Comparative study on ecosystem responses to anthropogenic activities and natural stressors among inland, shelf and oceanic waters around Japan

Motomitsu TAKAHASHI, *FRA, Japan*

Sachihiko ITOH, *University of Tokyo*

Naoki YOSHIE, *Ehime University*

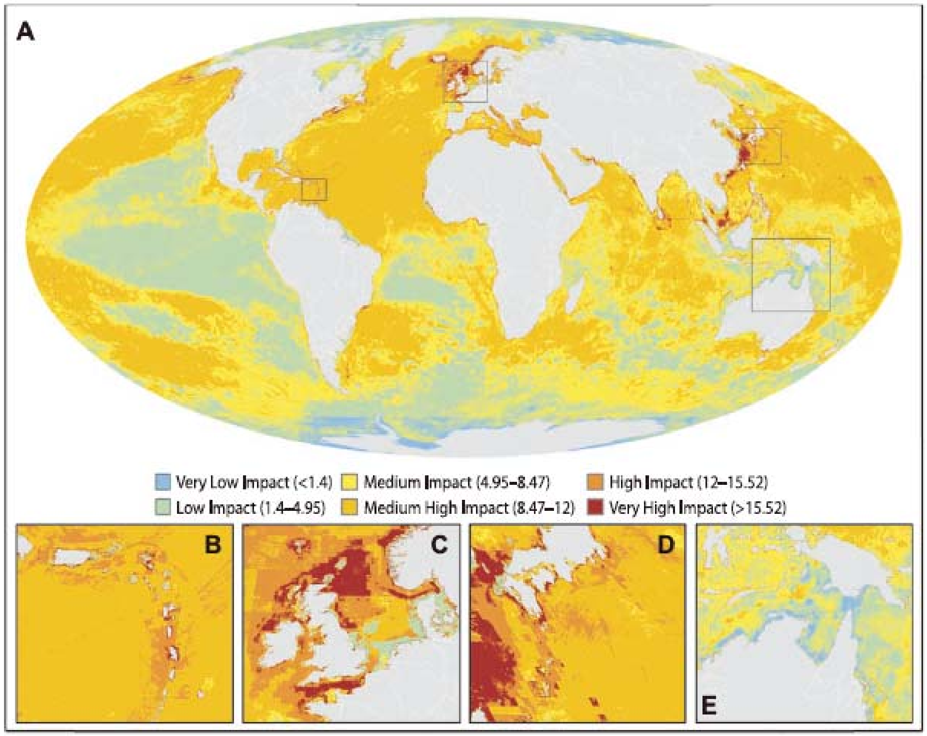
Kazuhiko MOCHIDA, *FRA, Japan*

Masakazu HORI, *FRA, Japan*

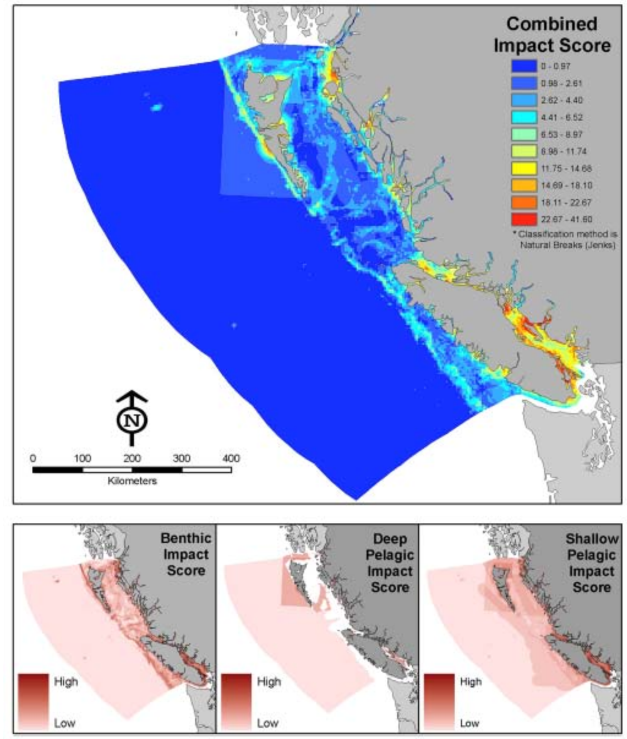
Shigeru ITAKURA, *FRA, Japan*

Background

Understanding cumulative impacts of multiple stressors is urgent issues to manage ecosystem serveices properly.



Halpern et al. (2008)



Ban et al. (2010)

PICES WG-28 will develop ecosystem indicators to characterize ecosystem responses to multiple stressors.

Habitat-stressors matrix

Impacts of human activities and natural stressors were evaluated based on an expert-based screening method.

Human activities ↕ Natural stressors

Activities/Stressors	**Intertidal**	**Coastal**	**Shelf**	**Oceanic**
1. Polution from land 2. Coastal engineering 3. Coastal development 4. Direct human impact 5. Ecotourism 6. Commertial activity 7. Aquaculture 8. Fishing - demersal 9. Fishing - pelagic 10. Fishing - illegal 11. Offshore development 12. Polution from ocean 13. Freshwater input 14. Sediment input 15. Nutrient input 16. HABs 17. Hypoxia 18. Species invasion 19. Sea level change 20. Sea temperature	1. Rocky 2. Beach 3. Mud 4. Salt marsh	1. Seagrass 2. Kelp forest 3. Rocky reef 4. Suspension feeder reef 5. Sub-tidal soft bottom	1. Soft bottom 2. Hard bottom 3. Ice 4. Pelagic water column	1. Soft bottom slope 2. Hard bottom slope 3. Soft bottom benthic 4. Seamount 5. Vents 6. Soft bottom canyon 7. Hard bottom canyon 8. Deep pelagic water column 9. Upper pelagic water column

Modified from Halpern et al. (2007)

Scoring vulnerabilities

For each cell, vulnerability were scored as spatial scale, frequency, functional impact, resistance, recovery time.

Weak ↔ Strong

Vulnerabilities	**1**	**2**	**3**	**4**
Spatial scale	< 10 km^2	10-100 km^2	100-1000 km^2	> 1000 km^2
Frequency	> 5 yrs	1-5 yrs	Seasonal	Continuous
Functional impact	Species	Single trophic	Multitrophic	Community
Resistance	Positive impact	High	Moderate	Low
Recovery time	< 1 yr	1-10 yrs	10-100 yrs	> 100 yrs

For each vulnerability, certainty was scored as 4 levels.

Unsure ↔ Sure

	1	2	3	4
Certainty	< 15 %	15–50 %	50–85 %	> 85 %

How to treat scores

Impacts (*I*) of stressors were evaluated using the weighted mean vulnerability (*v*) with certainty (*c*).

$$I = \sum v \cdot c \, / \, C_{total}$$

East China Sea

Habitat	Sub-habitat	Activity/Stressor	Spatial scale		Frequency		Trophic impact		Resistance to change		Recovery time		Impact: *I*
			v	*c*	*v*	*c*	*v*	*c*	*v*	*c*	*v*	*c*	
INTERTIDAL	beach	Fishing - pelagic	2	2	3	2	2	2	2	2	2	2	**2.10**
COASTAL	sub-tidal soft bottom	Nutrient inputs	2	2	2	2	2	2	2	2	2	2	**2.00**
COASTAL	sub-tidal soft bottom	Coastal engineering	3	4	3	4	4	3	4	4	3	3	**3.11**
SHELF	soft bottom	Freshwater input	4	3	3	3	3	3	3	2	3	2	**3.00**
SHELF	soft bottom	Sediment input	3	3	4	3	3	2	2	2	2	2	**2.50**
SHELF	soft bottom	Nutrient inputs	3	3	4	3	3	3	2	3	3	2	**2.64**
SHELF	soft bottom	Polution from land	3	3	4	3	3	3	3	3	3	2	**2.86**
SHELF	soft bottom	Fishing - demersal	4	3	4	3	4	3	4	3	3	3	**3.47**
SHELF	soft bottom	Fishing - pelagic	3	3	4	3	2	3	3	3	3	3	**2.67**
SHELF	soft bottom	Sea temperature	4	4	4	4	4	4	3	3	3	3	**3.22**
SHELF	soft bottom	HABs	2	3	3	3	3	3	3	3	3	3	**2.60**
SHELF	soft bottom	Hypoxia	2	2	3	2	3	3	4	2	3	2	**2.91**
SHELF	soft bottom	Offshore development	1	3	2	2	3	3	3	2	2	2	**2.17**
OCEANIC	soft bottom slope	Sea temperature	4	4	4	4	4	4	3	3	3	3	**3.22**

