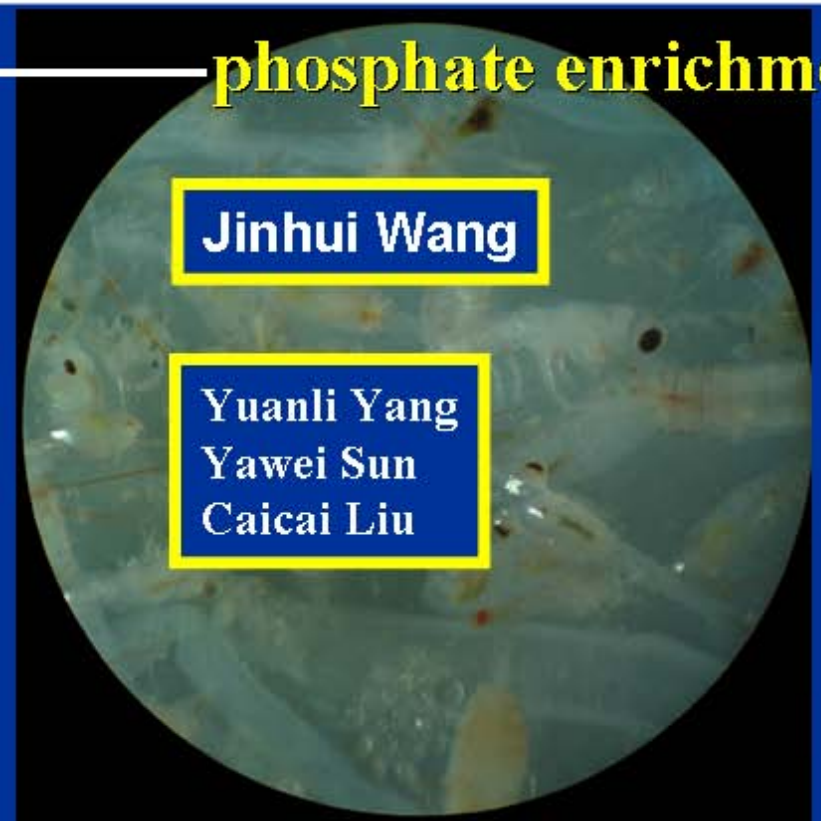
Marine Environmental Monitoring Program
East China Sea Environmental Monitoring Center
Dong Tang road 630, Shanghai 200137
P.R.China

Response of zooplankton populations to Eutrophication in Changjiang Estuary:

phosphate enrichment in mesocosm and field study



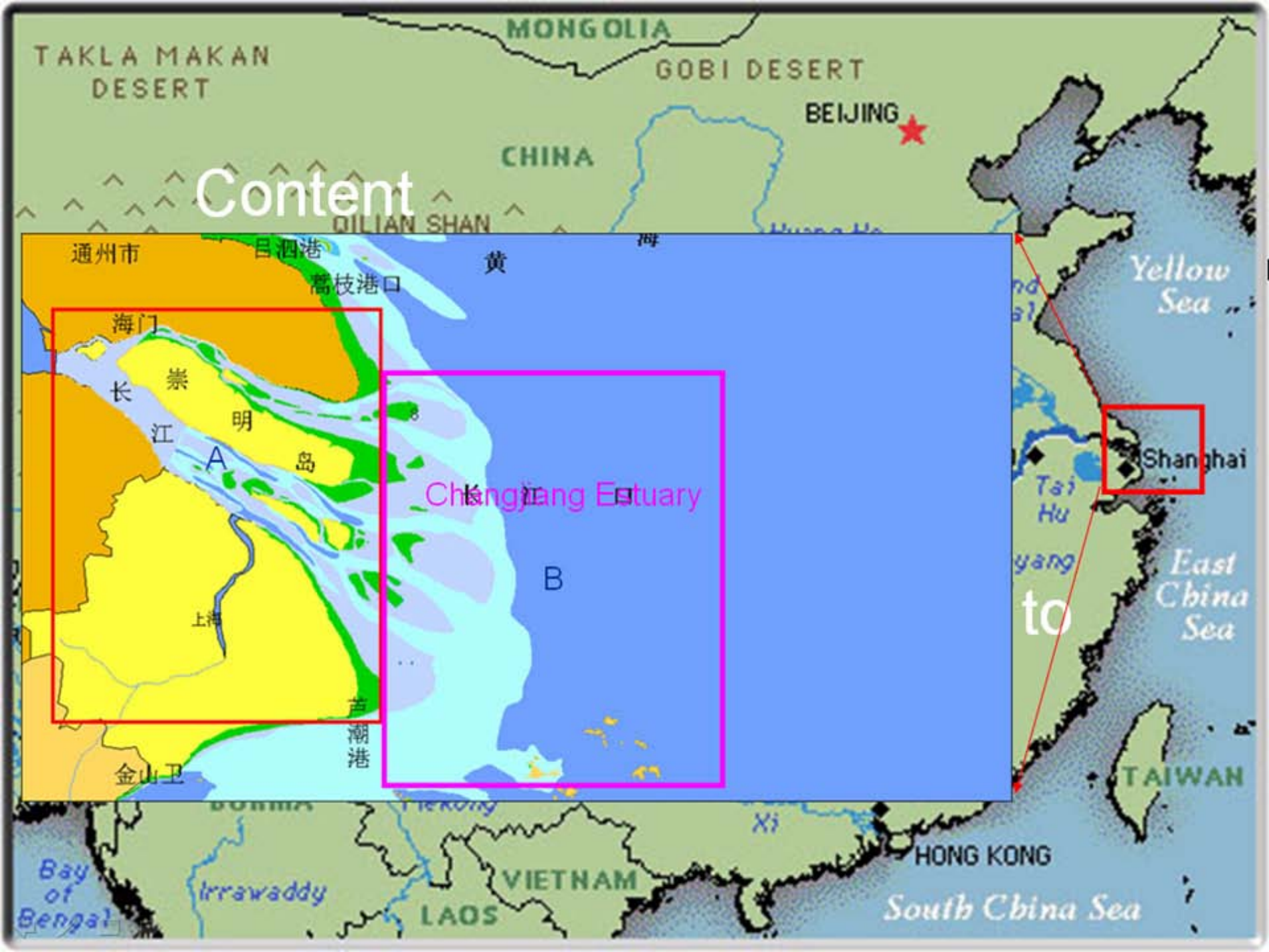
Jinhui Wang

Yuanli Yang
Yawei Sun
Caicai Liu

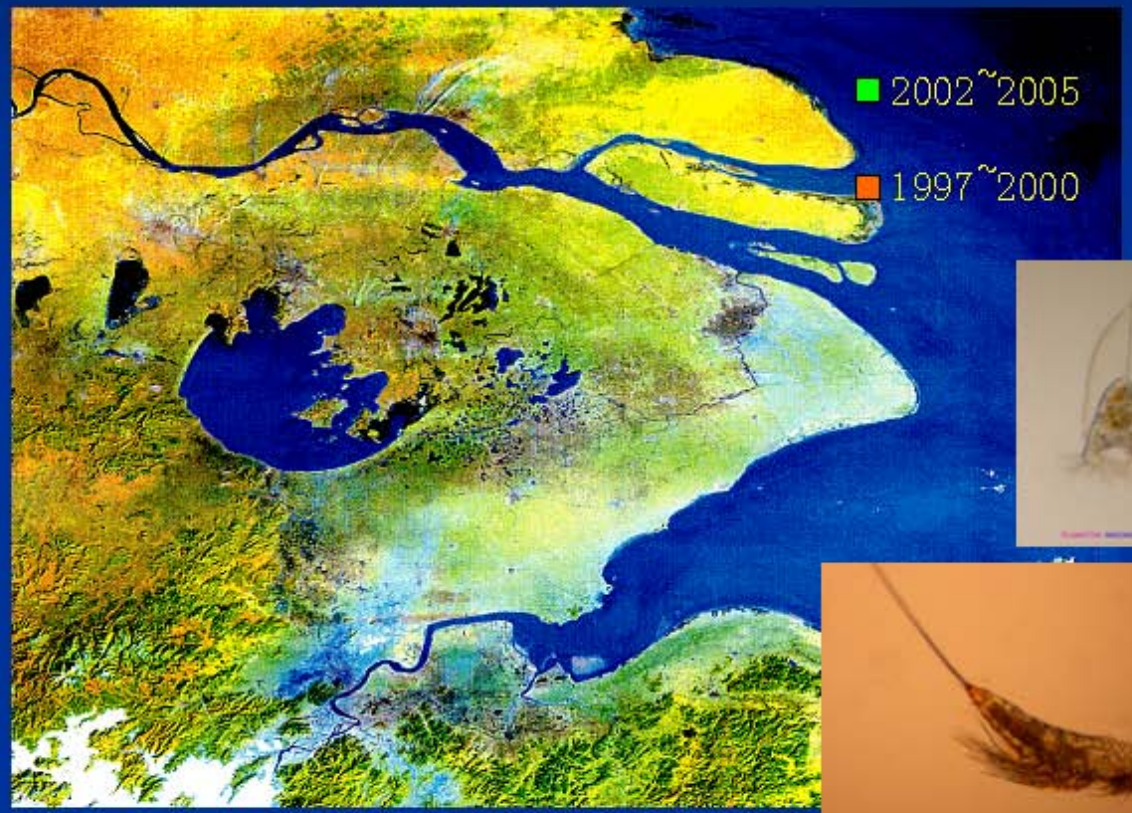
Content

Part 1 Zooplankton in Changjiang estuary

Part 2 Zooplankton response to Phosphate enrichment


Content
MONGOLIA
TAKLA MAKAN DESERT
GOBI DESERT
BEIJING
CHINA
QILIAN SHAN
通州市
吕泗港
鳶枝港口
黄
海
海门
长
江
崇
明
岛
A
B
Changjiang Estuary
上海
芦
潮
港
金山卫
Yellow Sea
Shanghai
Tai Hu
East China Sea
to
TAIWAN
HONG KONG
South China Sea
VIETNAM
LAOS
Irrawaddy
Bay of Bengal

Zooplankton community



289

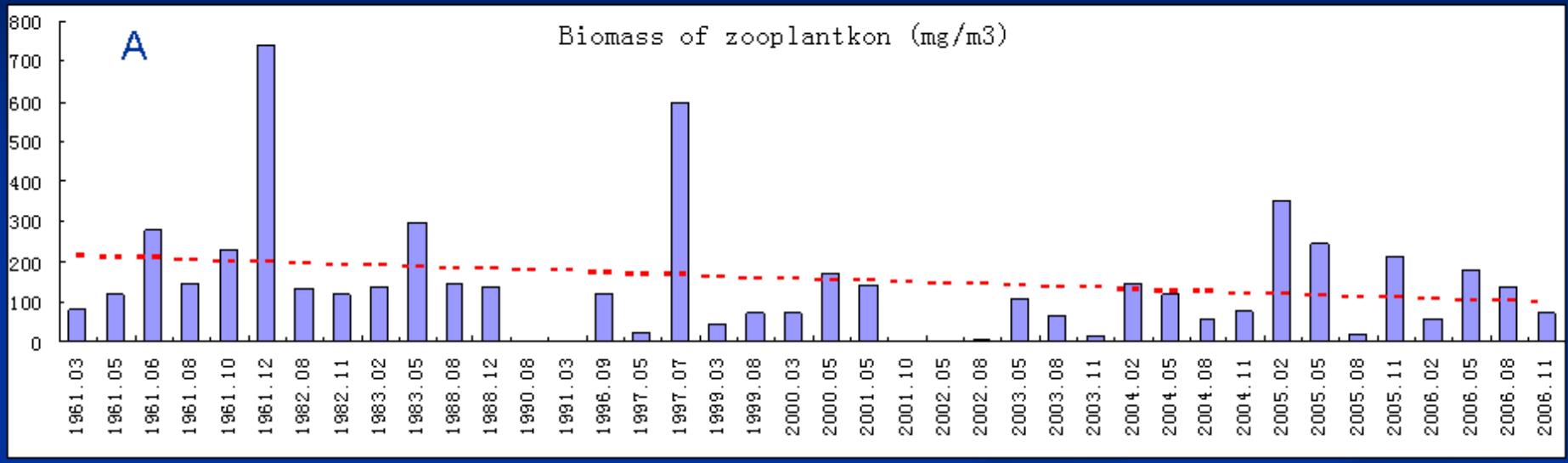
374

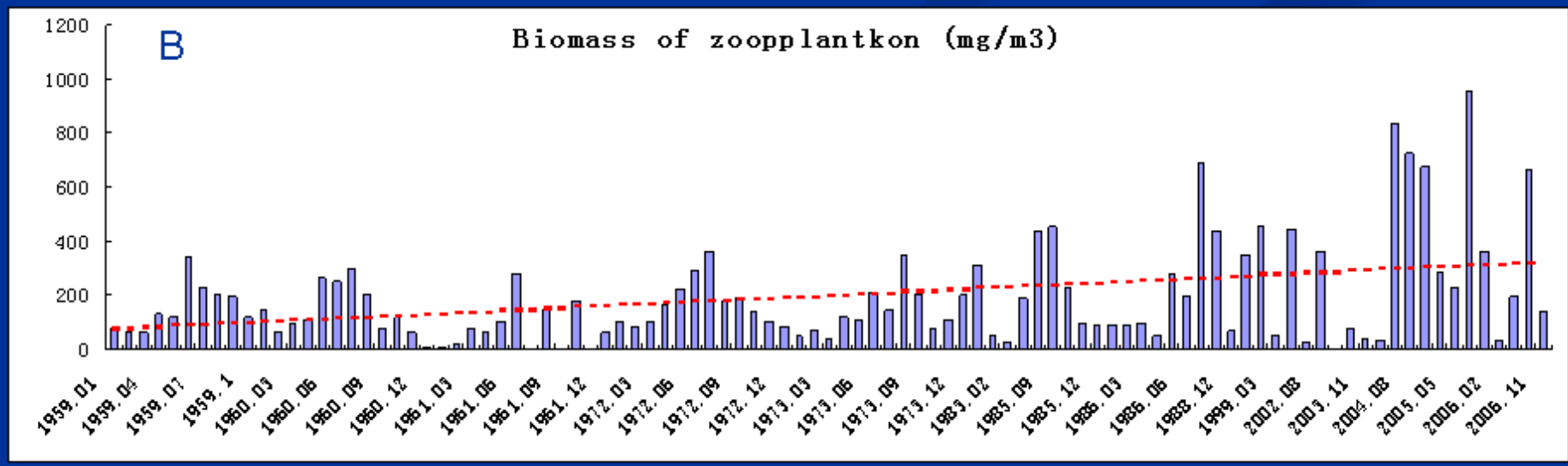
Pelagic Polychaeta
Pelagic Gastropod
Isopoda
Siphonophore管水母
Hyocrozoa水螅水母
Ctenophora栉水母类
Tunicata被囊类
Cladocera枝角类
Chaetognatha毛颚类
Sergestinae樱虾类
Ostracoda介形类
Mysidacea糠虾类
Euphasia磷虾类
Cumacea涟虫类
Copepoda桡足类
Ciliate纤毛虫

0 20 40 60 80 100 120 140 160 180

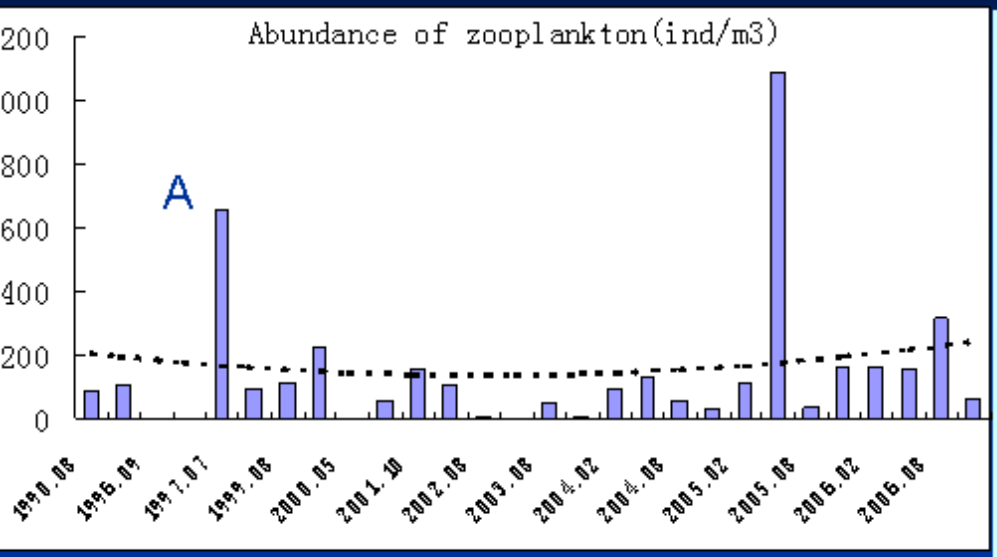
ECSEMC - SOA

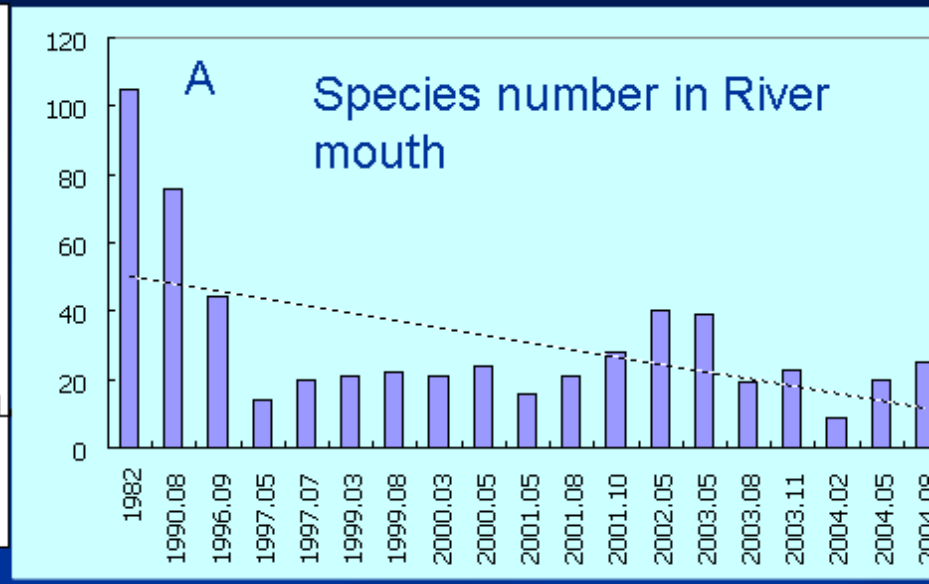
Biomass of Zooplankton

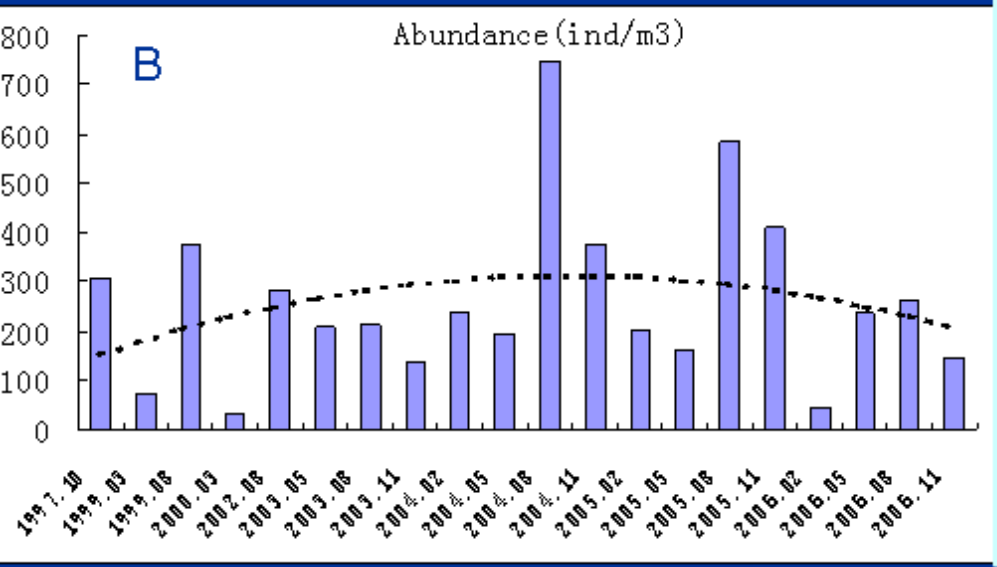


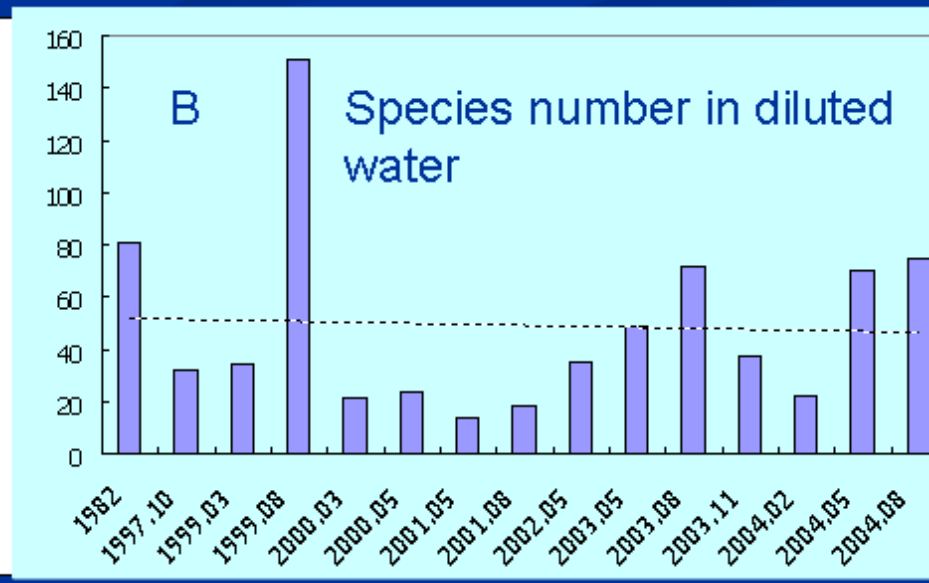


The zooplankton species number and abundance





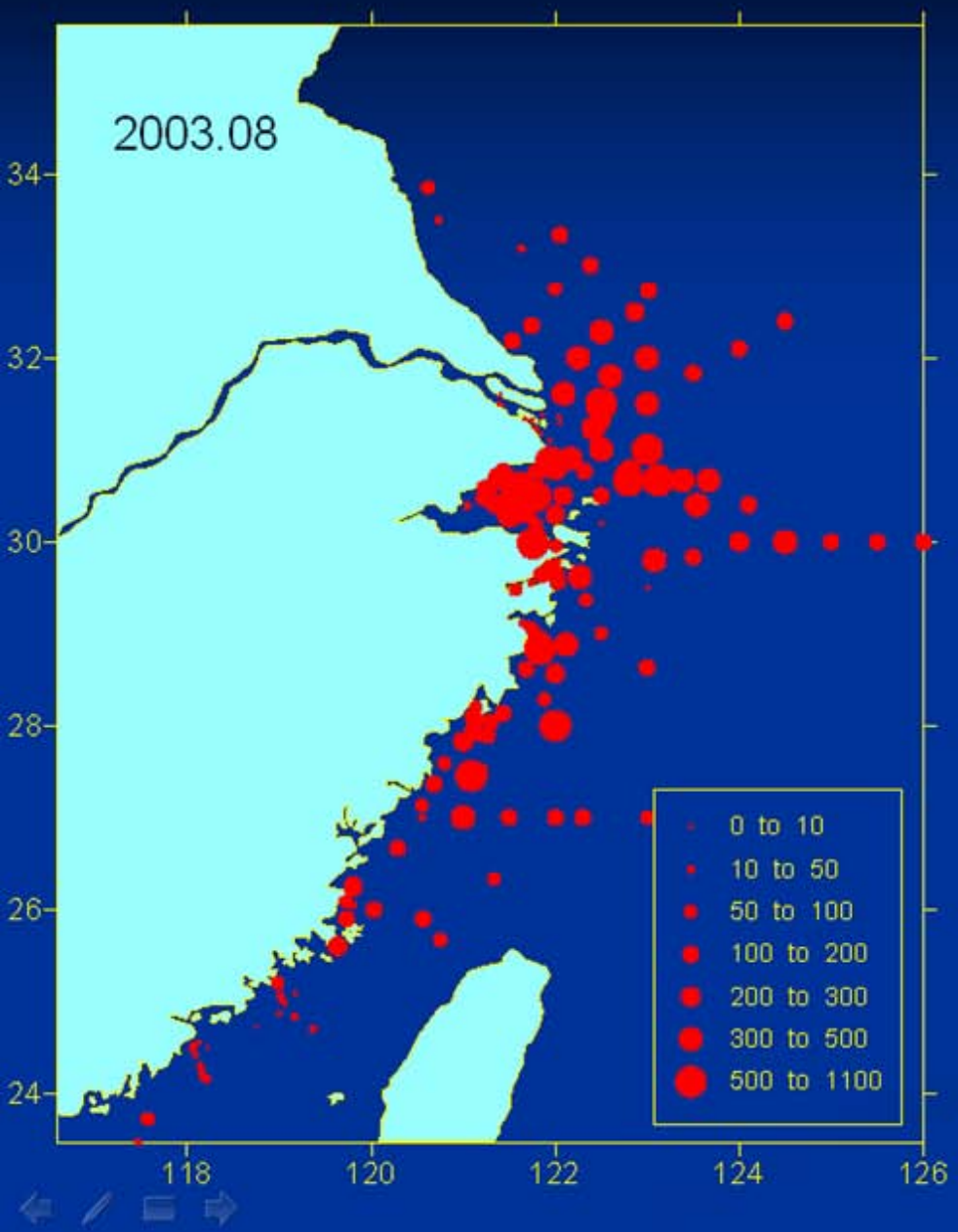




The seasonal variaton of zooplankton species, abundance and biomass

	Sampling time	Winter	Spring	Summer	Autum
River mouth (A)	Species Number	9	25	31	34
	Abundance ind/m³	252/18~548	64/20~148	55/6~197	35/4~99
	Biomass (mg/m³)	50/18.8~116	33/10~100	54/28~117	148/10~750
	Dominant species	Sinocalanus sinensis	Sinocalanus sinensis	Acartia pacifica	Paracalanus crassirostris
		Tortanus vermiculus	Schmackeria poplesia	Paracalanus aculeatus	
		Schmackeria poplesia			
Changjiang Diluted water (B)	Sampling time	2	5	8	11
	Species Number	25	95	106	78
	Abundance ind/m³	215.6/2.4~3060	193/23-533	391/55~780	187/1~2140
	Biomass (mg/m³	42/1.6~412.5	838/26~7042	723/186~2155	818/2~4800
	Dominant species	Schmackeria poplesia	Calanus sinicus	Muggiaca atlantic	Sinocalanus sinensis
		Labidocera euchaeta	Paracalanus aculeatus	Paracalanus aculeatus	Acartia bifilosa
			Paracalanus sp	Acartia pacifica	

