Eutrophication and Oligotrophication Processes in the Seto Inland Sea and their relationships to the Satoumi concept

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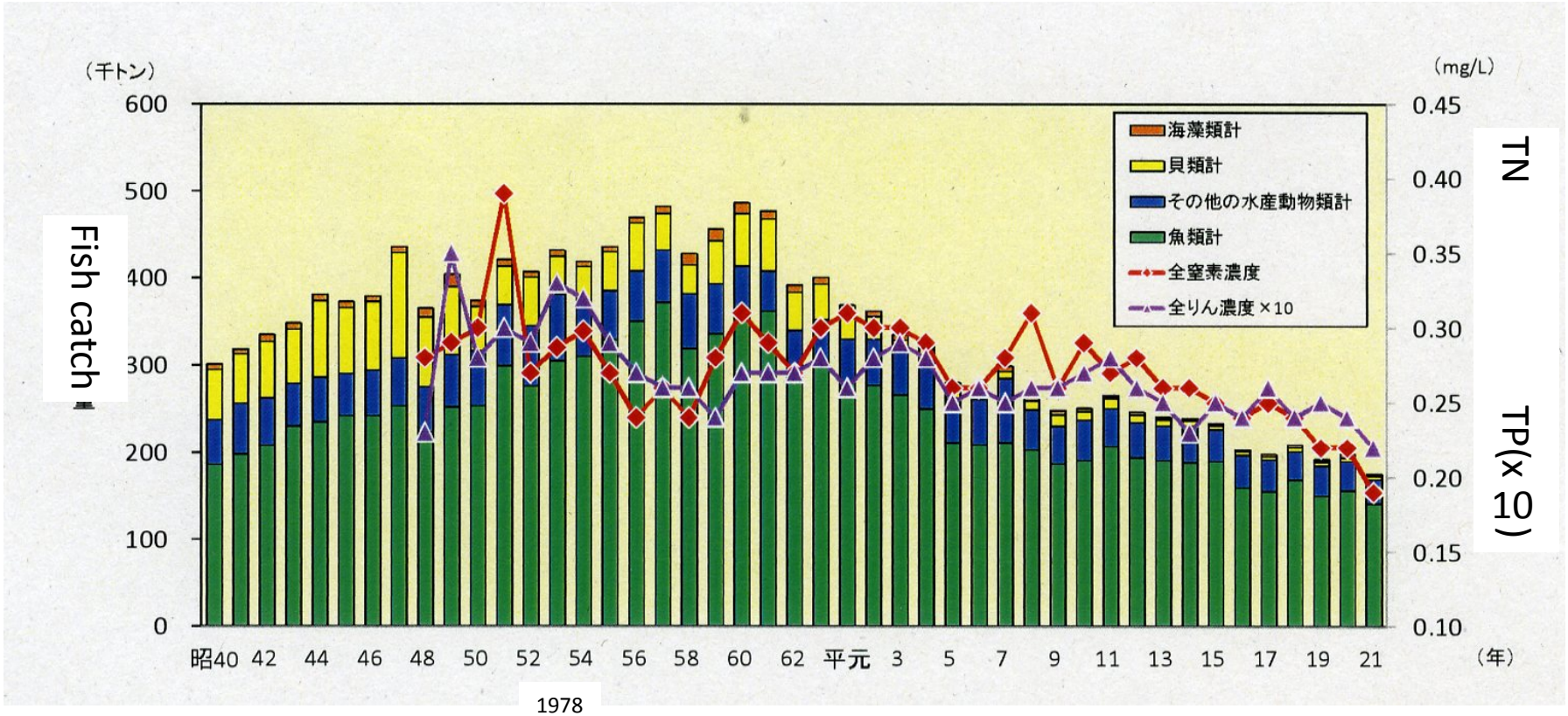
Seto Inland Sea

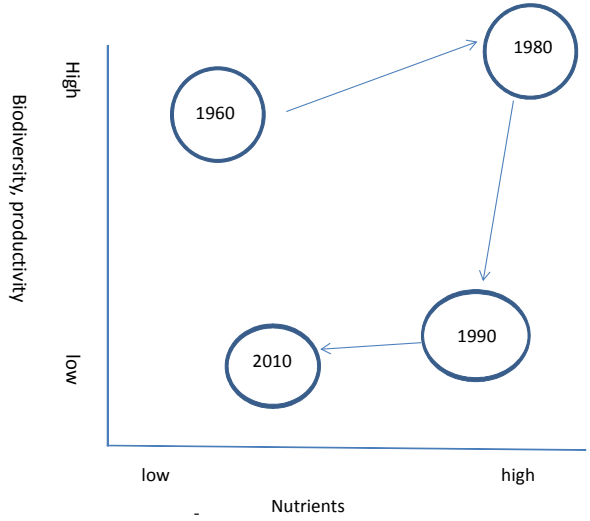
TN･TP concentrations and Fish catch



1978:Total Loads Control Law

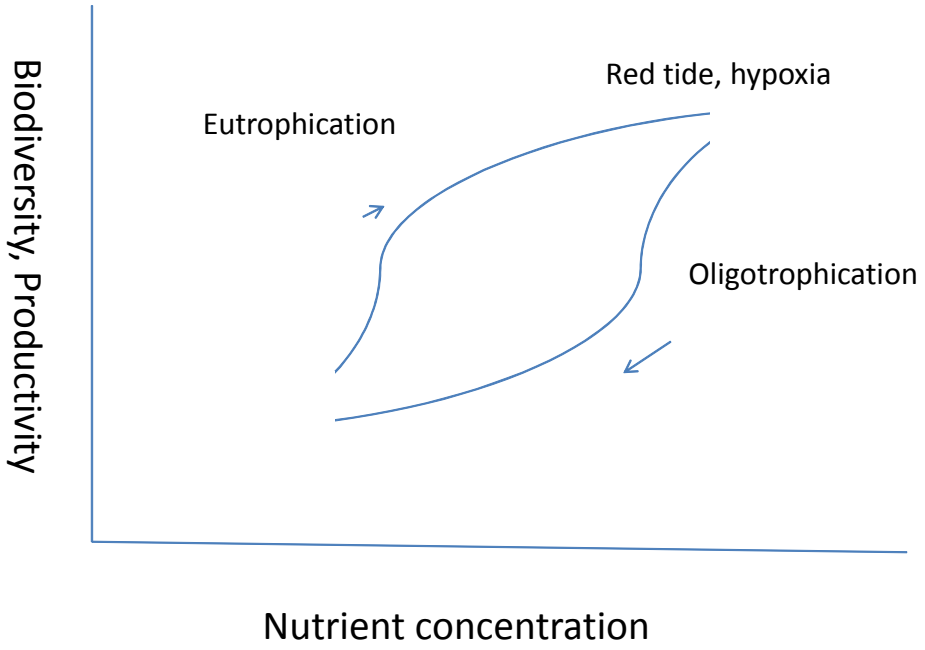
1963:New Industrial City Law

Hysterisis



1955 -1970 Rapid economic growth
1979 Total Load Regulation
1985 Fish catch max
1990 DIN decrease

