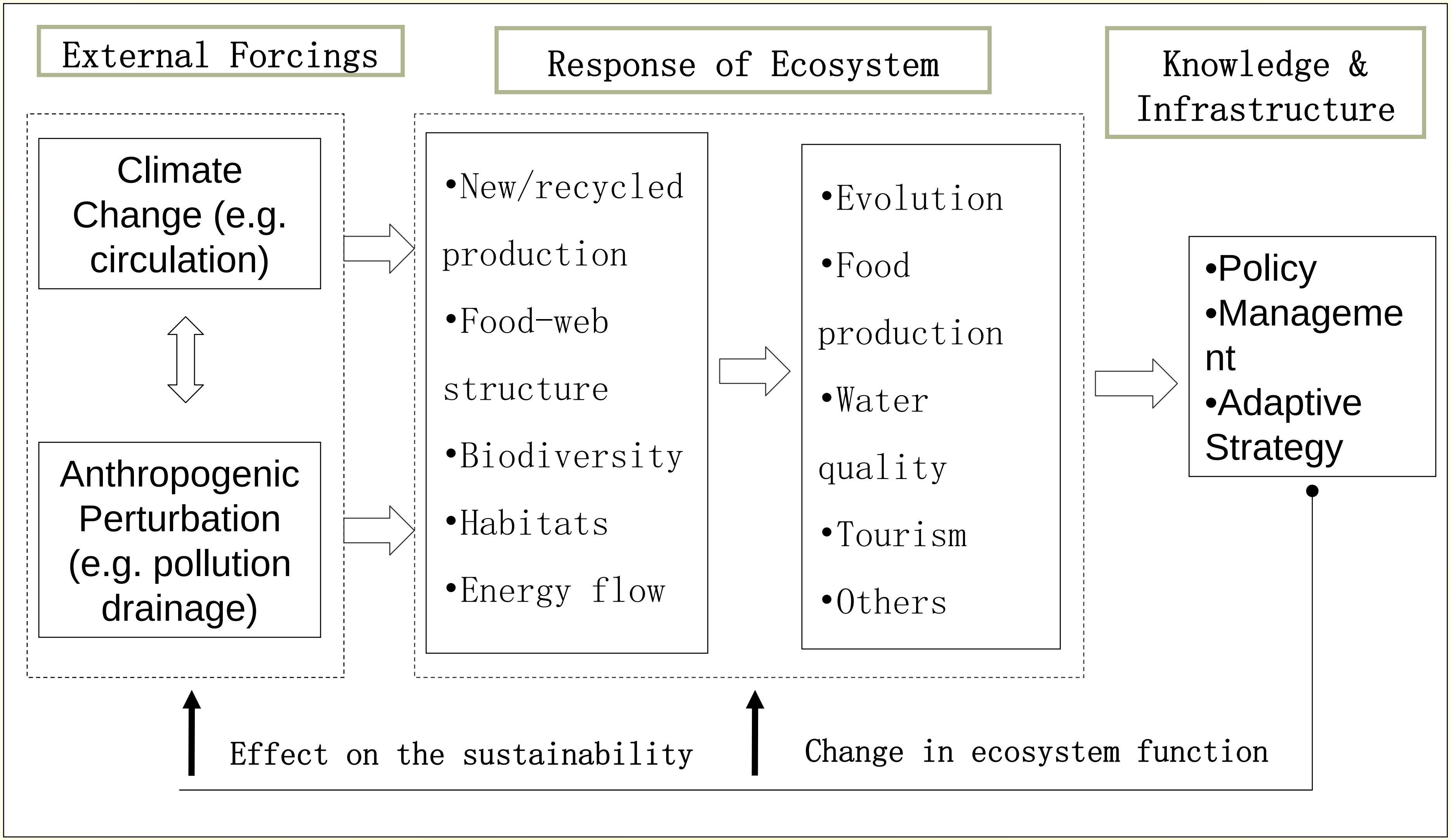
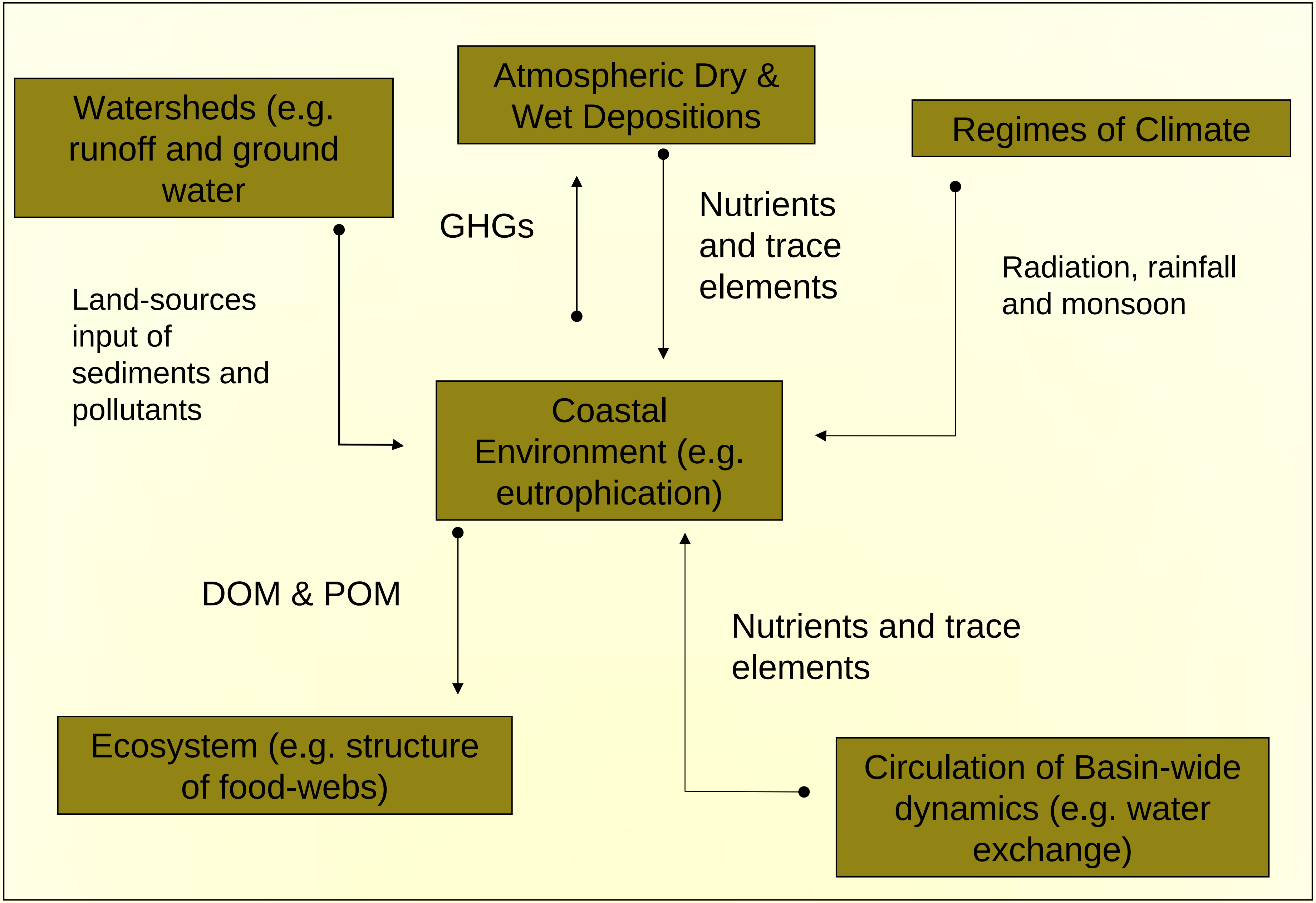
Remobilization of Nutrients from Watersheds and Eutrophication in Marine Recipients

Jing Zhang* and NSFC Task Team
*State Key Laboratory of Estuarine and Coastal Research, East China Normal University, Shanghai 200062, China

Acknowledgements

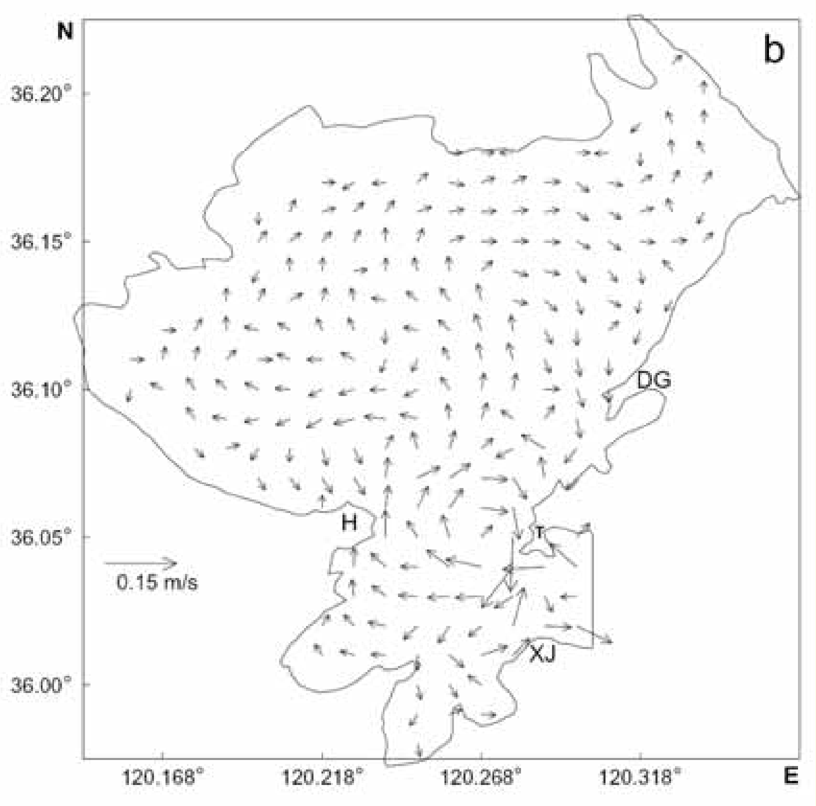
- Team members for the Jiaozhou Bay studies: S.M. Liu, G.L. Zhang, J.L. Ren, Z. Liu, S.L. Yang, B. Deng, J. Bai, H.W. Gao, D.Y. Liu, G.Q. Liu, G.S. Liu, J. Liu, H.K. Sun, J.Y. Wang, and H. Wei
- NSFC funding to the project: “Nutrient Loss from the Watersheds and Eutrophication of the Jiaozhou Bay” (No. 40036010)
- Students and other colleagues from ECNU and OUQ
- NOWPAP for the invitation

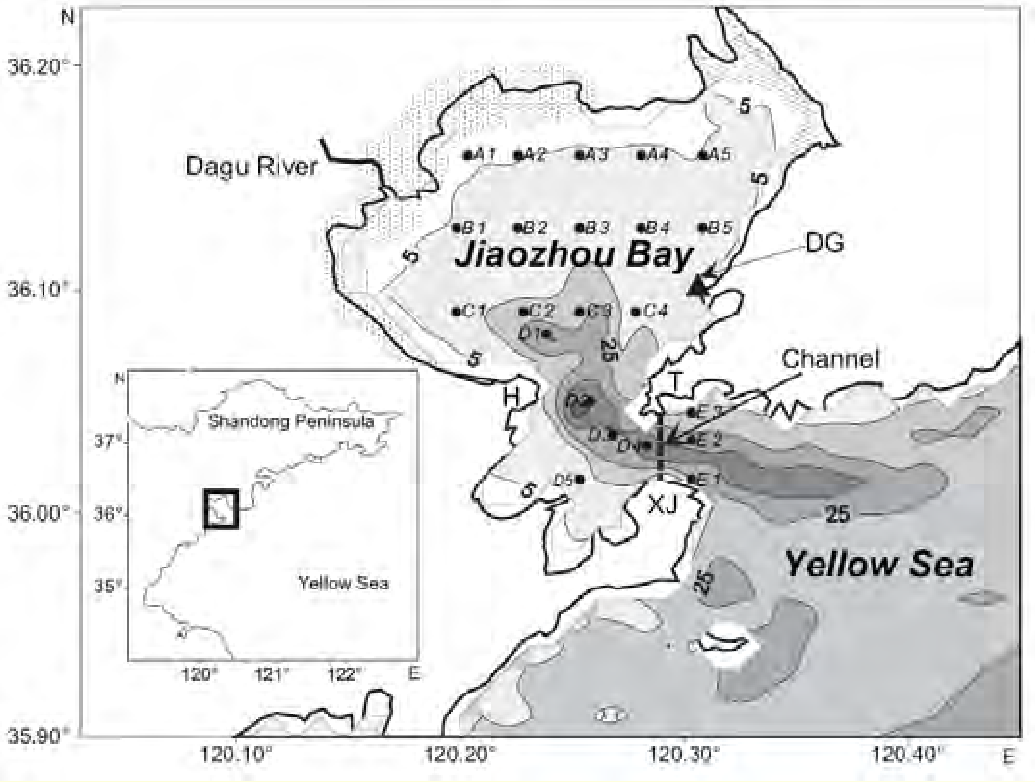

External Forcings
Response of Ecosystem
Knowledge & Infrastructure
Climate Change (e.g. circulation)
Anthropogenic Perturbation (e.g. pollution drainage)
•New/recycled production
•Food-web structure
•Biodiversity
•Habitats
•Energy flow
•Evolution
•Food production
•Water quality
•Tourism
•Others
•Policy
•Management
•Adaptive Strategy
Effect on the sustainability
Change in ecosystem function


Watersheds (e.g. runoff and ground water
Atmospheric Dry & Wet Depositions
Regimes of Climate
GHGs
Nutrients and trace elements
Radiation, rainfall and monsoon
Land-sources input of sediments and pollutants
Coastal Environment (e.g. eutrophication)
DOM & POM
Nutrients and trace elements
Ecosystem (e.g. structure of food-webs)
Circulation of Basin-wide dynamics (e.g. water exchange)

Objectives of the Study

- To evaluate the change in land use in the watersheds and its impact on the coastal recipients in terms of nutrient loss
- To understand the coastal hydro-dynamics and biogeochemistry in regulating the processes of eutrophication





Background Information about the Jiaozhou Bay

- Surface Area: 353.4 km^2 (2006), 452 km^2 (1971), 560 km^2 (1928), ca. 50-55% of surface is 0-5 m
- Drainage area: ca. 7500 km^2 with population of ca. 7×10^6
- Water depth: 7 m on average, with max depth of 64 m
- Tide: Dominated by semidiurnal M2, contributing 80-90% of kinetic and potential energy; tide is 2.8 m on average (Range: 1.02-4.75 m)
- Connection to the Yellow Sea: A channel of 2.5 km wide
- Riverine influx: 0.5-1×10^9 m^3/yr, most of them are seasonal with dams

地图
卫星
混合地图
S309
S218
青岛流亭机场
S202
丹山水库
营海镇
胶州湾高速
G204
李沧区
G20青银高速
胶州湾
G308
四方区
红石崖镇
S328
市北区
信号山公园
鲁迅公园
汇泉湾
市南区
麦岛
太平湾
团岛湾
S398
Google
Imagery ©2011 TerraMetrics, 地图数据 ©2011 Mapabc - 使用条款

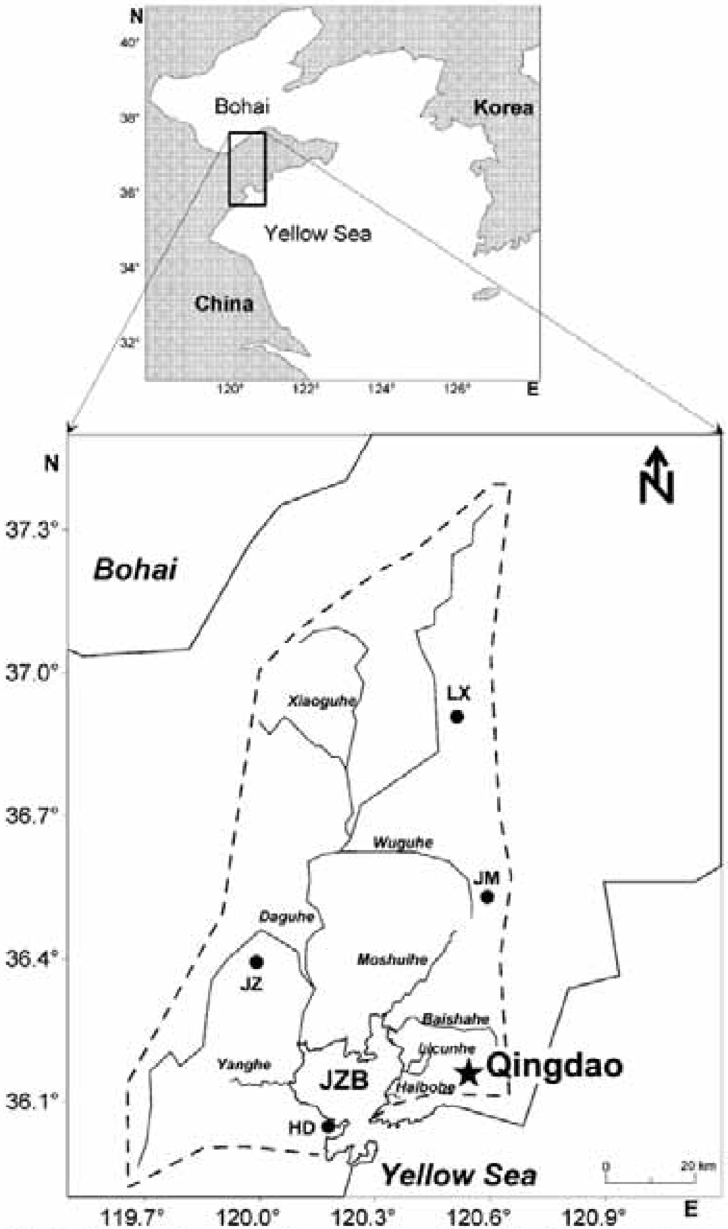
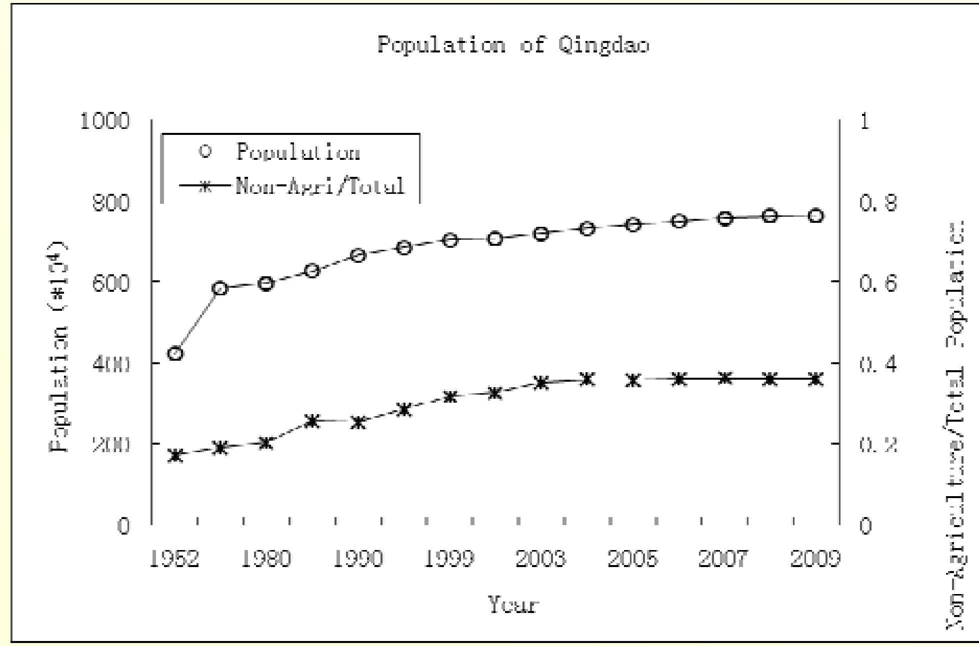
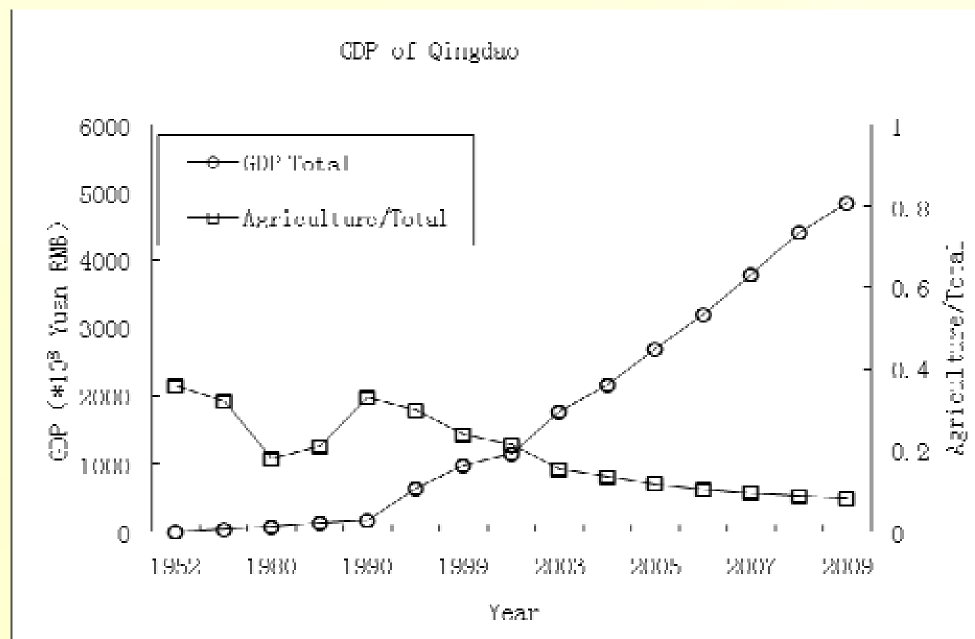
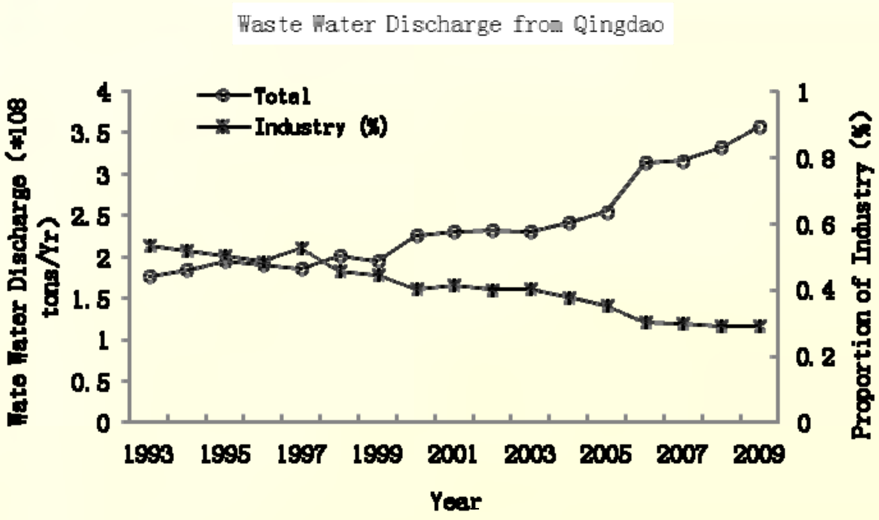
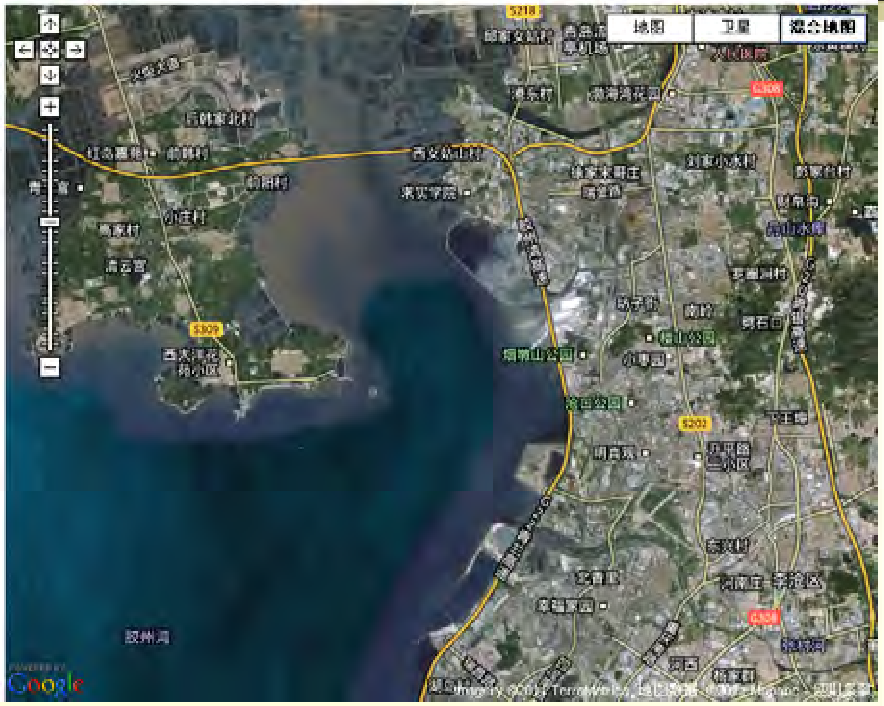