The distribution of Zooplankton biomass



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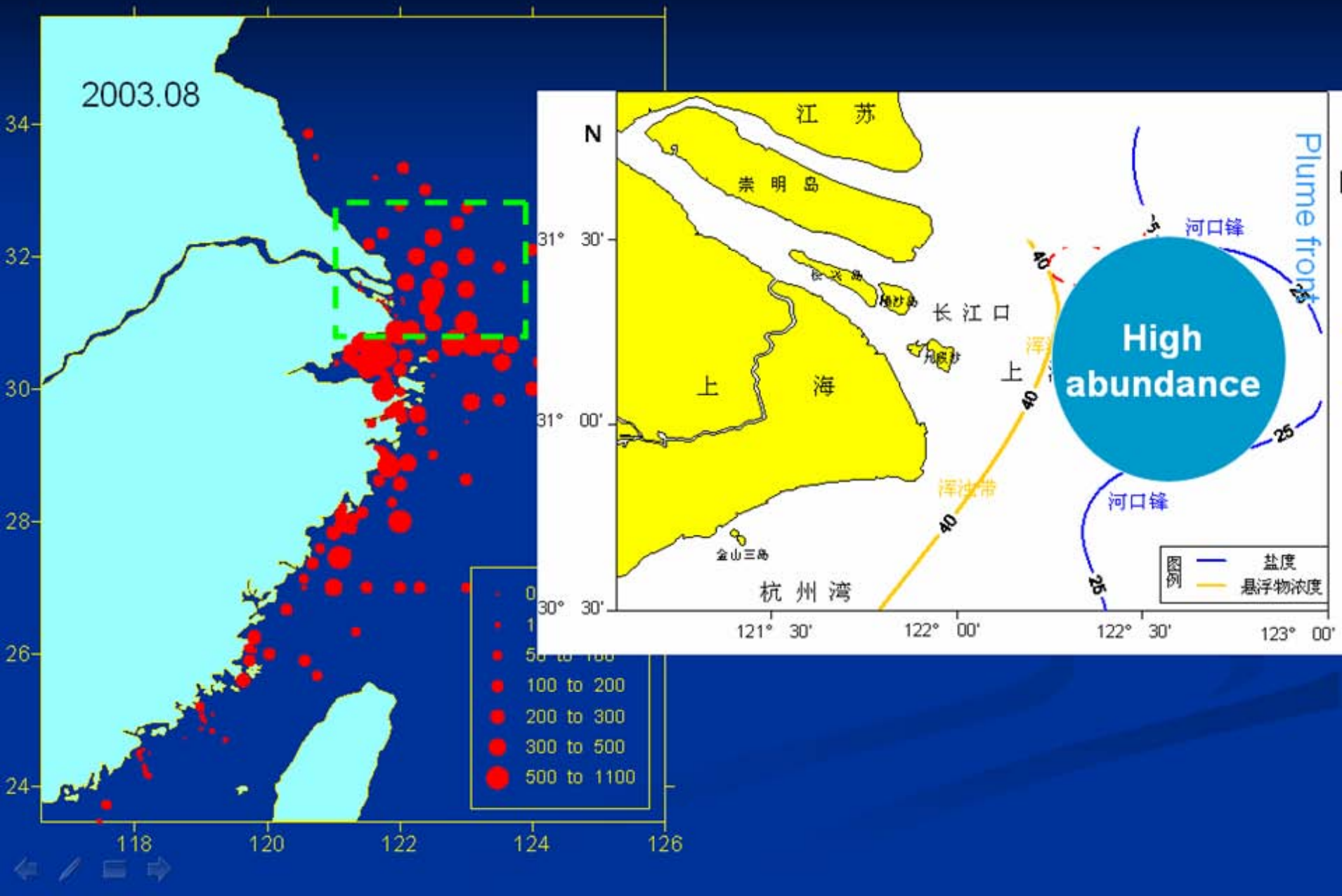
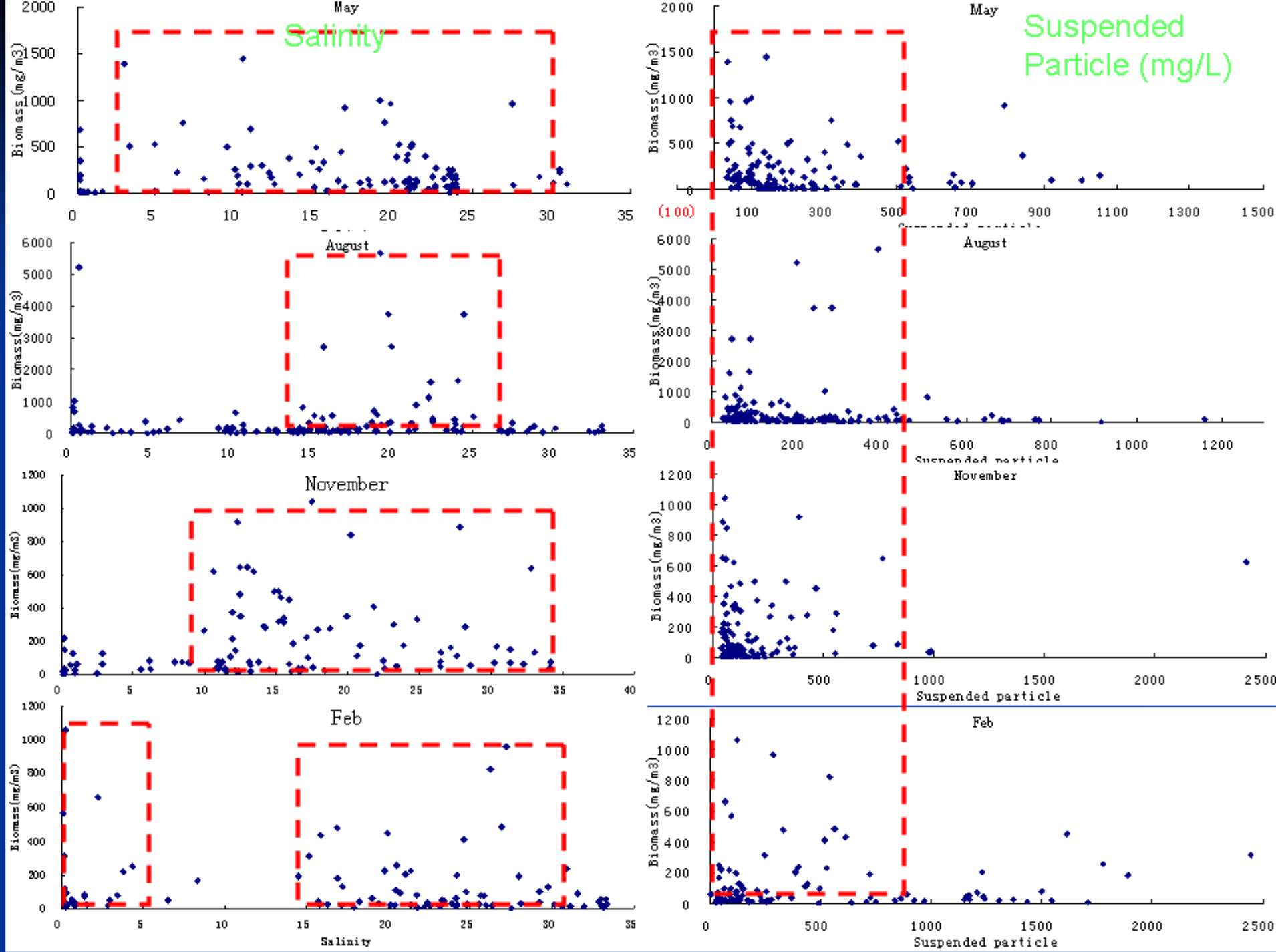
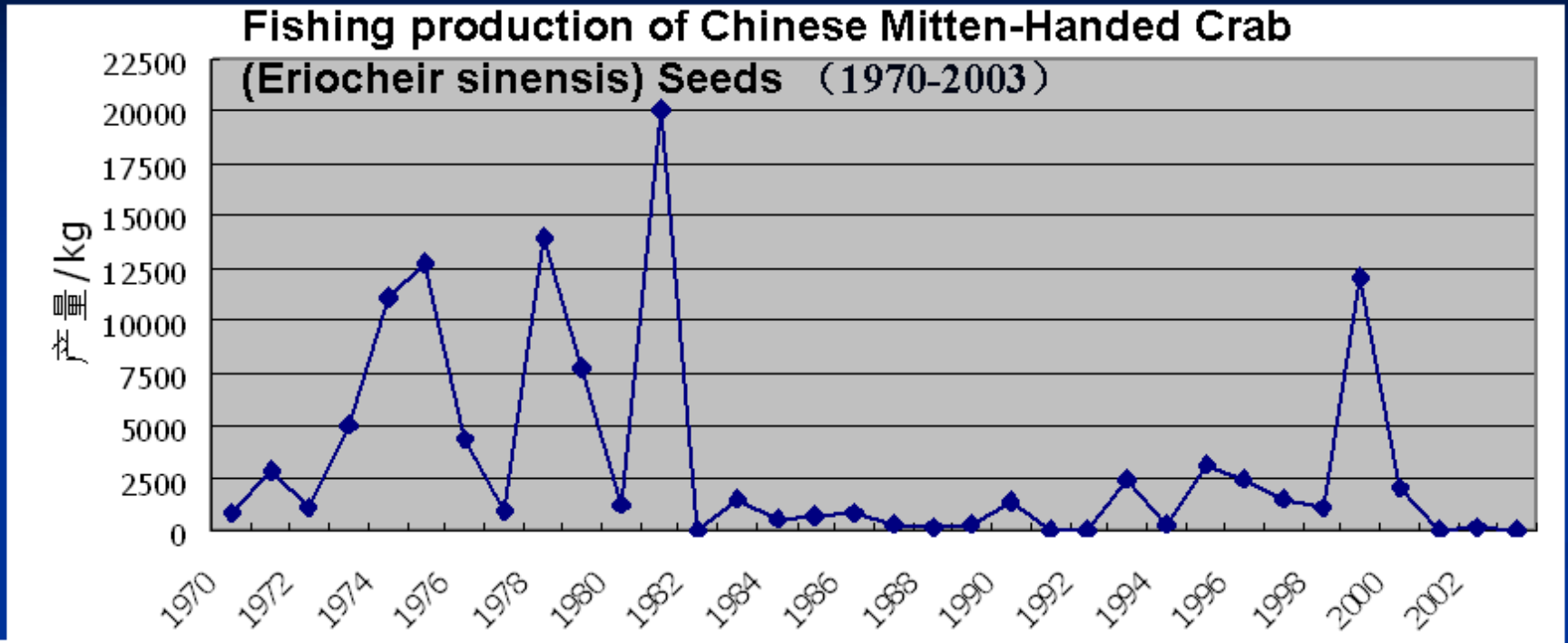
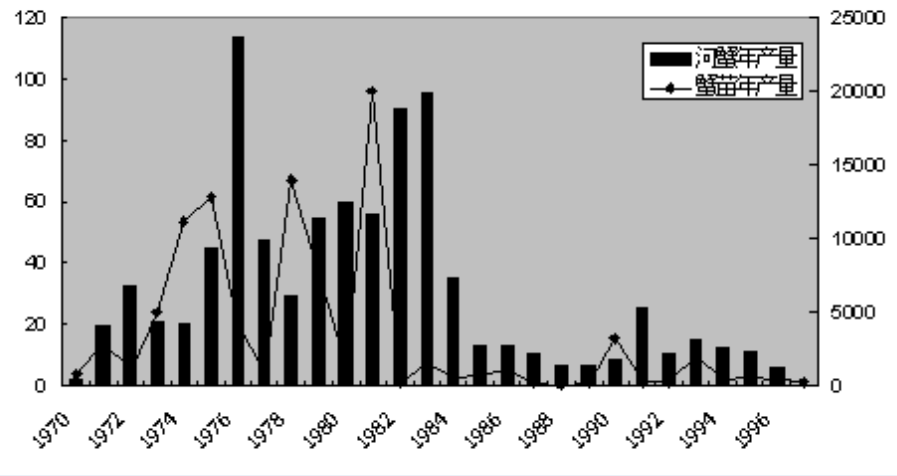
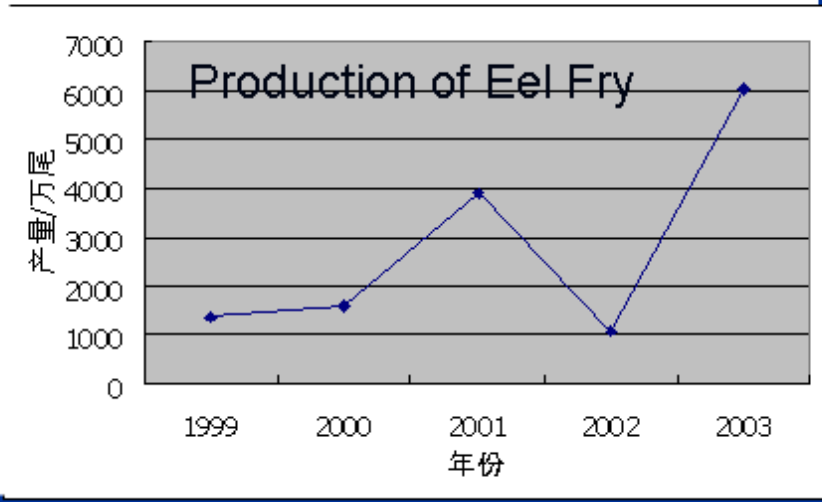



May
Salinity
Biomass(mg/m3)
August
November
Feb
Salinity
May
Suspended Particle (mg/L)
Biomass(mg/m3)
August
November
Feb
Suspended particle

Commercial production of some planktonic larvae





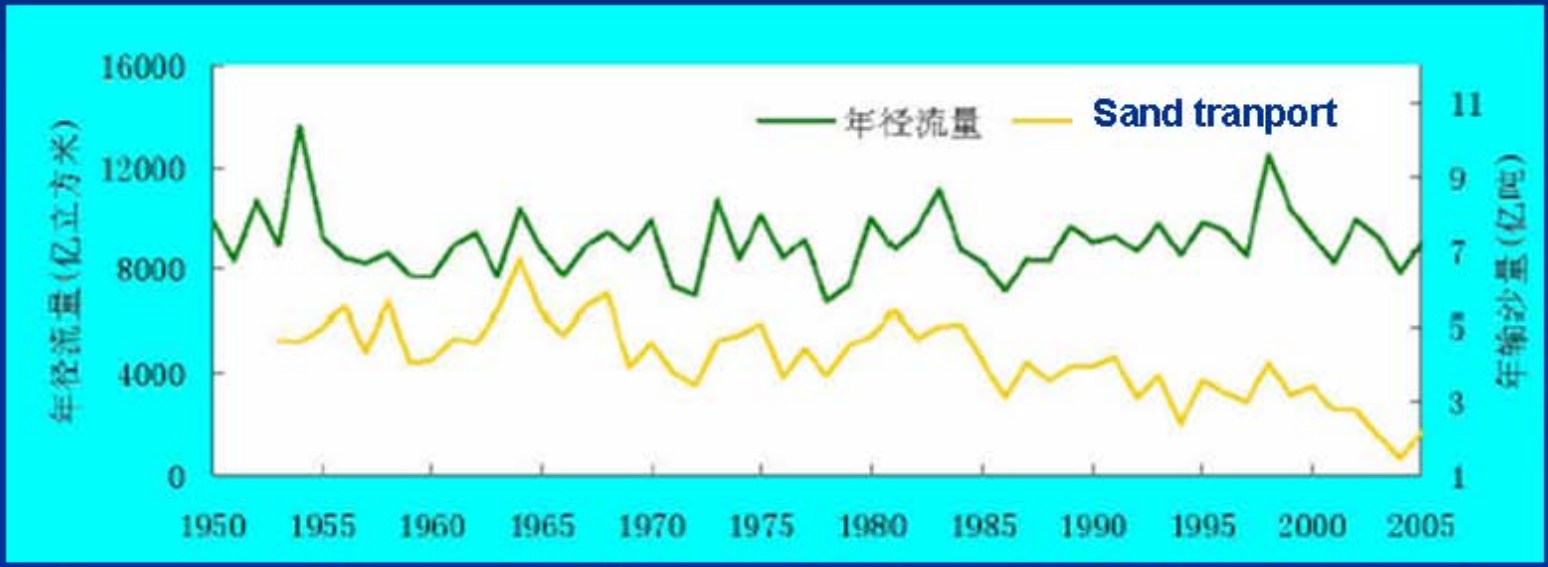


Waht causes the zooplankton changing

The sand transport flux and Runoff of Changjiang Estuary

The average annual runoff of Changjiang Estuary is 905 billion m3 (1950~2005)

The average annual sand transport flux is about 0.43 billion ton (1950~2005)



Year	Average Runoff (Billion m3)	Compared with Average	Sand content(kg/m^3)	Compared with Average	sand transport flux(Billion Ton)	Compared with Average
1950~2000	905		0.486		0. 43	
2000	927	2. 4%	0.366	-24. 7%	0. 34	-21. 7%
2001	825	-8. 9%	0. 336	-30. 9%	0. 28	-36. 3%
2002	993	9. 7%	0.277	-43. 0%	0. 28	-36. 5%
2003	925	2. 2%	0.223	-54. 1%	0. 21	-52. 4%
2004	788	-12. 9%	0.186	-61. 7%	0. 15	-66. 1%

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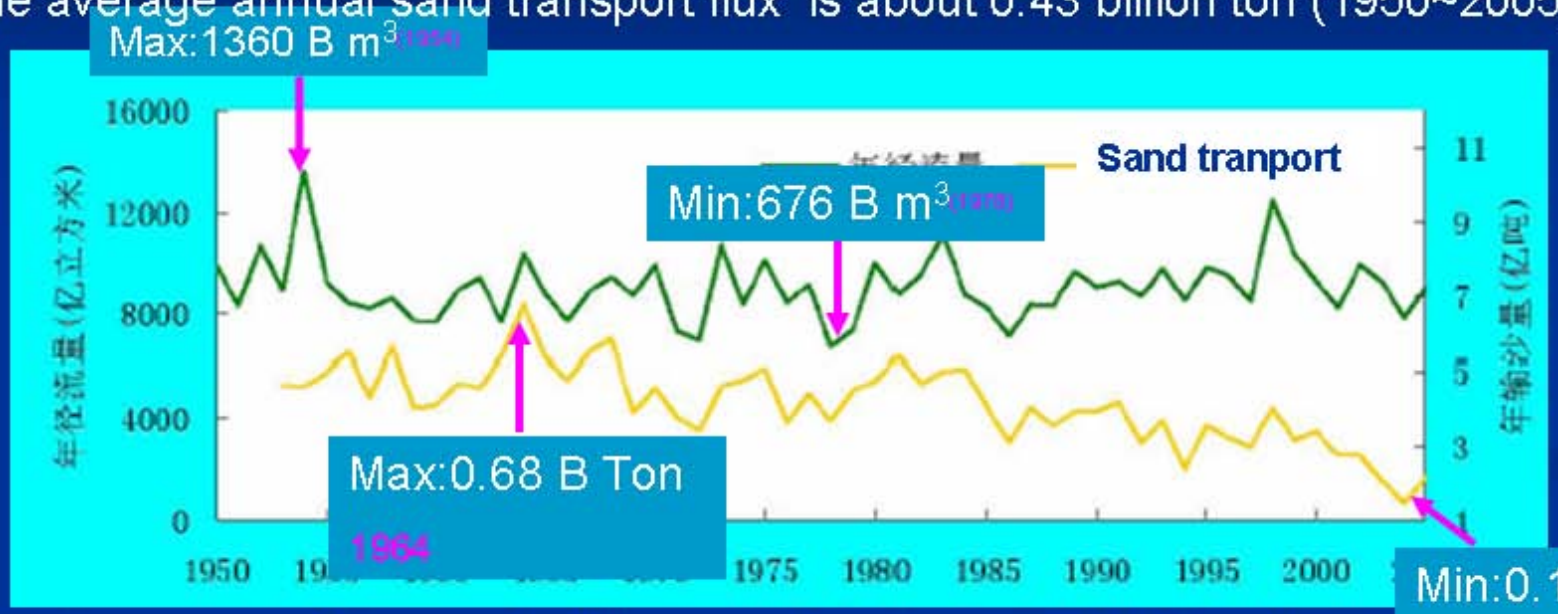

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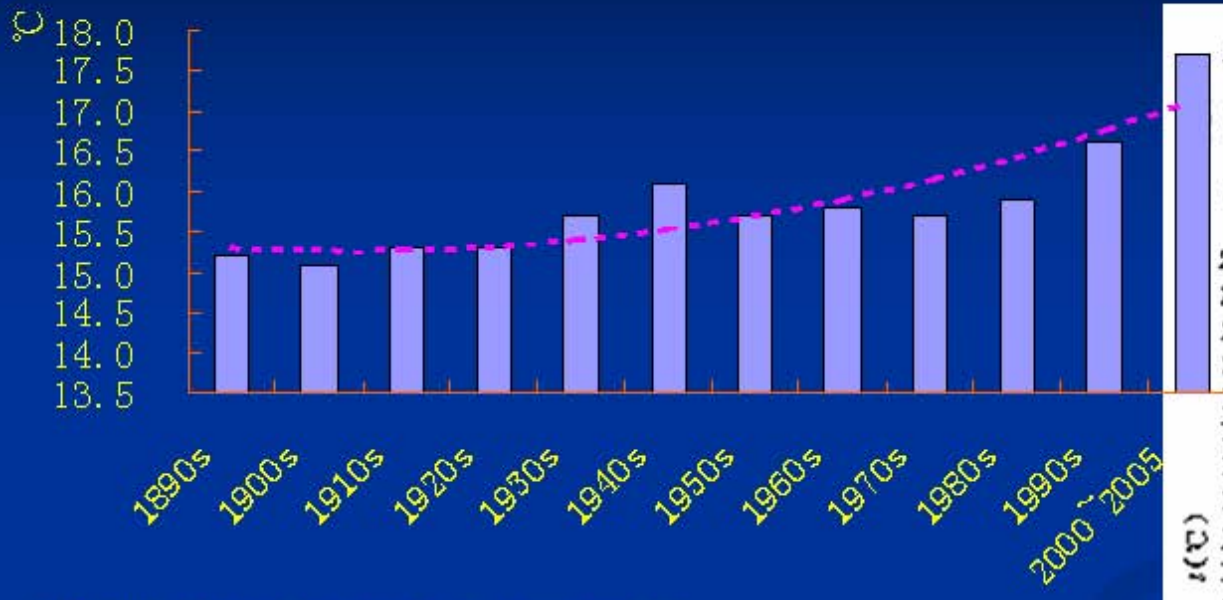
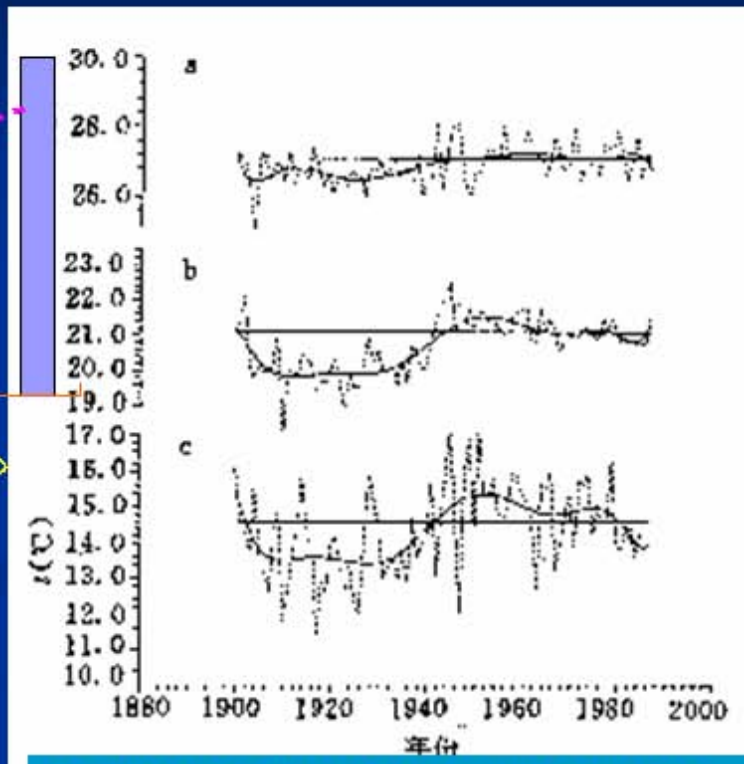
Warming tendency in Changjiang Estuary



Slight increasment in summer

The air temperature osillation period is about 2.1~2.4a , and water temperature is about 3.2a .warming tendency of water temperature is similar with air temperature but lagged about 6 a in Changjiang tendency.



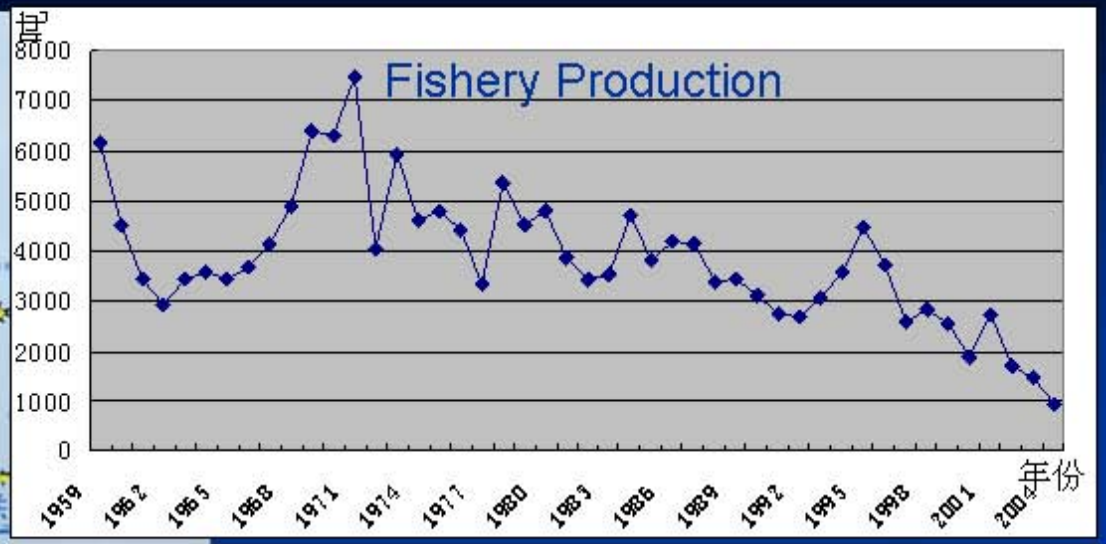
a average temperature in summer

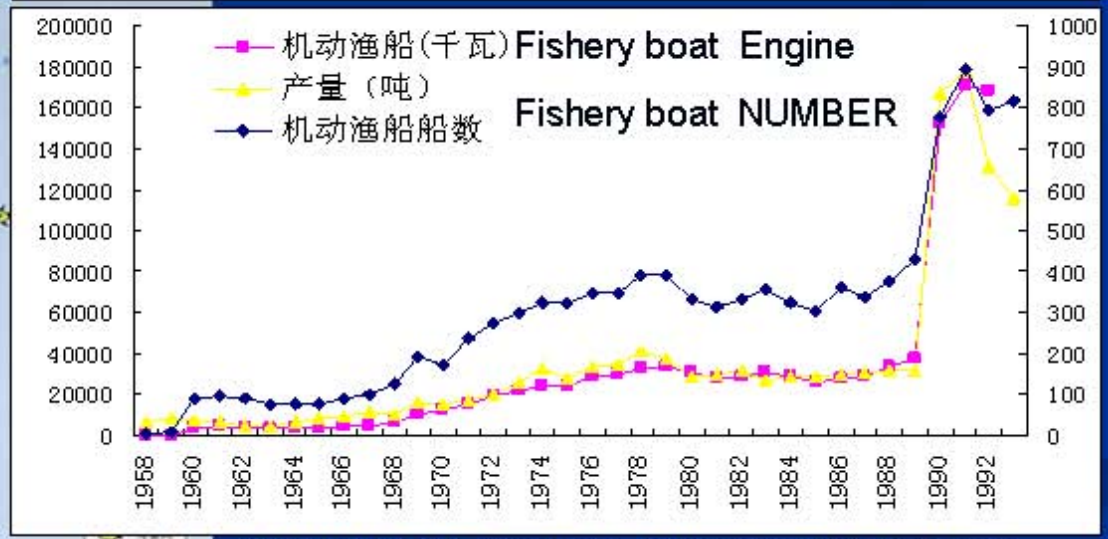
b annual average temperature

c average temperature in winter

阎俊岳，李江龙，东海及邻近地区百年来的温度变化，海洋学报，1997，Vol19（6）：121-126

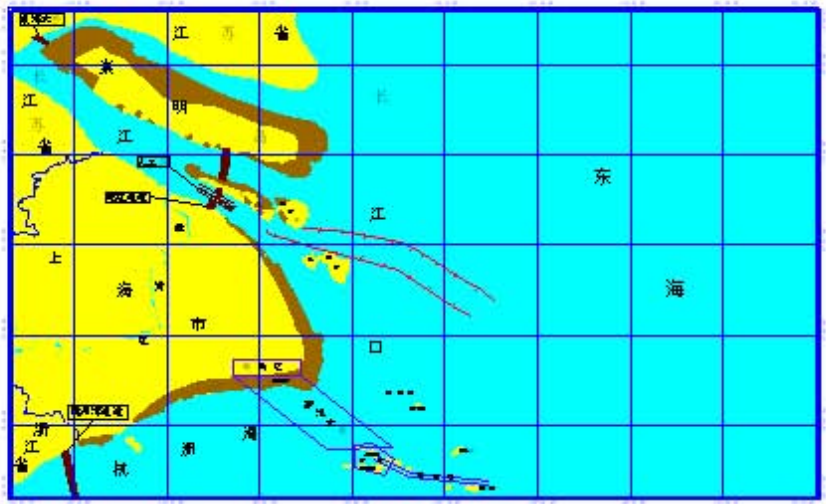
The increasing removal of predator on ecosystem



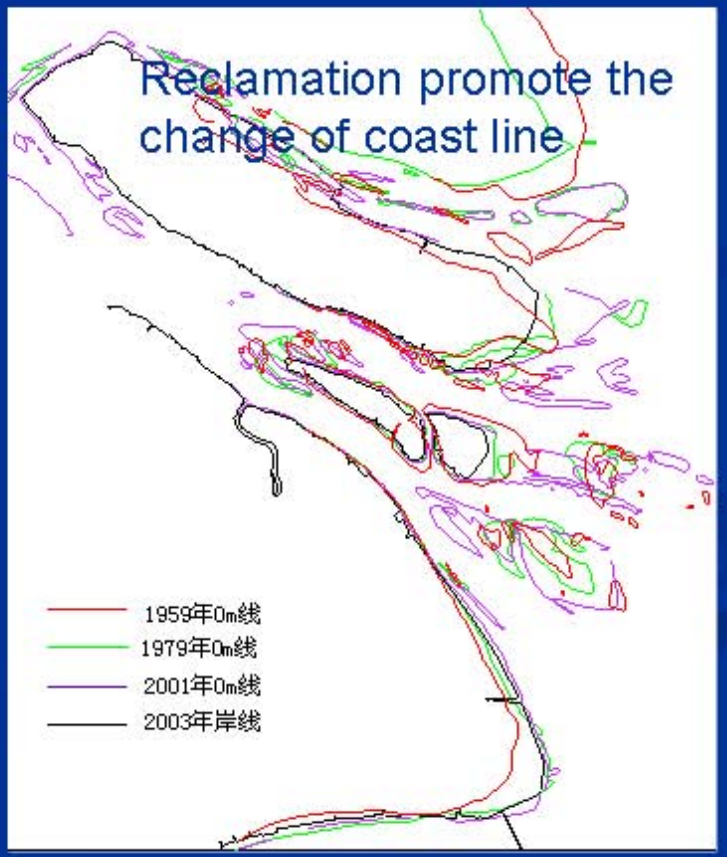


Global fishery has fully exploited two thirds of all fish stocks(Botsford et al 1997), with implications for lower food web structure and dynamics

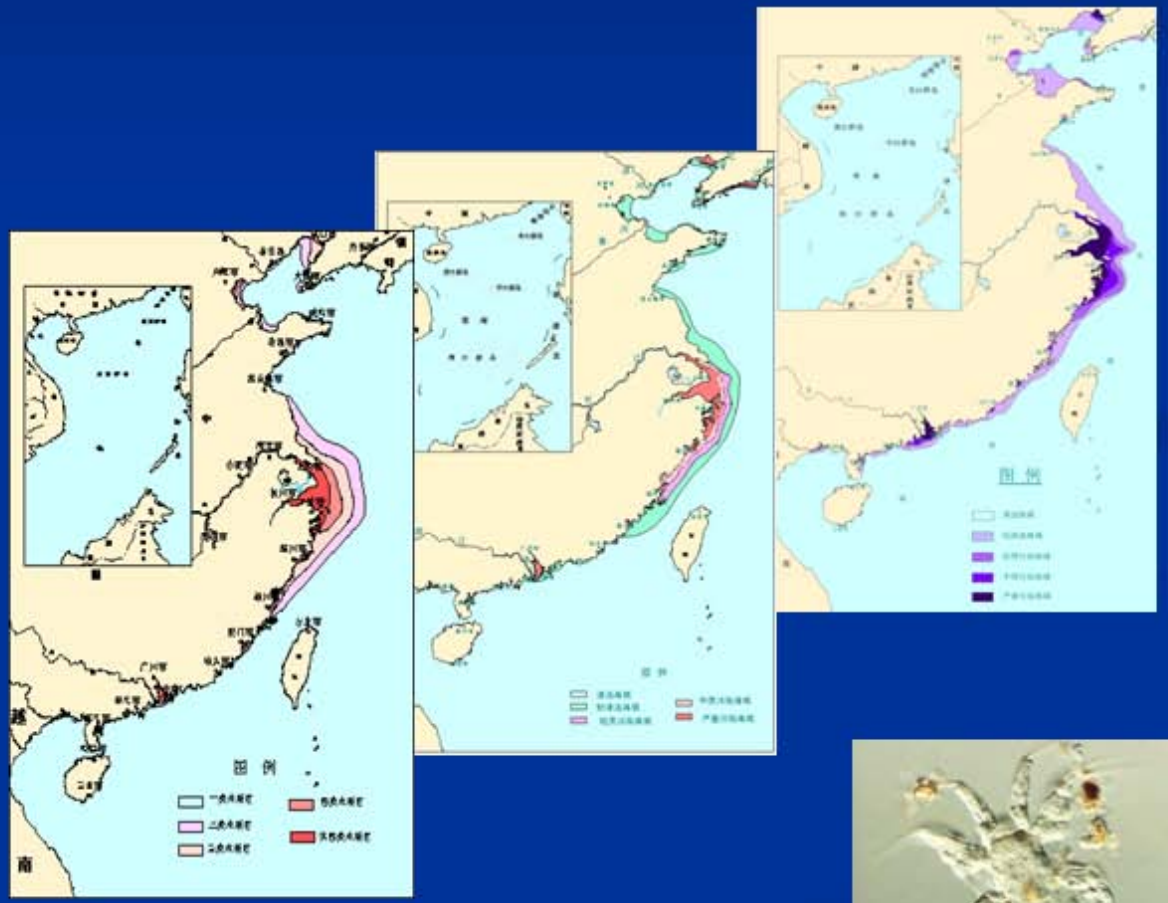
Oceanographical changes caused by coastal and River Valley projects



- THREE GORGE DAM
- SOUTH-NORTH WATER TRANSFER



Eutrophication in Changjiang Estuary



Enrichment with nutrients and organic compounds that limit primary or secondary production is one of

the most pervasive human alterations of the environment and profoundly affects species composition,

food web structure, and ecosystem

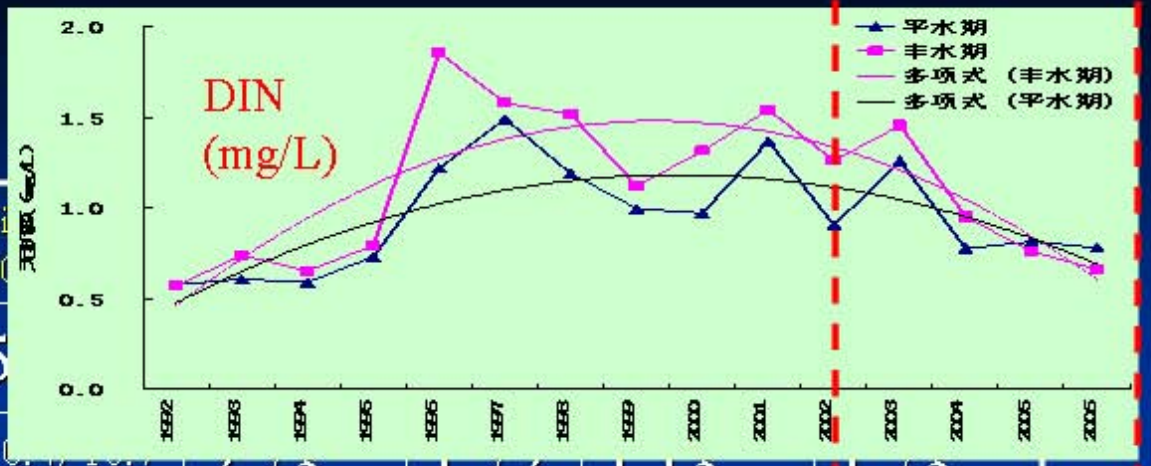
Nutrient inputs to the Changjiang Estuary

