Nutrient Response to Sewage Abatement in Hong Kong

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Outline

- **Background of natural factors influencing water quality**

- **Anthropogenic inputs – Pearl River discharge**
  - Sewage discharge

- **Meeting the challenges**
  - sewage treatment for Victoria harbor

Why Is Hong Kong Not As Bad As Expected?

- **Physical Factors – monsoon winds**
  - river discharge and rainfall
  - wind and tidal mixing
- **Chemical and Biological factors**

•These factors govern the ecosystem <u>sensitivity</u> to various anthropogenic inputs.

• Need to understand how the ecosystem functions.

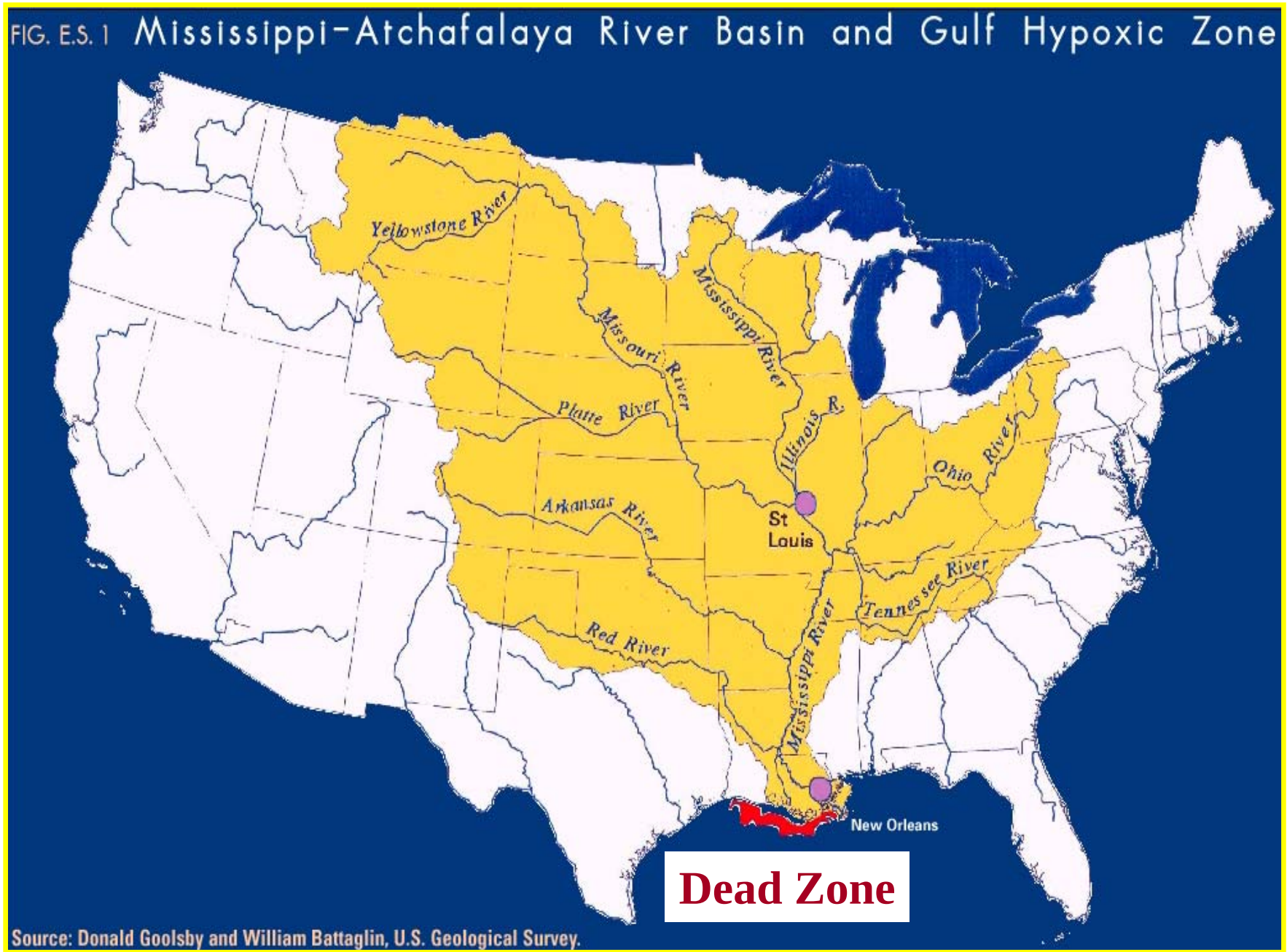
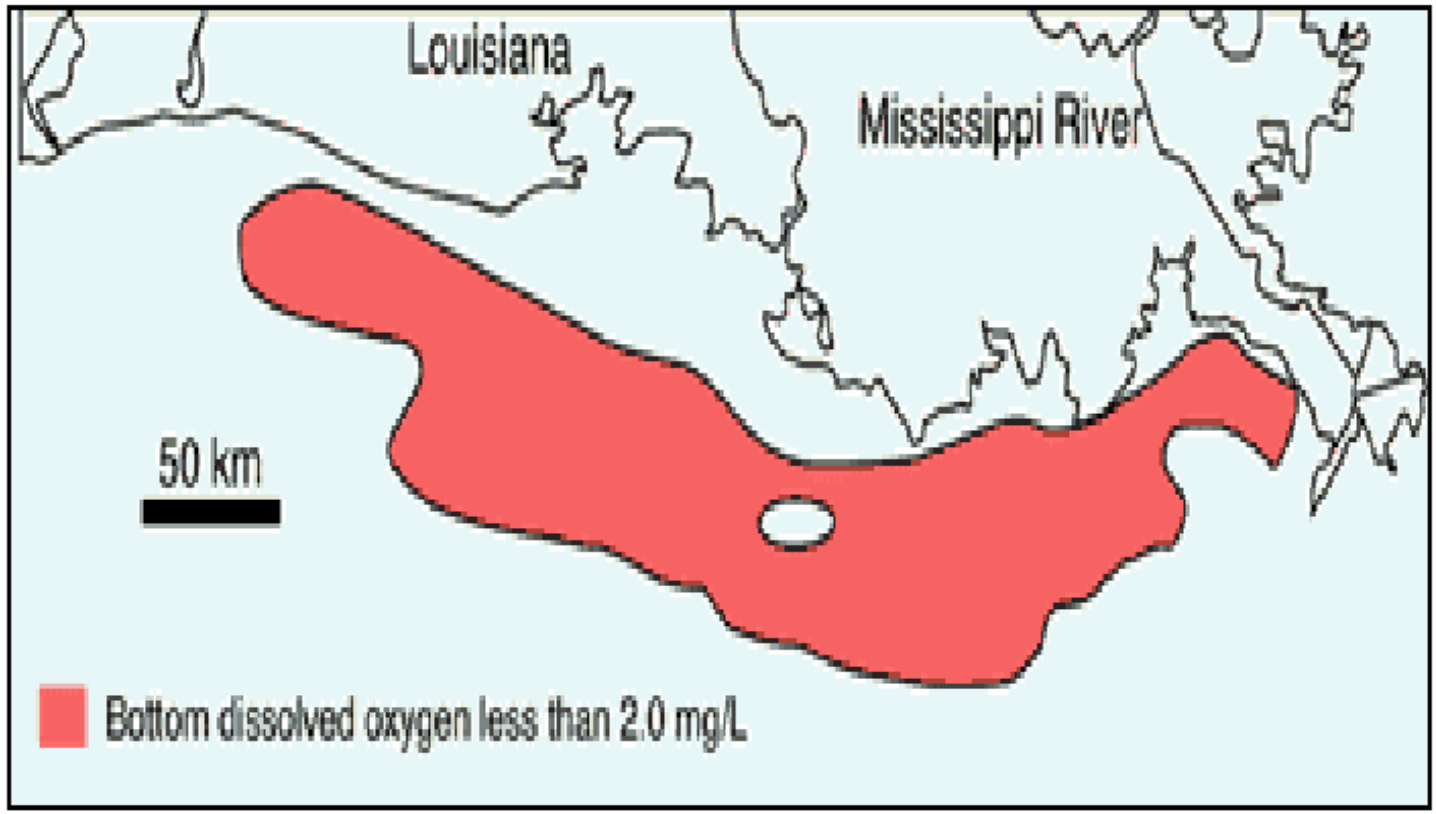


FIG. E.S. 1 Mississippi-Atchafalaya River Basin and Gulf Hypoxic Zone
Yellowstone River
Missouri River
Mississippi River
Platte River
Illinois R.
Ohio River
Arkansas River
St Louis
Tennessee River
Red River
Mississippi River
New Orleans
Dead Zone
Source: Donald Goolsby and William Battaglin, U.S. Geological Survey.

Northern Gulf of Mexico:

a large area of hypoxia "dead zone" (20,000 km^2)

(<2 O_2 mg/L)

