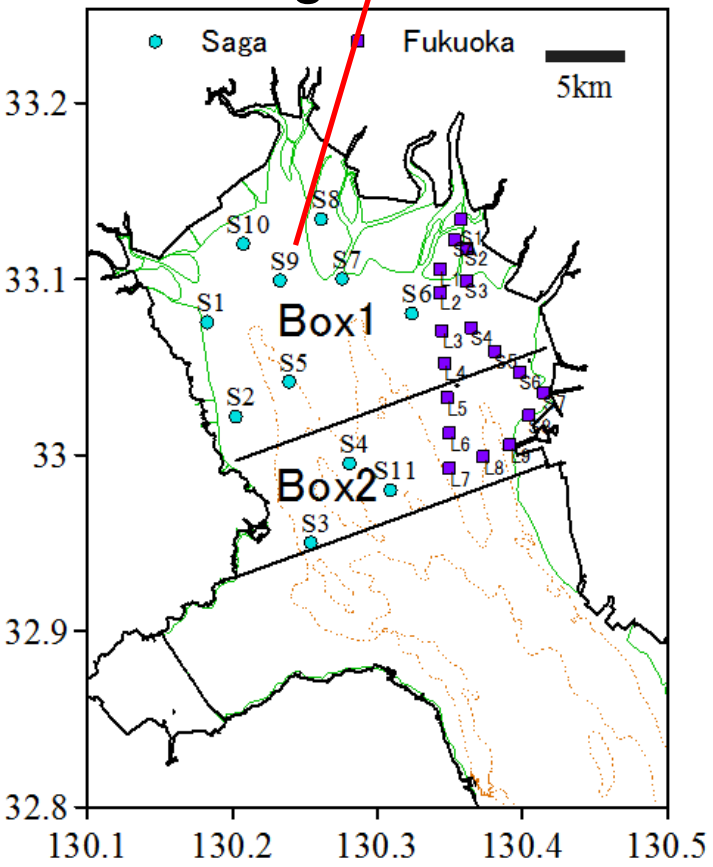
Salinity and COD

River discharge, riverine load of COD (Chikugo, Yabe, Kase and Rokkaku River)

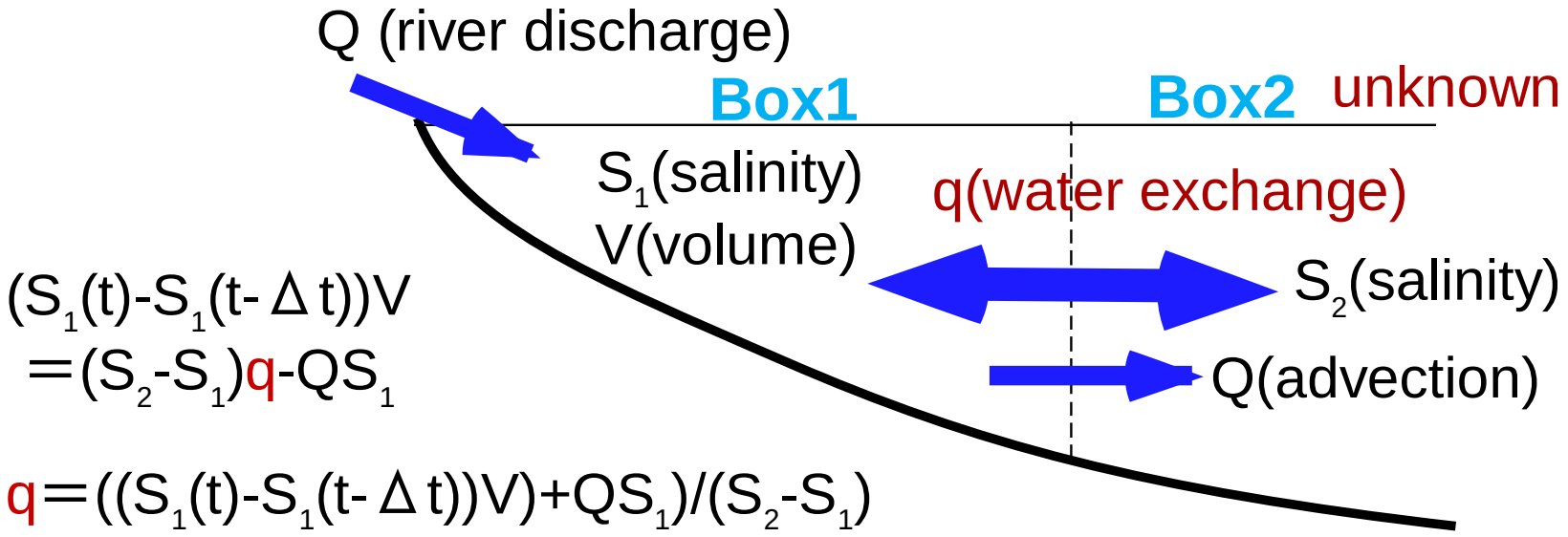
(Hayami and Fujii, accepted)