Fig. 2 The study area of the Jiaozhou Bay (JZB) Project shows the catchments for the major rivers, including Yanghe, Daguhe, Moshuihe, Baishahe, Licunhe, and Haibohe. The domestic centers, i.e., Qingdao, Jimo (JM), Laixi (LX), Jiaozhou (JZ), and Huangdao (HD) are also shown

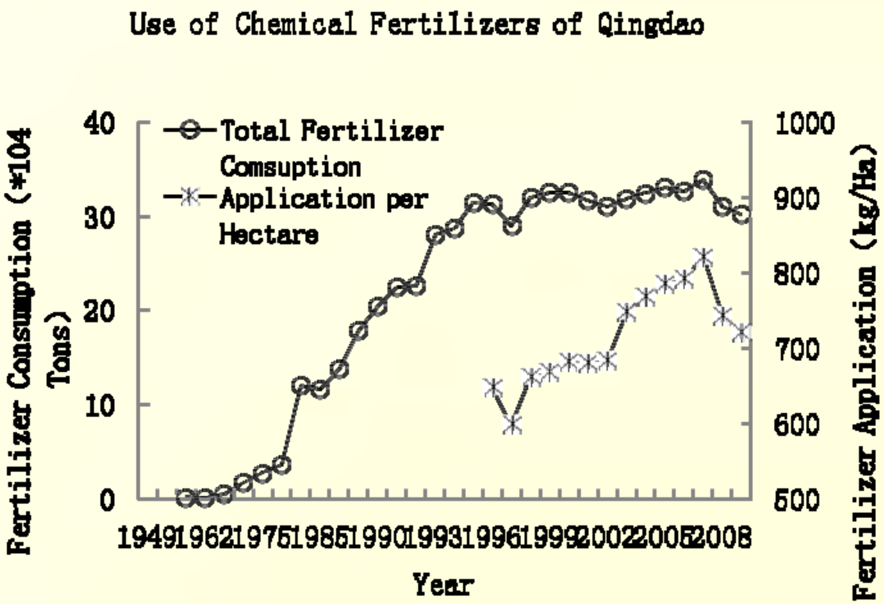


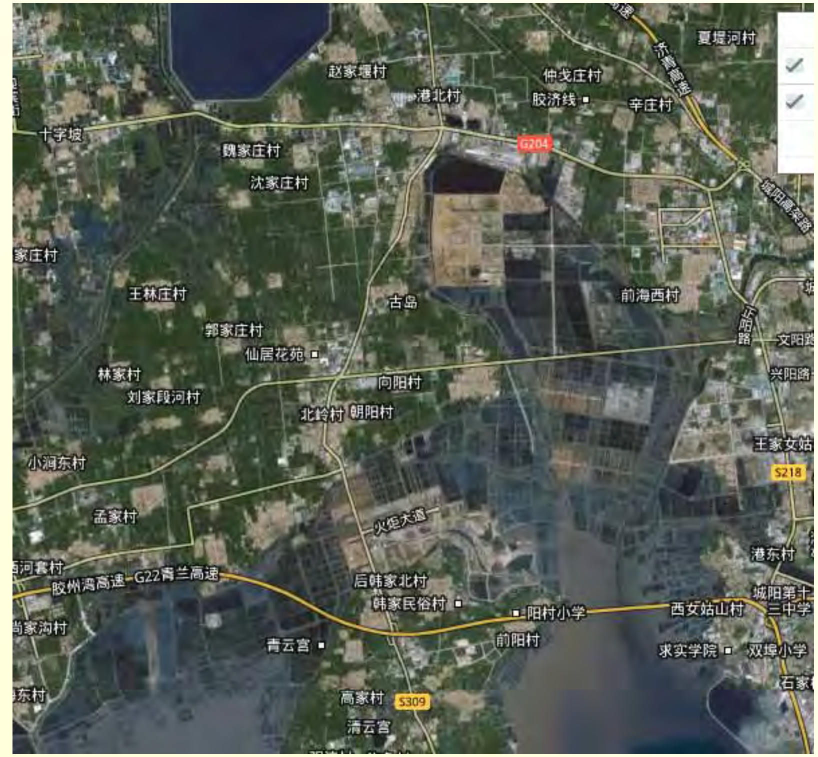




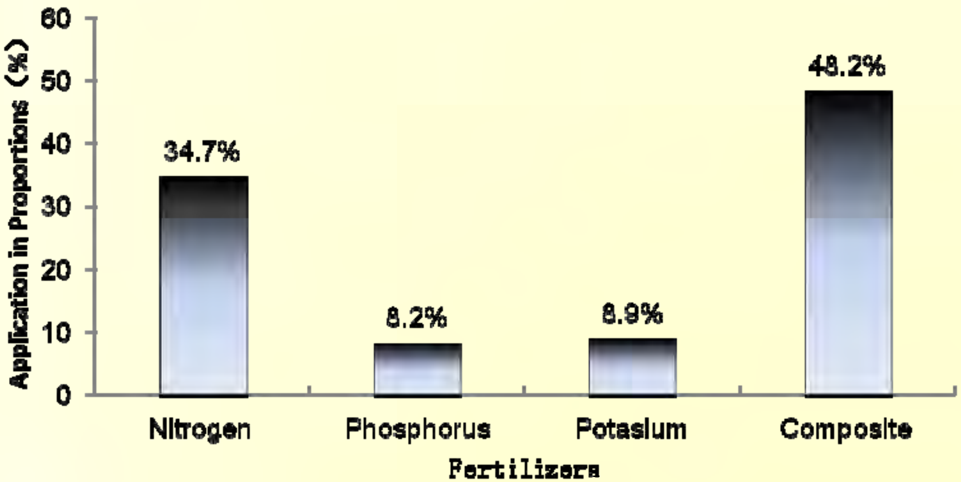


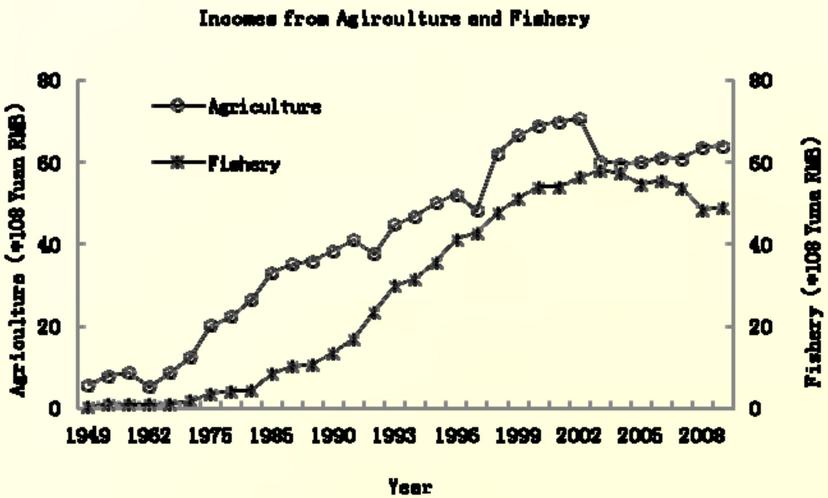
Period	PO_4^{3-}	SiO_3^{2-}	NO_3^-	NO_2^-	NH_4^+	References
1950	0.1-0.7	5-20				Xin, 1953
1962-1963	0.14±0.03		0.38±0.15	0.17±0.13	1.6±0.6	Shen, 2002
1983-1986	0.43±0.17	2.4±1.1	1.8±1.0	0.39±0.23	6.5±3.7	Shen, 2002
1991-1998	0.33±0.11	2.0±1.9	2.0±1.1	0.66±0.40	8.2±2.5	Shen, 2002
2001	0.1-0.5	1.4-8.2	6.1-32.2	1.2-4.2	8.3-10.8	Liu et al., 2005



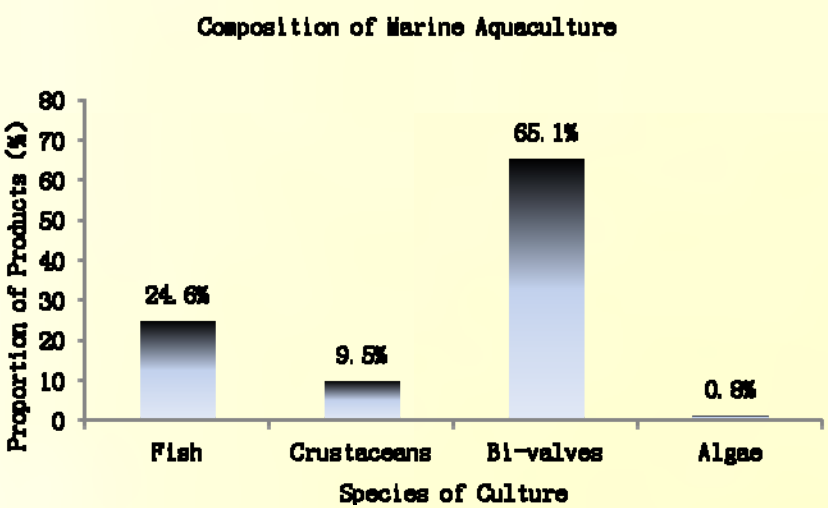


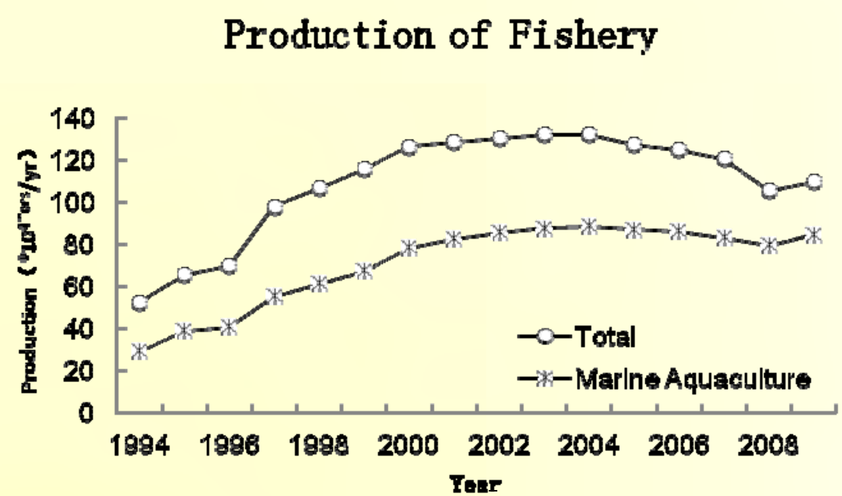
Fertilizer Applications




Incomes from Agiroulture and Fishery
Agriculture
Fishery
Agriculture (*108 Yuan RMB)
Fishery (*108 Yuan RMB)
0
20
40
60
80
1949 1962 1975 1985 1990 1993 1996 1999 2002 2005 2008
Year

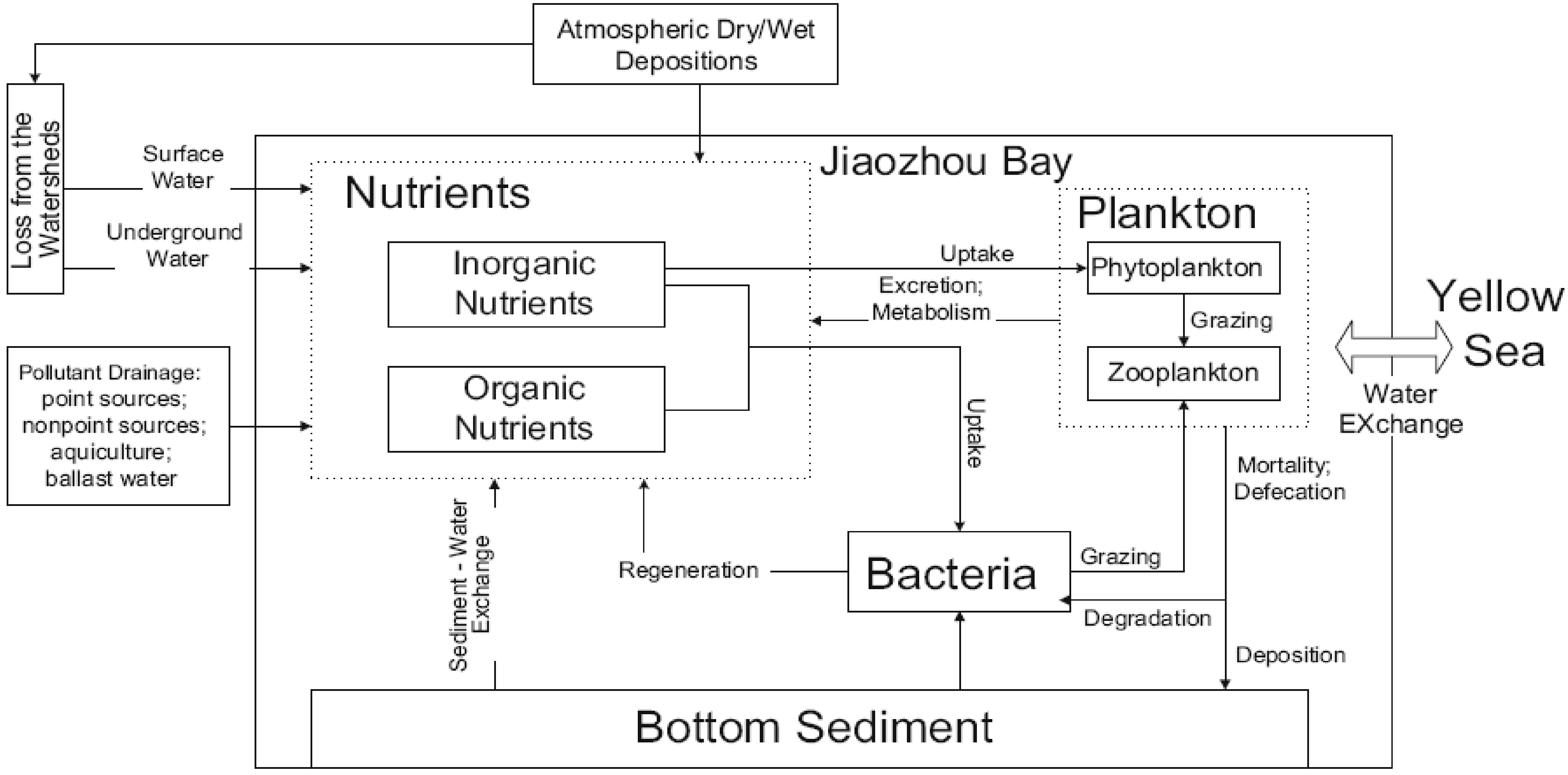

地图
卫星
混合地图
孟家村
法家庄村
小东滩
下疃村
上疃村
东河套村
G22青兰高速
胶州湾高速
后韩家北
山角村
码头村
尚家沟村
红岛嘉苑
前韩村
青云宫
罗家营村
潮海西村
营海镇
小庄村
高家村
清云宫
S309
西大洋花苑小区
大后旺村
小海庄村
前海庄村
大坨
戈庄村
胶州湾高速
胶州湾
Imagery ©2011 TerraMetrics, 地图数据 ©2011 Mapabc - 使用条款