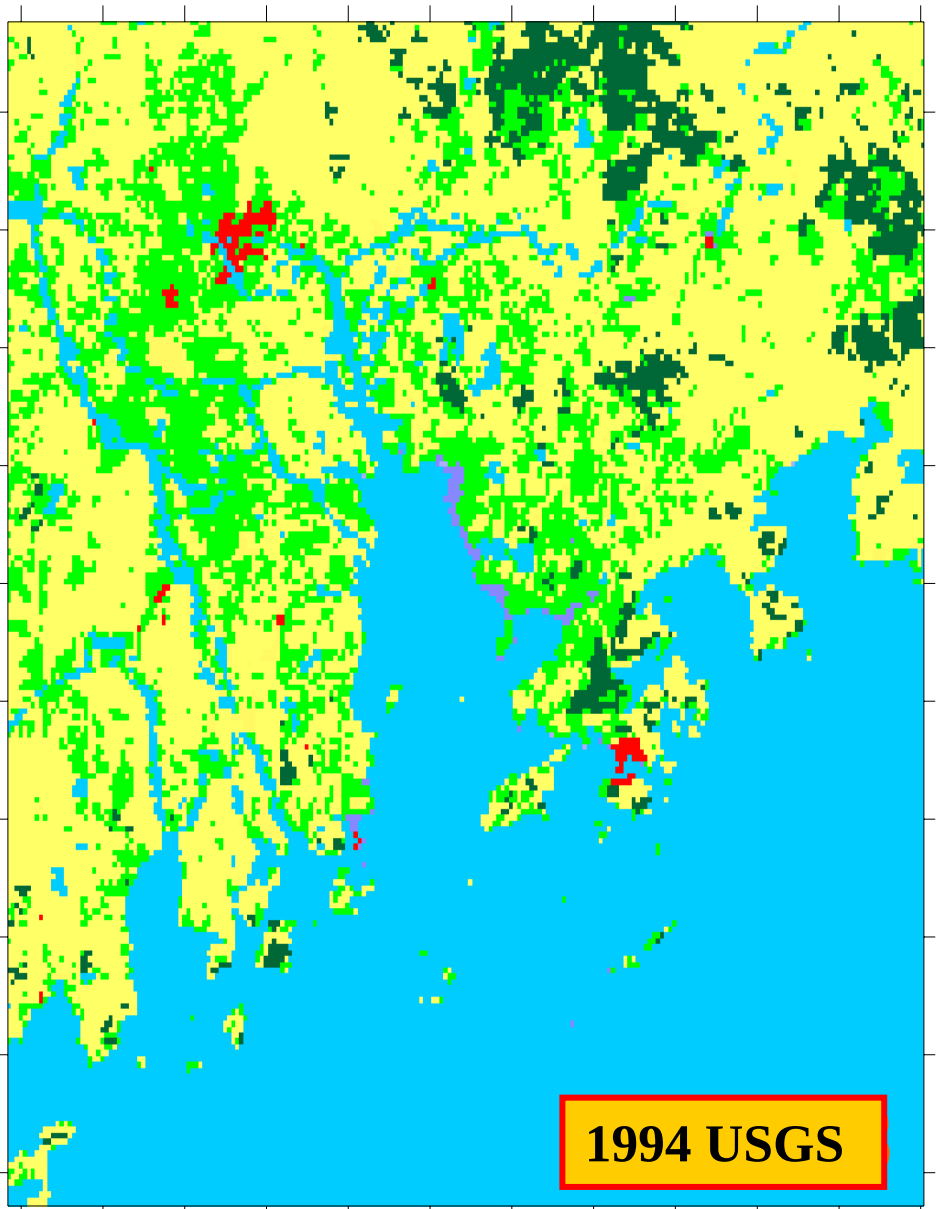


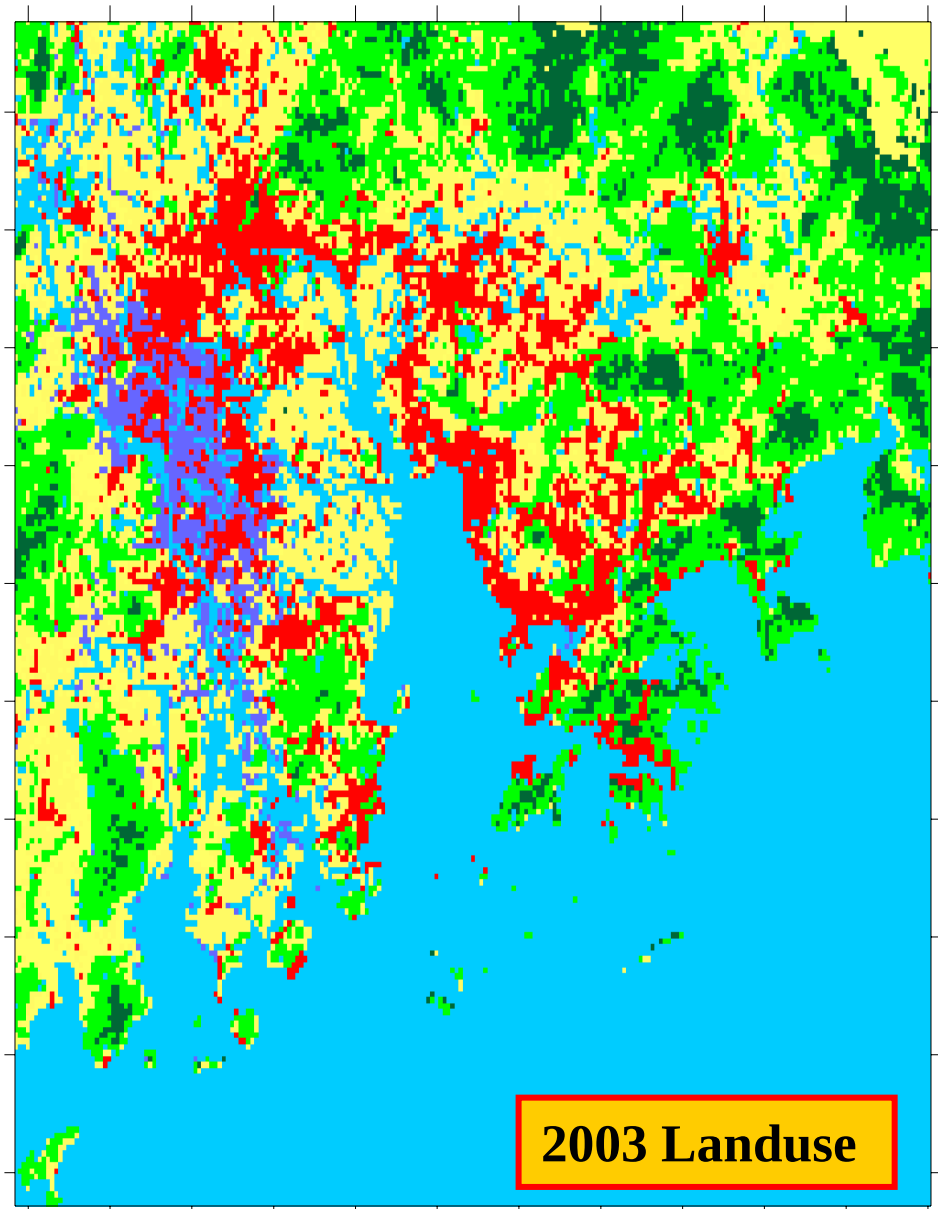
Science 281, (1998)

South China Sea

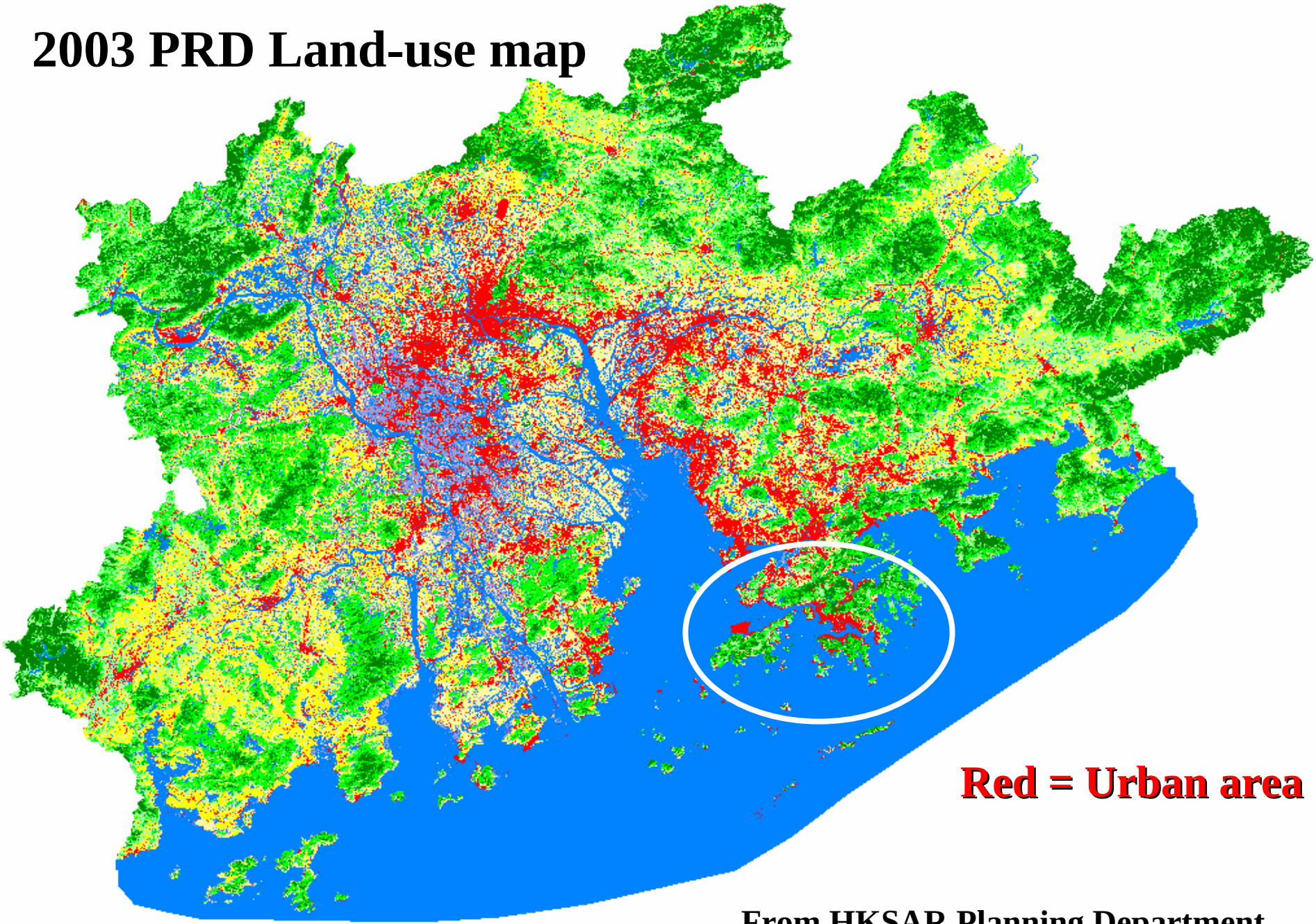
- Nutrient-poor sea
- Hong Kong western and southern waters **excessive nutrients**

