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# Assessment of Eutrophication in Potential Eutrophic Zones in Masan Bay

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# Outline

1. General Background for Eutrophication

2. Background for Dead Zone related with low DO

3. A Case Study of Eutrophication and Hypoxia in Korea

4. Assessment of eutrophication in Jinhae/Masan Bay:
   1. Long-term data analysis in Masan Bay_(1995-2005)
   2. Nutrient loading and COD in Masan Bay_(2005-2010)
   3. Recent data analysis in Jinhae/Masan Bay_(2010-2015)

# 1. General Background for Eutrophication

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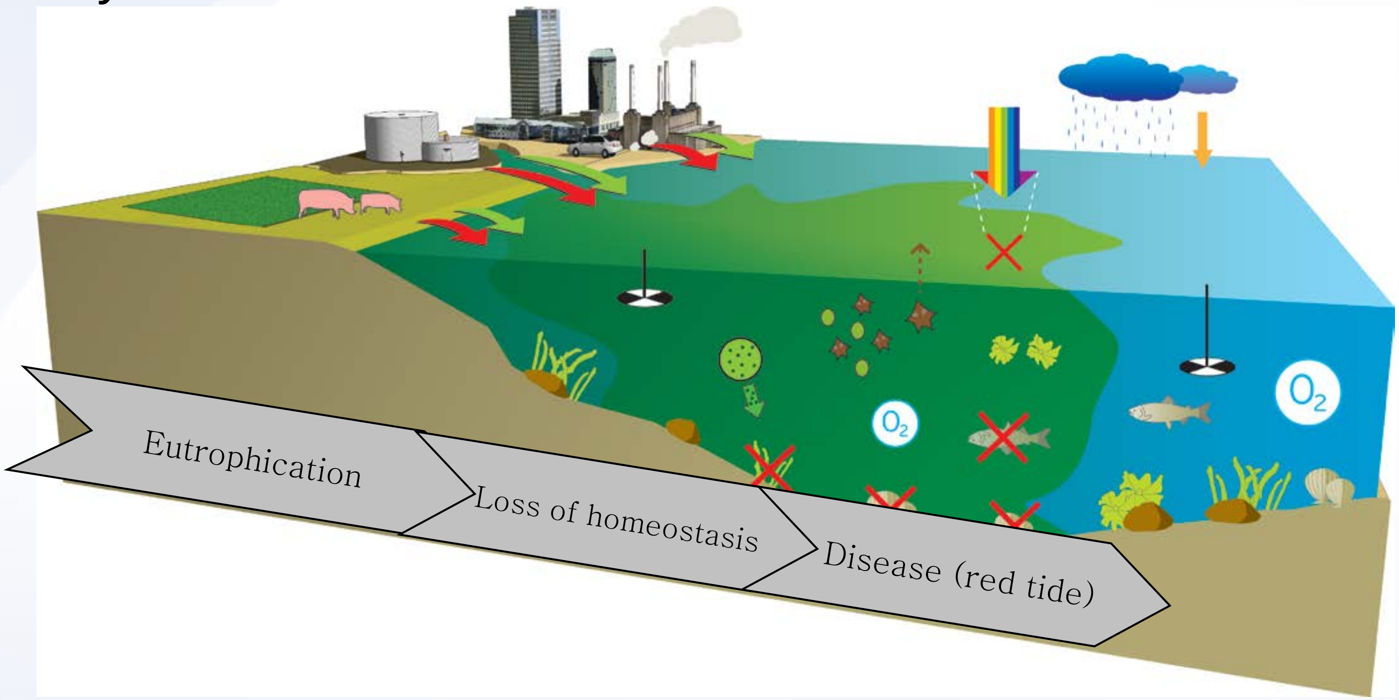
## Ecosystem in coastal water

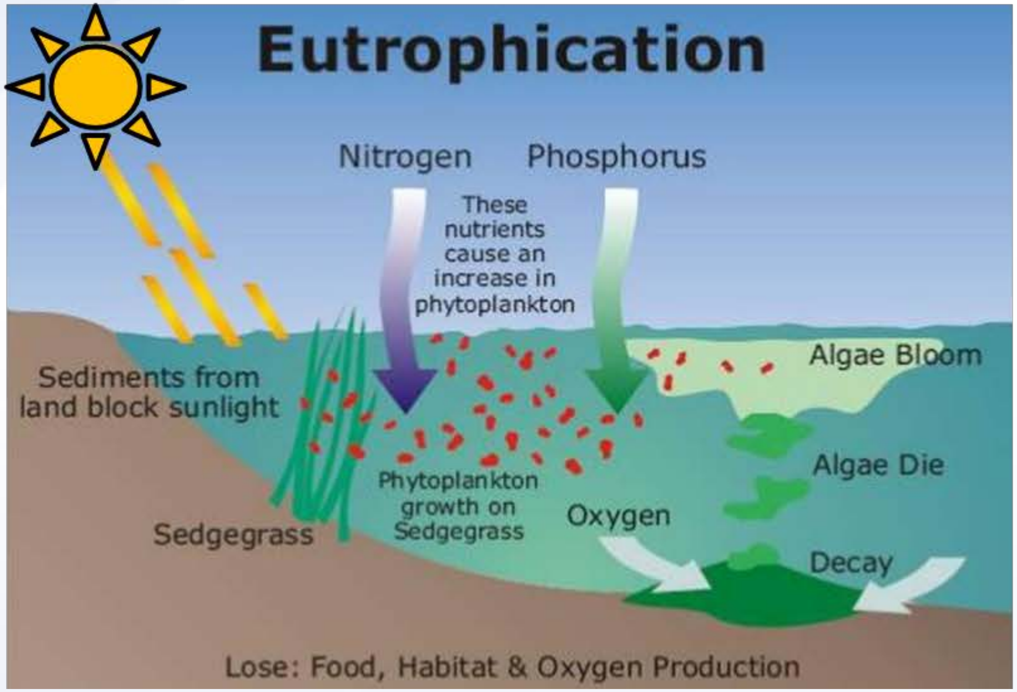



Our coastal areas continue to suffer pressures from human population growth, increased industrial development, and even climate change.

Following urbanization and industrialization, coastal areas can become significant sinks for anthropogenic nutrient, leading to abrupt environmental changes and threats to ecosystem sustainability.

# 1. General Background for Eutrophication

## Coastal eutrophication process




**Nutrients loading**

**Algal bloom event**

**Algae die and decay**

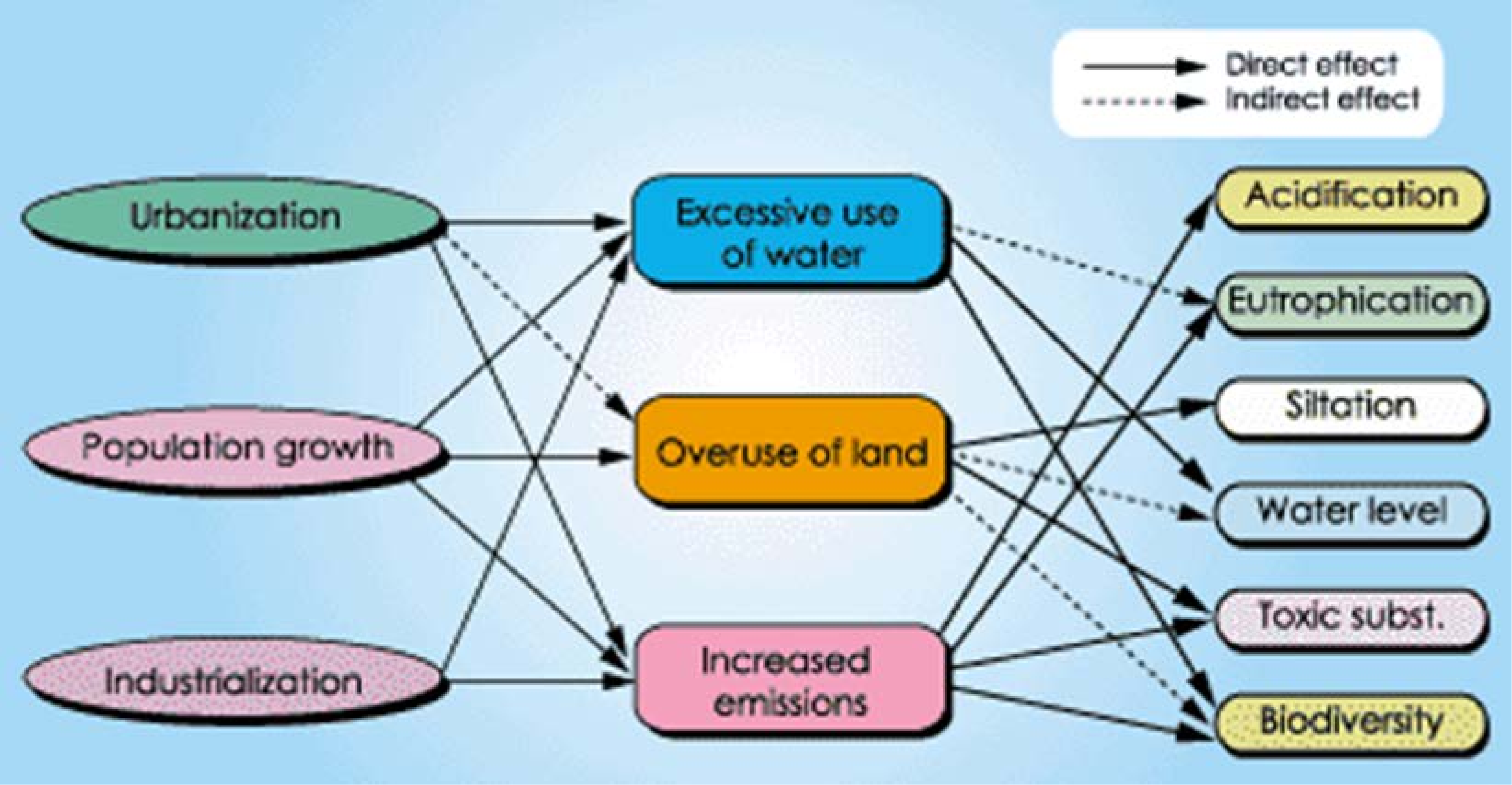
**Low oxygen or hypoxia**

Eutrophication is regarded as the major cause of the worldwide increase in the number of hypoxic coastal zones since the 1960s (Diaz and Rosenberg, 2008). Hypoxia in Korean coastal waters is caused mainly by eutrophication, due to anthropogenic activities in watersheds.

As one serious consequence of eutrophication, most semi-enclosed bay became quickly and heavily polluted by a variety of wastes, which led to harmful algal blooms. These blooms make major contributions to the development of hypoxia in Korean coastal regions, leading to substantially enhanced biological oxygen consumption in water columns and sediments.

# 1. General Background for Eutrophication

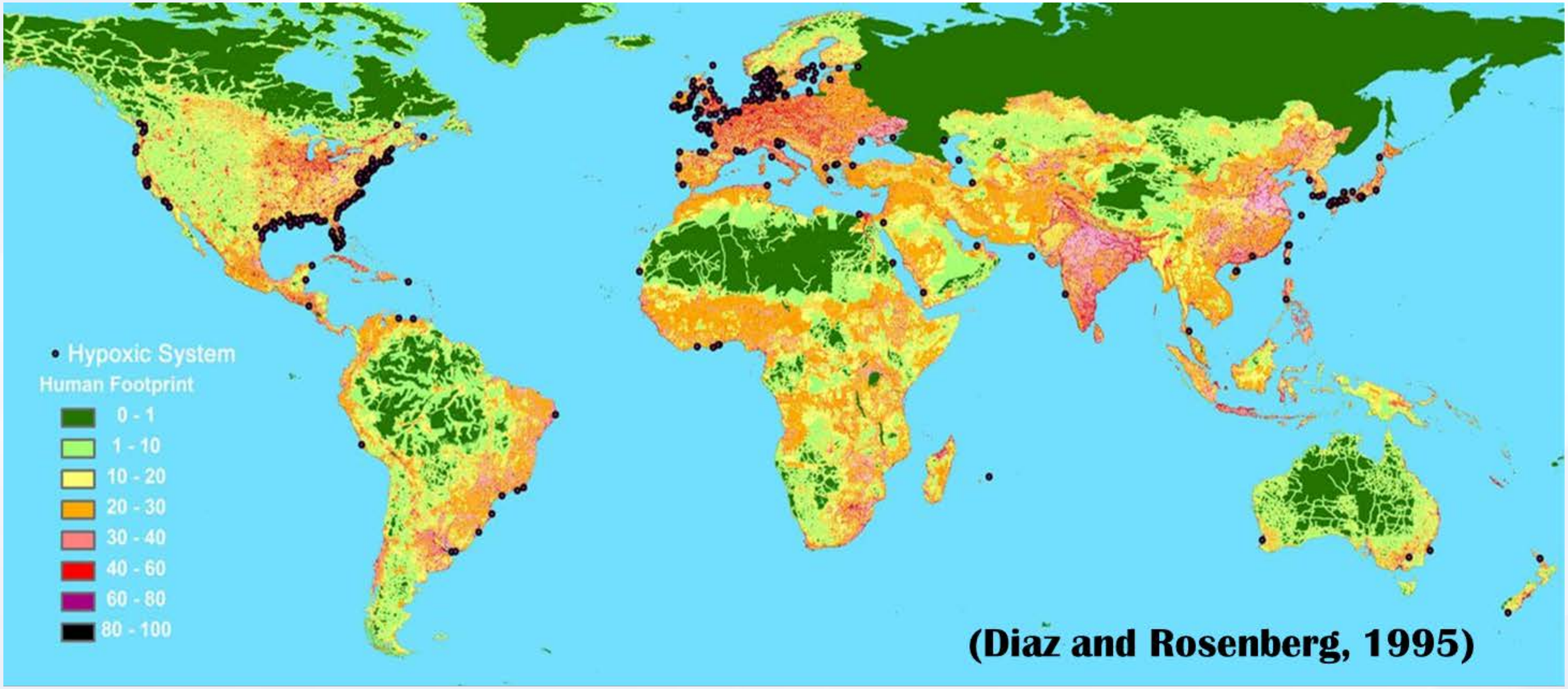
- Direct effect and indirect effect for coastal eutrophication




Population growth, urbanization Industrialization produces various pollutants into the oceans area. Consequently, the phenomenon such as ocean acidification, eutrophication, harmful algal blooms (HABs) happens and thus, biodiversity is changed, directly or indirectly.