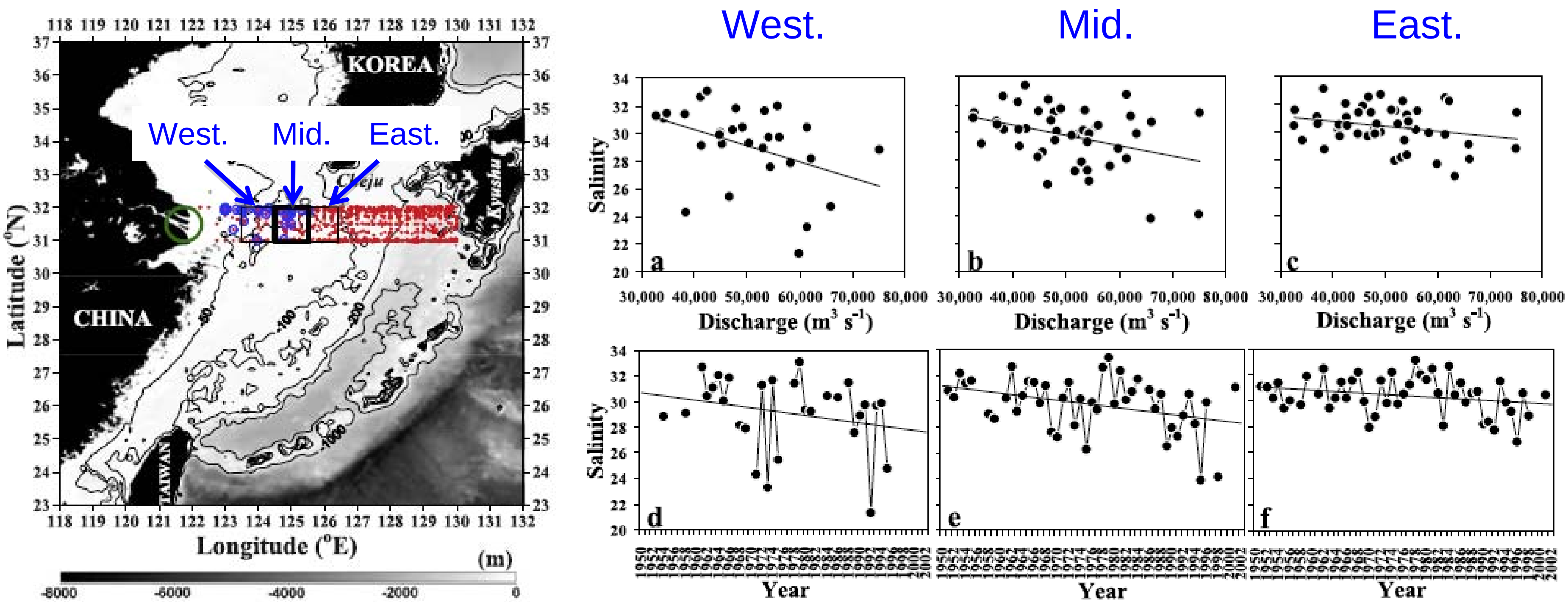
East China Sea (Shelf water)

≦ 2.0 | 2.1-2.5 | 2.6-3.0 | 3.1-3.5

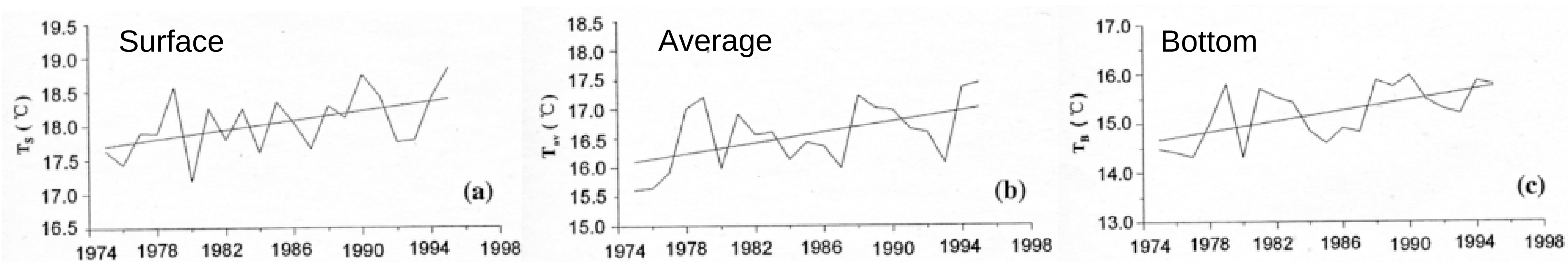
Activities/Stressors	Intertidal Beach	Coastal Sub-titdal soft bottom	Shelf Soft bottom	Oceanic Soft bottom slope
1. Polution from land			2.9	
2. Coastal engineering		3.1		
8. Fishing - demersal			3.5	
9. Fishing - pelagic	2.1		2.7	
11. Offshore development			2.2	
13. Freshwater input			3.0	
14. Sediment input			2.5	
15. Nutrient input		2.0	2.6	
16. HABs			2.6	
17. Hypoxia			2.9	
20. Sea temperature			3.2	3.2

1. Demersal fishing strongly affects to the shelf ecosystems.
2. Increasing temperature affects to the entire waters.
3. Changjang River affects strongly to water quality.