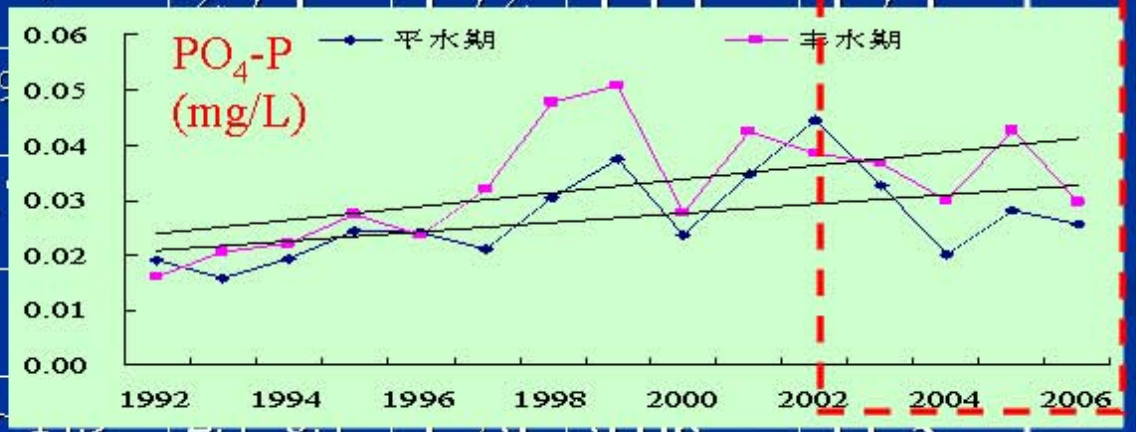
time	SiO_3^{2-} 10^{10}mol/yr	PO_4^{3-} 10^{8}mol/yr	DIC10^{1} ^{2}mol/yr	NO_3^- 10^{10}mol/yr	DIN10^{10}mol/yr
1959	5.38	8.47	1.47	1.44	1.45
1960s	10.4/10.7	2.73	1.72	1.13	1.73
1970s	8.99/9.3	1.10	1.50	1.22	1.86
1980s	9.73/-	2.20	1.66	4.47	5.31
1990s		6.10	1.72	8.19	10.2
1995~1999	9~14.9	2.4~3.4	1.79	9.06	11.3

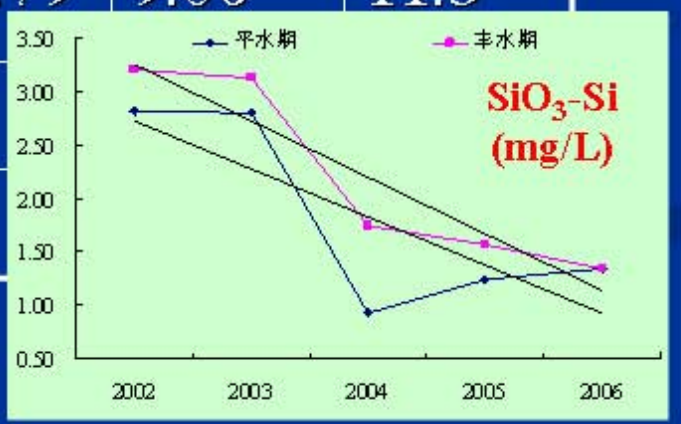
cite from Huang Qinghui 2002

Nutrient inputs to the Changjiang Estuary

time	Si
1959	5
1960s	10.4/10.7
1970s	8.9
1980s	9.
1990s	
1995~1999	9~

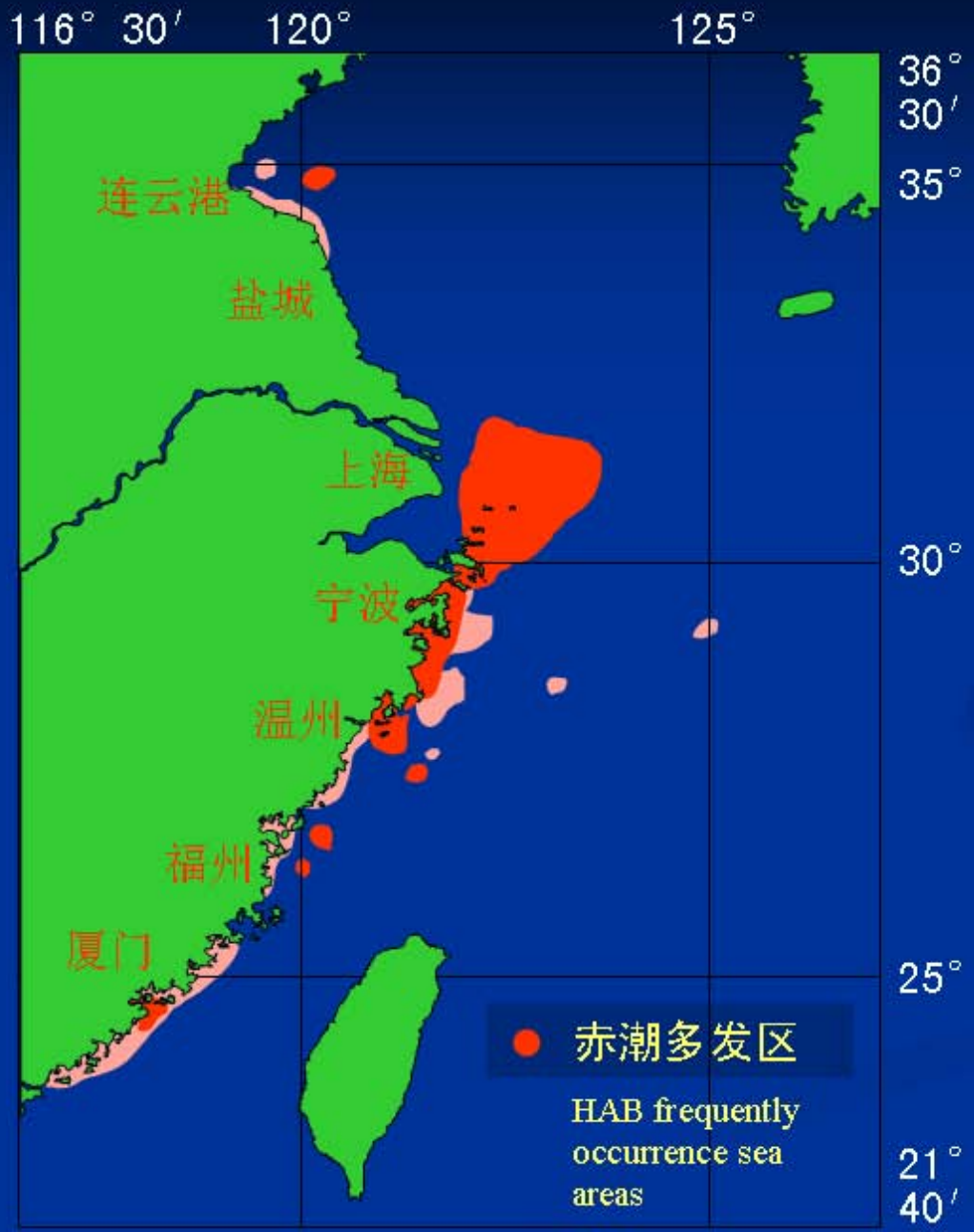




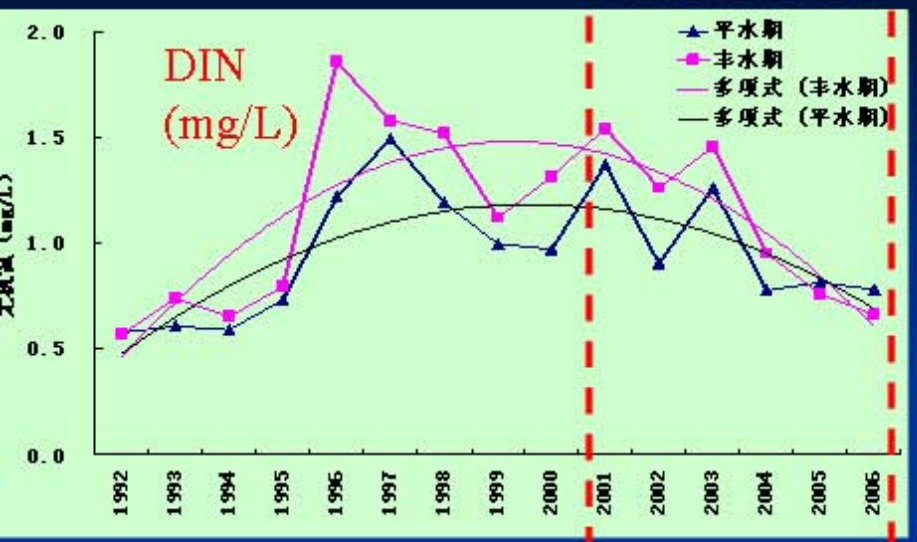


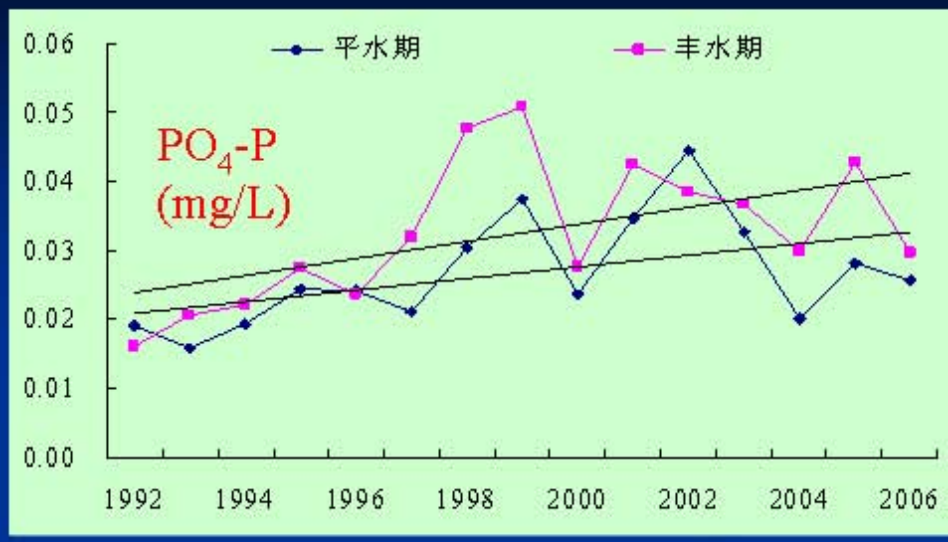
cite from Huang Qinghui 2002

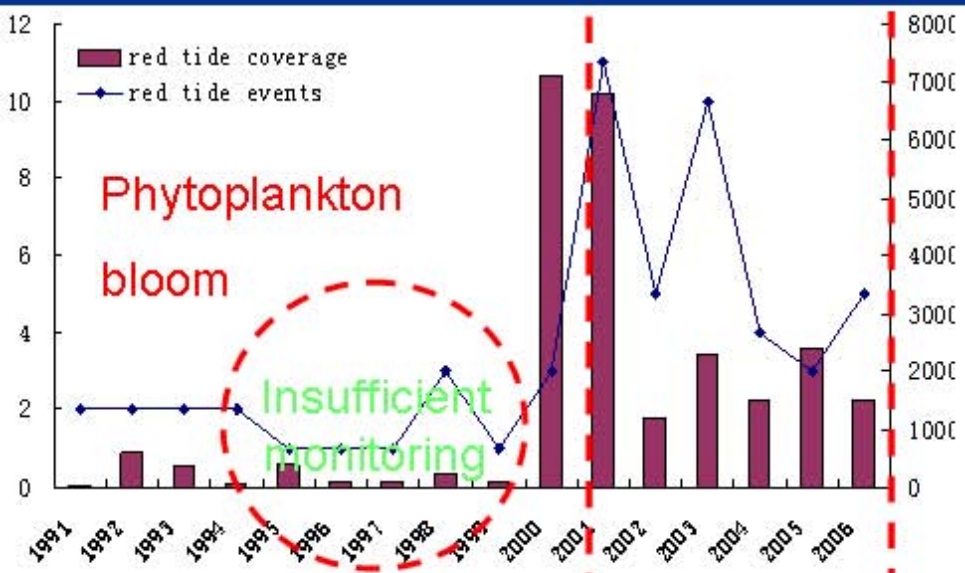
Harmful Algal Bloom

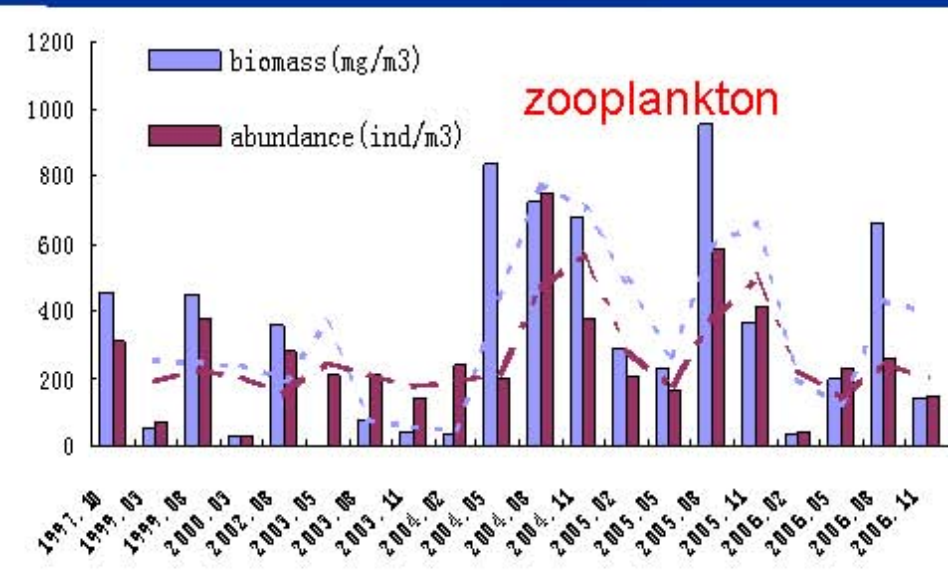


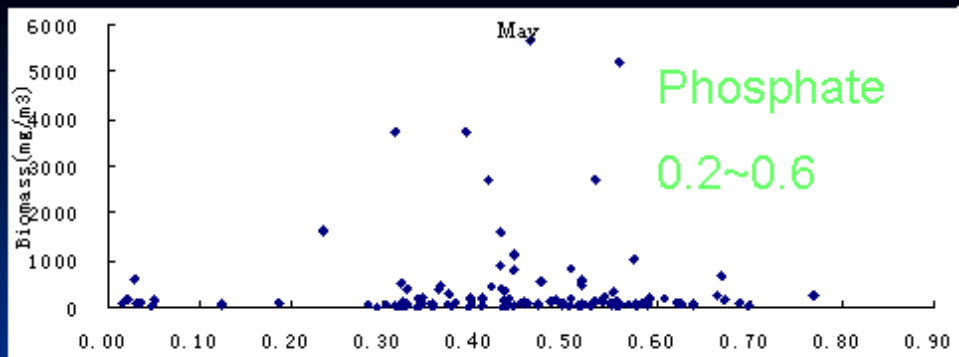
Coorelation of Zooplankton with nutrients

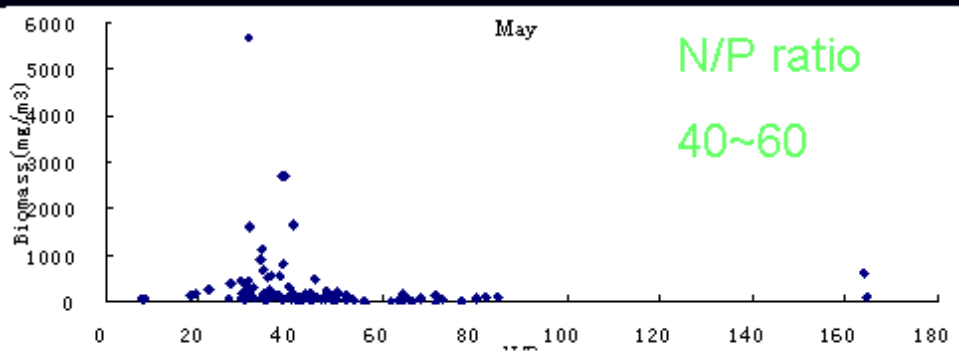


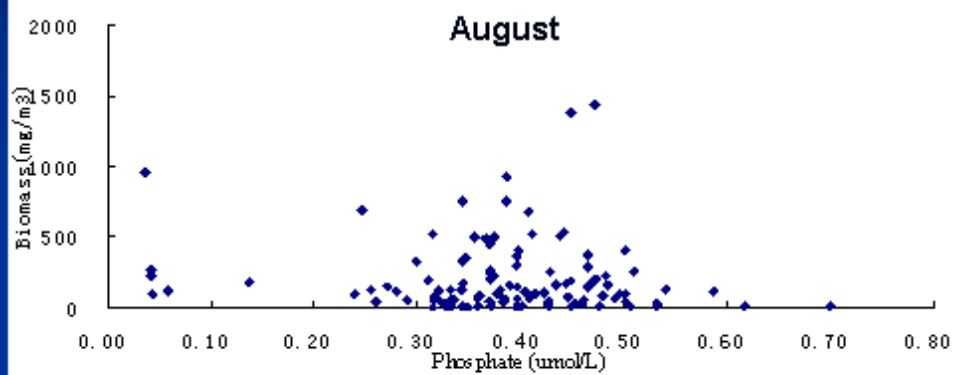


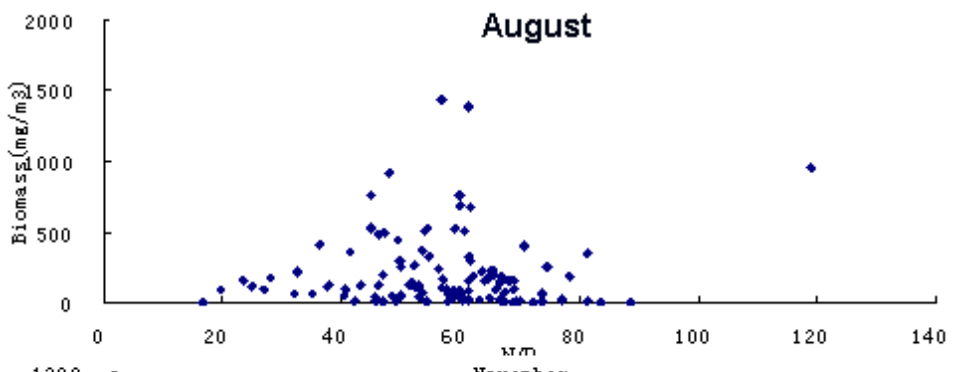


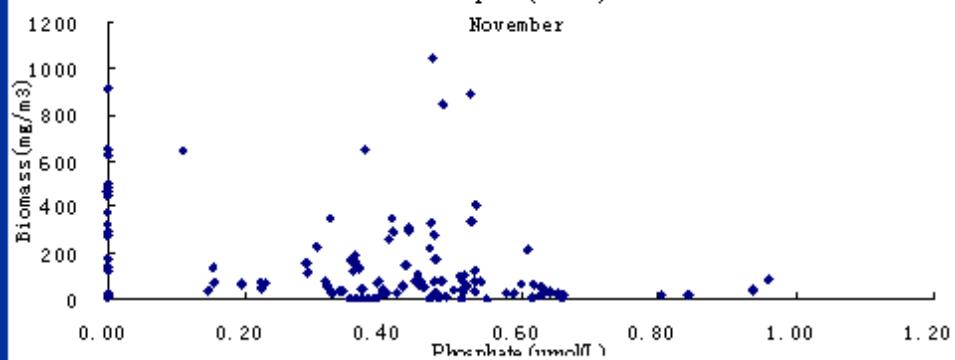


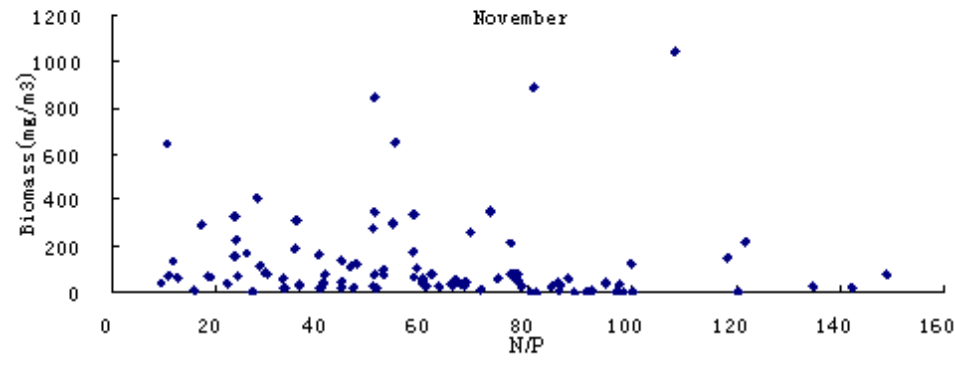

May
Phosphate
0.2~0.6
Biomass(mg/m3)
0 1000 2000 3000 4000 5000 6000
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90

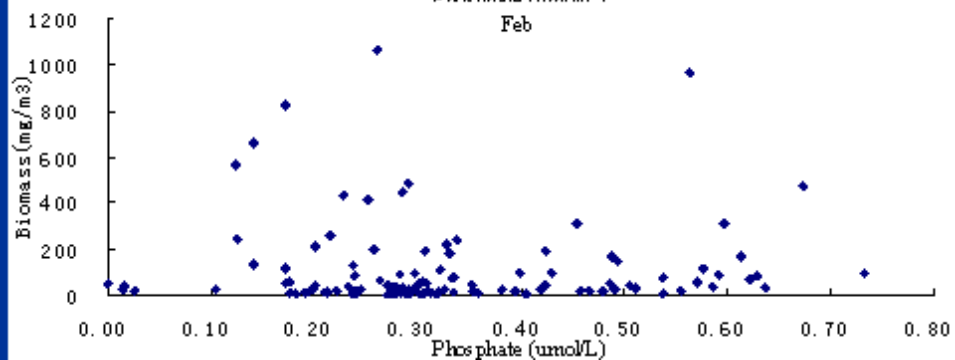

May
N/P ratio
40~60
Biomass(mg/m3)
0 1000 2000 3000 4000 5000 6000
0 20 40 60 80 100 120 140 160 180

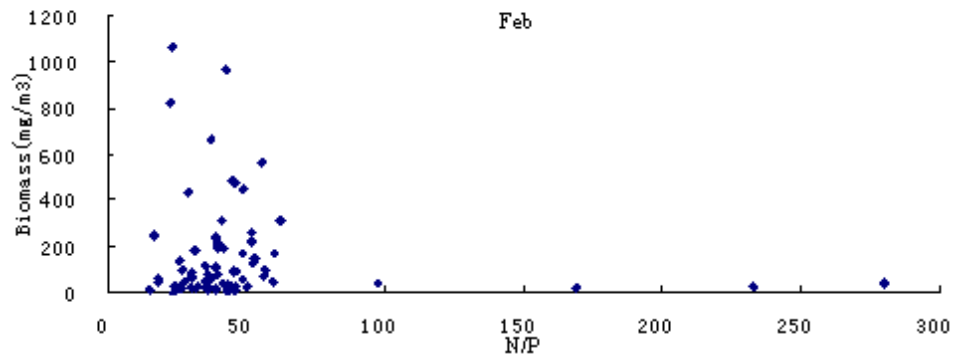

August
Biomass(mg/m3)
0 500 1000 1500 2000
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80
Phosphate (umol/L)


August
Biomass(mg/m3)
0 500 1000 1500 2000
0 20 40 60 80 100 120 140


November
Biomass(mg/m3)
0 200 400 600 800 1000 1200
0.00 0.20 0.40 0.60 0.80 1.00 1.20

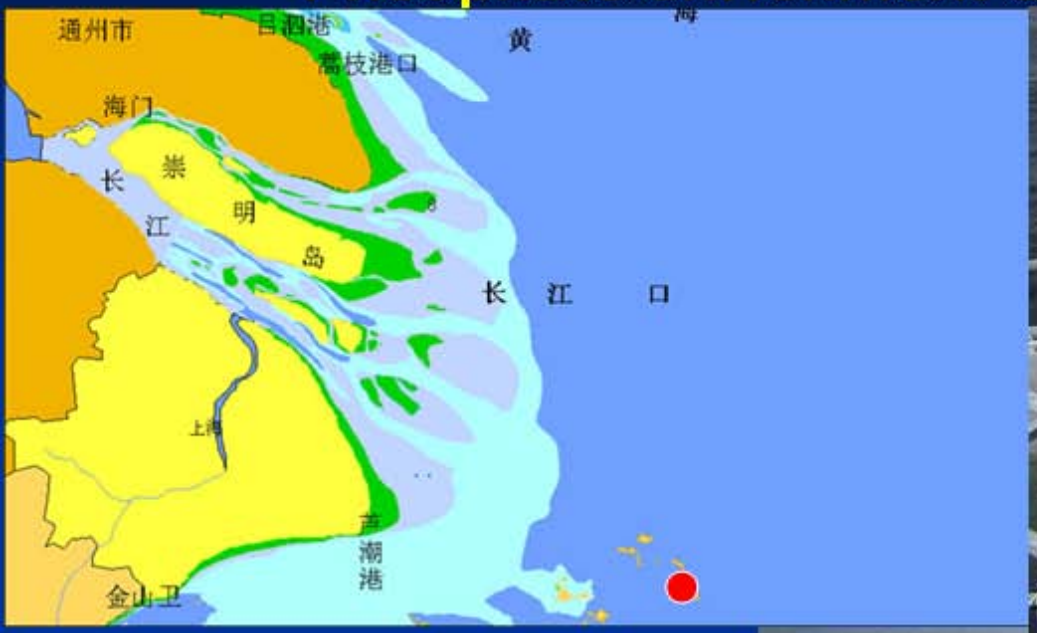

November
Biomass(mg/m3)
0 200 400 600 800 1000 1200
0 20 40 60 80 100 120 140 160
N/P


Feb
Biomass(mg/m3)
0 200 400 600 800 1000 1200
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80
Phosphate (umol/L)


Feb
Biomass(mg/m3)
0 200 400 600 800 1000 1200
0 50 100 150 200 250 300
N/P

Part 2 zooplankton response to P enrichment

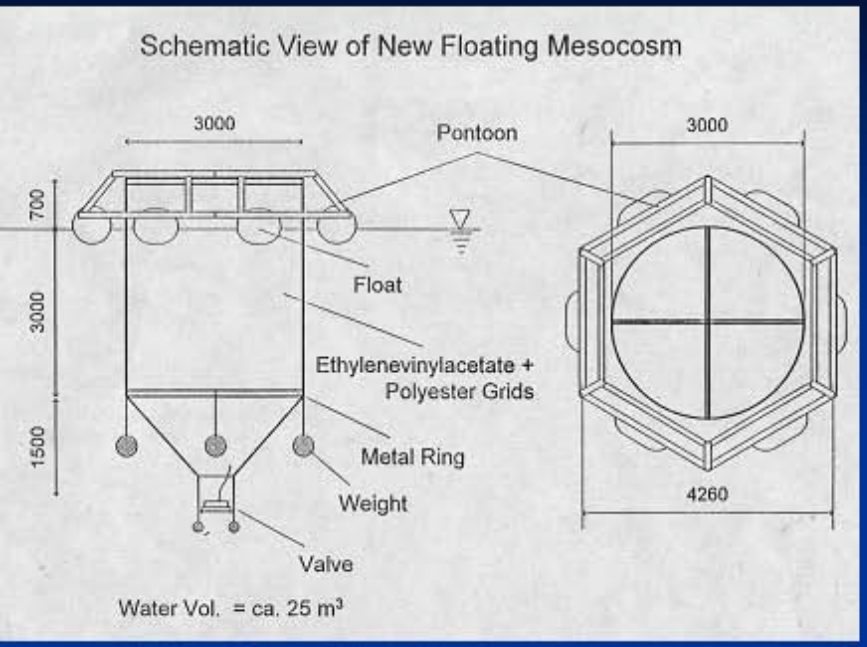
Phosphate enrichment experiment in Mesocosm



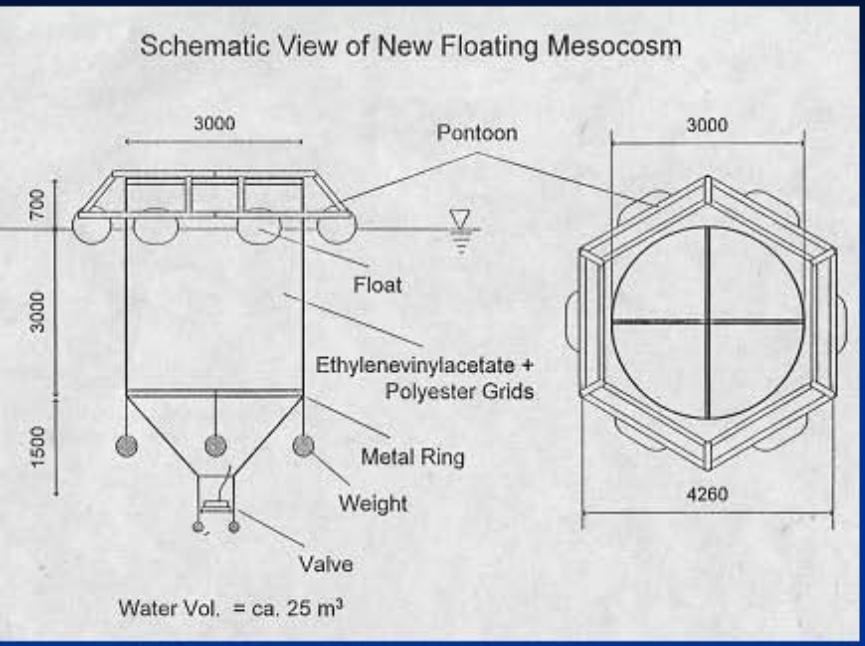
To understand how further loading of phosphate to Changjiang estuary will affect plankton growth and trophic statue in food webs, marine ecosystems in the estuary were enclosed in mesocosoms in Autum and Spring.