# 2. Background for Dead Zone

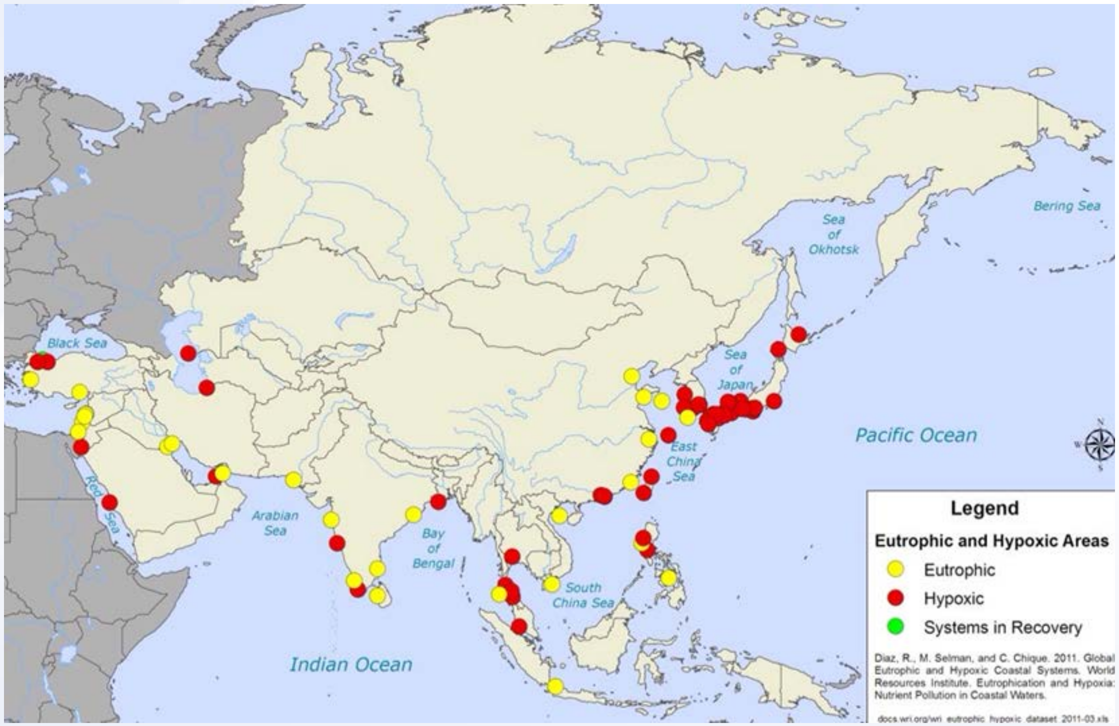
## Hypoxia area in the world



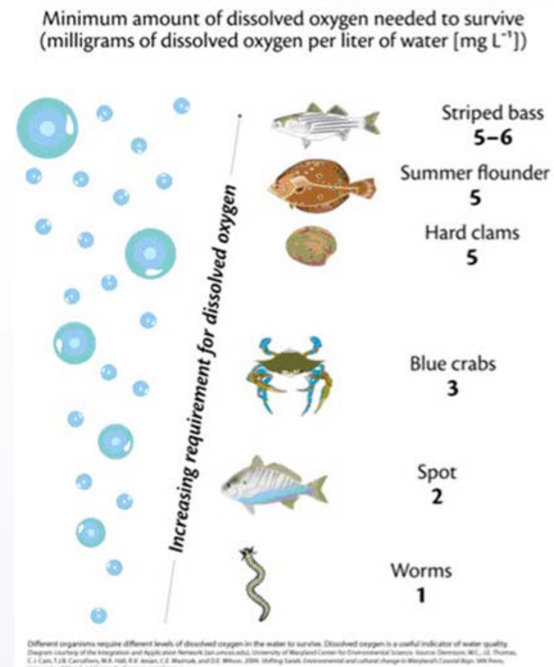

Coastal zones receive large quantities of nutrients from inflowing rivers by human activities. Consequently, loads of pollutant lead to eutrophication and the depletion of dissolved oxygen (DO). Hypoxia area is one of the major environmental concerns in coastal areas throughout the world.

# 2. Background for Dead Zone

## Geographical features of eutrophic and hypoxic area in AISA




The demand for DO of marine organisms is very different.



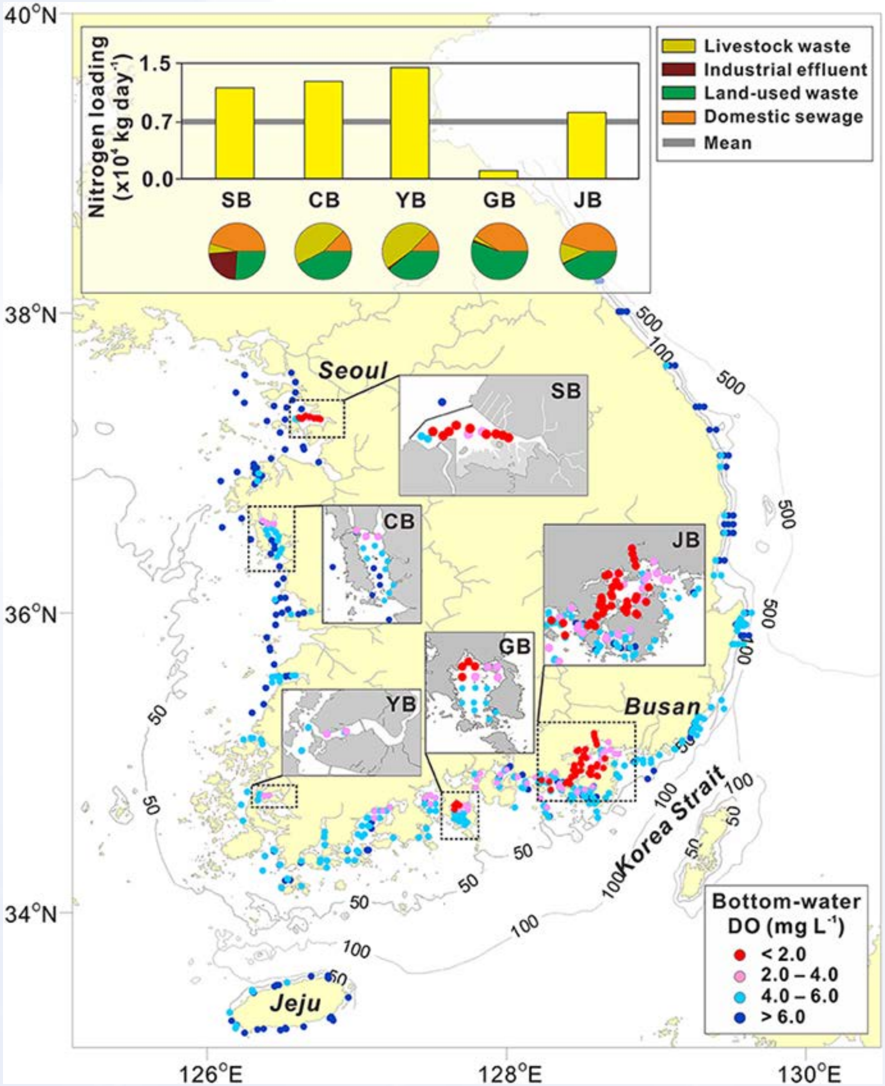

http://www.watershedcounts.org/marine_water_quality.html

In case of Asia, hypoxic zones appear strongly in Korea, Japan and China even developing county of Southeast Asia. However, we can not find the eutriphic and hypoxic area in Russia.

Actually, opportunistic species, clam worm (Polychaeta) can survive from 1 mg $L^{-1}$ of DO and marine fishes can survive from 5 mg $L^{-1}$.

# 3. A Case Study in Korea

## Geographical features of eutrophic and hypoxic area in KOREA




Lee et al., 2018

A map showing the minimum values of bottom-water dissolved oxygen (DO) recorded in Koran coastal waters. Five representative hypoxic regions—Shihwa Bay (SB), Cheonsu Bay (CB), Yeongsan Bay (YB), Gamak Bay (GB), and Jinhae Bay (JB)—are highlighted on the map.

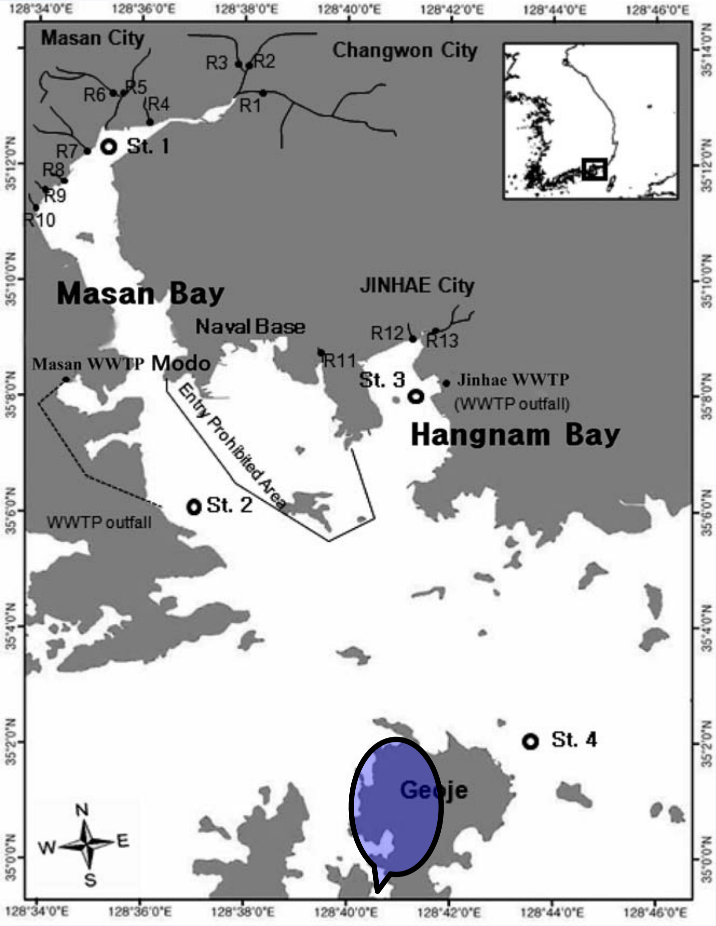
The solid gray line indicates the mean value of the total N loading in the Korean coastal region. The dots represent the bottom-water DO concentrations (red dots, < 2 mg $L^{-1}$; pink dots, 2–4 mg $L^{-1}$; light-blue dots, 4–6 mg $L^{-1}$; blue dots, > 6 mg $L^{-1}$).

Red colors are referred to as "Korean dead zones".
Eutrophication due to land-based pollutants forms an hypoxia water mass

Typical examples are the "Masan and Jinhae Bay".

# 3. A Case Study in Korea

## Map of eutrophic and hypoxic area in Masan Bay




Masan Bay has shown a slow rate of water exchange and a trapping effect on contaminants discharged from surrounding industrial complexes and cities. Masan and Changwon industrial complexes, including petrochemical, heavy metal, electrical, and plastic industries, as well as heavily populated cities, are located adjacent to the bay (Hong et al., 2009b; Khim et al., 1999a; Moon et al., 2008b).

Masan Bay has been listed as a Special Management Coastal Zone (SMCZ) by the Korean government since 2000, in association with increased contaminant levels (Choi et al., 2009a,b).

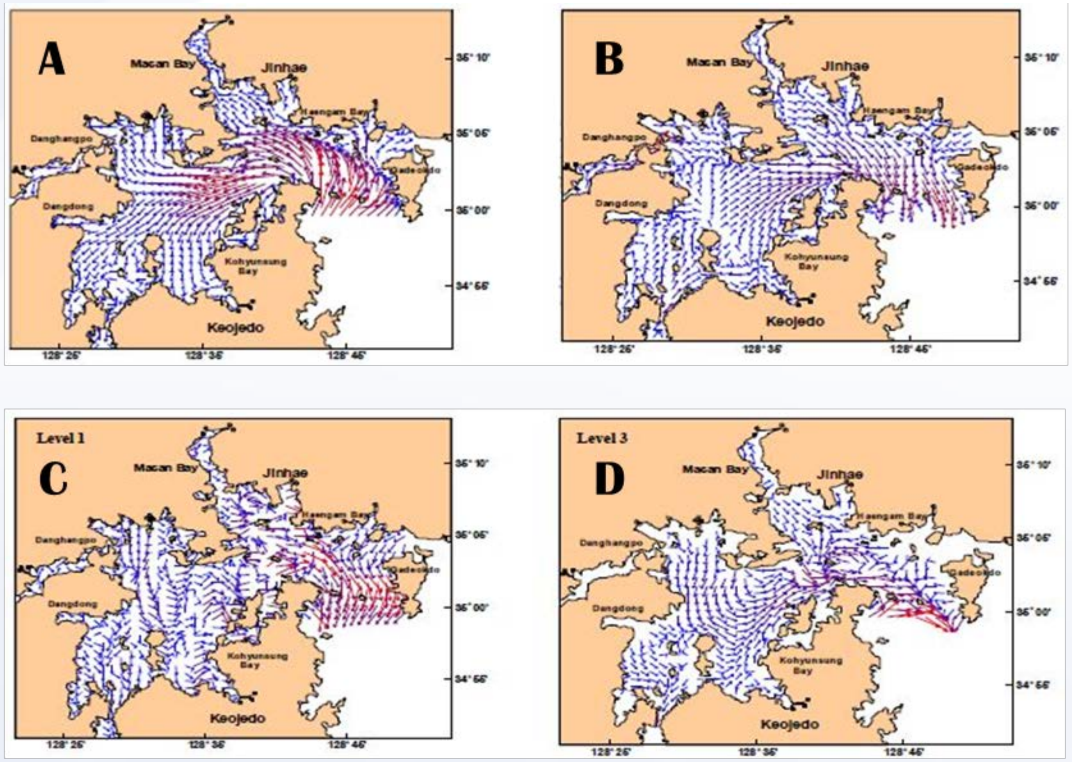
These studies showed that Masan Bay was heavily polluted by the trace organic chemicals originating from surrounding industrial complexes and municipal cities.

