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TOKYO CITY UNIVERSITY

Nitrogen and Phosphorus Cycles in Constructed Tidal Flat in Tokyo Bay

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The Role of Tidal Flat for Coastal Environment

- Habitat
- Fishery
- Water Quality
- Water Birds
- Education
- Recreation

The Purpose of the Study

- The Role of Tidal Flat on Water Environment
- To Know the Nutrient Flux in the Tidal Flat
- To Grasp the Mechanism of Nutrient Cycle in the Tidal Flat

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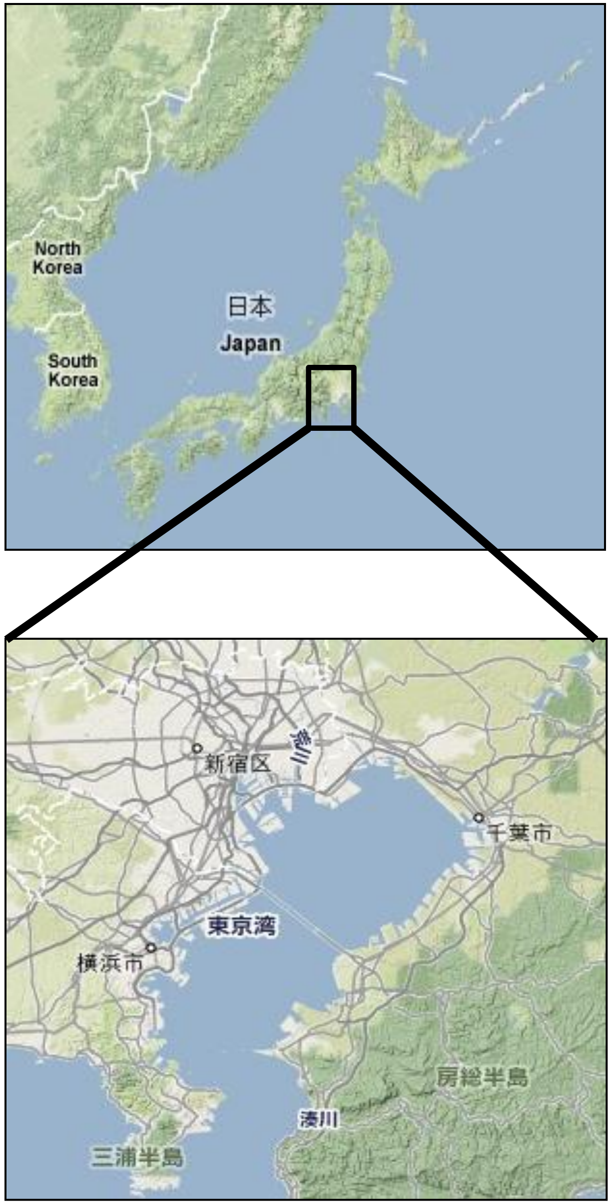
Tokyo Bay

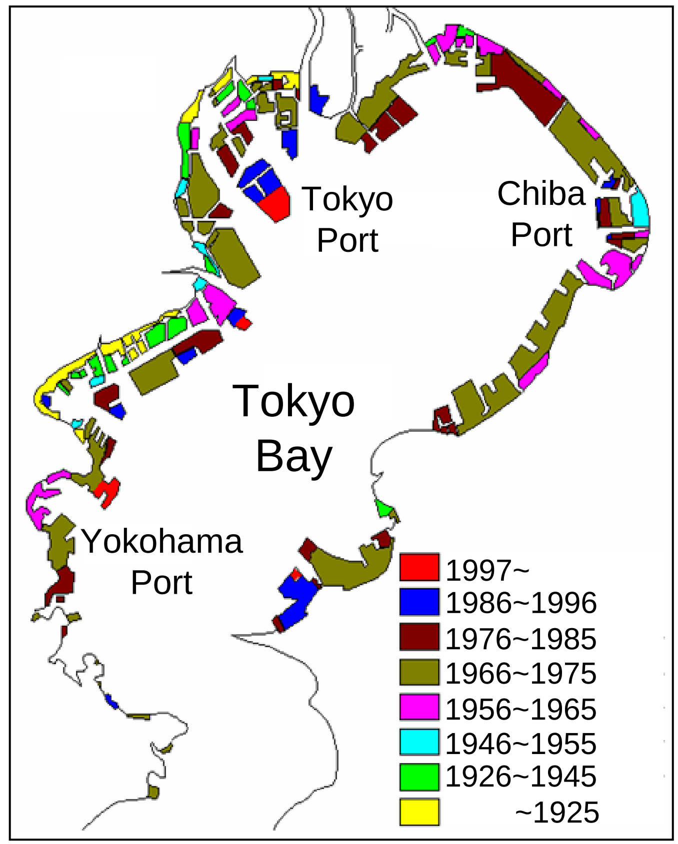
Area 960km^2

Mean Depth 15m

Population 26million



Tokyo Bay



Reclamation Lands （>95% disappearred)

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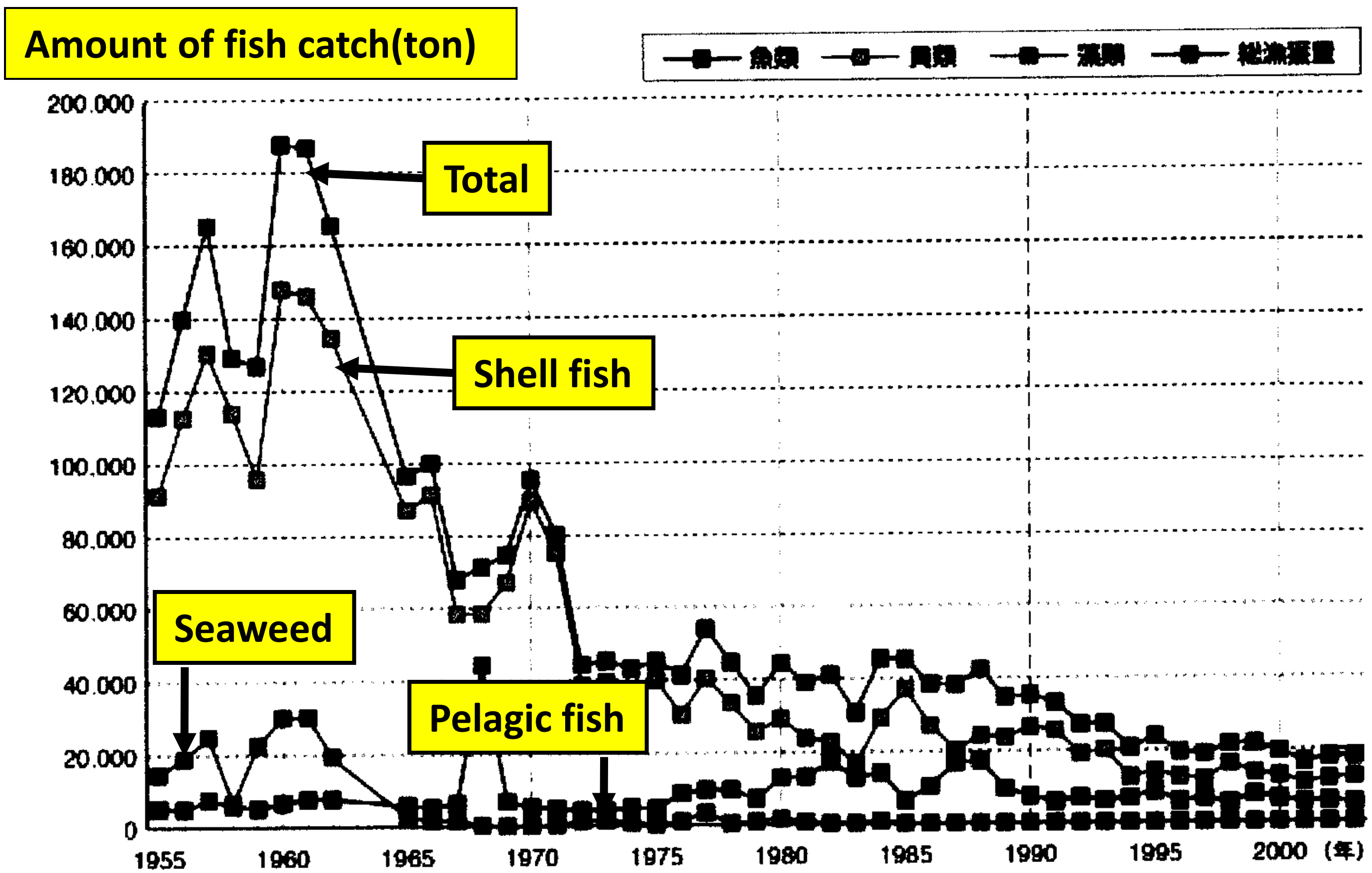
Trend of Fishery Production in Tokyo Bay



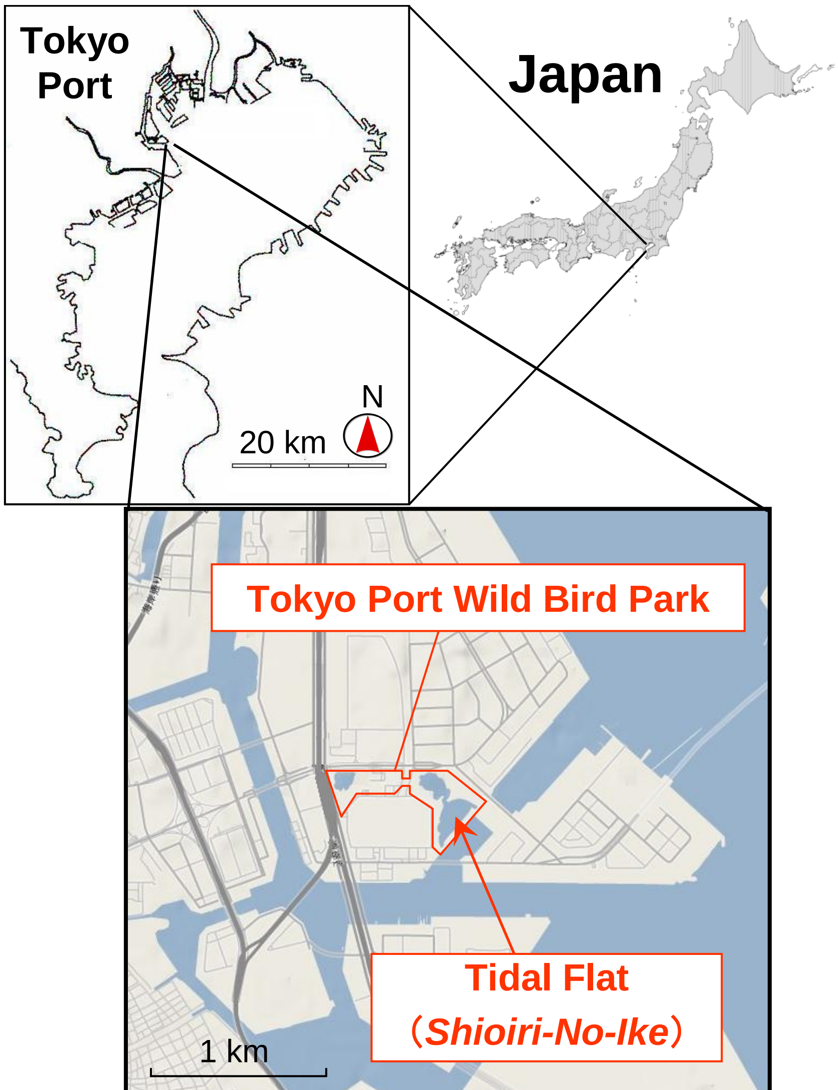
Tidal Flat in the Tokyo Port Wild Bird Park

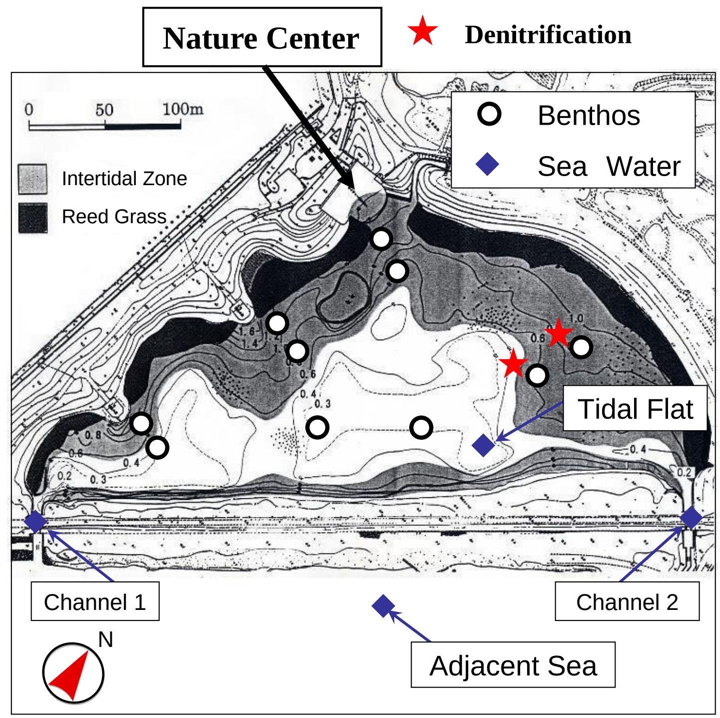
Study Site

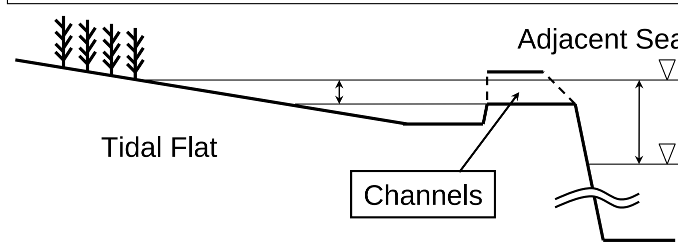
Tokyo Port Wild Birds Park artificial tidal flat ($57000 m^2$)