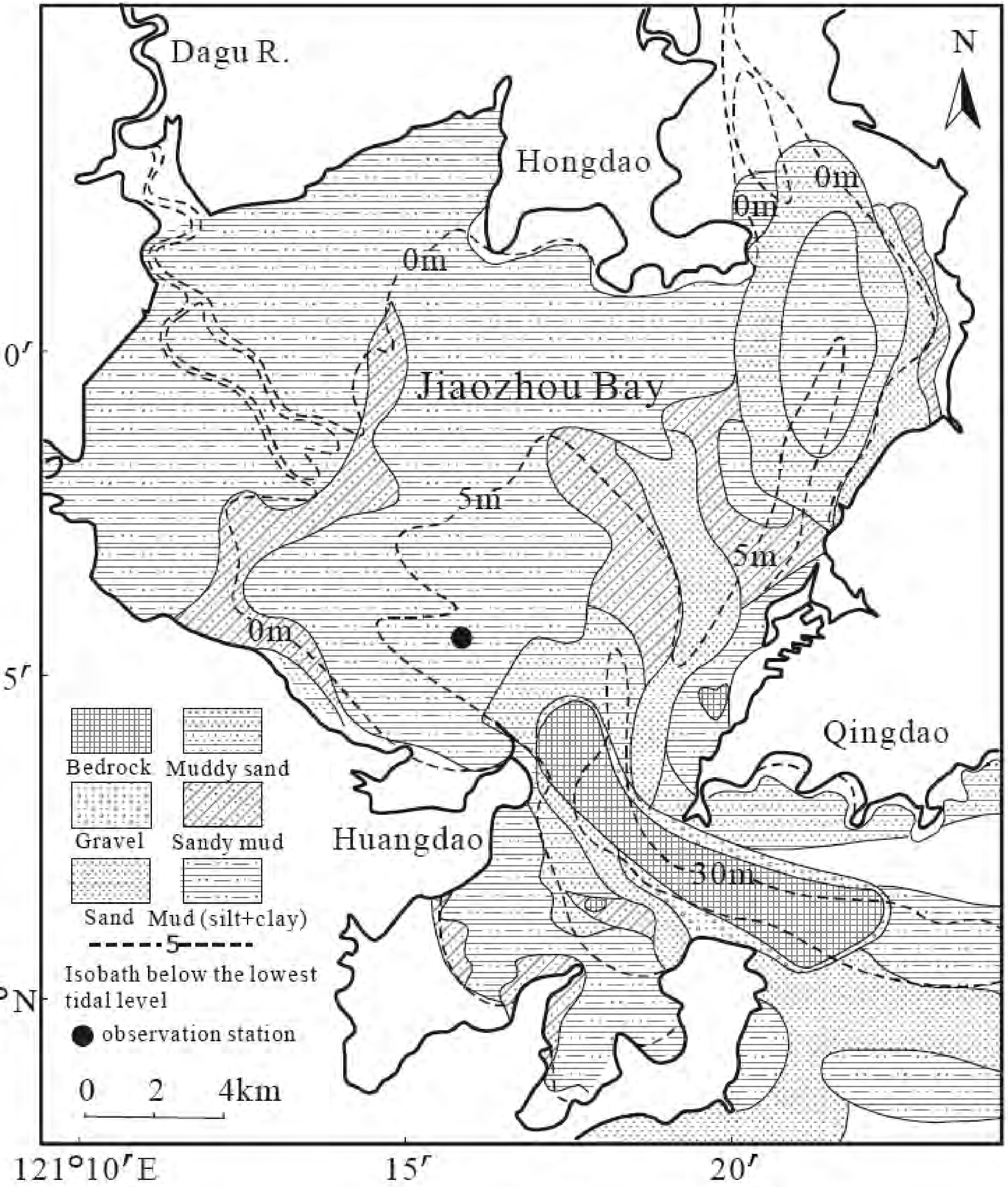

Composition of Marine Aquaculture
Proportion of Products (%)
0
10
20
30
40
50
60
70
80
24.6%
9.5%
65.1%
0.8%
Fish
Crustaceans
Bi-valves
Algae
Species of Culture

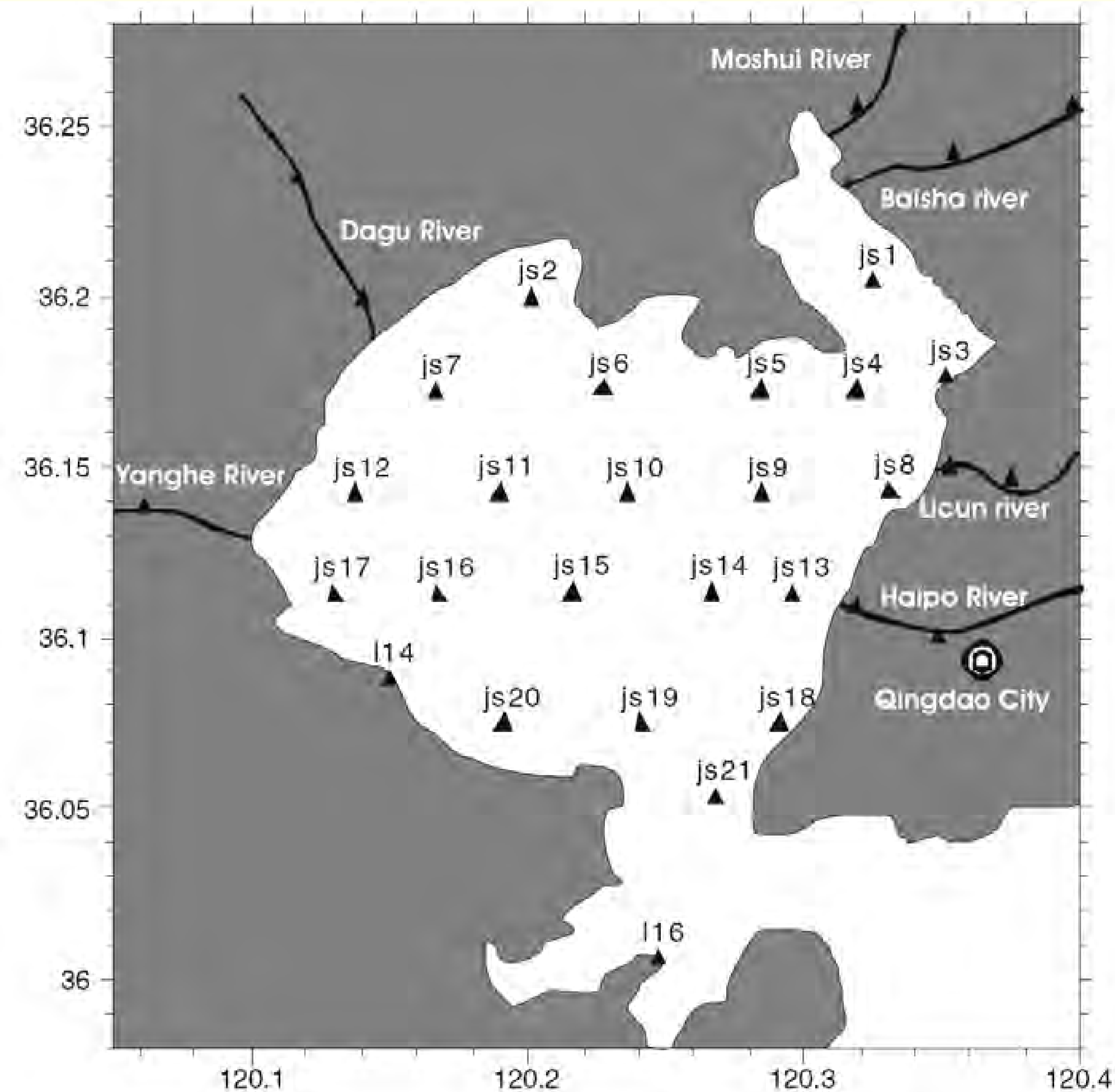

Production of Fishery
Production
0
20
40
60
80
100
120
140
Total
Marine Aquaculture
1994 1996 1998 2000 2002 2004 2006 2008
Year

Working Hypothesis

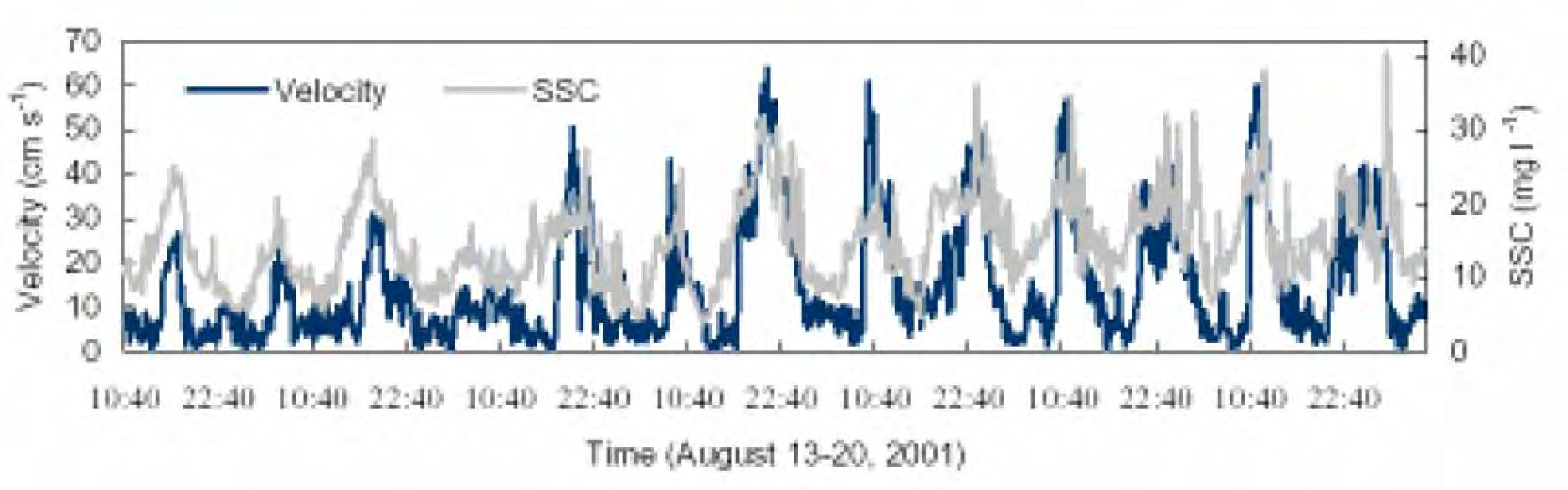
Although land-use change in the watersheds has induced an increase in plant nutrient influx into the coastal waters, the evolution of eutrophication of the Jiaozhou Bay is regulated by the oceanographic processes……



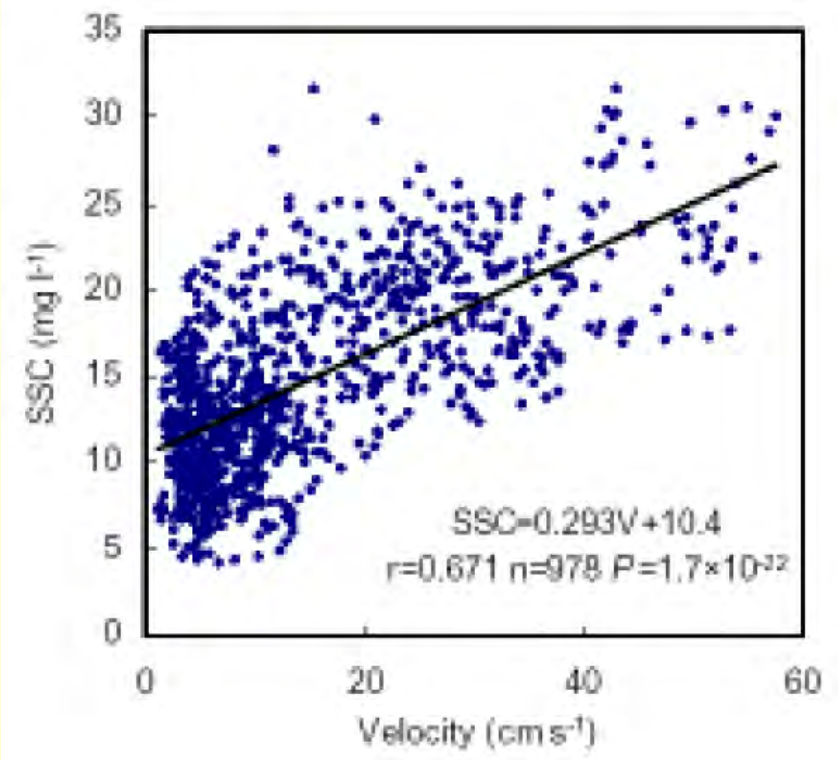

Dagu R.
N
Hongdao
0m
0m
0m
10′
Jiaozhou Bay
5m
5m
0m
05′
Qingdao
Bedrock
Muddy sand
Gravel
Sandy mud
Huangdao
Sand
Mud (silt+clay)
30m
5
Isobath below the lowest tidal level
6°N
observation station
0 2 4km
121°10′E
15′
20′



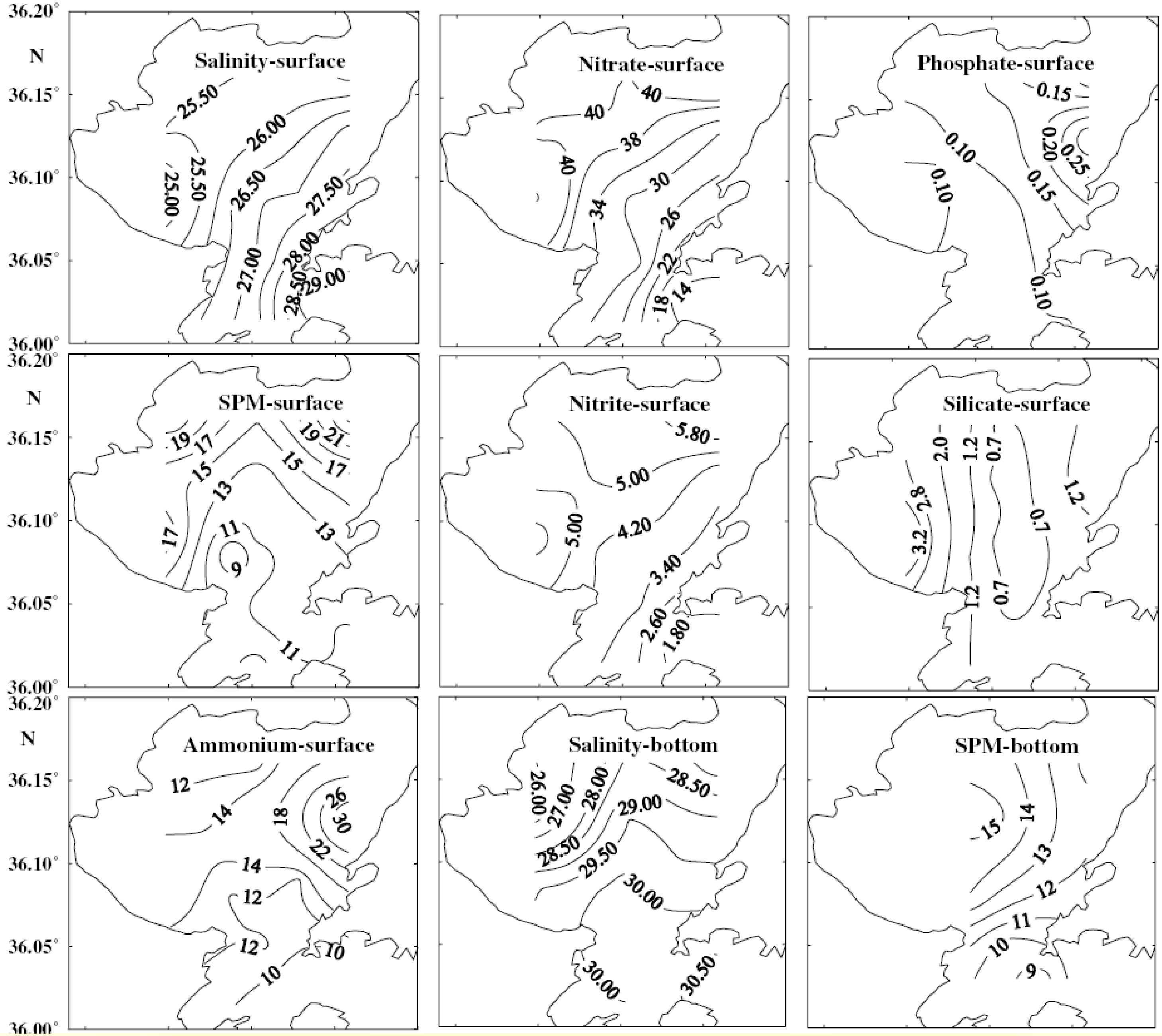
Moshui River
Baisha river
Dagu River
Yanghe River
Licun river
Haipo River
Qingdao City
js1
js2
js3
js4
js5
js6
js7
js8
js9
js10
js11
js12
js13
js14
js15
js16
js17
js18
js19
js20
js21
l14
l16
36.25
36.2
36.15
36.1
36.05
36
120.1
120.2
120.3
120.4



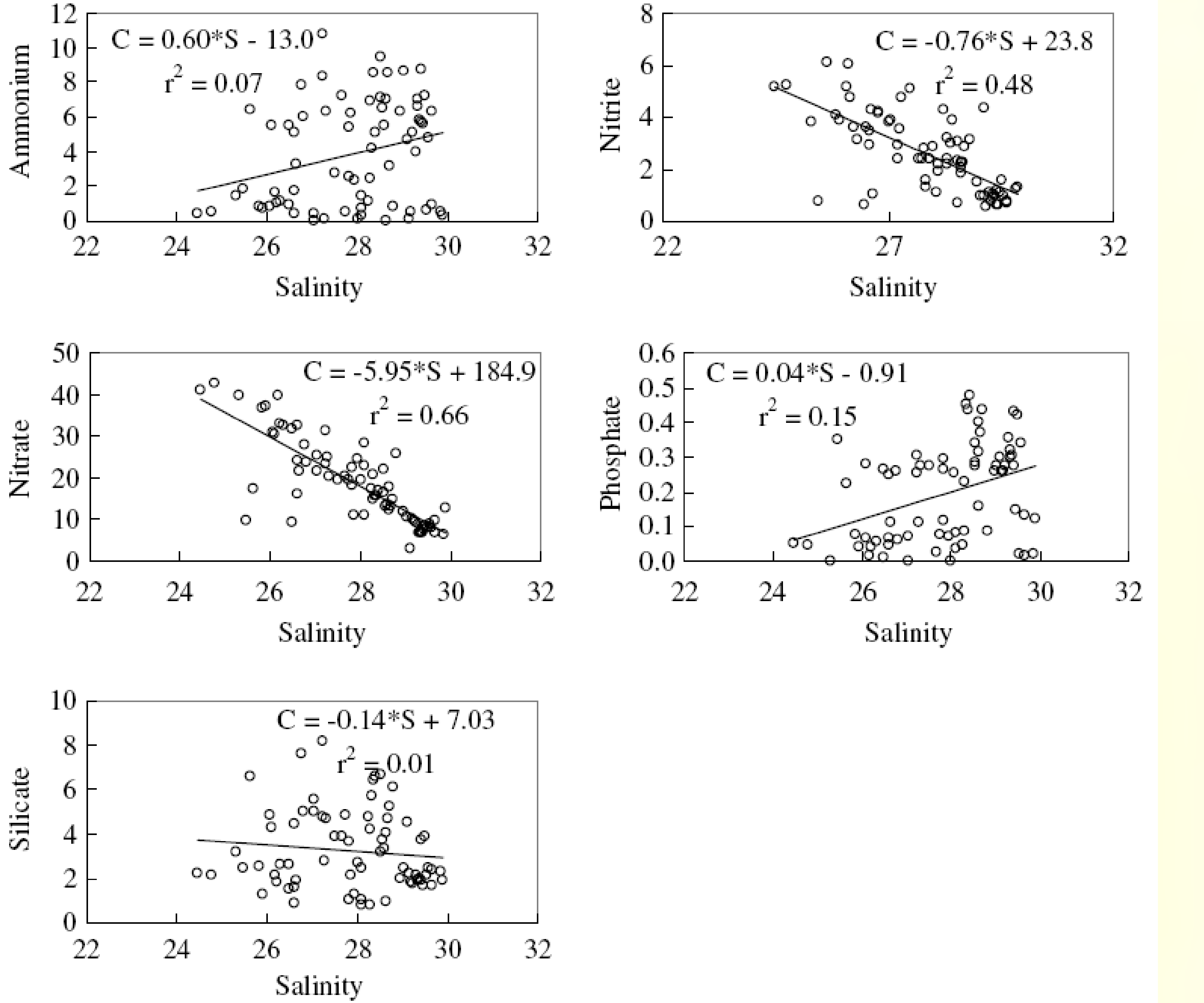
Velocity
SSC
Velocity (cm s-1)
SSC (mg l-1)
10:40
22:40
Time (August 13-20, 2001)