Masan Bay is one of the most polluted estuaries and semi-enclosed bay in Korea

# 3. A Case Study in Korea

## Oceanographic features in Jinhae/Masan Bay

The velocity of the tidal current: 30-40 cm/sec (mouth part near Gaduk Island); 20-30 cm/sec (middle)




**A: flood tide** **B: ebb tide**
**C: at the surface** **D: at the middle**

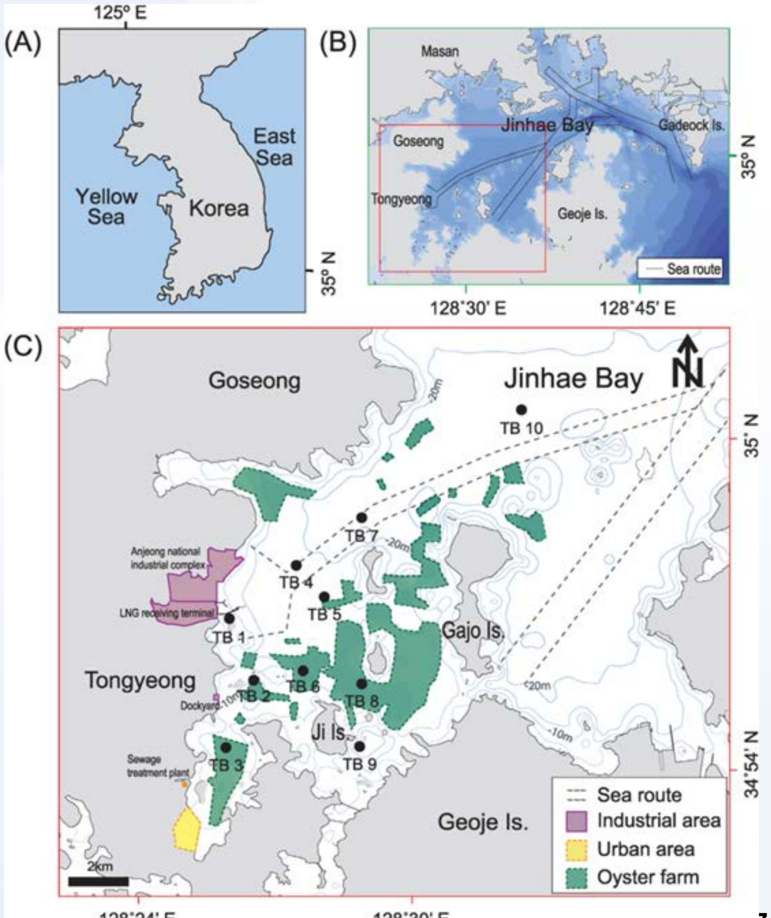
Gadeok Channel is the primary pathway for the exchange of seawater between Jinhae Bay and the South Sea

Due to low exchange rate in western area, phytoplanktpon blooms have frequently occurred and accumulated in western area of semi-enclosed bay, resulting sharp summer oxygen depletion, loss of aquatic life, and aesthetic problems.

The circulation of sea water is closely related with formation of hypoxia zones in the Jinhae/Masan Bay.

# 3. A Case Study in Korea

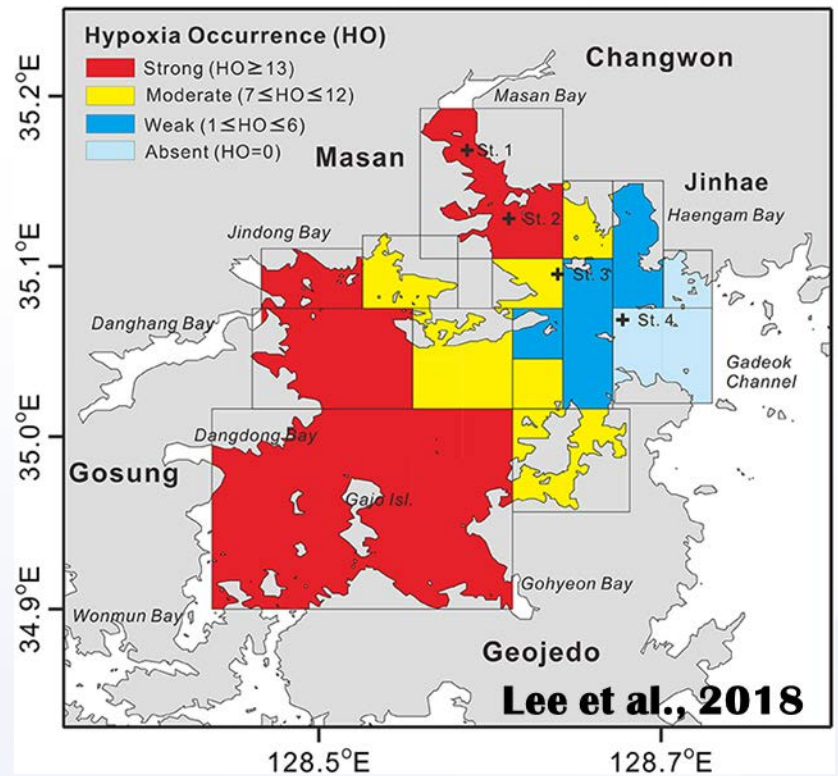
## Hypoxia occurrence due to farming area in Jinhae/Masan Bay




Bae et al., 2017

In another aspect, formation of hypoxic zones significantly correlated with the locations of oyster farms in the Jinhae Bay.

The criterion of dissolved oxygen < 3mg $L^{-1}$

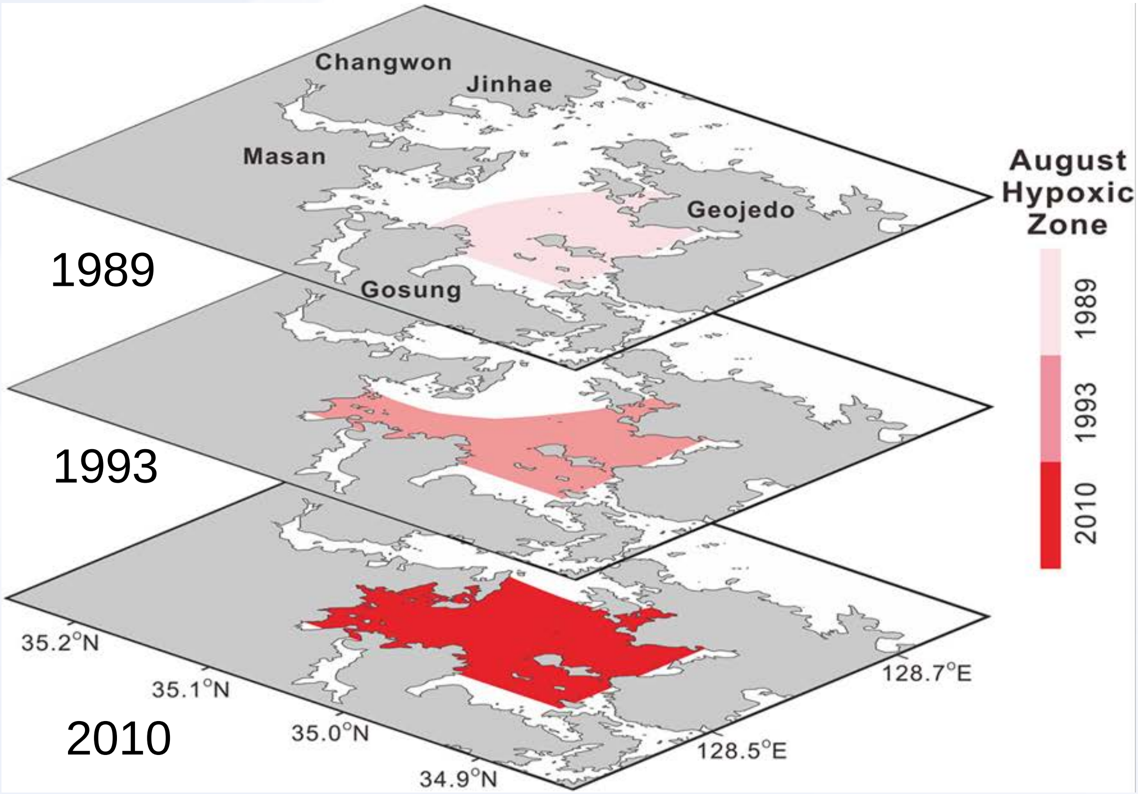



The oyster farm is extremely dense, the organic matter from oyster have been continuously deposited in western area since 1983.

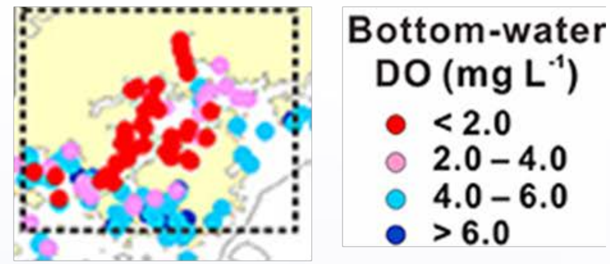
As a result, hypoxia zone has widely spread in western area, particularly in summer.

# 3. A Case Study in Korea

## Summer Hypoxic zone in Jinhae Bay




Decadal variation in the areal extent of summer (August) hypoxia in Jinhae Bay



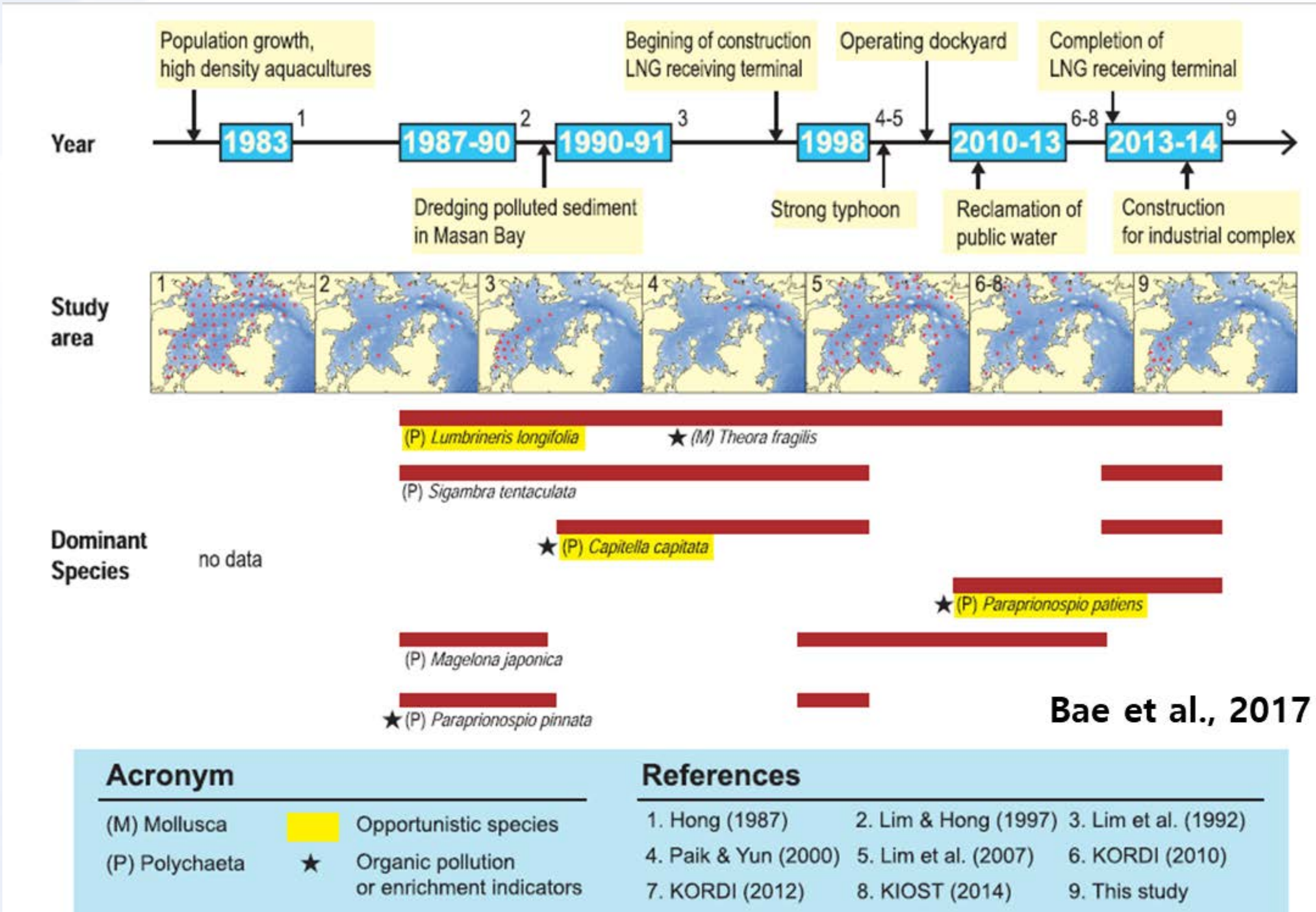

**Lee et al., 2018**

**Kim et al., 2013**

The hypoxic zone in the Jinhae Bay has been expanded and stronger in summer, It is related with dense oyster culture farm, implying that it can be led to accelerate the hypoxic zone of inner bay because the bottom water during summer stratified period does not well mix to surface water (limitation of water vertical mixing).