Fine resolution land-use 1994 vs 2003



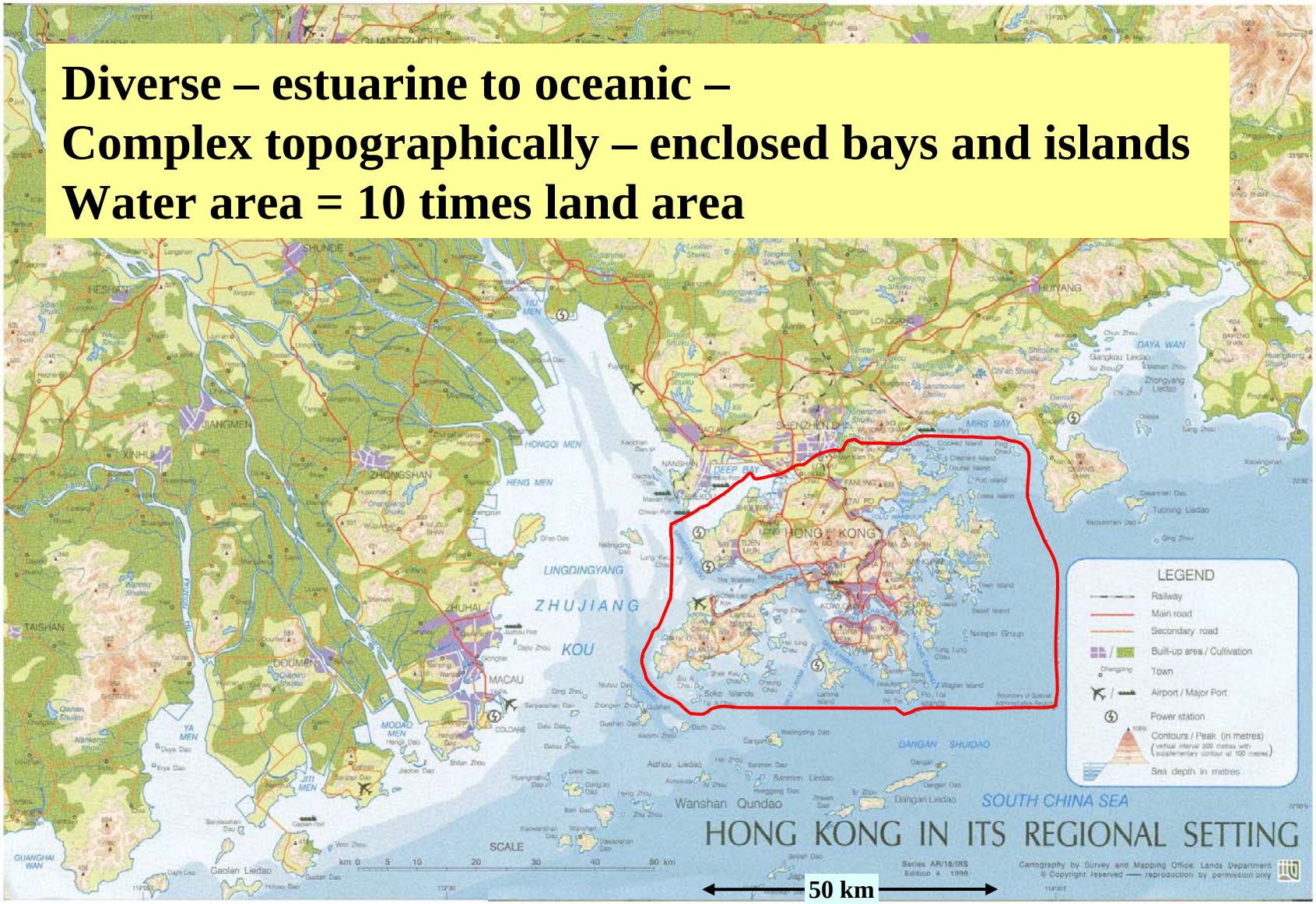


2003 PRD Land-use map



From HKSAR Planning Department

Pearl River Estuary & Hong Kong
Wide and Shallow Estuary



10 Water Quality Zones in Hong Kong

Figure 1.1 Water Control Zones in Hong Kong

Shallow (10 m) with some deeper 25 m channels

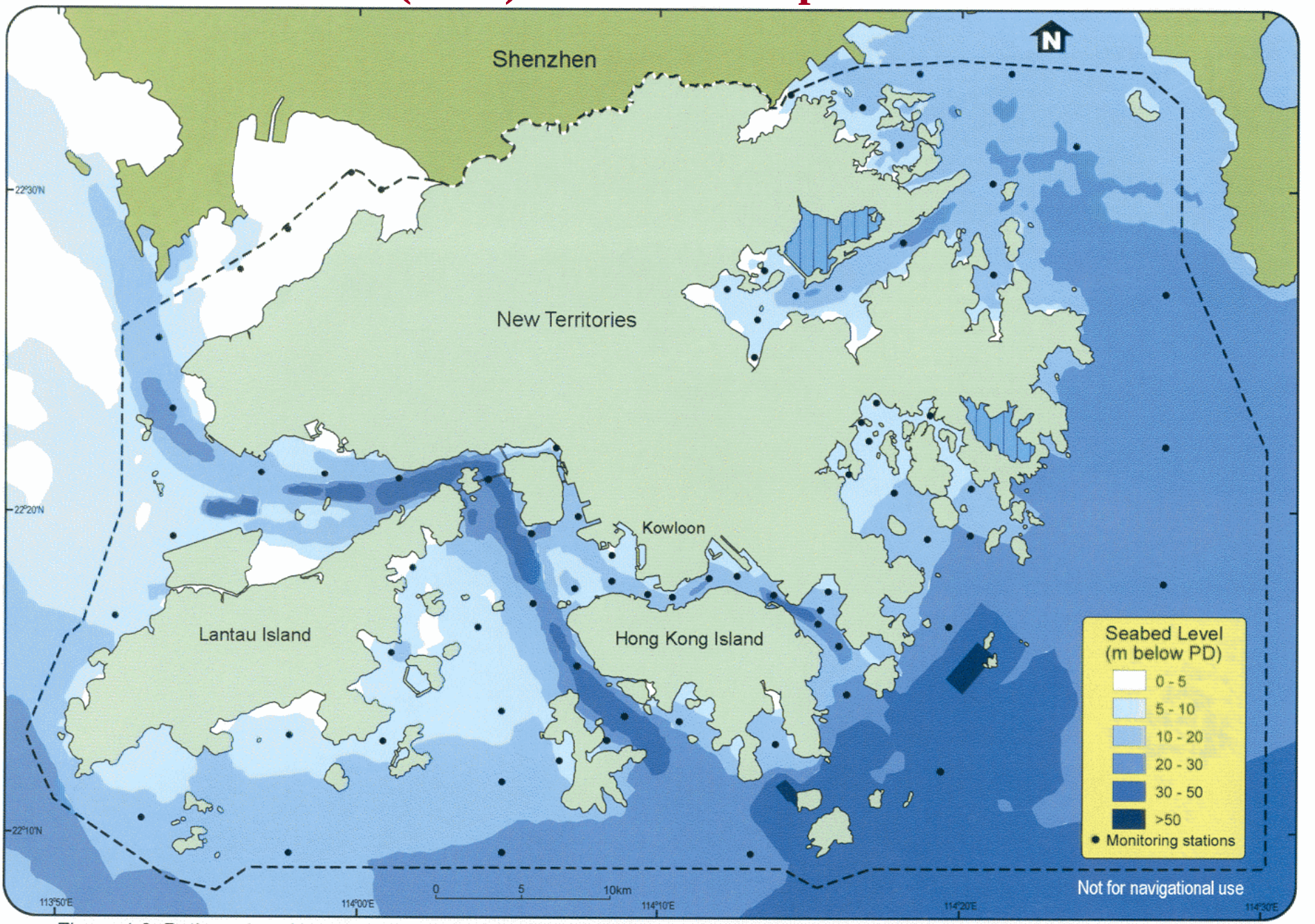
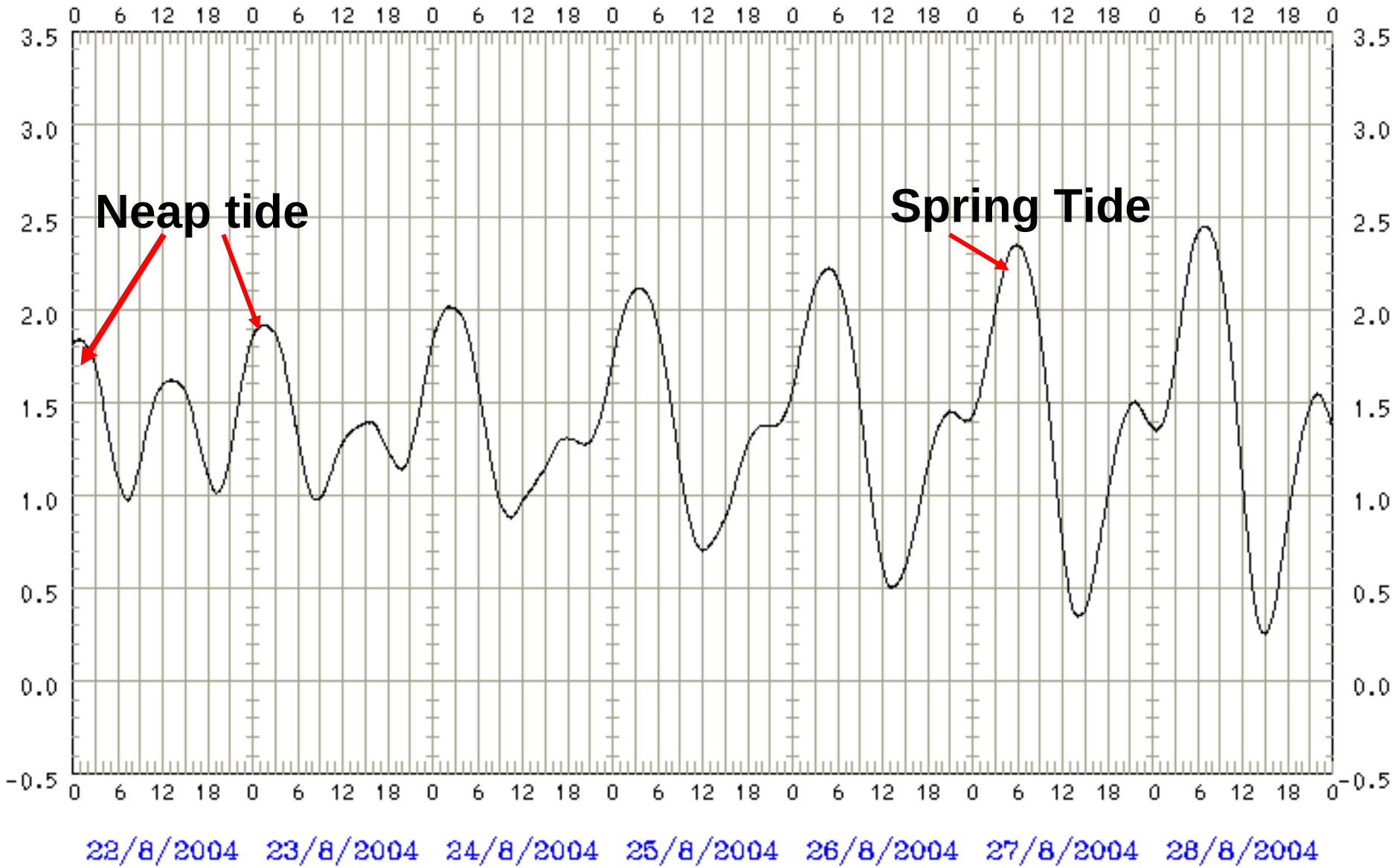


Figure 1.8 Bathymetry of Hong Kong Marine Waters in 2001

Tidal Mixing

Important in mixing O_2 into bottom waters and nutrients in the water column.