Clarify the different mechanisms of eutrophication and oligotrophication



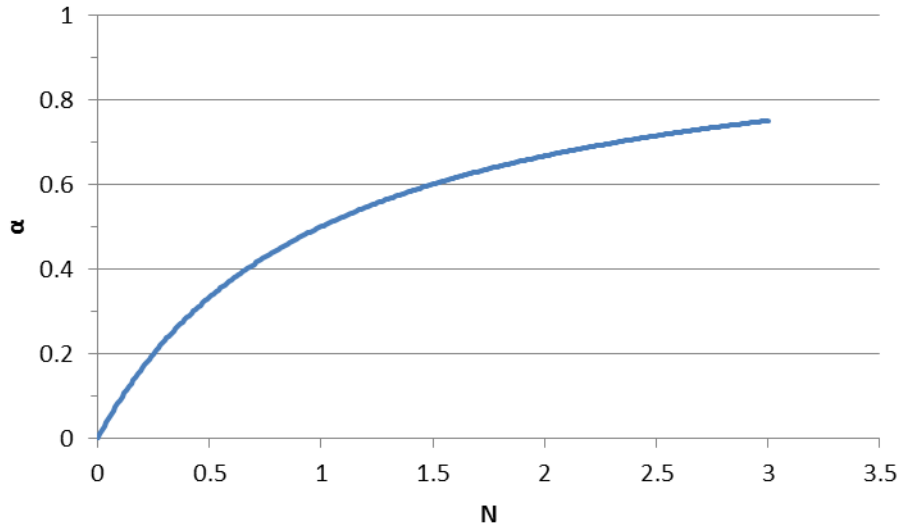
Multiple equilibrium solutions

- Phytoplankton cell density（X’）

（Michaelis-Menten kinetics）

$$\frac{dX'}{dt} = G\frac{N}{N + K_S}X' = \alpha X' \quad (1)$$

$$X' = e^{\alpha t} \quad (2)$$

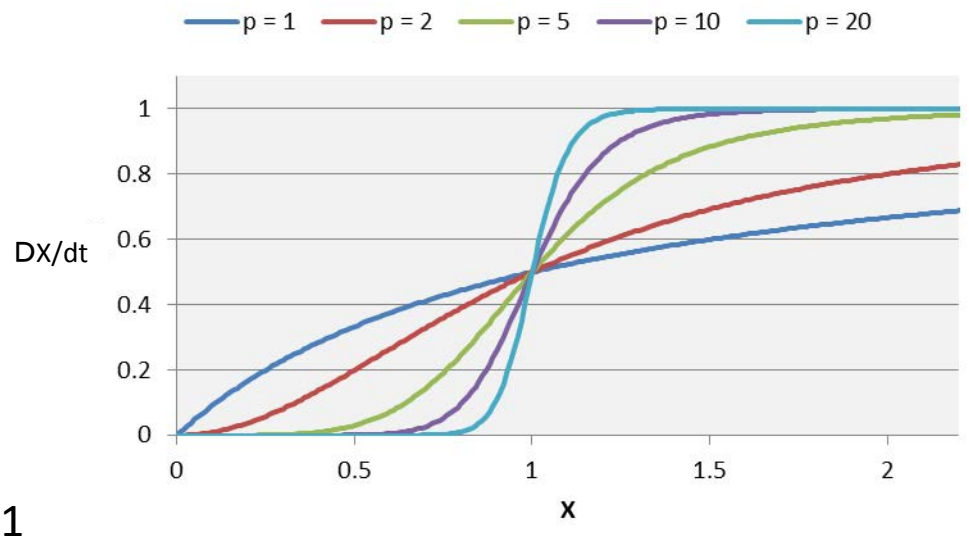


Ks=1

- Phytoplankton population (X) dynamics

（sigmoid (logistic) function）

$$\frac{dX}{dt} = \frac{cX^{p}}{X^{p} + h^{p}} \quad (3)$$



c＝h＝1

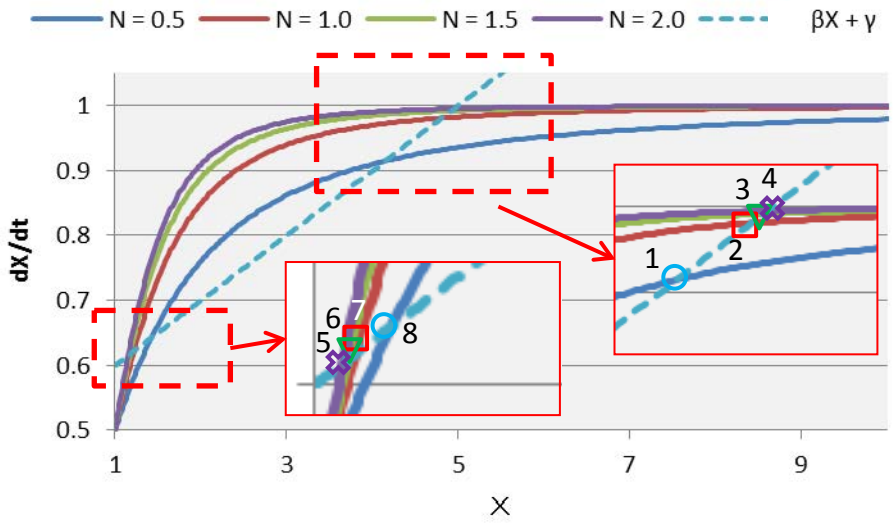
- Growth and Death･Grazing

$$\frac{dX}{dt} = \frac{X^{p}}{X^{p}+1} - (\beta X + \gamma) \quad (4)$$

$$X = \delta X' = \delta e^{\alpha t} \quad (5)$$

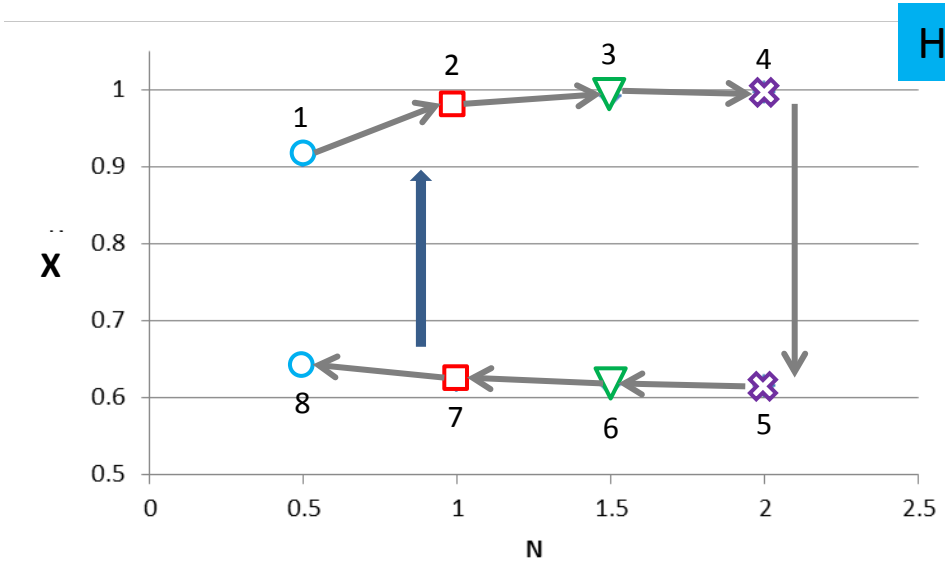
- dX/dt=0（quasi-steady） 1st term = (2nd+3rd)term

（p=1、β=0.1、γ=0.5）



Double intersections＝multi-equilibrium solutions

Nutrient concentration（N) and Phytoplankton population（X)