Supported by SOA China and National Institute for Environmental Studies in Japan

Deployment of Mesocosm

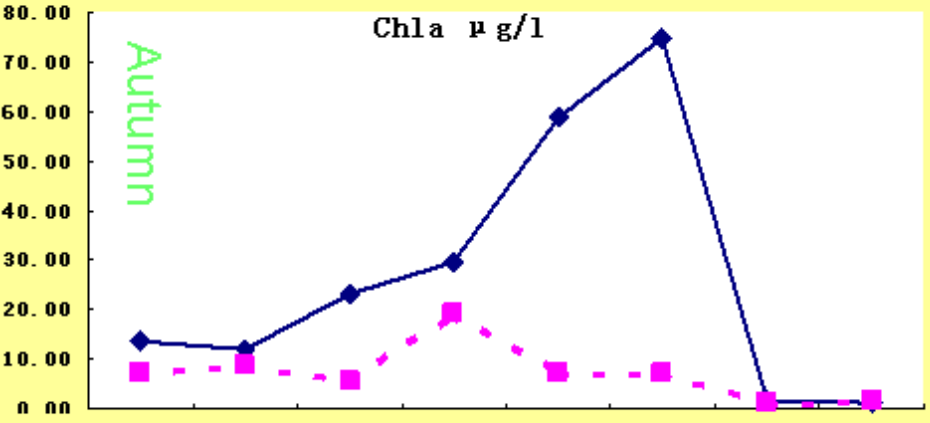


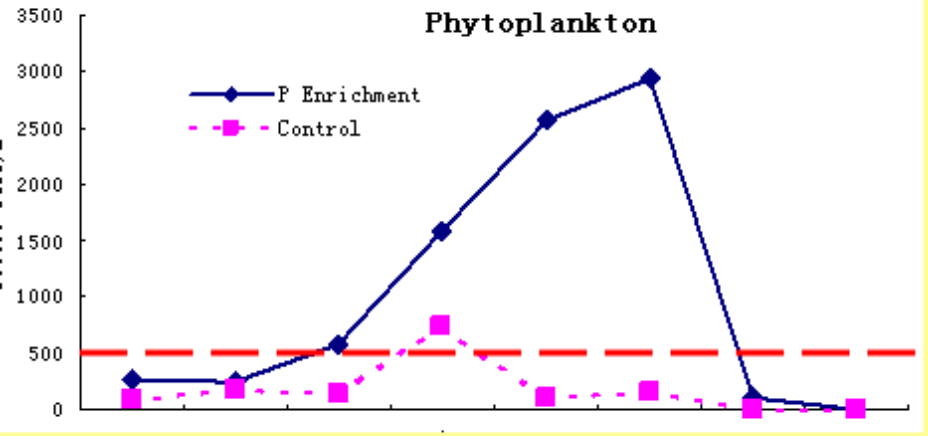
Deployment of Mesocosm

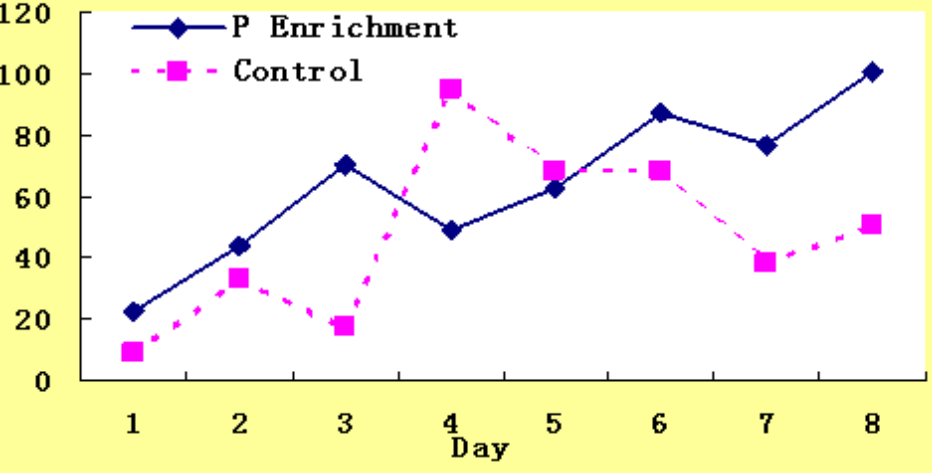


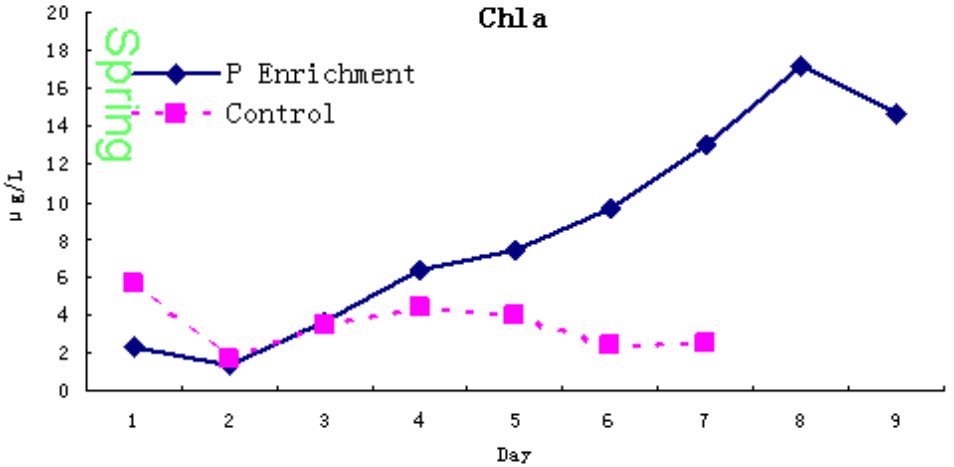
Mesocosm experiments were conducted at anchor place off the LUHUA island in Changjiang estuary. Mesocosm used in Autum and that in Spring are very similar except some improvements, no inflow or outflow occurred across the boundary of the enclosure. In October ,the phosphate in enrichment mesocosm was adjusted from 0.78umol/L to 3.25umol/L. At midnight of 18 may, 2 umol/l phosphate(NaH_2PO_4) was reached in P enrichment enclosure. Sampling was conducted on 1 meter at 9:00.Sample water (10 liters) was passed through two zooplankton nets(100um mesh and 20um mesh) in order, all samples were fixed with 8% formalin immediately after collection to identity and count zooplankton cells.

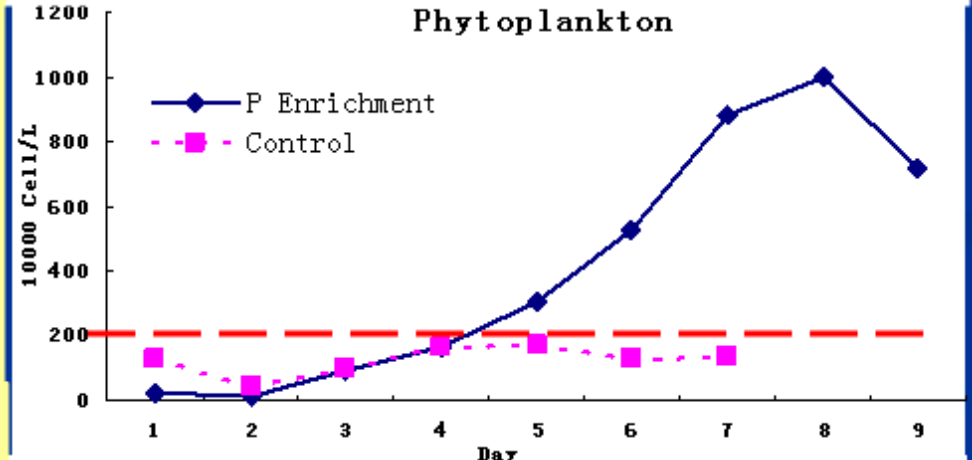
Blooms may easily occur at the projected level of phosphorous loading

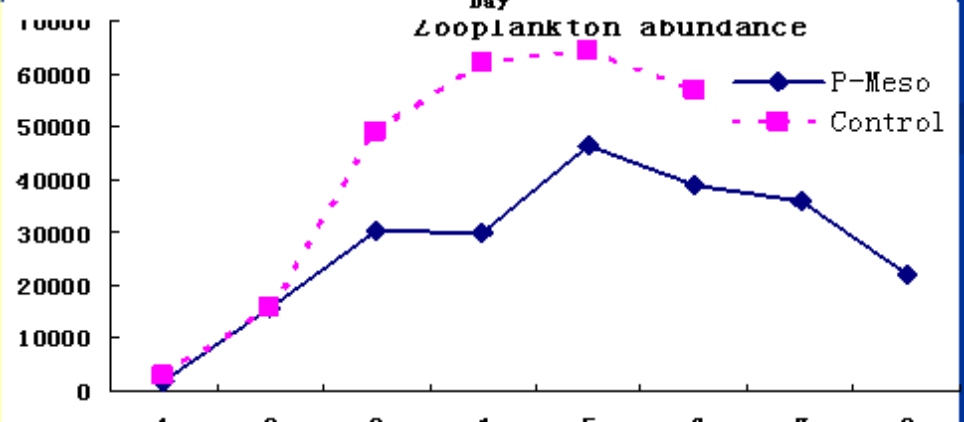

Chla μg/l
Autumn
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00


Phytoplankton
P Enrichment
Control
3500
3000
2500
2000
1500
1000
500
0


P Enrichment
Control
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
Day


Chla
Spring
P Enrichment
Control
μg/L
20
18
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
Day

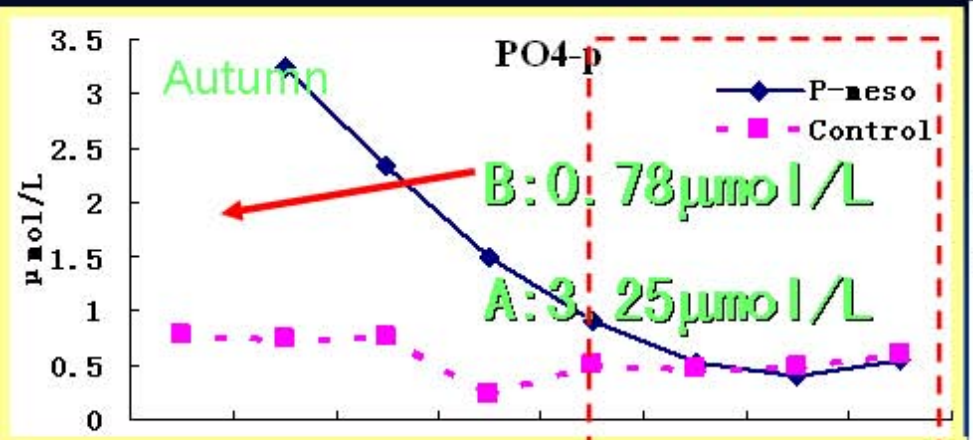

Phytoplankton
P Enrichment
Control
10000 Cell/L
1200
1000
800
600
400
200
0
1
2
3
4
5
6
7
8
9
Day

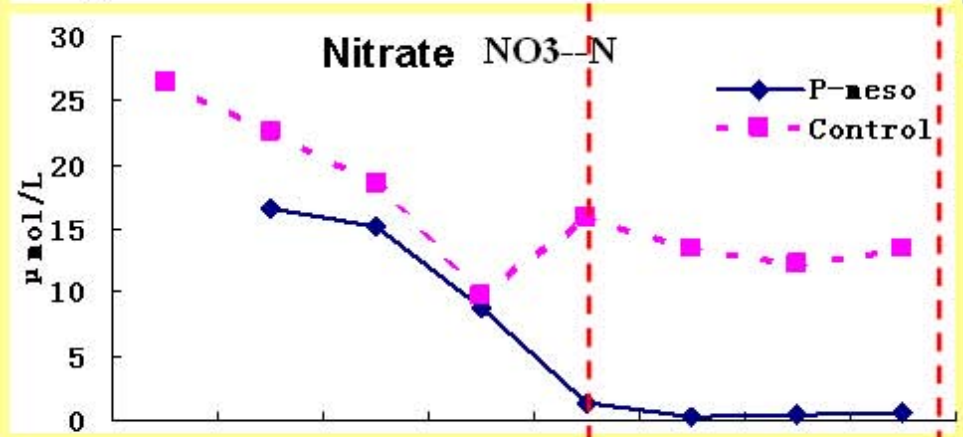

Zooplankton abundance
P-Meso
Control
60000
50000
40000
30000
20000
10000
0

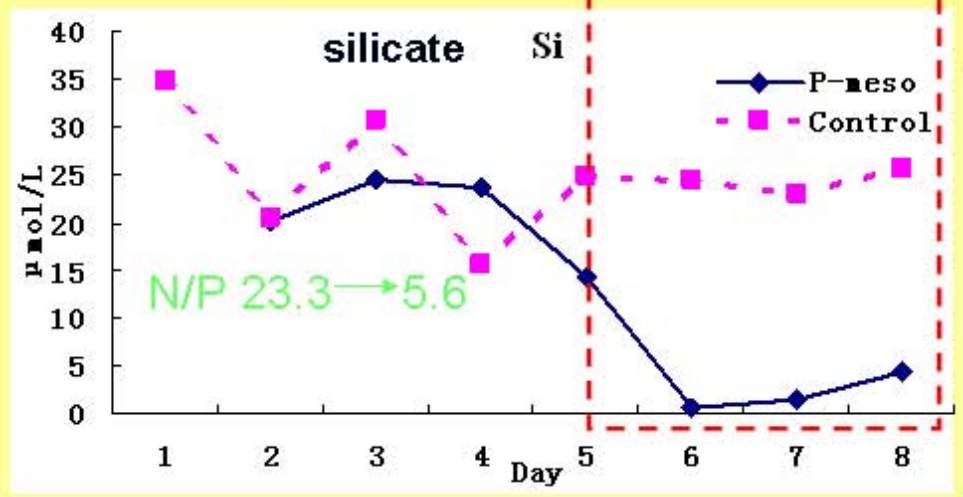
On Autum, the zooplankton population exhibited a progressive increase during both control and enrichment experiments ,Zooplankton abundance at the end of P enrichment experiment was up to 5 times it's initial level.

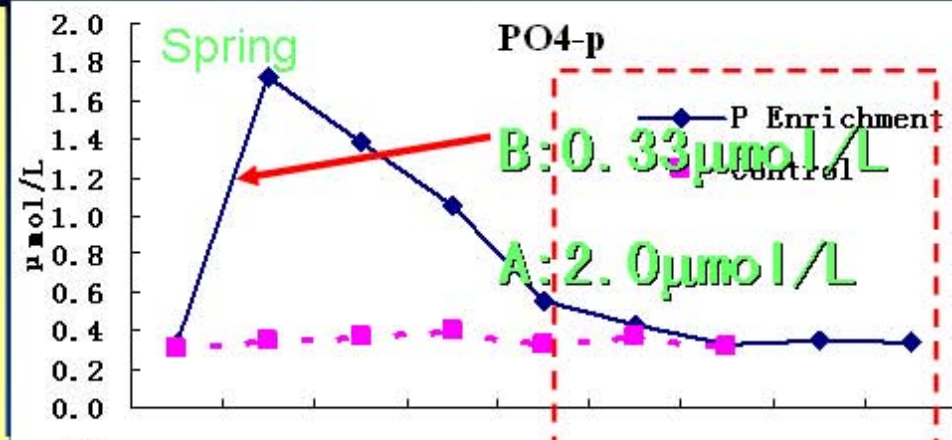
The initial abundance of zooplankton in the P enrichment experiment was approximately twice that in the control, although sea water were input simultaneously. In general, patterns of zooplankton abundance were similar in both experiments, but abundance of the control rise more dramatically on the developing stage mainly contributing to microzooplankton (size between 20-100um) .

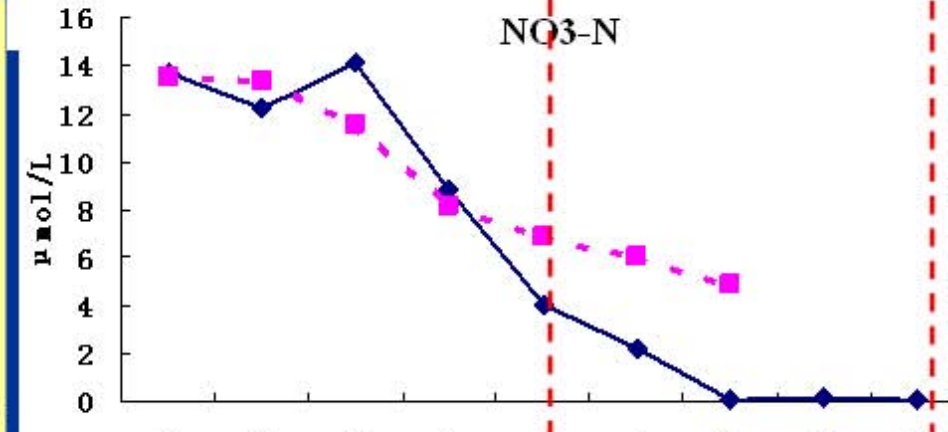
On spring, the abundance of zooplankton in P enrichment mesocosm was less than that in Control, due to the relatively degression of copepoda when P enrichment, although the ciliate dramatically increase in the P mesocosm.

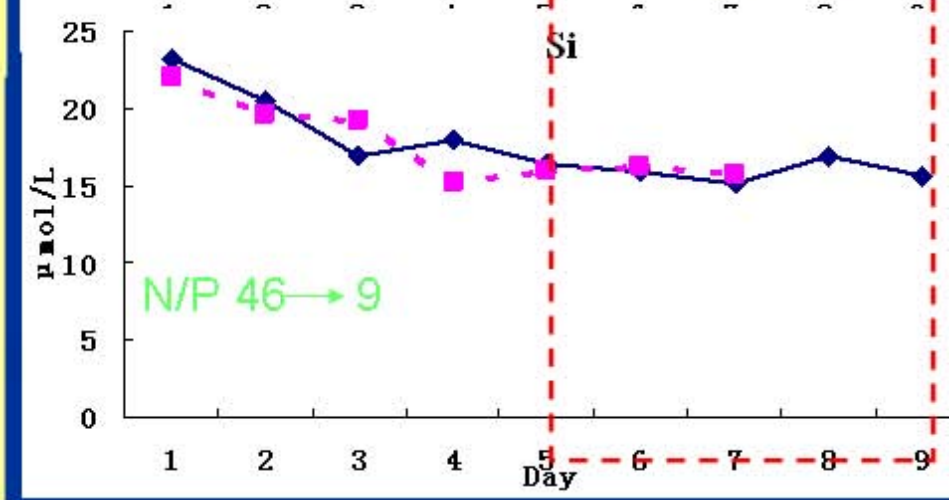

Autumn
PO4-p
P-meso
Control
B:0.78μmol/L
A:3.25μmol/L
μmol/L

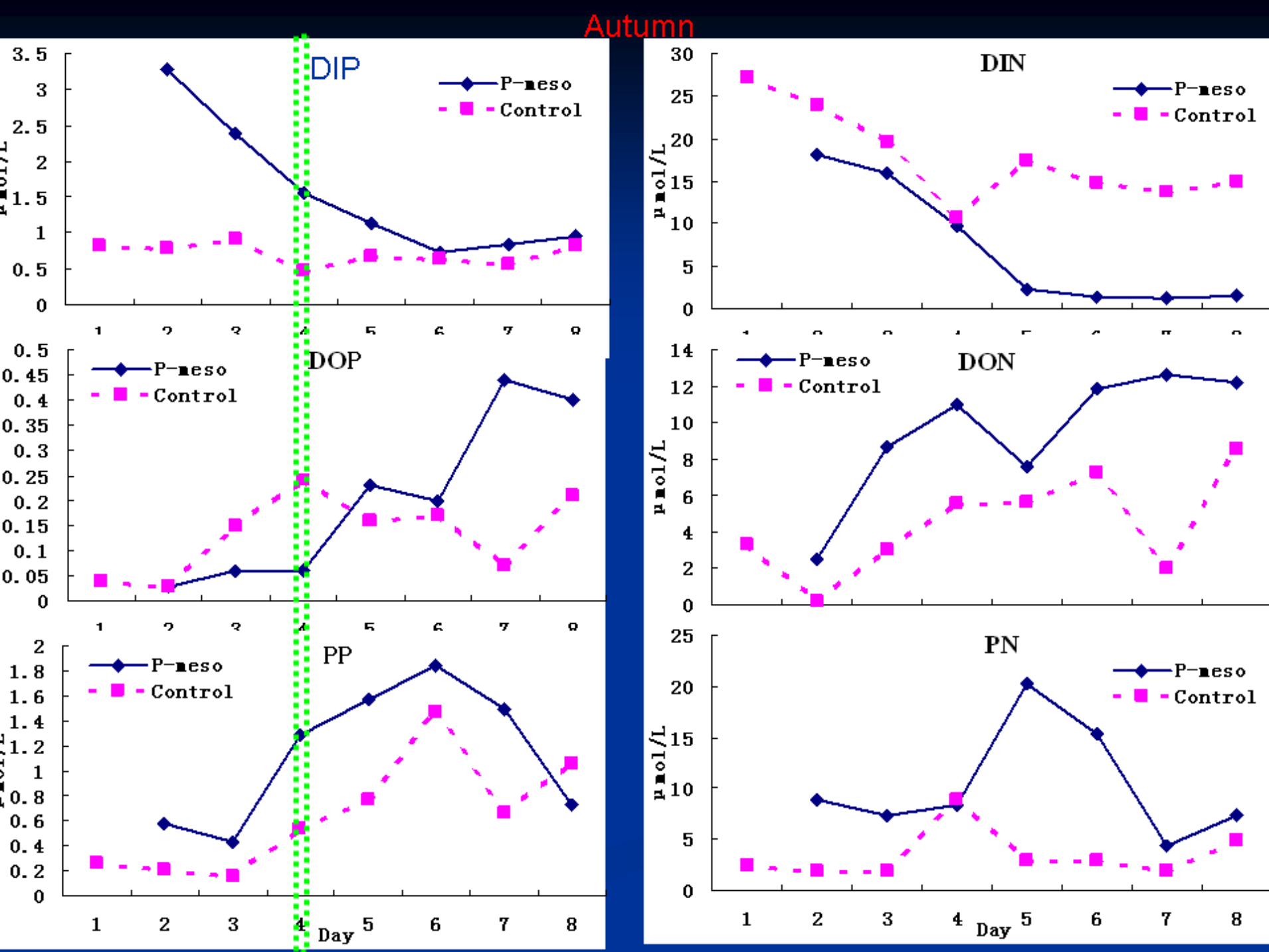

Nitrate NO3--N
P-meso
Control
μmol/L

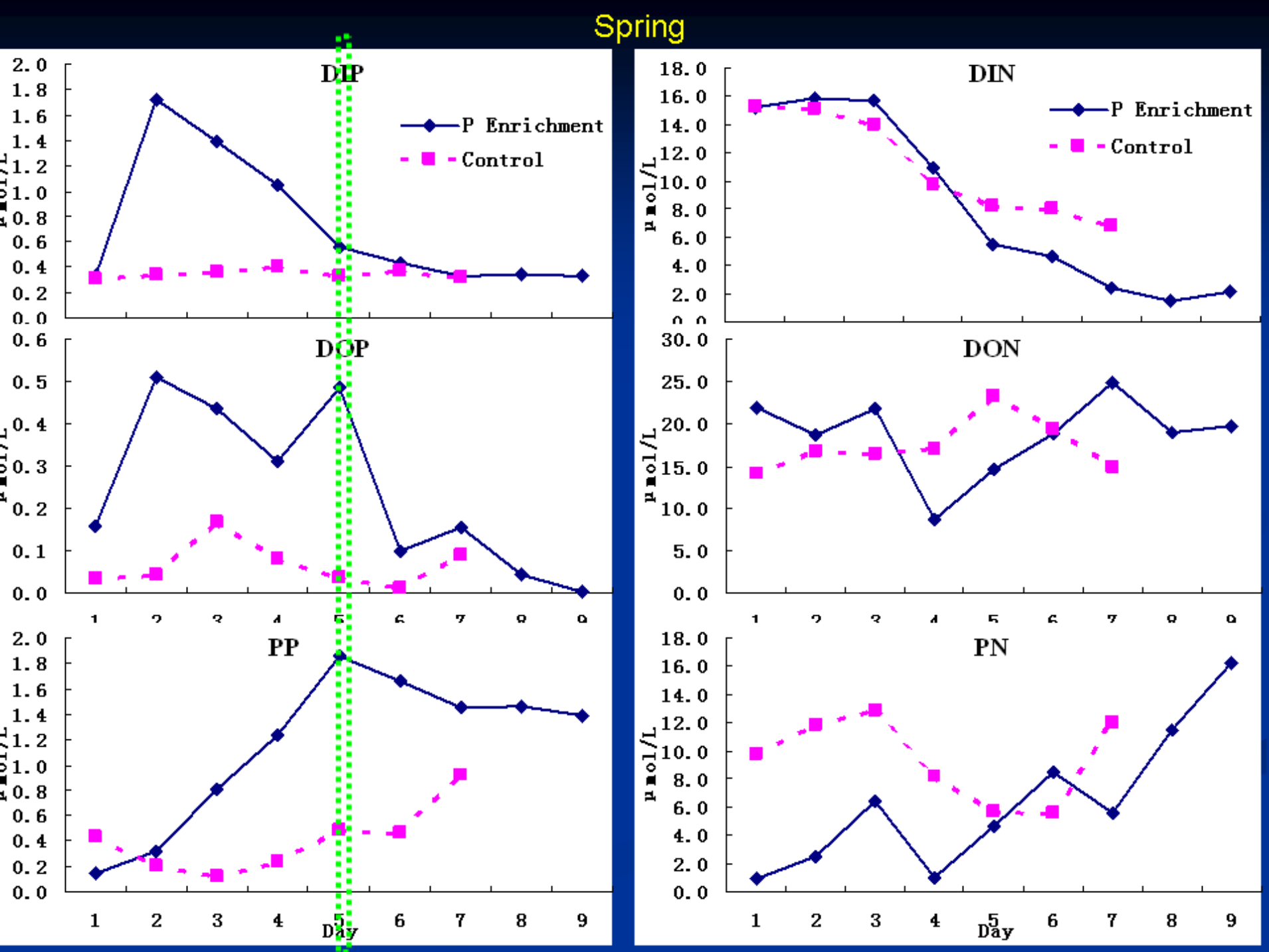

silicate Si
P-meso
Control
N/P 23.3→5.6
μmol/L
Day


Spring
PO4-p
P Enrichment
Control
B:0.33μmol/L
A:2.0μmol/L
μmol/L


NO3-N
μmol/L

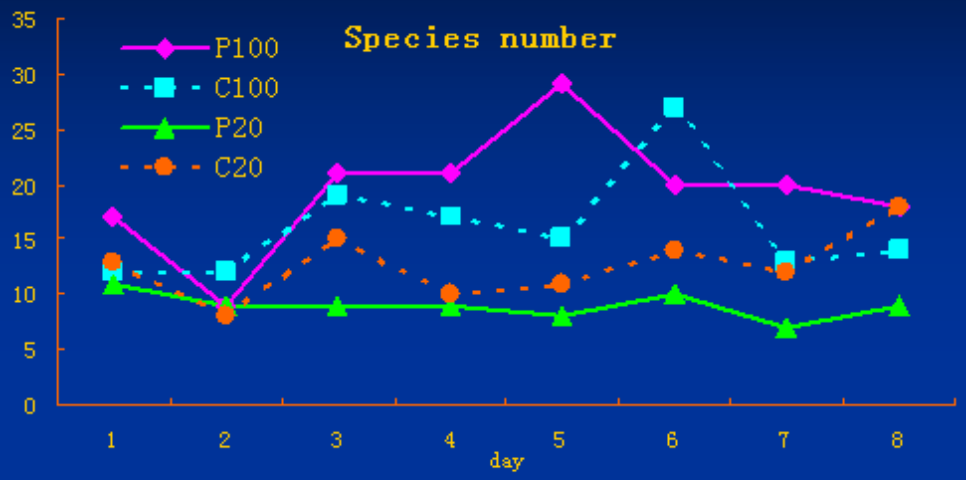

Si
N/P 46→9
μmol/L
Day


Autumn
DIP
P-meso
Control
μmol/L
DIN
P-meso
Control
μmol/L
DOP
P-meso
Control
DON
P-meso
Control
μmol/L
PP
P-meso
Control
μmol/L
PN
P-meso
Control
μmol/L
Day
Day

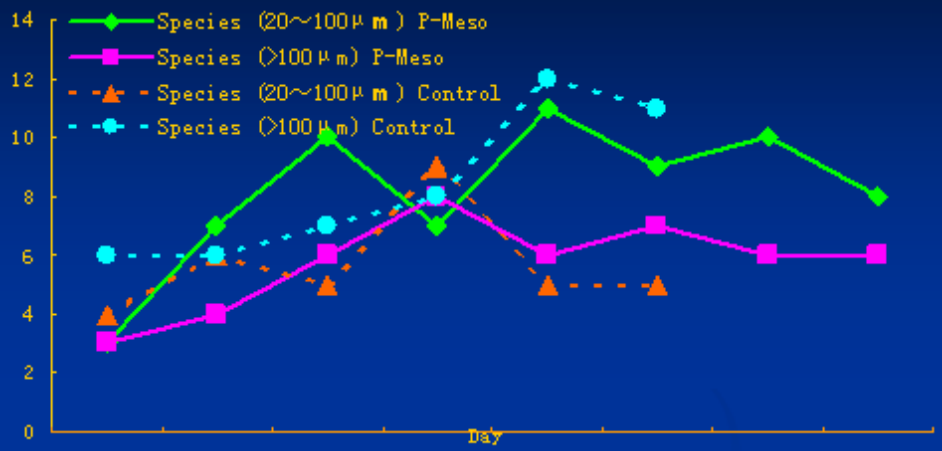

Spring
DIP
DIN
DOP
DON
PP
PN
P Enrichment
Control
μmol/L
Day

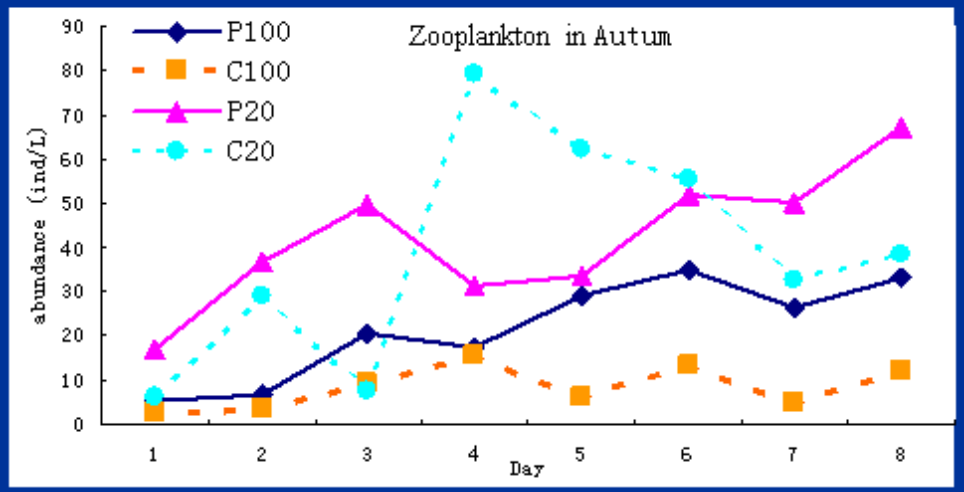
The response of microzooplankton and mesozooplankton to Phosphate enrichment