Tidal Height During Neap and Spring Tides

Wind Mixing

- **Wind mixing can help reduce the occurrence of hypoxia (mixes O_2 from the air into deep waters**

- **Reduces the formation algal blooms by dilution.**

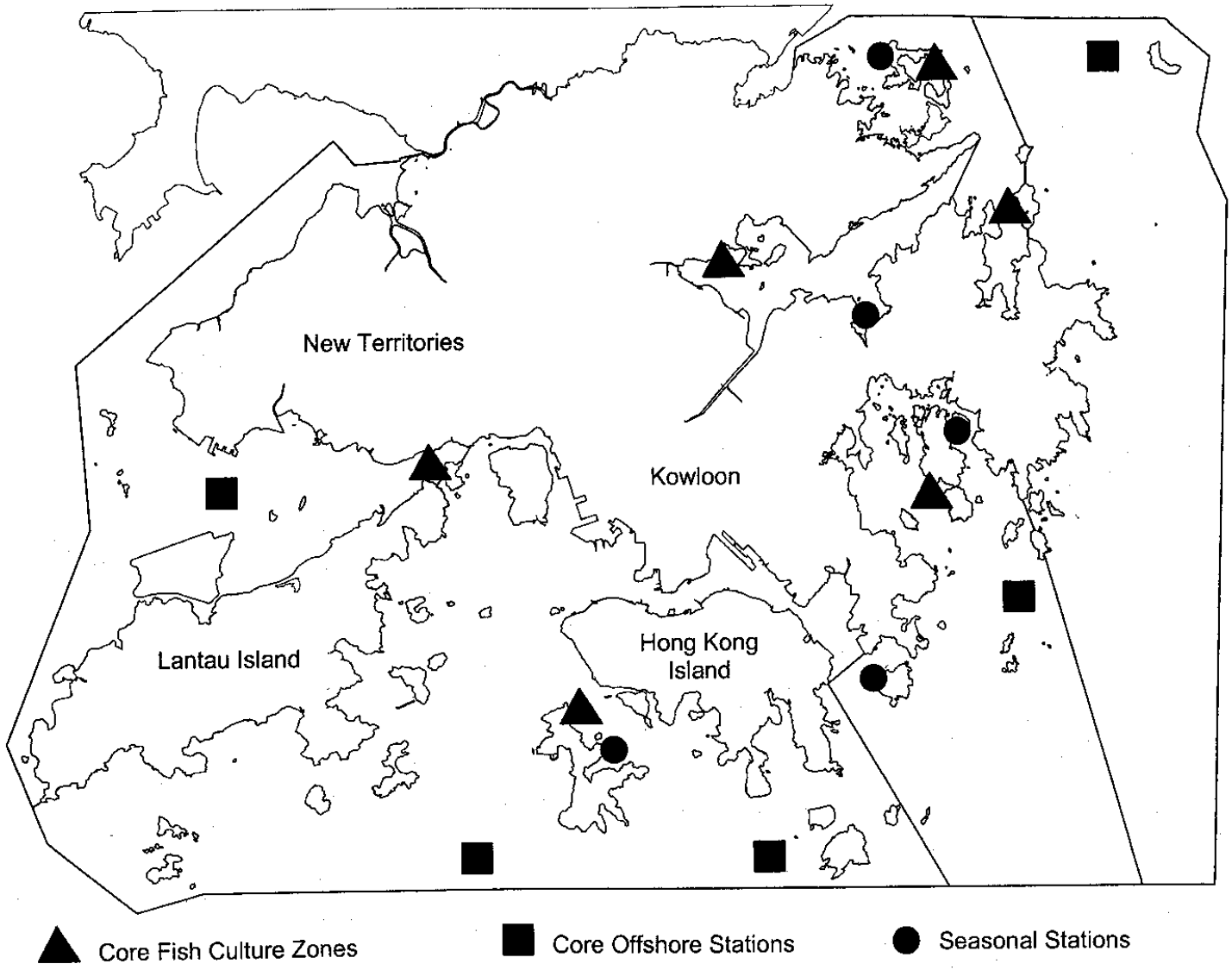


Fig. 5. Locations of the sampling stations in AFCD phytoplankton monitoring progamme.

AFCD Phytoplankton Monitoring Stations

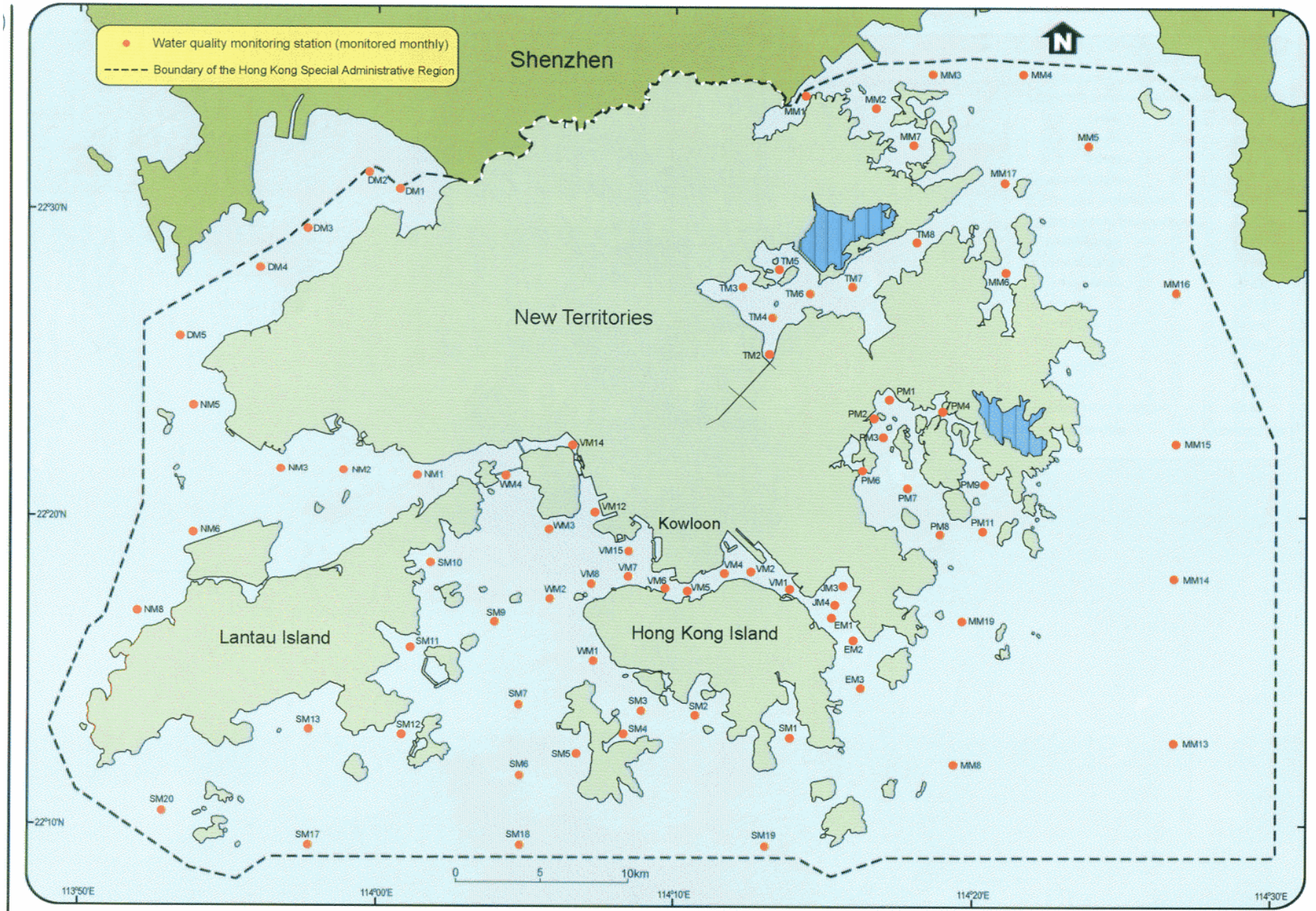


Figure 1.2 76 water quality monitoring stations in open waters of Hong Kong in 2001