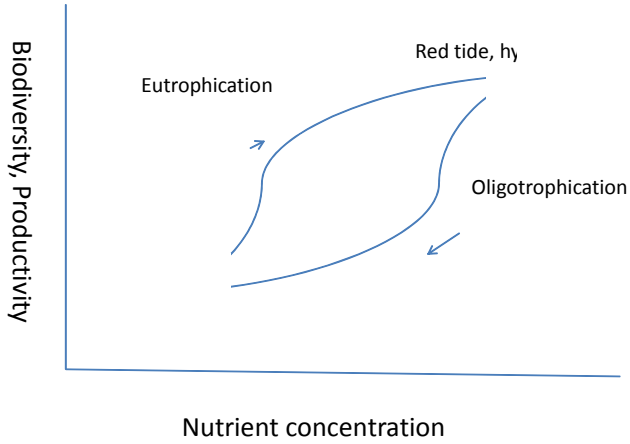


Hypoxia

Regime shift

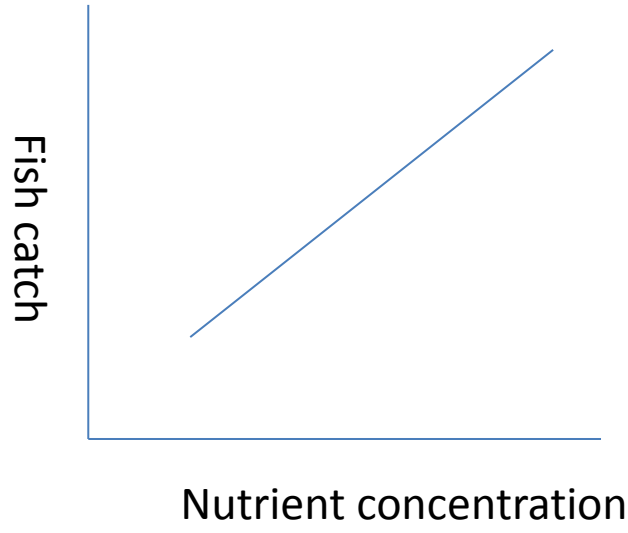
Another regime shift

Disappearance of Hypoxia ?

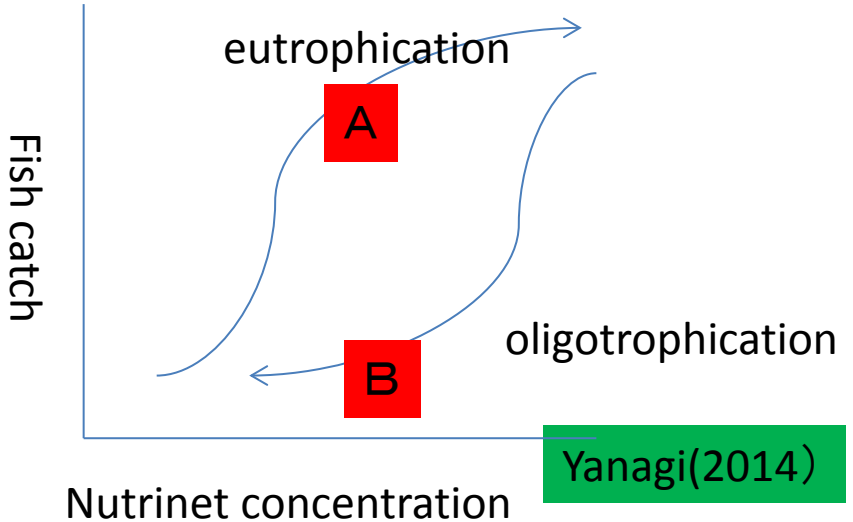


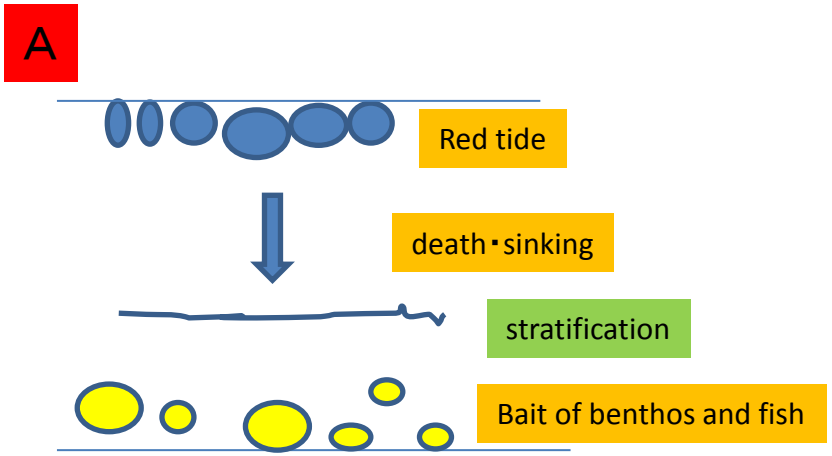
Nutrient concentration and fish catch

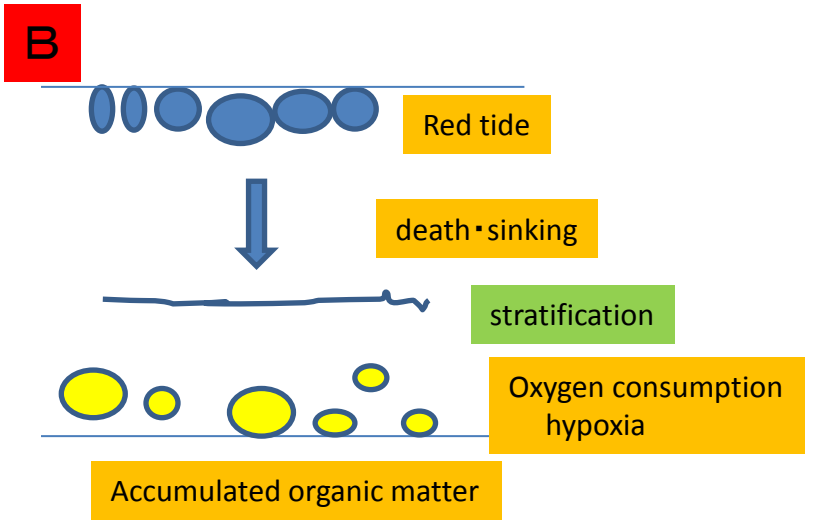
In the beaker（linear）



Seto Inland Sea（non-linear)







Two ways from B to A (Regime Shift)

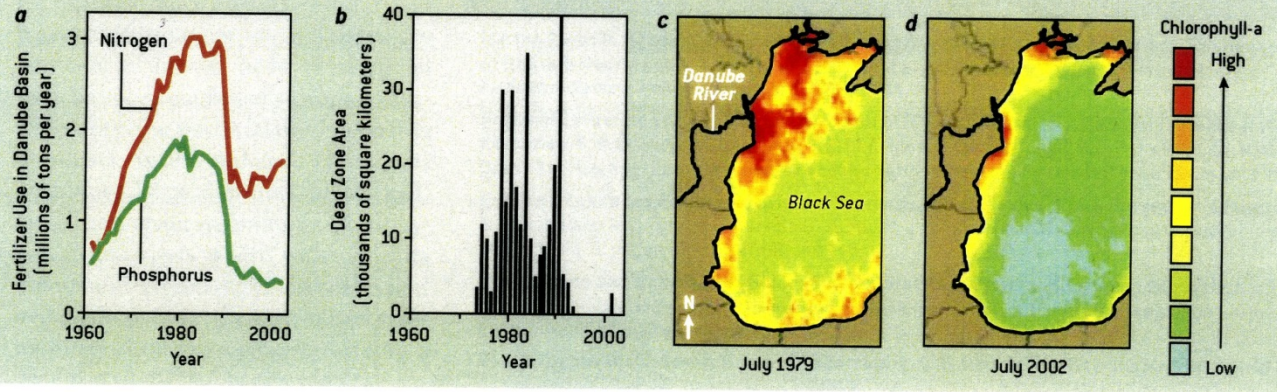
- Wait for the disappearance of hypoxia
  by decreasing the nutrient concentration