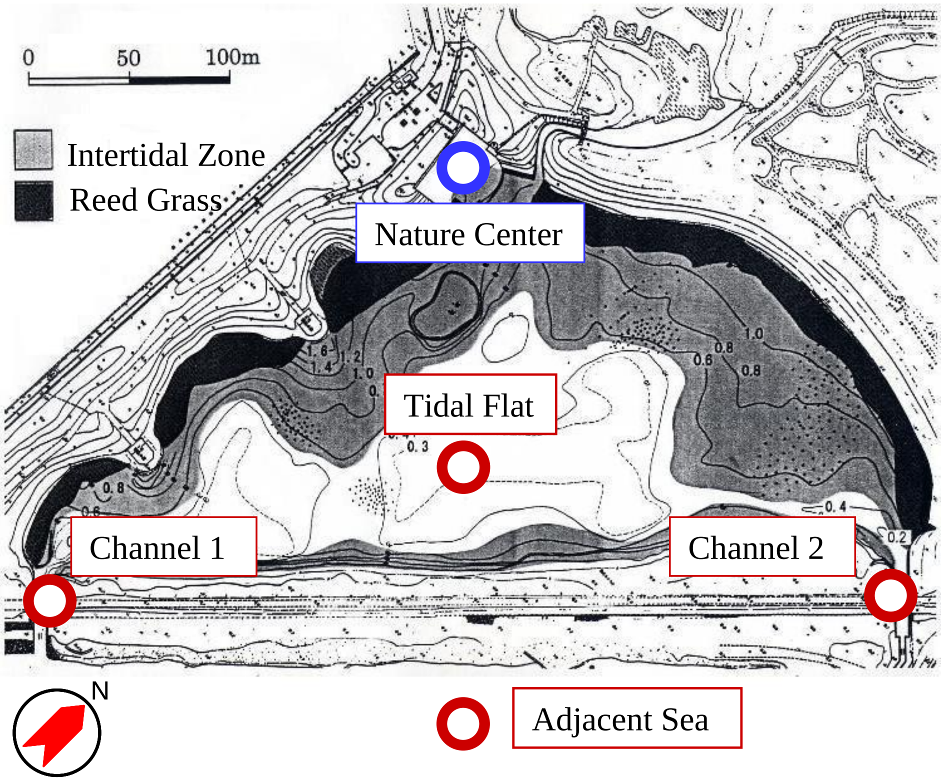
1960's : reclamation

1989 : open for birds park

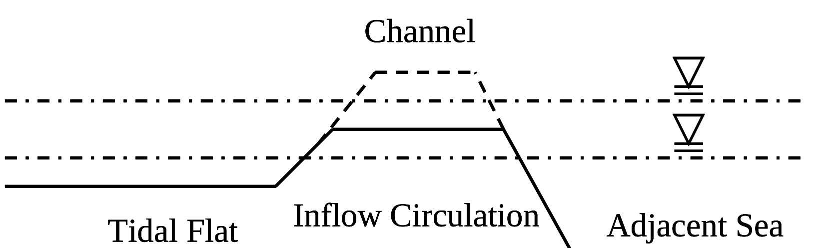




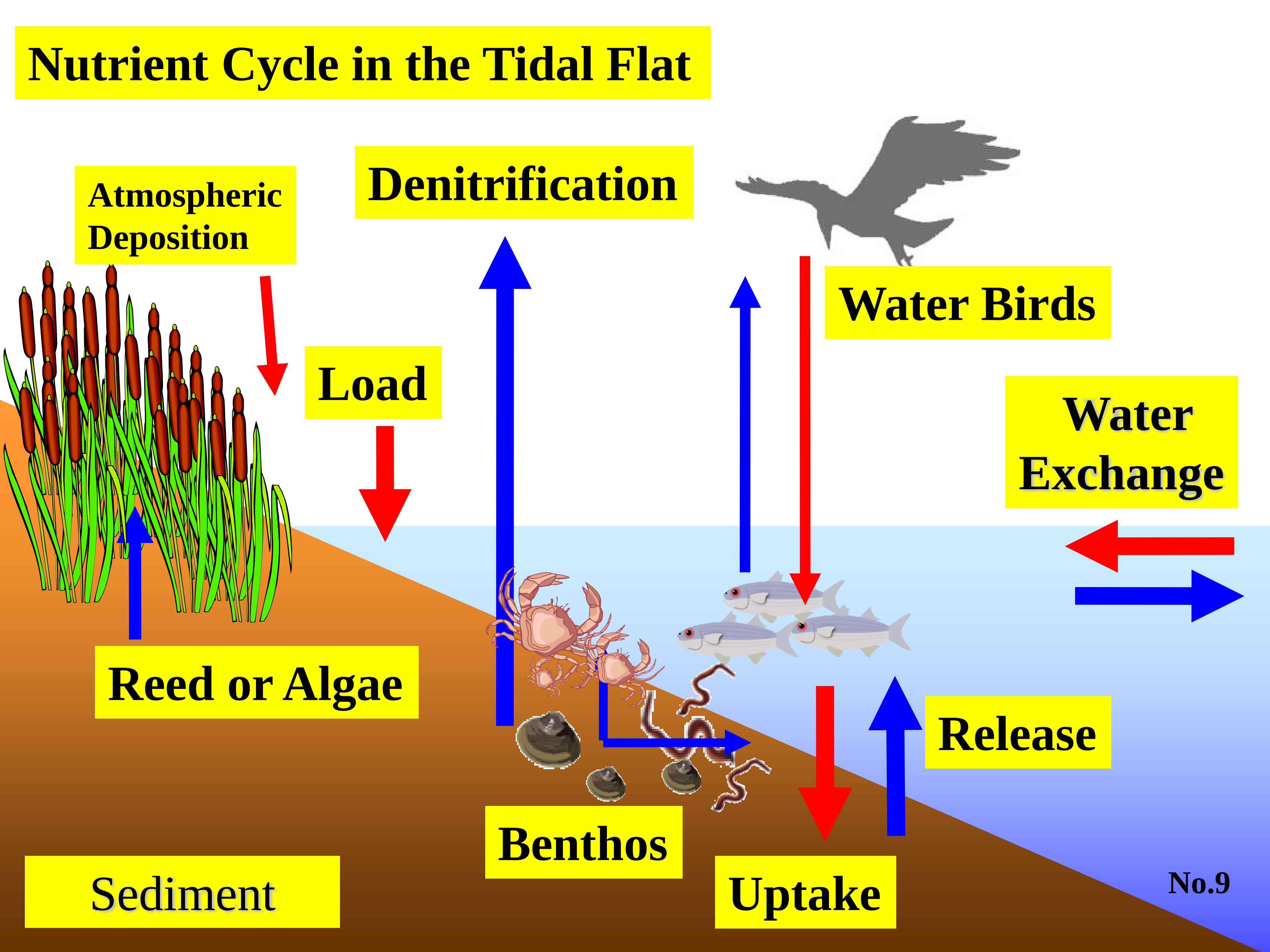




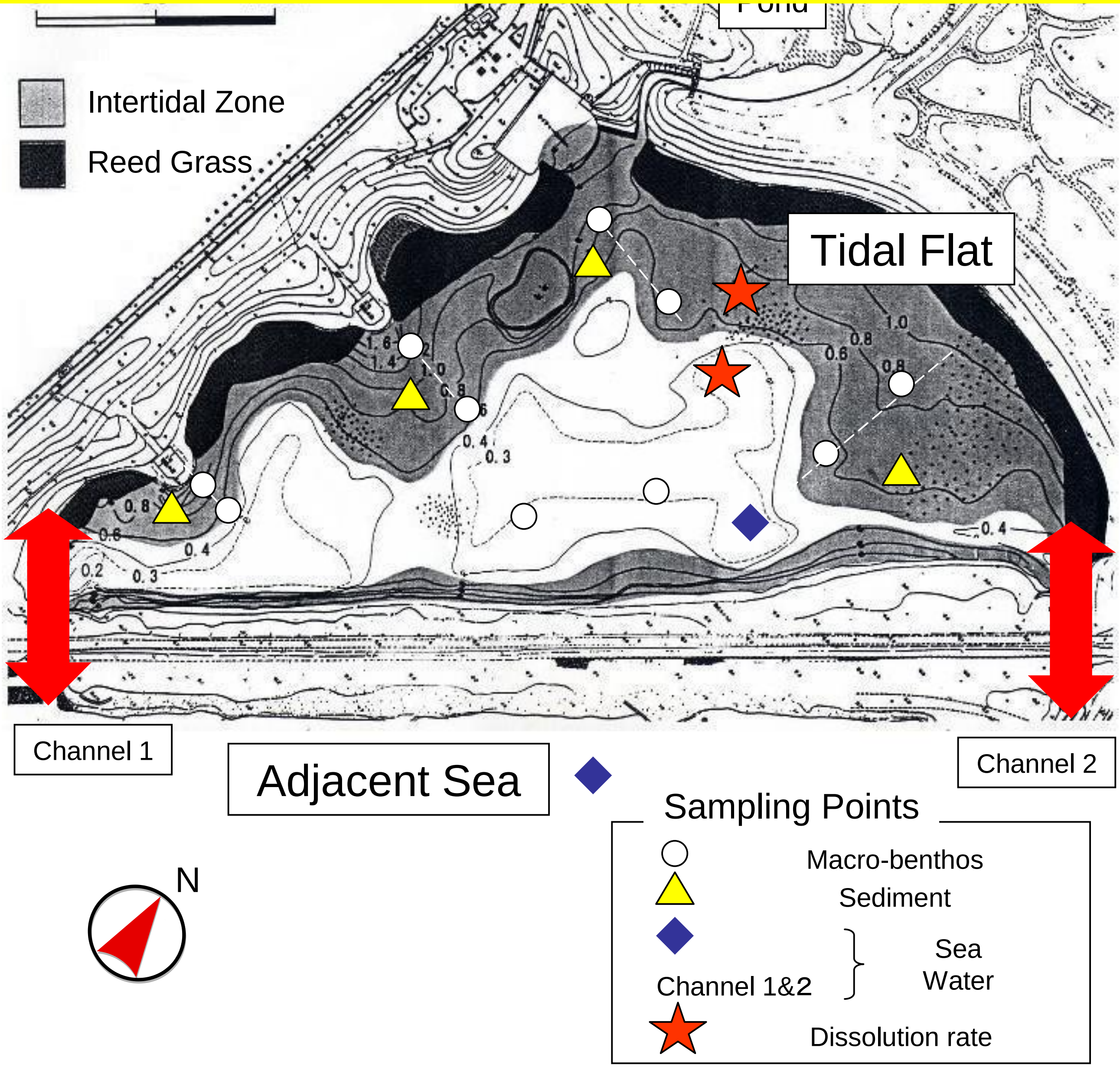
0
50
100m
Intertidal Zone
Reed Grass
Nature Center
Tidal Flat
Channel 1
Channel 2
N
Adjacent Sea