EPD's Water Quality Monitoring Stations

Increase in TIN and NO_3 from 1986-2001

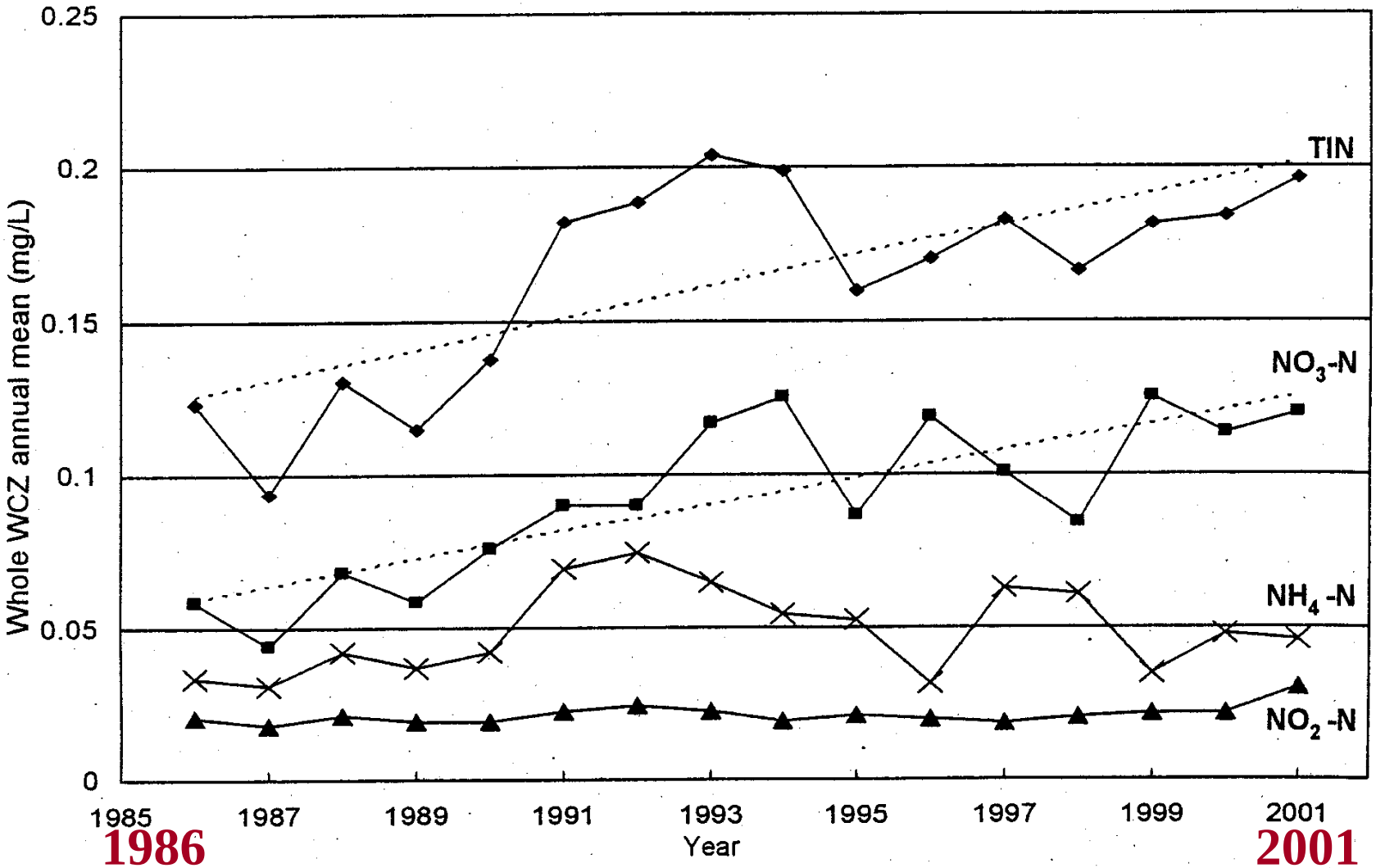
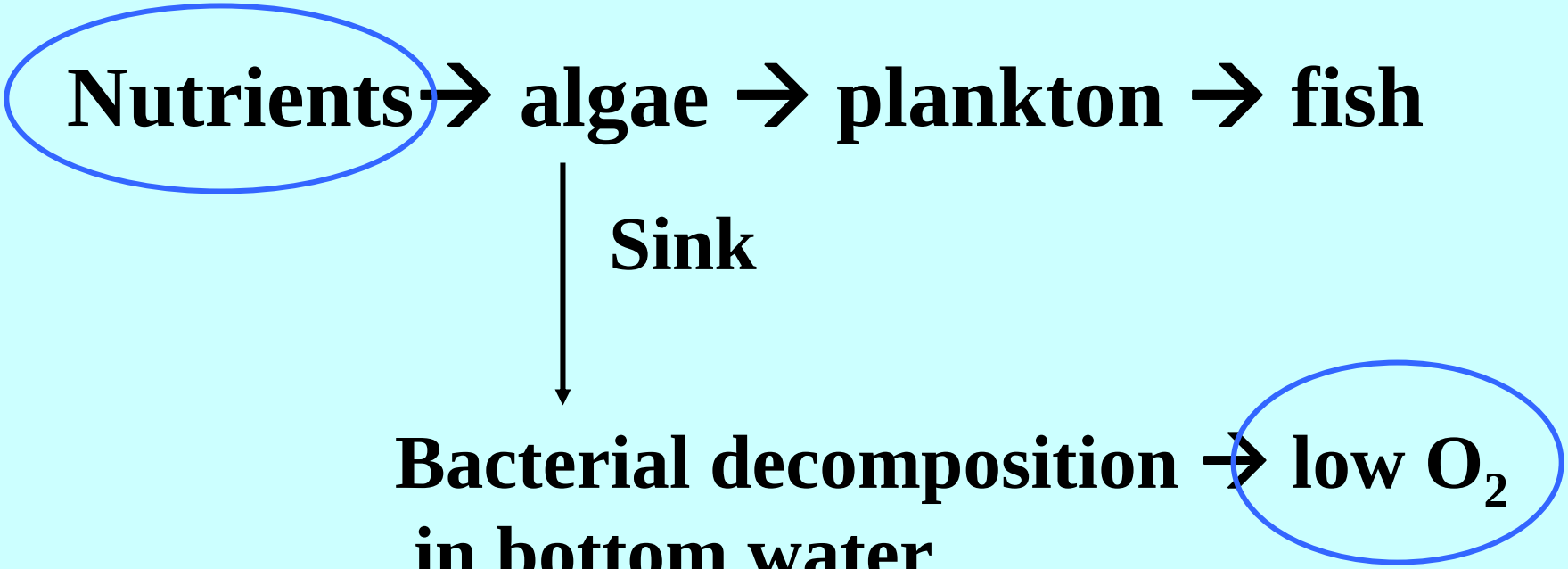


Figure 3.4 Temporal trends of inorganic nitrogen components in the Southern WCZ, 1986 - 2001

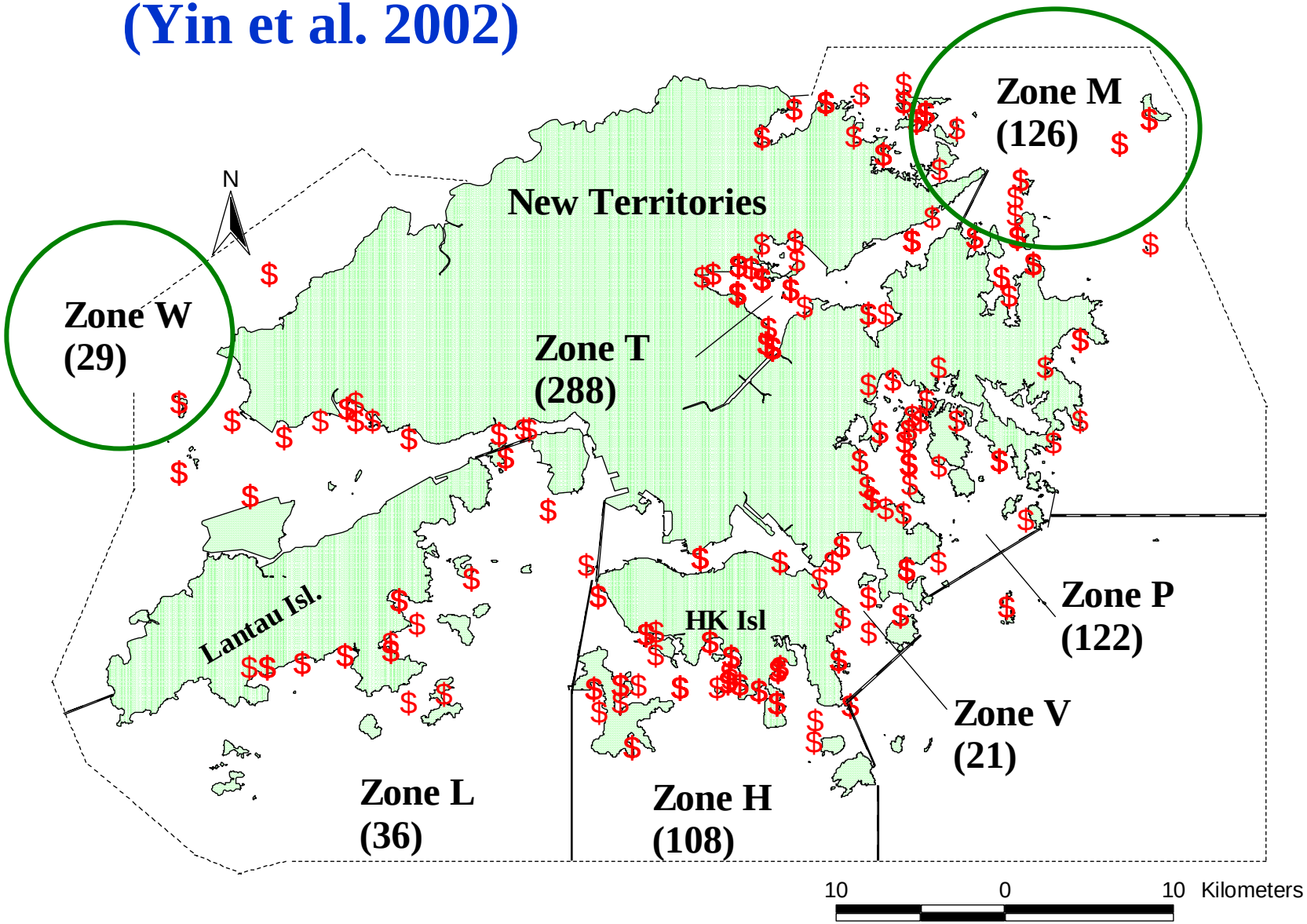
Excessive Nutrients Can Cause Low O_2 in Bottom water



Studies on population dynamics of HABs will lead to a better understanding of events such as cyanobacterial blooms in the Baltic Sea.

Surface Algal Bloom

Red Tides in Hong Kong during 1983-98 (Yin et al. 2002)



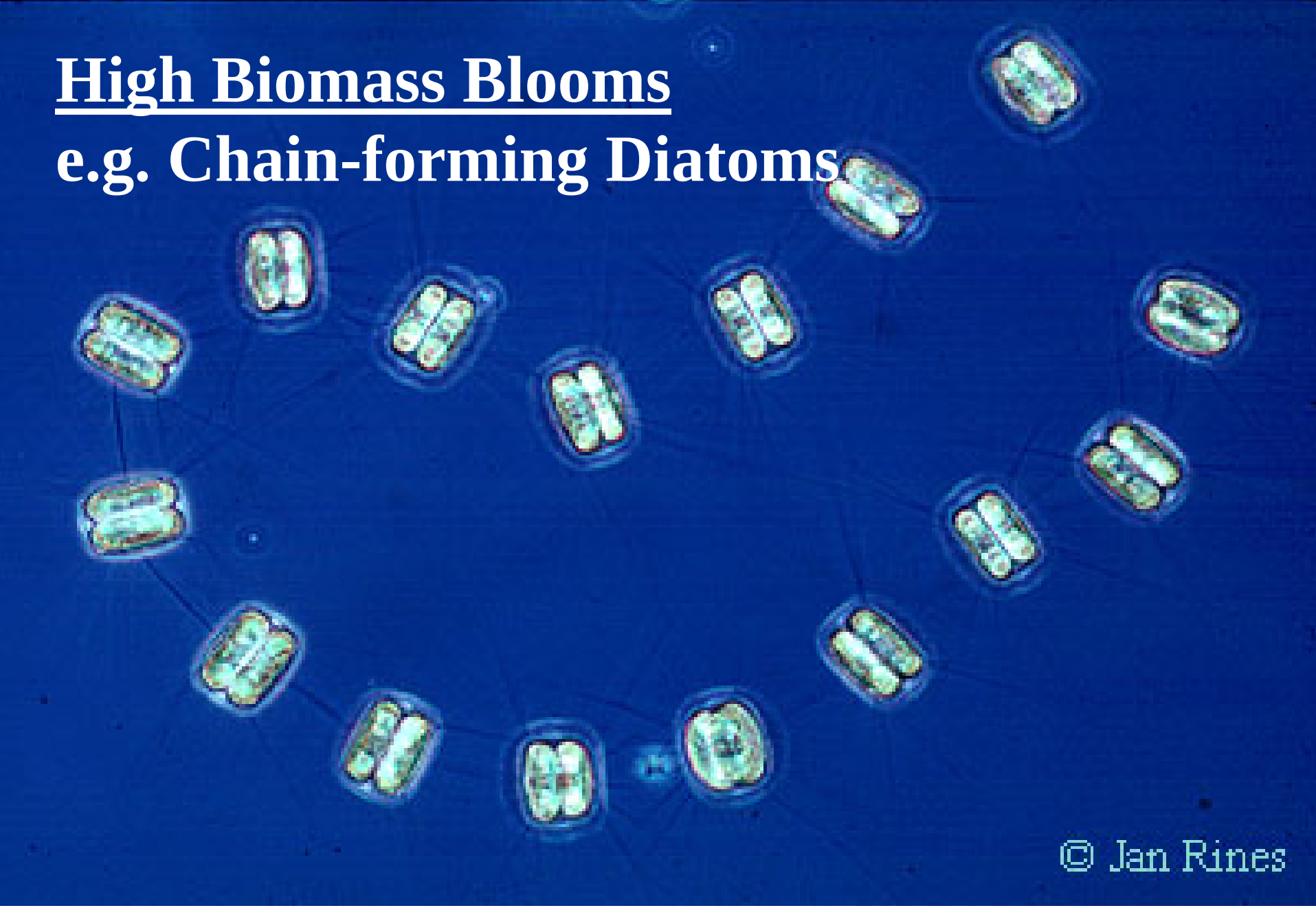
High Number of Red Tides in Eastern Waters

- Most red tides occur in spring when river discharge is low
- Occur in Mirs Bay – far from the Pearl River estuary.