- Create “satoumi”

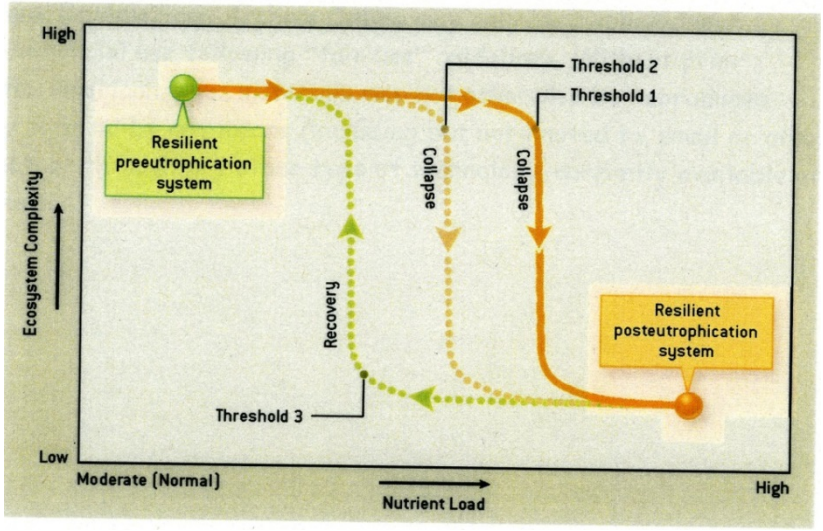
The Black Sea Comes Back

The recovery of the Black Sea dead zone underscores the need to reduce agricultural, sewage and other nutrient runoff from the land if affected areas are to be restored to health. The dead zone adjacent to the northwest coast of the Black Sea began to revive only after the communist system collapsed in 1989, which prevented the continuation of intensive farming—including large-scale raising of livestock and heavy application of fertilizers containing nitrogen and phosphorus (*a*)—that had been in place since the 1960s. Nutrient residues made their way into the Danube River and other watersheds and eventually down into the Black Sea, which caused the dead zone to appear in 1973 and to return in the summer for the next 21 years (*b*). Red color in a satellite image from 1979 (*c*), for instance, clearly reveals a large expanse of overfertilized water. (In that image and in *d*, eutrophication was assessed by determining the concentrations of chlorophyll-a, an indicator of plant growth, in surface waters.)

Within five years after the intensive farming ended, the degraded region had returned to life (*b* and *d*), relapsing only during the exceptionally hot summer of 2001. By 2002 mussel communities in the area had reestablished themselves. The sea may again be at risk, however, as central European economies recover and agriculture there begins to intensify again.



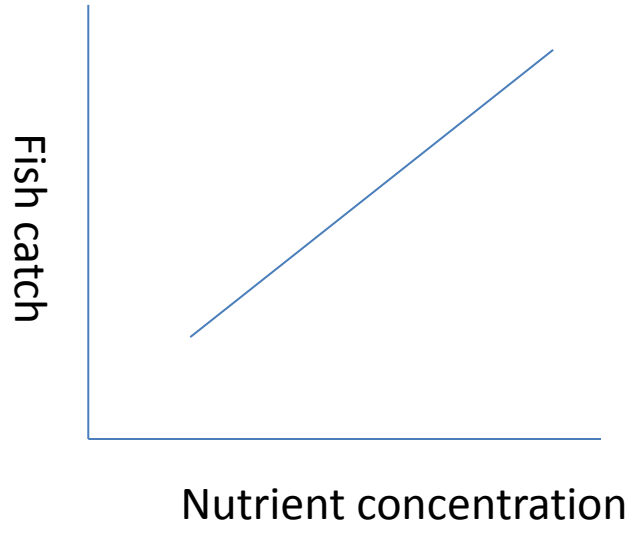
1960 : National Planed Agliculture
1973 : Hypoxia
1998 : Collapse of Siviet-Union
2002 : Disappearance of Hypoxia
Recovery of Benthos



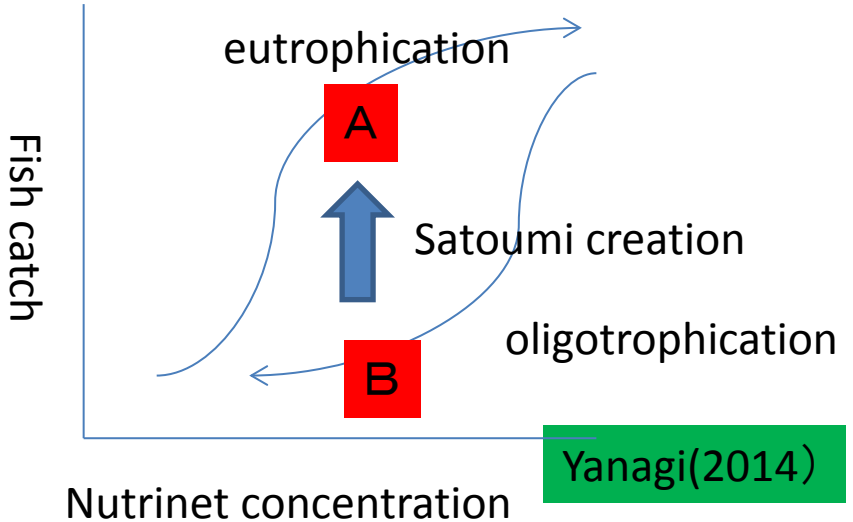
L.Mee(2006)