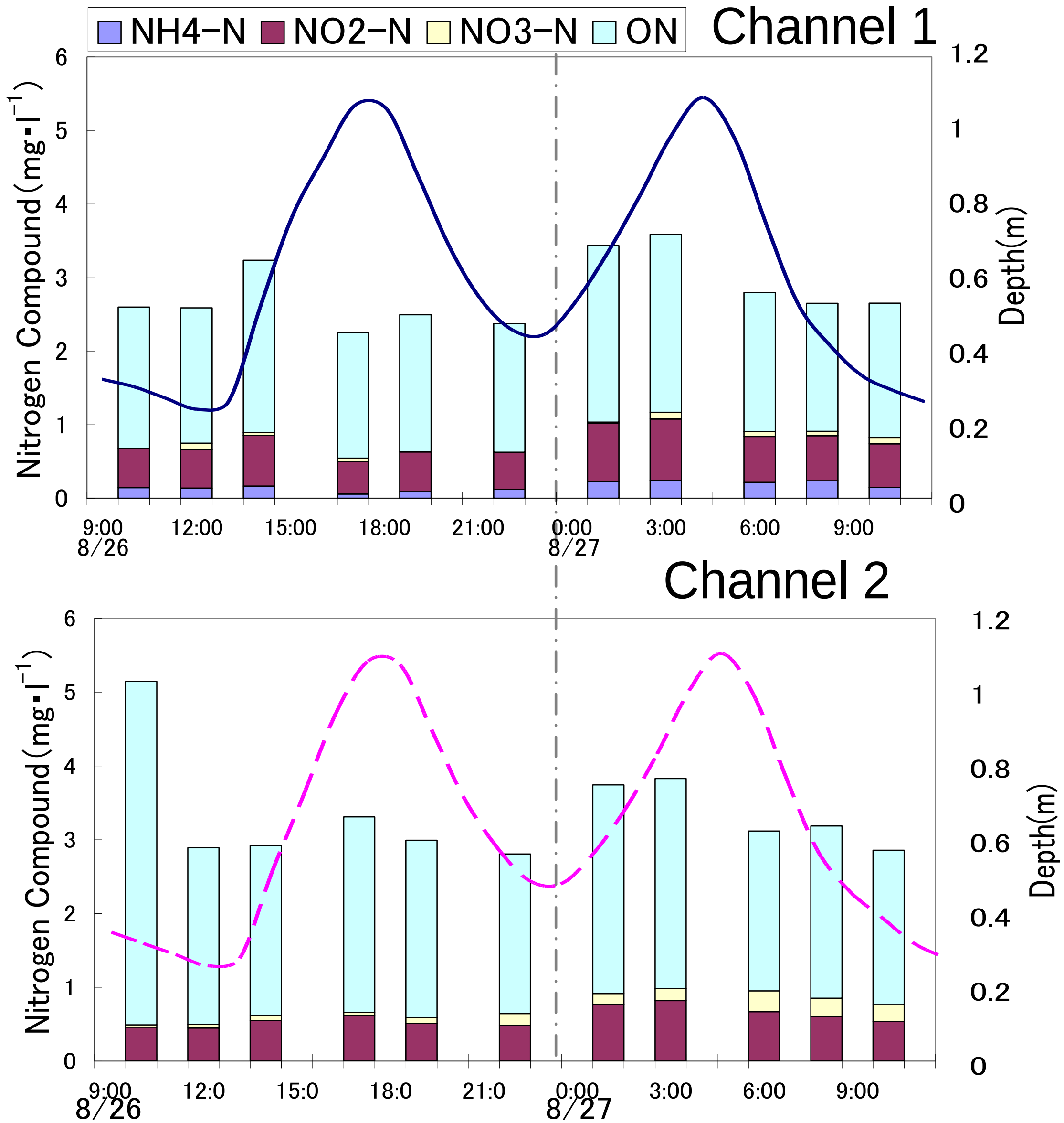
Channel
Tidal Flat
Inflow Circulation
Adjacent Sea


Nutrient Cycle in the Tidal Flat
Atmospheric Deposition
Denitrification
Water Birds
Load
Water Exchange
Reed or Algae
Release
Benthos
Uptake
Sediment
No.9

Nutrient Flux between Tidal Flat and Adjacent Sea



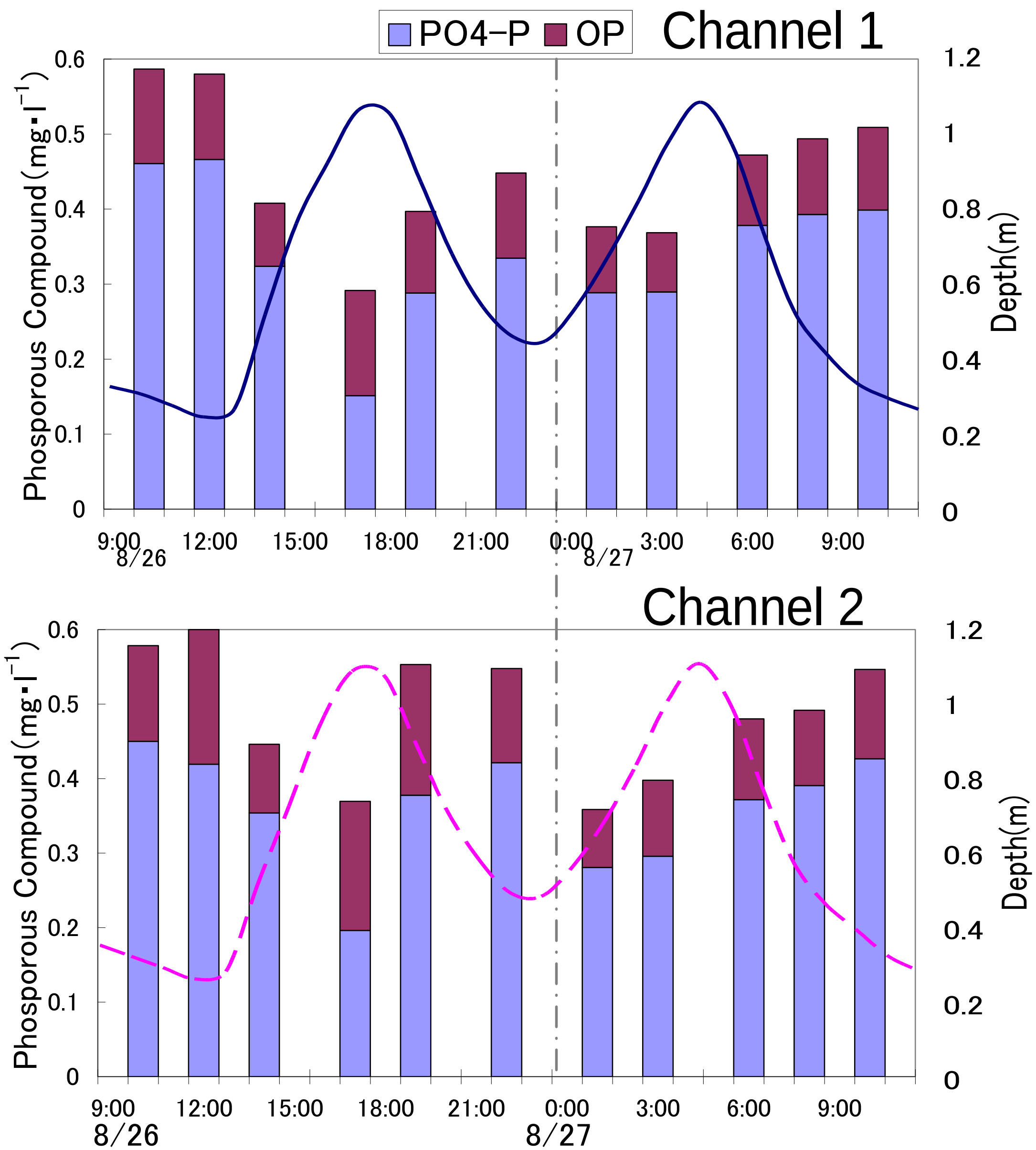
Observation Results (elevation, concentration of N)



$$Flux\ N = \sum_{I=1}^{2} \sum_{t=1}^{N} Q_{I,t} \cdot C_{I,t}$$

$$Q_t = \left(\zeta_{t+1} - \zeta_t\right) A_t$$

Observation Results (elevation, concentration of P)



$$Flux\ P = \sum_{I=1}^{2} \sum_{t=1}^{N} Q_{I,t} \cdot C_{I,t}$$

$$Q_t = \left(\zeta_{t+1} - \zeta_t\right) A_t$$

Nutrient Fluxes between Tidal flat and Adjacent Sea

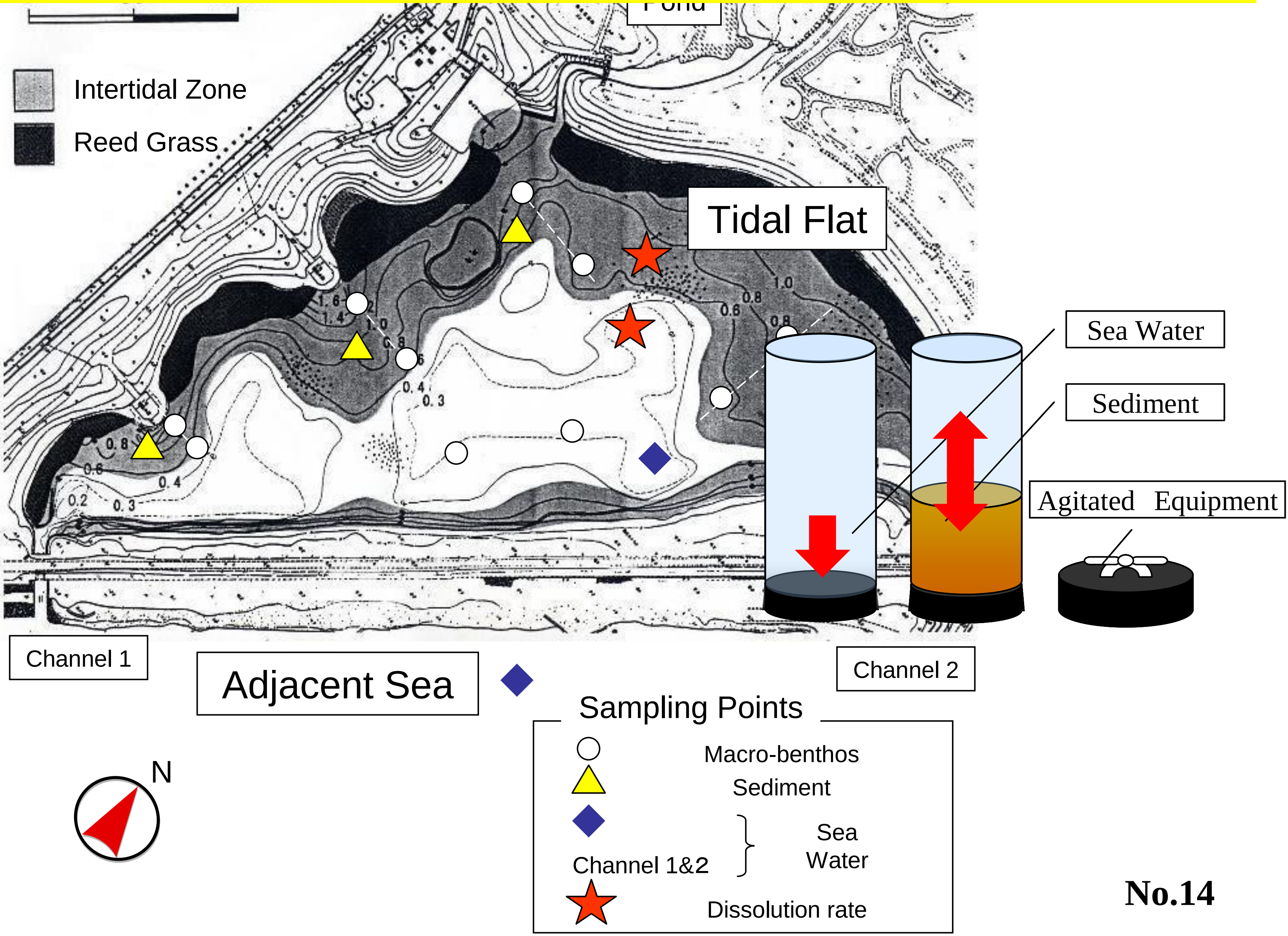
($mg/m^2/2tides$)

	2007	2008	2009		2010	
	Aug.	Aug.	Aug.	Dec.	Aug.	Dec.
TP	-107	-74.4	-41.8	21.6	-162	-53.8
PO_4-P	-101	7.8	-67.4	11.6	-79	-2.7
TN	281	592	740	326	421	298
NO_3-N	58.2	522	461	287	329	-71.7
NH_4-N	-24.7	-75.9	20.4	51.4	-25.3	76.1
Chl-a	46.3	0.97	11.4	18.8	18.5	-1.1