# 3. A Case Study in Korea

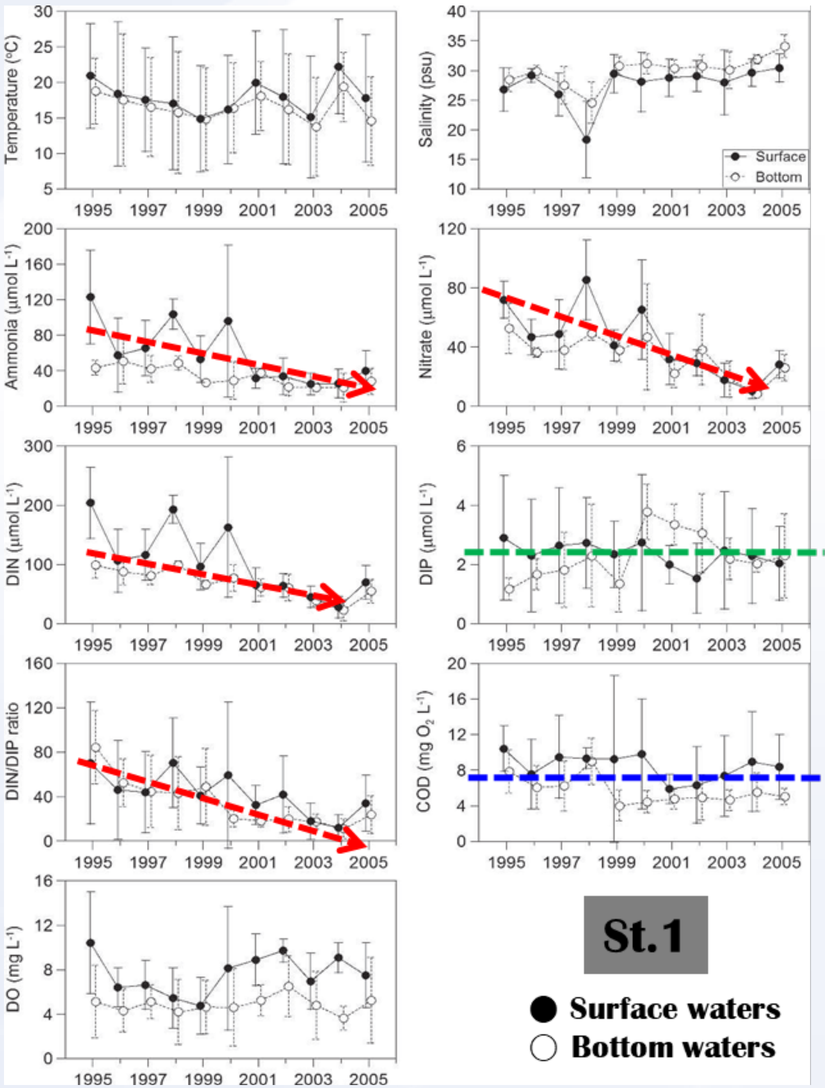
## Summer Hypoxic zone and benthic organisms in Jinhae Bay

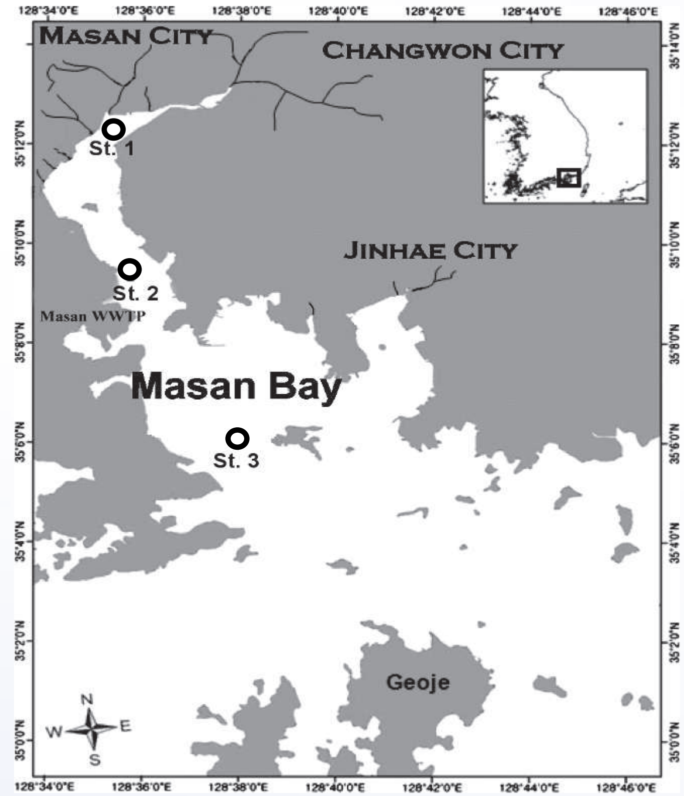



The oyster farms located in the inner most area seem to provide organic rich bottoms being dominated by opportunistic and/or organic pollution indicator species.

# 4. Assessment of eutrophication in Jinhae/Masan Bay

## Seasonal/ long-term trends in environmental factors (1995-2005)




Annual variations of temperature, salinity, ammonia, nitrate, DIN, DIP, DIN/DIP ratio, COD, and DO in inner Masan Bay from 1995 to 2005. Error bars represent one standard deviation.

Kim et al. 2012

Concentrations of inorganic N sources were gradually decreased from 1995.

# 4. Assessment of eutrophication in Jinhae/Masan Bay

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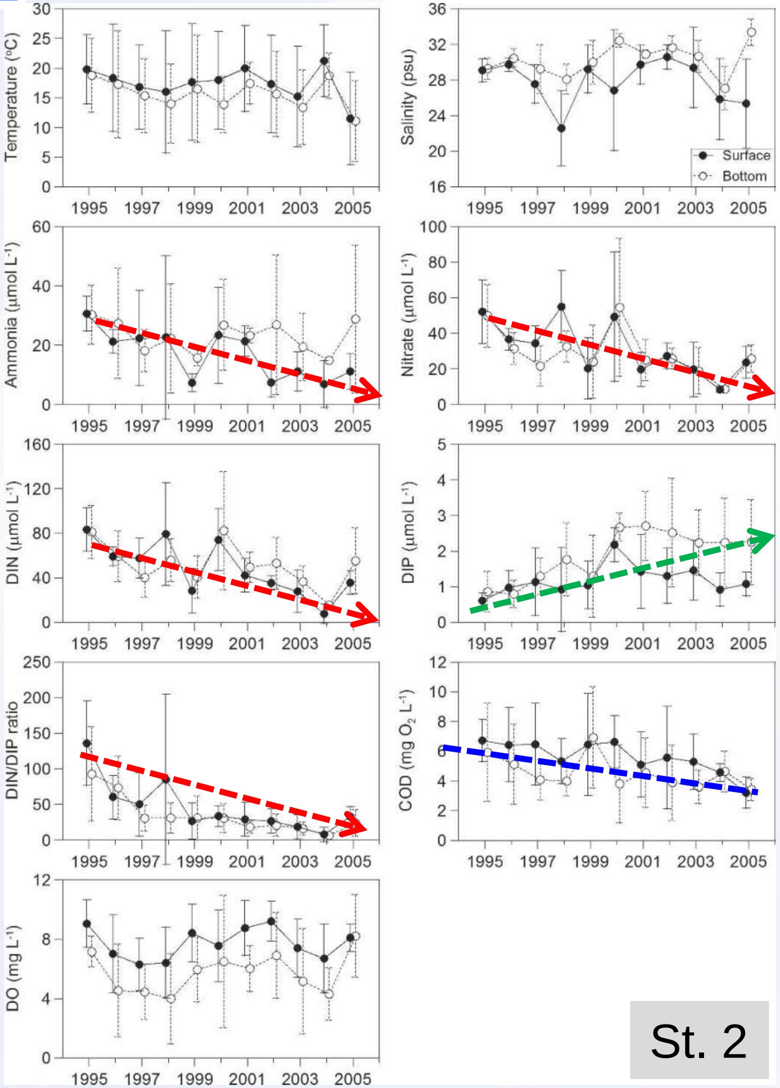
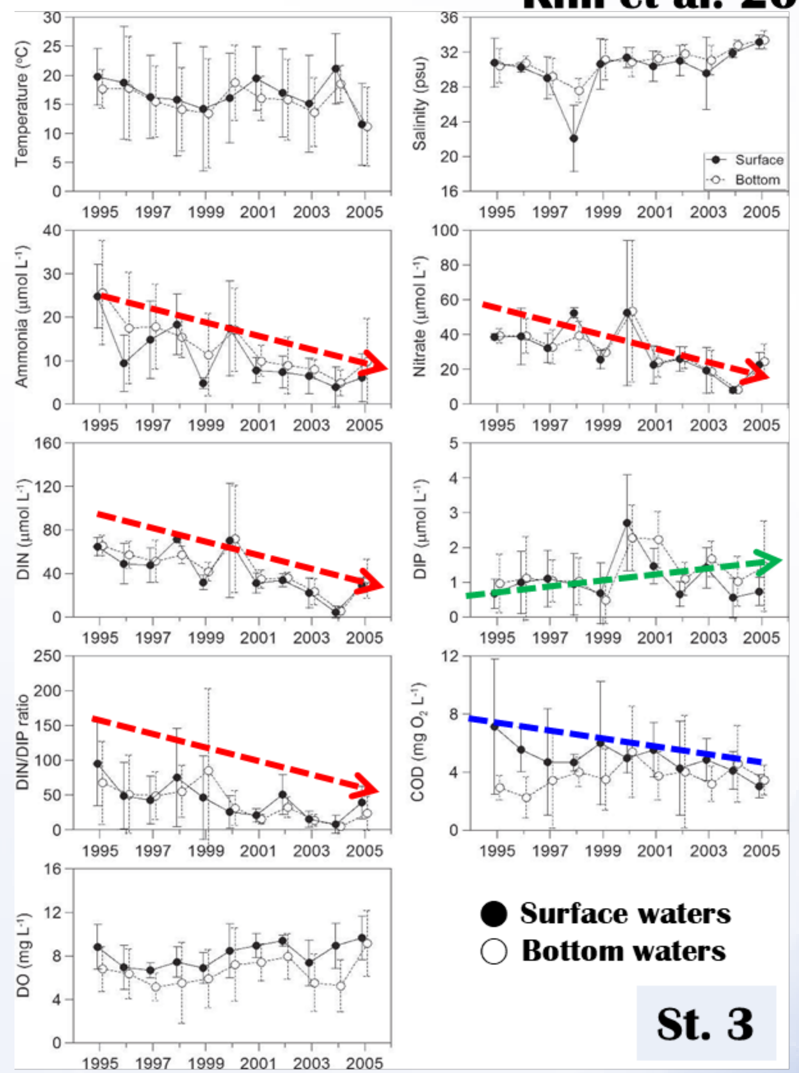
## Seasonal/ long-term trends in environmental factors (1995-2005)

Kim et al. 2012




On the other hand, in outer site of the bay, DIP was slightly increased. However, the concentrations of inorganic N sources and COD were gradually decreased

# 4. Assessment of eutrophication in Jinhae/Masan Bay

Chang et al., 2012

## Seasonal/ long-term trends in environmental factors (2005-2010)

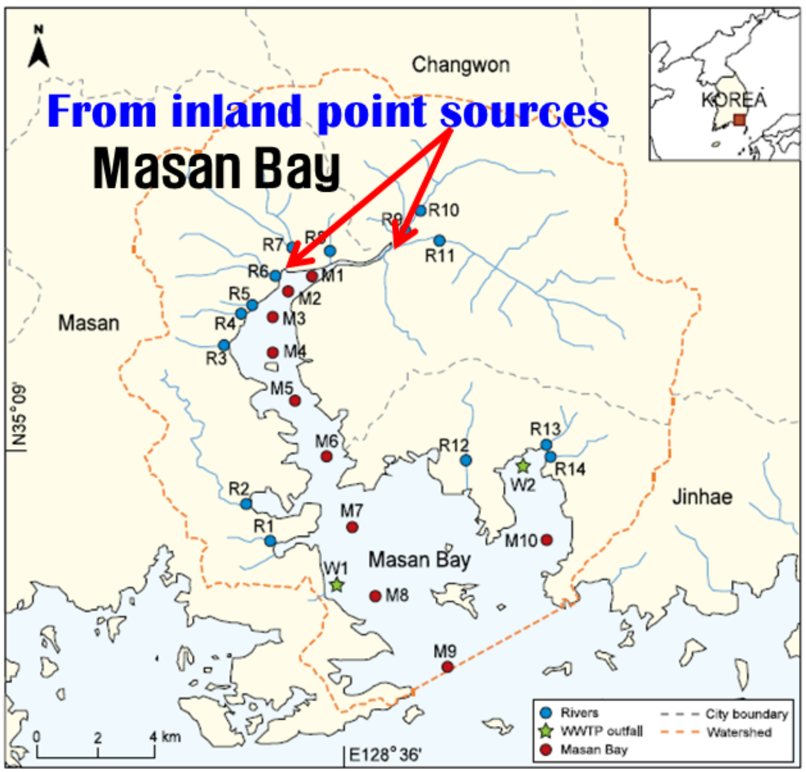
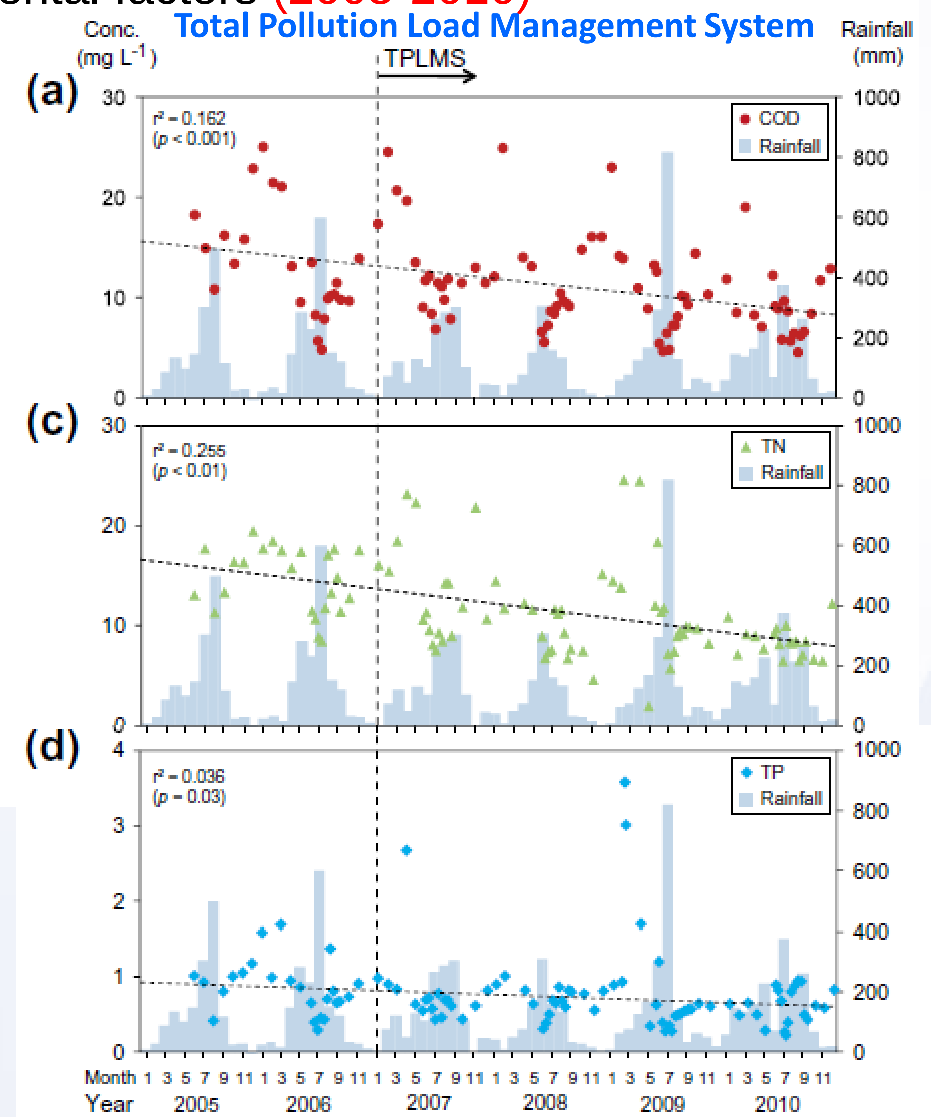