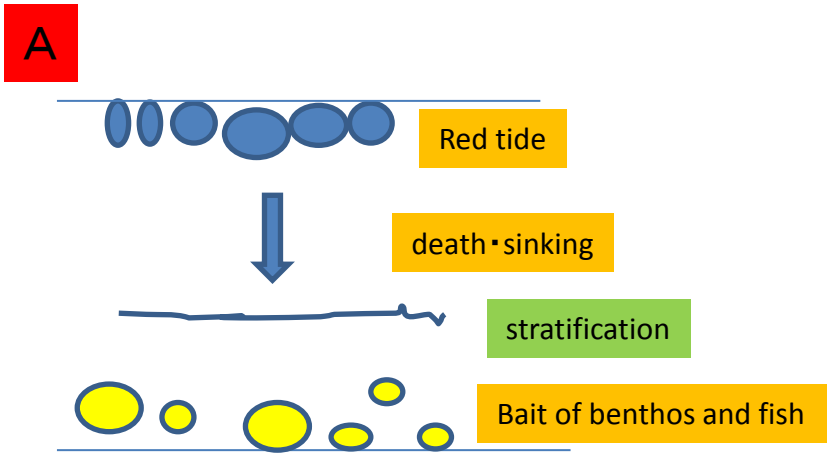
Nutrient concentration and fish catch

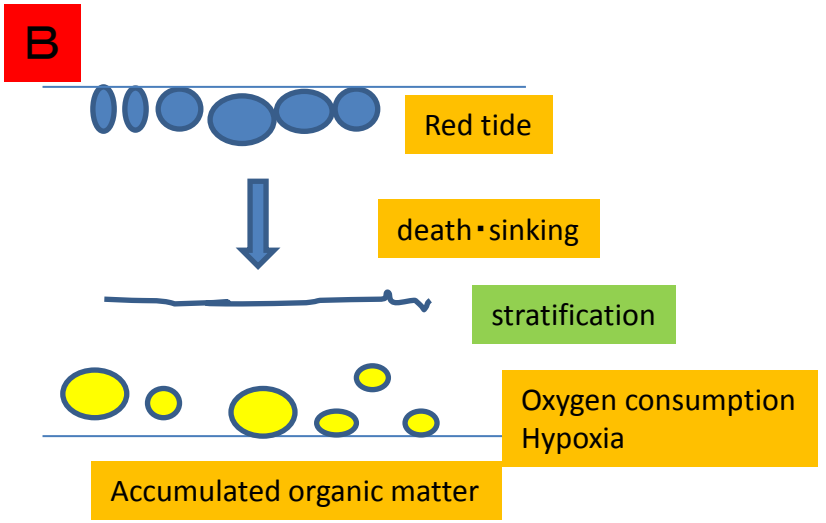
In the beaker（linear）



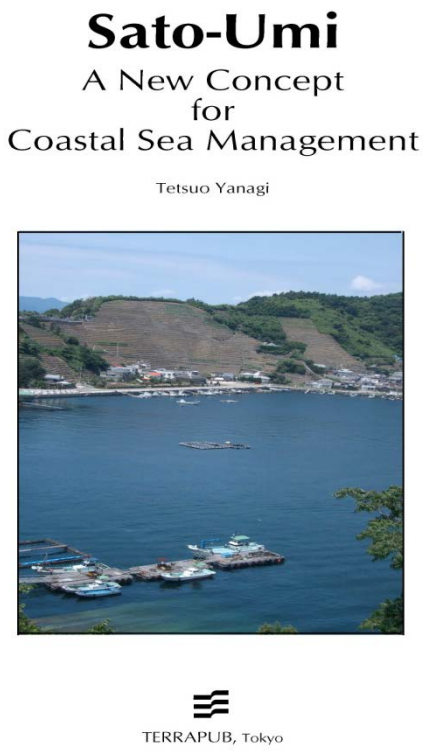
Seto Inland Sea（non-linear)



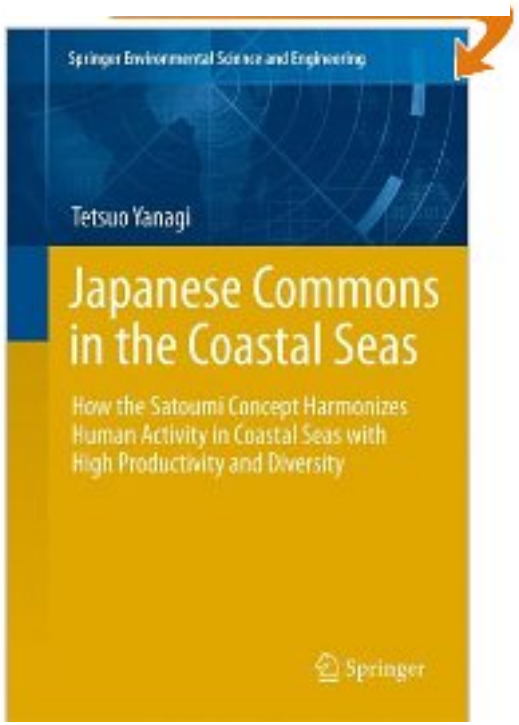




Satoumi: coastal sea with high bio-diversity and productivity under the human interaction (Yanagi, 1998)