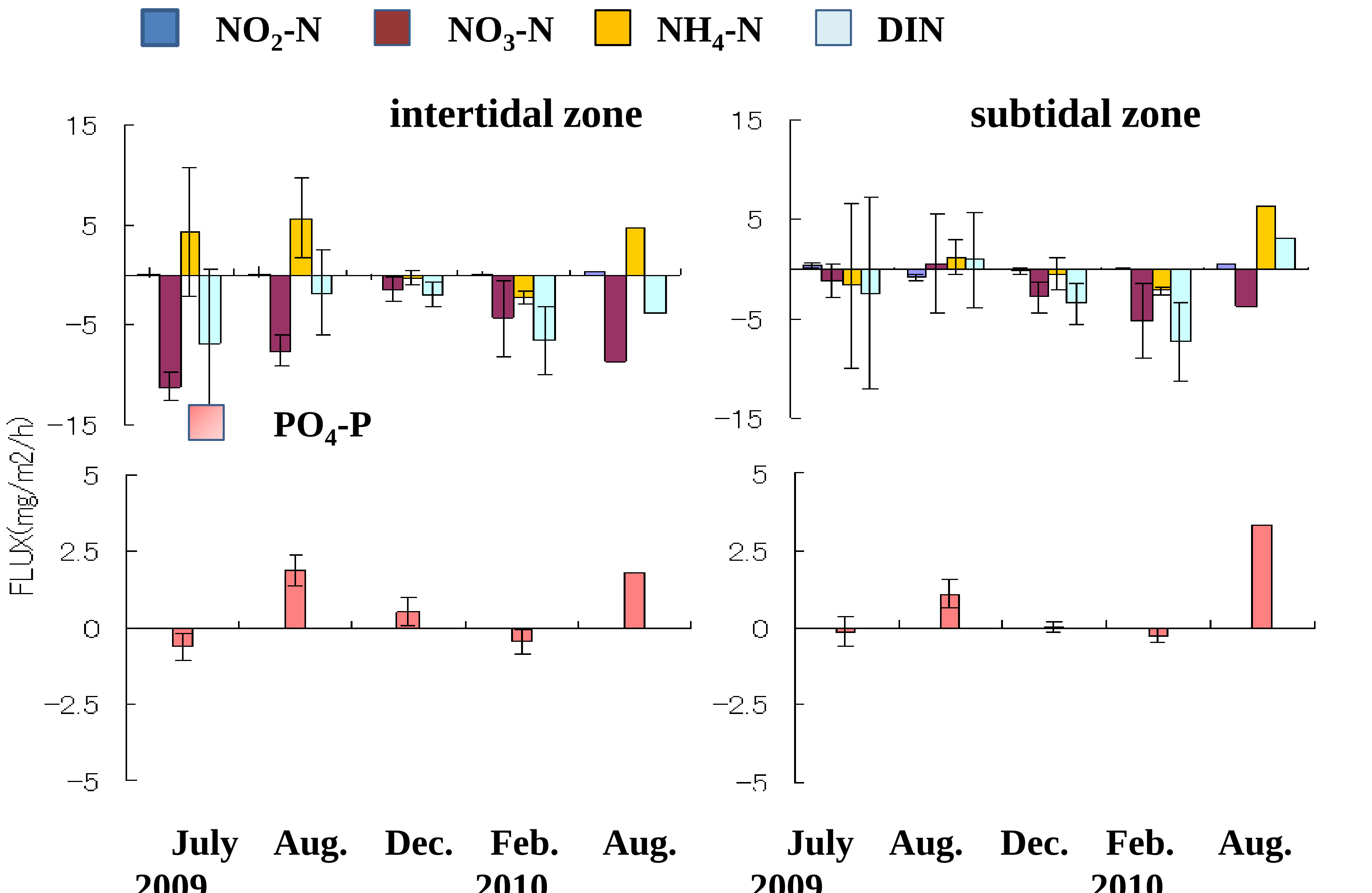
Red Digit : inflow flux from adjacent sea to tidal flat

Black Digit : outflow flux from tidal flat to adjacent sea

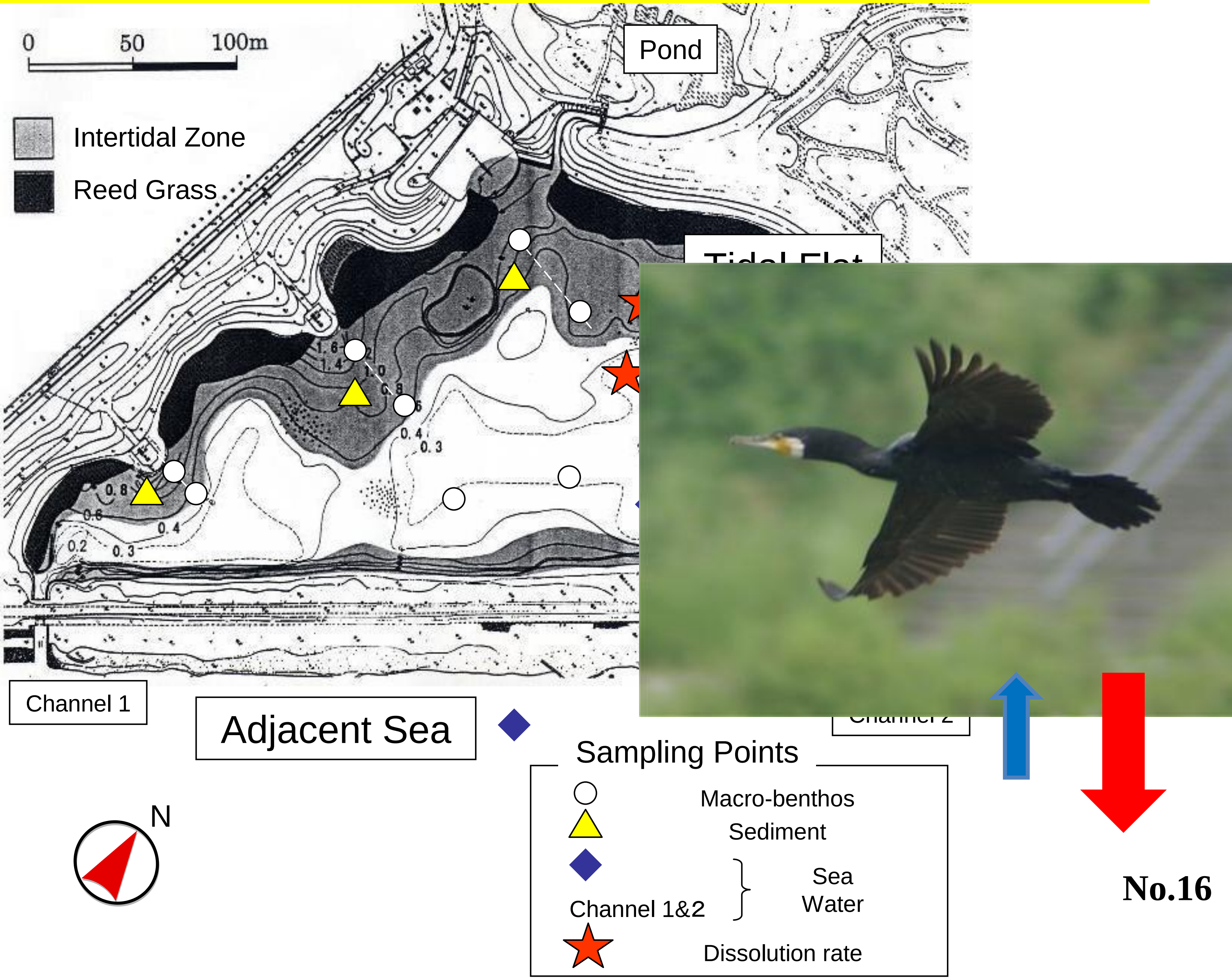
Nutrient Flux between Sediment and Overlying Water



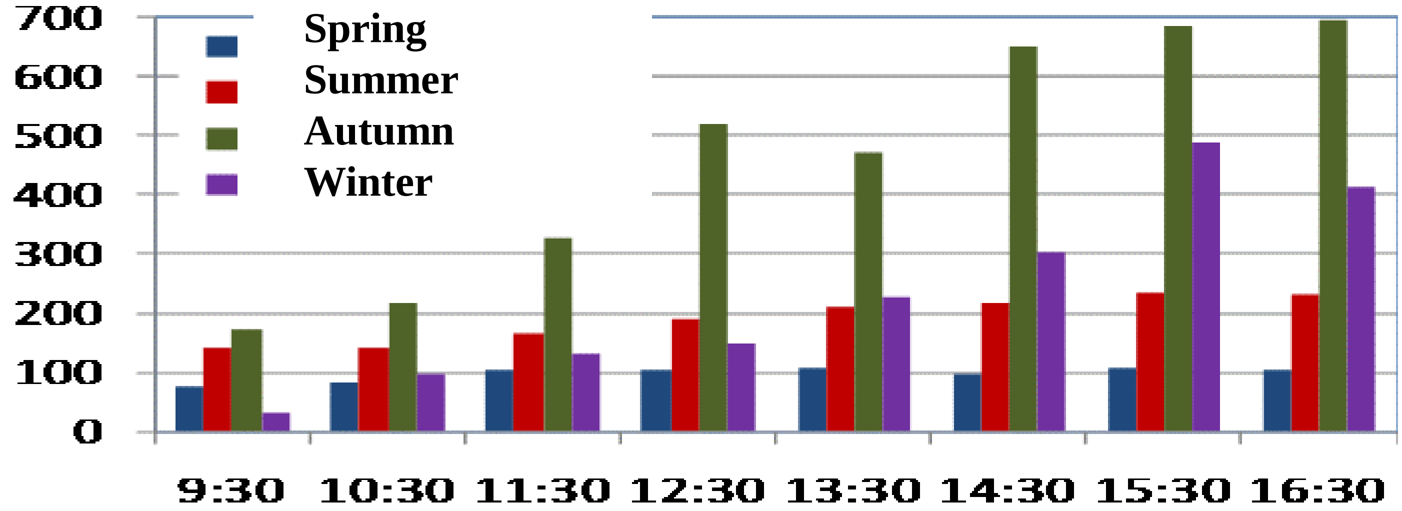
Nutrient Flux between Sediment and Overlying Water



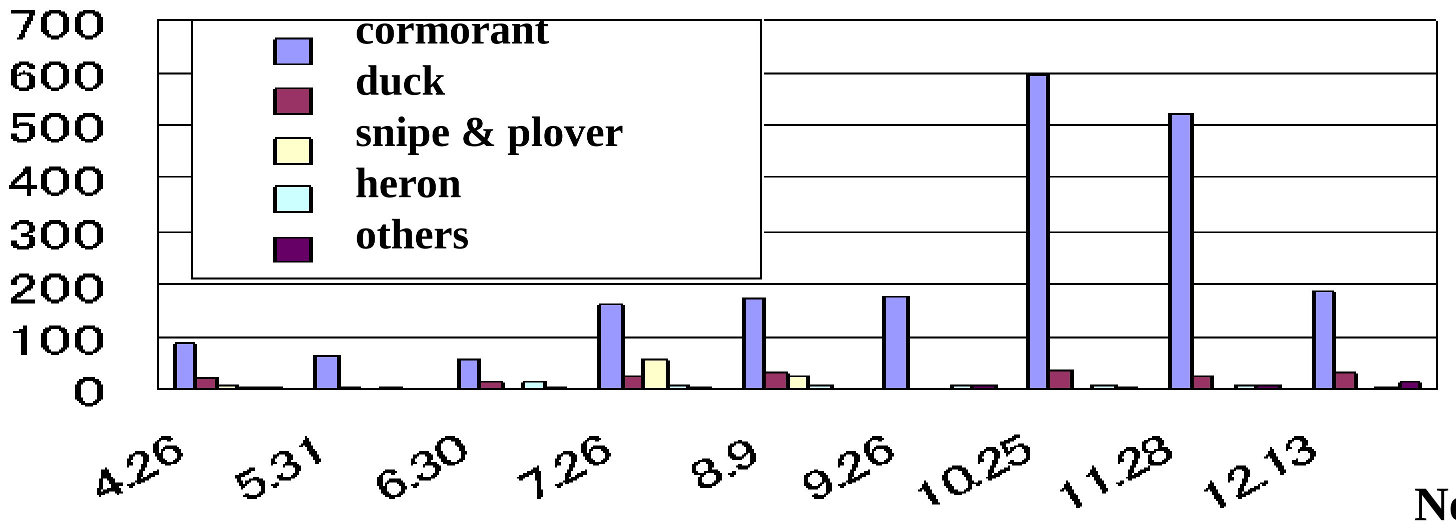
Nutrient Flux from Water Birds (food or excretion)



Observation Results (number of water birds)



Hourly variations of number of water birds in the flat



Monthly variations of number of water birds in the flat

Nutrient flux by water birds

$$BC = \frac{1}{A}\sum_{i} N_i \left(K \times FW_i \times N_{FC} - C_i \times DW_i \times N_{EC} \right)$$