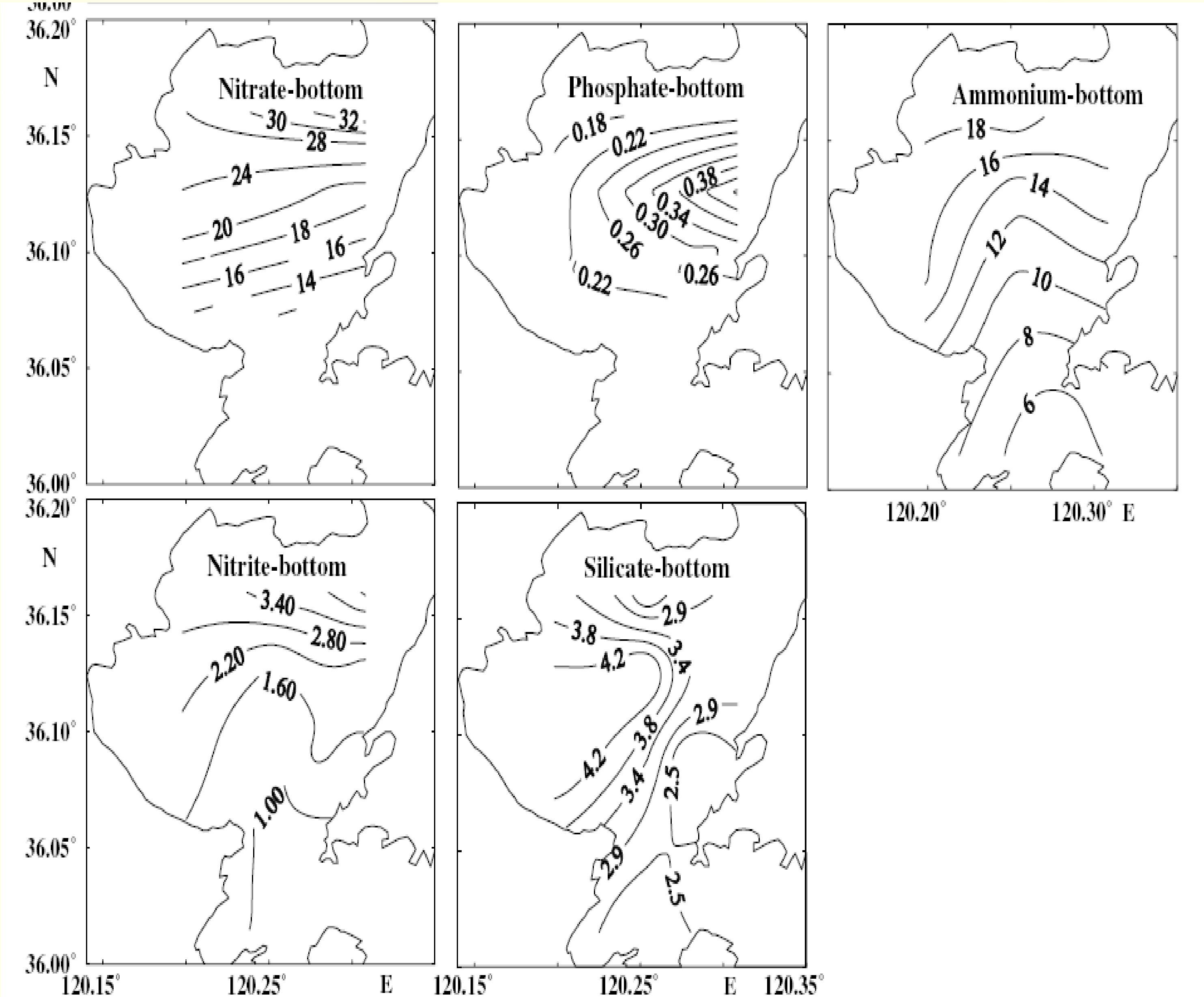
SSC (mg l-1)
Velocity (cm s-1)
SSC=0.293V+10.4
r=0.671 n=978 P=1.7×10-22



36.20°
N
36.15°
36.10°
36.05°
36.00°
Salinity-surface
25.50
26.00
25.50
25.00
26.50
27.50
27.00
28.00
28.50
29.00
Nitrate-surface
40
40
40
38
30
34
26
22
18
14
Phosphate-surface
0.15
0.10
0.20
0.25
0.10
0.15
0.10
SPM-surface
19
17
19
21
15
15
17
13
17
11
13
9
11
Nitrite-surface
5.80
5.00
5.00
4.20
3.40
2.60
1.80
Silicate-surface
2.0
1.2
0.7
2.8
3.2
1.2
0.7
1.2
0.7
Ammonium-surface
12
14
18
26
30
22
14
12
12
10
10
Salinity-bottom
26.00
27.00
28.00
28.50
29.00
28.50
29.50
30.00
30.00
30.50
SPM-bottom
15
14
13
12
11
10
9



C = 0.60*S - 13.0
r^2 = 0.07
Ammonium
Salinity
C = -0.76*S + 23.8
r^2 = 0.48
Nitrite
Salinity
C = -5.95*S + 184.9
r^2 = 0.66
Nitrate
Salinity
C = 0.04*S - 0.91
r^2 = 0.15
Phosphate
Salinity
C = -0.14*S + 7.03
r^2 = 0.01
Silicate
Salinity



Nitrate-bottom
30
32
28
24
20
18
16
16
14
Phosphate-bottom
0.18
0.22
0.38
0.34
0.30
0.26
0.22
0.26
Ammonium-bottom
18
16
14
12
10
8
6
Nitrite-bottom
3.40
2.80
2.20
1.60
1.00
Silicate-bottom
2.9
3.8
3.4
4.2
2.9
3.8
4.2
3.4
2.5
2.9
2.5
36.20°
N
36.15°
36.10°
36.05°
36.00°
120.15°
120.25°
120.35°
120.20°
120.30°
E

Table 3
Nutrient concentrations in major rivers that empty into Jiaozhou Bay (μM)

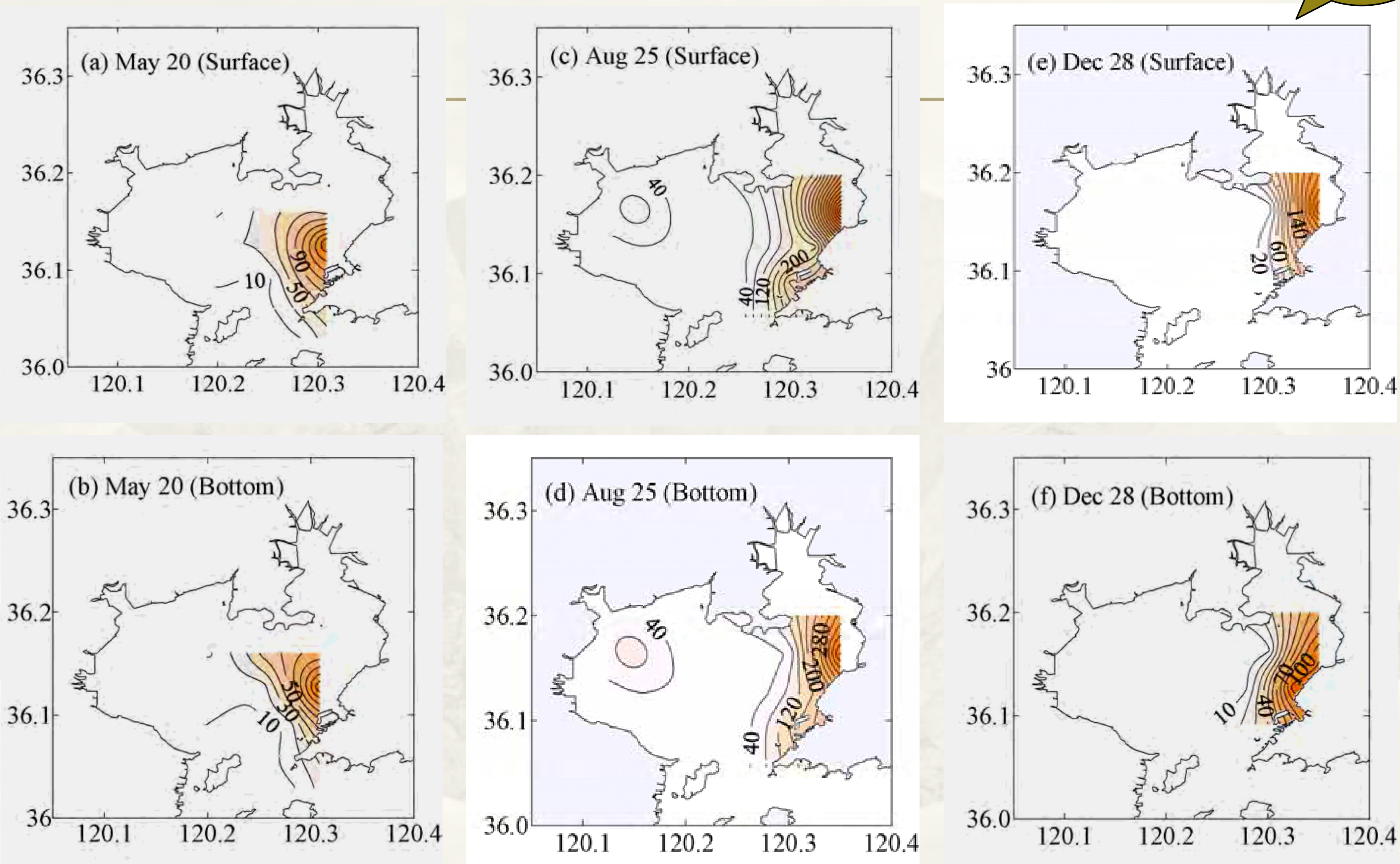
River	NH_4^+	NO_3^-	NO_2^-	PO_4^{3-}	SiO_3^{2-}	N/P	Si/N
Dry season (March 2002)							
Licunhe	60.1	3.1	2.1	90.1	370.8	0.7	5.7
Daguhe	25.4	34.2	0.7	0.1	12.7	626	0.1
Yanghe	26.6	163.9	1.2	0.1	21.0	3566	0.1
Moshuihe	156.1	436.1	0.3	33.5	280.4	18	0.5
Bashahe	58.0	304.2	18.4	1.9	30.1	205	0.1
Flood season (August 2002)							
Licunhe	274.6	4.0	0.6	60.5	333.7	4.6	1.2
Daguhe	19.6	1.4	0.0	0.7	156.5	31.2	7.4
Yanghe	5.3	6.2	0.3	0.3	71.1	43.2	6.0
Moshuihe	1081	4.0	0.3	63.9	285.9	17.0	0.3
Bashahe	18.9	221	9.6	0.6	55.7	400.0	0.2

Table 7 Quantity of water and nutrients discharged from the Daguhe to JZB

Time	Discharge[a] (10^6 m^3/yr)	Nutrients (concentration (Con): μmol/l, Discharge (DIS): 10^4 mol/yr)					
		NO_3^- Con[b,c]	DIS	NO_2^- Con[b,c]	DIS	SiO_2 Con[b,c]	DIS
1967	239.0	309.52	7,397.6	4.76	113.8	114.00	2,724.6
1981	No runoff						
1982	2.4	0.00	0.0	178.57	42.5	133.00	31.7
1983	No runoff						
1984	No runoff						
1985	391.0	23.93	935.6	3.14	122.9	133.00	5,200.3
1986	6.0	19.43	11.7	1.14	0.7	133.00	79.8
1987	5.8	73.43	42.5	2.36	1.4	133.00	77.0
1988	11.9	21.00	24.9	1.57	1.9	133.00	157.6
1989	No runoff						
1997	148.4	64.52	957.5	5.43	80.6	133.00	1,973.7
1998	219.2	35.00	767.2	1.89	41.5	133.00	2,915.4
1999	8.8	73.33	64.2	5.71	5.0	133.00	116.5
2000	No runoff						
2001	258.9	182.86	4,734.2	8.36	216.4	133.00	3,443.4

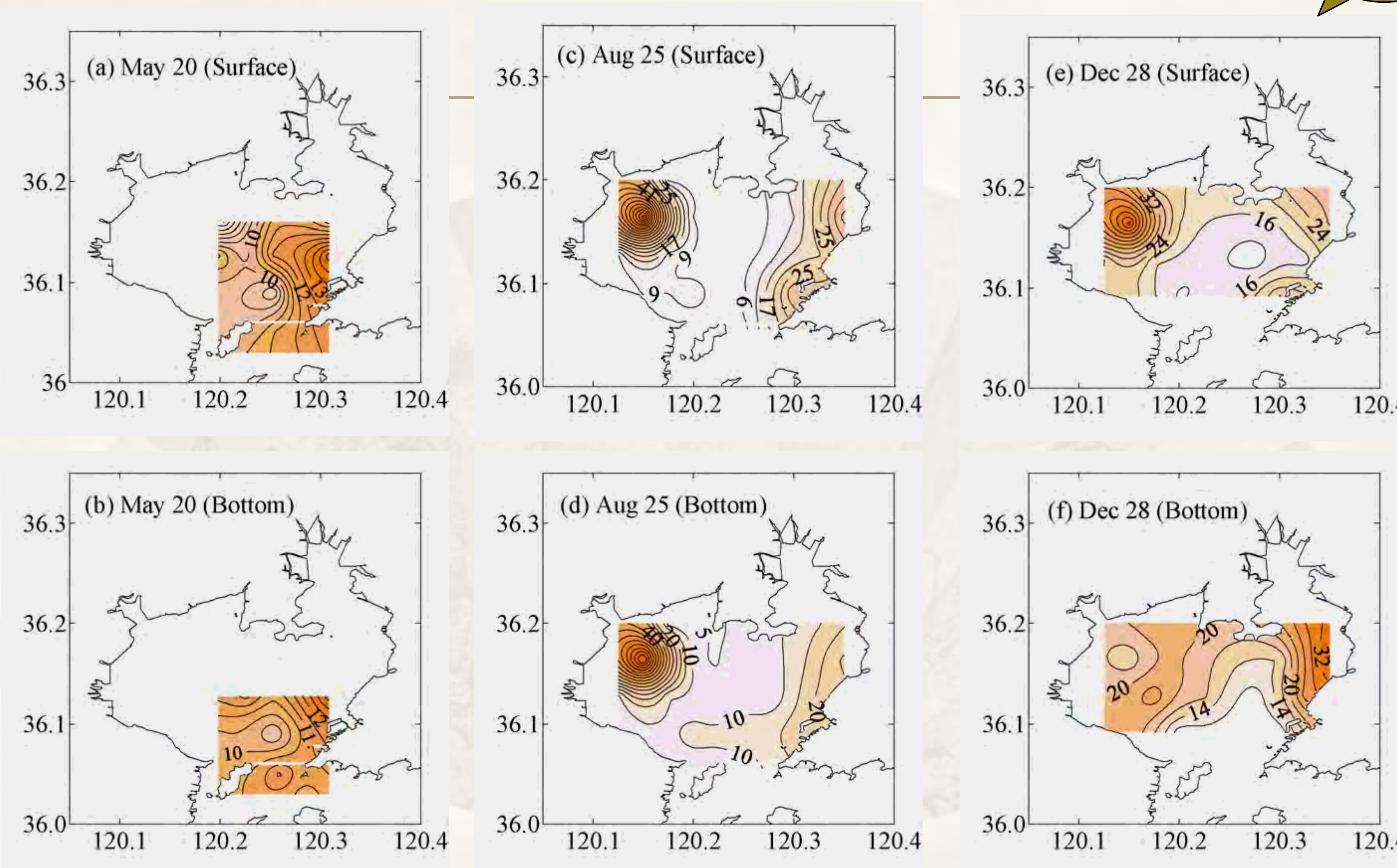
[a] The Qingdao Hydrologic Bureau, [b] the Qingdao Water Environment Pollution Survey Evaluation Report (1967–1988), [c] the Water Environment Detection Center of Qingdao (1997–2001)

CH_4



Horizontal distributions of CH_4 concentrations (nmol/L) in the Jiaozhou Bay during May, August and December of 2003

N_2O



Horizontal distributions of N_2O concentrations (nmol/L) in the Jiaozhou Bay during May, August and December of 2003

Dissolved CH_4 in the river waters around the Jiaozhou Bay and the riverine input

Rivers	CH_4 (μ mol/L)					Flow[a] (m^3/s)	Riverine input (10^6mol/yr)
	2001.08	2001.10	2002.03	2002.05	Average		
Moshui River	2.86	37.9	95.0	42.9	44.7±38.0	0.923	1.30
Licun River	11.0	19.8	40.3	53.9	31.2±19.5	0.34	0.335
Loushan River	6.21	9.19		13.2	9.52±3.49	0.11[b]	0.033
Yang River	0.526	0.317	0.215	0.793	0.463±0.255	1.78	0.026
Dagu River	1.49	0.857	2.37	0.167	1.22±0.938	23.7	0.912
Sum						26.9	2.61

Dissolved N_2O in the river waters around the Jiaozhou Bay and the riverine input

Rivers	N_2O (nmol/L)			Flow[a] (m^3/s)	Riverine input (10^3 mol/yr)
	2002.03	2002.05	Average		
Moshui River	76.0	32.8	54.4	0.923	1.58
Licun River	158	206	182	0.34	1.95
Loushan River	141	781	461	0.11[b]	1.60
Yang River		33.5	33.5	1.78	1.88
Dagu River	387	518	453	23.7	339
Sum				26.9	346

CH_4

Table 2. Seasonal variation of CH_4 fluxes in different regions of Jiaozhou Bay

Region	stations	CH_4 fluxes ($\mu mol \cdot m^{-2} \cdot d^{-1}$)					
		Spring (May 2002/ May 2003)		Summer (Aug. 2003)		Winter (Dec. 2003)	
		LM86	W92	LM86	W92	LM86	W92
I	5(6)	178±162	374±342	364±284	878±685	118±144	232±282
II	6(1)	5.15	10.8	31.2±42.3	75.3±102	4.58±1.40	8.98±2.75
III	6(14)	11.3±13.0	23.7±27.3	21.9±20.1	52.9±48.5	4.24±3.58	8.31±7.02

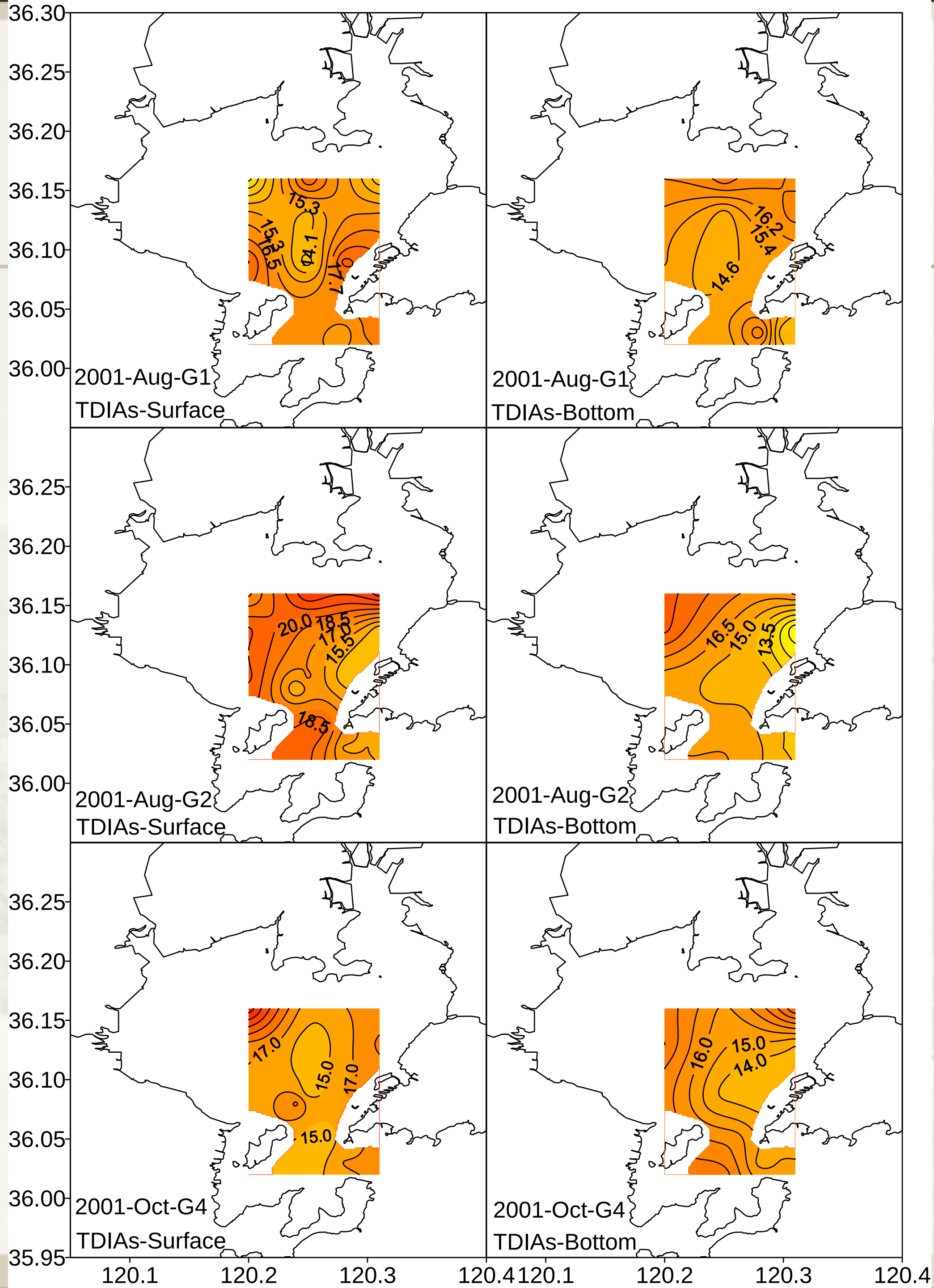
Numbers in the parentheses are number of stations observed in spring