Fig. 1. Map showing the sampling locations in the study area. Sampling details are fully given in Table 1

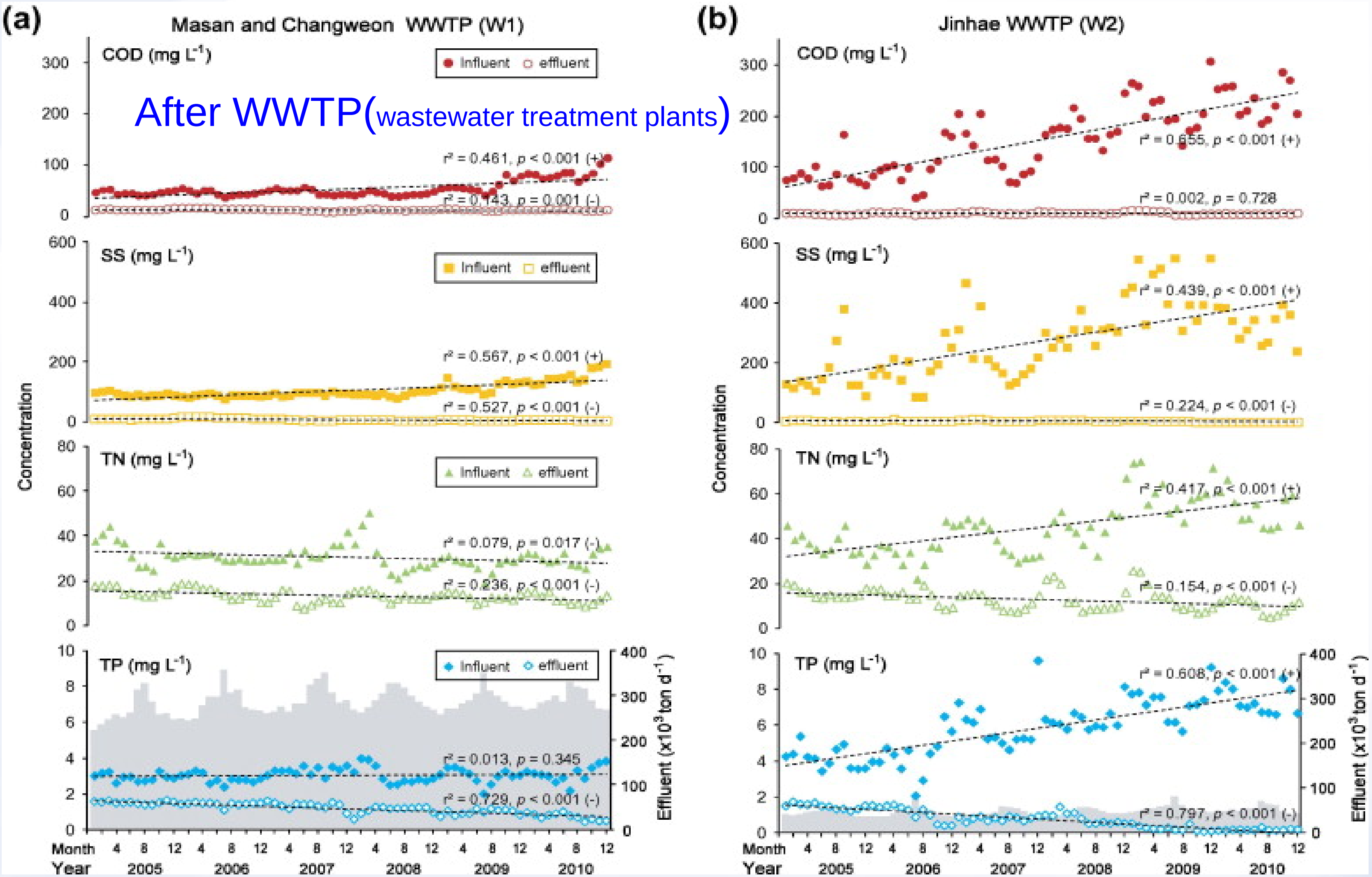



Temporal changes in concentrations (mg $L^{-1}$) of (a) COD, (c) TN, and (d) TP in freshwater measured from 14 sites (given as mean) in the inland rivers over the six-year period (2005–2010), rainfall data (mm) during the corresponding period was given as background information.

The amounts of COD, TN and TP loading from the rivers were gradually decreasing.

# 4. Assessment of eutrophication in Jinhae/Masan Bay

## Seasonal/ long-term trends in environmental factors (2005-2010)



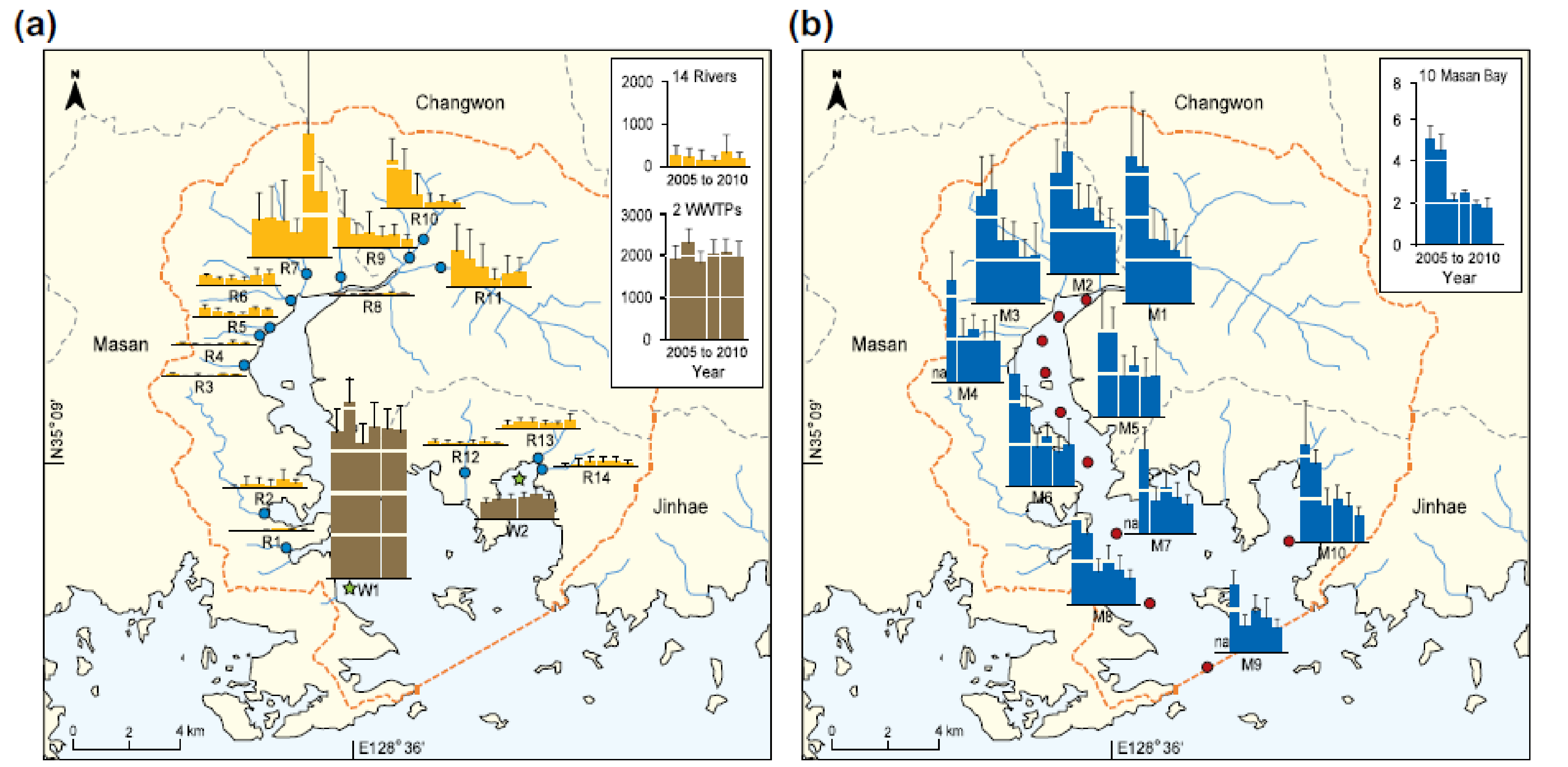

Temporal changes in concentrations (mgL1) of COD, SS, TN, and TP in influent and effluent measured from (a) Masan and Changweon WWTP (W1) and (b) Jinhae WWTP (W2) over the six-year period (2005–2010).

After WWTP treatment, the effluents of COD, SS, TN and TP were noticeably decreased.