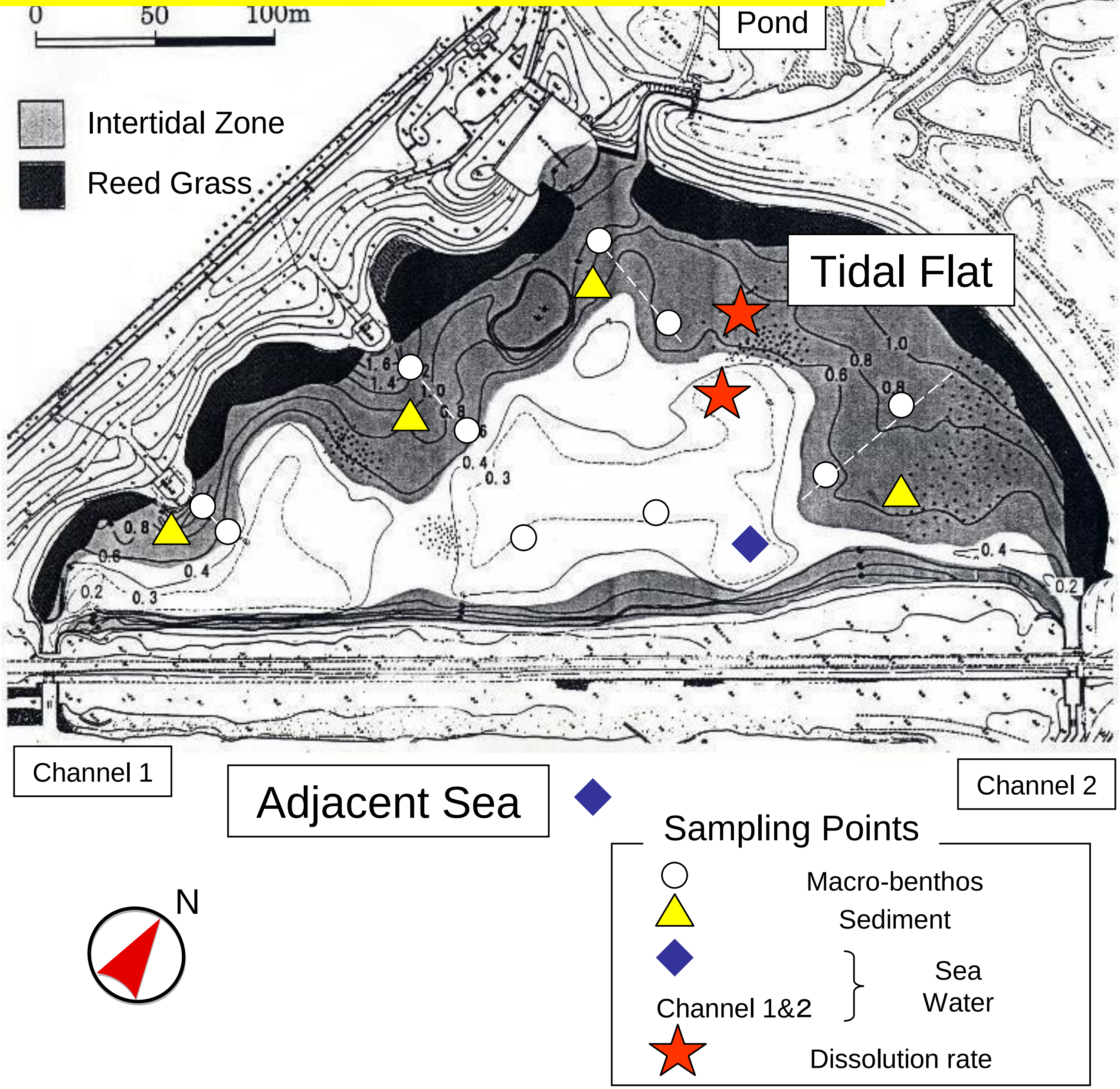
BC : Nutrient flux by water birds
N_i : Number of water birds (i species)
K : the rate of feeding action
FW_i : the amount of food by water birds
N_{FC} : Nutrient content of the food
C_i : the rate of excretion loaded to flat
DW_i : the amount of excrement by birds
N_{EC} : Nutrient content of the excrements

Nutrient Flux from birds to Tidal Flat

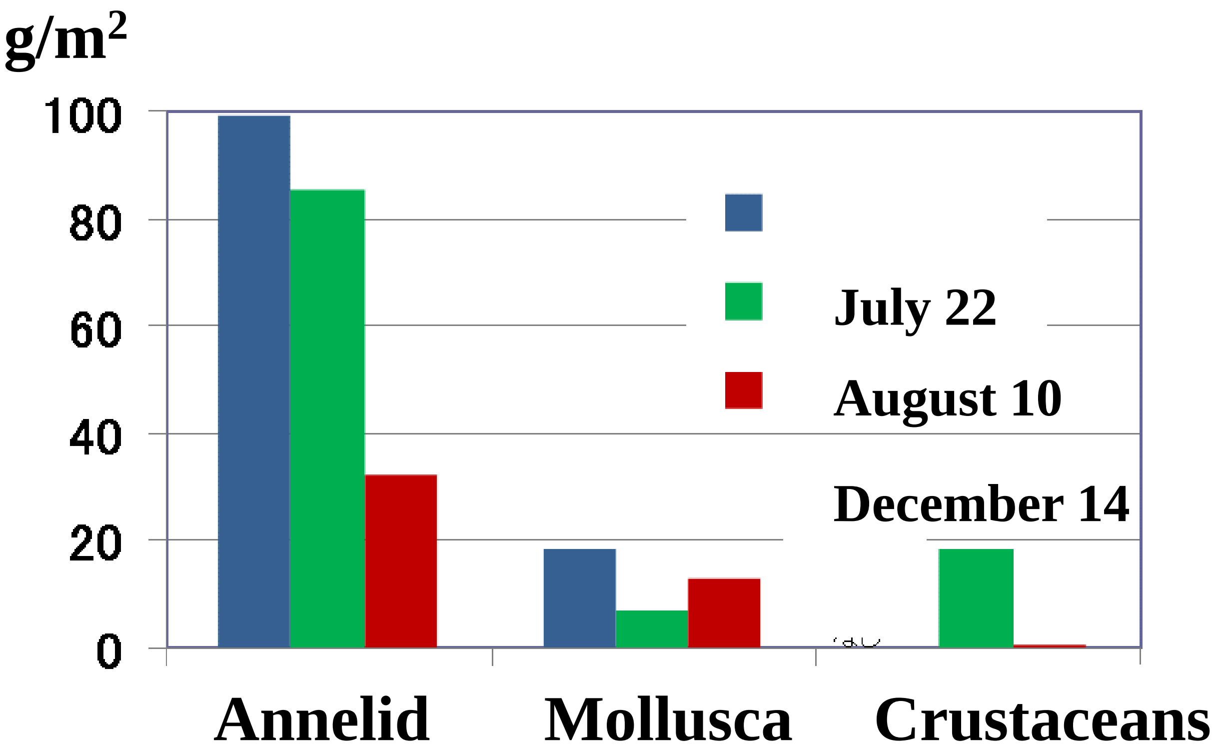
N:9.36mg/m^2/d

P:5.68mg/m^2/d

Nutrient Flux by Benthos and Reed



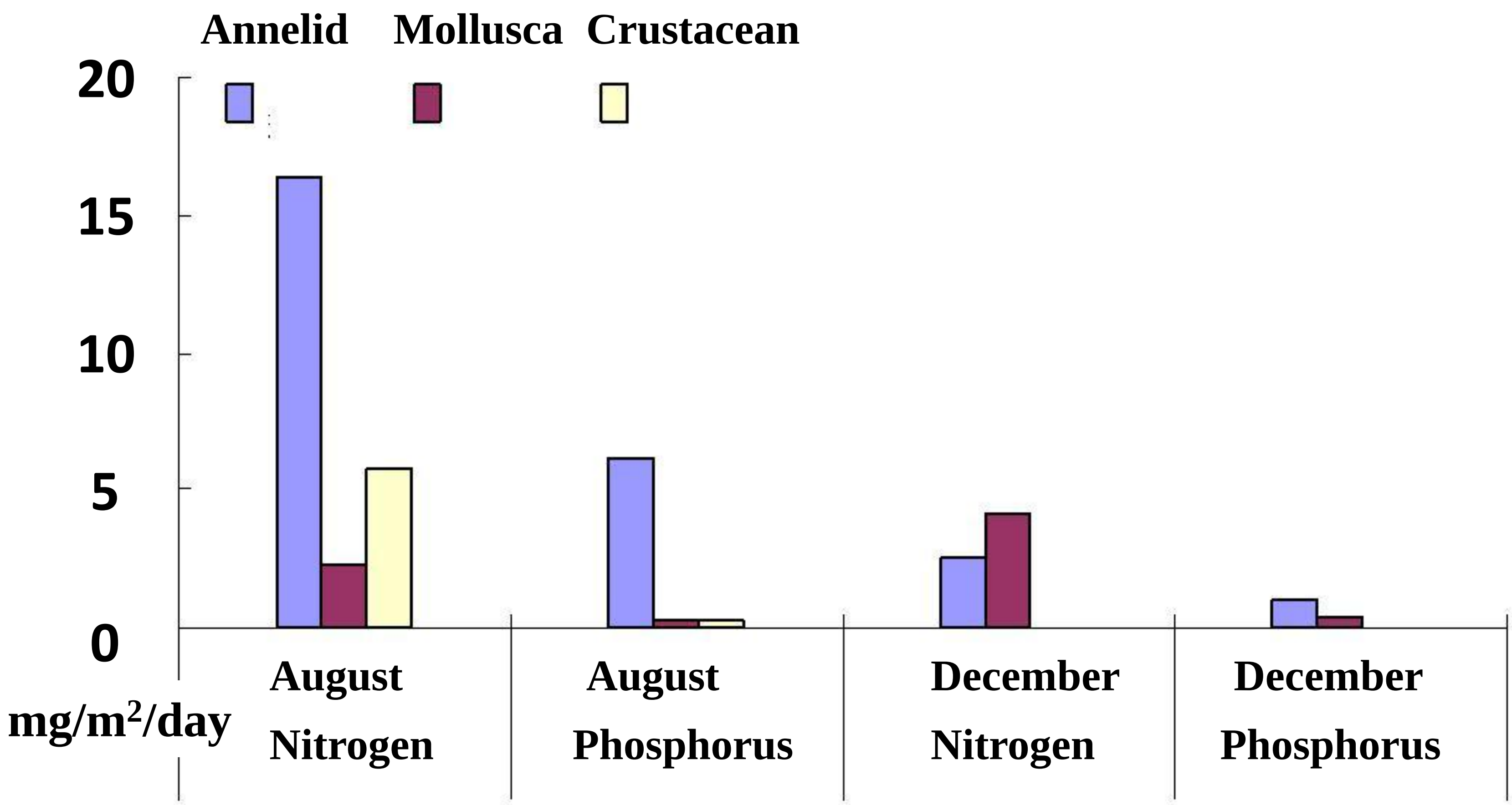
Nutrient flux by Benthos



$$N_{fd} = O_{fd} \times (1 - E_C) \times C$$

$$O_{fd} = M \times (P/B)/T$$

N_{fd} : Nutrient removal by Benthos
O_{fd} : the amount of food by Benthos
E_C : Excretion efficiency
C : Nutrient content of the food
M : Biomass of the Benthos
P/B : PB ratio of product
T : Efficiency of conversion



Annelid
Mollusca
Crustacean
20
15
10
5
0
mg/m2/day
August Nitrogen
August Phosphorus
December Nitrogen
December Phosphorus

$$NE_R = N \times A_R \times N_{AR} / A$$

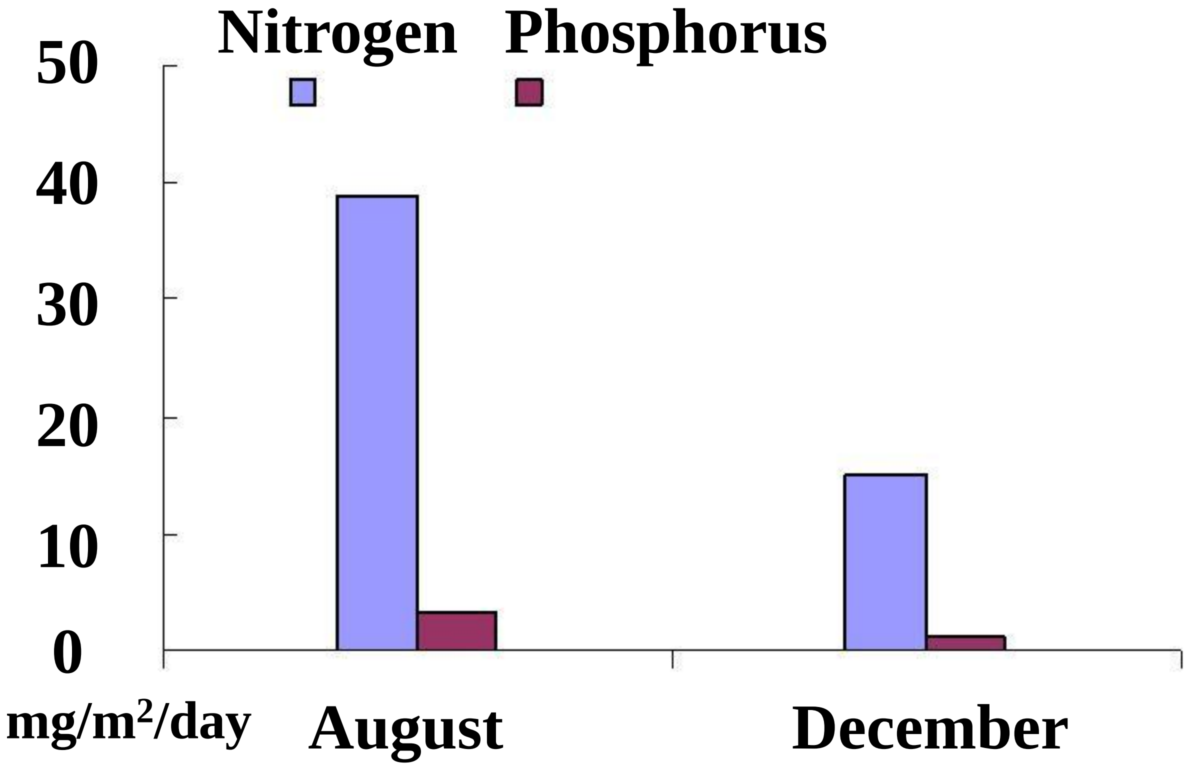
***NE_R* : the amount of nutrient removal**