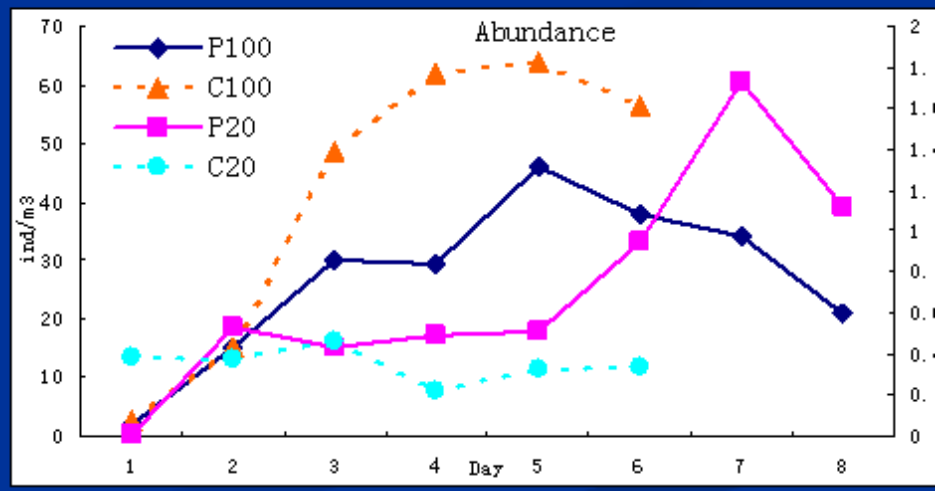
Autum



Spring



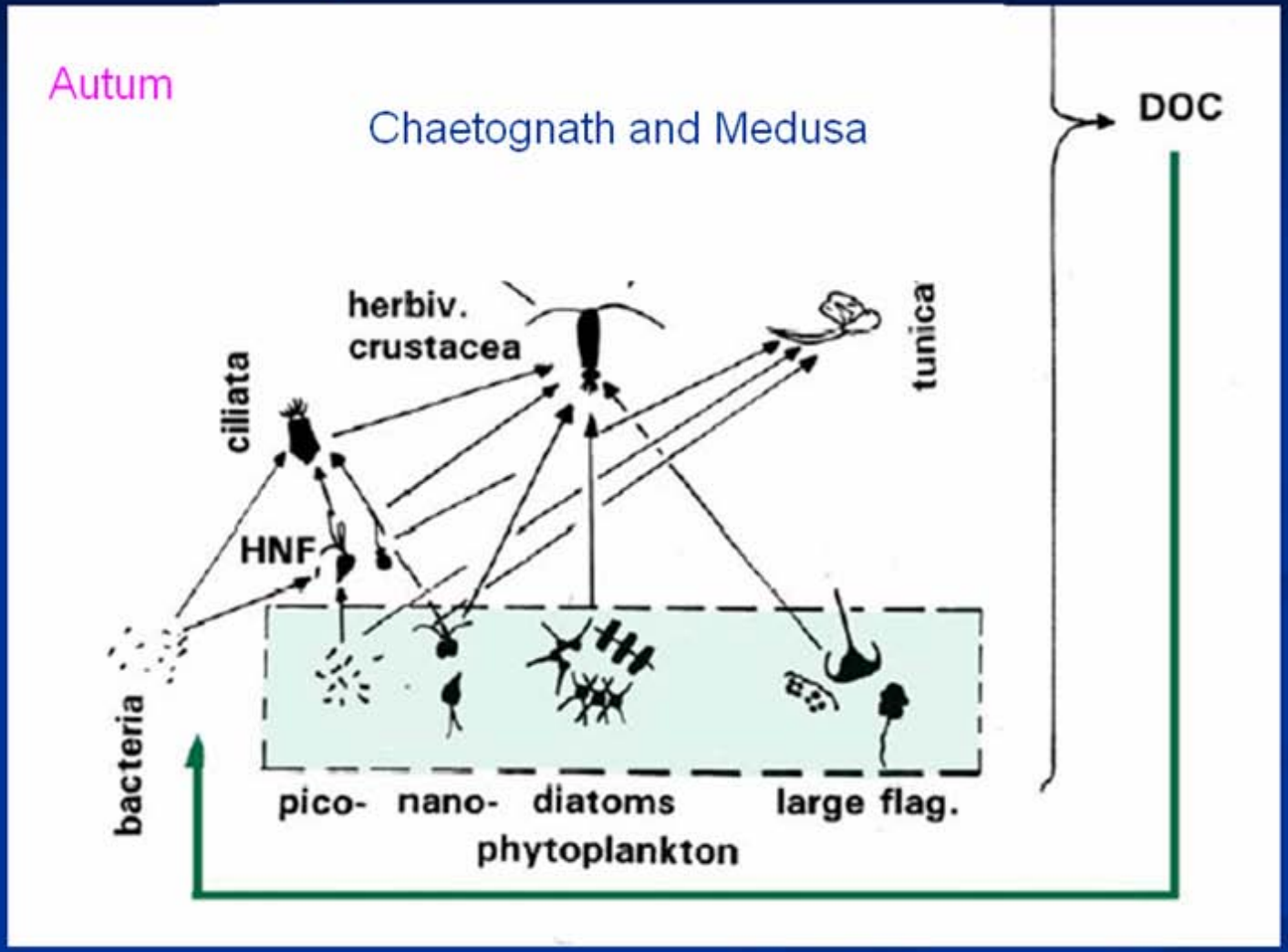




When diatom dominated, both micro- and meso-zooplankton benefit

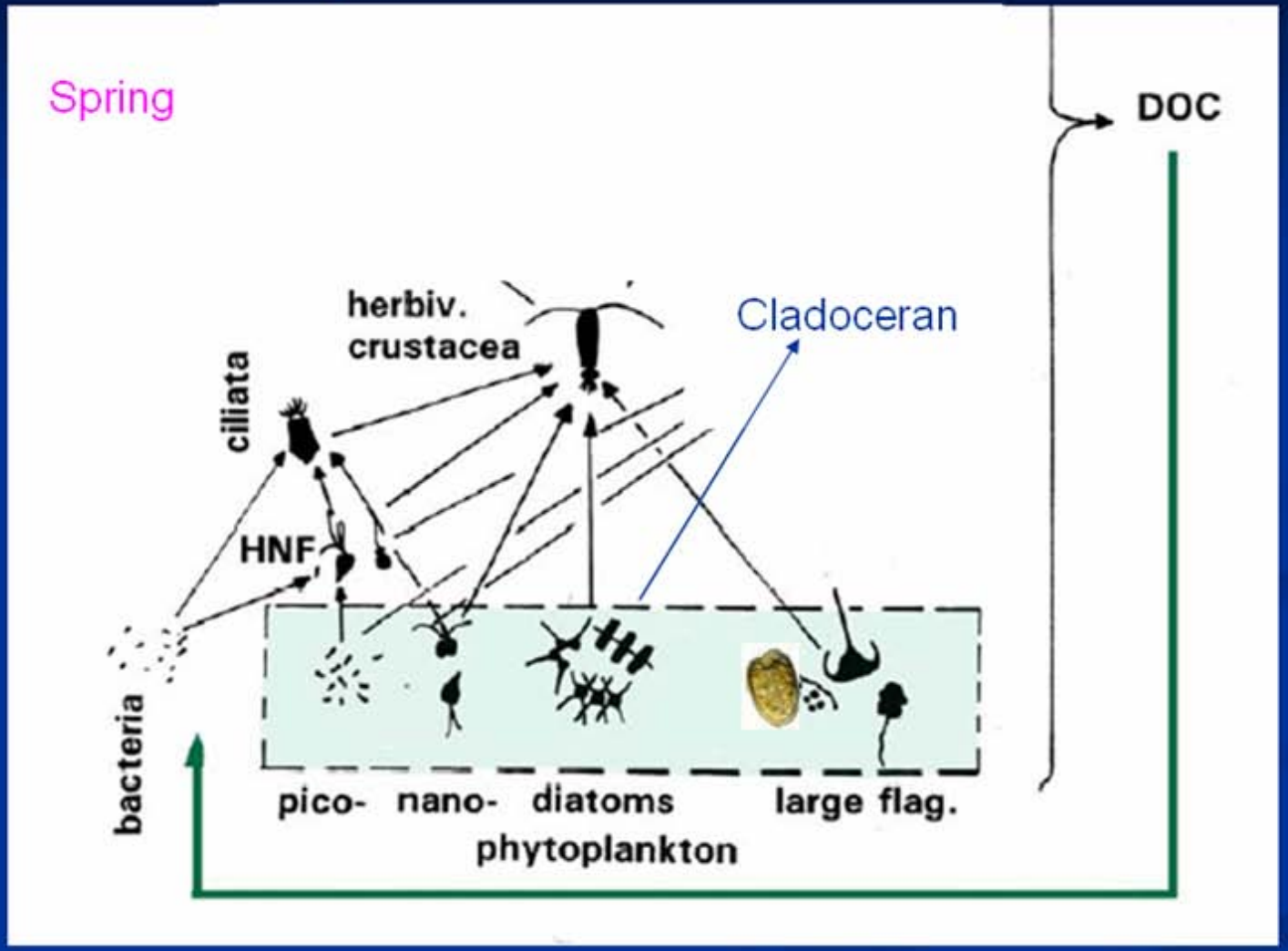
When dinoflagellate dominated, micro- benefit but the meso-zooplankton inhibited

Simplified food web in mesocosm



Food chain may be elongated as picoplankton- heterotrophic nanofalgellates-ciliates-zooplankton-predatory zooplankton

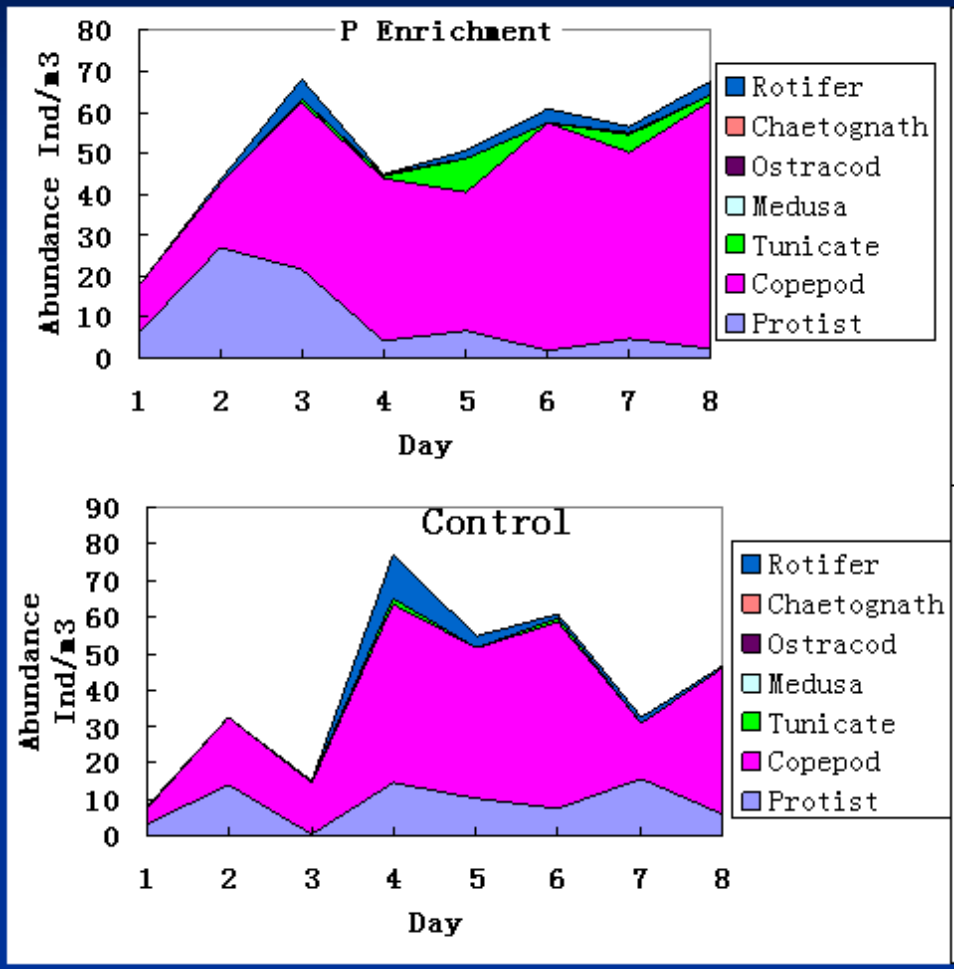
Simplified food web in mesocosm



Food chain may be elongated as picoplankton- heterotrophic nanofalgellates-ciliates-zooplankton-predatory zooplankton

Zooplankton communities in different food condition

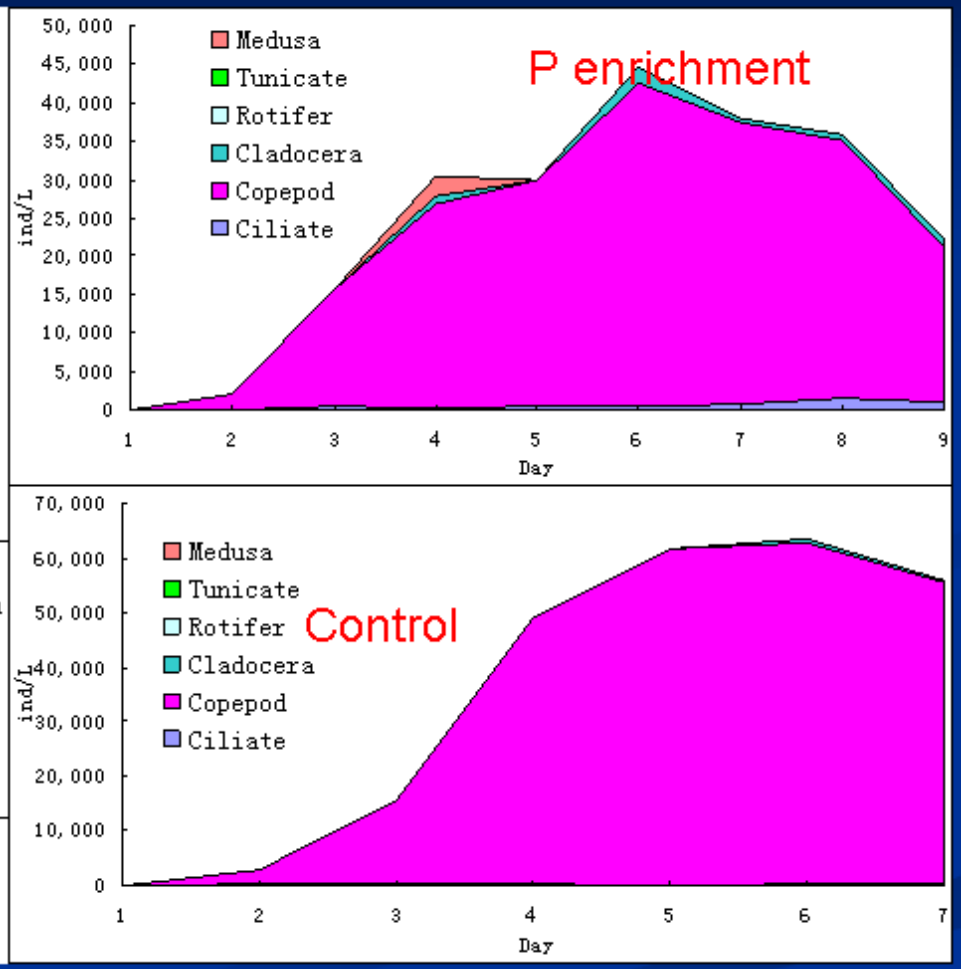
Autum



Ciliate↓ Copepoda↑ Rotifer↑ tunicate↑

Chaetognath and Medusa as the higher order counsumer

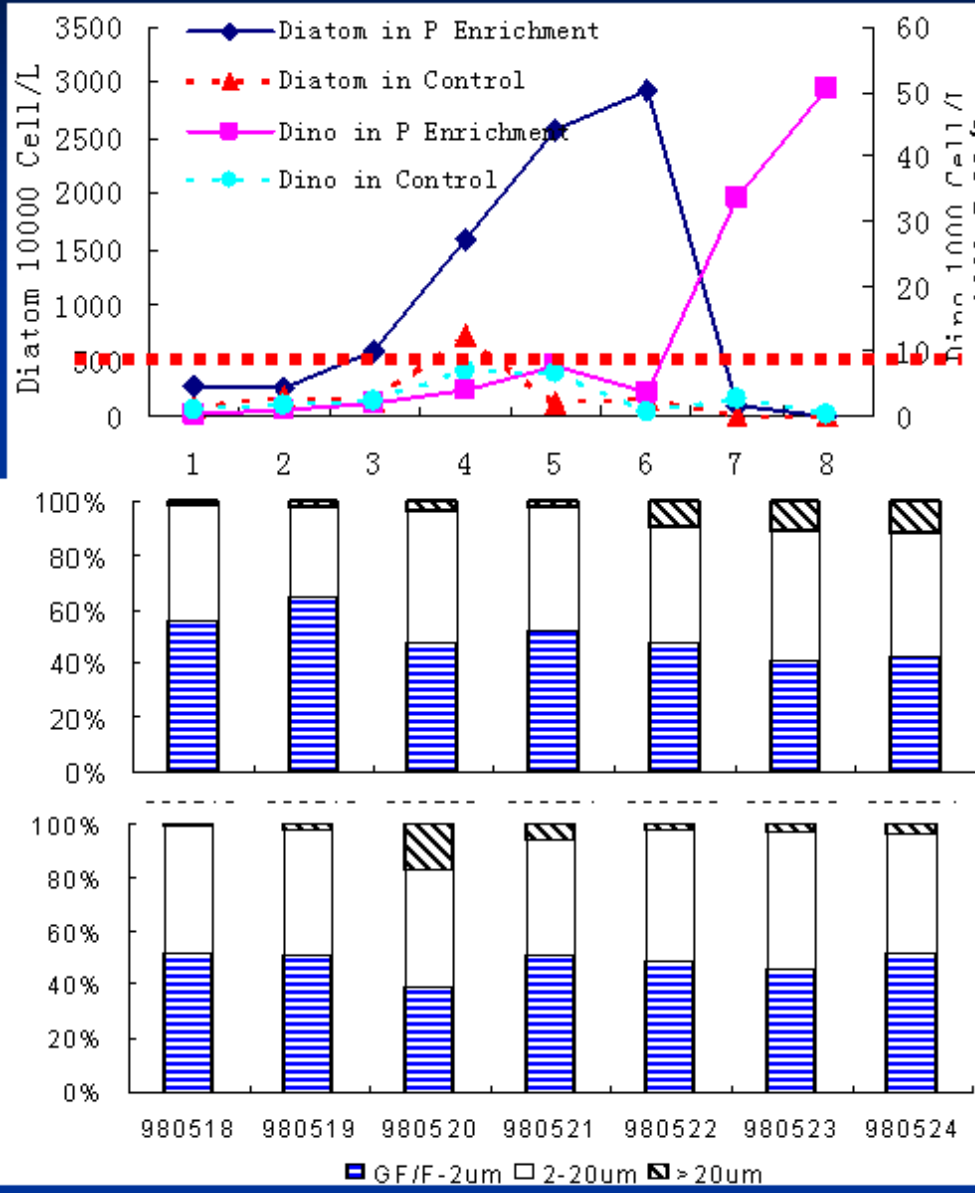
Spring

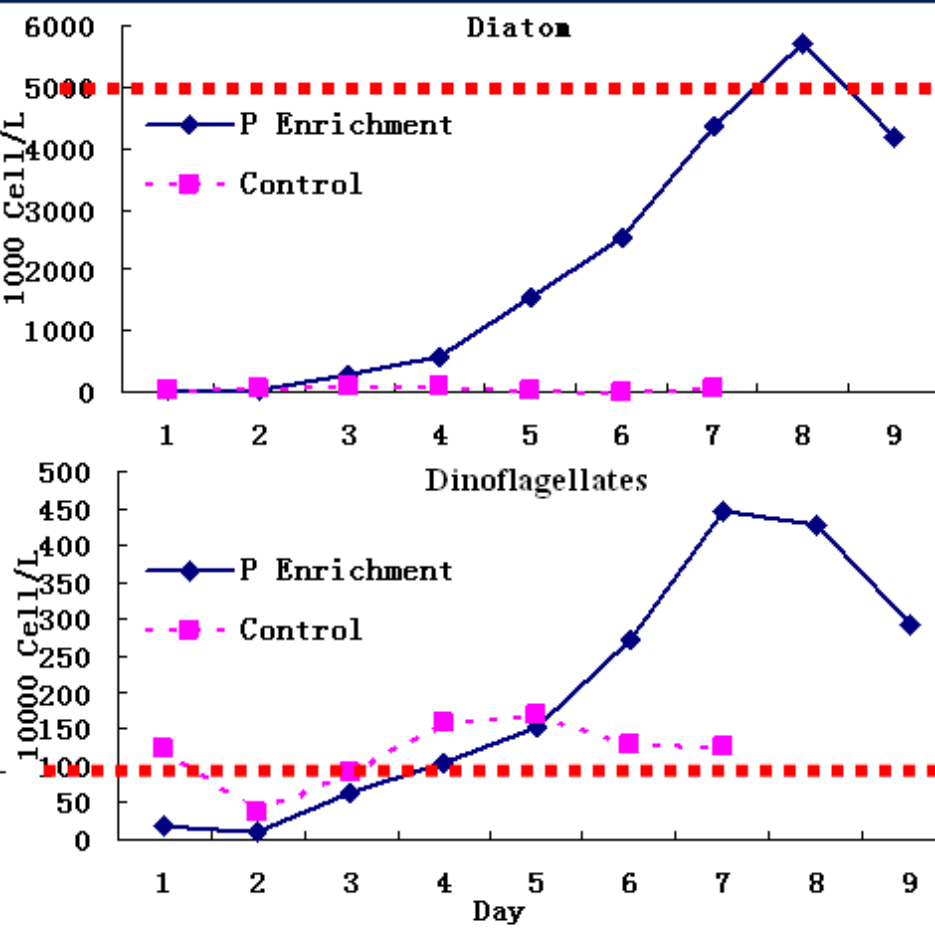


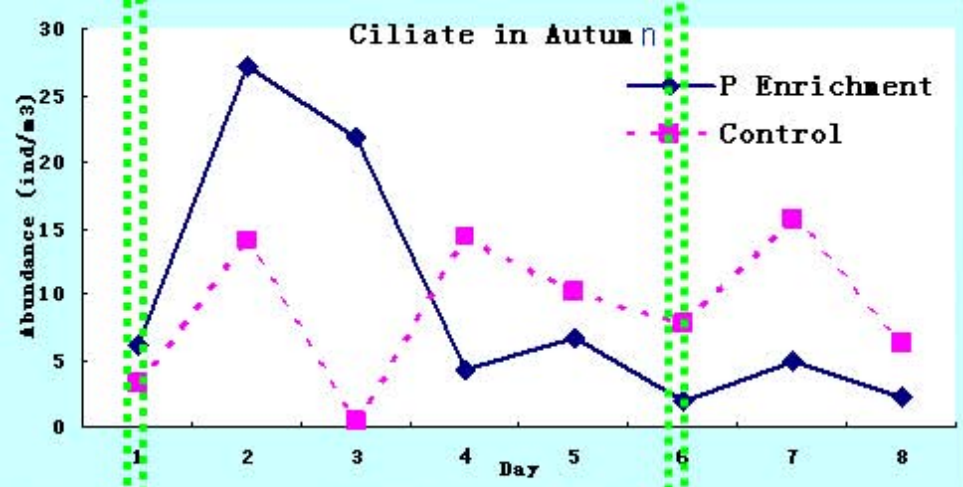
Ciliate↑ Copepoda↓ Cladoceran↑

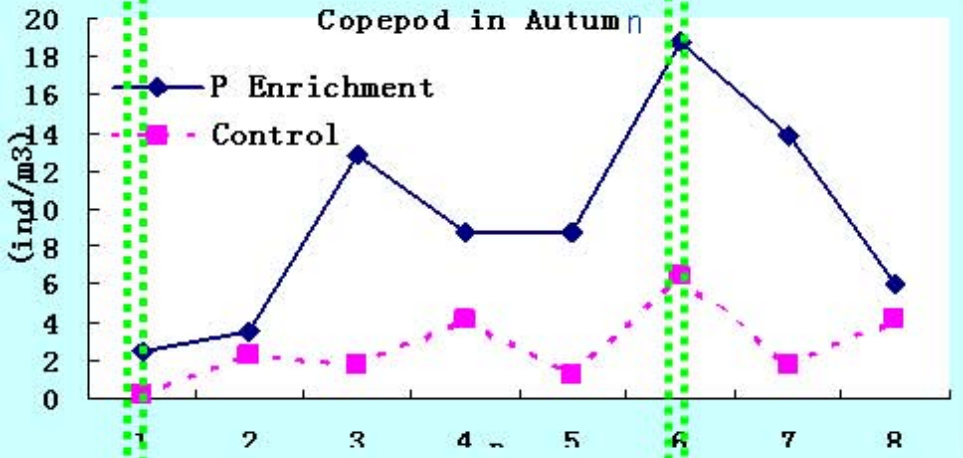
Cladoceran and Copepoda as the higher order counsumer

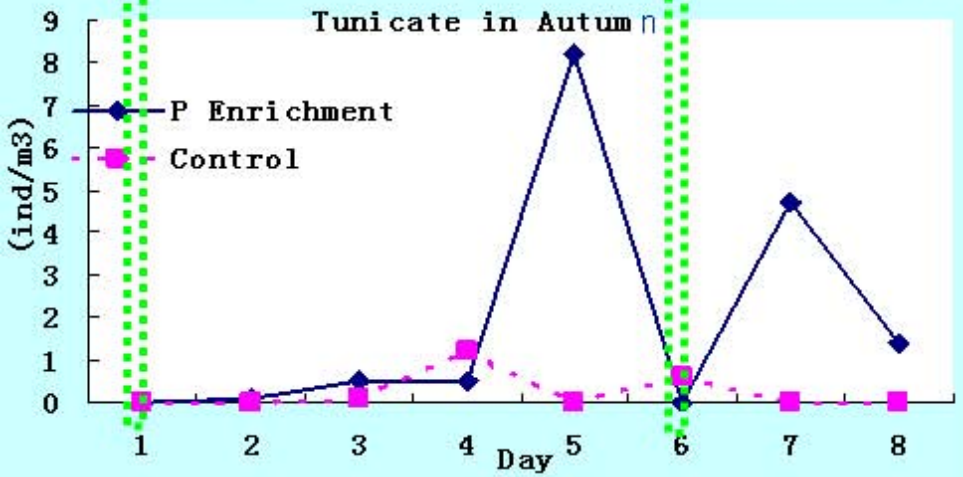
Food available and preferable is important for zooplankton

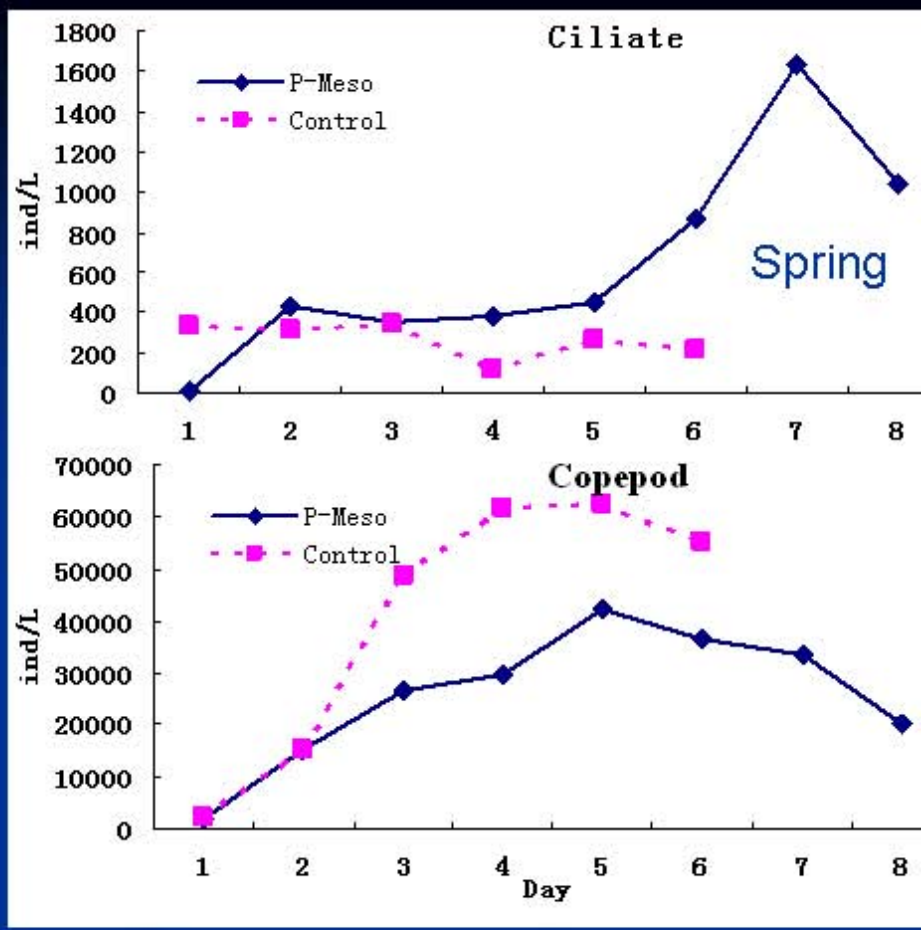


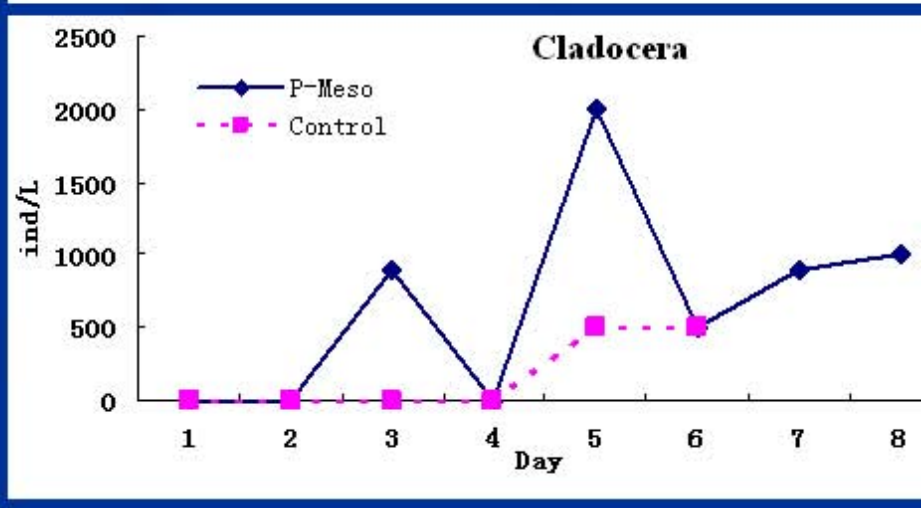



Ciliate in Autumn
P Enrichment
Control
Abundance (ind/m3)
Day

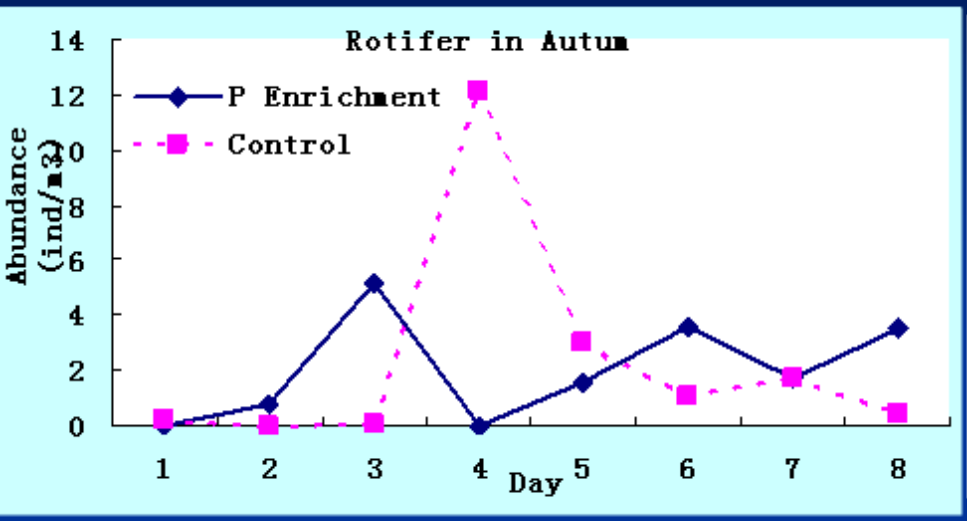

Copepod in Autumn
P Enrichment
Control
(ind/m3)


Tunicate in Autumn
P Enrichment
Control
(ind/m3)
Day

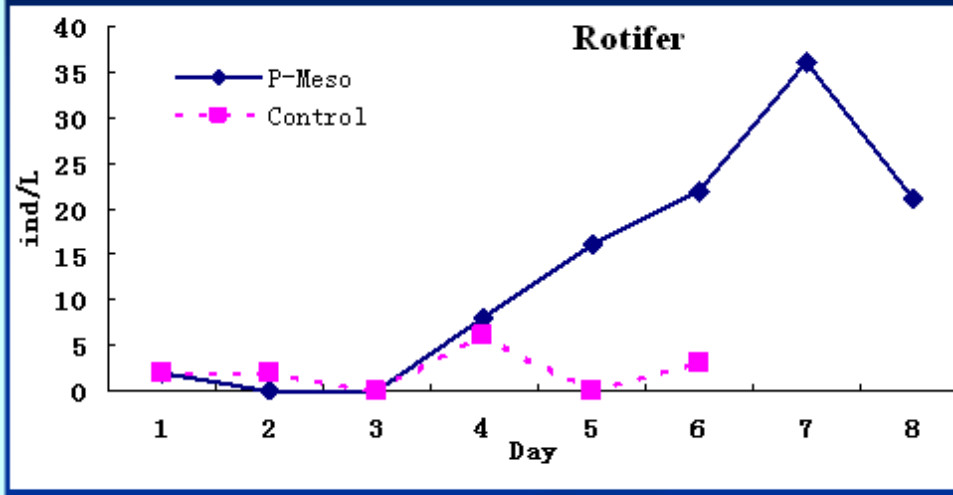

Ciliate
P-Meso
Control
ind/L
Spring
Copepod
P-Meso
Control
ind/L
Day


Cladocera
P-Meso
Control
ind/L
Day

Autumn



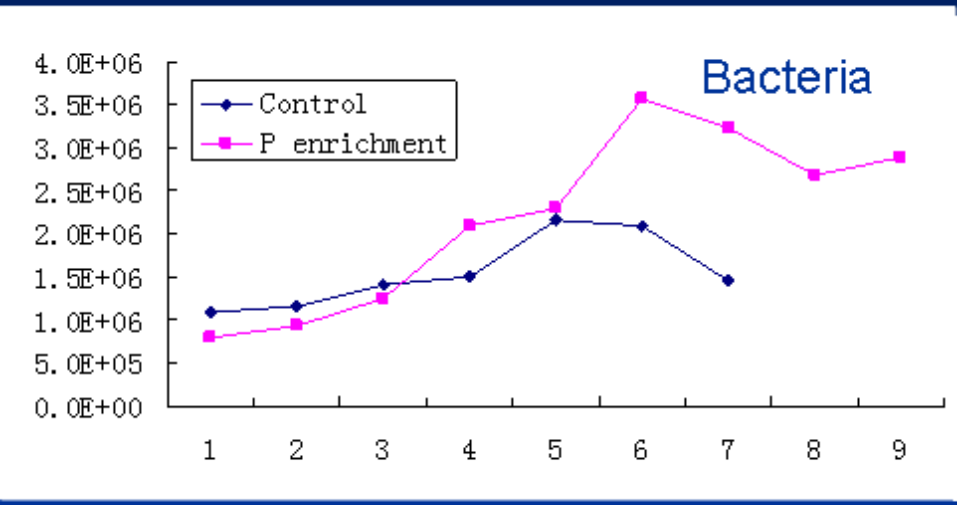
Spring

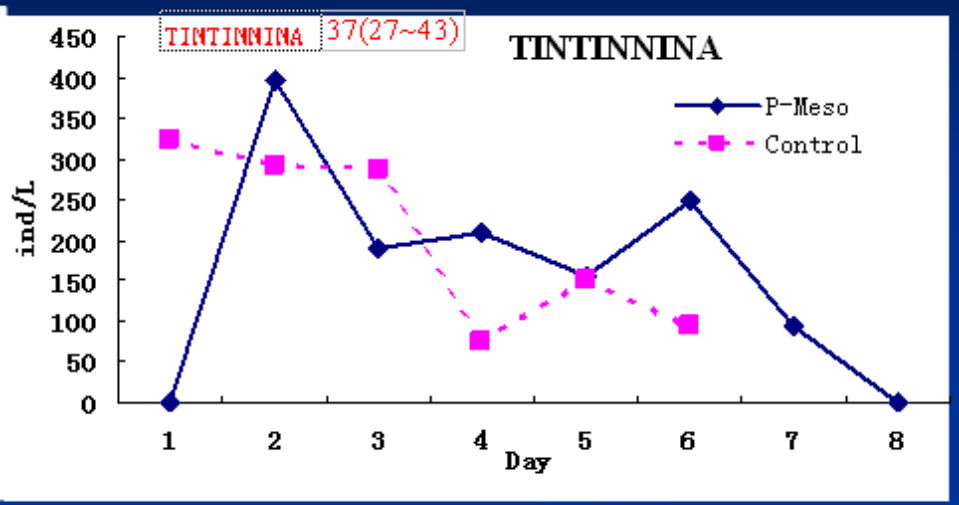


The rotifer graze Ciliate and dinoflagellate.