Calculate the budgets of salt and COD in Box 1

Monitoring stations



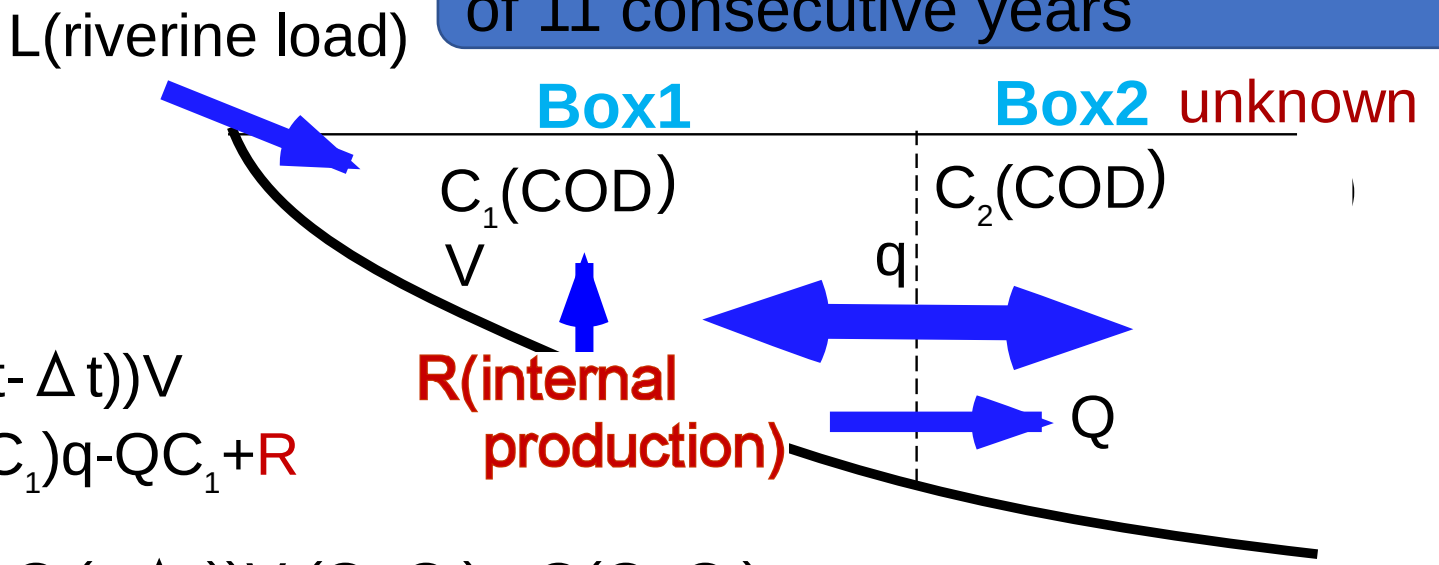
Method: Box model analysis



$$(S_1(t)-S_1(t-\Delta t))V = (S_2-S_1)q-QS_1$$

$$q=((S_1(t)-S_1(t-\Delta t))V)+QS_1/(S_2-S_1)$$

Make calculations for the mean field of 11 consecutive years