***N* : number of reed per unit area (1m2)**

***A_R* : area of reed habitat**

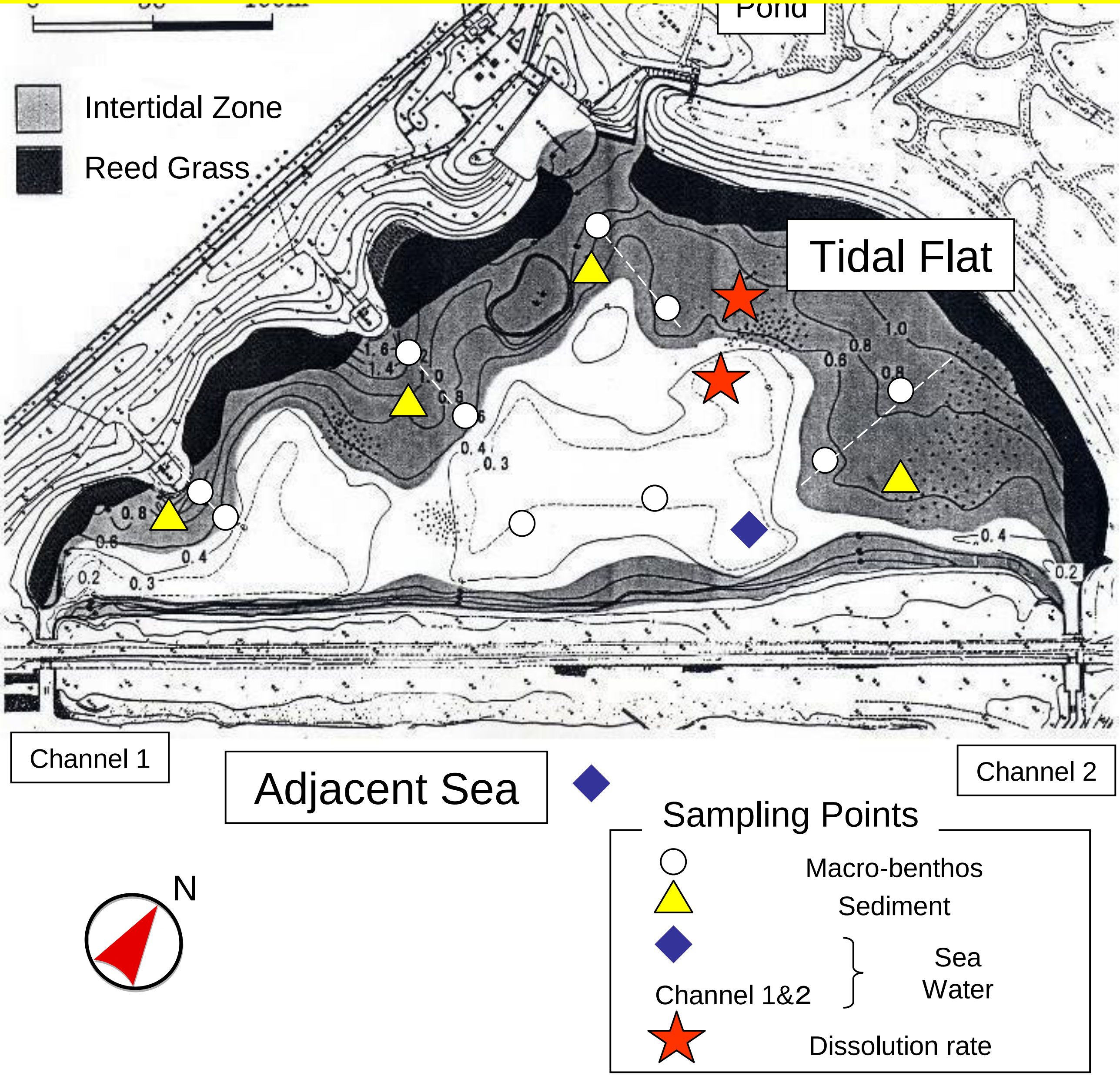
***N_{AR}* : assimulation rate by reed**

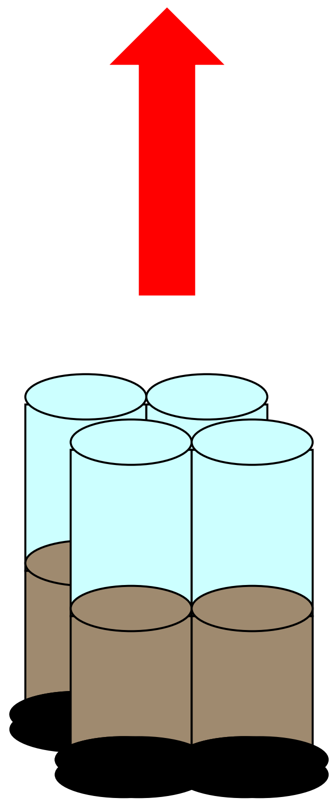
***A* : area**



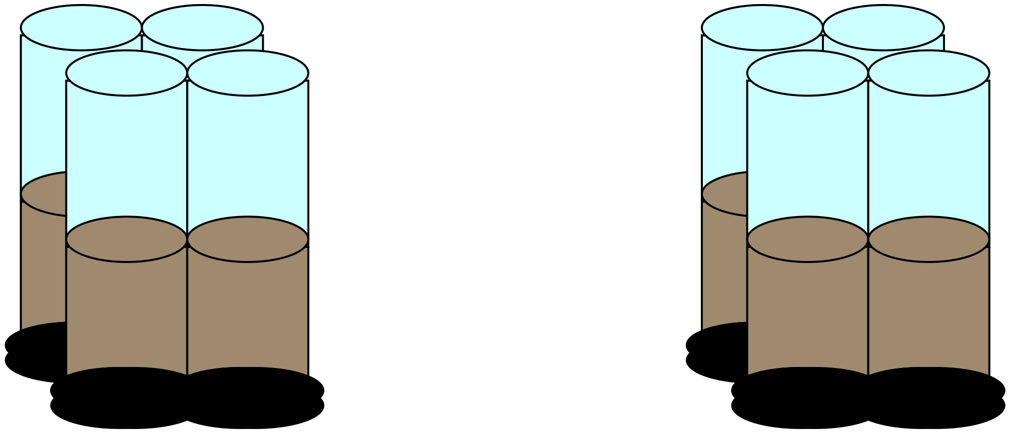
Nitrogen
Phosphorus
50
40
30
20
10
0
mg/m2/day
August
December

Nutrient Flux by Dentrification and Anammox





r-IPT Method (after Risgaard et al. 2003)
(Revised Isotope Pairing Technique)

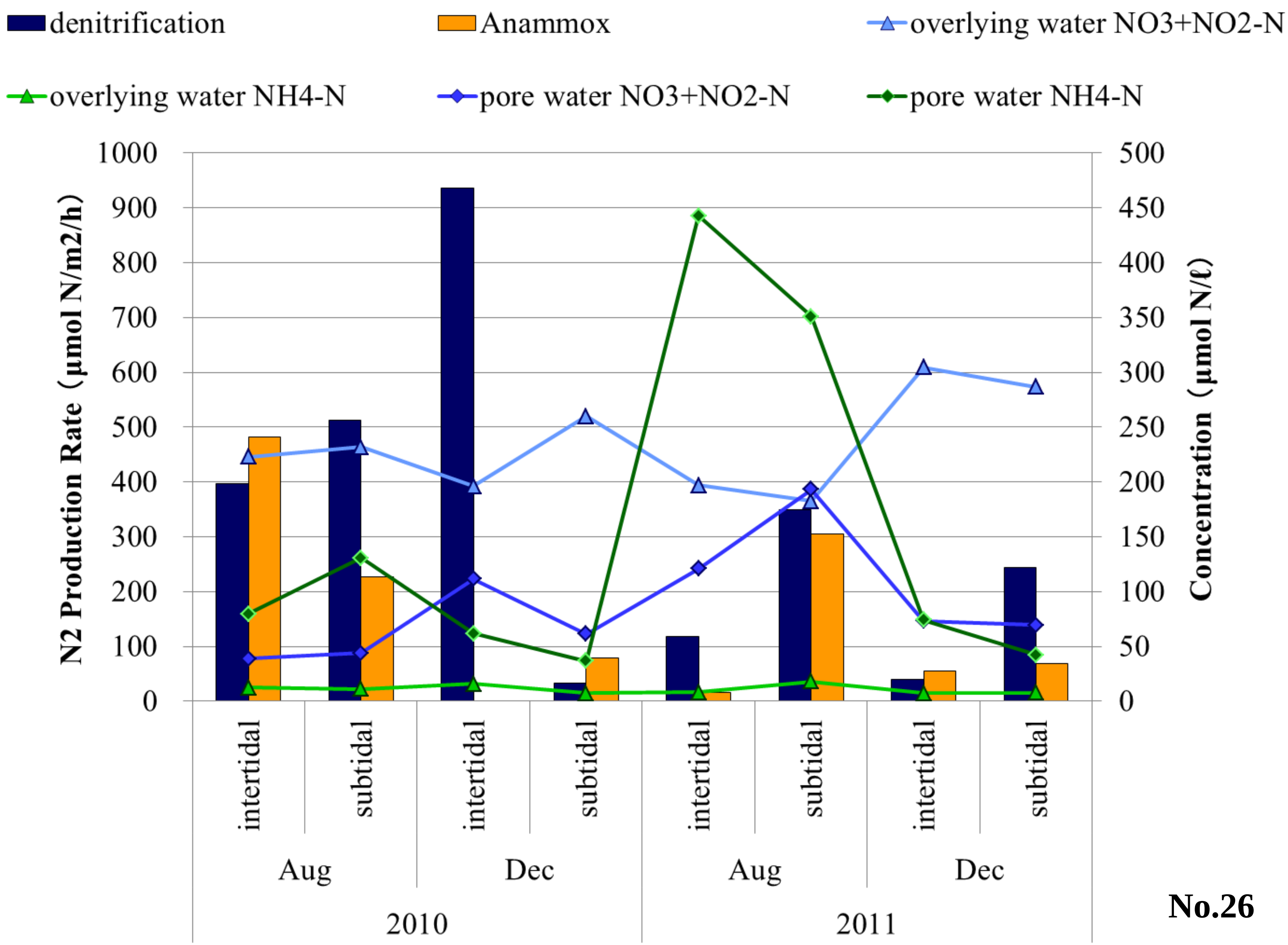


incubation (1) 100µmol $^{15}NO_3$ **incubation (2) 200µmol $^{15}NO_3$**

$$r\text{-}IPTp^{14} = 2r_{14} \cdot \left(p^{29}N_2 + p^{30}N_2 \cdot (1 - r_{14}) \right)$$

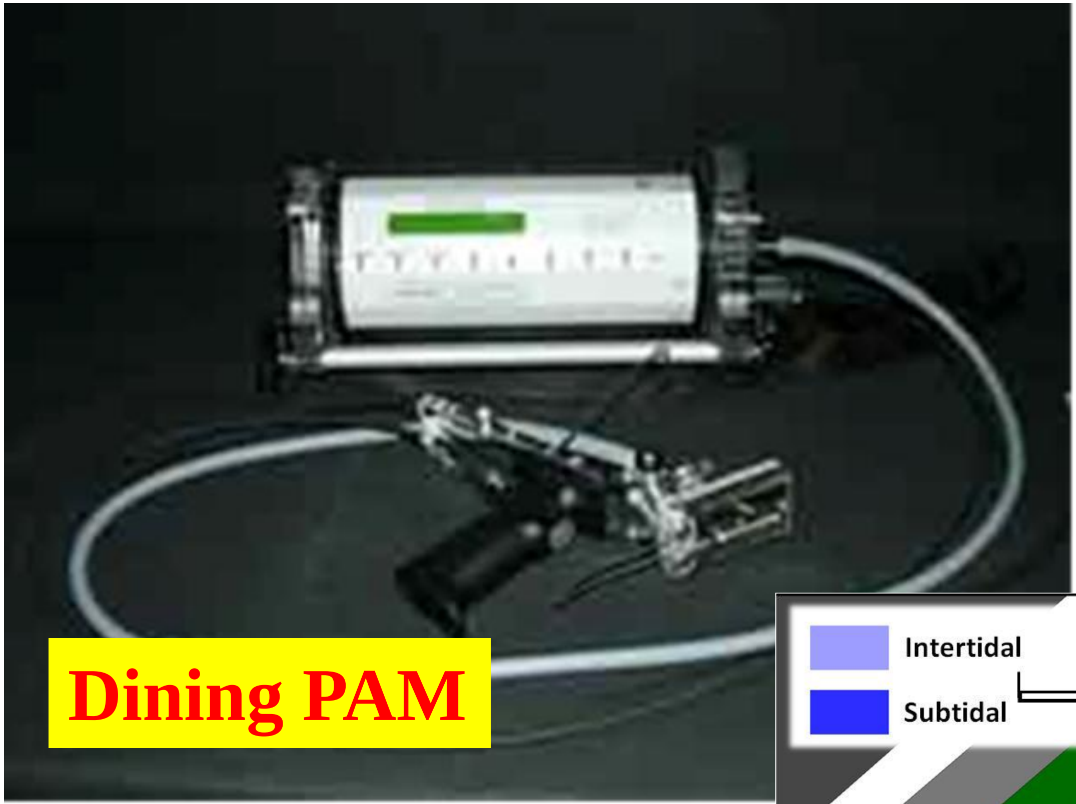
Original IPT Method (after Nielsen 1992)