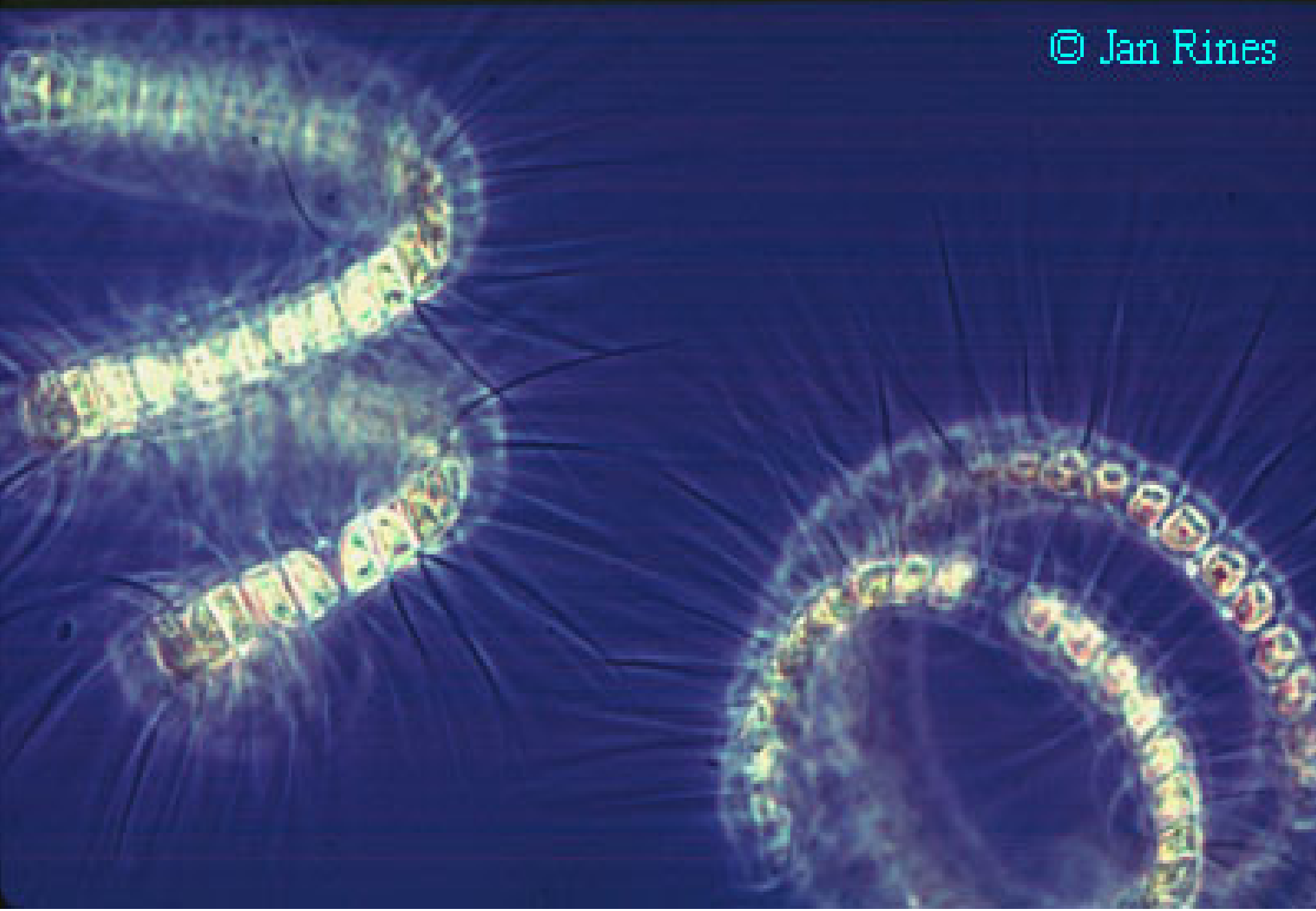
High Biomass Vs Toxic Red Tides

- **High biomass algal blooms which cause low O_2 bottom waters seems to be a more serious concern than toxic red tide blooms.**

High Biomass Blooms
e.g. Chain-forming Diatoms



Thalassiosira sp.



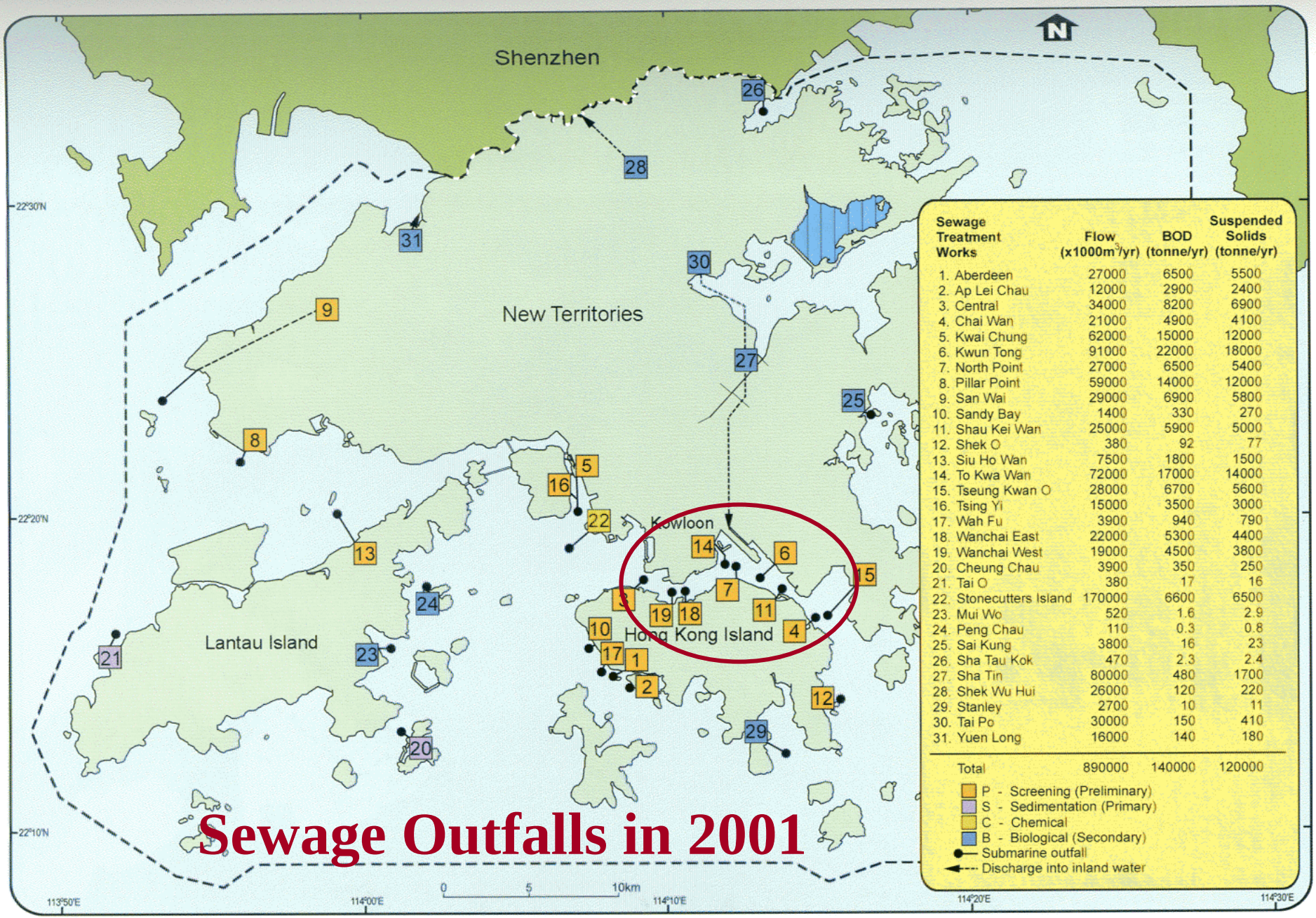
Chaetoceros debilis

Nutrient Sources

- **Sewage – continuous all year – excess phosphorus**
  sewage treatment → ecosystem response (improving)
  BUT – chl biomass increase in southern waters?

- **Pearl River discharge**
  – summer (rain), excess nitrogen and transported offshore
  - phosphorus potentially controls algal biomass in summer in waters near Pearl River.