N_2O

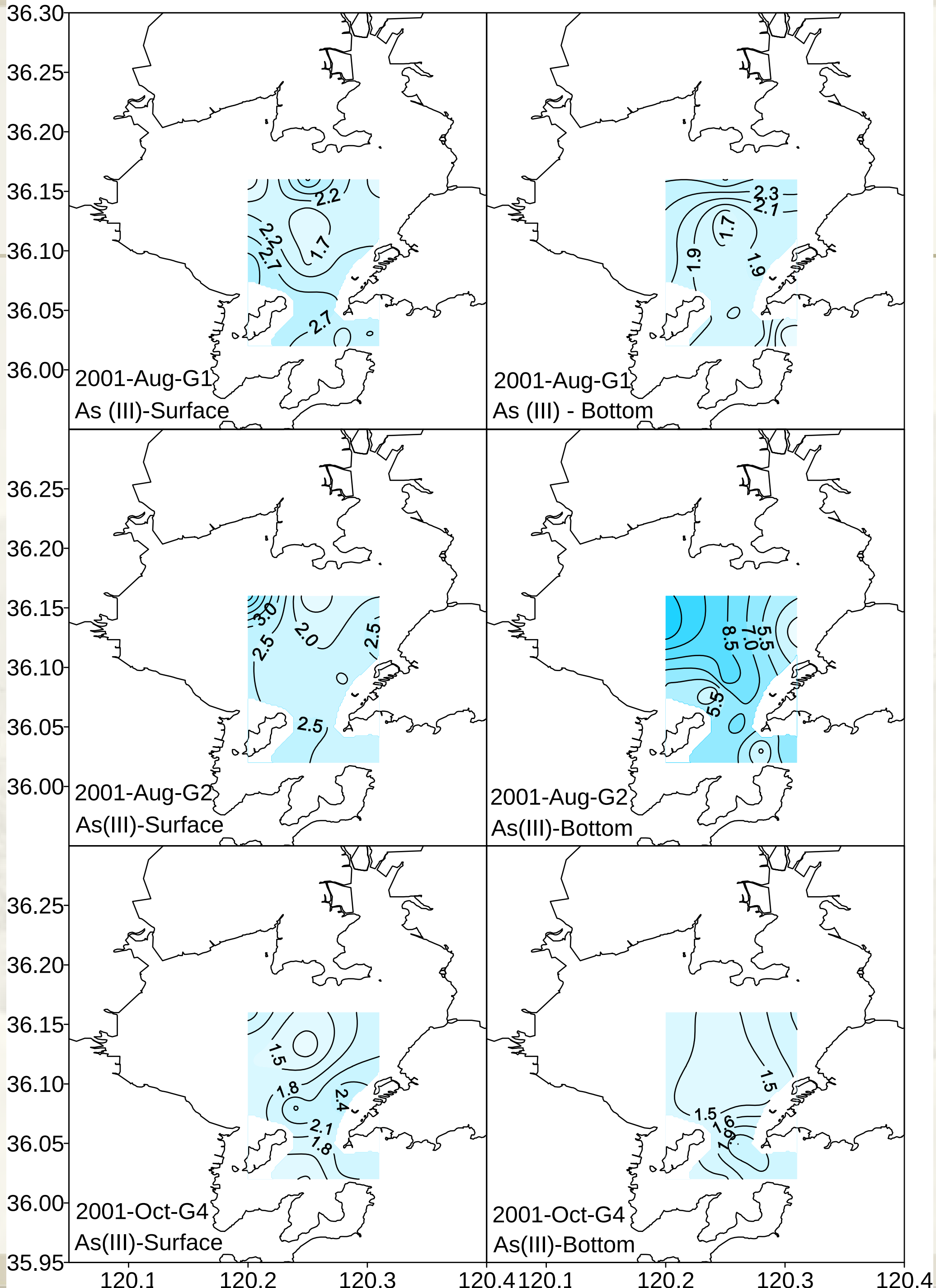
Table 3. Seasonal variation of N_2O fluxes in different regions of Jiaozhou Bay

Region	stations	N_2O fluxes ($\mu mol \cdot m^{-2} \cdot d^{-1}$)					
		Spring (May 2002/ May 2003)		Summer (Aug. 2003)		Winter (Dec. 2003)	
		LM86	W92	LM86	W92	LM86	W92
I	5(6)	17.7±24.7	37.3±51.9	21.3±14.3	50.5±27.4	11.4±7.90	22.4±15.5
II	6(0)			22.6±44.2	43.4±84.8	16.3±21.3	32.0±41.8
III	6(14)	1.50±3.73	3.16±7.86	3.03±2.78	5.81±5.32	-0.67±2.74	-1.31±5.37

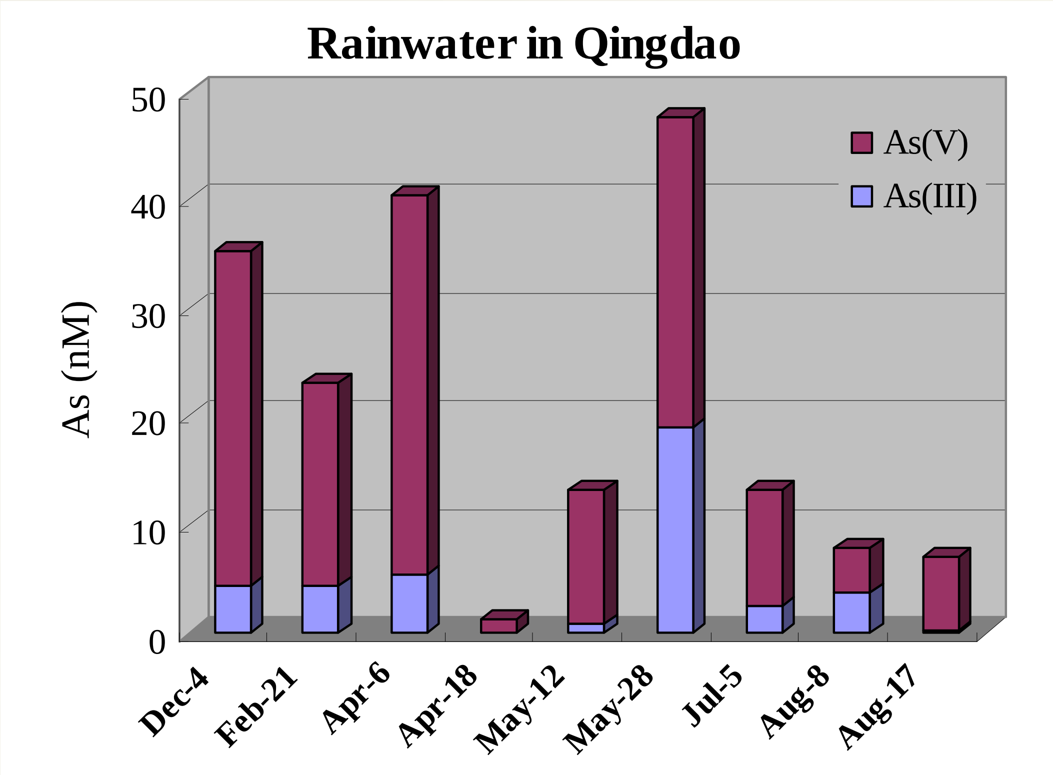
Numbers in the parentheses are number of stations observed in spring

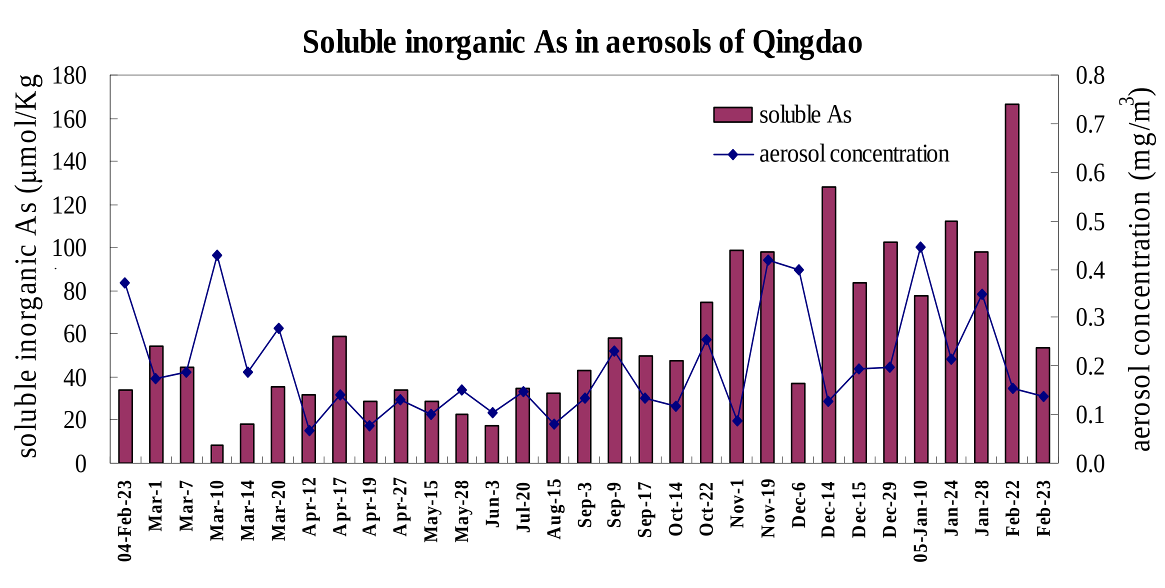


TDIAs in August and October 2001



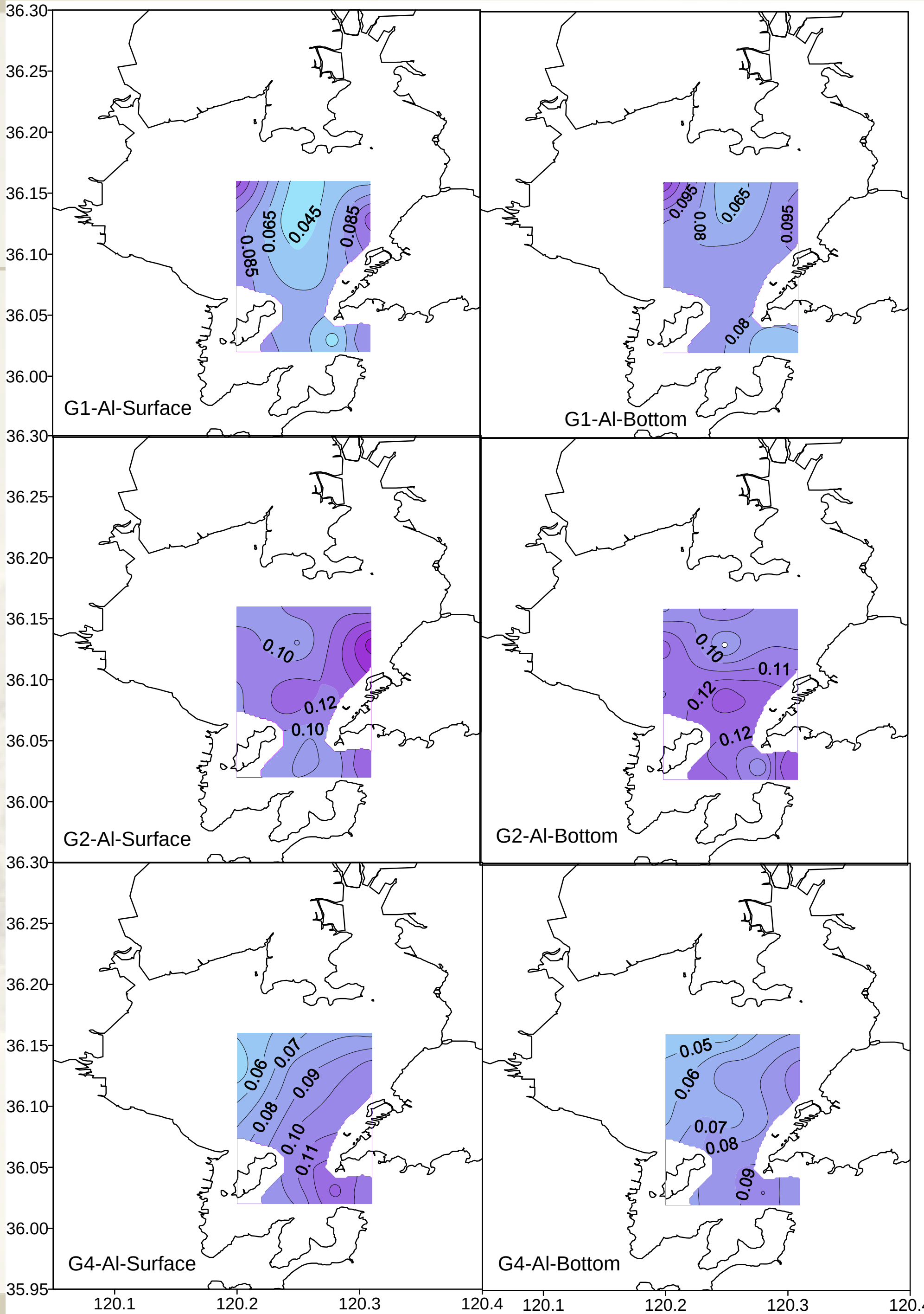
As^{3+} in August and October 2001


Rainwater in Qingdao
As (nM)
As(V)
As(III)
0
10
20
30
40
50
Dec-4
Feb-21
Apr-6
Apr-18
May-12
May-28
Jul-5
Aug-8
Aug-17

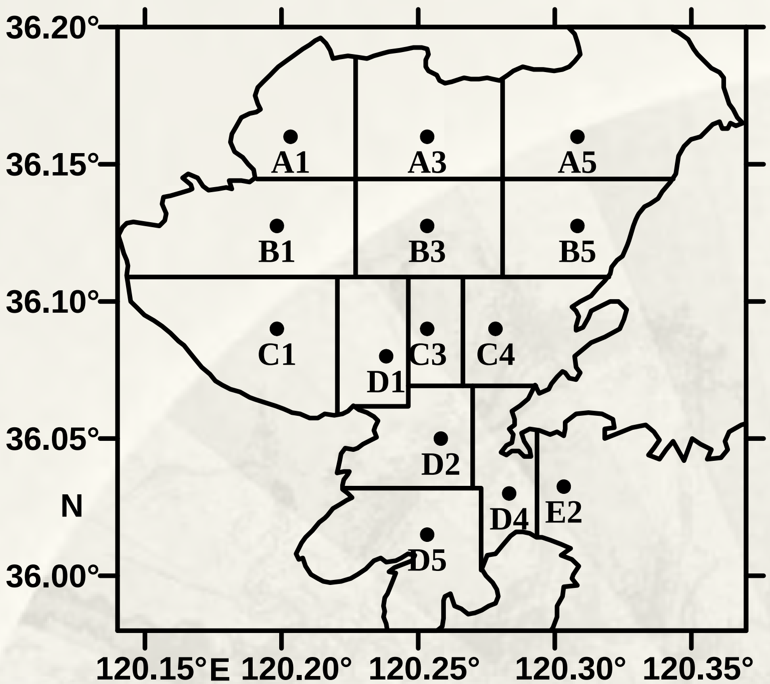

Soluble inorganic As in aerosols of Qingdao
soluble inorganic As (µmol/Kg)
aerosol concentration (mg/m3)
soluble As
aerosol concentration
0
20
40
60
80
100
120
140
160
180
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
04-Feb-23
Mar-1
Mar-7
Mar-10
Mar-14
Mar-20
Apr-12
Apr-17
Apr-19
Apr-27
May-15
May-28
Jun-3
Jul-20
Aug-15
Sep-3
Sep-9
Sep-17
Oct-14
Oct-22
Nov-1
Nov-19
Dec-6
Dec-14
Dec-15
Dec-29
05-Jan-10
Jan-24
Jan-28
Feb-22
Feb-23

As Budgets

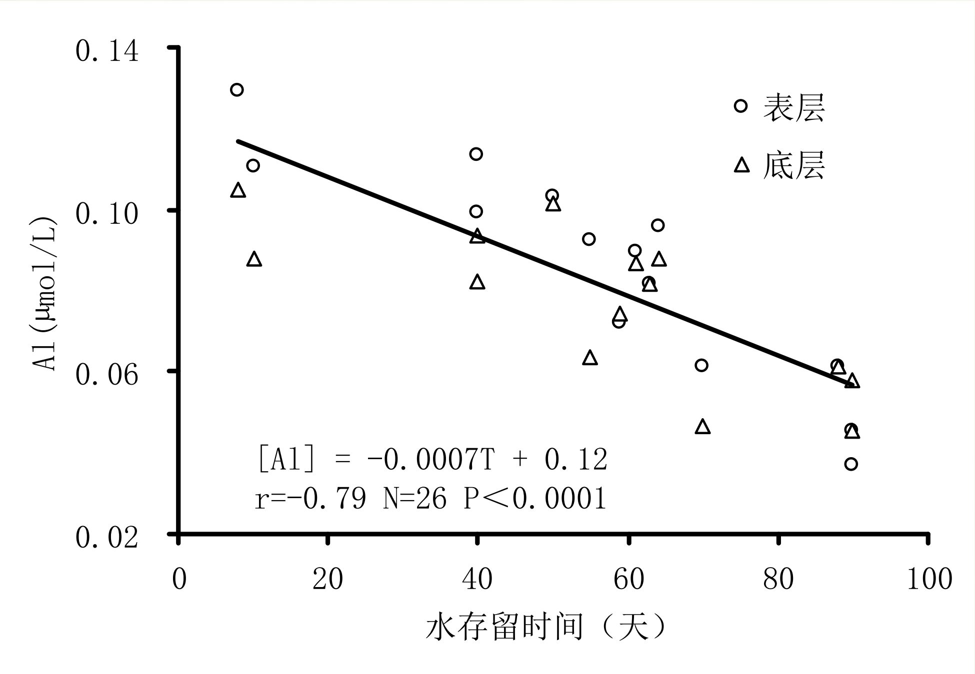
Pathways	**Flux（mol yr^{-1}）**
River	$(13.4 \pm 4.6) \times 10^3$
Rainfall	5.6×10^3
Aerosols	0.14×10^3
Ground waters	0.51 ± 0.92
Waste waters	1.01×10^3
Yellow Sea → Jiaozhou Bay	$(410 \pm 95) \times 10^3$
Jiaozhou Bay → Yellow Sea	$(11.8 \pm 2.4) \times 10^3$

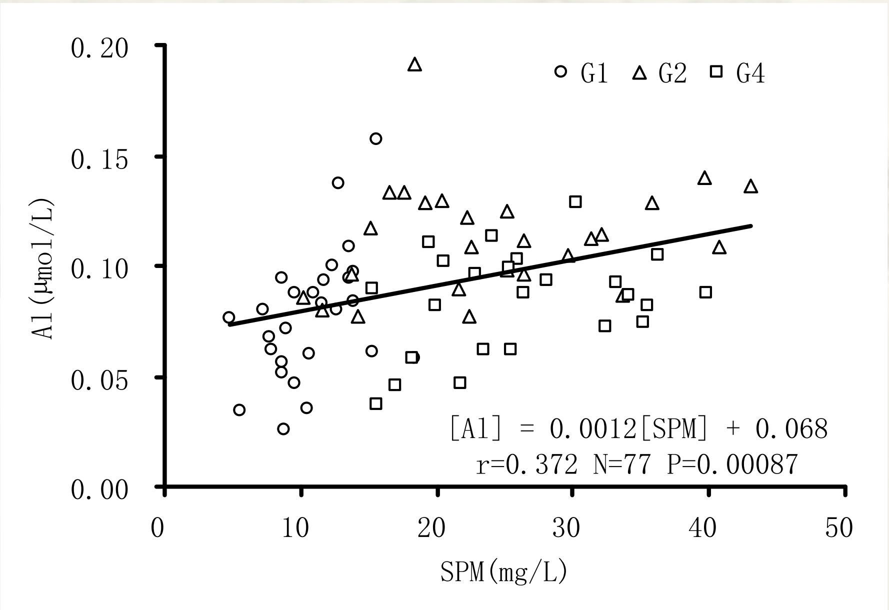


Dissolved Al in August and October 2011。

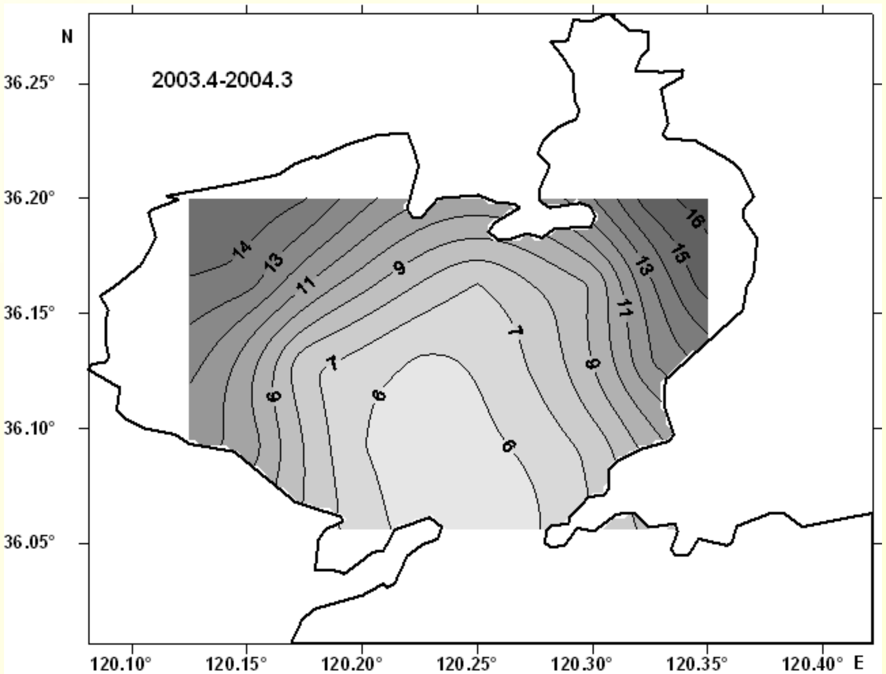


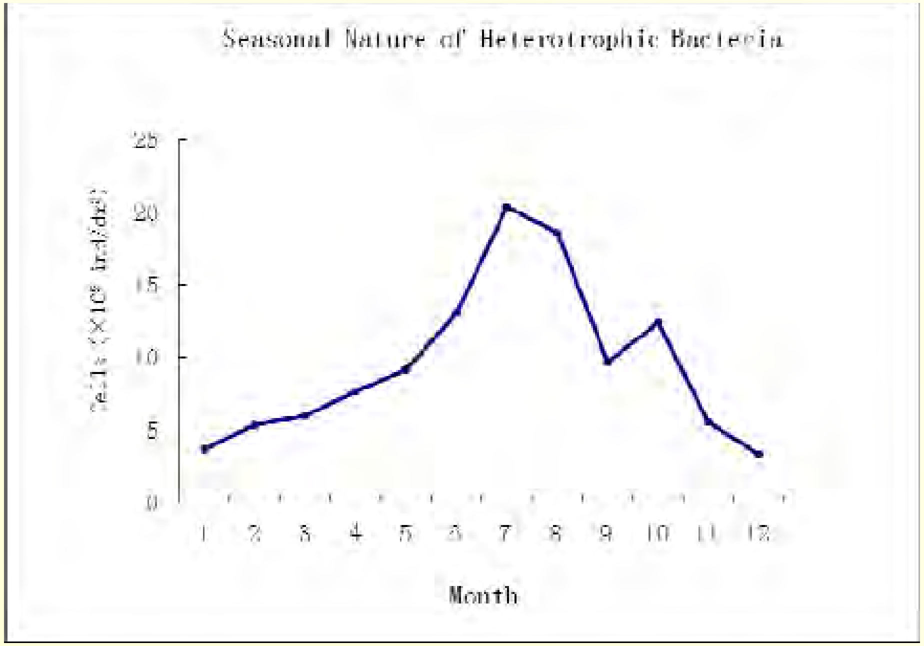
Sub-regions of Al distribution





Heterotrophic bacteria (cell/dm^3)