Warming and freshening in the East China Sea

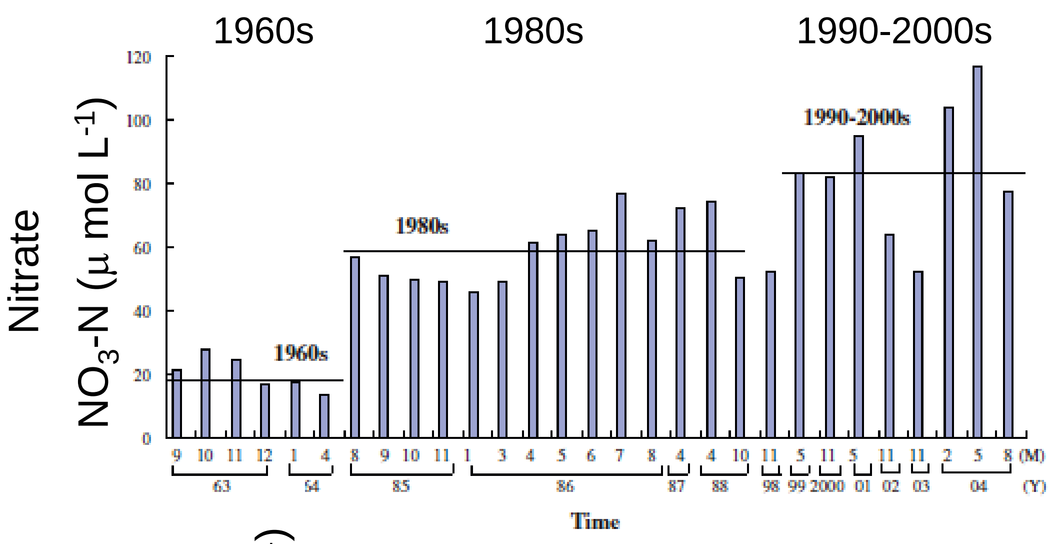


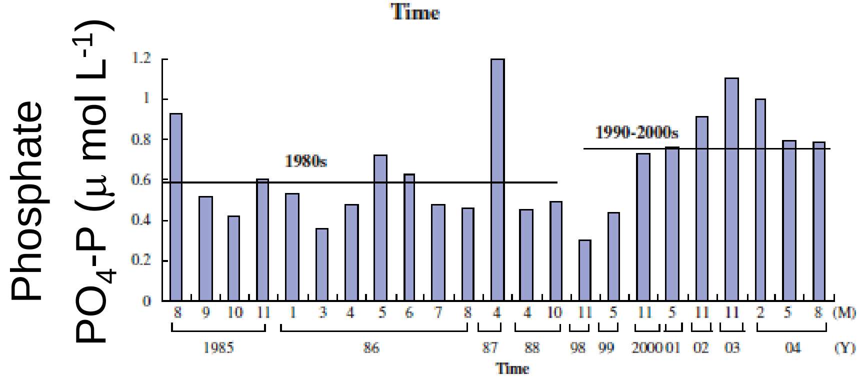
Surface salinity decreased during 1950 – 2002. Siswanto et al. (2008)



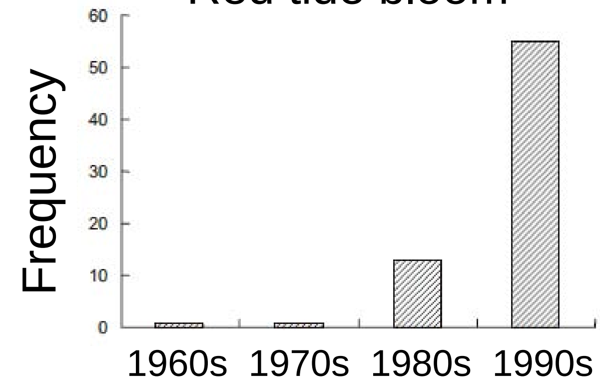
Temperature increased during 1975 – 1995. Ning et al. (2011)

Nutrient increase and harmful algal bloom off the Changjang Estuary

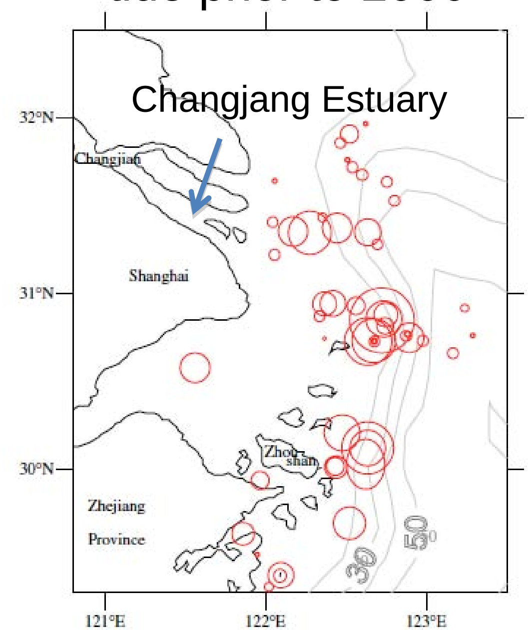




Red tide bloom



Occurrence of red tide prior to 2000

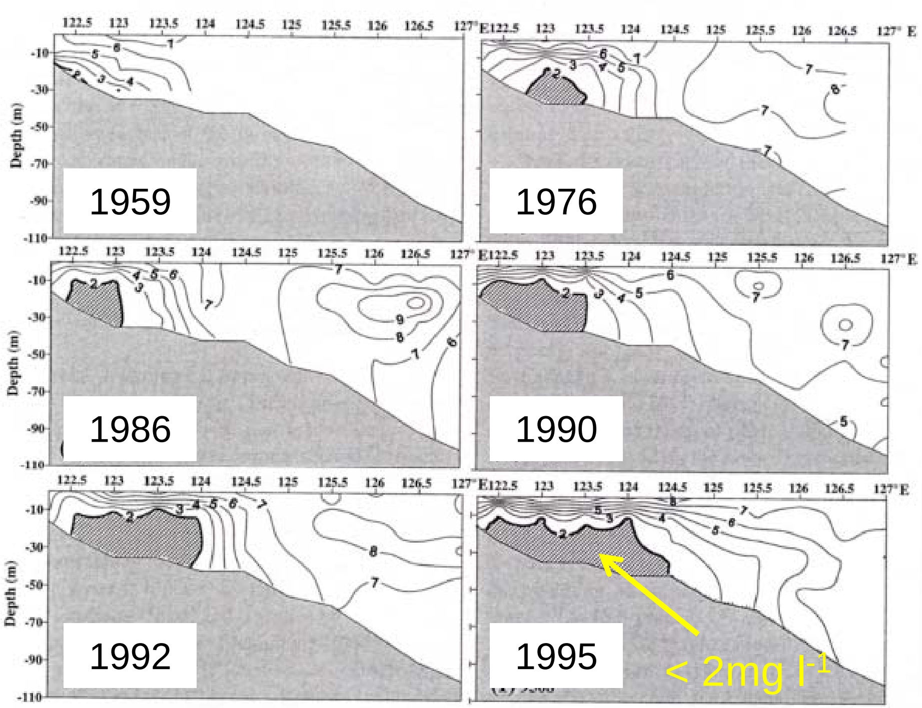


Frequency of red tide bloom increased with the increase in nutrient input after 1980s off the Changjang Estuary.

Zhou et al. (2008)

Eutrophication, hypoxia and acidification of subsurface coastal water

Summer dissolved oxygen off the Changjang Estuary.

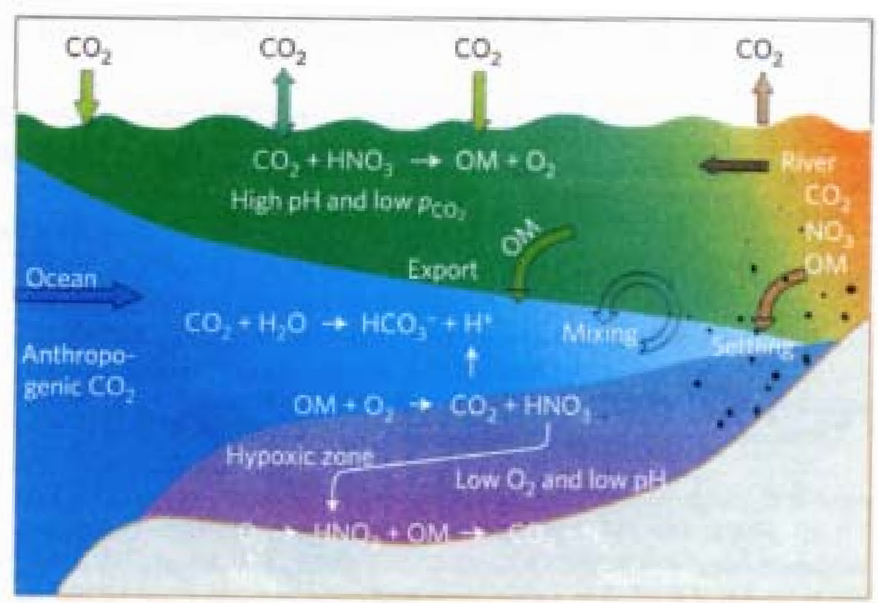


Potential causes –

- Taiwan Warm Current
- Strong stratification in summer
- Phytoplankton bloom

Ning et al. (2011)

A conceptual model for a large river plume eutrophication and subsurface hypoxia and acidification

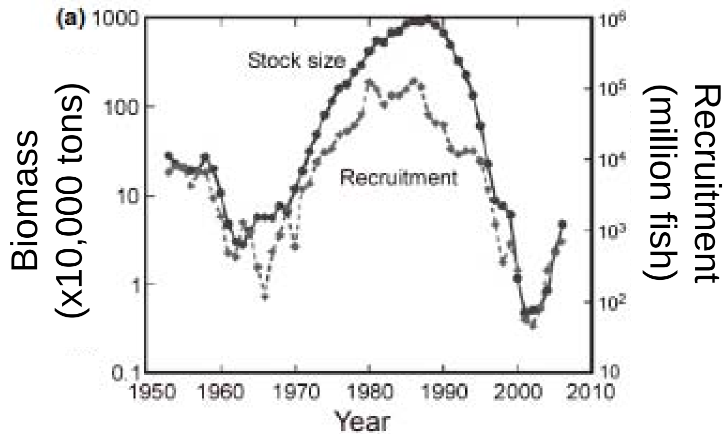


Eutrophication results in not only hypoxia but also acidification in waters off Mississippi and Changjang Rivers.