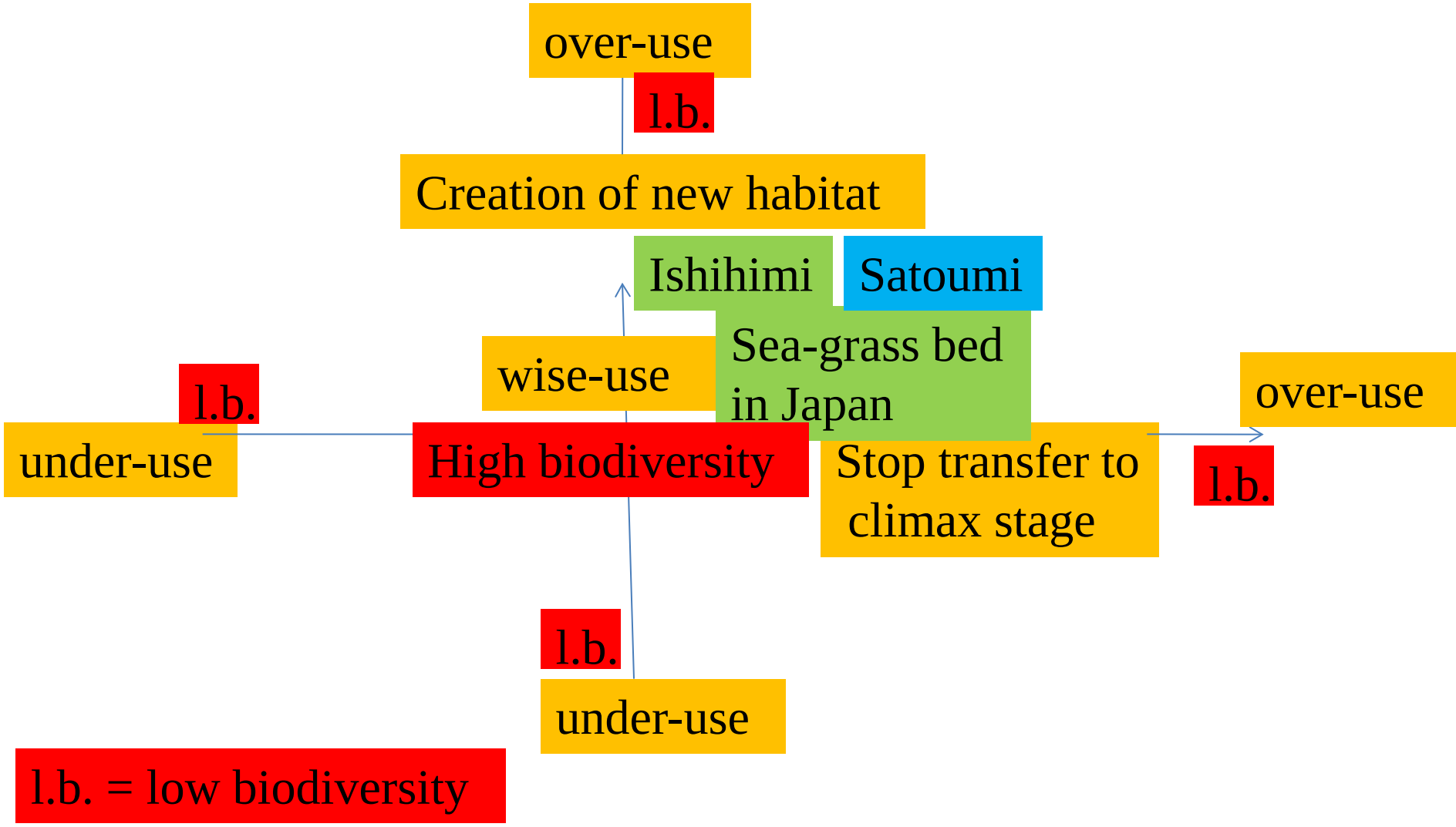


2007

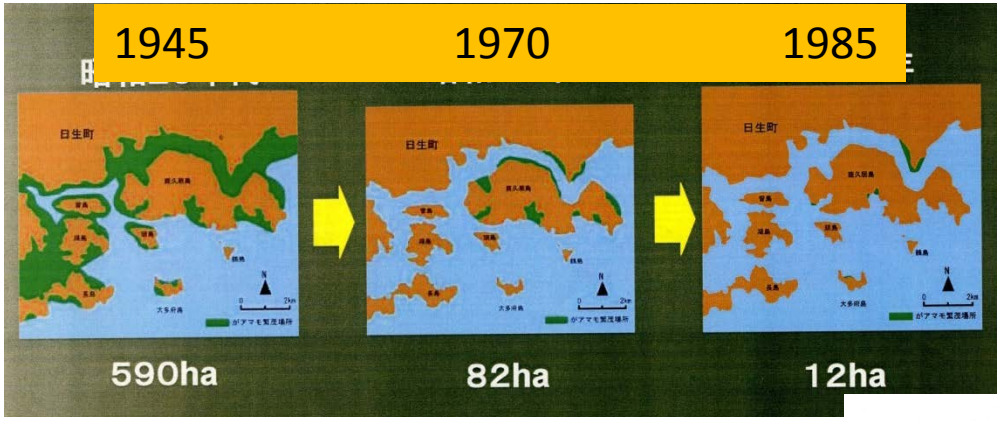


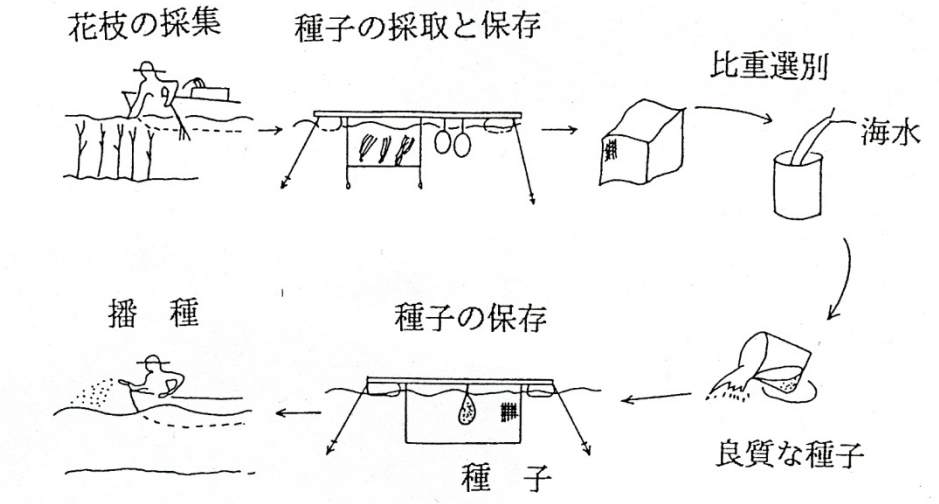
2012

Biodiversity and human interaction



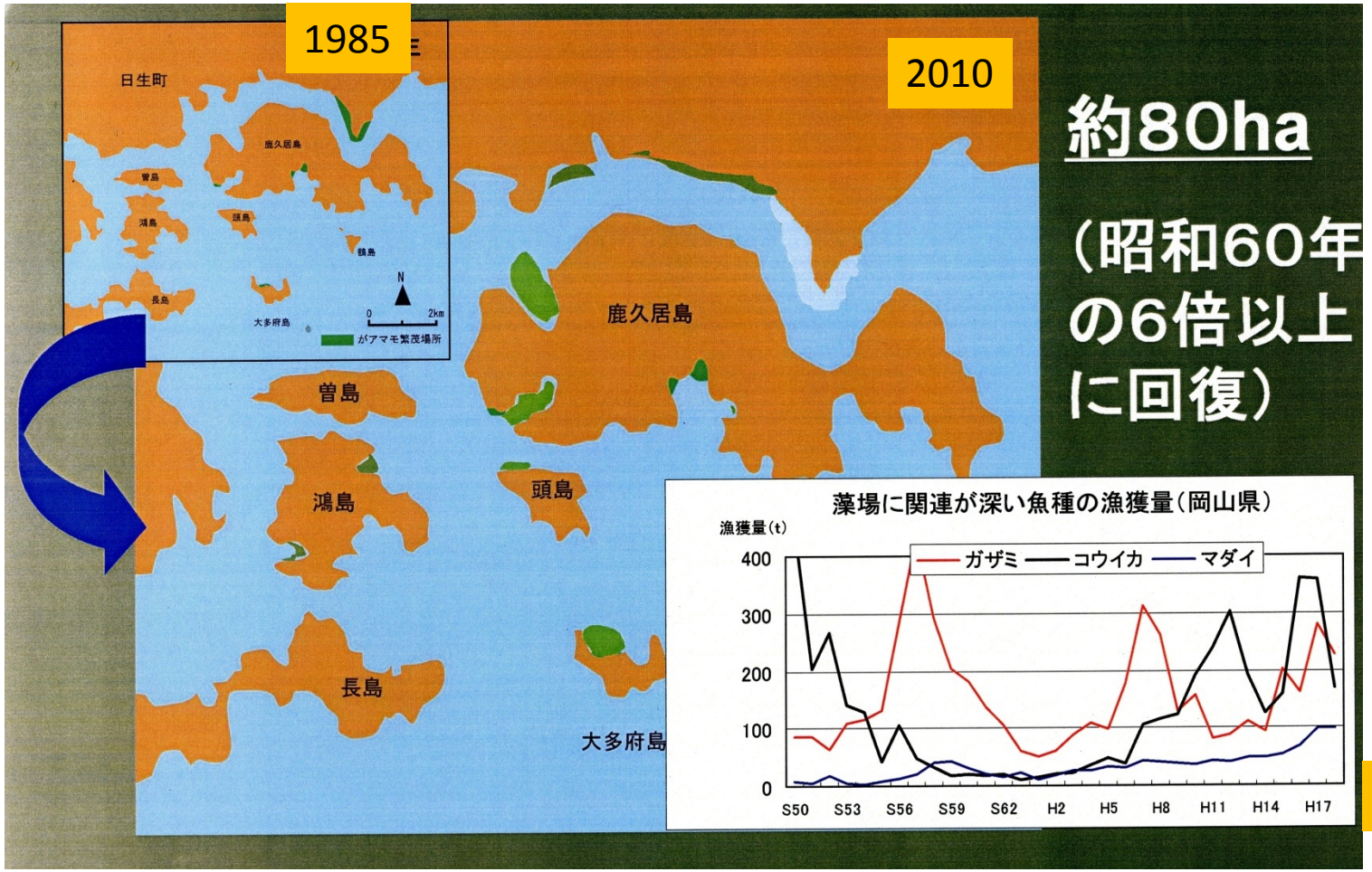
Decrease of eel-grass bed → Decrease of fish catch by set net