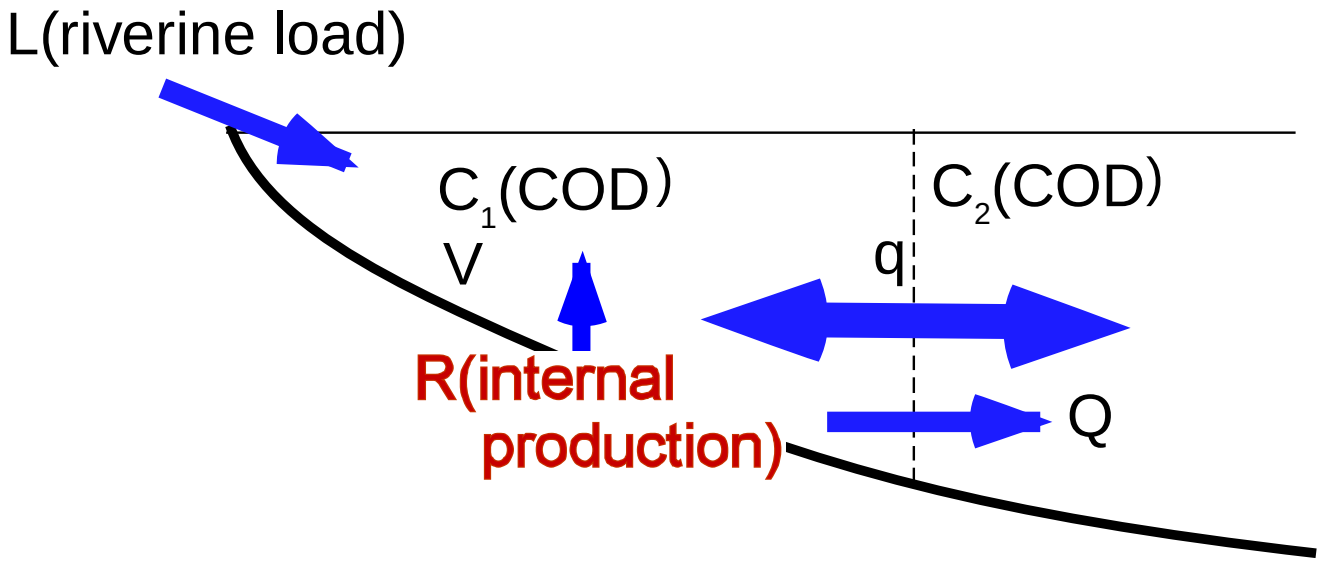


$$(C_1(t)-C_1(t-\Delta t))V = L+(C_2-C_1)q-QC_1+R$$

$$R=(C_1(t)-C_1(t-\Delta t))V-(C_2-C_1)q-Q(C_0-C_1)$$

Possible reasons

1)Increase in initial value (COD in June)
2)Increase in internal production
3)Decrease in runoff by advection and water exchange
4)Increase in terrestrial load