- Heterotrophic bacteria biomass is 5.06×10^9-15.64×10^9 cell/dm^3 (Average: 9.64×10^9 cell/dm^3)
- Use of TP by heterotrophic bacteria is 0.9-1.7 μmol/cell.h, PO4—P turn-over time is 7-40 days
- Production by heterotrophic bacteria is 1.29 μg C/L.h on average, decreasing from west to the bay mouth

Table 7
Nutrient budgets (10^6 mol yr^{-1}) in Jiaozhou Bay

	NO_3^-	NH_4^+	PO_4^{3-}	SiO_3^{2-}	Data sources
Atmospheric deposition (surface area = 390 km^2)					Result/ 7
Wet deposition	7.33 ± 4.91	14.3 ± 5.9	0.29 ± 0.23	1.67 ± 0.38	
Dry deposition	6.16 ± 4.0	12.4 ± 10.6	0.04 ± 0.03	0.014 ± 0.011	
Subtotal	13.5 ± 8.9	26.8 ± 16.5	0.33 ± 0.26	1.68 ± 0.39	
Stream discharge	28.3 ± 22.6	33.827.0	2.49 ± 1.99	61.2 ± 49.0	Table 4
Wastewater	6.77 ± 2.03	314 ± 94	2.57 ± 0.77	13.8 ± 4.1	Result/6
Input	48.6 ± 33.5	375 ± 138	5.39 ± 3.02	76.7 ± 53.5	
Residual flow (=$V_R \times [C]_R$, $V_R = 712.5 \times 10^6$ m^3 yr^{-1}, C_R =($[C]_2 + [C]_1$)/2)					
	−2.97 ± 0.30	−2.88 ± 0.29	−0.29 ± 0.03	−5.49 ± 0.55	
Mixing volume (=V_X ($[C]_2 - [C]_1$), $V_X = 32215 \times 10^6$ m^3 yr^{-1})					
	−41.6 ± 4.2	−199 ± 20	2.90 ± 0.29	161 ± 16	
Sink/source	−4.03 ± 0.27	−173 ± 64	−8.00 ± 4.48	−232 ± 162	
Sediment–water (the product of directly observed fluxes at station J2 and surface area)					
Benthic flux	13.8 ± 1.8	−5.84 ± 0.99	−4.41 ± 1.54	67.8 ± 17.6	Fig. 7

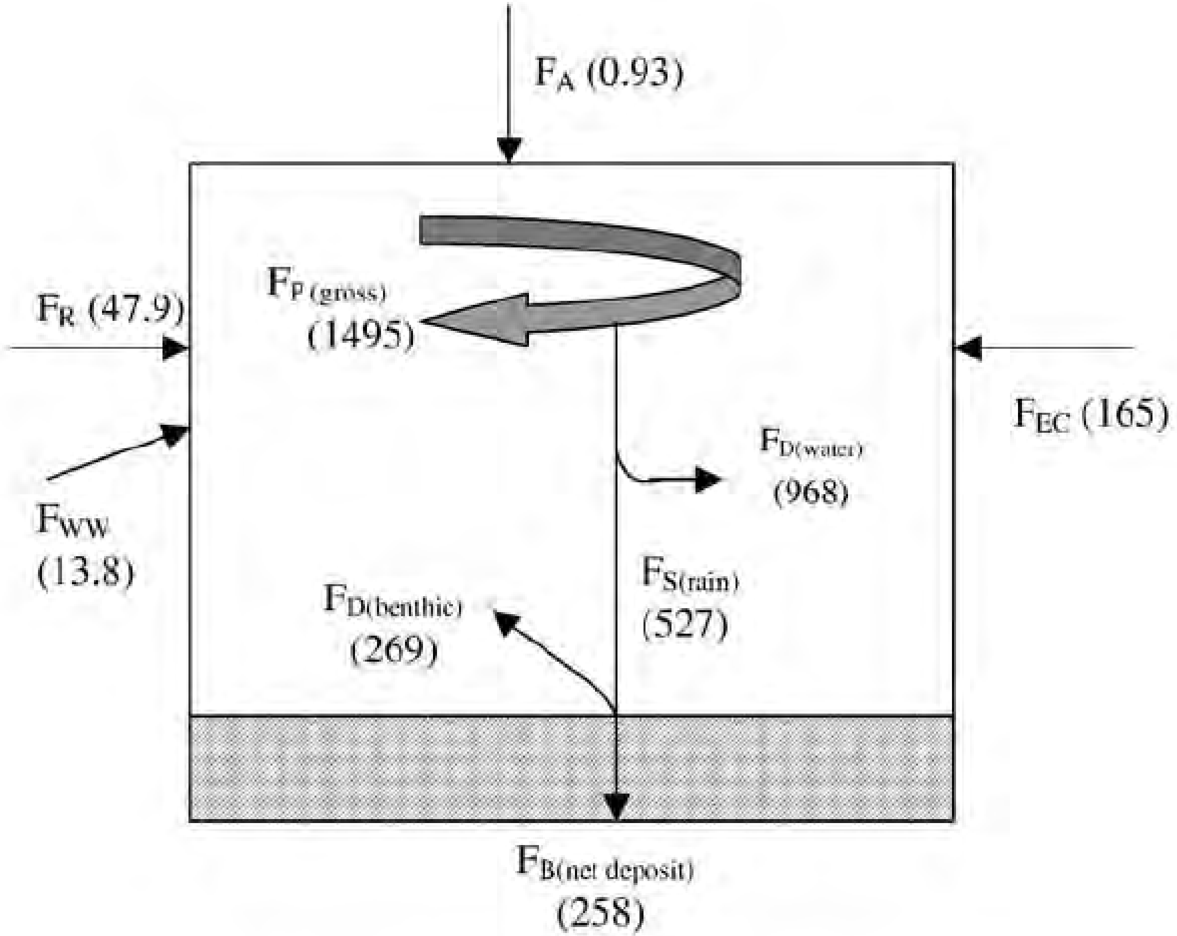


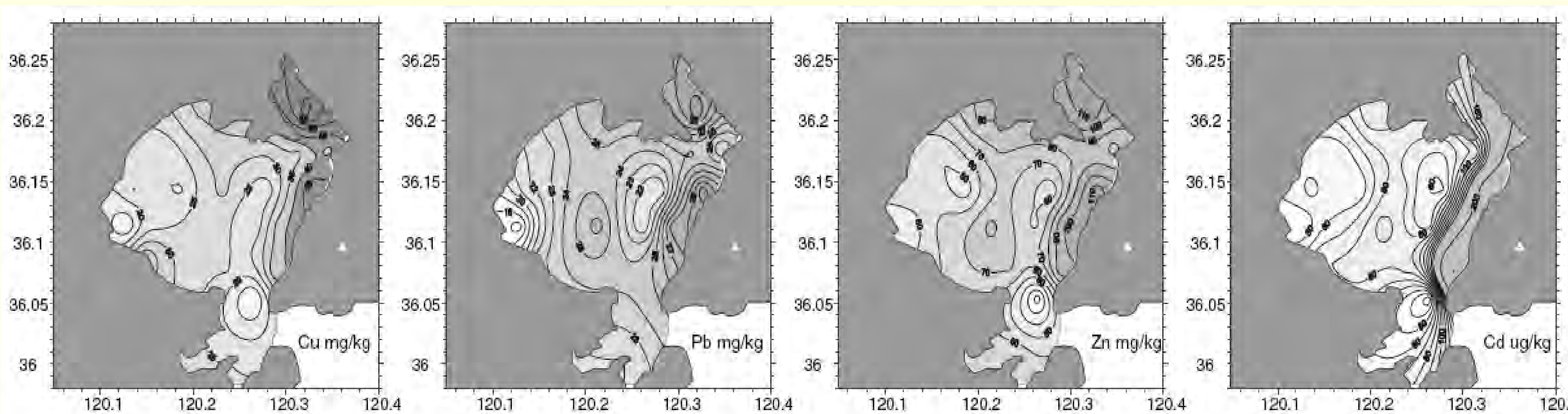
Fig. 4. Silicon budget (10^6 mol yr^{-1}) in Jiaozhou Bay. River input, F_R; atmospheric deposition, F_A; wastewater discharge, F_{WW}; deposition of BSi in sediment, F_B; BSi gross production, F_P (gross); silicic acid flux recycled in the water column, $F_{D(water)}$; silicic acid flux at the sediment–water interface, F_D (benthic); BSi flux that reaches the sediment–water interface, F_S (rain); total silicon (i.e., silicic acid plus BSi) exchange flux from the Yellow Sea, F_{EC}.

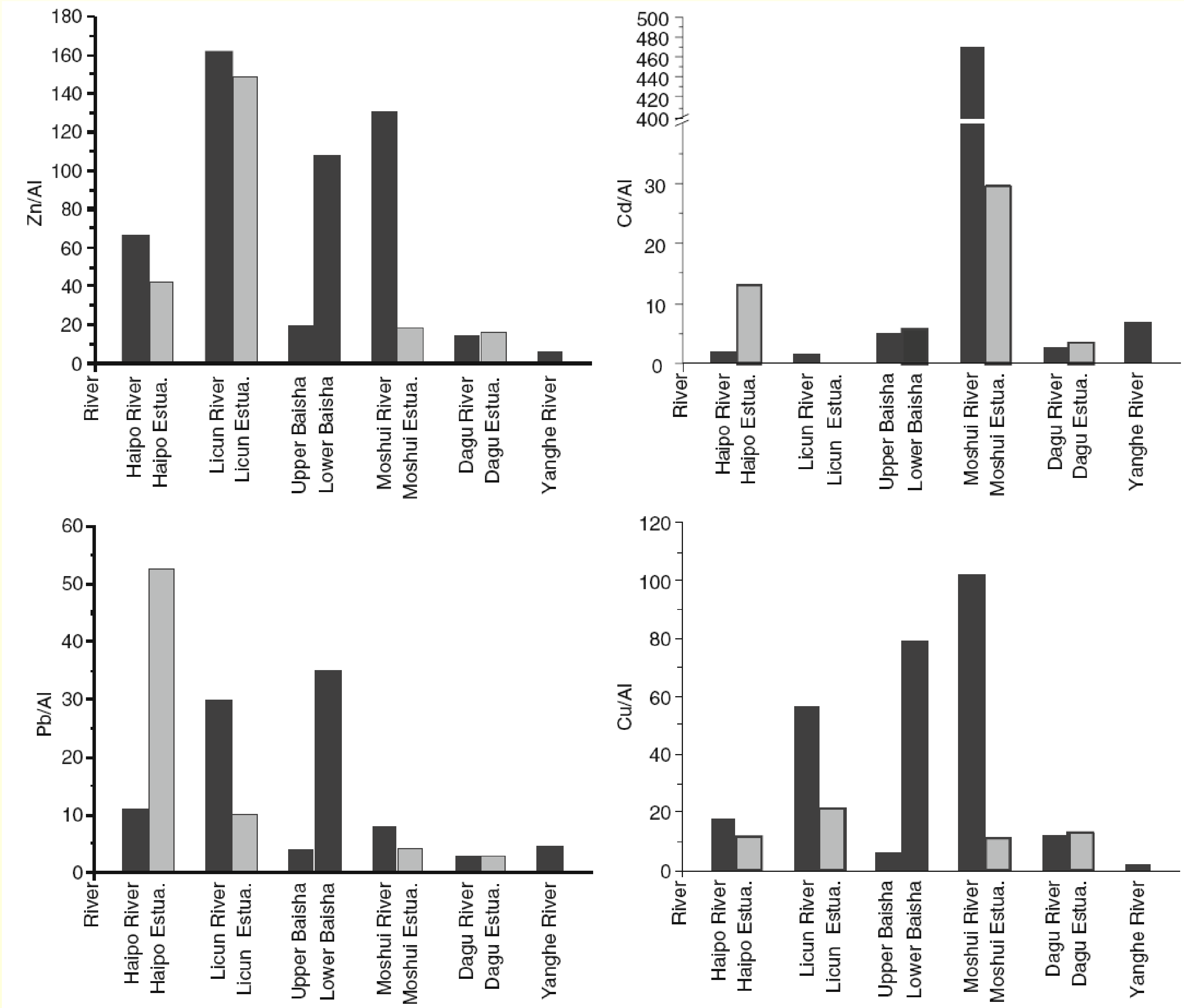
Table 2 Element concentration of river sediment

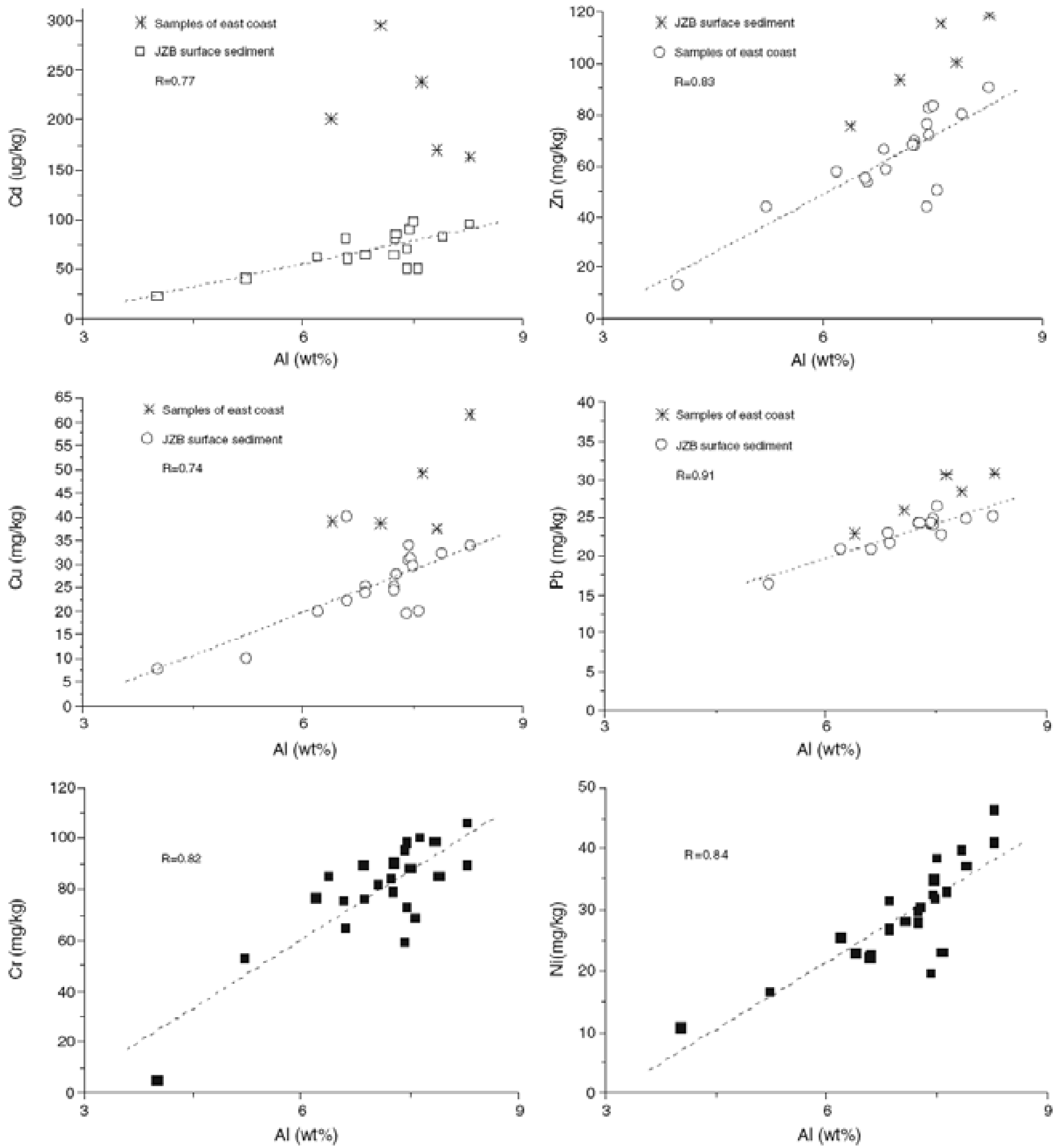
Rivers	0–2 µm	2–63 µm	>63 µm	Na	Mg	Ca	K	Al	Fe	Sr	Mn	Cr	Cu	Ni	Ti	V	Zn	Cd	Pb
Haipo	16.34	80.53	3.15	2.1	0.6	2.0	2.7	6.4	2.8	244.2	347.5	78.8	111.3	35.7	2729	41.2	425.9	0.125	71.8
Haipo Estua.	0.78	8.03	91.16	2.3	0.4	1.3	3.2	3.7	2.3	152.0	298.9	46.5	42.1	11.8	1794	29.9	156.4	0.486	195.0
Licun	18.81	76.31	4.89	1.0	0.8	5.7	1.3	4.2	2.3	305.6	905.4	86.1	234.9	35.5	2363	41.2	672.5	0.069	125.0
Licun Estua.	26.84	73.14	0	2.2	2.3	11.5	1.7	6.5	3.9	877.9	843.4	113.9	135.1	44.4	3882	68.9	956.9	–	65.8
Upper Baisha	3.80	13.01	83.26	1.0	0.8	2.2	1.7	9.3	3.5	155.5	2277.5	80.3	55.6	30.4	2693	95.3	175.0	0.450	35.2
Lower Baisha	17.66	80.81	1.55	1.5	1.2	3.5	1.7	5.8	3.7	219.2	1467.3	104.7	457.8	45.8	3765	82.8	627.0	0.324	203.3
Moshui	3.62	17.93	78.45	1.7	0.9	2.8	2.0	5.9	3.1	275.8	687.7	118.5	603.7	125.8	3335	58.8	767.7	27.614	46.9
Moshui Estua.	4.74	31.17	64.08	1.7	0.5	0.9	2.2	5.5	2.2	229.2	457.0	86.5	61.9	33.7	4418	54.5	100.7	1.626	23.8
Dagu	16.61	80.09	3.32	1.5	1.4	0.8	2.4	9.0	4.9	169.3	992.2	124.3	108.2	69.9	4875	104.3	126.8	0.252	26.6
Dagu Estua.	12.82	74.30	12.88	1.8	1.0	0.9	2.3	7.5	3.3	203.0	917.7	90.1	96.2	38.5	4048	69.4	120.6	0.263	22.2
Yanghe	0.14	4.16	95.70	1.6	0.2	0.9	2.4	4.5	1.8	155.8	386.7	29.8	7.2	8.3	2630	32.3	28.7	0.308	20.3
JZB sediment	12.59	60.78	26.63	2.2	1.0	1.1	2.5	7.1	3.1	203.8	854.6	79.3	29.7	29.2	3726	75.2	71.2	0.101	24.2
Preindustrial				2.1	1.4	0.9	2.6	8.3	4.4	157.1	863.5	87.7	25.8	43.2	4630	110.7	84.8	0.059	26.2

Units for Na, Mg, Ca, K, Al, and Fe are wt.%; units for Sr, Mn, Cr, Cu, Ni, Ti, V, Zn, Cd, Pb are mg/kg; Units for grain size composition are volume percent

Preindustrial refer to average of preindustrial samples corrected from sediment core in the center of the Jiaozhou Bay, and considered as a background level before industrialized. Radiometric dating of the sediment core was calculated according to Liu et al. (2008)