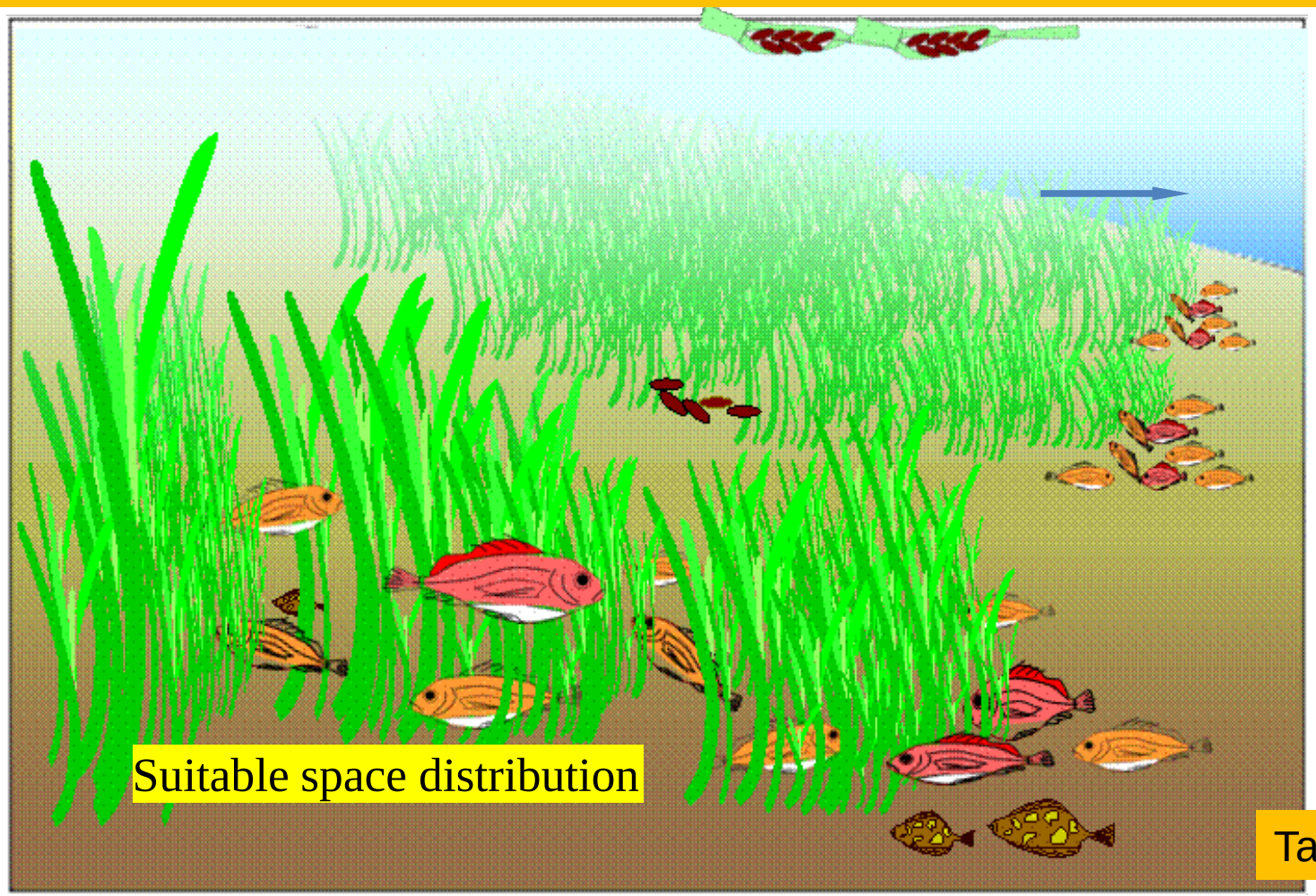
Creation of eel-grass bed by local Fishermen (1985～)

Increase of eel-grass bed and fish catch by set net



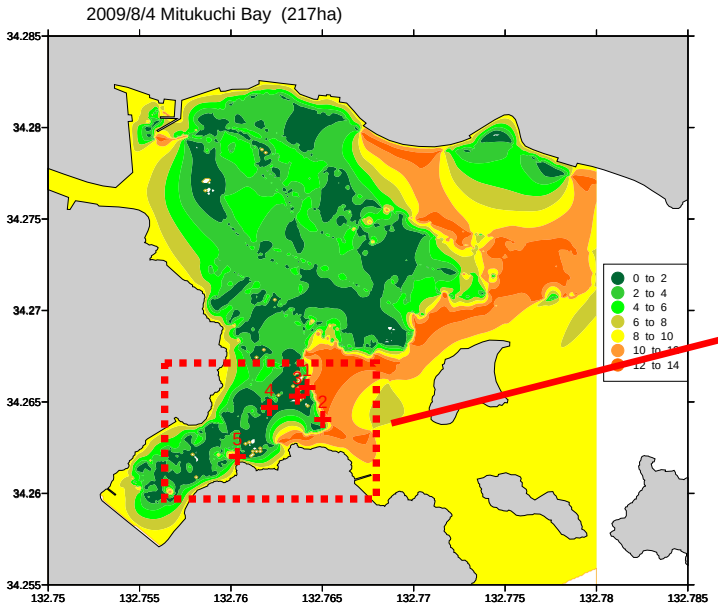
Set net

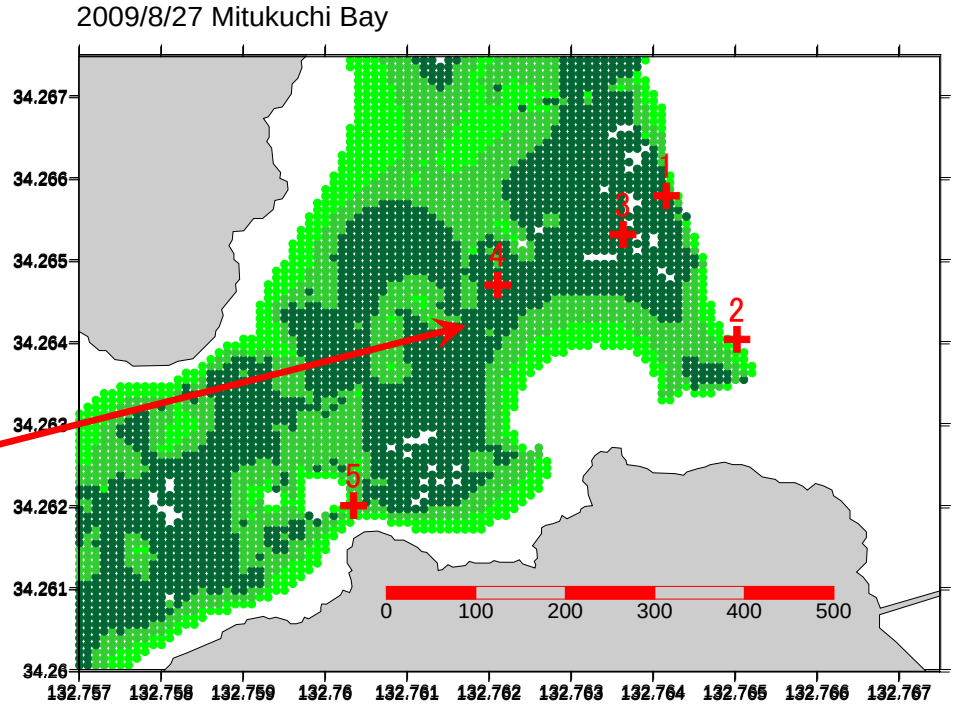
We can observe
few fish at the central part (climax) in the eel grass bed
and
much fish in the spot or the boundary between the eel grass bed and the sand area
by scuba diving.