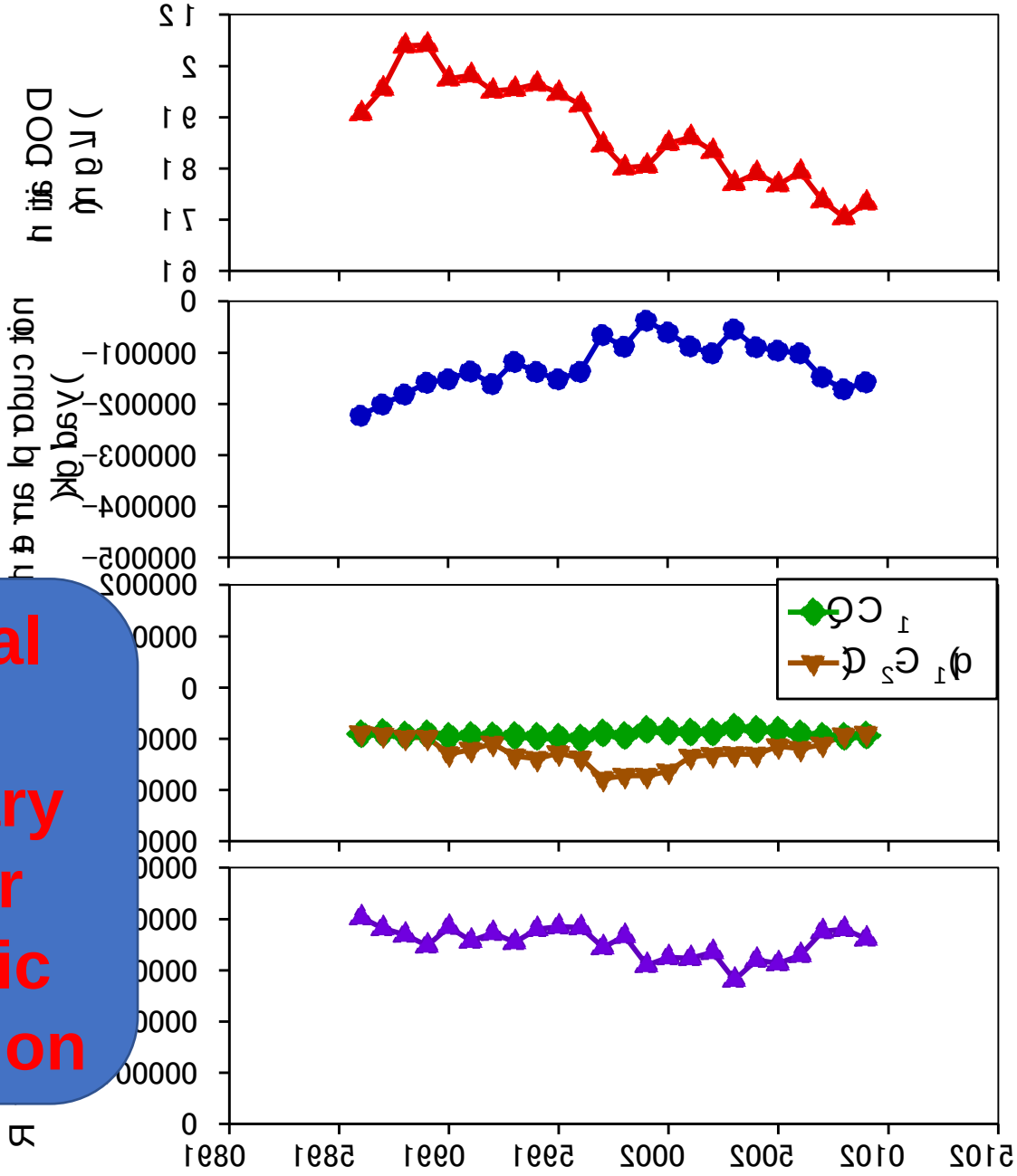
Interannual change in COD budgets in July&August

1980s-early 90s

initial value: increased from 1986-88, but then decreased.

internal production: increased

Increase in internal production =increase in primary production and/or decrease in organic matter decomposition



Summary The monitorings of Ariake Sea

1) Continuous real-time monitoring
   - ✓Catch the short time variations (ca. hypoxia development in neap tide)
   - ✓Understand their mechanism
   - ✓Useful for fisheries (laver culture, etc)

2) Monthly monitoring (more than 40 years)
   - ✓Clarify the long term variations and their mechanism

3) Other (e.g. benthos and bottom sediment)

   3 or 5 times in a year (Saga Univ.), 2 times in a year (Ministry of Environment), etc