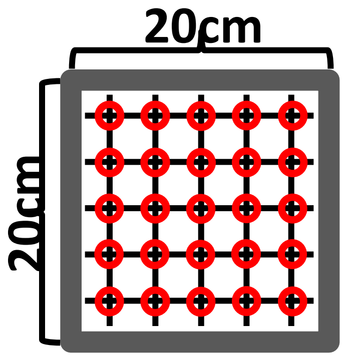
$$p^{14} = \frac{p^{29}N_2}{2 \cdot p^{30}N_2} \left(2 \cdot p^{30}N_2 + p^{29}N_2 \right)$$


denitrification
Anammox
overlying water NO3+NO2-N
overlying water NH4-N
pore water NO3+NO2-N
pore water NH4-N
N2 Production Rate（μmol N/m2/h）
Concentration（μmol N/ℓ）
1000
900
800
700
600
500
400
300
200
100
0
450
350
250
150
50
intertidal
subtidal
Aug
Dec
2010
2011

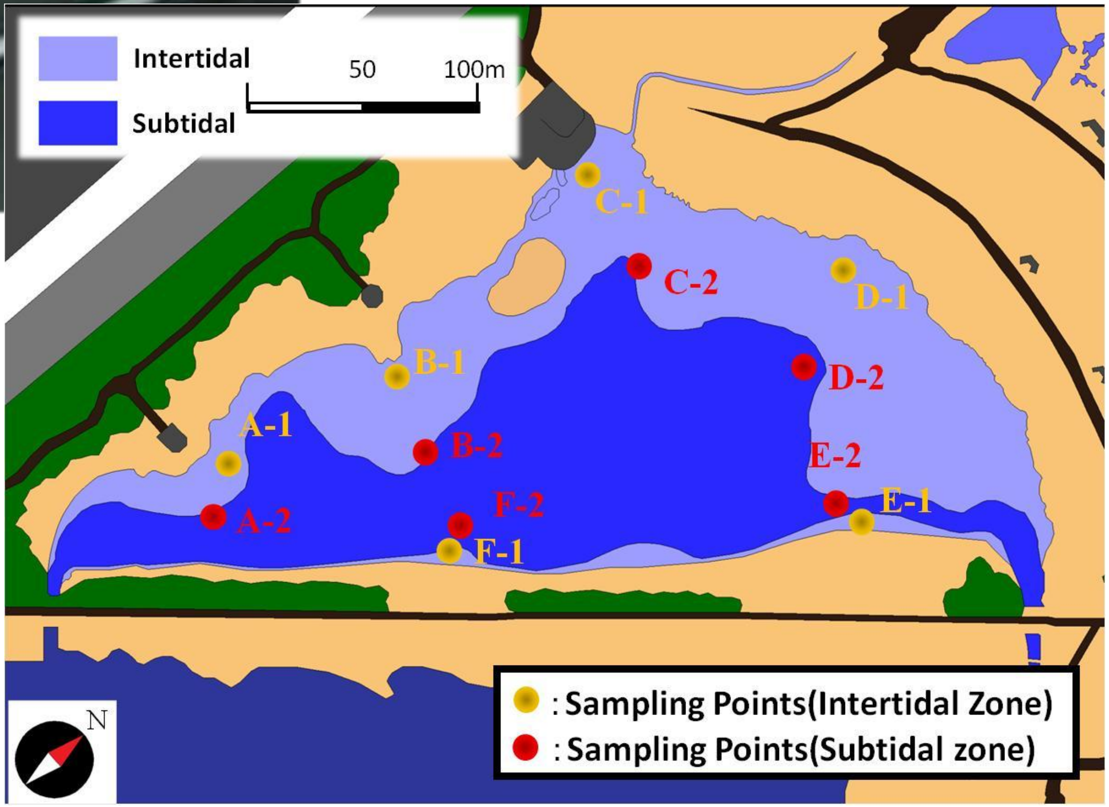
No.26

Nutrient Flux by microphytobenthos

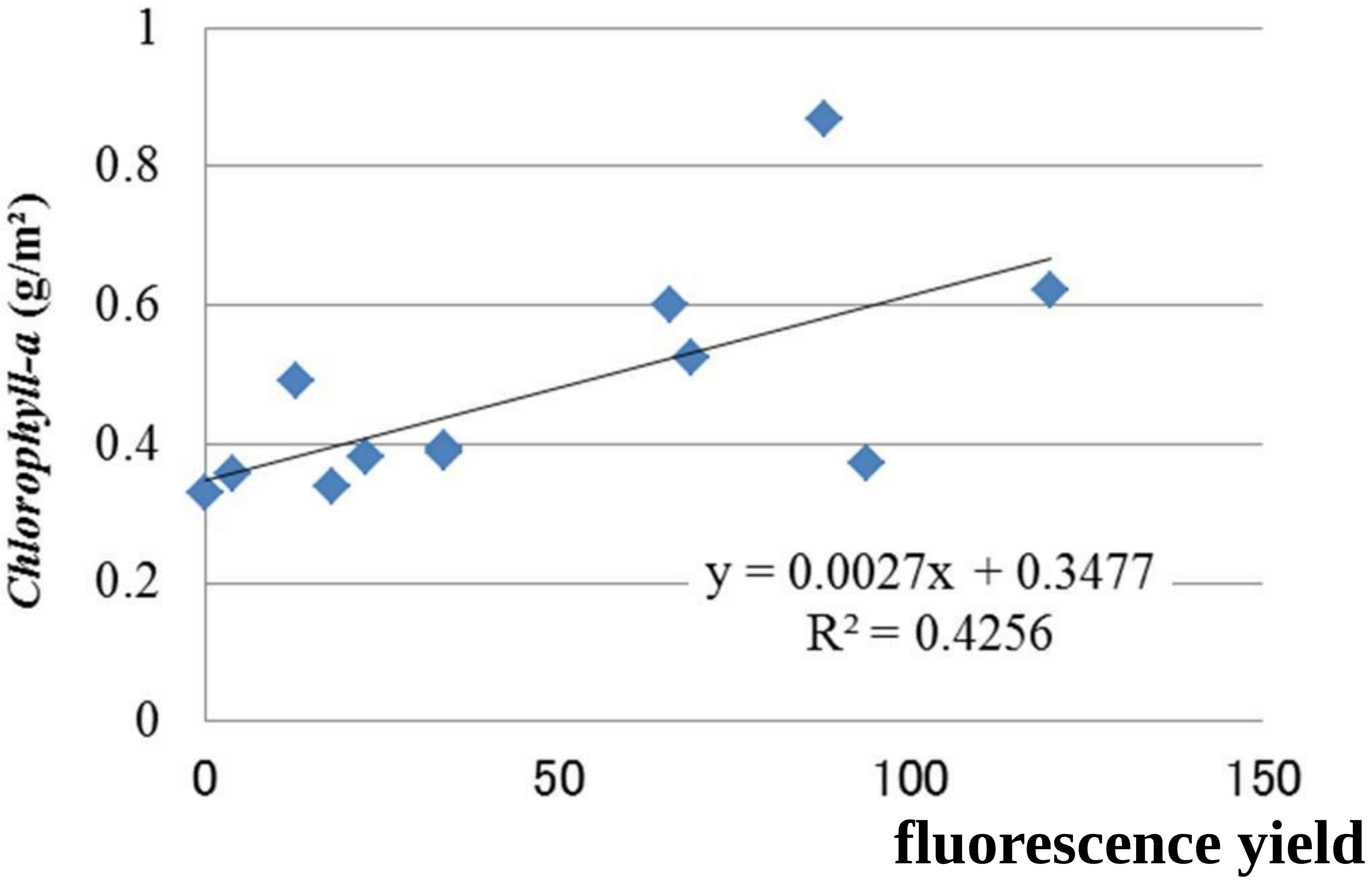




: Measuring point (20cmx20cm:quadrat)



Relationship between Chlorophyll-a(laboratory) and fluorescence yield(Diving PAM)



Measuring Station		Chlorophyll-a(mg/m²)			
		2010		2011	
		Aug.	Dec.	Aug.	Dec.
Sandy Mud	A-1	0.38	0.19	0.25	0.24
	B-1	1.28	0.24	0.18	0.29
	C-1	0.45	0.48	0.19	0.27
	D-1	0.68	0.21	0.17	0.17
Gravel	E-1	0.35	0.15	0.26	0.36
	F-1	0.33	0.33	0.27	0.38
Sandy Mud	A-2	0.90	0.50	0.58	0.21
	B-2	0.61	0.14	0.19	0.16
	C-2	0.44	0.13	0.17	0.28
	D-2	0.37	0.12	0.28	0.20
Gravel	E-2	0.32	0.09	0.28	0.44
	F-2	0.31	0.19	0.35	0.36
Total N	**mol N**	**19.5**	**8.0**	**8.7**	**9.2**
Total P	**mol P**	**1.22**	**0.50**	**0.54**	**0.58**