The rotifer and copepoda can somewhat co- occurrence due to the different food source

The affects of Phosphate enrichment on Ciliate





Earlier research shows:

Oligotrichous naked ciliates consume particles (0.5–10 μ m).

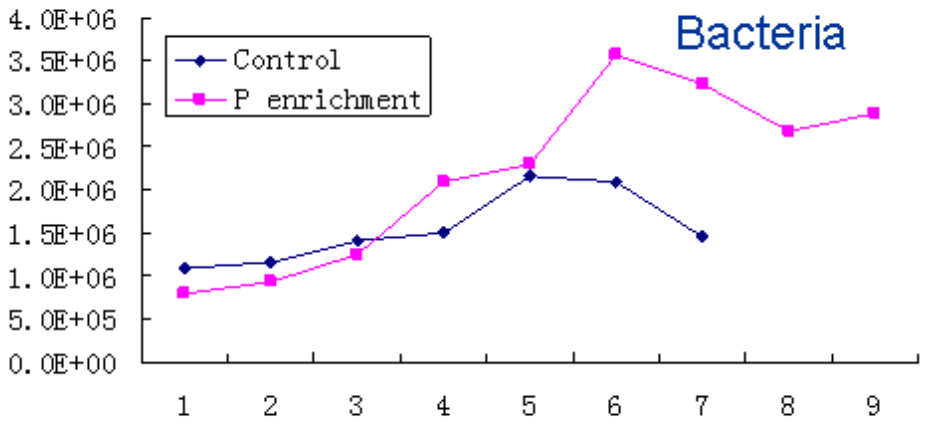
Ciliates < 30 μ m take 72% picoplankton and 28% nanoplankton.

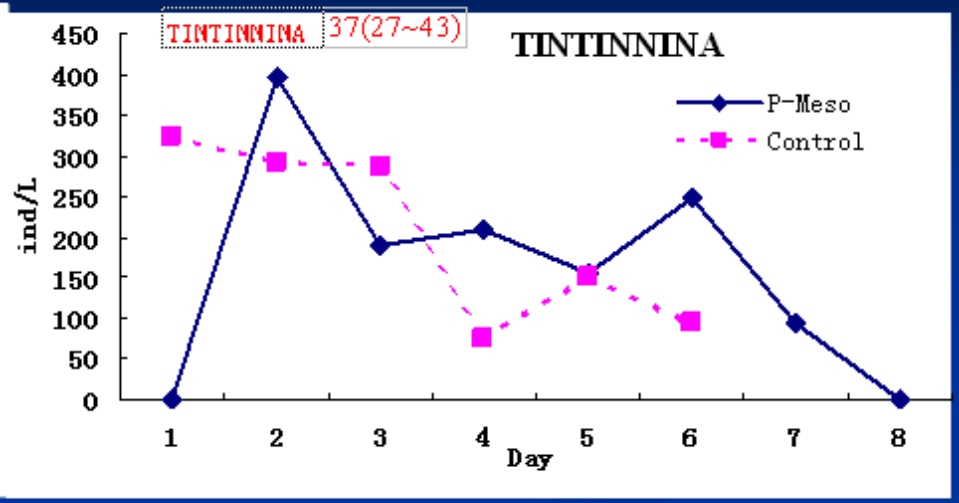
ciliates (30 μ m ~50 μ m) take (30% pico- and 70% nanoplankton),

larger ciliates (> 50 μ m) take nanoplankton almost exclusively (95% nano- and 5% picoplankton).

. Rassoulzadegan, M. Laval-Peuto and R. W. Sheldo, Partitioning of the food ration of marine ciliates between pico- and nanoplankton , Hydrobiologia, 1988,Vol159(1)

The affects of Phosphate enrichment on Ciliate





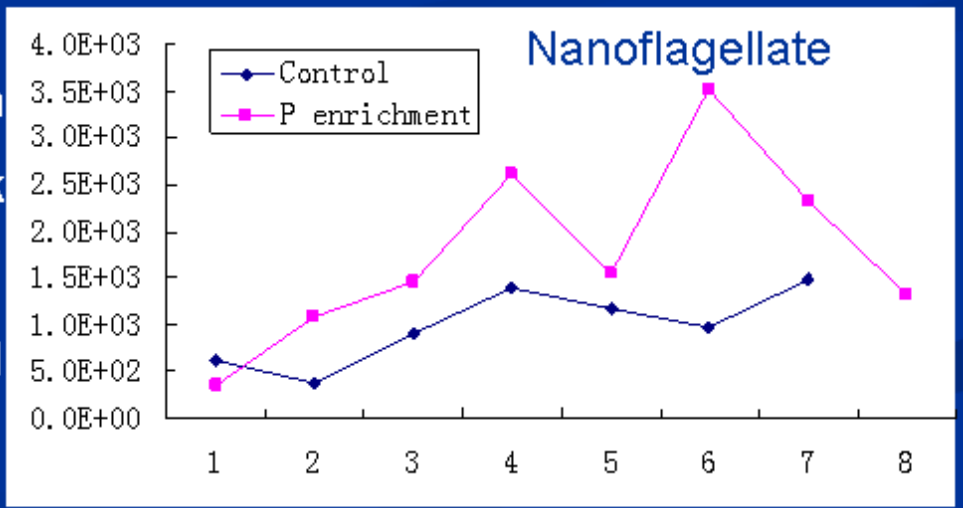
Earlier research shows:

Oligotrichous naked ciliates consum

Ciliates < 30 μ m take 72% picoplank

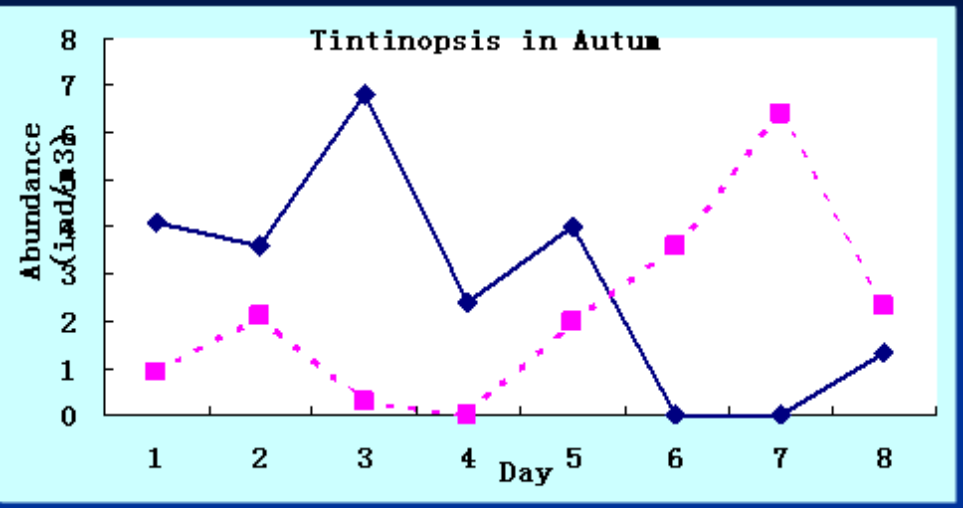
ciliates (30 μ m ~50 μ m) take (30%

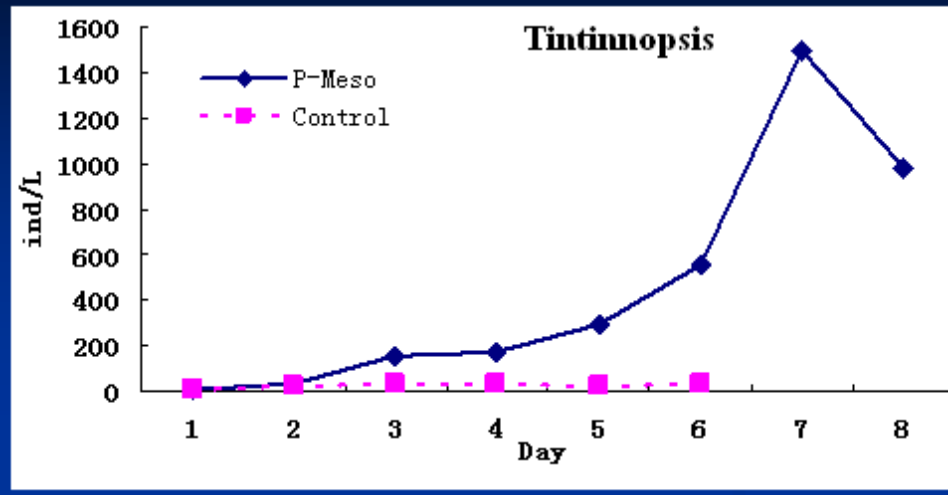
larger ciliates (> 50 μ m) take nanopl and 5% picoplankton).

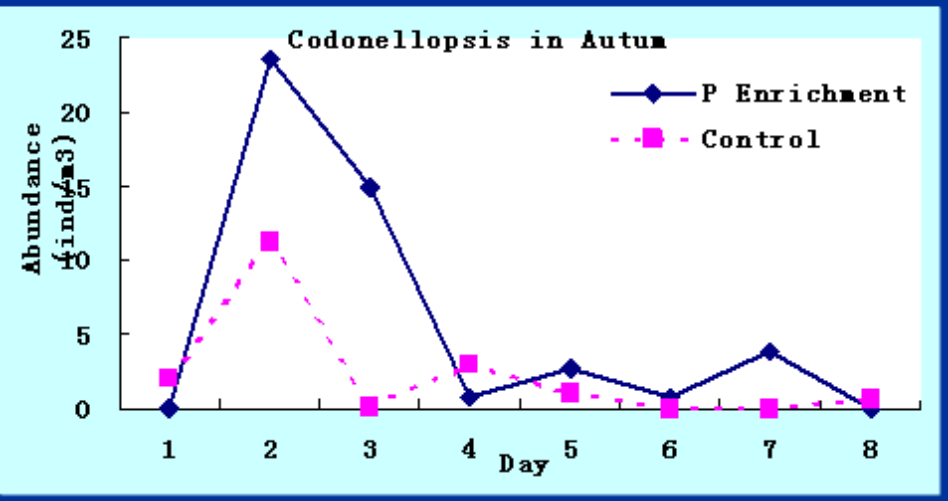


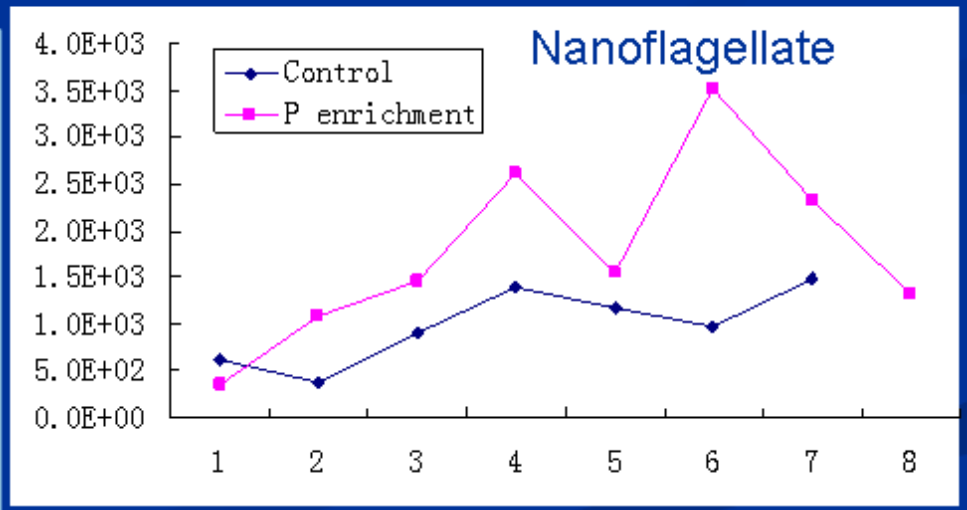
. Rassoulzadegan, M. Laval-Peuto and R. W. Sheldo, Partitioning of the food ration of marine ciliates between pico- and nanoplankton , Hydrobiologia, 1988,Vol159(1)

