A Review of Nutrient Concentrations in the Eastern Seto Inland Sea, Japan

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The Seto Inland Sea is located in the western part of Japan.

Length 500 km
Width 5 ～ 50 km
Area 17,000km²
Depth 30m

The Seto Inland Sea is the largest enclosed sea in Japan.
Beautiful landscape including about 600 islands

the most industrially developed area.

About 34 million people live in the coastal area.
Agricultural Effluent

Industrial Effluent Urban Wastewater

Rapid Urbanization
Centralization of Industry and Population

High Economic Growth from the 1960s onward

Red Tides

Phytoplankton

Nutrient
The Law for Conservation of Environment of Seto Inland Sea was enacted in 1973.
The enactment of the Law for Conservation of Environment of Seto Inland (1973)

History

Fig. Occurrence of red tides in the Seto Inland Sea, 1970 - 2005.
Short columns indicate incidents with fishery damage such as fish-kills.
Trends in fishery production in the Seto Inland Sea
(Source: Ministry of Agriculture, Forestry and Fisheries)
With the decrease of red tide occurrence, the fisheries yield have also declined.

Trends in fishery production in the Seto Inland Sea
(Source: Ministry of Agriculture, Forestry and Fisheries)

The culture of *Nori (Porphyra)* has been most heavily damaged.
Seaweed, Nori (Porphyra) is an important food for Japanese.
Harima-Nada, the eastern part of the Seto Inland Sea is well known for *Nori* culture.
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However, recent *Nori* culture in this area was heavily damaged due to insufficient low nutrients.
Fig. Variations of surface nutrients in Harima-Nada (Nishikawa et al. 2010)
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DIN concentrations have decreased significantly after 1990.

Fig. Variations of surface nutrients in Harima-Nada (Nishikawa et al. 2010)
Annual yield (100 million)

- First bleaching
- Insufficient low nutrient for Nori culture

Annual Nori yield in Kagawa prefecture
Annual *Nori* yield in Kagawa prefecture
\[ y = 0.0119x + 5.09 \]
\[ R^2 = 0.861 \]
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$R^2 = 0.861$

Annual yield (Hundred million sheets)

Rainfall amount (mm, Oct. to Feb.)
Annual yield (100 million sheets)

Rainfall amount (mm, Oct. to Feb.)

$y = 0.0119x + 5.09$

$R^2 = 0.861$
Nutrient supply in the coastal waters

Seawater nutrient concentrations have decreased

Graph showing decreasing nutrient levels from 1970 to 2010.
The reasons for the recent decrease of nutrients concentrations

(1) decrease of nutrient loading from riverine sources

(2) decrease of recent rainfall amount and change of the manner of rainfall

(3) decrease of the upward nutrient flux across the overlying water-sediment interface.
The reasons for the recent decrease of nutrients concentrations

(1) decrease of nutrient loading from riverine sources

(2) decrease of recent rainfall amount and change of the manner of rainfall

(3) decrease of the upward nutrient flux across the overlying water-sediment interface.
One explanation for the gradual decrease of DIN concentrations from 1970 is due to the law enacted by the Environmental Agency.

But the reason of the recent decrease of DIN concentrations is still unknown.
The reasons for the recent decrease of nutrients concentrations

(1) decrease of nutrient loading from riverine sources

(2) decrease of recent rainfall amount and change of the manner of rainfall

(3) decrease of the upward nutrient flux across the overlying water-sediment interface.
Annual precipitation in Kagawa prefecture

Annual precipitation (mm)


1991 1993 1995 1997 1999 2001 2003 2005 2007 2009
The change of annual precipitation can not be observed. Any tendency for example, decrease of annual precipitation could not be observed.
The rate of one day rainfall as percent of annual rainfall
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But there was no evidence. Statistically, no sufficient changes were observed.
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It is likely that the change of rainfall amount and its manner did not influence the nutrient decrease.
The reasons for the recent decrease of nutrients concentrations

(1) decrease of nutrient loading from riverine sources

(2) decrease of recent rainfall amount and change of the manner of rainfall

(3) decrease of the upward nutrient flux across the overlying water-sediment interface.
Seasonal variations of DIN concentrations at the surface and bottom layers at Harima-Nada, Seto Inland Sea, Japan

Tada et al. 2008
P flux from the sediments was determined in 1982

Now?
Comparison of upward P flux from sediment in 1982 and 2010 using core incubation method.

*: different method (calculated from vertical profiles of phosphate in the pore water using Fick’s law)
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*: different method (calculated from vertical profiles of phosphate in the pore water using Fick’s law)
The potential ability of releasing bottom sediment nutrients likely decreased due to a change in sediment quality.
Conclusion

We discussed the reasons for the recent decreases in nutrient concentrations within the context of:

(1) decrease of nutrient loading from riverine sources

(2) decrease of recent rainfall amount and change of the manner of rainfall

(3) decrease of the upward nutrient flux across the overlying water-sediment interface.

Based on the analysis of our data set, (1) and (2) reason can not explain the recent nutrient decrease.

Among these three reasons, (3) one is the most important reason to explain the recent nutrient decrease.

Namely, the potential ability of releasing nutrients from bottom sediment likely decreased due to a change in sediment quality.
Thank you for your attention
After 2002 when *Nori* bleaching started to occur, the rainfall amount in September was low. But the reason was unknown.