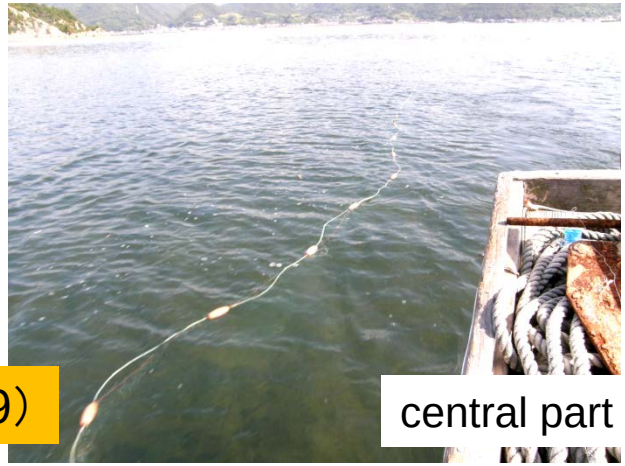


Tanimoto（2009）

Gill net experiment (2009/8/26～27)
spot or boundary：Stas 1、2、5
central part：Stas 3、4






central part


boundary

Tanimoto（2009）

２．H21研究進捗状況

(2)新たな里海方策の提案

アマモ場内外における刺し網結果（魚介類の種類数と個体数）

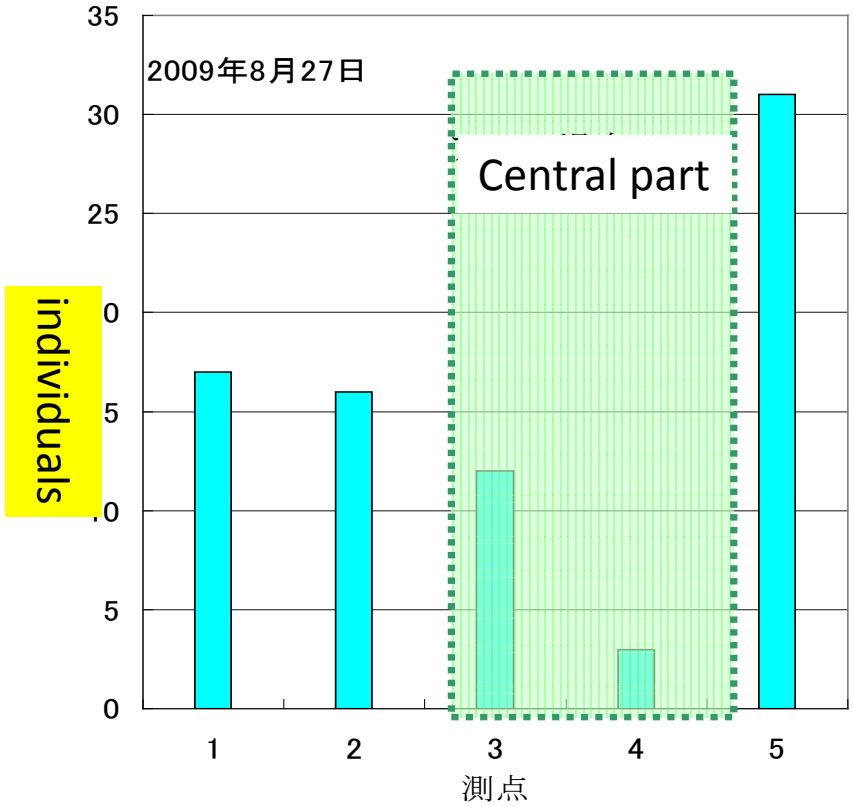
藻場外（藻場の切れ目）3地点における魚介類の平均種類数：10、個体数：10

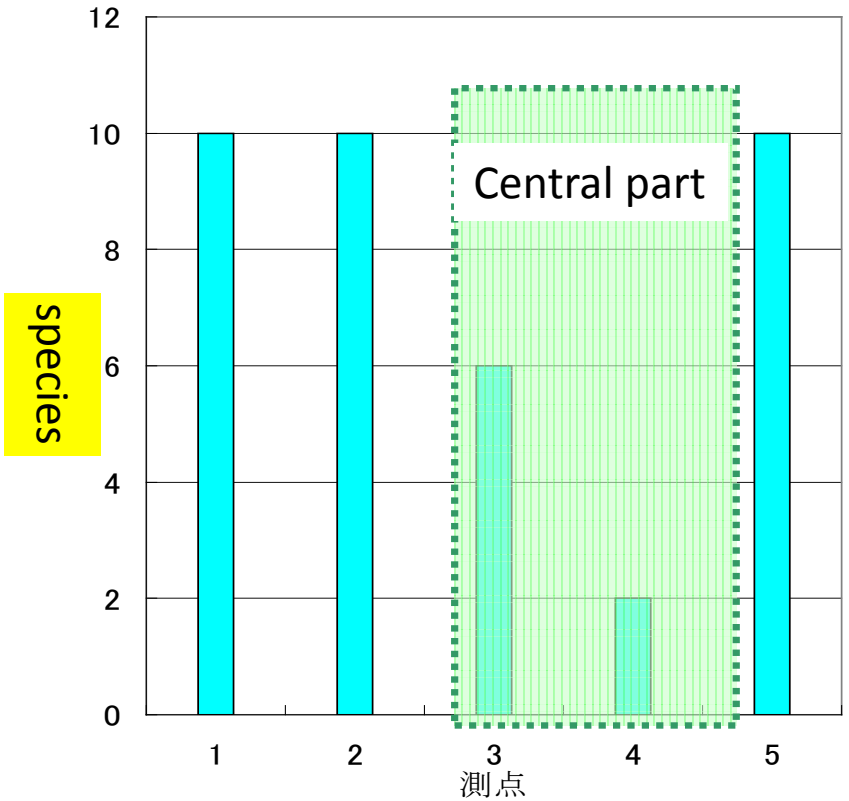
藻場内2地点における平均種類数：5、個体数：4

魚介類は藻場内より藻場の切れ目（ある程度空間のある場所）を利用

Tanimoto（2009）

1		2		3		4		5	
魚種	数量	魚種	数量	魚種	数量	魚種	数量	魚種	数量
ギザミ	1	ギザミ	1	メバル	1	オコゼ	1	メバル	1
メバル	3	メバル	4	フグ	2	フグ	2	コノシロ	8
コノシロ	1	コノシロ	1	コノシロ	3			コチ	2
アイナメ	1	コチ	1	ネコサメ	2			サバ	1
タイ	1	タイ	1	ハゼ	1			キス	2
ハゼ	1	ハゼ	3	イシガニ	3			コイワシ	1
エソ	1	オコゼ	1					イシガニ	13
イシガニ	5	タナゴ	1					シャコ	1
ウニ	2	イシガニ	2					ニシ	1
ニシ	1	ナマコ	1					ヒトデ	1





Special Project by the Ministry of Environment

Development of Coastal Management Method to Realize the Sustainable Coastal Sea (2014-2018)

Theme1

1. Seto Inland Sea

Nutrients concentration
High biodiversity and production
Total load control

Theme2

2. Sanriku coastal sea

Environment recovery from Tsunami
Satoumi creation
Material flux from forest to coastal sea

Theme3

3. Japan Sea coastal area

MPA for biodiversity
MPA and fisheries
International management

Theme4

4. Social and Human sciences

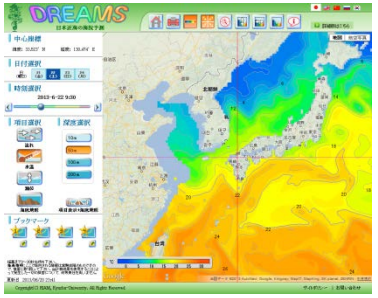
Economic value of ecosystem service
Sustainability and ICM
Satoumi story for citizen

Theme5

Integrated numerical model development

Synthesis

Philosophy for coastal sea management
Measures for establishment of sustainable coastal sea area
Integrated model as a support tool for policy makers



Integrated Coastal Sea Model

visualization

Environmental Policy

Committee（Three types）

1.5 million US$/year

Realize clean, rich and prosperous coastal sea

Global dispatching

Conclusions

- The relation between fish catch and nutrient concentration is not linear but has some hysteresis due to the sediment pollution.
- Satoumi creation is very effective for the recovery of fish catch.