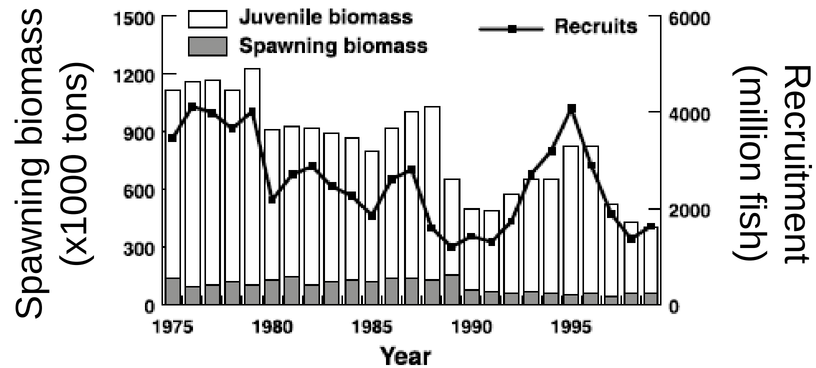
Cai et al. (2011)

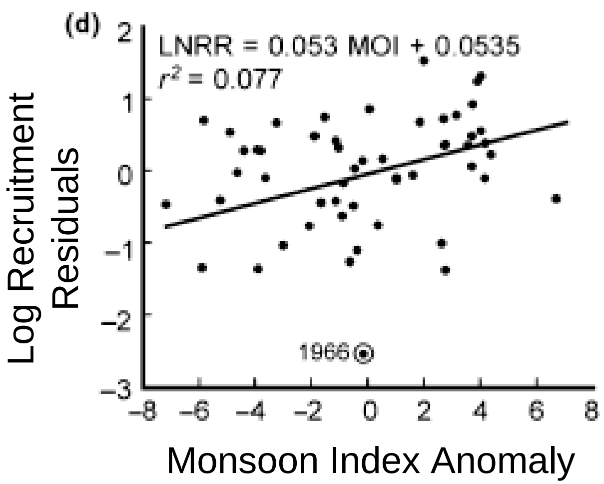
Impacts of climate change to population dynamics of fishes in the East China Sea

Japanese sardine

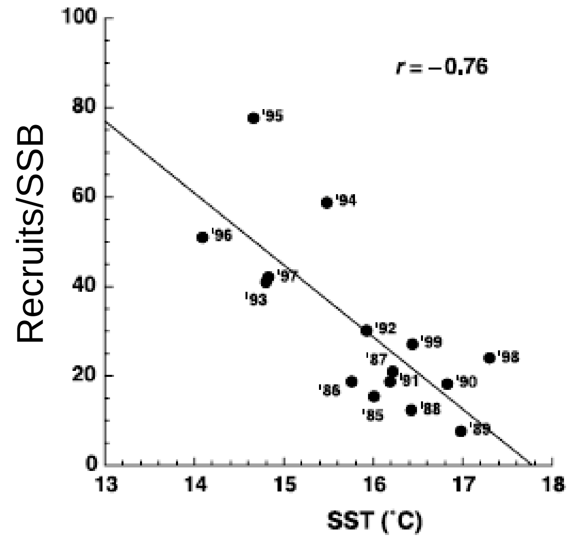


Chub mackerel





Oshimo et al. (2009)



Hiyama et al. (2002)

Winter monsoon and water temperature affect production of small pelagic fishes.

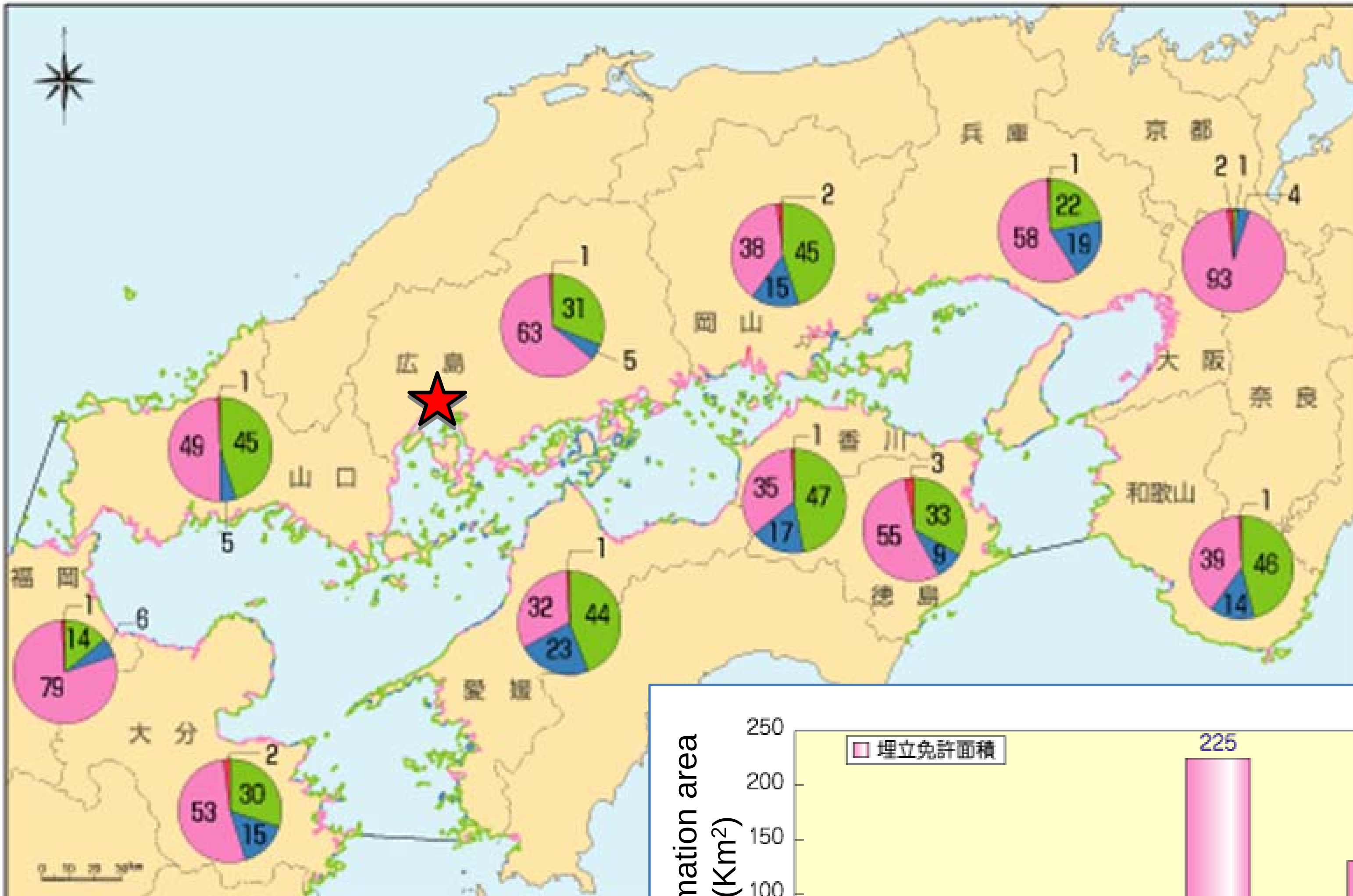
Seto Inland Sea (Inland water)