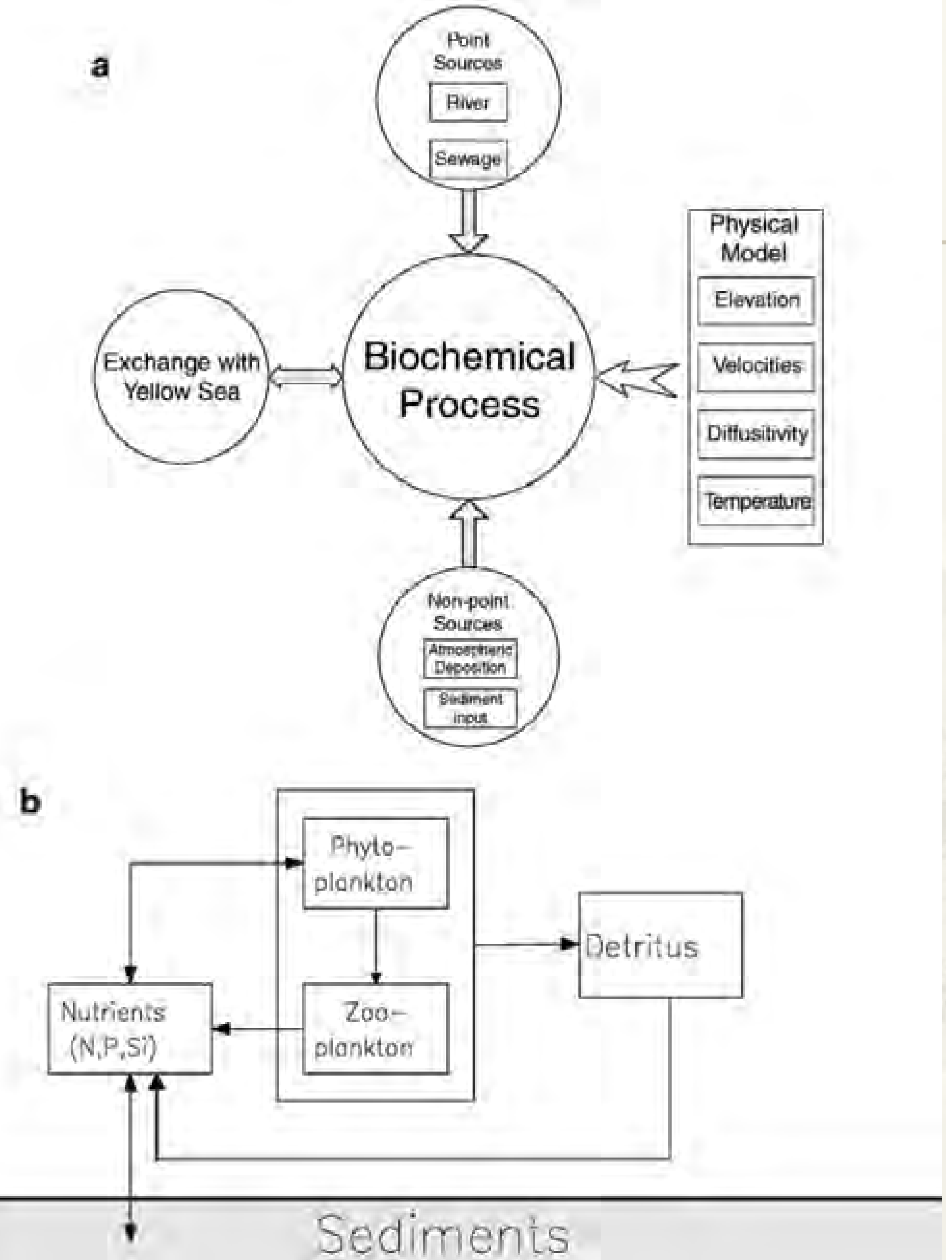


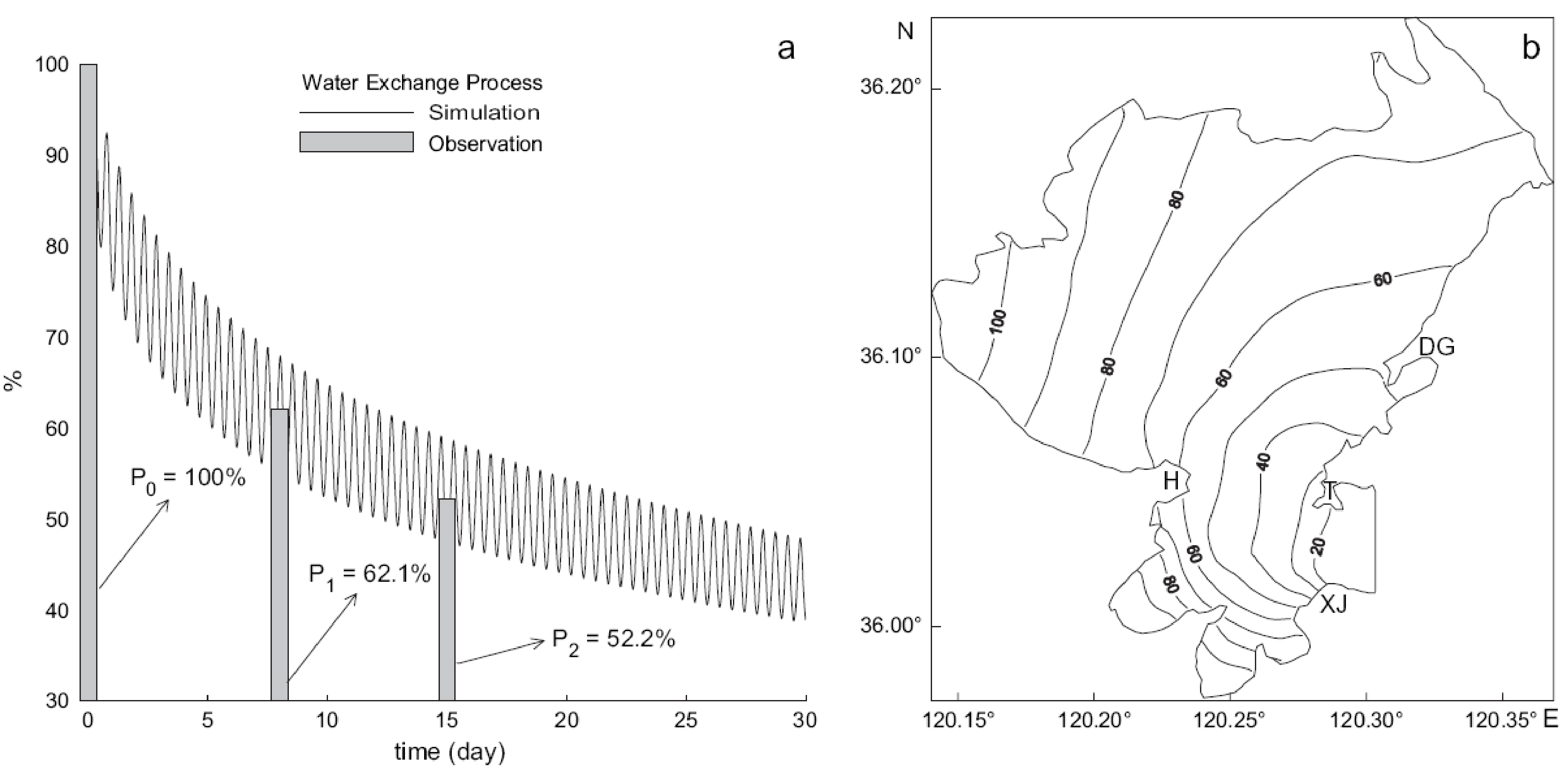

Zn/Al
0
20
40
60
80
100
120
140
160
180
Cd/Al
0
10
20
30
400
420
440
460
480
500
Pb/Al
0
10
20
30
40
50
60
Cu/Al
0
20
40
60
80
100
120
River
Haipo River
Haipo Estua.
Licun River
Licun Estua.
Upper Baisha
Lower Baisha
Moshui River
Moshui Estua.
Dagu River
Dagu Estua.
Yanghe River



Samples of east coast
JZB surface sediment
R=0.77
Cd (ug/kg)
Al (wt%)
JZB surface sediment
Samples of east coast
R=0.83
Zn (mg/kg)
Al (wt%)
Samples of east coast
JZB surface sediment
R=0.74
Cu (mg/kg)
Al (wt%)
Samples of east coast
JZB surface sediment
R=0.91
Pb (mg/kg)
Al (wt%)
R=0.82
Cr (mg/kg)
Al (wt%)
R=0.84
Ni(mg/kg)
Al (wt%)

Fig. 2 Structures of the 3-dimensional physical–biological model used in this study. The physical model output (e.g., current field) drives the transport process of biological tracers, and the nutrients exchange occurring at multiple interfaces (e.g., JZB–YS, JZB–rivers, and water–atmosphere) are considered (**a**). The key biochemical processes such as hotosynthesis, plankton metabolism, and detritus mineralization, are coupled and illustrated by arrows (**b**)




a
Water Exchange Process
Simulation
Observation
%
100
90
80
70
60
50
40
30
0
5
10
15
20
25
30
time (day)
P0 = 100%
P1 = 62.1%
P2 = 52.2%
b
N
36.20°
36.10°
36.00°
120.15°
120.20°
120.25°
120.30°
120.35°
E
100
80
60
40
20
DG
H
T
XJ

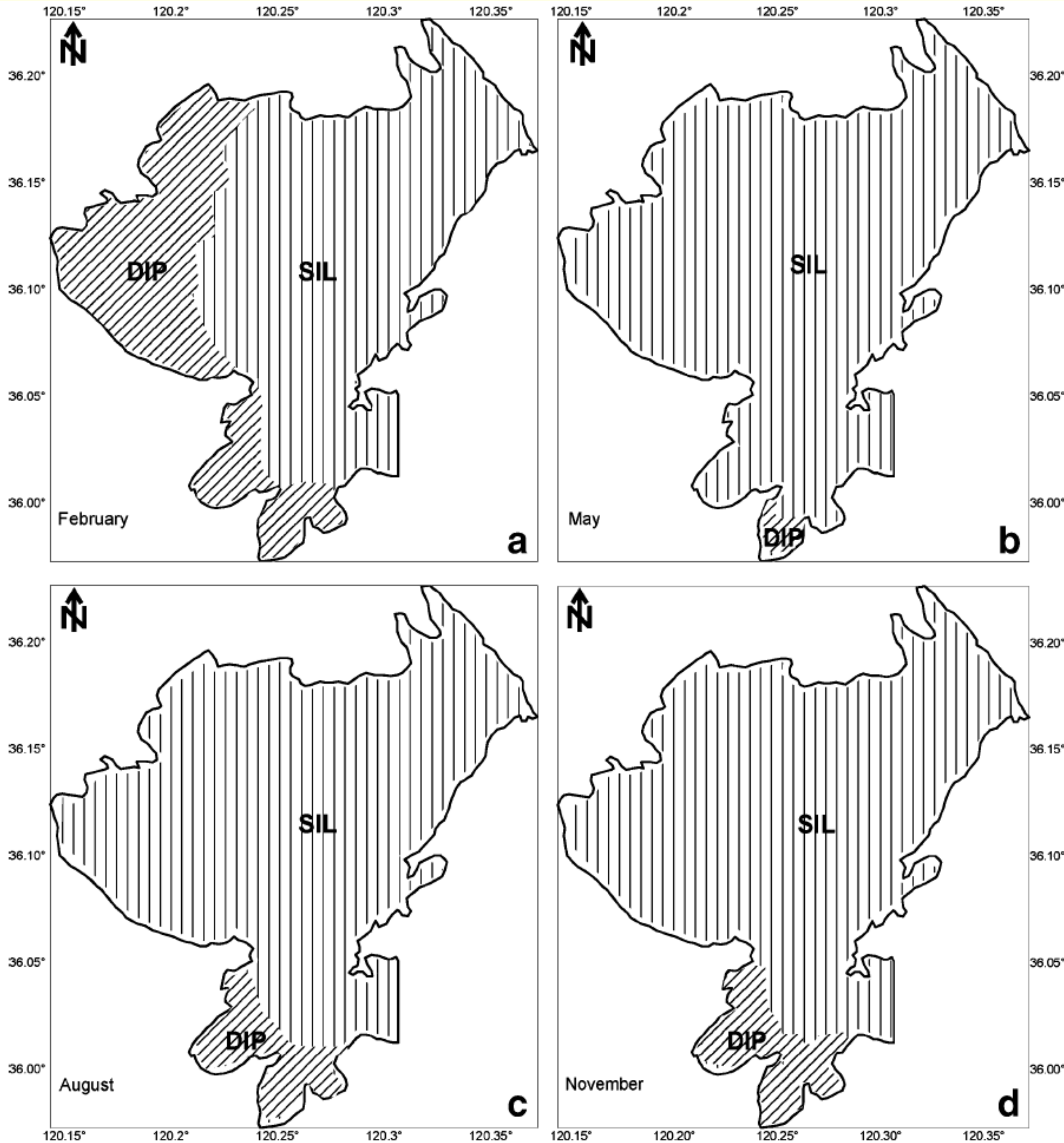
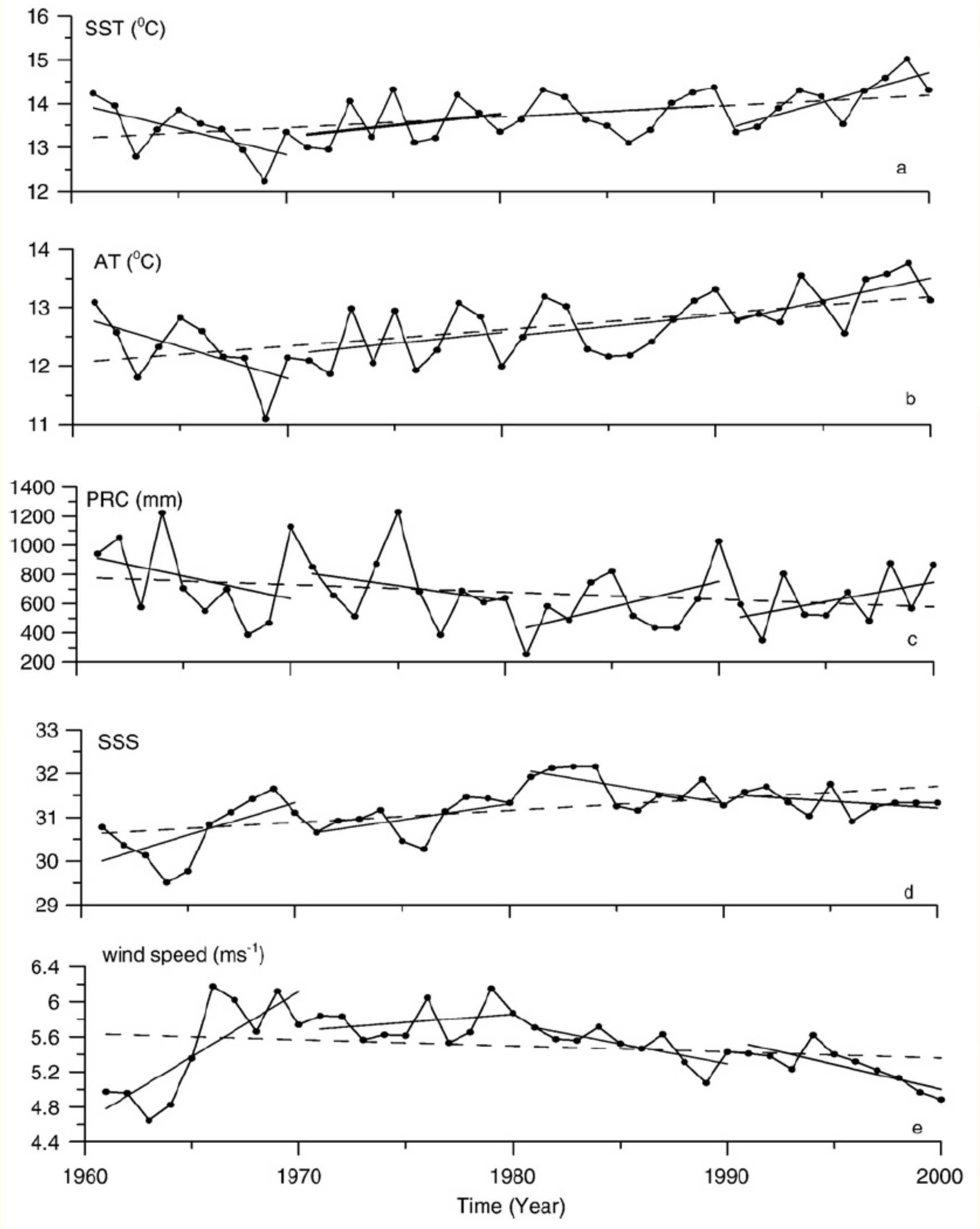
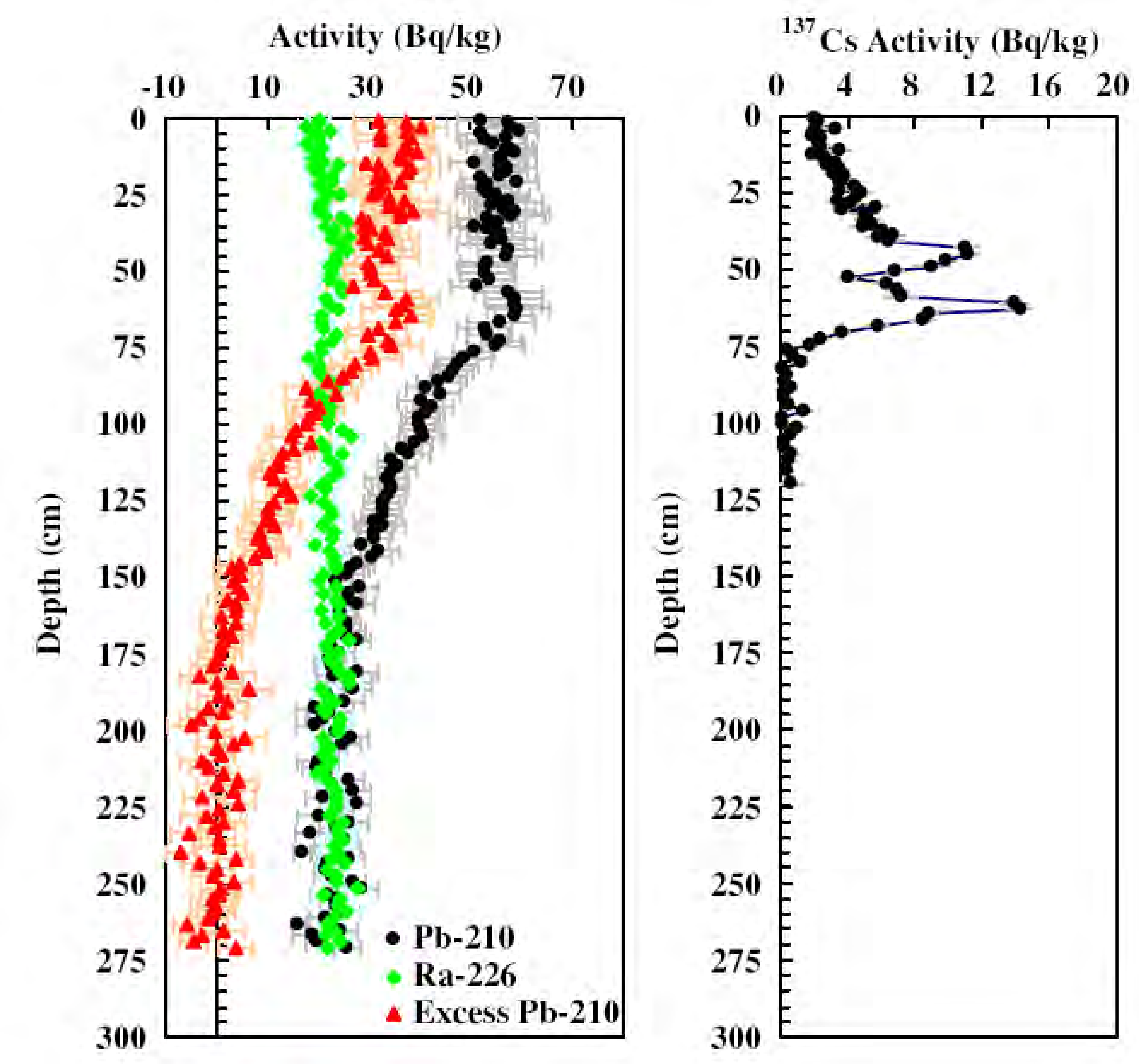