# 4. Assessment of eutrophication in Jinhae/Masan Bay

## Long-term trends in COD budget in Masan Bay (2005-2010)

**After wastewater treatment plants (1993), COD has been continuously reduced**

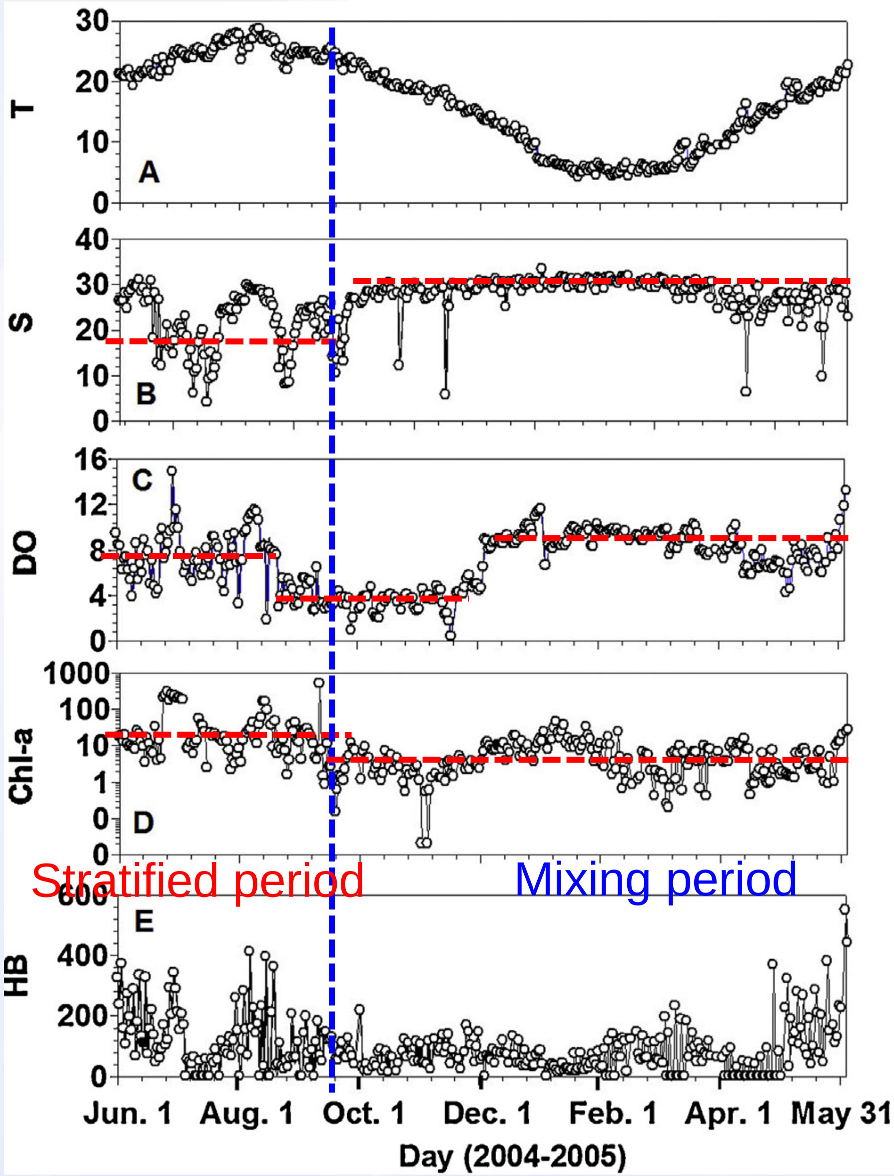


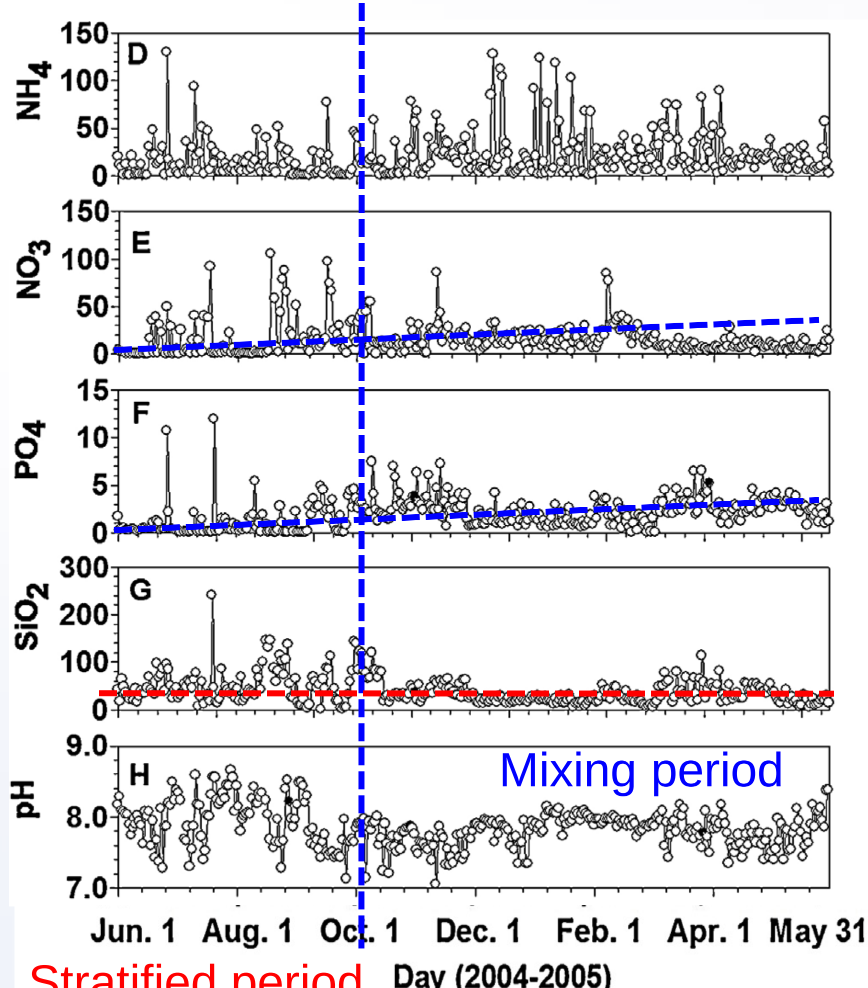

Spatiotemporal distribution of COD budget in Masan Bay, showing (a) annual mean COD loads ($kgd^{-1}$) from the inland rivers and WWTPs and (b) annual mean COD concentrations ($mgL^{-1}$) in the Masan Bay over the six-year period (2005–2010).

COD budgets were decreased **after introduction of TPLMS (Total Pollution Load Management System, 2006)** in the Masan Bay

# 4. Assessment of eutrophication in Jinhae/Masan Bay

Daily variations in environmental factors at St. 1 in Masan Bay (2004-2005)




Jeong et al. 2013

Daily variations in environmental factors

# 4. Assessment of eutrophication in Jinhae/Masan Bay

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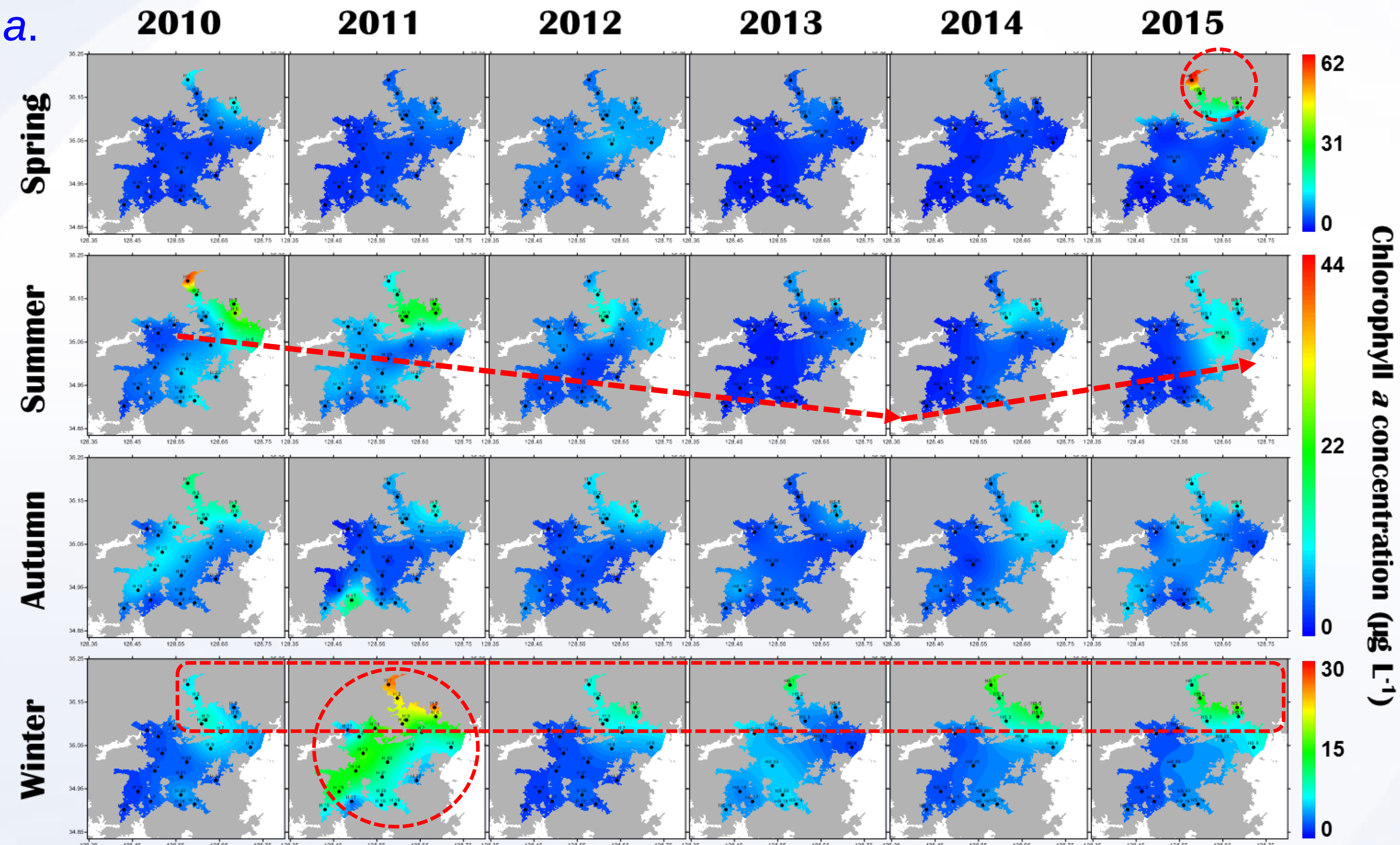
## Seasonal variations in biotic(Chl.*a*) factor in Jinhae/Masan Bay (2010-2015)

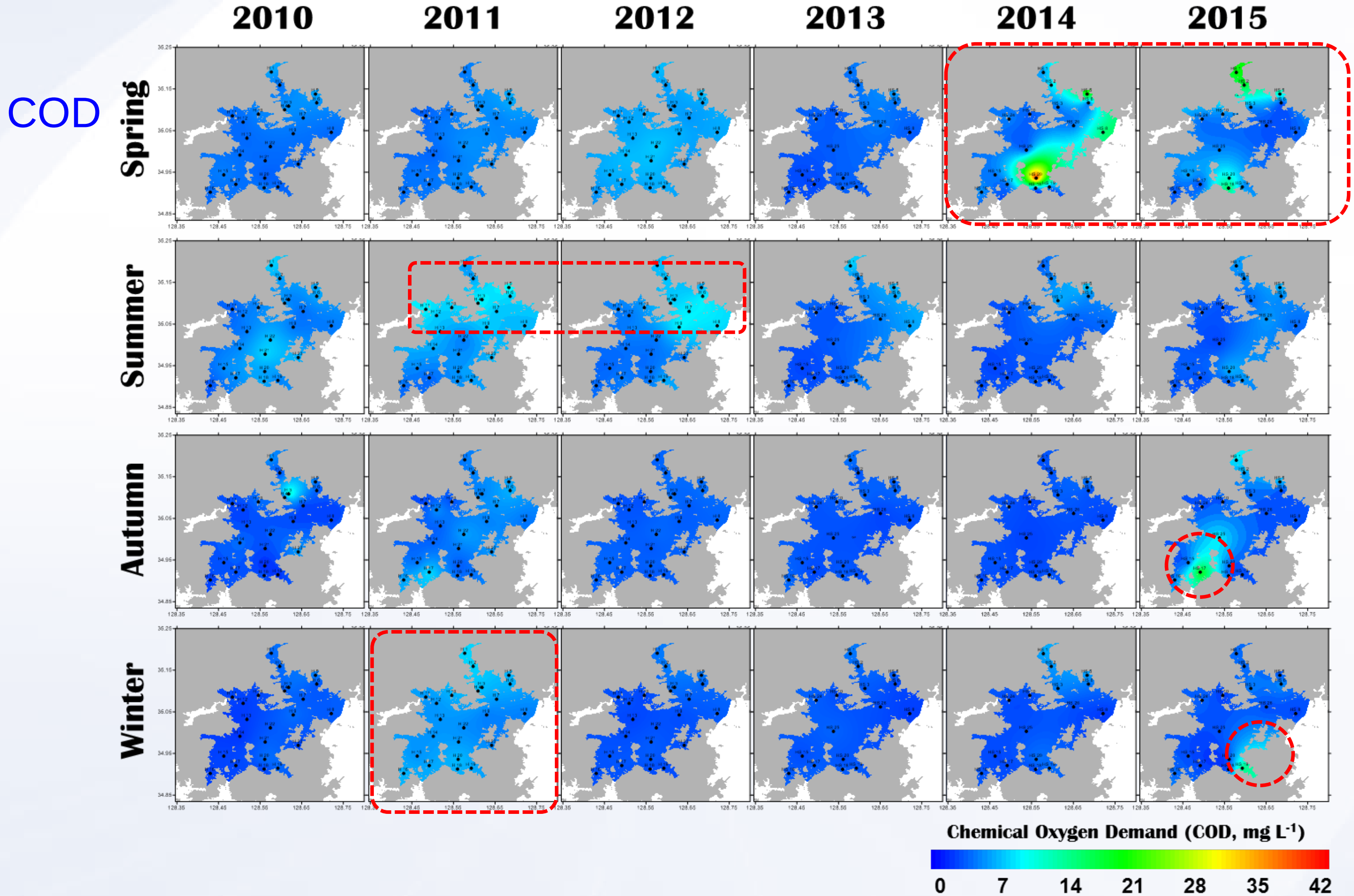
Chl *a*.




- In spring, Chl. *a* was very high in Masan Bay and observed to be 62 μg $L^{-1}$ in 2015.
- In summer, Chl. *a* trend were decreased until 2013, and then increases again after 2014, particularly in Masan Bay.
- In autumn, the tendency of Chl. *a* was high in Masan Bay.
- In winter, Chl. *a* was high throughout the Jinhae Bay as well as Masan Bay in 2011.

# 4. Assessment of eutrophication in Jinhae/Masan Bay

Seasonal variations in COD (chemical oxygen demand) in Jinhae/Masan Bay(2010-2015)




- Recently (in 2014 and 2015), COD increase with Masan and south of Jinhae Bay in spring season.
- In autumn, COD of the southern Jinhae Bay was intermittent higher than other area.
- Although there is no clear correlation between Chl. a and COD, overall COD also tends to increase whe n bloom occurs like winter season in 2011.