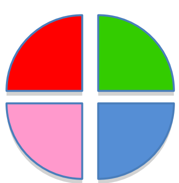
□ ≦ 2.0   2.1-2.5   2.6-3.0   3.1-3.5

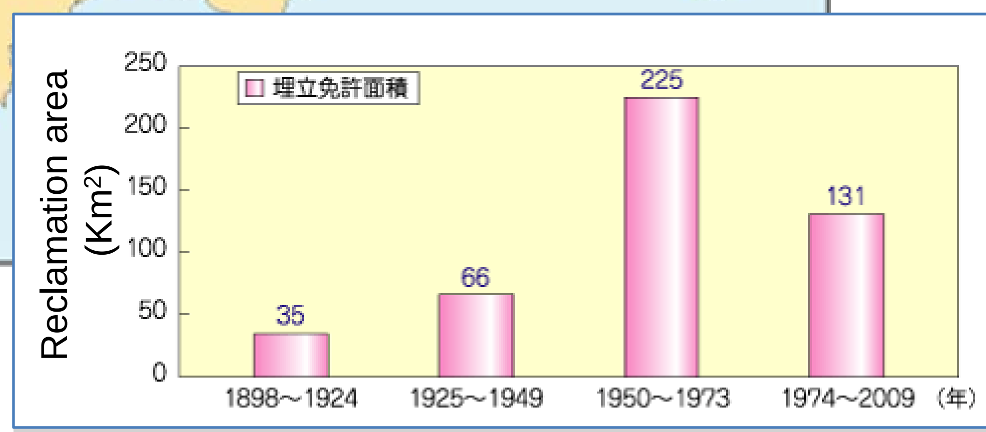
Activities/Stressors	Intertidal			Coastal				
	Rocky	Mud	Beach	Seagrass	Kelp forest	Rocky reef	Suspention feeder reef	Sub-titdal soft bottom
1. Pollution from land	1.6	2.2	1.8	1.8	1.8	1.8	3.4	2.2
2. Coastal engineering	2.9	2.9	2.9	2.7	2.5	2.3	2.5	2.5
3. Coastal development	3.2	3.2	3.2	3.2	1.1	1.2	3.4	3.4
4. Direct human impact		2.6	2.8	3.0	2.8	2.6	2.6	2.6
5. Ecotourism	1.4	1.4	1.4	1.4	1.2			
7. Aquaculture		2.5	2.7				2.7	2.7
8. Fishing - demersal	2.6	2.3		2.6	1.8		2.0	2.4
9. Fishing - pelagic				1.8		2.0	2.6	2.0
12. Pollution from ocean	3.0	3.0	3.0	3.4	3.4	3.4	2.8	3.4
13. Freshwater input	2.1	2.8	2.5	2.4	2.3	2.3	2.5	2.7
14. Sediment input	2.6	2.3	2.3	2.8	2.7	2.7	3.0	3.0
15. Nutrient input	3.5	3.5	3.3	3.0	3.1	3.5	3.1	3.1
16. HABs	2.4	2.6	2.6		2.8	2.6	2.7	2.6
17. Hypoxia	2.2	2.6	2.6		2.4	2.7	2.0	2.7
18. Species invasion	2.8	2.6	2.8	2.8	2.8	2.8	2.6	2.8
19. Sea level change	3.2	3.2	3.2	3.2	3.2	2.6	3.0	2.6
20. Sea temperature	3.1	3.1	3.1	3.5	3.5	3.3	3.3	3.1

1. Coastal development and engineering affects to the ecosystem directly.
2. Pollution from ocean and nutrient input affects to water quality.
3. Sea level change and increasing temperature affect to the entire waters.