HK waters are very productive



Sewage Treatment Works	Flow (x1000m³/yr)	BOD (tonne/yr)	Suspended Solids (tonne/yr)
1. Aberdeen	27000	6500	5500
2. Ap Lei Chau	12000	2900	2400
3. Central	34000	8200	6900
4. Chai Wan	21000	4900	4100
5. Kwai Chung	62000	15000	12000
6. Kwun Tong	91000	22000	18000
7. North Point	27000	6500	5400
8. Pillar Point	59000	14000	12000
9. San Wai	29000	6900	5800
10. Sandy Bay	1400	330	270
11. Shau Kei Wan	25000	5900	5000
12. Shek O	380	92	77
13. Siu Ho Wan	7500	1800	1500
14. To Kwa Wan	72000	17000	14000
15. Tseung Kwan O	28000	6700	5600
16. Tsing Yi	15000	3500	3000
17. Wah Fu	3900	940	790
18. Wanchai East	22000	5300	4400
19. Wanchai West	19000	4500	3800
20. Cheung Chau	3900	350	250
21. Tai O	380	17	16
22. Stonecutters Island	170000	6600	6500
23. Mui Wo	520	1.6	2.9
24. Peng Chau	110	0.3	0.8
25. Sai Kung	3800	16	23
26. Sha Tau Kok	470	2.3	2.4
27. Sha Tin	80000	480	1700
28. Shek Wu Hui	26000	120	220
29. Stanley	2700	10	11
30. Tai Po	30000	150	410
31. Yuen Long	16000	140	180
Total	890000	140000	120000

P - Screening (Preliminary)
S - Sedimentation (Primary)
C - Chemical
B - Biological (Secondary)
Submarine outfall
Discharge into inland water

Figure 1.7 Major public sewage treatment works, outfalls and pollution load in Hong Kong in 2001

Transect from Western Waters Through Victoria Harbor

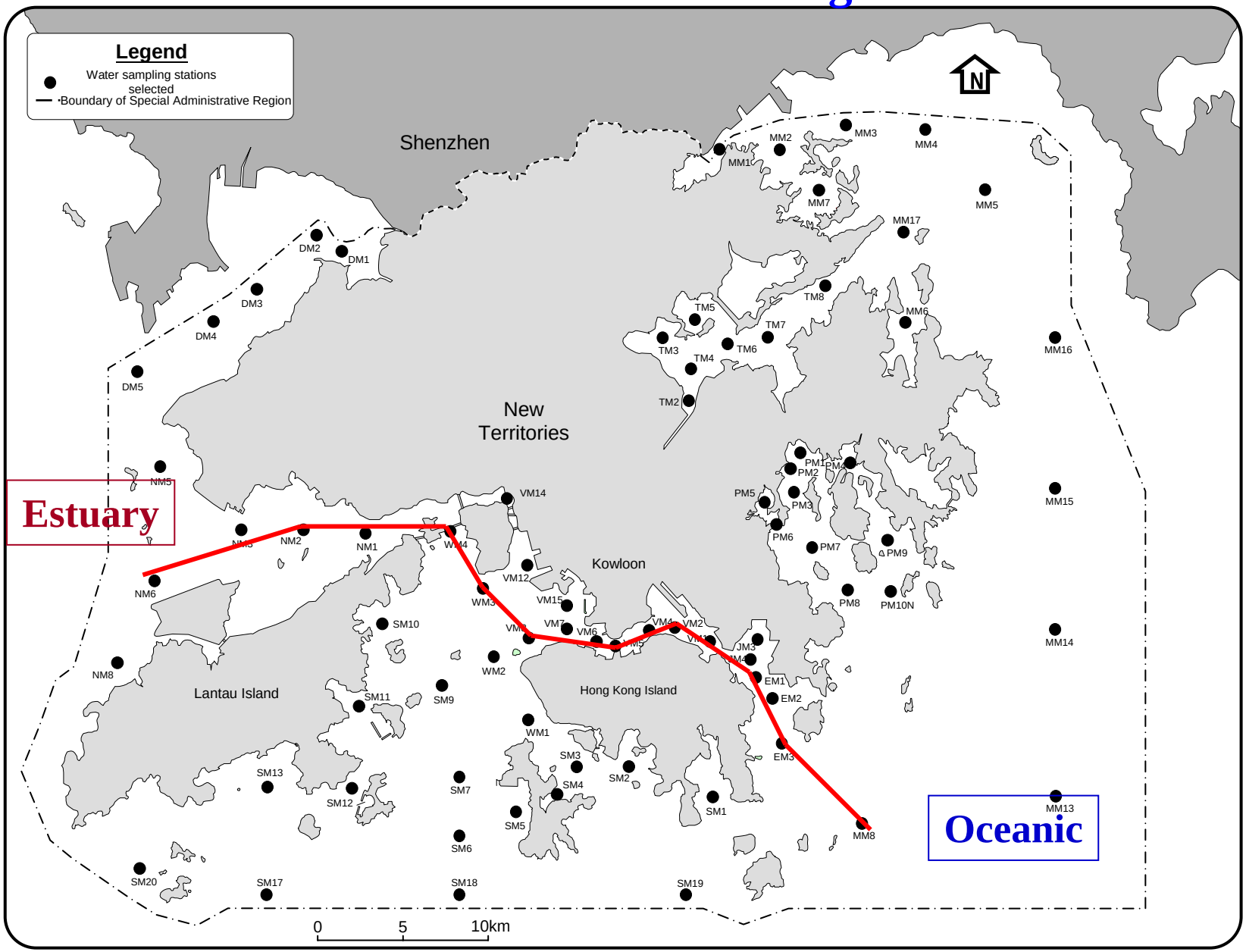
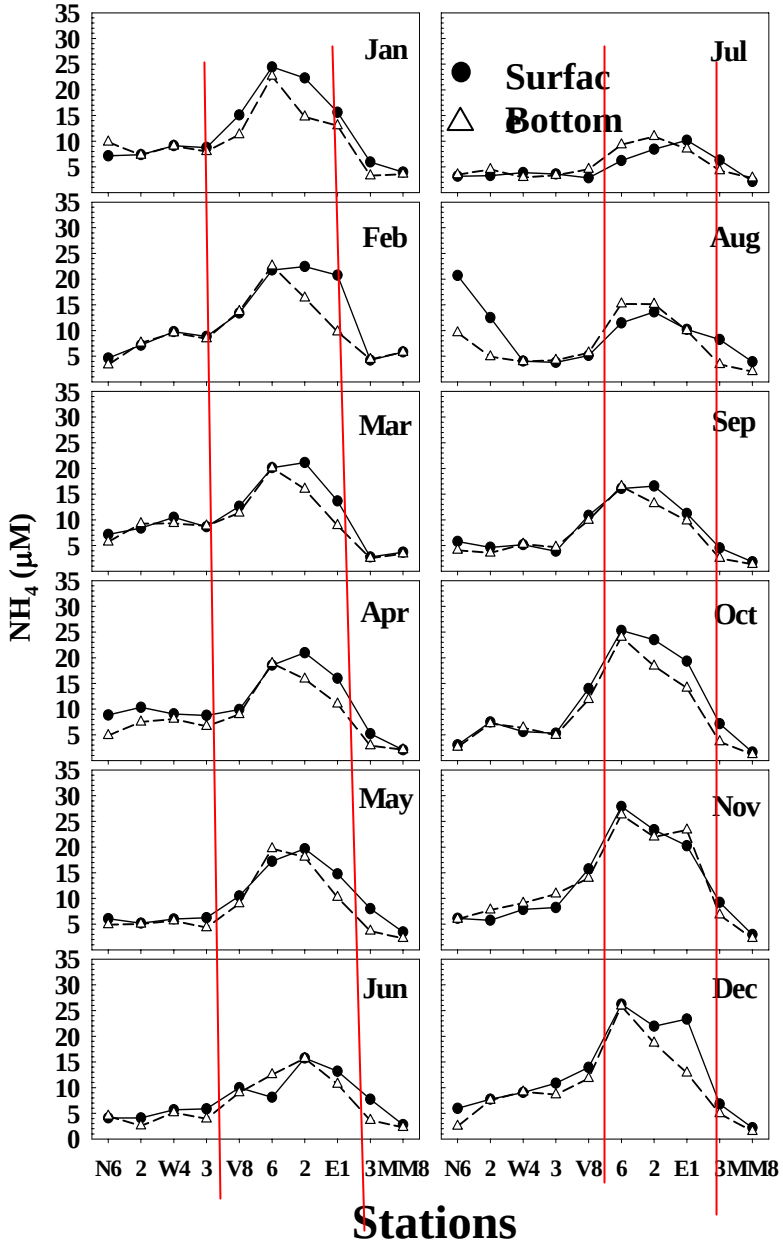


Figure showing EPD routine water sampling stations

Vertical Mixing in Victoria Harbor



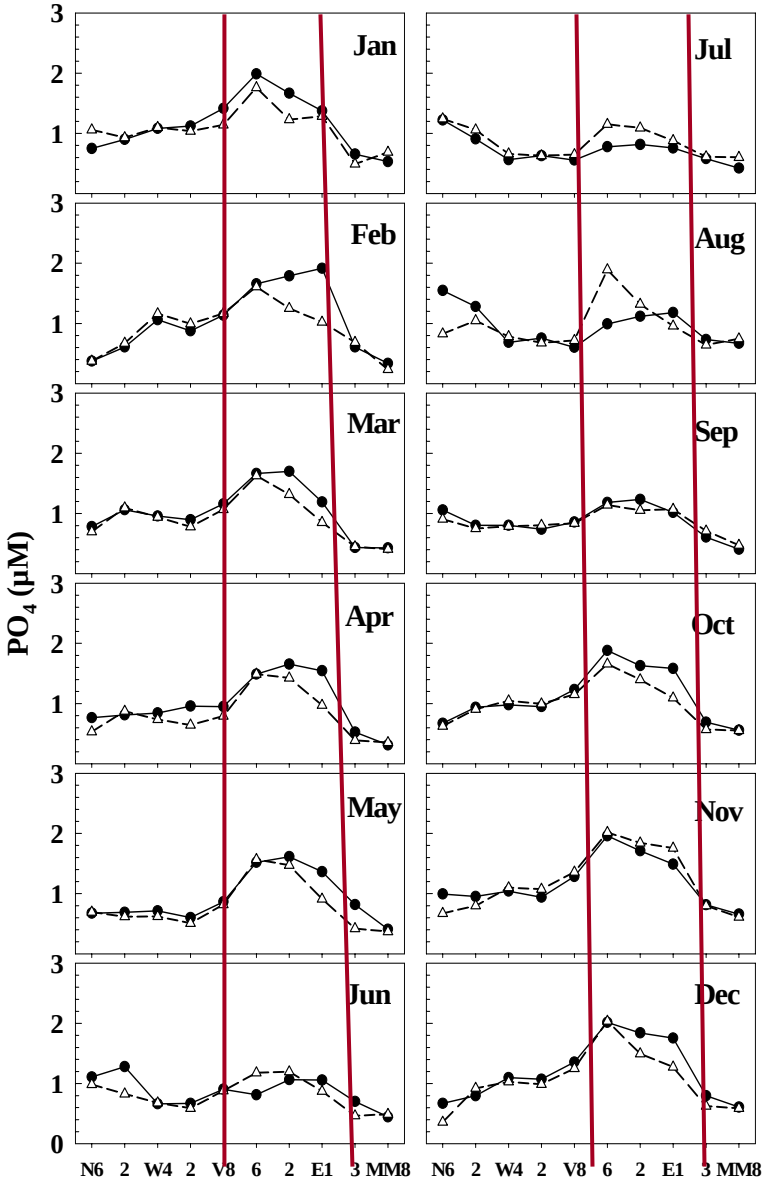
NH_4 is a good marker for sewage input in Victoria Harbor.

From: Yin & Harrison 2005
Mar Poll Bull

Average NH_4 during 1990-2000 for each station across the transect.