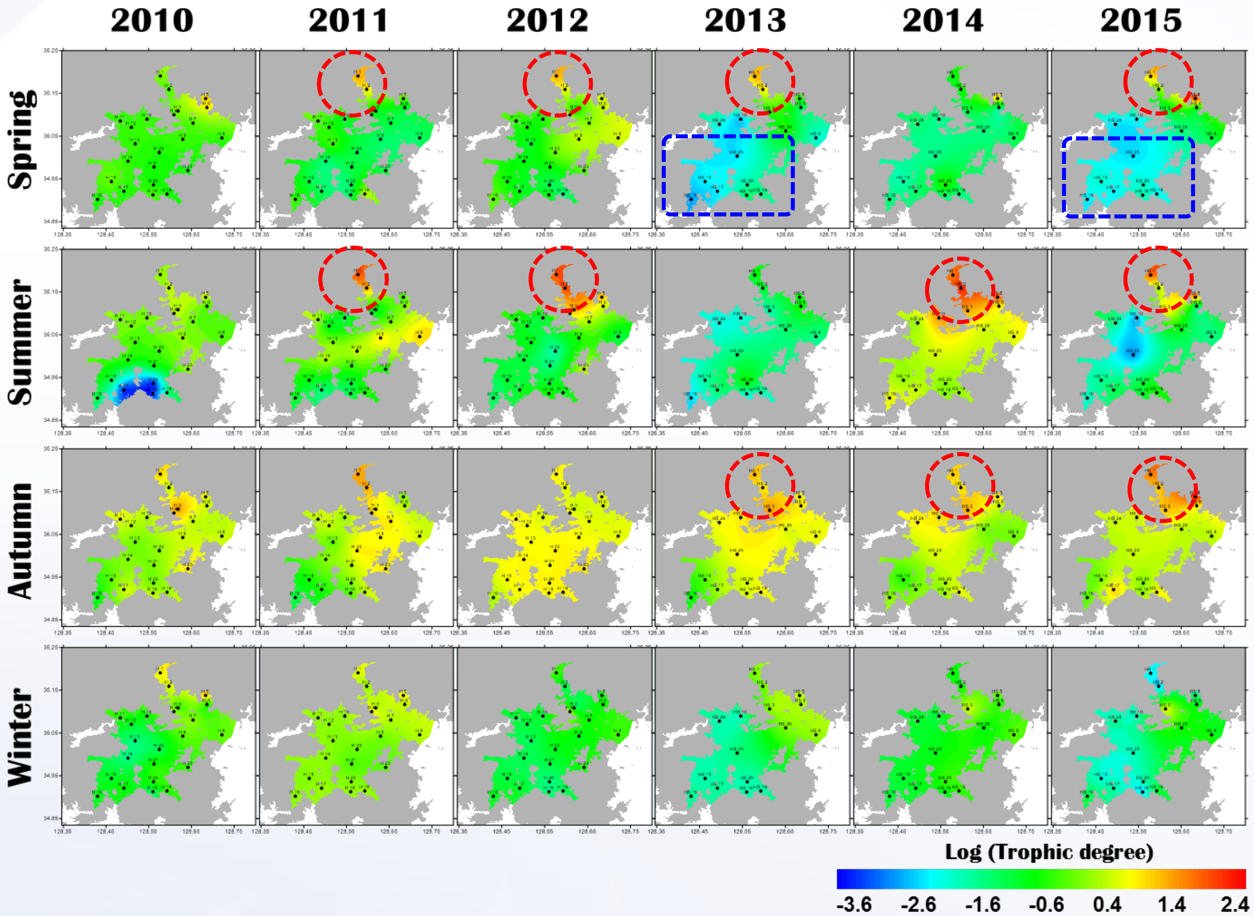
# 4. Assessment of eutrophication in Jinhae/Masan Bay

## Seasonal variations in eutrophic degree in Jinhae/Masan Bay (2010-2015)

Eutrophic index

$$\frac{COD \times DIN \times DIP}{3.43}$$

Okaichi 1972



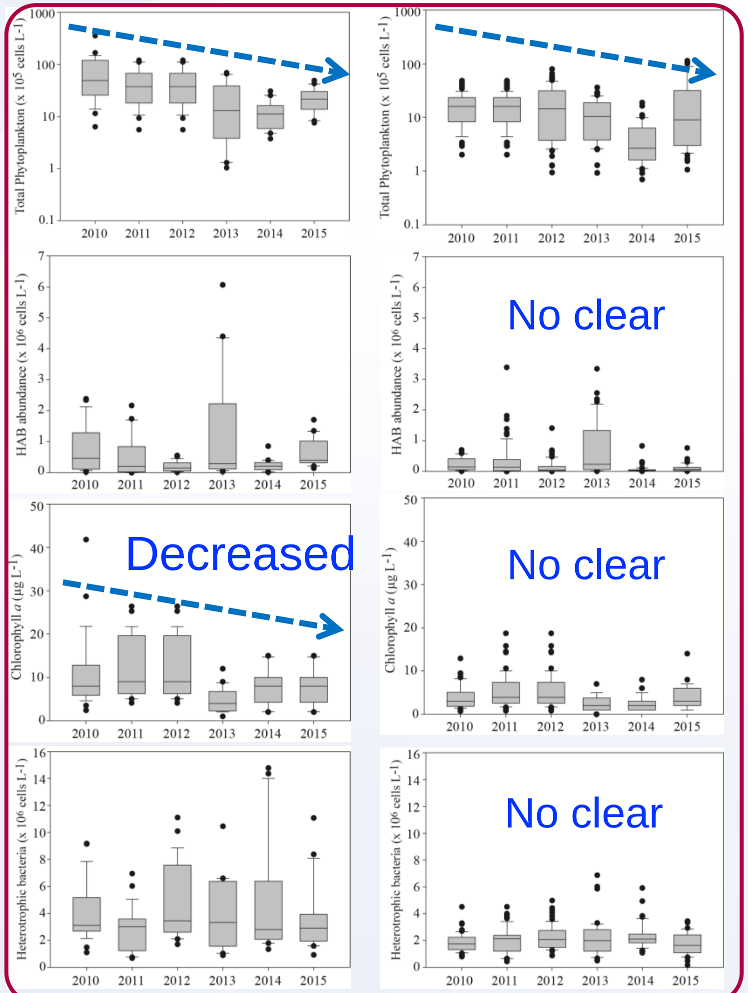

- In spring, Masan Bay has a high eutrophic degree, but the degree tends to decline in the western parts of bay.
- In summer, eutrophic degree is also high in Masan Bay, particularly in 2011, 2012, 2014 and 2015.
- In autumn, eutrophic degree was increased in most of station of Jinhae/Masan Bay.
- In winter, we can not find the high eutrophic degree, which may have related with low COD levels and DIN.

- As a whole, eutrophic degree was high in the inner area of Masan Bay, whereas it was kept to low in the western parts of Jinhae Bay.

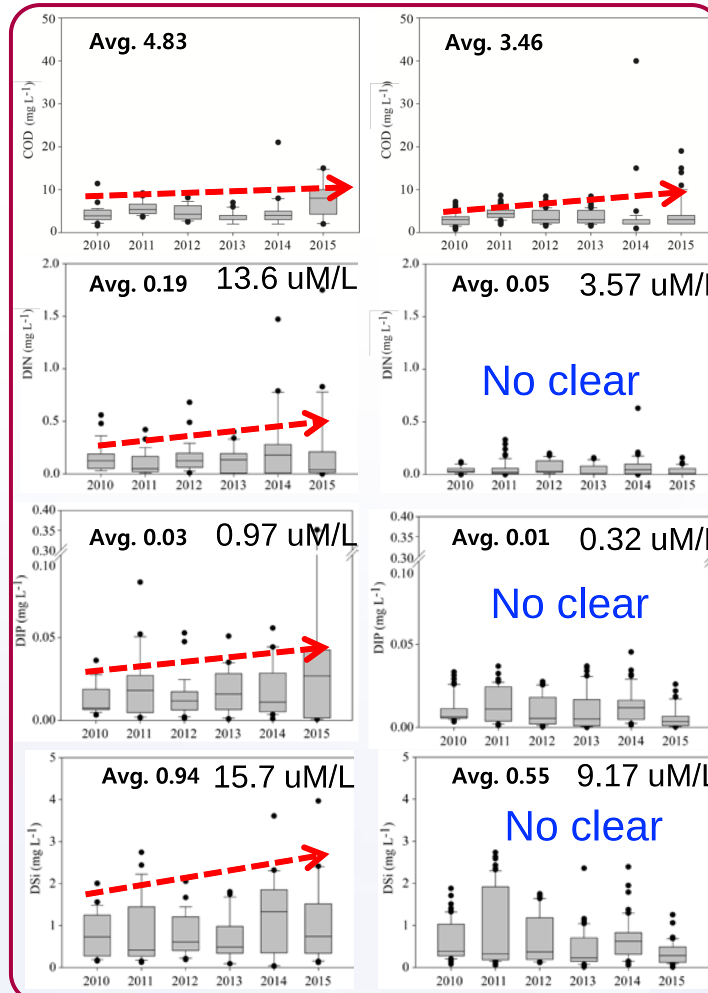
# 4. Assessment of eutrophication in Jinhae/Masan Bay

## Seasonal variations in biotic and abiotic factors in Jinhae/Masan Bay (2010-2015)

Masan Jinhae




Masan Jinhae




- Total phytoplankton was gradually decreased in Masan Bay and Jinhae Bay
- COD was slightly increased in Jinhae/Masan Bay. DIN and DIP were also slightly increased in Masan Bay.
- In Jinhae Bay, although COD was slightly increased, the other factors were not clear.

# 4. Assessment of eutrophication in Jinhae/Masan Bay

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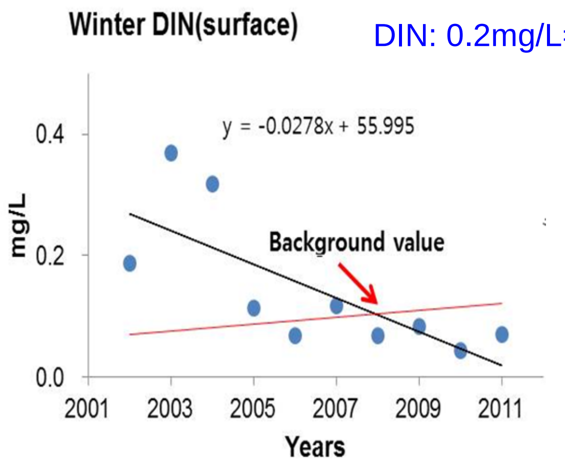
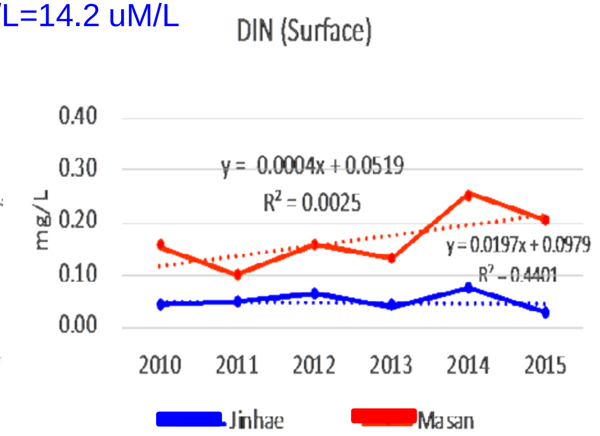
## Year trend of winter DIN, DIP and eutrophic degree in Jinhae/Masan Bay (2010-2015)

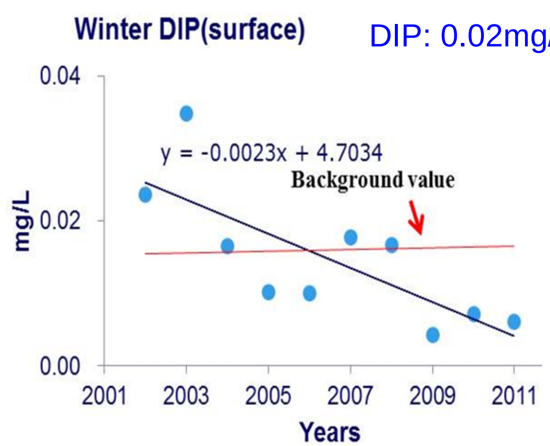
### Annual variation of DIN and DIP in Jinhae Bay

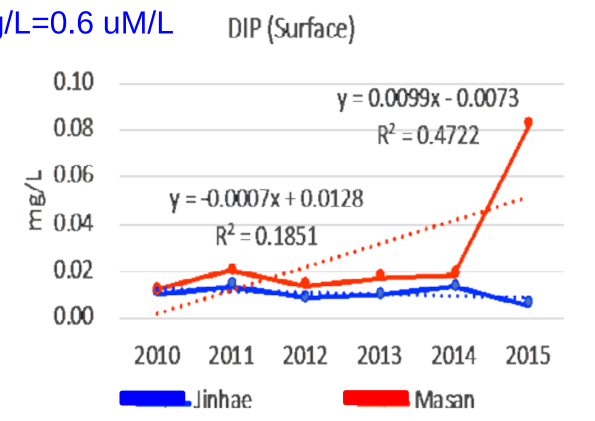
DIN: 0.2mg/L=14.2 uM/L



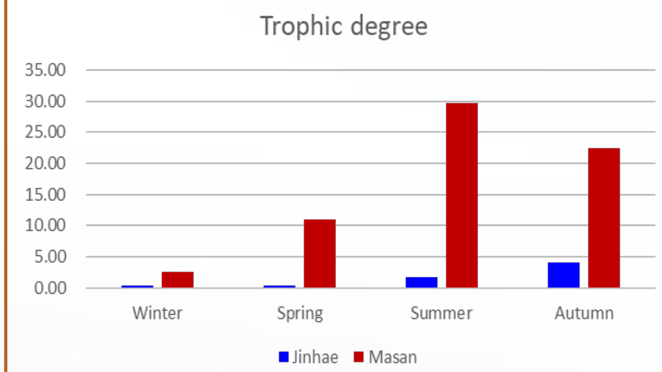

DIP: 0.02mg/L=0.6 uM/L

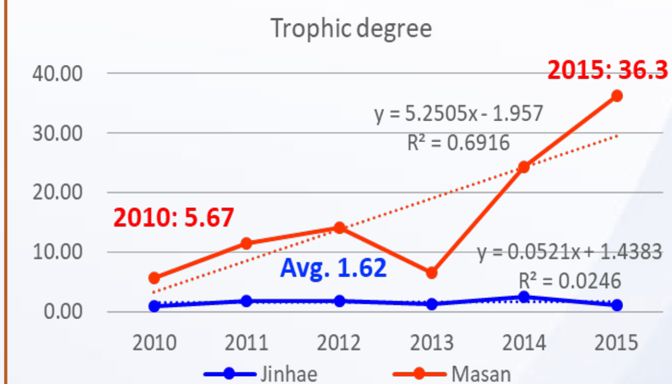



- Annual average of DIN and DIP in winter was gradually decreased from 2001 to 2011, whereas the nutrients were slightly increased from 2013