Coastal development reduced natural shore lines

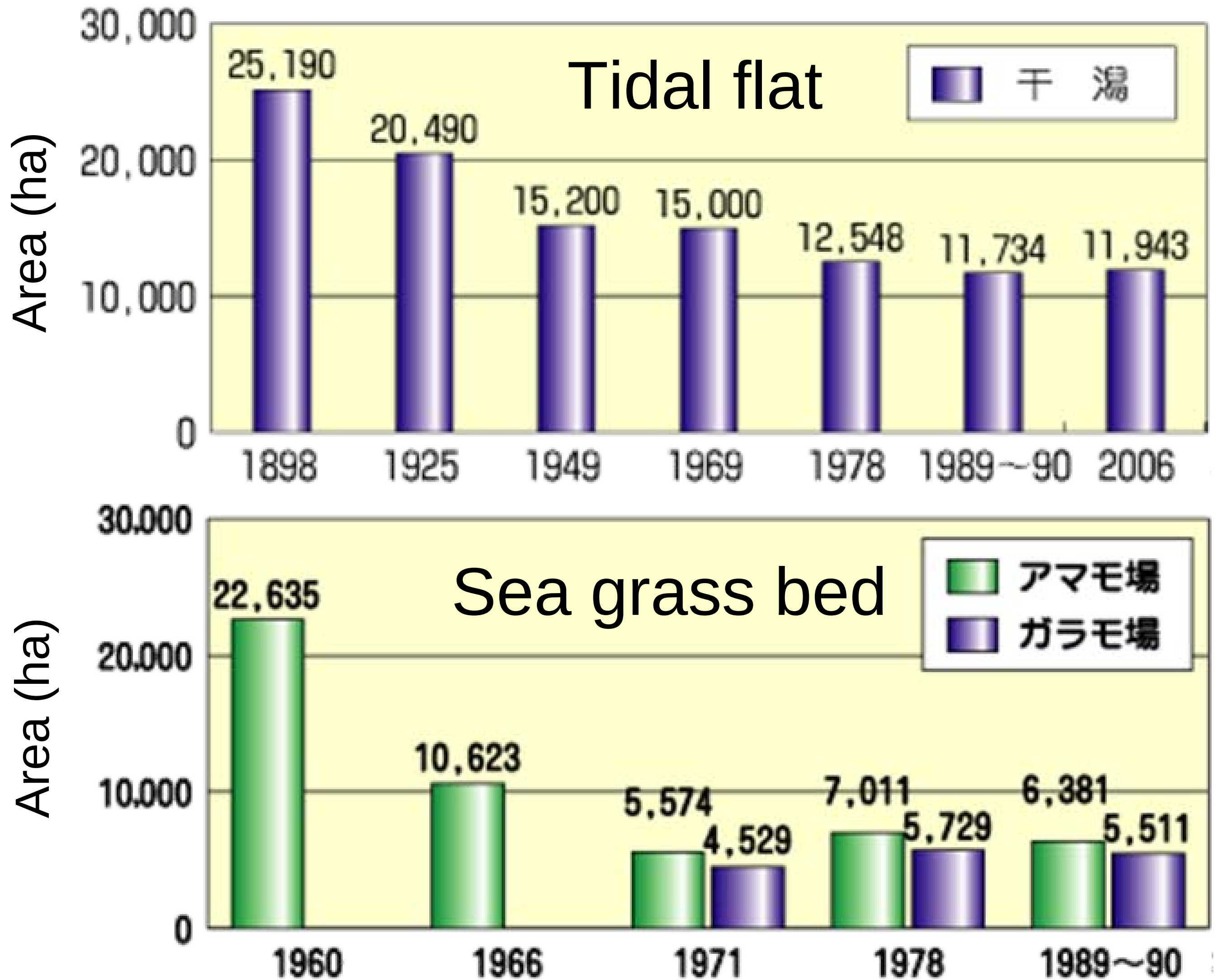






The ministry of the environment, Japan

Decrease in tidal flat and sea grass bed

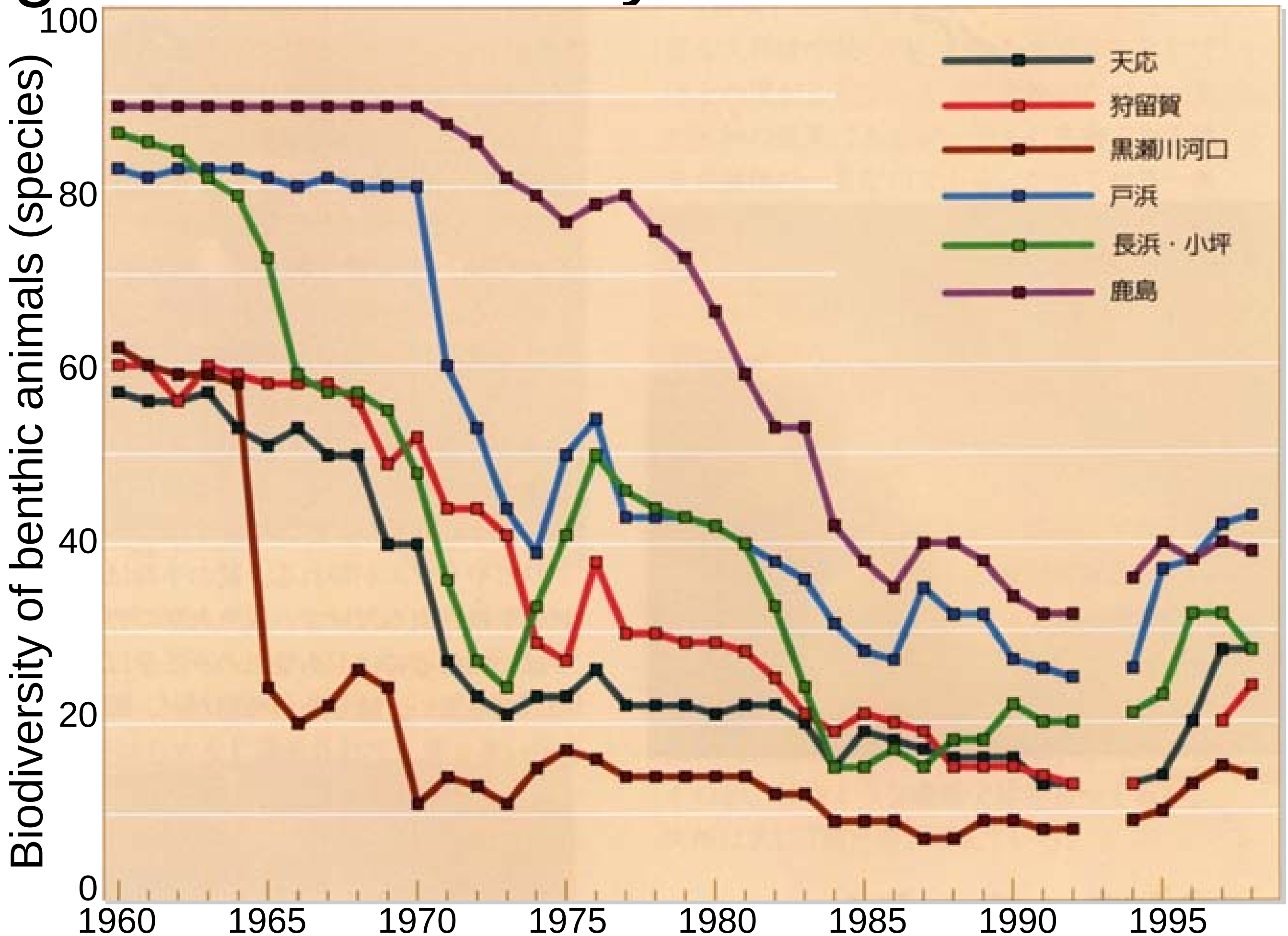


Coastal development had caused decrease in tidal flat and sea grass bed until early 1980s.

The ministry of the environment, Japan

Time changes in biodiversity of benthic animal

Seto Inland Sea



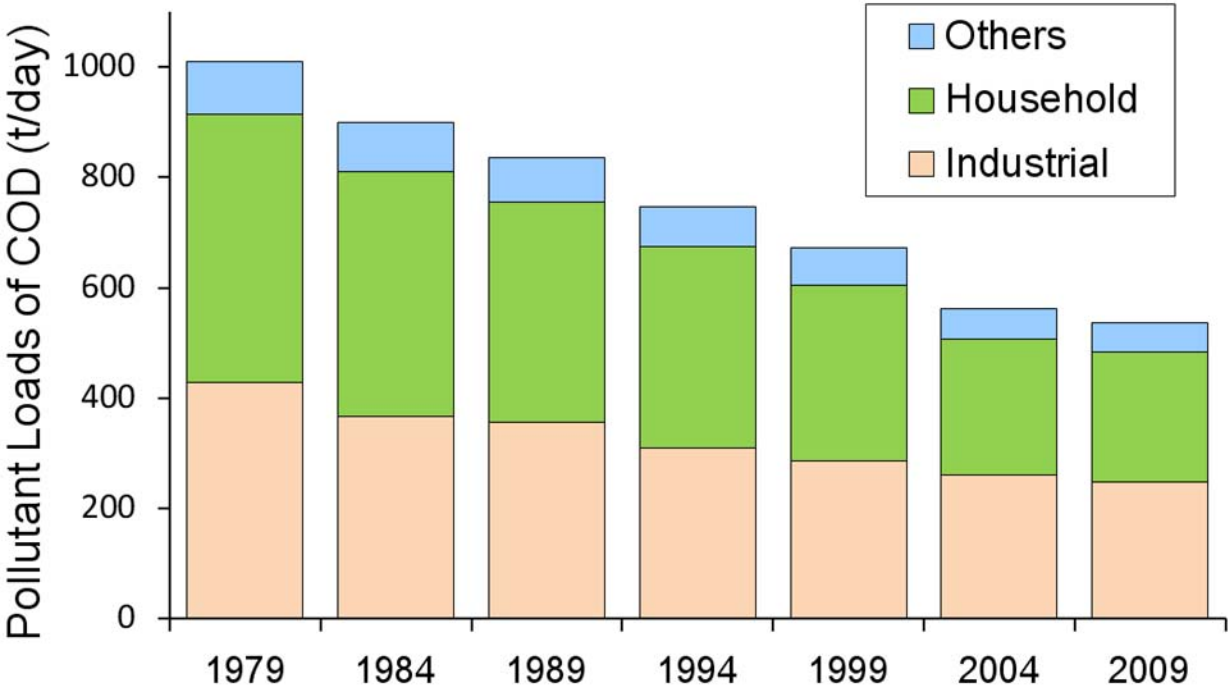
Interannual changes in the biodiversity of benthic animal at 6 stations around Kure City in Hiroshima prefecture.