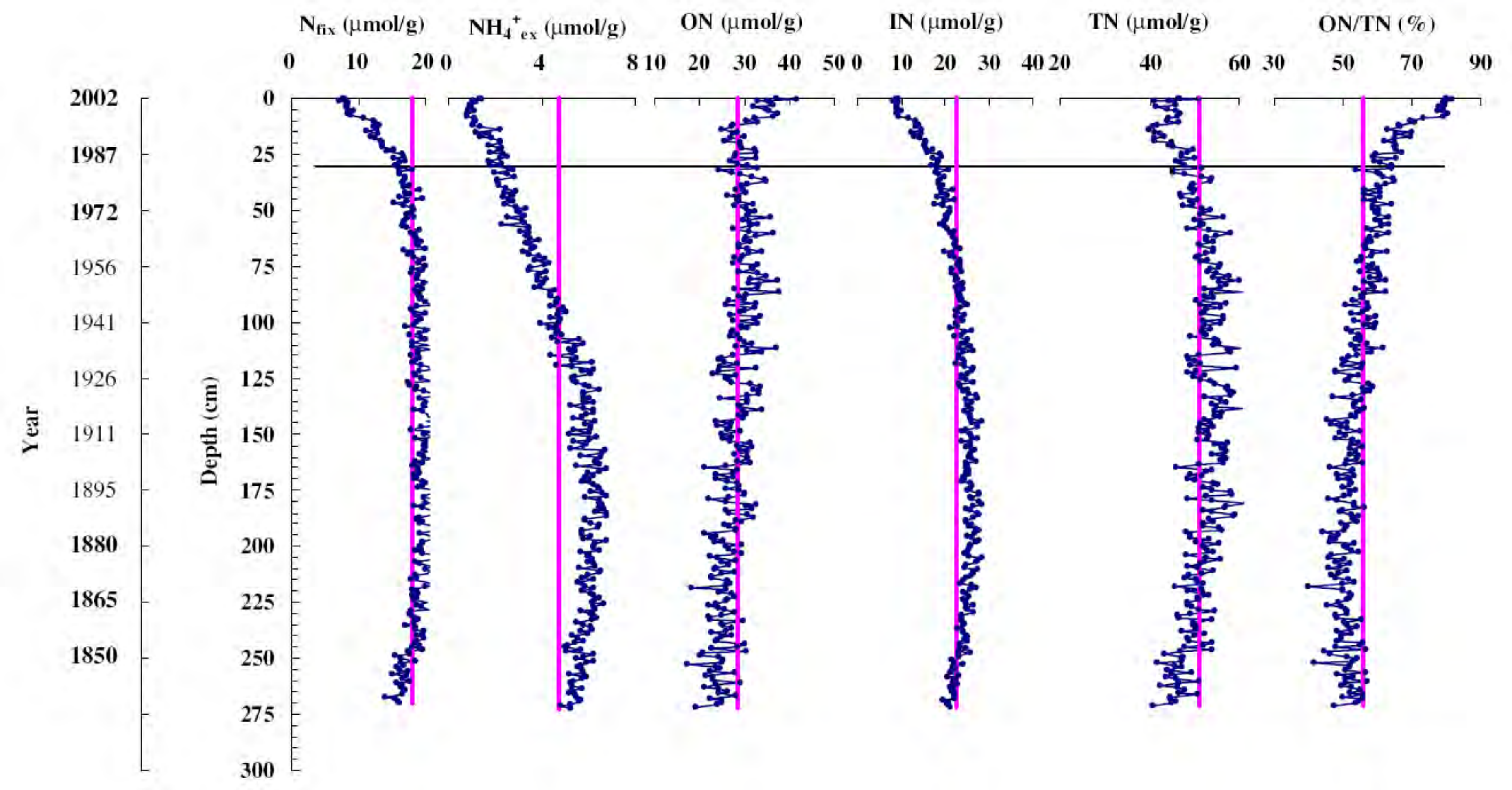
Fig. 6 Limiting elements for phytoplankton growth in surface layer in February (**a**), May (**b**), August (**c**), and November (**d**). The symbols of 'DIP' and 'SIL' mean that the phytoplankton growth is limited by DIP and SIL, respectively. It indicates that DIN is not a limiting element for phytoplankton



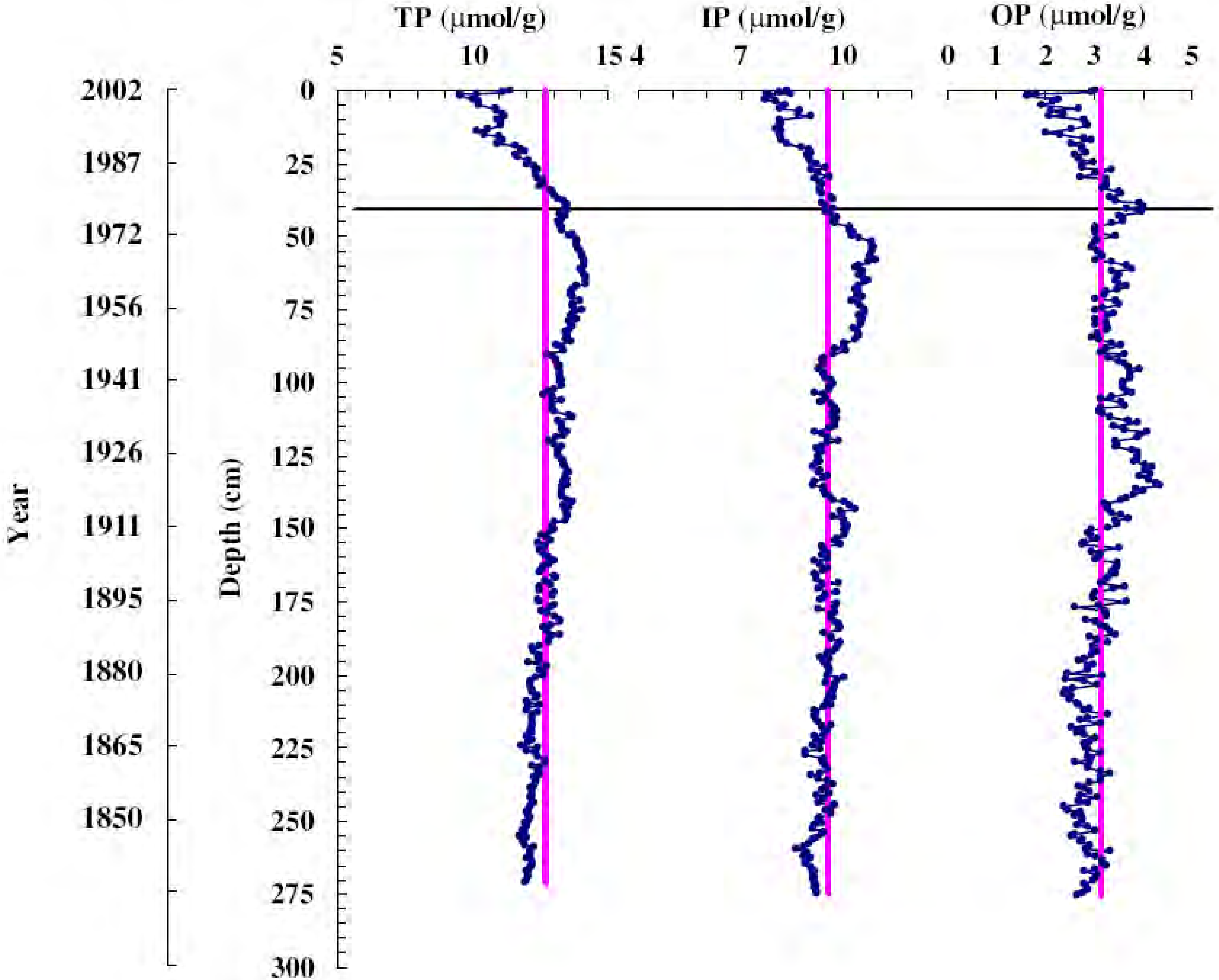
SST (°C)
a
AT (°C)
b
PRC (mm)
c
SSS
d
wind speed (ms-1)
e
Time (Year)



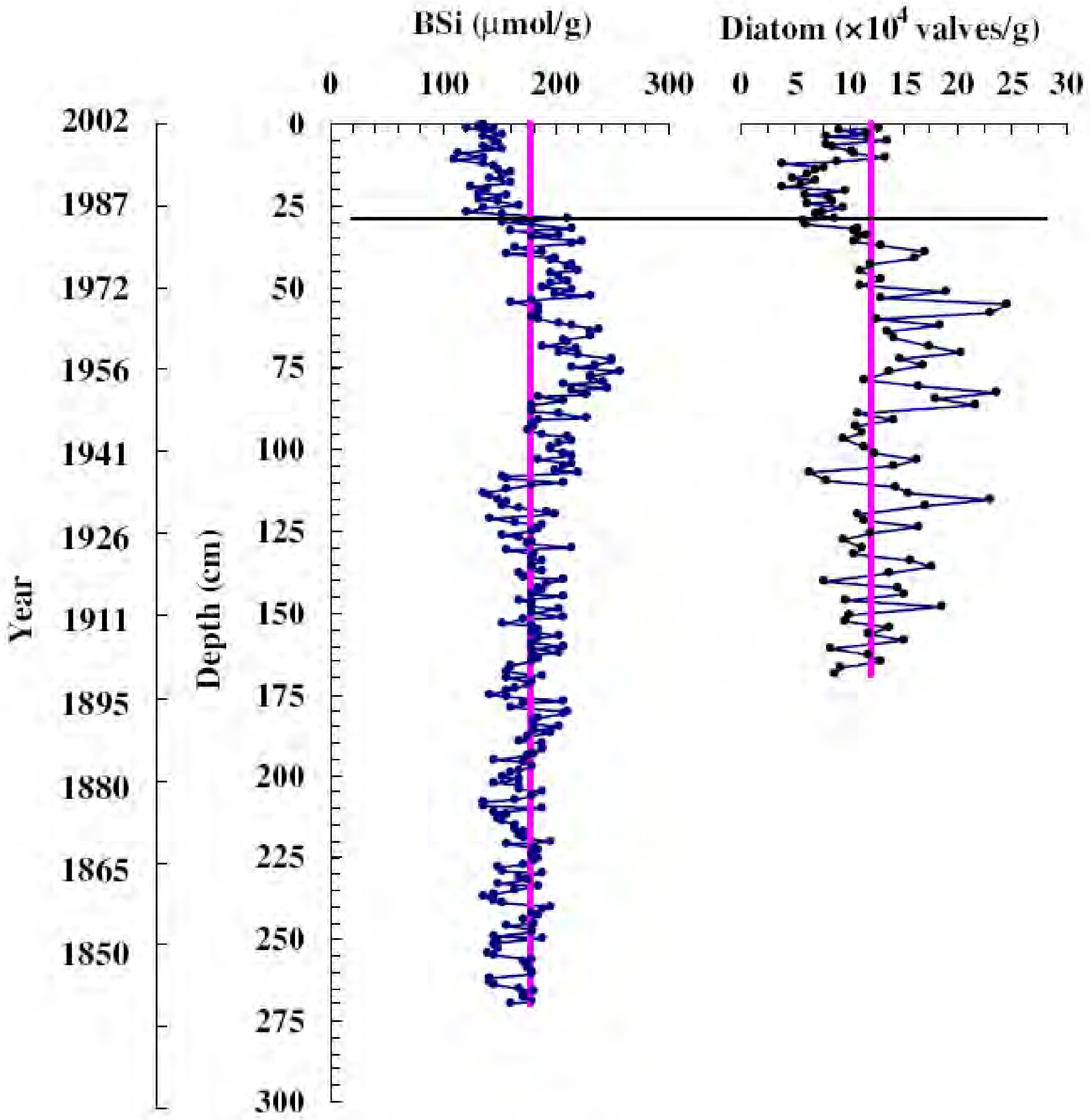
Activity (Bq/kg)
-10
10
30
50
70
0
25
50
75
100
125
150
175
200
225
250
275
300
Depth (cm)
Pb-210
Ra-226
Excess Pb-210
137 Cs Activity (Bq/kg)
0
4
8
12
16
20
Depth (cm)



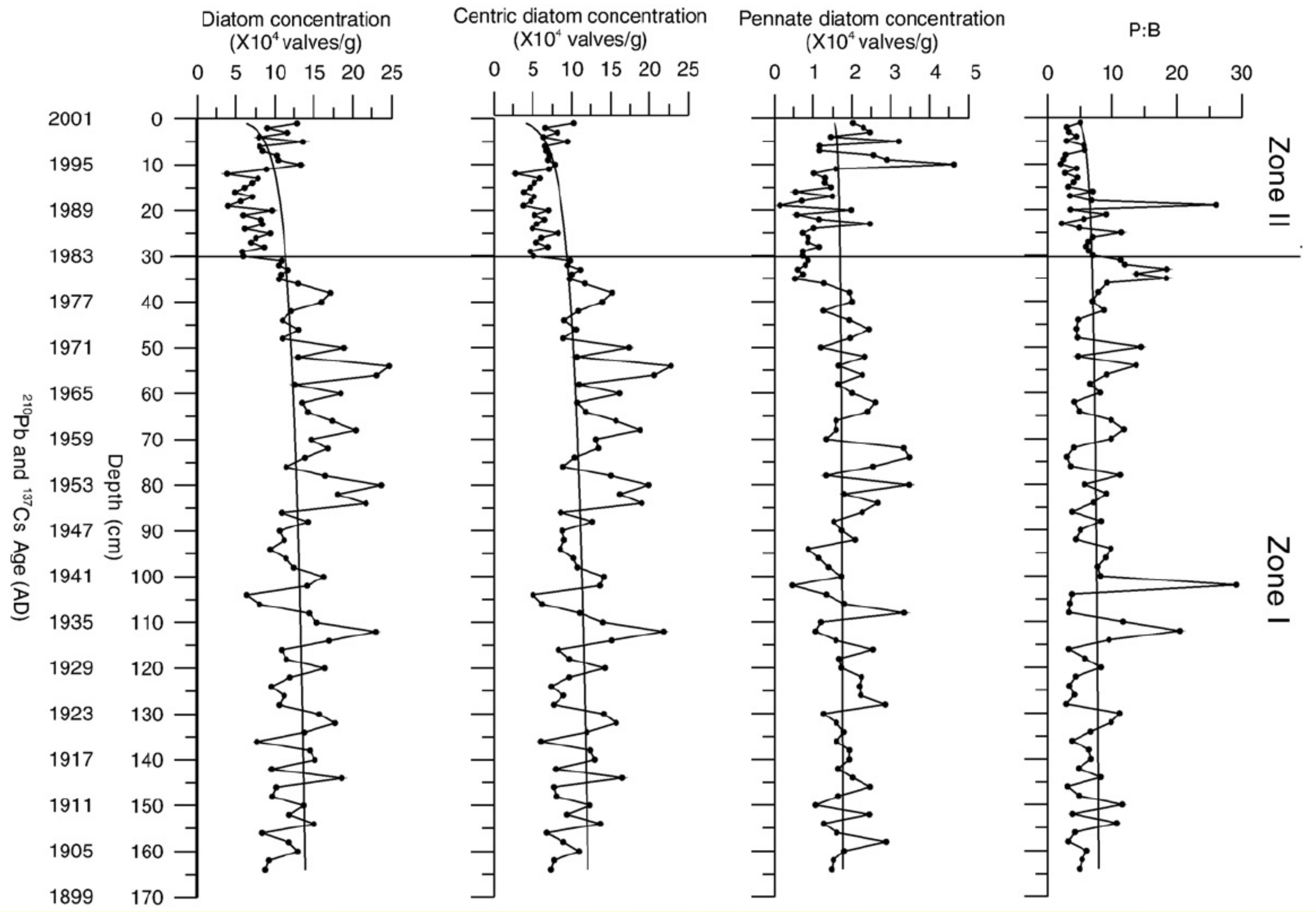
N_{fix} (μmol/g)
$NH_4^+{}_{ex}$ (μmol/g)
ON (μmol/g)
IN (μmol/g)
TN (μmol/g)
ON/TN (%)
Year
Depth (cm)

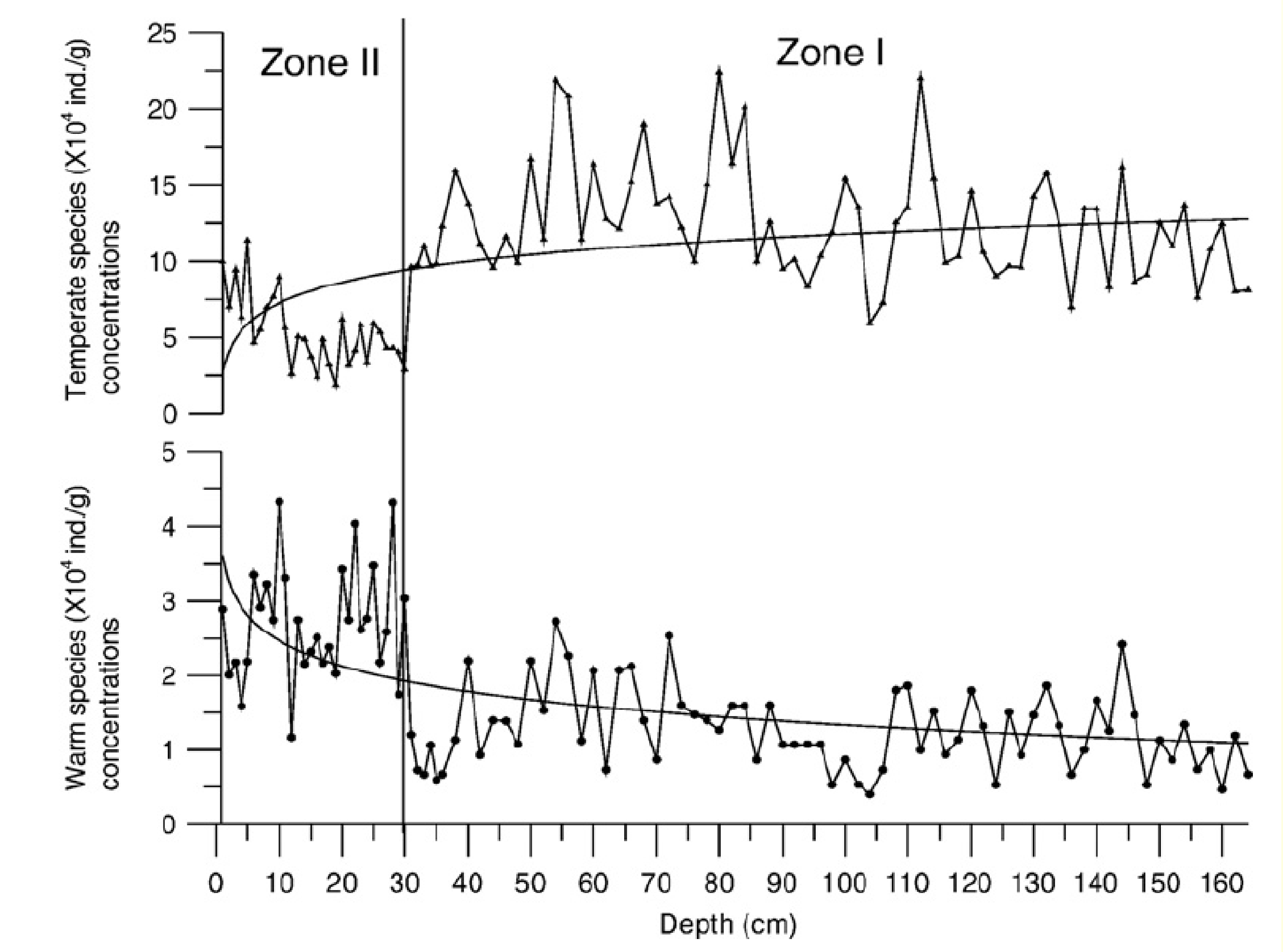


TP (µmol/g)
IP (µmol/g)
OP (µmol/g)
5
10
15
4
7
10
0
1
2
3
4
5
Year
2002
1987
1972
1956
1941
1926
1911
1895
1880
1865
1850
Depth (cm)
0
25
50
75
100
125
150
175
200
225
250
275
300



BSi (μmol/g)
Diatom (×10⁴ valves/g)
0
100
200
300
0
5
10
15
20
25
30
Year
2002
1987
1972
1956
1941
1926
1911
1895
1880
1865
1850
Depth (cm)
0
25
50
75
100
125
150
175
200
225
250
275
300


Diatom concentration (X10⁴ valves/g)
Centric diatom concentration (X10⁴ valves/g)
Pennate diatom concentration (X10⁴ valves/g)
P:B
Zone II
Zone I
Depth (cm)
²¹⁰Pb and ¹³⁷Cs Age (AD)
2001
1995
1989
1983
1977
1971
1965
1959
1953
1947
1941
1935
1929
1923
1917
1911
1905
1899



Zone II
Zone I
Temperate species (X10^4 ind./g) concentrations
Warm species (X10^4 ind./g) concentrations
0
5
10
15
20
25
0
1
2
3
4
5
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
Depth (cm)

Conclusions and Way Forward

- Change in land use and urbanization have induced a considerable variation of nutrients in the marine recipient, like Jiaozhou Bay with change in budgets and skewed specie ratio
- Compared to other coastal environments of China, concentration of nutrients in the Jiaozhou Bay are not at the top, hydrographic processes play an important role in regulating the nutrient regimes in the system, e.g. comparable tour-over time with flushing time
- Over last 50-100 years, the food-web structure at low trophic level (e.g. phytoplankton) has been modified following the nature of climate change and human being activities in combination

Information for Management

- Hydrography
- Nutrient loading
- Water quality
- Recreation
- Industry vs tourism