**Trophic degree**
**= COD(mg/L) x DIN(μM) x $PO_4$-P(μM) / 3.43**

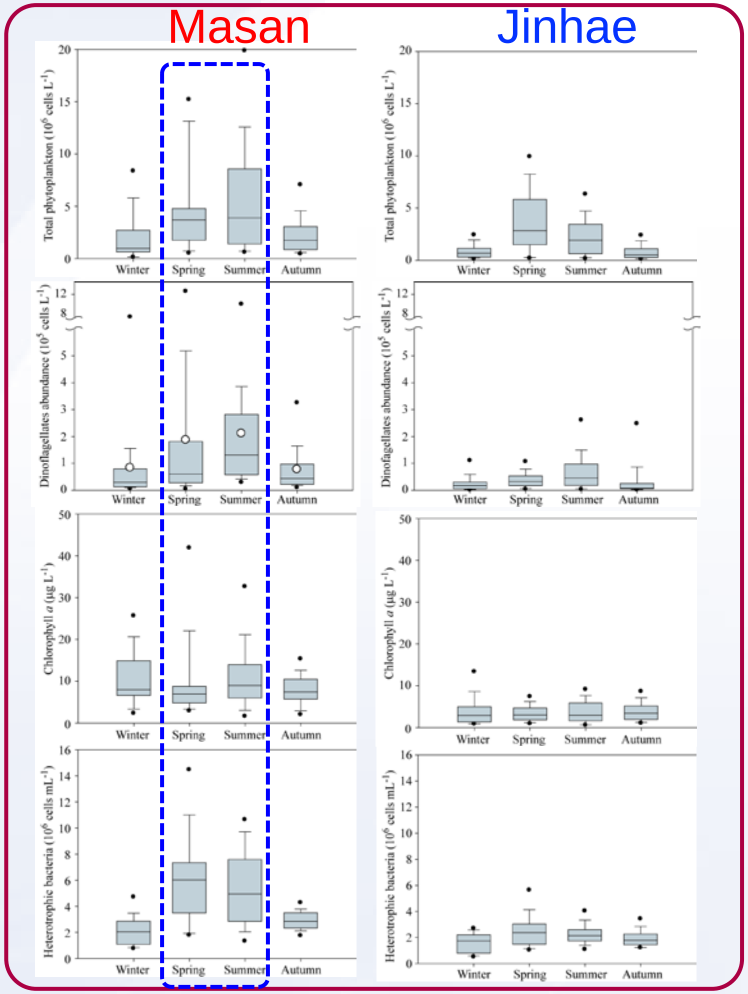


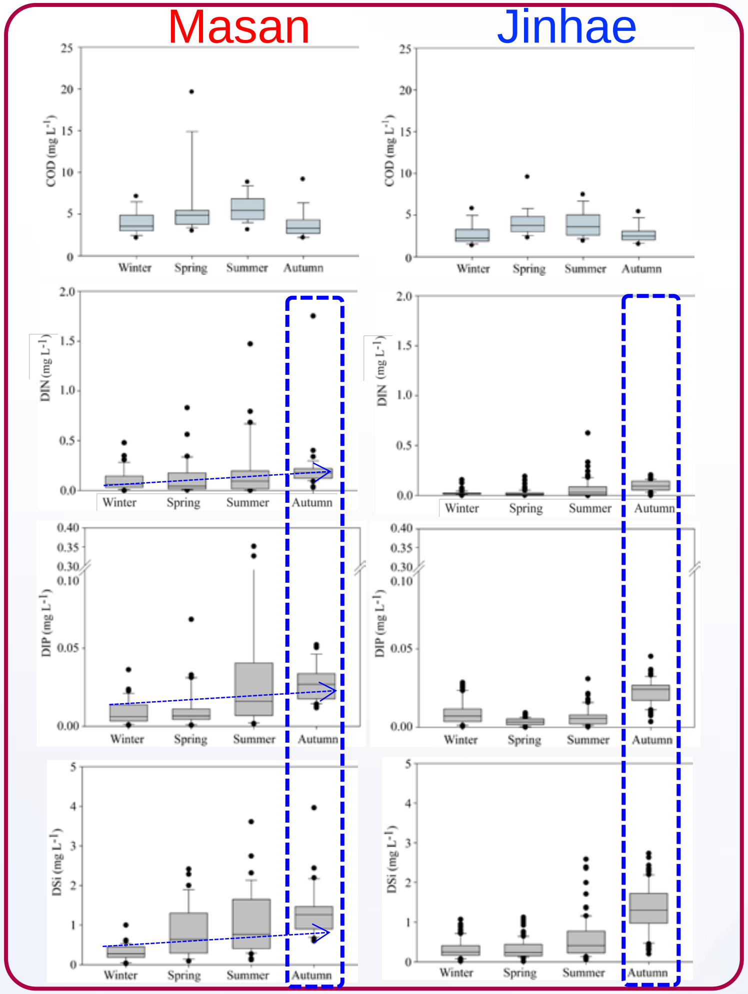




- Eutrophic degree was high in autumn and winter, particularly in Masan Bay.
- In the case of Masan Bay, the eutrophic degree had sharply increased from 5.67 in 2010 to 36.3 in 2015
- However, eutrophic degree in Jinhae have low levels

# 4. Assessment of eutrophication in Jinhae/Masan Bay

## Seasonal variations in biotic and abiotic factors in Masan Bay (2010-2015)



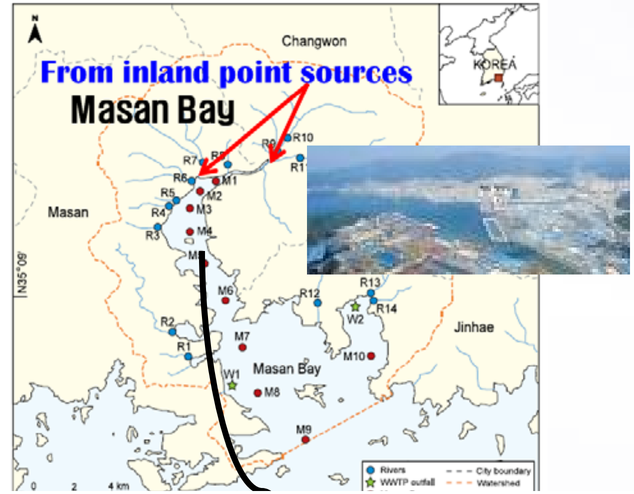




- Seasonally, the phytoplankton biomass and harmful algal blooms was high in spring and summer.
- As a whole, biomass in Masan Bay is higher than those of Jinhae Bay, particularly in spring and summer.
- The nutrient levels was high in autumn and it was particularly increased from spring to autumn.

# Conclusion

Jinhae Bay

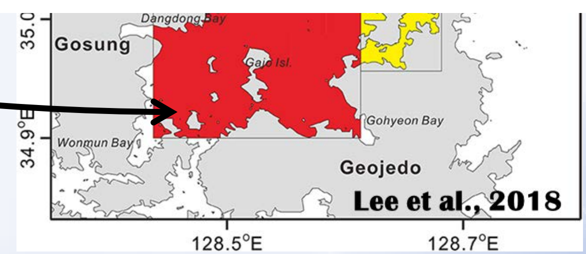
Masan Bay





- The hypoxia in the **Jinhae Bay** is attributed to **eutrophication due to oyster culture farm and thermal stratification** based on the **naturally sluggish water circulation, particularly in only summer season.**

- In case of **Masan Bay, the hypoxia is due to eutrophication resulting from domestic land used, and industrial waste input,** which have been influenced by **limitation of water circulation of semi-enclosed bay**

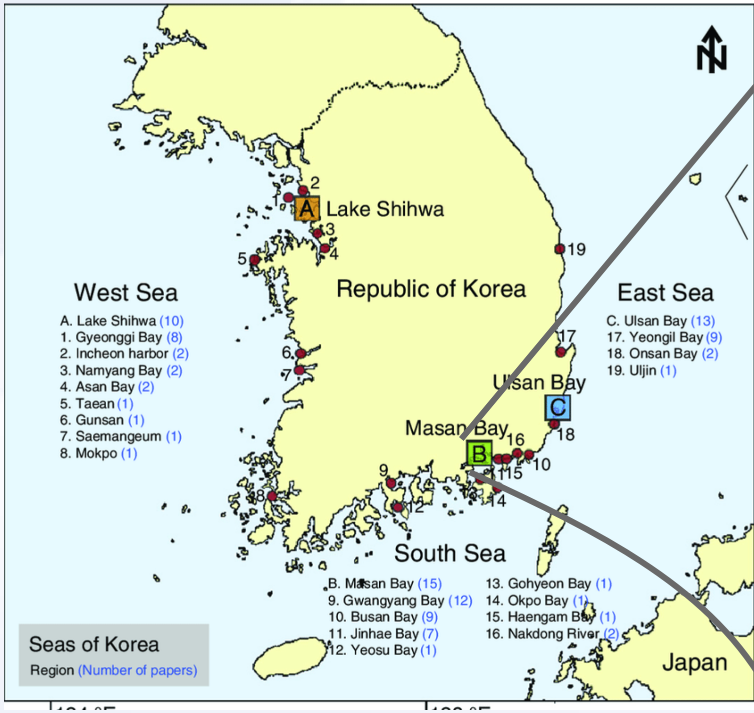


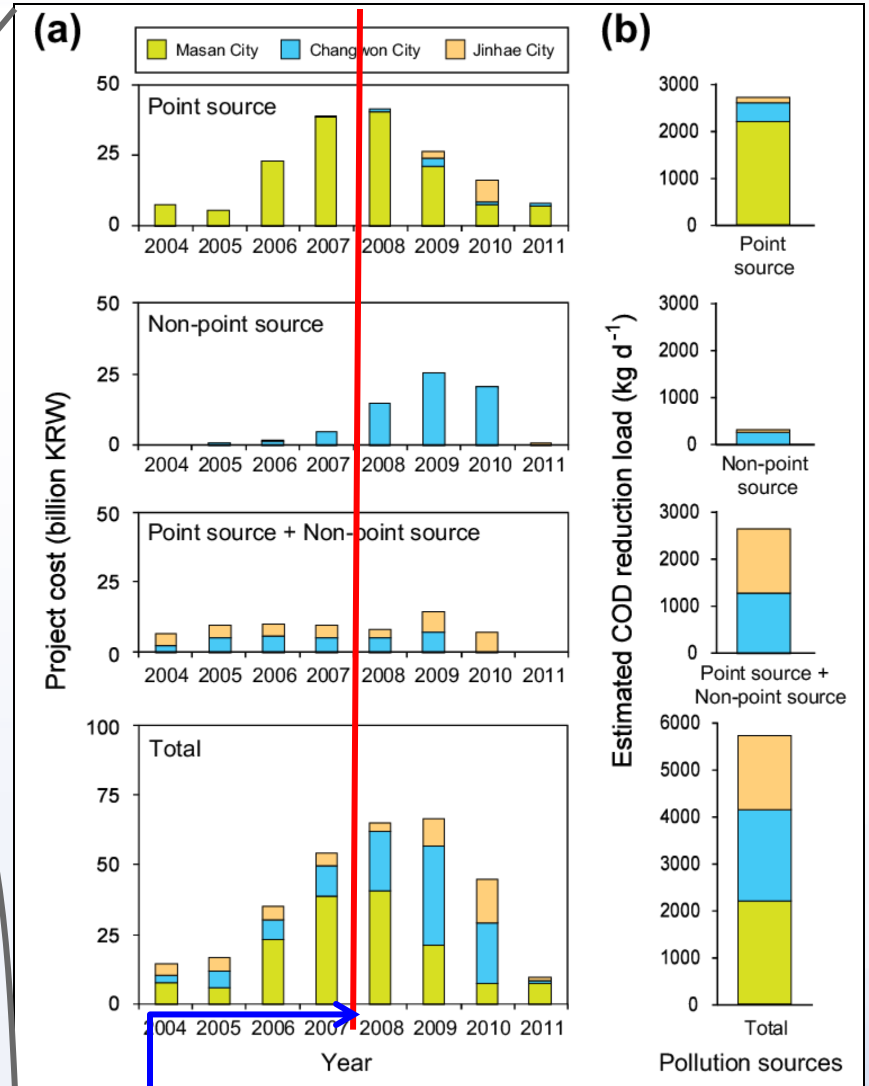
# Summaries and Conclusion

- The Masan and Jinhae Bay is most eutrophicate zone due to urbanization and human activities in Korea
- After establishment of wastewater treatment plants (1993) and introduction of TPLMS (Total Pollution Load Management System, 2006), COD and the inflow of nutrients has been reduced in the Masan Bay.
- Seasonally fluctuated but the eutrophication has tend to ease since 2010 in the Masan Bay.
- The western part of Jinhae Bay formed and expanded the hypoxic area due to operation of many oyster farms and thermal stratification based on the naturally sluggish water circulation.
- In order to improve the water quality of this area, it is imperative to manage the nutrient inputs from non-point sources through reduction or limitation of the aquaculture-farms (i.e., oyster farms) and dredging of organic detritus in future

# Thank you for attention !

# 4.Assessment of eutrophication in Jinhae/Masan Bay




The total pollution load management system (TPLMS) was first applied in 2007 to the highly developed Masan Bay watershed, Korea.

## Nutrient levels

| DIN(uM) | DIN(mg/L) | DIP(uM) | DIP(mg/L) | DSi(uM) | DSi(mg/L) |
|---|---|---|---|---|---|
| 0.01 | 0.00014 | 0.01 | 0.00031 | 0.01 | 0.0006 |
| 0.1 | 0.0014 | 0.1 | 0.0031 | 0.1 | 0.006 |
| 1 | 0.014 | 1 | 0.031 | 1 | 0.06 |
| 10 | 0.14 | 10 | 0.31 | 10 | 0.6 |
| 100 | 1.4 | 100 | 3.1 | 100 | 6 |

mg/L 일때는 1000배

ug/L= uM환산 (나누면 됨)
N 14
P 31
Si 60

TABLE 6. A scheme for trophic classification proposed for the Baltic Sea including coastal waters. Phytoplankton biomass and chlorophyll *a* data are annual means from the euphotic layers; nutrient concentrations are winter data (seasonal means) from the upper mixed layer

| | Phytoplankton primary production ($g\ C\ m^{-2}\ yr^{-1}$) | Phytoplankton biomass ($mg\ m^{-3}$) | Chl *a* ($mg\ m^{-3}$) | $PO_4$ ($mmol\ m^{-3}$) | DIN ($mmol\ m^{-3}$) |
|---|---|---|---|---|---|
| Oligotrophic | <100 | <500 | <0·8 | <0·2 | <2 |
| Mesotrophic | 100–250 | 500–2000 | 0·8–4 | 0·2–0·8 | 2–10 |
| Eutrophic | 250–450 | 2000–4000 | 4–10 | 0·8–3·0 | 10–60 |
| Polytrophic | >450 | >4000 | >10 | >3 | >60 |

(Wasmund et al. 2001)