Nitrogen Cycle in the Tidal Flat in Summer

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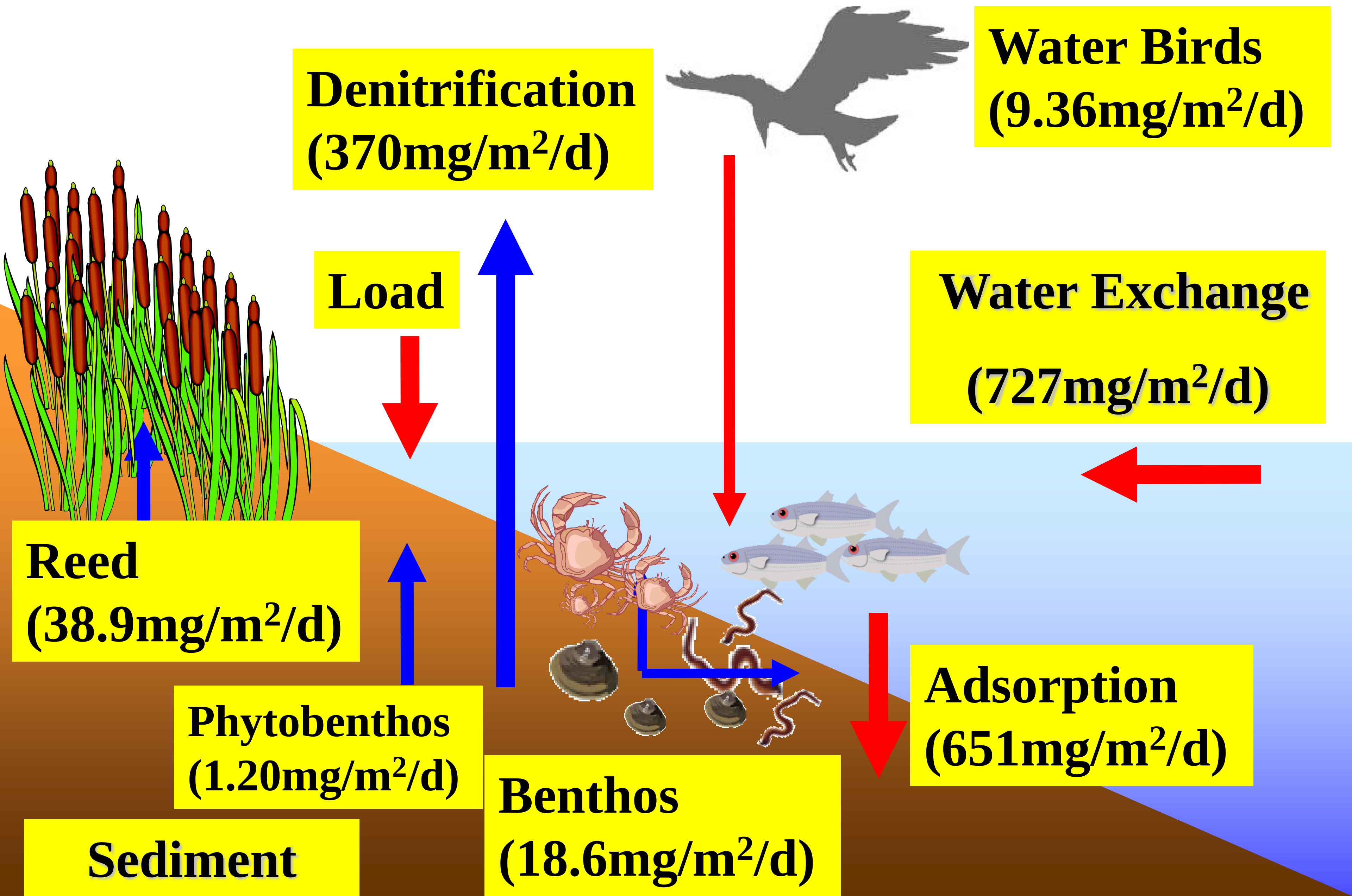
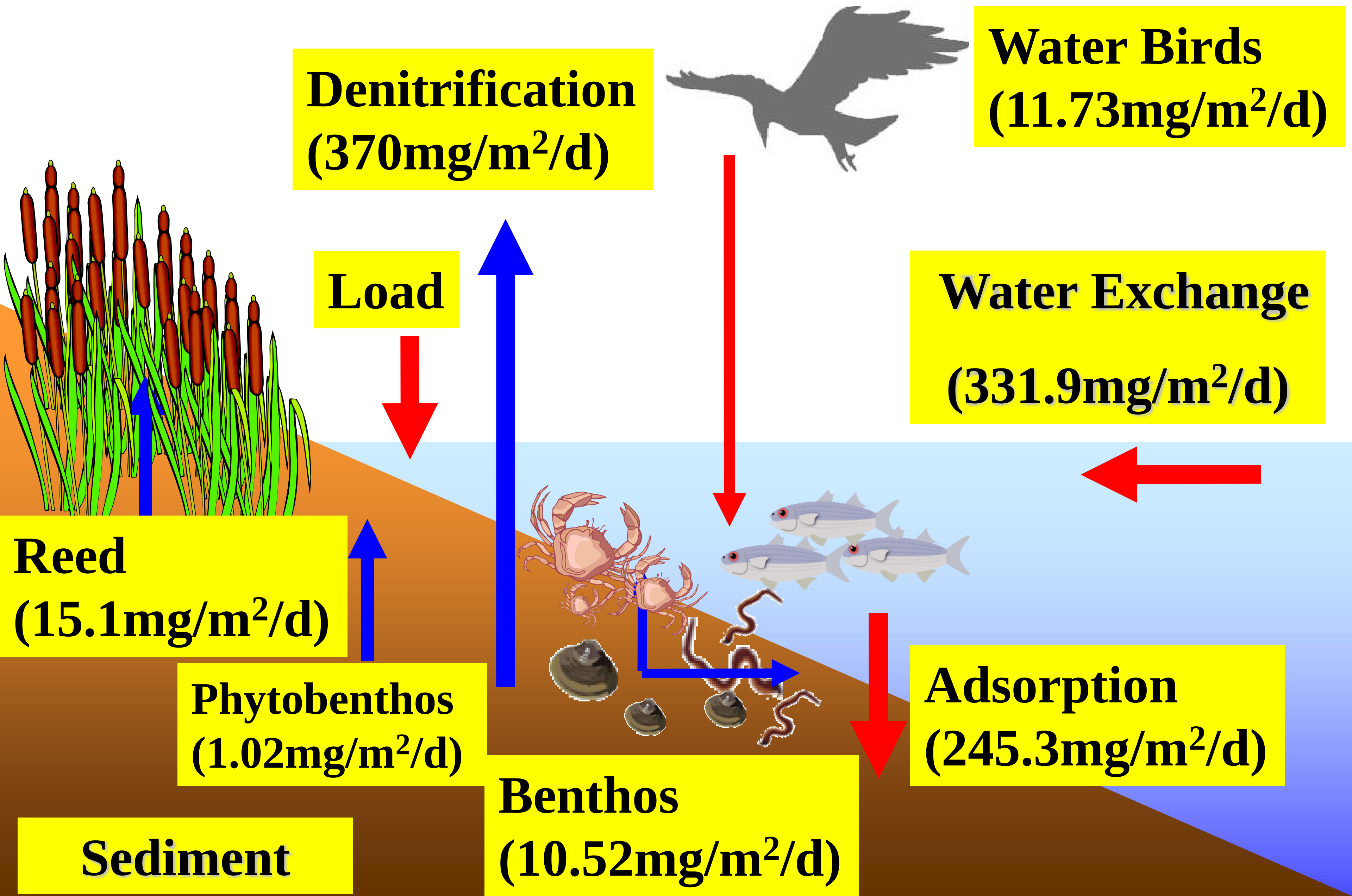


Nitrogen Cycle in the Tidal Flat in Winter



Phosphorus Cycle in the Tidal Flat in summer

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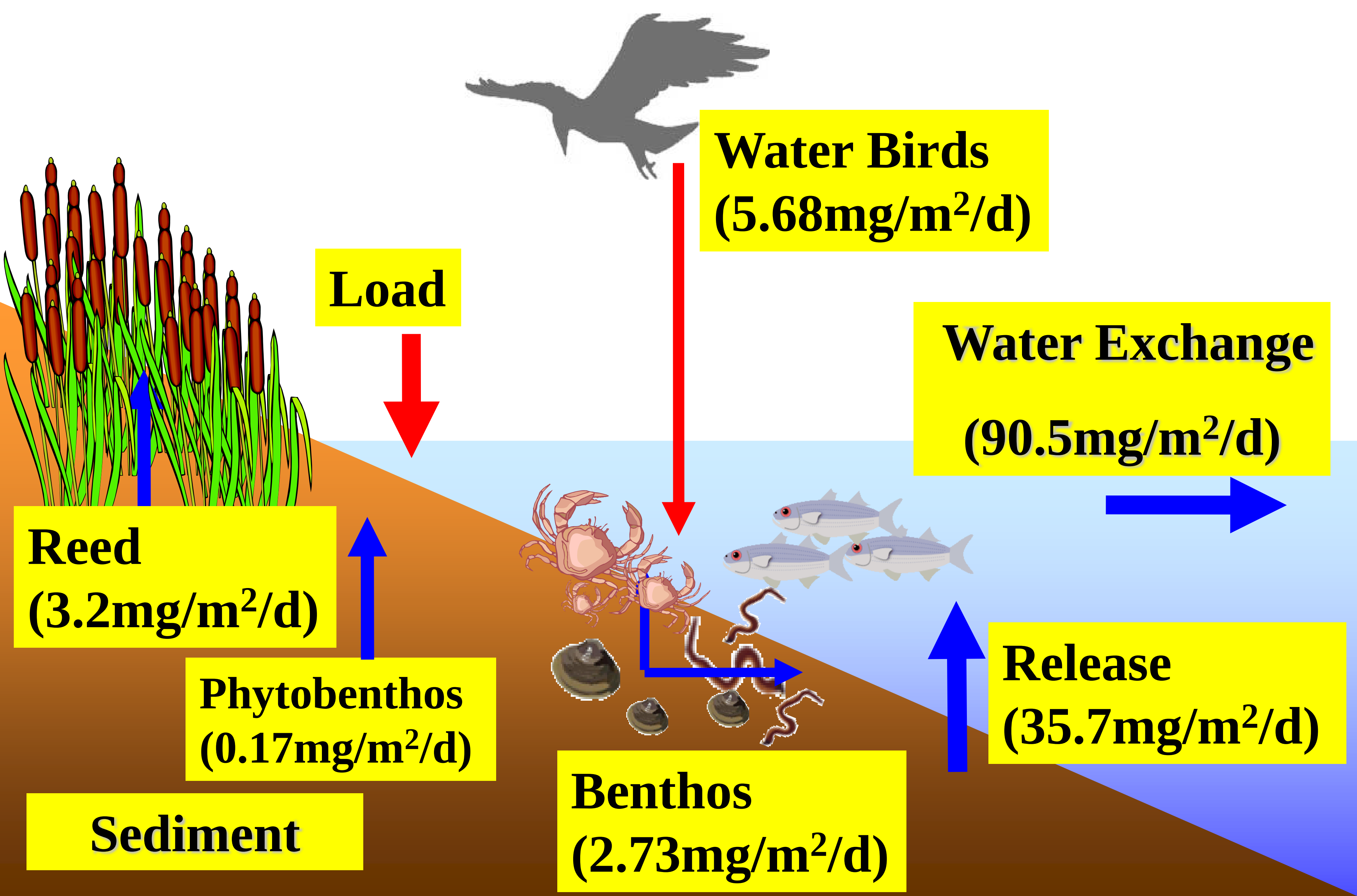

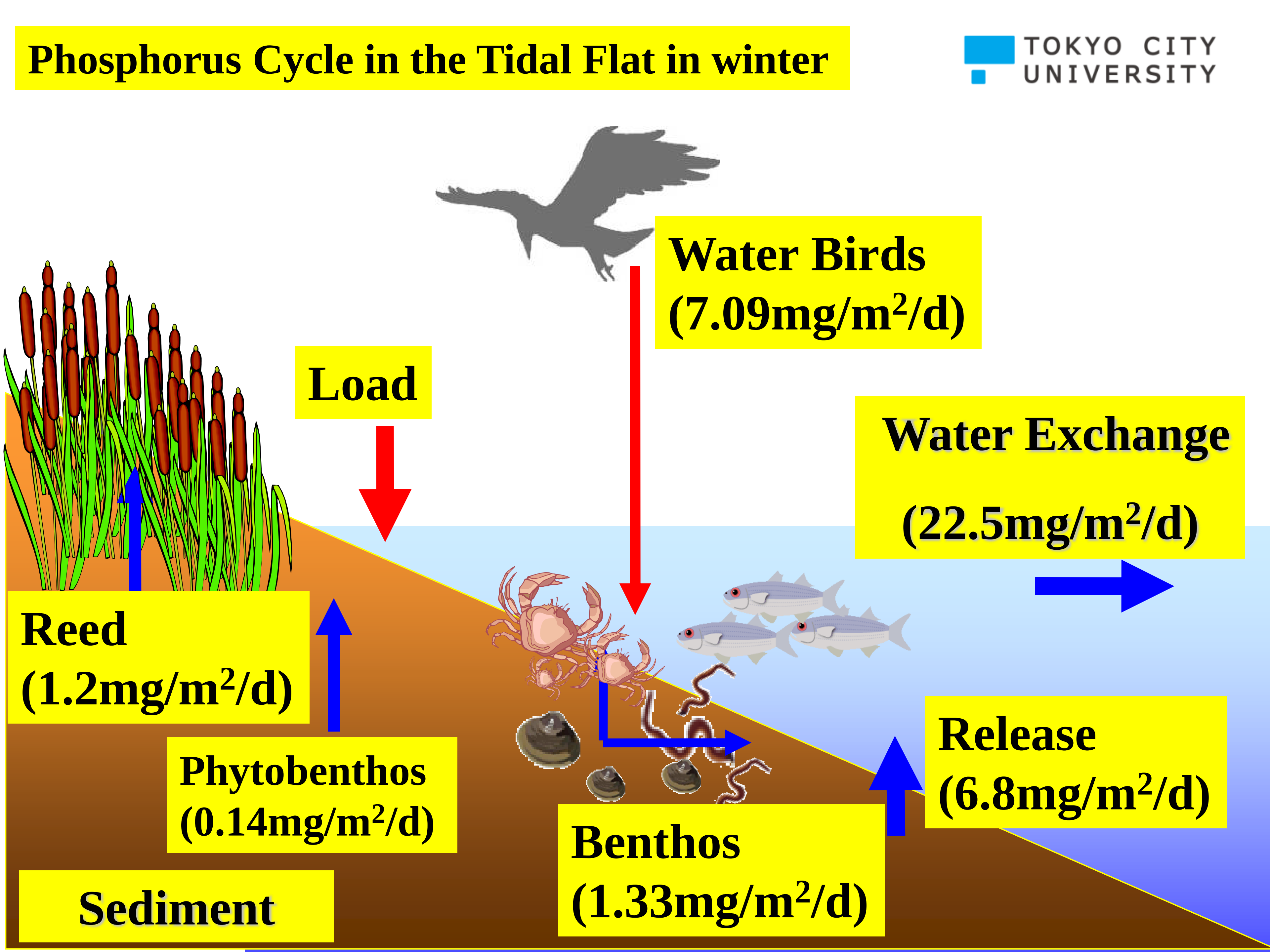

Phosphorus Cycle in the Tidal Flat in winter
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Water Birds (7.09mg/m²/d)
Load
Water Exchange (22.5mg/m²/d)
Reed (1.2mg/m²/d)
Phytobenthos (0.14mg/m²/d)
Release (6.8mg/m²/d)
Benthos (1.33mg/m²/d)
Sediment

Concluding Remarks

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The Role of the Tidal Flat on Water Environment

- The Flat is net sink for Nitrogen, and is net source for Phosphorus
- The excretion of water birds is a source of Phosphorus, but the nutrient flux by birds is not so large
- The nutrient flux between sediment and overlying water in the flat is quite large
- The main factor of a net sink of Nitrogen is denitrification and anammox

Thank you so much !

Finish !