The affects of Phosphate enrichment on Ciliate

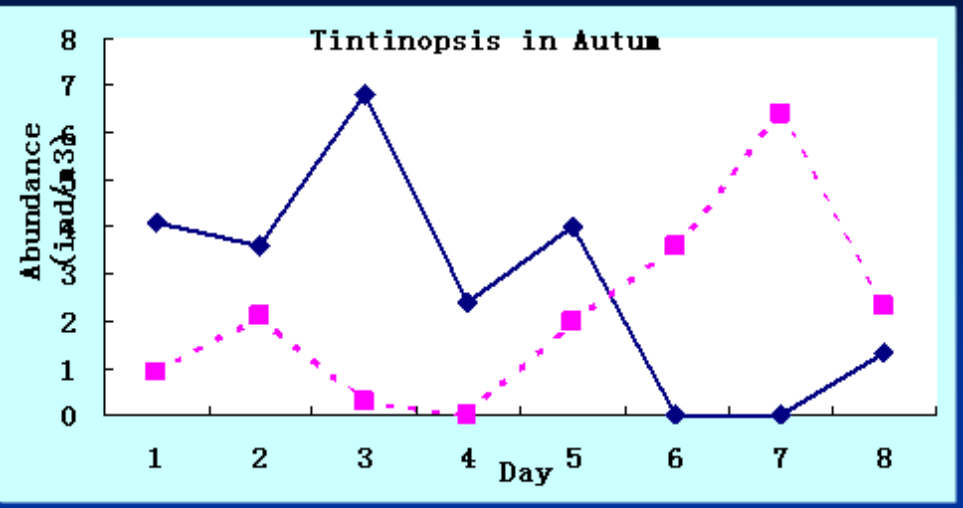


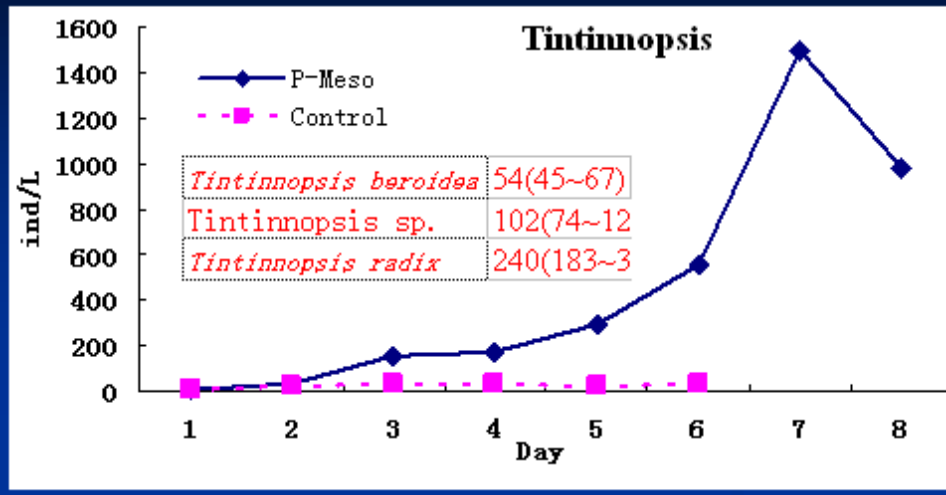


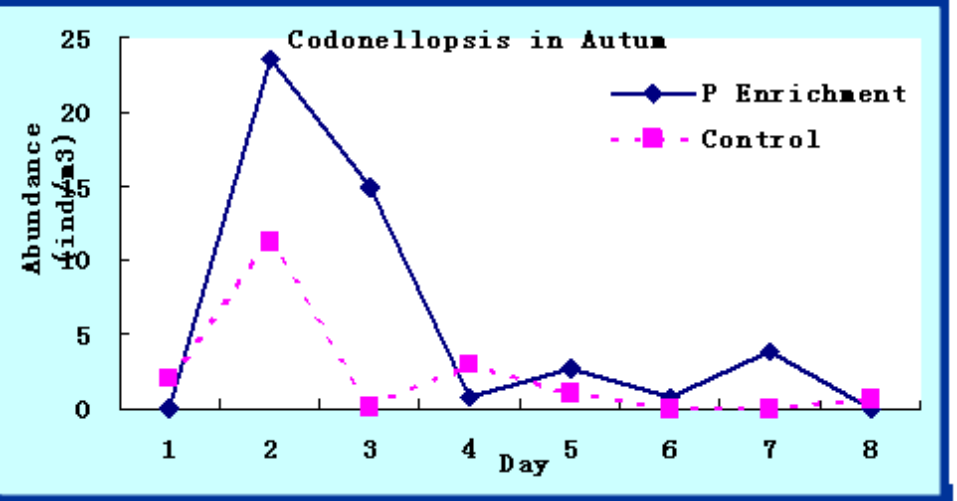


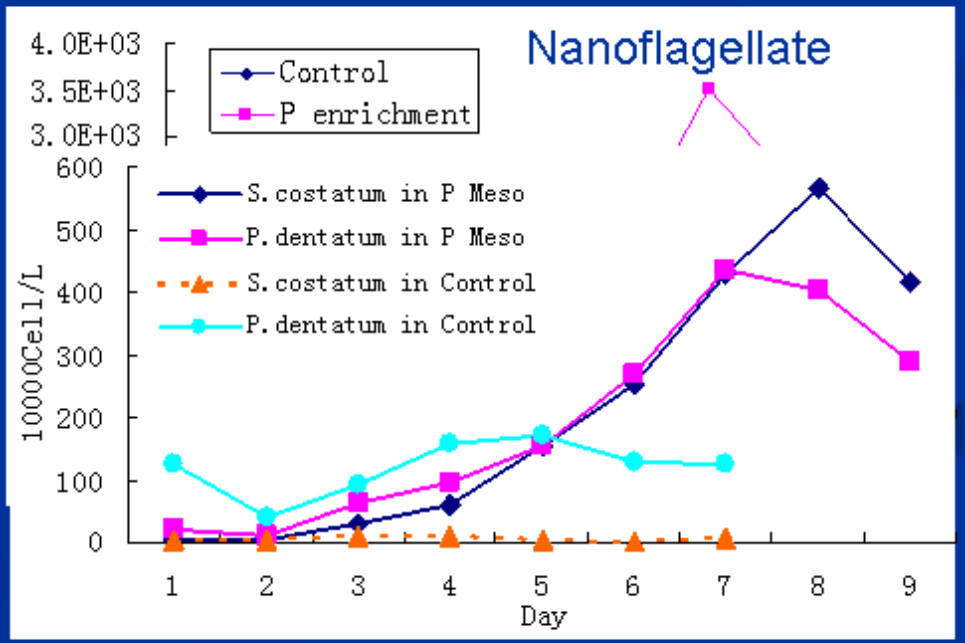


The affects of Phosphate enrichment on Ciliate

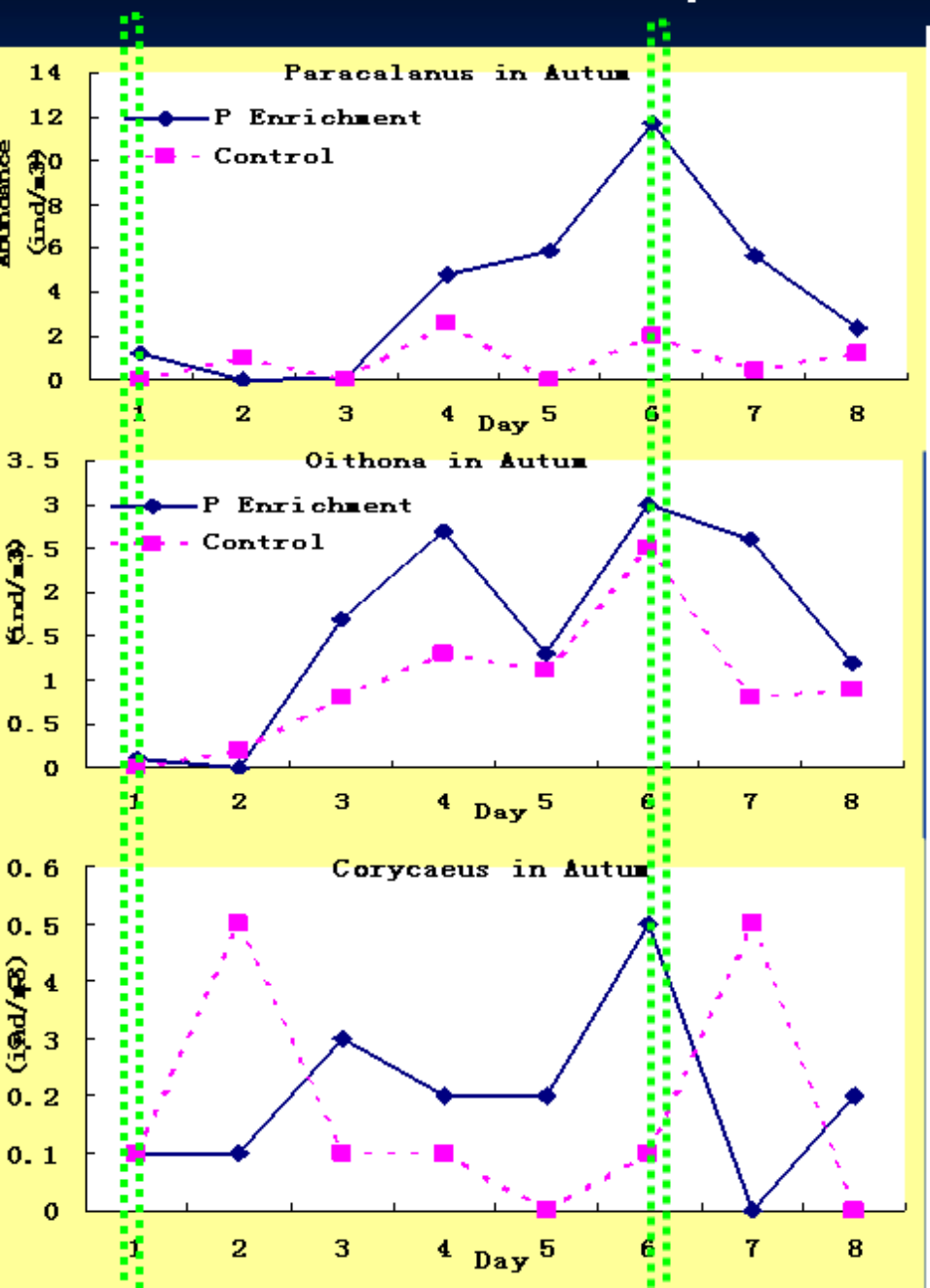


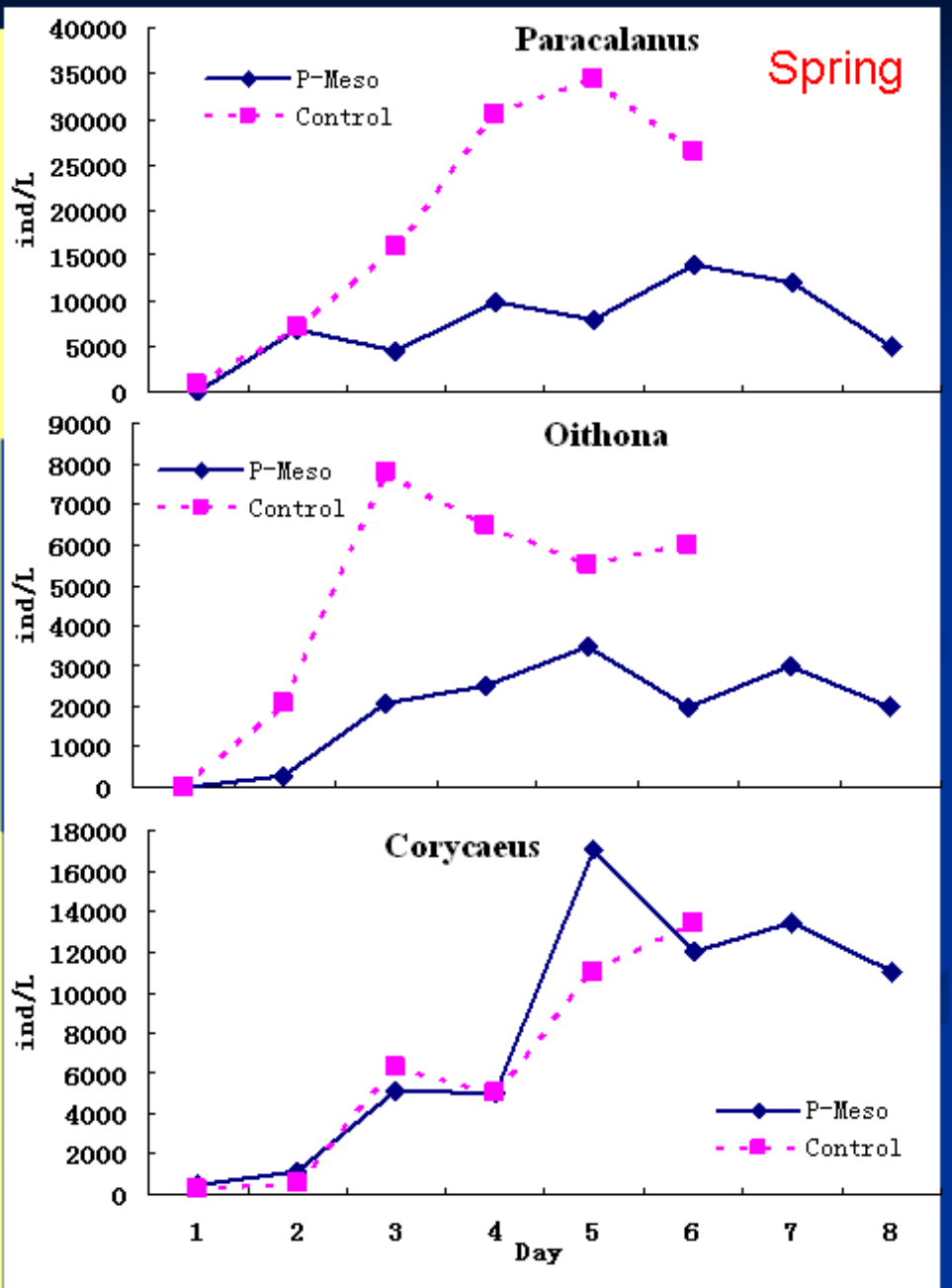




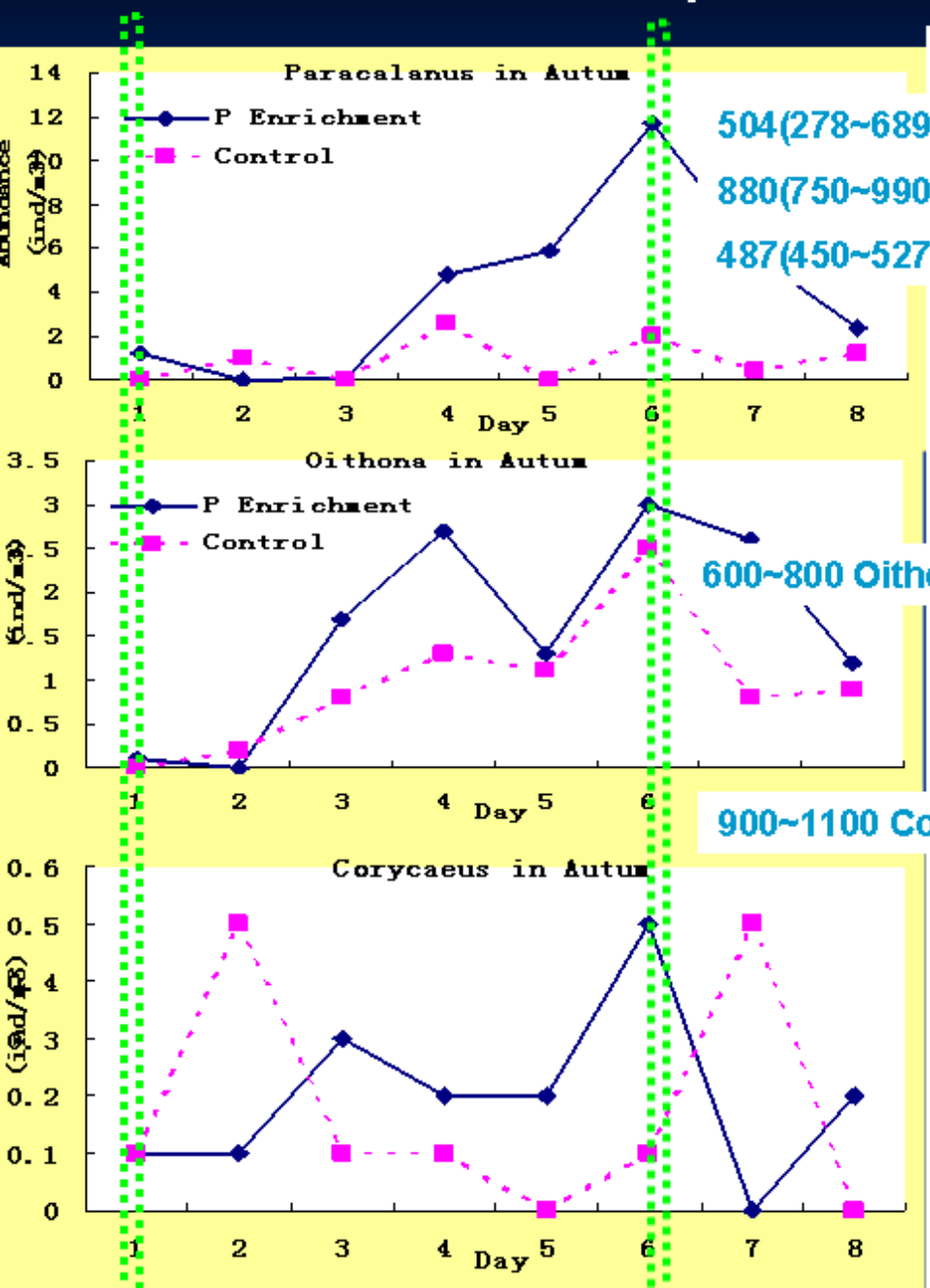


The affects of Phosphate enrichment on COPEPODA





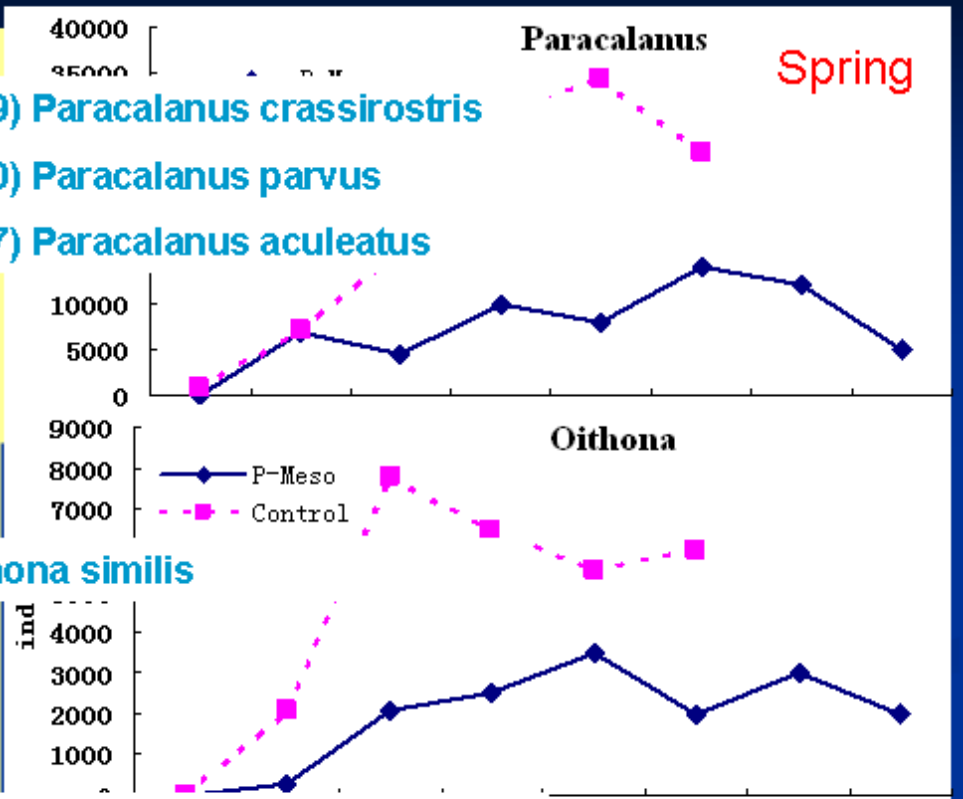
The affects of Phosphate enrichment on COPEPODA



504(278~689) Paracalanus crassirostris

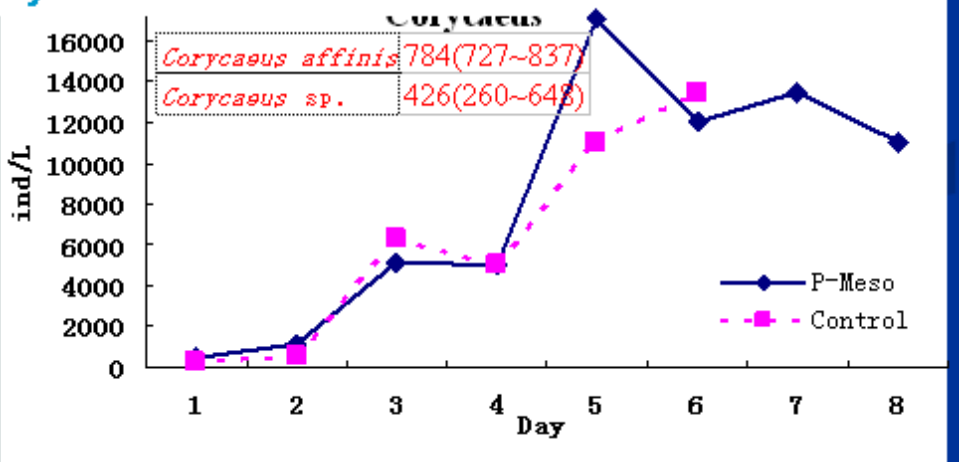
880(750~990) Paracalanus parvus

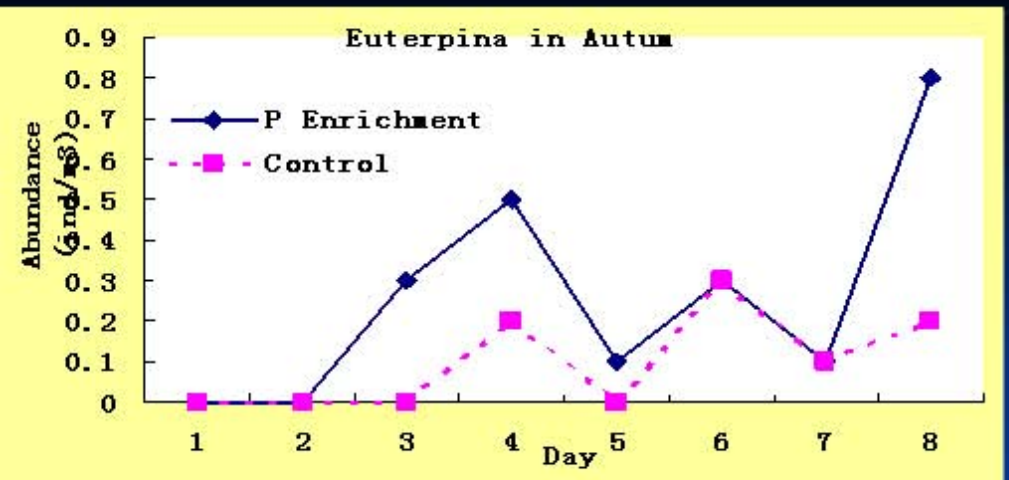
487(450~527) Paracalanus aculeatus

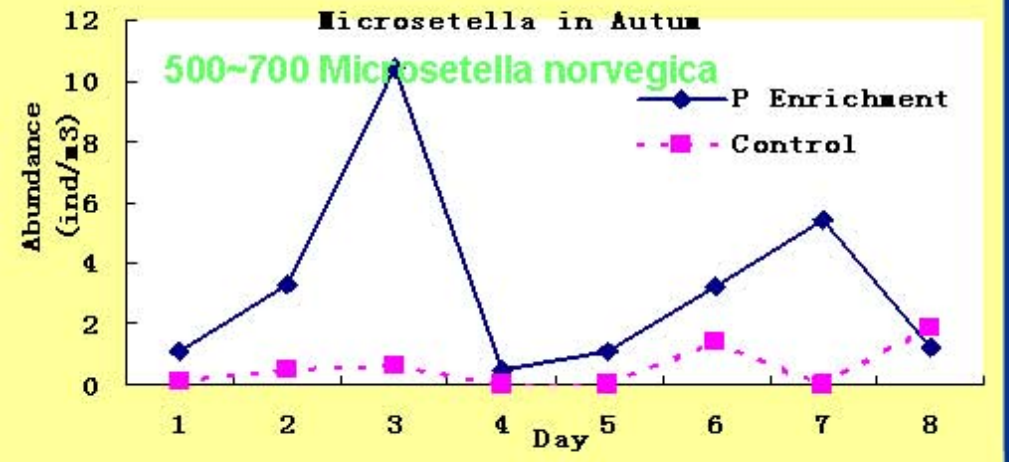


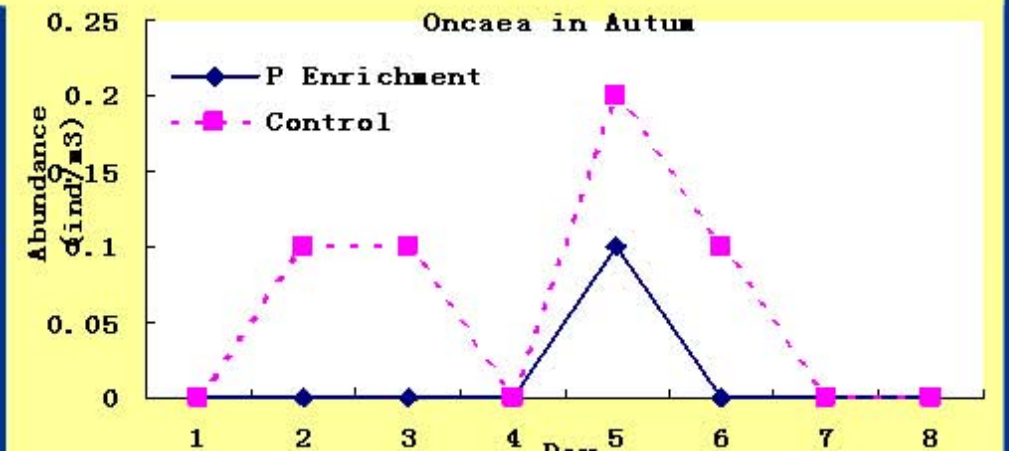
600~800 Oithona similis

900~1100 Corycaeus





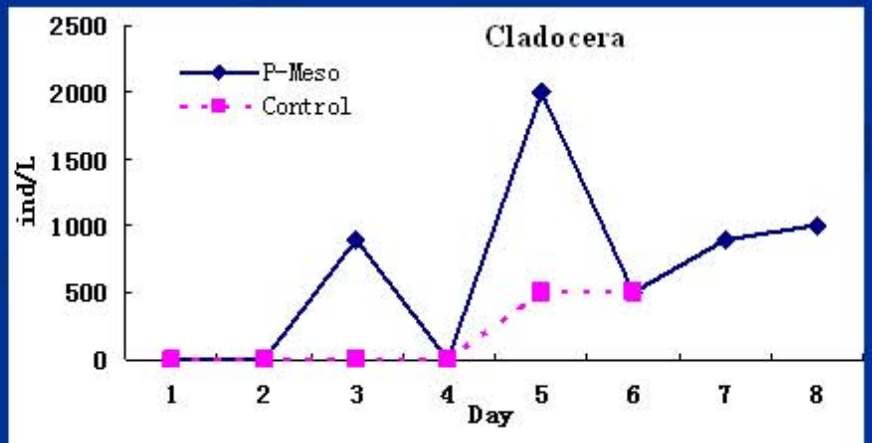




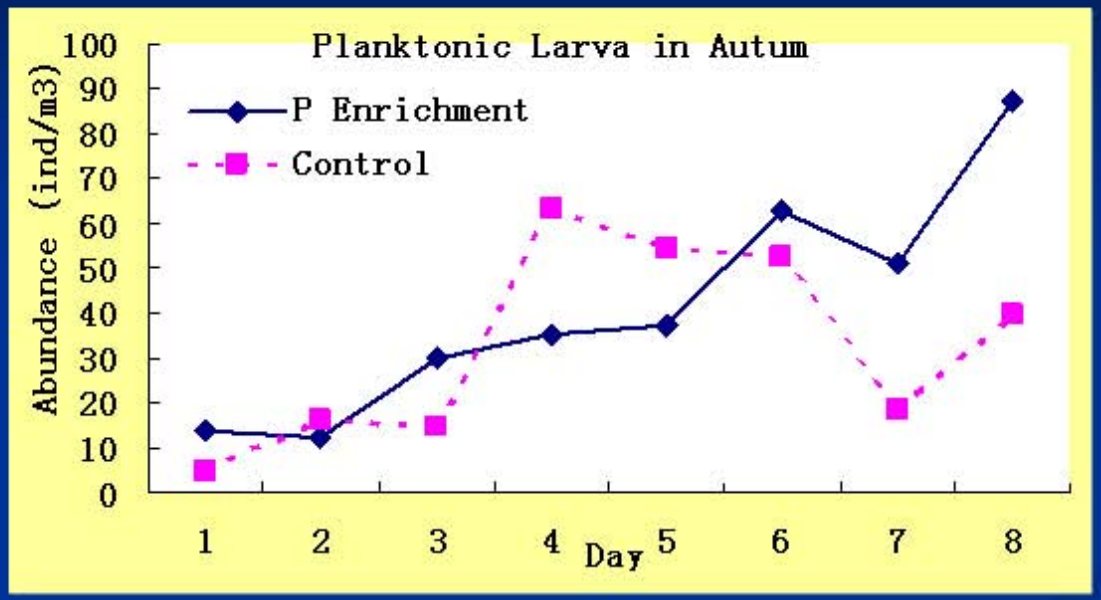
The Oncaea is not like other copepodas benefiting rapidly from the increasing diatom but lagged.

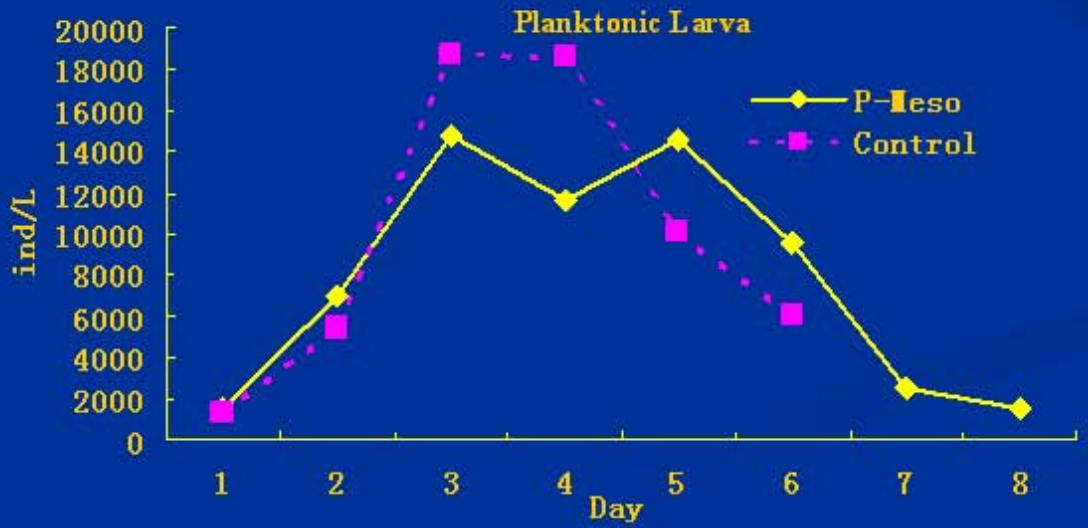
Some researches indicate marine snow are important food source for *Oncaea*, whose feeding appendages are suited to scraping the particles .

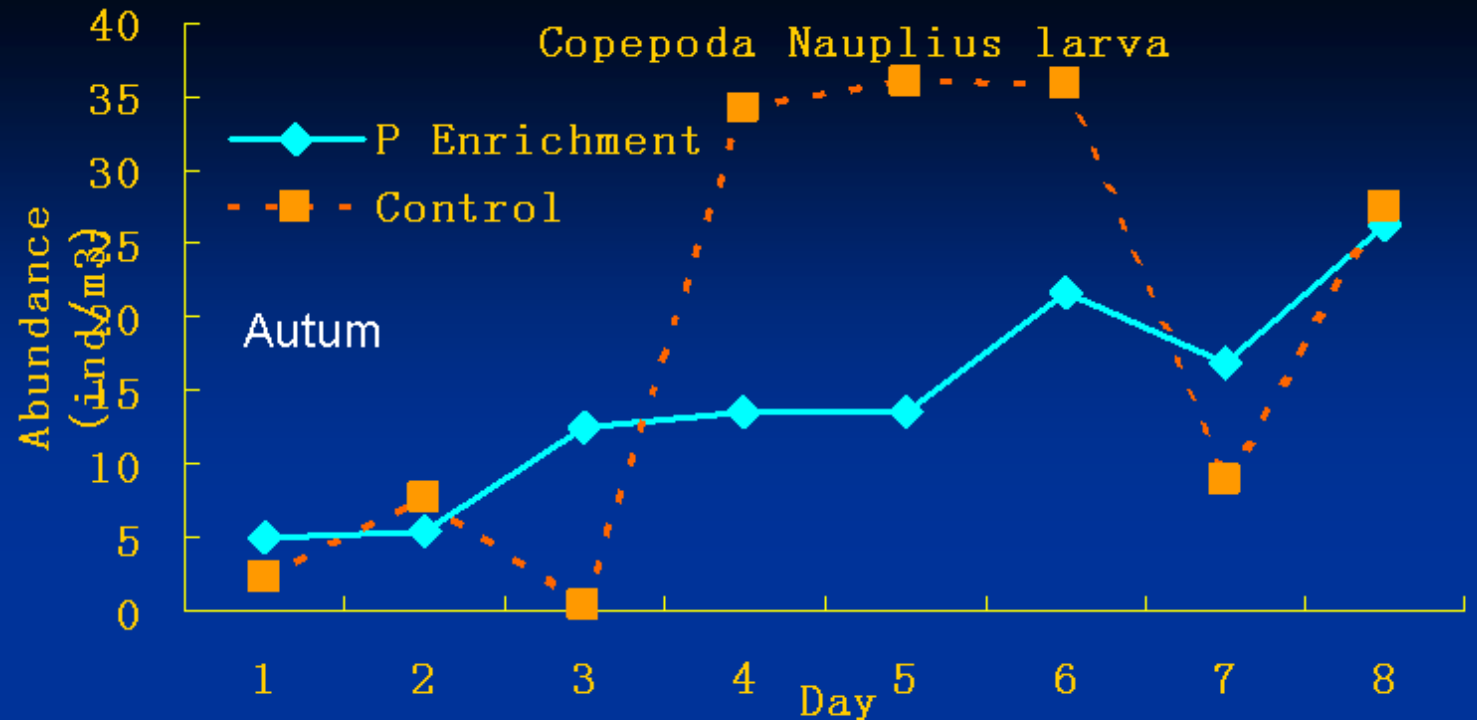
Our study shows correlation of *Oncaea* and Cladoceranindicate possible trophic association between the two groups of organisms

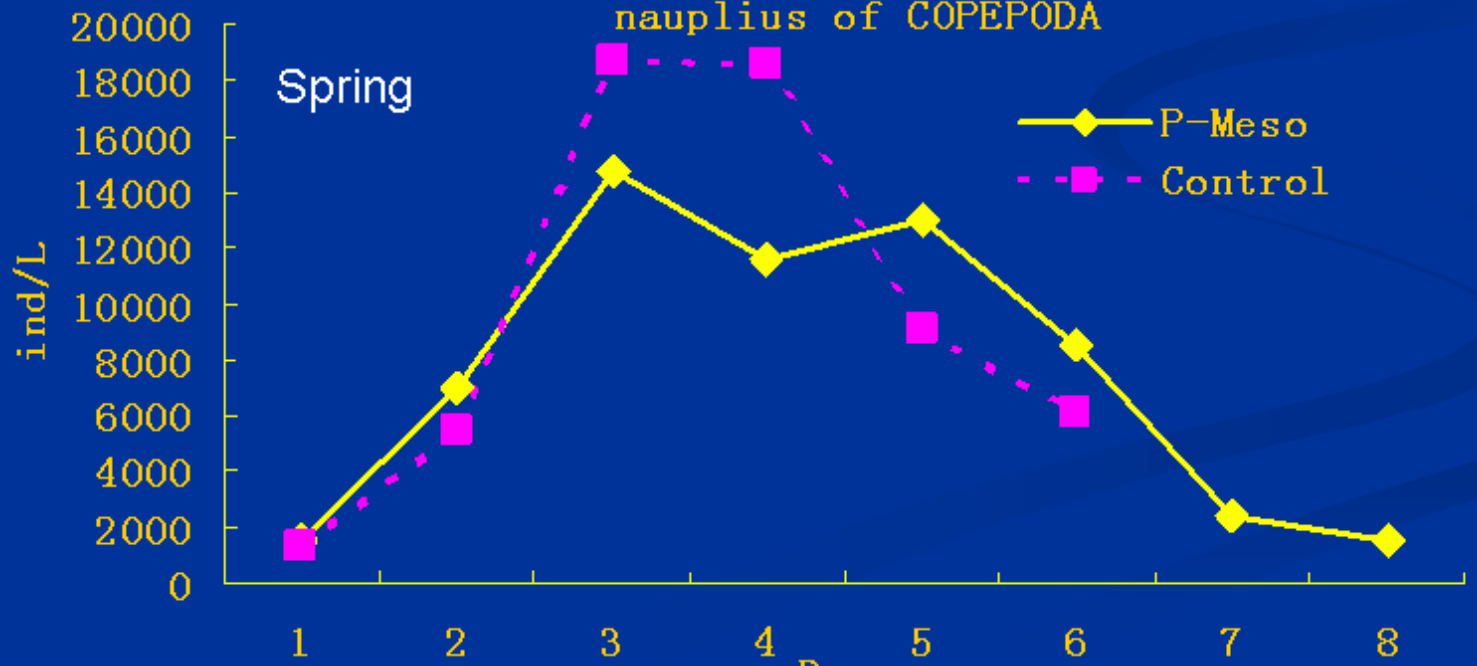


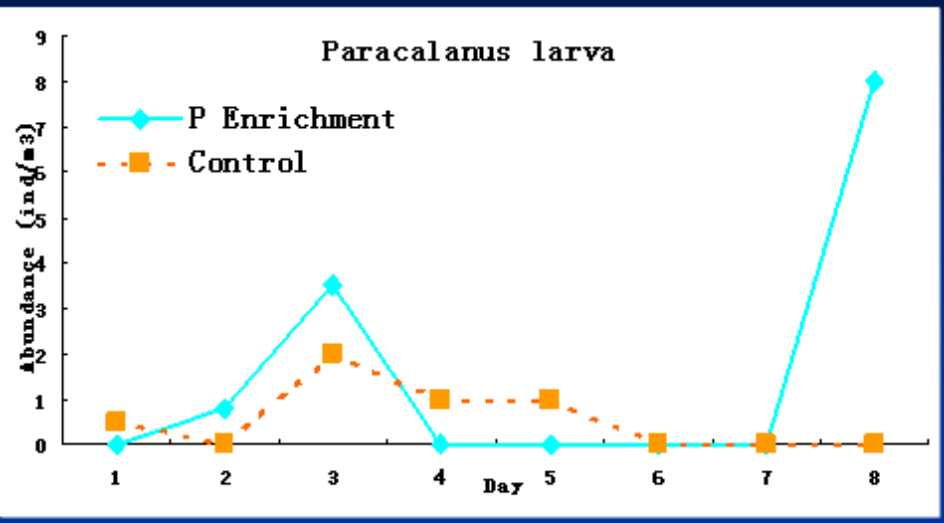
The affects of Phosphate enrichment on Larva

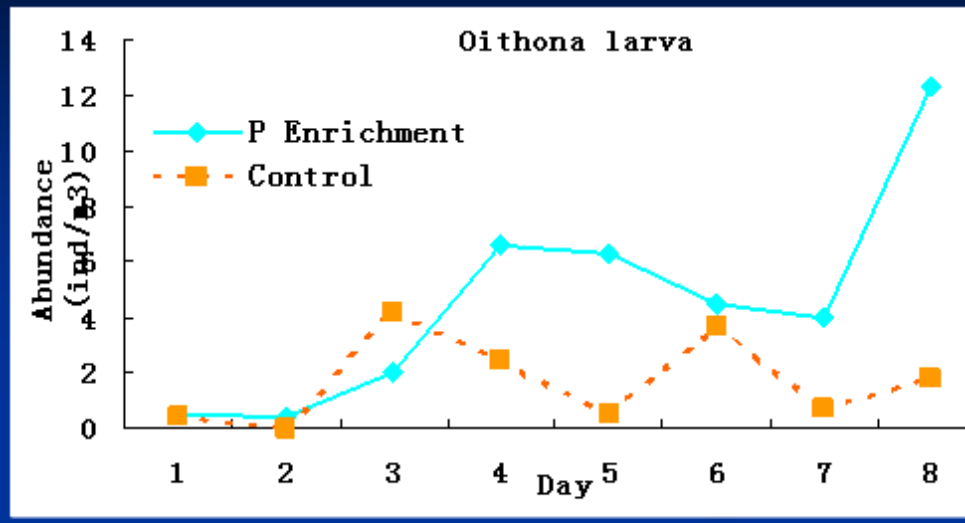


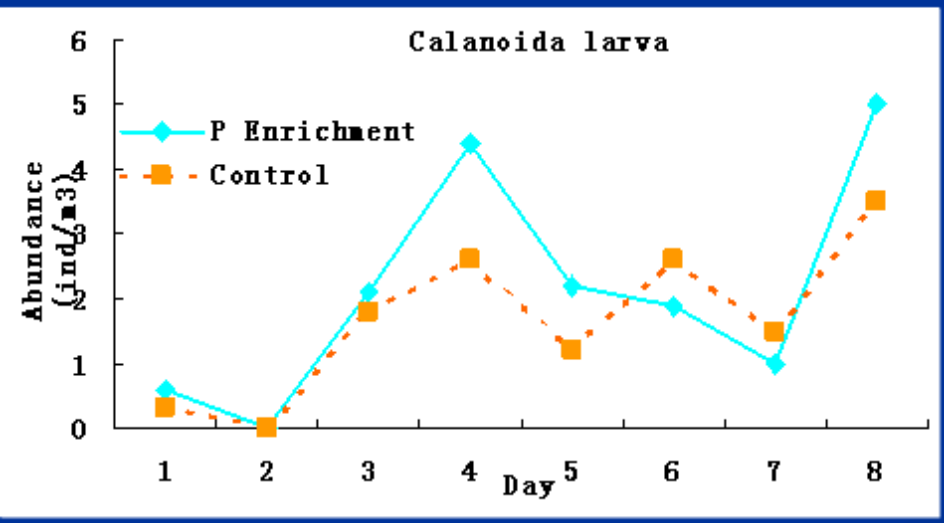


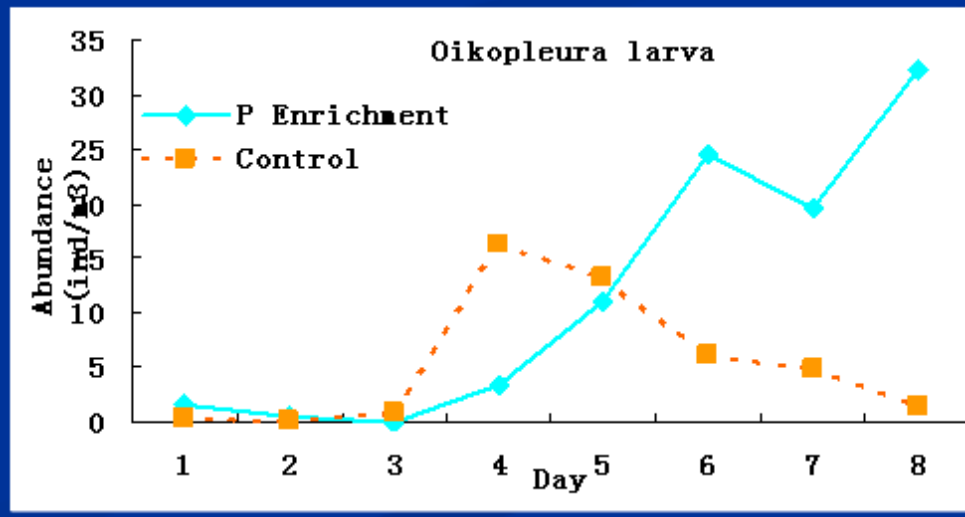

Copepoda Nauplius larva
P Enrichment
Control
Autum
Abundance (ind/m3)
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
Day


nauplius of COPEPODA
Spring
P-Meso
Control
ind/L
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1
2
3
4
5
6
7
8

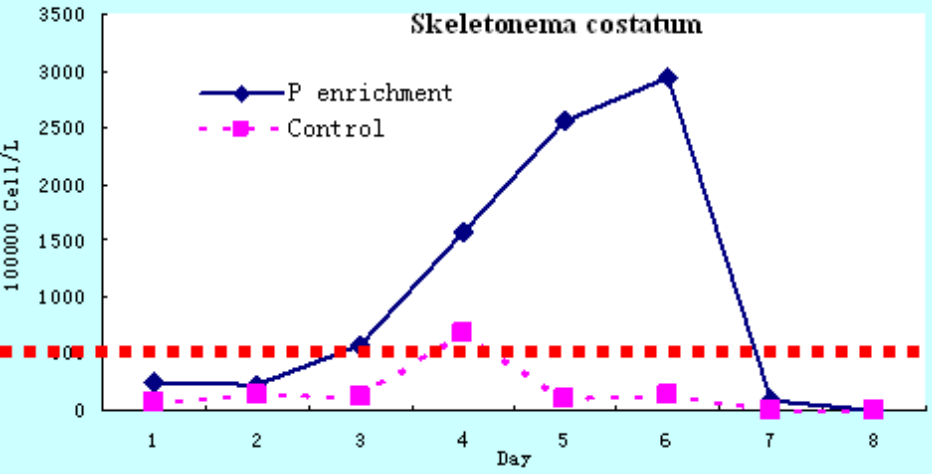

Paracalanus larva
P Enrichment
Control
Abundance (ind/m3)
Day

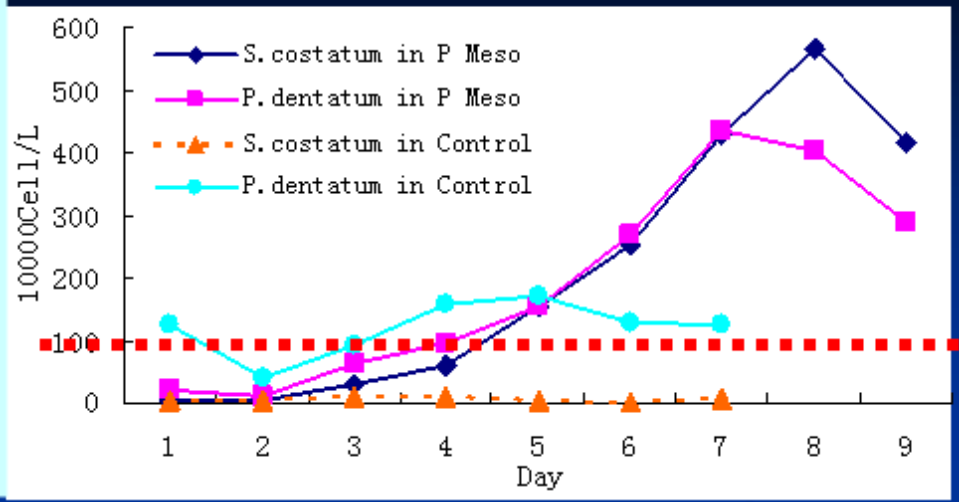

Oithona larva
P Enrichment
Control
Abundance (ind/m3)
Day


Calanoida larva
P Enrichment
Control
Abundance (ind/m3)
Day


Oikopleura larva
P Enrichment
Control
Abundance (ind/m3)
Day

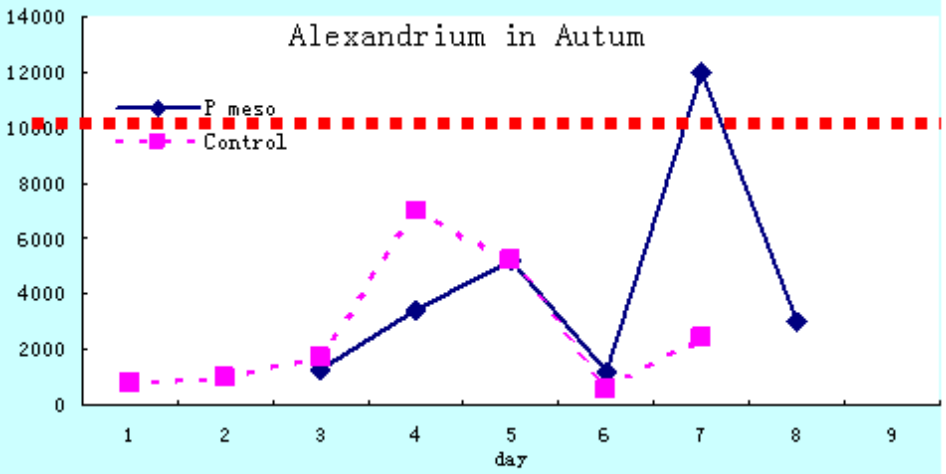
Does harmful algae affect the zooplankton?