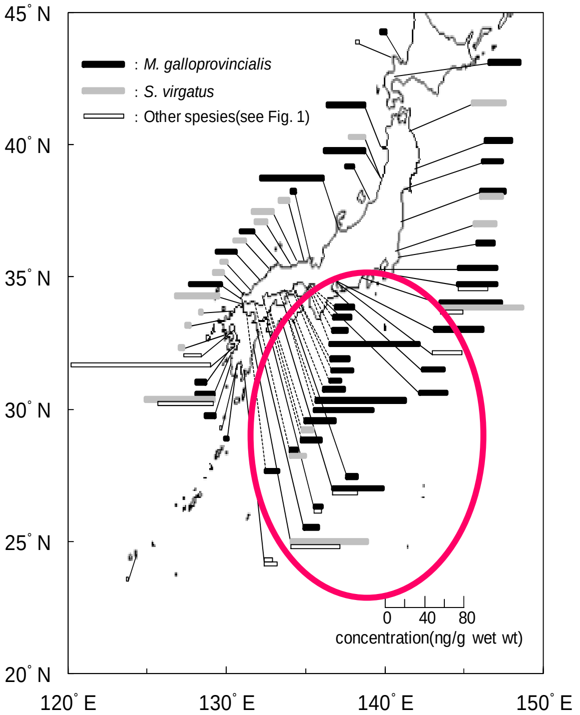
Fujioka (2000)

From the mid ‘60s to mid ’90s, the biodiversity of benthic animals had been decreased by environmental degradation.

After the mid ’90, it has been recovered with environmental reclamation.

Pollutant load into the Seto Inland Sea





Pollutant load into the Seto Inland Sea has decreased continuously since the end of 1970s.

The ministry of the environment, Japan

Distribution of polycyclic aromatic hydrocarbons (PAHs) in the bivalves collected from the coastal waters of the Inland Sea (red circle) shows that pollution still impacted the coastal ecosystems.

Tanaka and Onduka (2010)

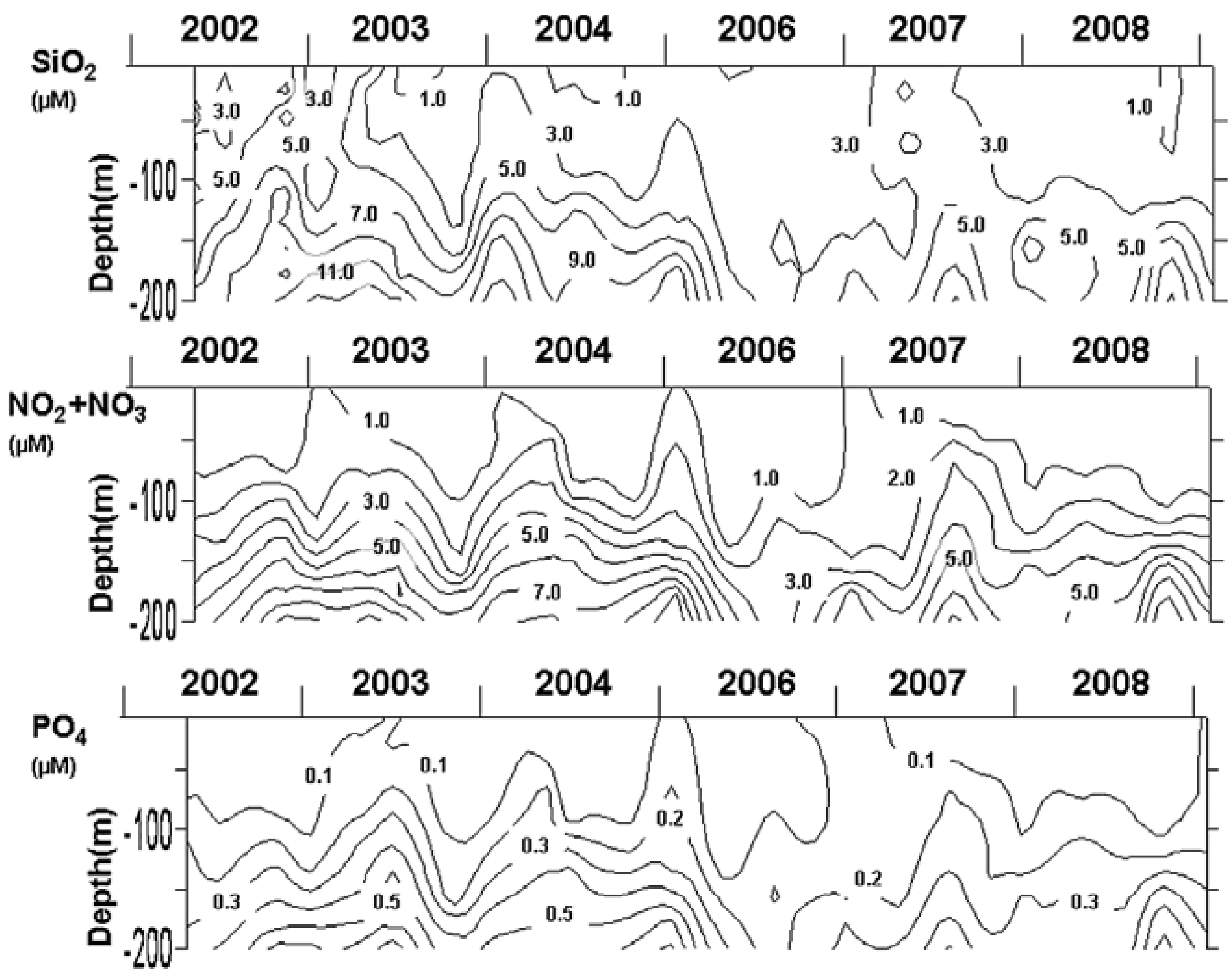
Kuroshio/Oyashio (Oceanic waters)

□ ≦ 2.0 2.1-2.5 2.6-3.0 3.1-3.5

Activities/Stressors	Shelf		Oceanic
	Pelagic water column	Soft bottom	Upper pelagic water column
8. Fishing - demersal		3.2	2.3
9. Fishing - pelagic	3.3		3.2
15. Nutrient input	3.2		2.9
17. Hypoxia	3.0	3.0	
19. Sea level change			3.2
20. Sea temperature	3.2	3.3	3.1

1. Increasing temperature affects to the entire waters.
2. Decreasing DO and nutrient concentrations are observed

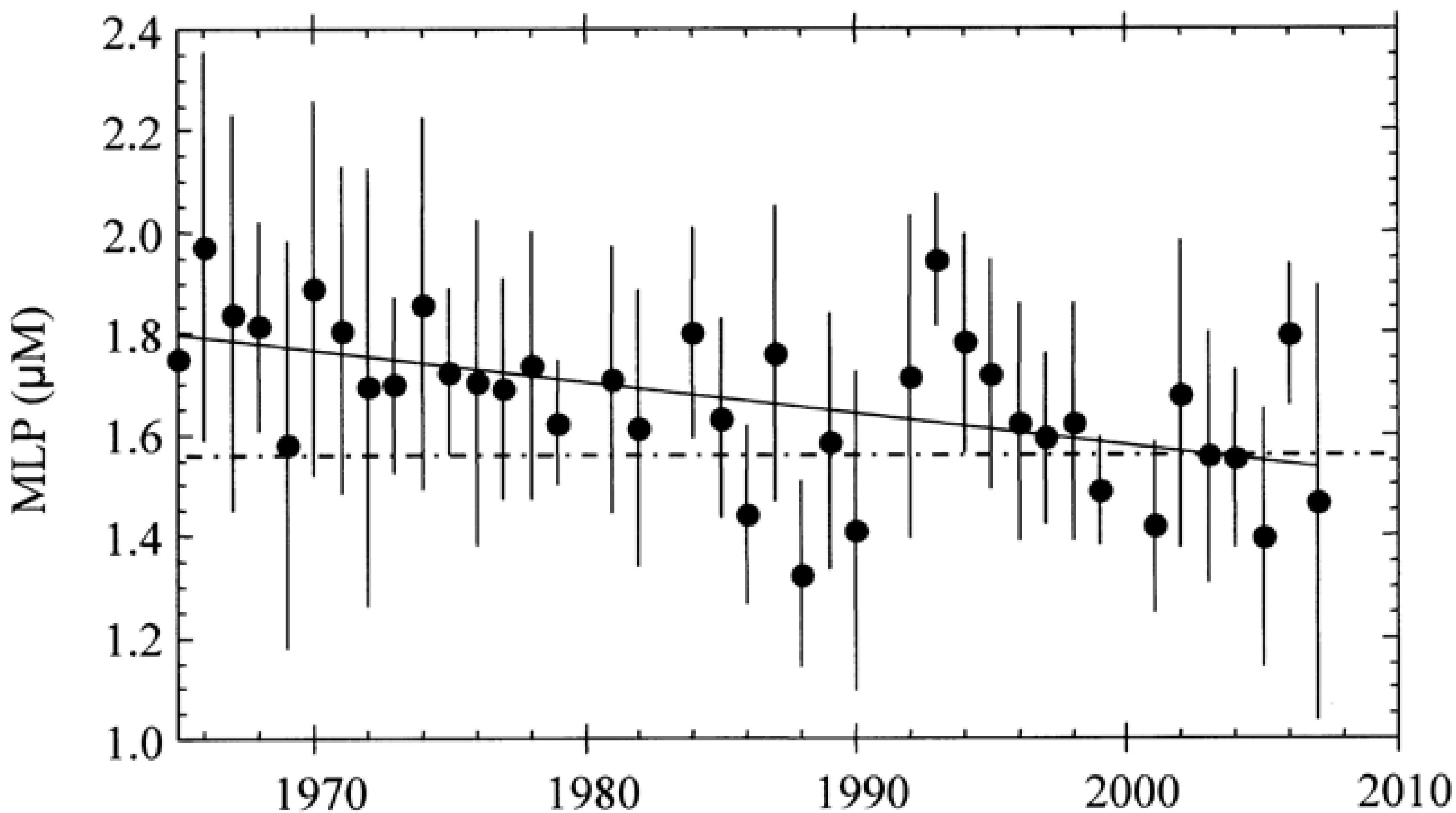
Decrease in nutrient concentration (Kuroshio)