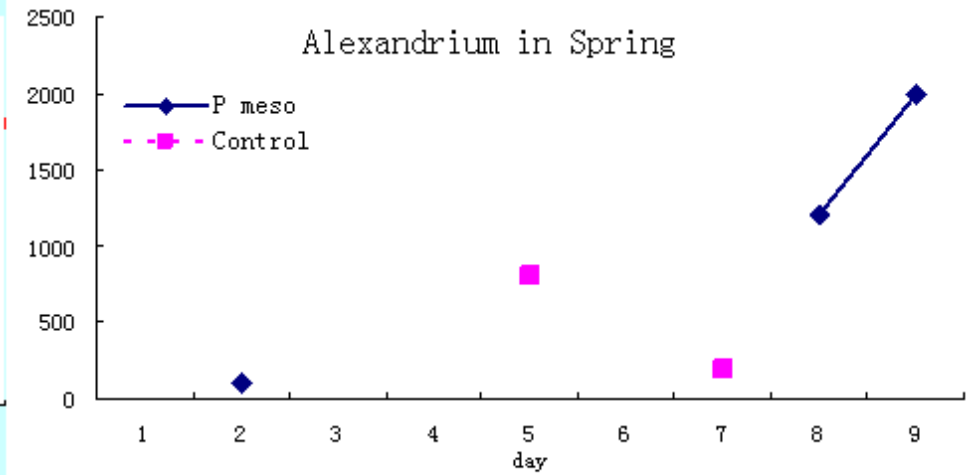




Harmless High abundance

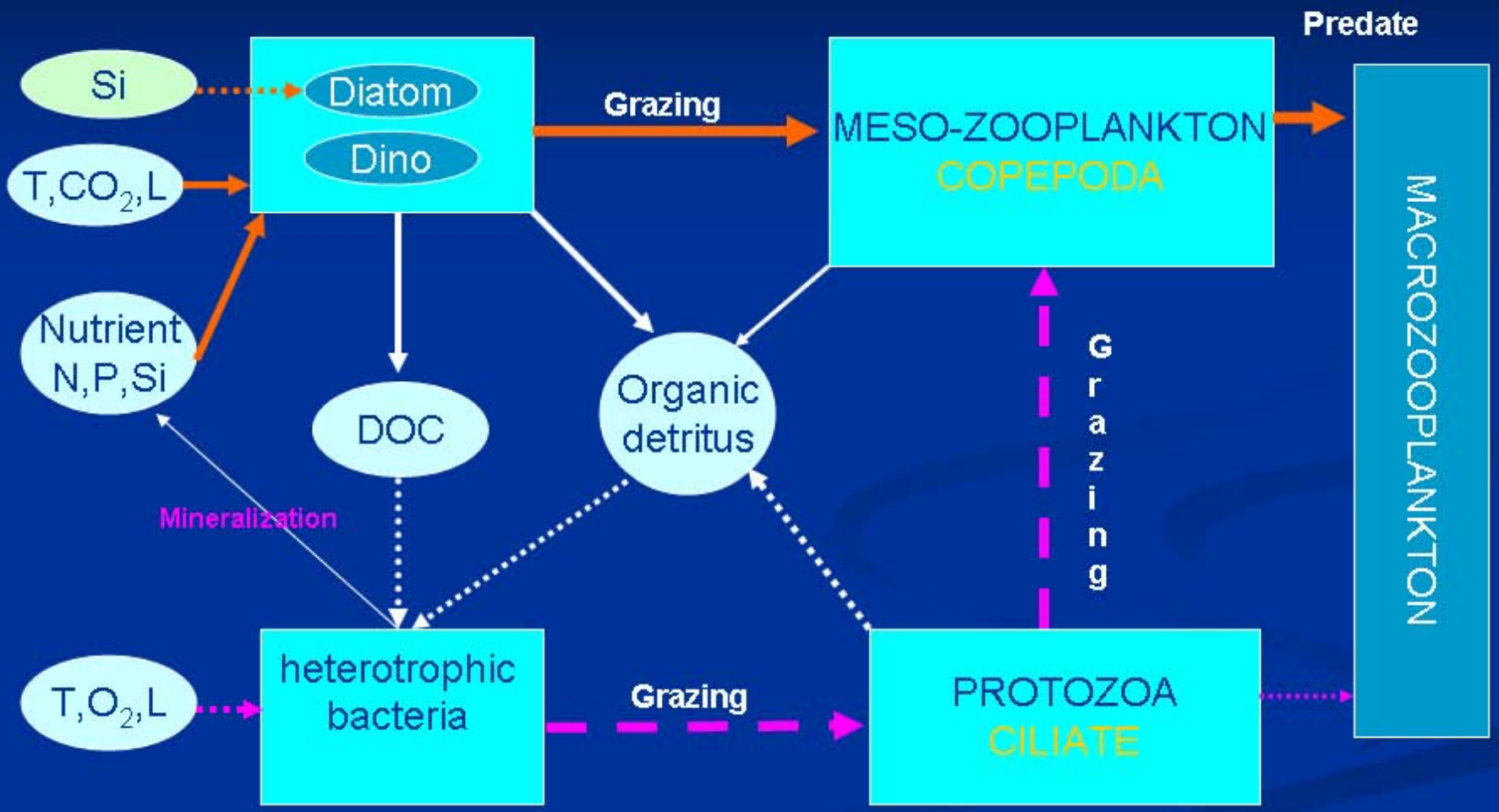
Harmful Low abundance





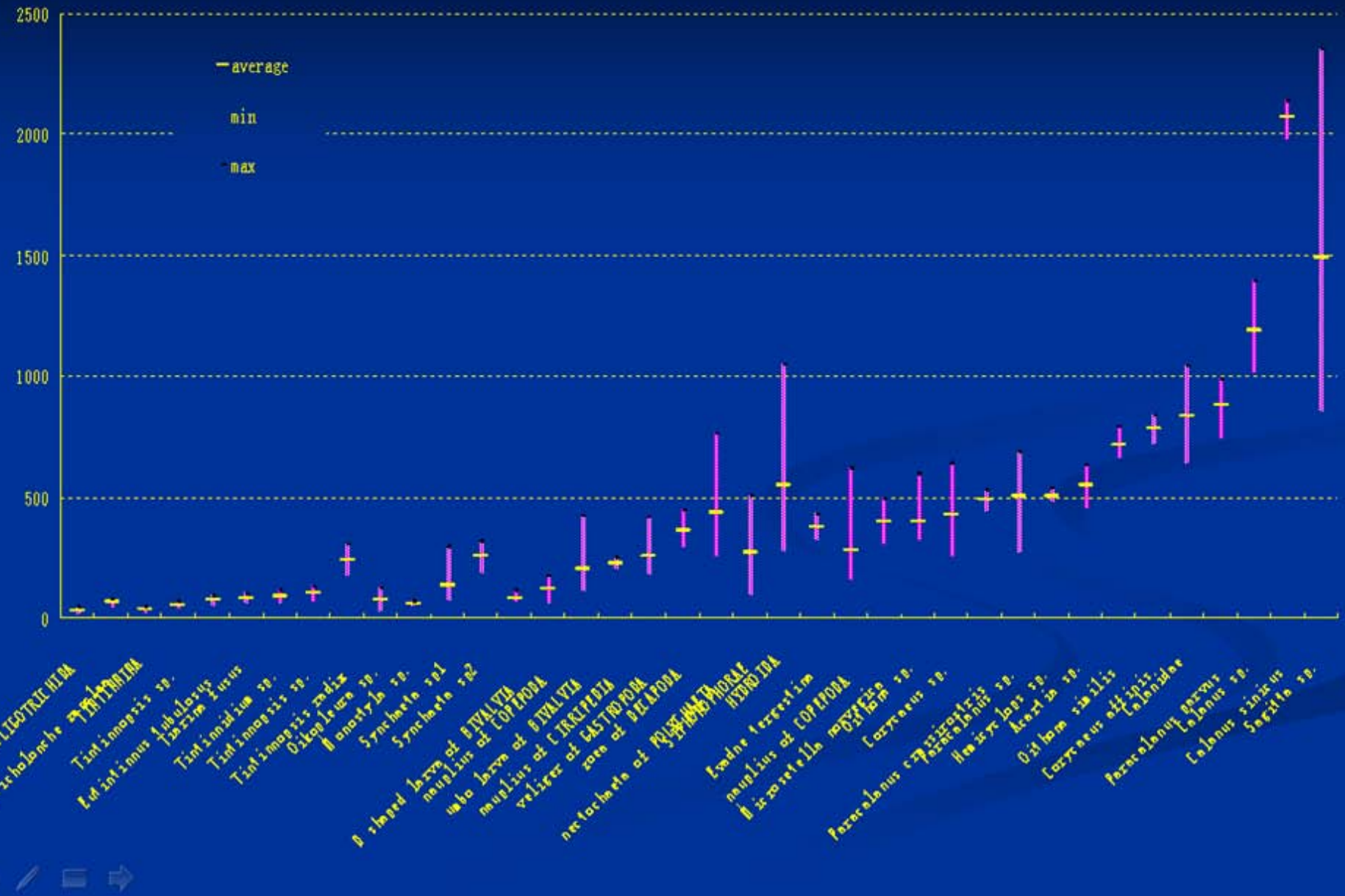
Other harmful algae found in mesocosm include *Karenia mikomotoi*, *Dinophysis caudata* etc

The trophic stucture in Mesocosm

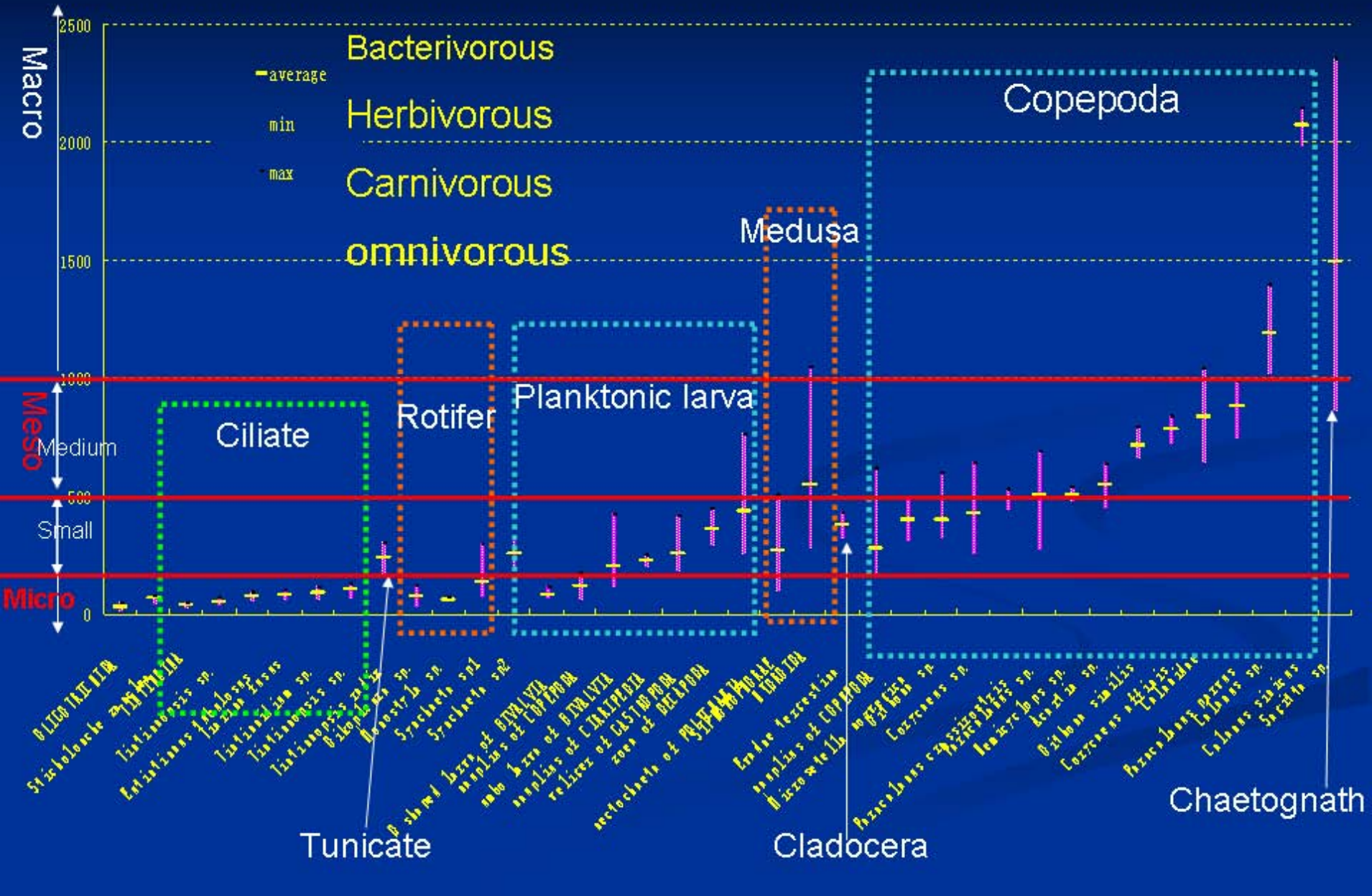


microbial food loop

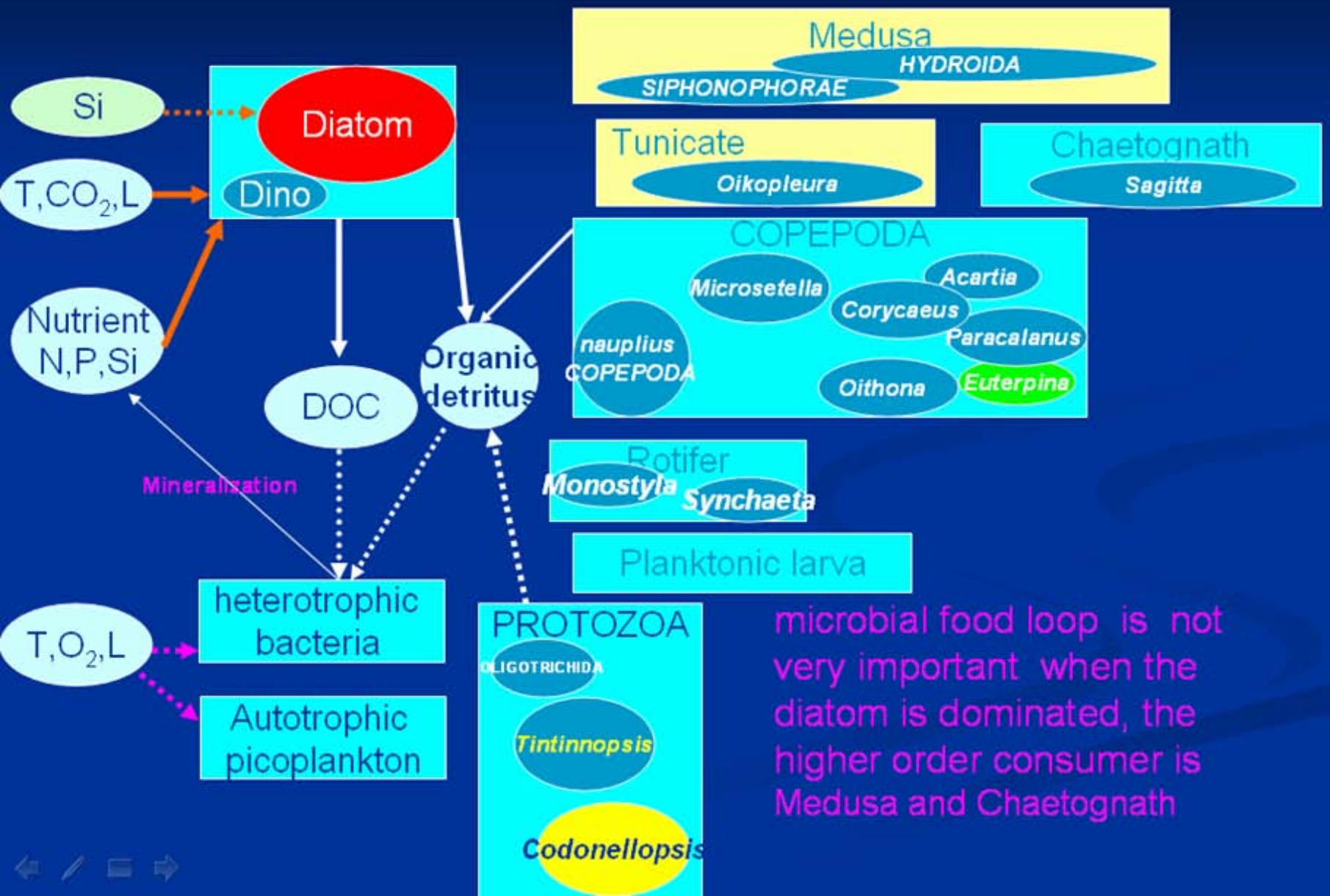
The size (μ m) fraction of Zooplankton in Mesocosm



The size (μ m) fraction of Zooplankton in Mesocosm

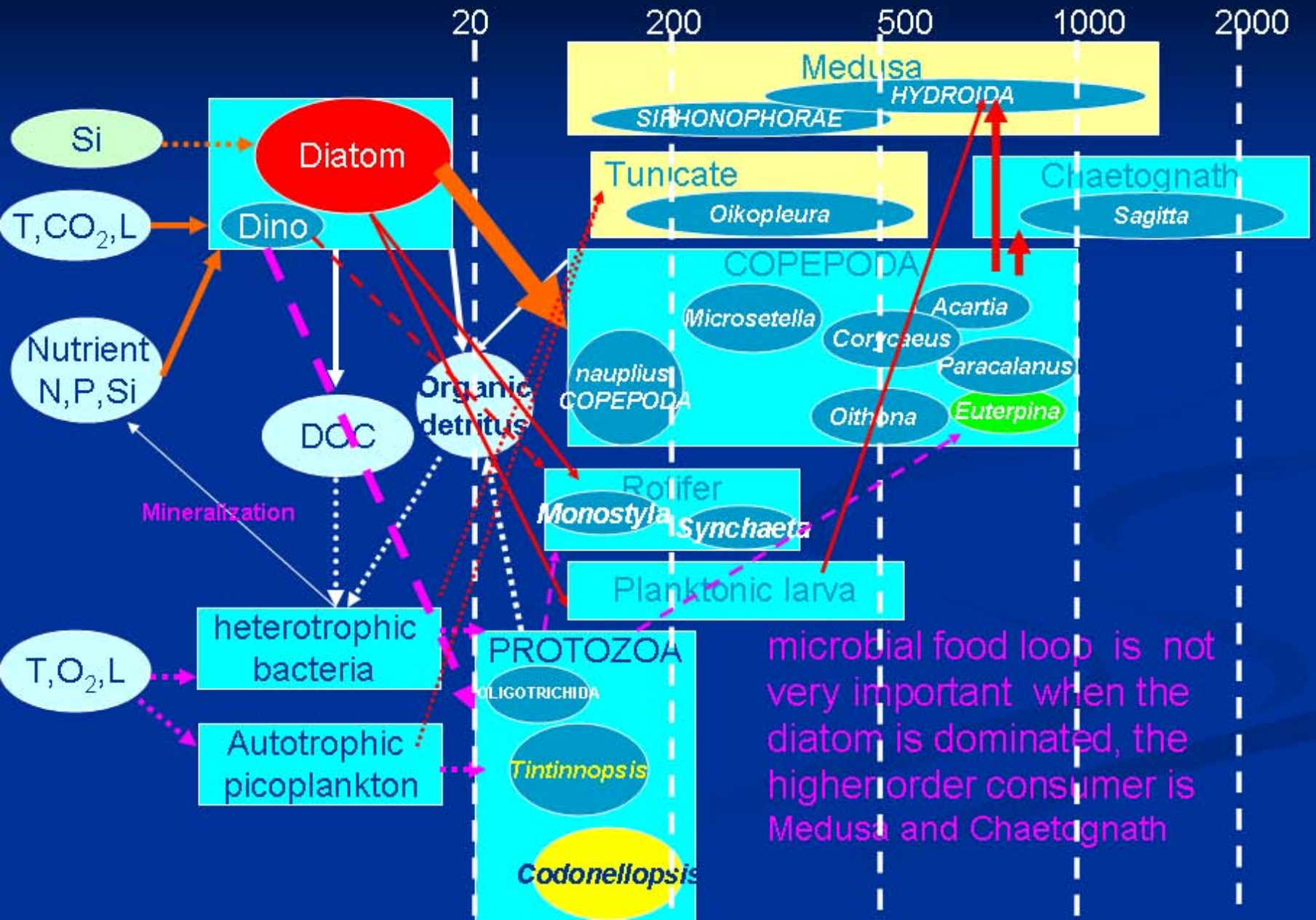


The trophic stucture in Autum

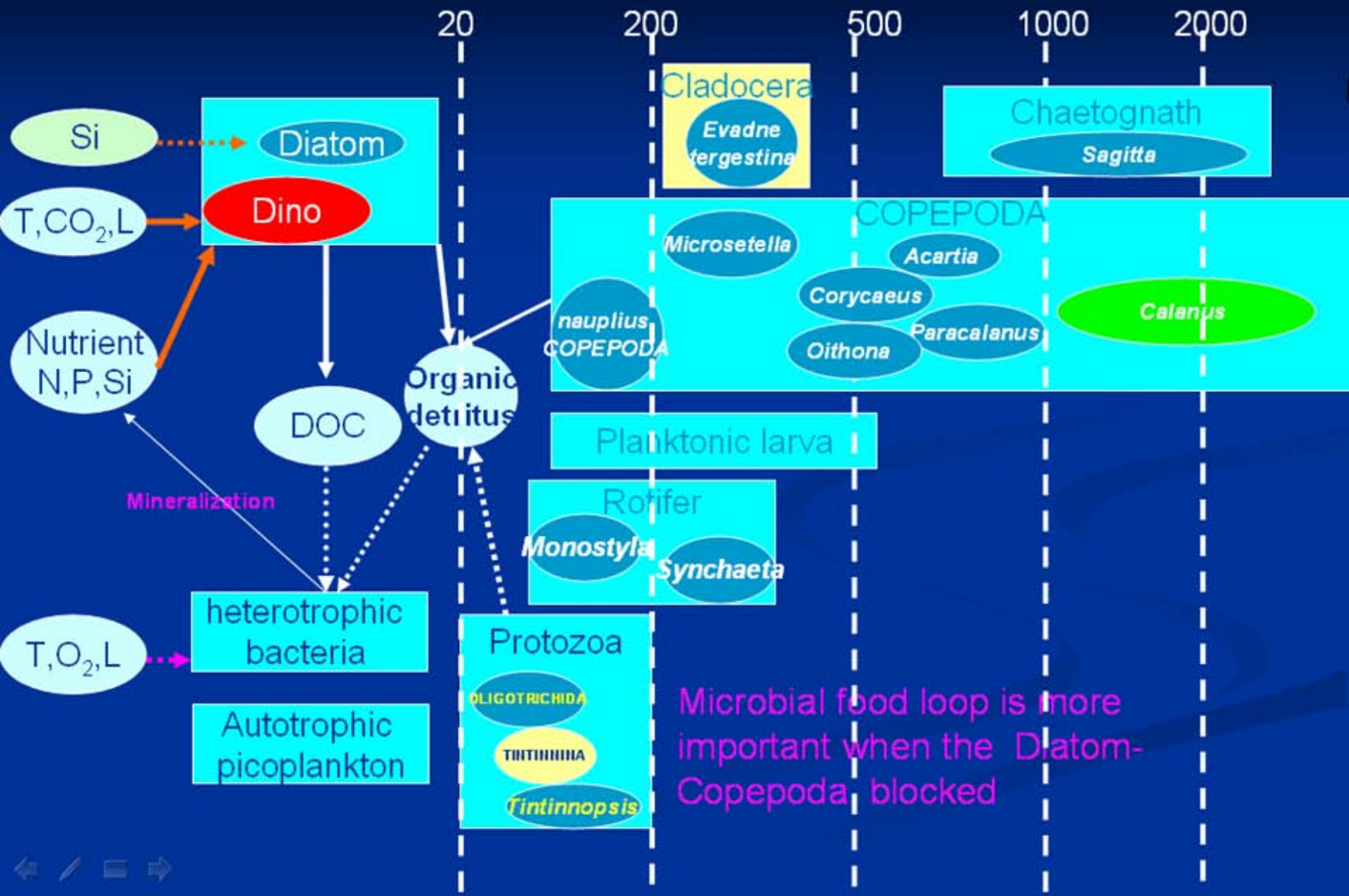


microbial food loop is not very important when the diatom is dominated, the higher order consumer is Medusa and Chaetognath

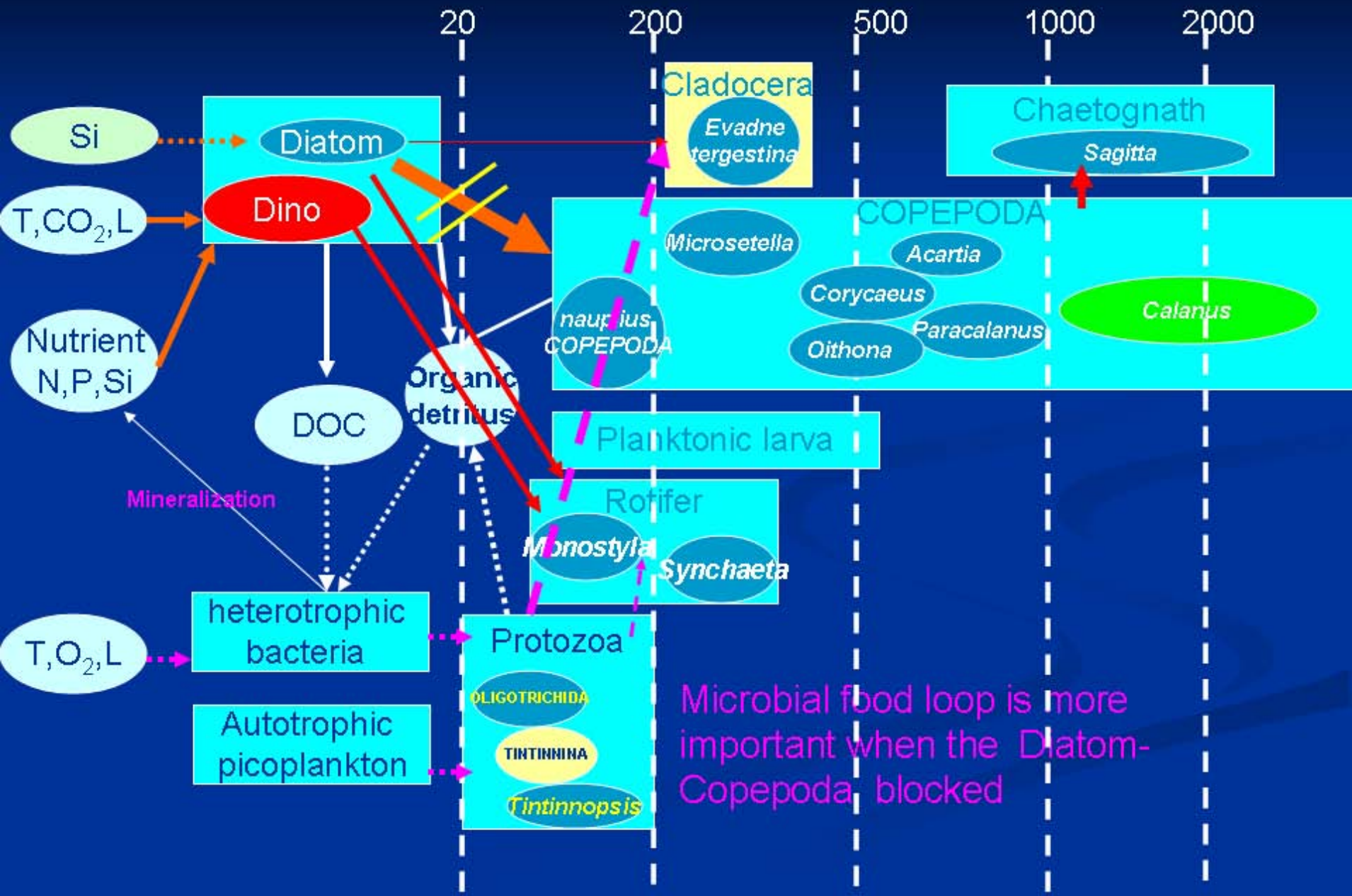
The trophic stucture in Autum



The trophic stucture in Spring



The trophic stucture in Spring



Summary:

1. Nutrients (P enrichment) regulate the zooplankton community via bacteria and phytoplankton indirectly, the phytoplankton community play an important role on the stability of zooplankton community during P enrichment. Response of Zooplankton to P enrichment depends on phytoplankton group, diatom benefit for mesozooplankton with more stable trophic structure and long food line, dinoflagellate benefit for microzooplankton with short food line in which microbial food loop emphasized.

2.Phosphate enrichment cause the abundance zooplankton increase and the community shift. Copepods prefer the diatom as food than dinoflagellate, the result indicate that control of algal blooms through grazing by zooplankton is more effective for diatoms than for dinoflagellates.

3. Different genus in the same group of zooplankton response to P enrichment not in the same way, feeding behavior and food preferable may be the key.

4. Deterministic mathematical models should be applied to explain the plankton ecosystem and diverse food links.

Thank you for your attention!

Acknowledgements:

State Oceanic Administration in China

National Institute for Environmental Studies in Japan