Decreasing trend of nutrient concentrations, possibly due to the rise in water temperature (increasing stratification)

Sugisaki et al. 2010, PICES Special Publication

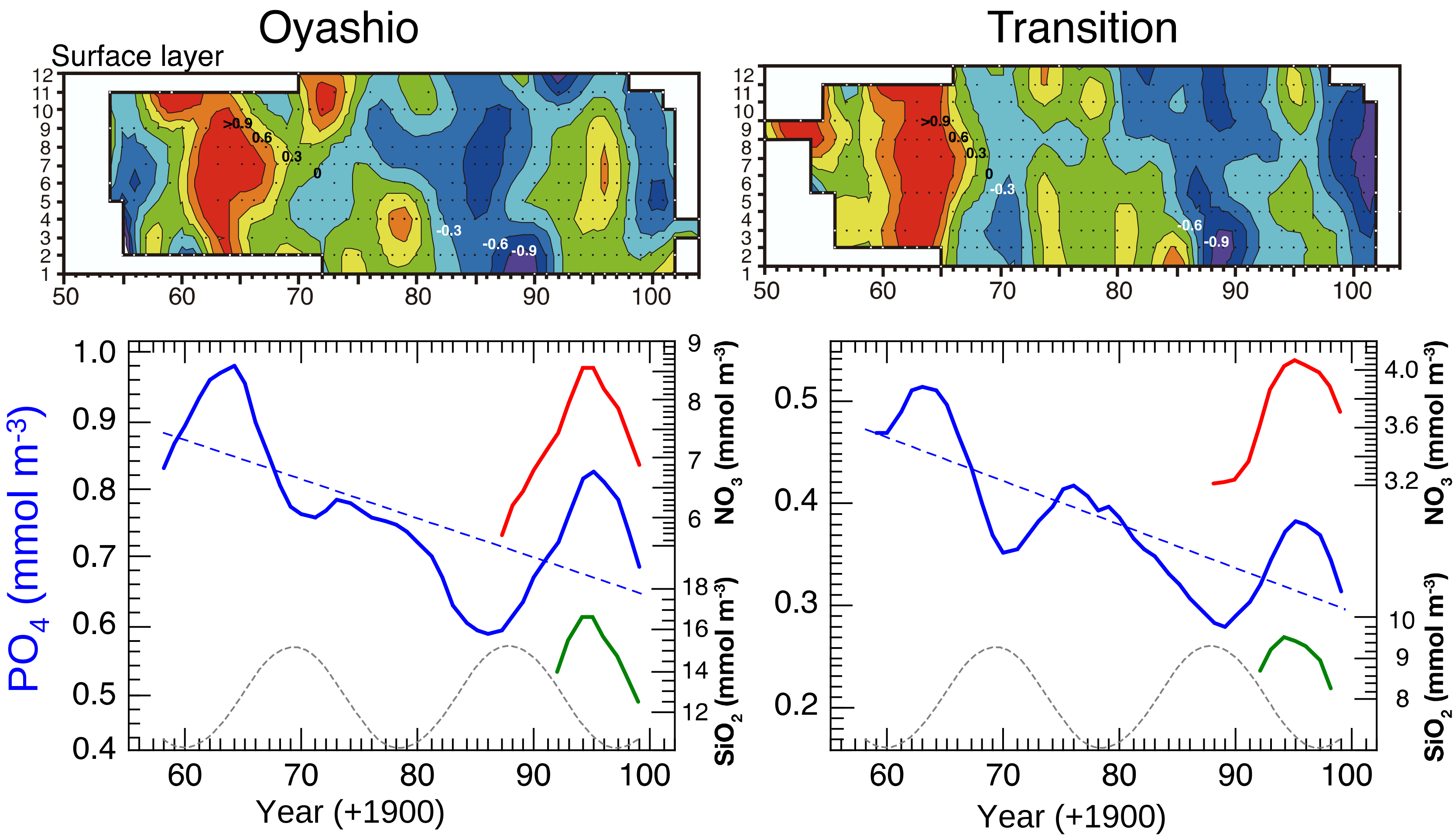
Decrease in nutrient concentration (Oyashio)



Decreasing trend of nutrient concentration within mixed layer, causing the decrease in net community production (Ono et al. 2002)

Sugisaki et al. 2010, PICES Special Publication
Ono et al. 2002GRL

Decadal variability in nutrient concentrations



Besides the decreasing trend in surface phosphate concentration, large-amplitude decadal fluctuation was observed, which was synchronous to 18.6-year nodal-tidal cycle.

Tadokoro et al. (2009)

Stressor-specific impacts among the 3 waters

Activities/Stressors	ECS	SETO	K/O
1. Polution from land	2.9	2.1	
2. Coastal enginnering	3.1	2.6	
3. Coastal development		2.7	
4. Direct human impact		2.7	
5. Ecotourism		1.4	
6. Commertial activity			
7. Aquaculture		2.6	
8. Fishing - demersal	3.5	2.3	2.8
9. Fishing - pelagic	2.4	2.1	3.3
10. Fishing - illegal			
11. Offshore development	2.2		
12. Polution from ocean		3.2	
13. Freshwater input	3.0	2.4	
14. Sediment input	2.5	2.7	
15. Nutrient input	2.3	3.2	3.0
16. HABs	2.6	2.6	
17. Hypoxia	2.9	2.5	3.0
18. Species invasion		2.8	
19. Sea level change		3.0	3.2
20. Sea temperature	3.2	3.2	3.2

Increasing sea temperature affects to all 3 ecosystems.

Coastal development and engineering have strong impacts to the ECS and SETO.

Demersal and pelagic fishing impact to the ECS and K/O, respectively.

Nutrient input has synergistic impacts to HABs and Hypoxia.

Problems for scoring

- Evaluation of impacts could be different among experts with different majority.
- Certainty of impacts are different among ecosystems, because quality and quantity of information are different.
- For ECS, more information in the intertidal and coastal waters along China are needed.
- For oceanic waters, few information may preclude appropriate evaluation of ecosystem responses.