● Surface

Δ Bottom



Phosphate

- **Low in dry season**
- **Little change in the estuarine-influenced waters during wet season**
- **Higher in Vic. Harbor**

From: Yin & Harrison 2005
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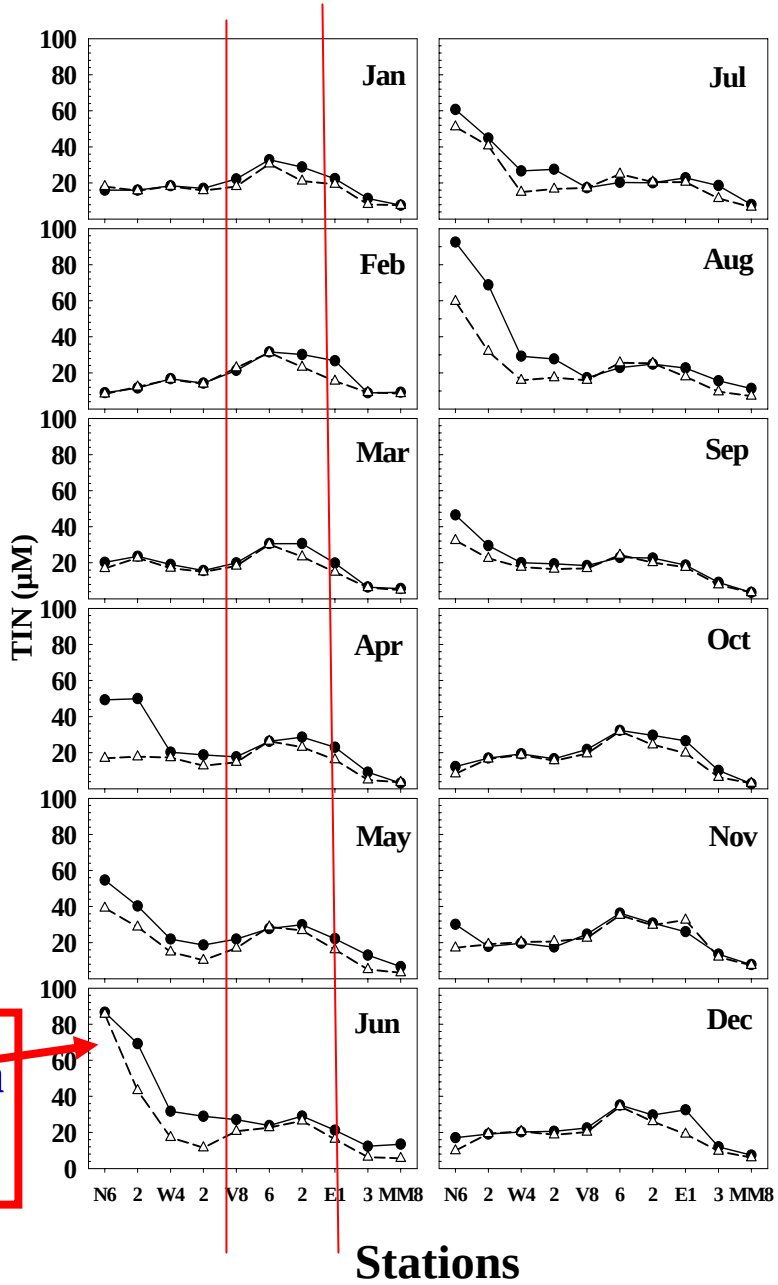
● Surface

Δ Bottom

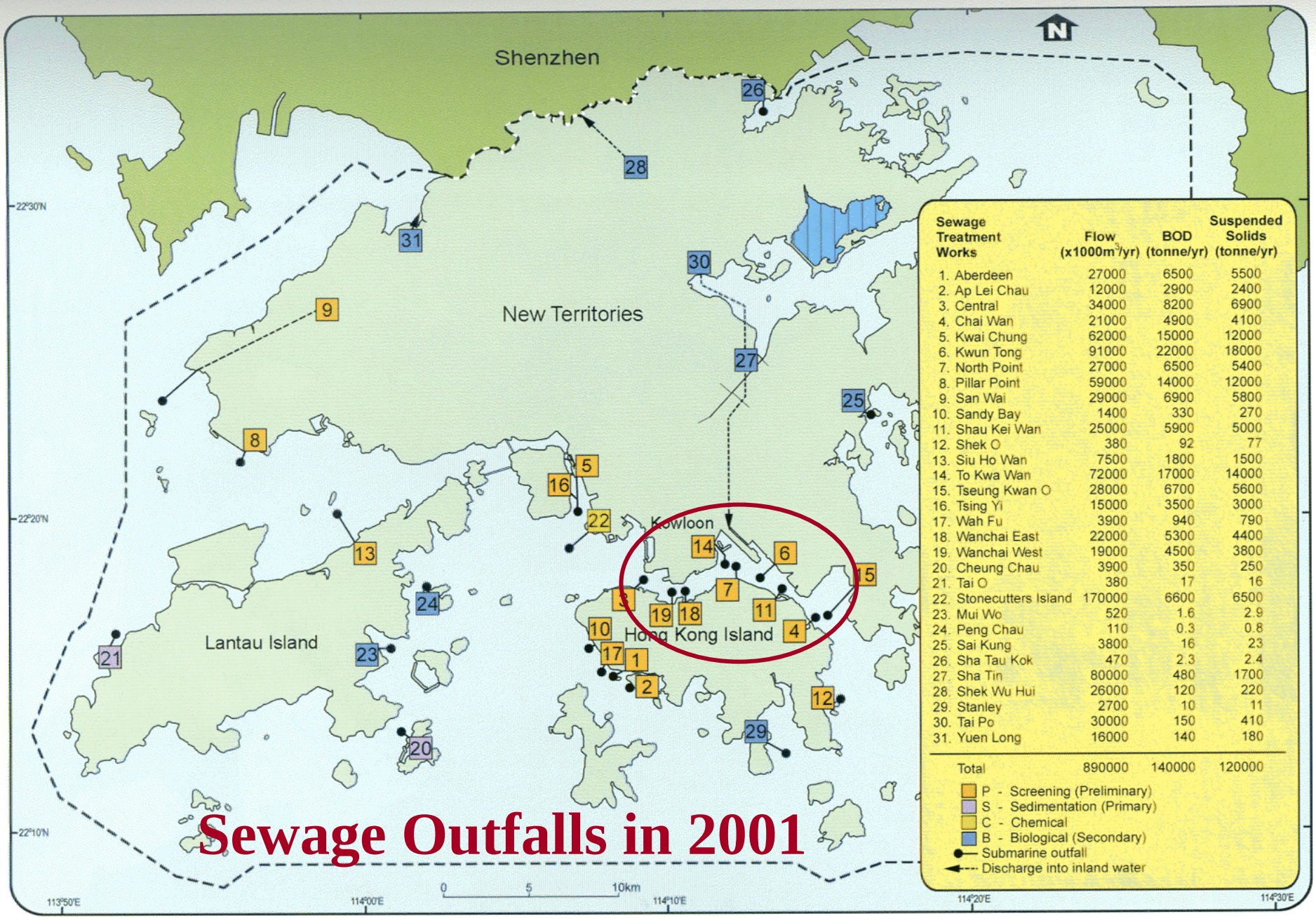


High N from Pearl River

Total Inorganic Nitrogen

- **Low in dry season**
- **High in western waters during wet season.**

From: Yin & Harrison 2005
Mar Poll Bull



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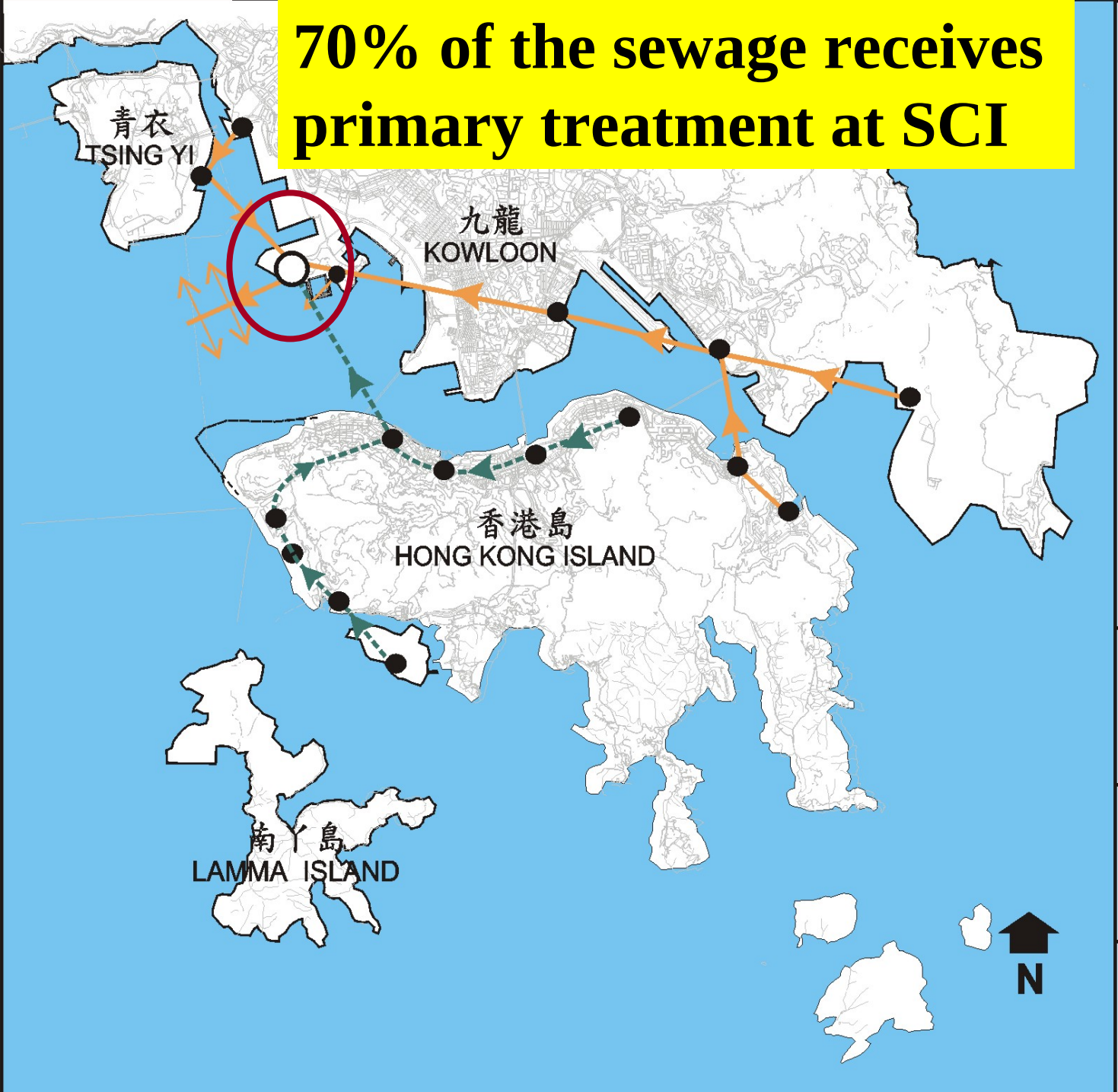
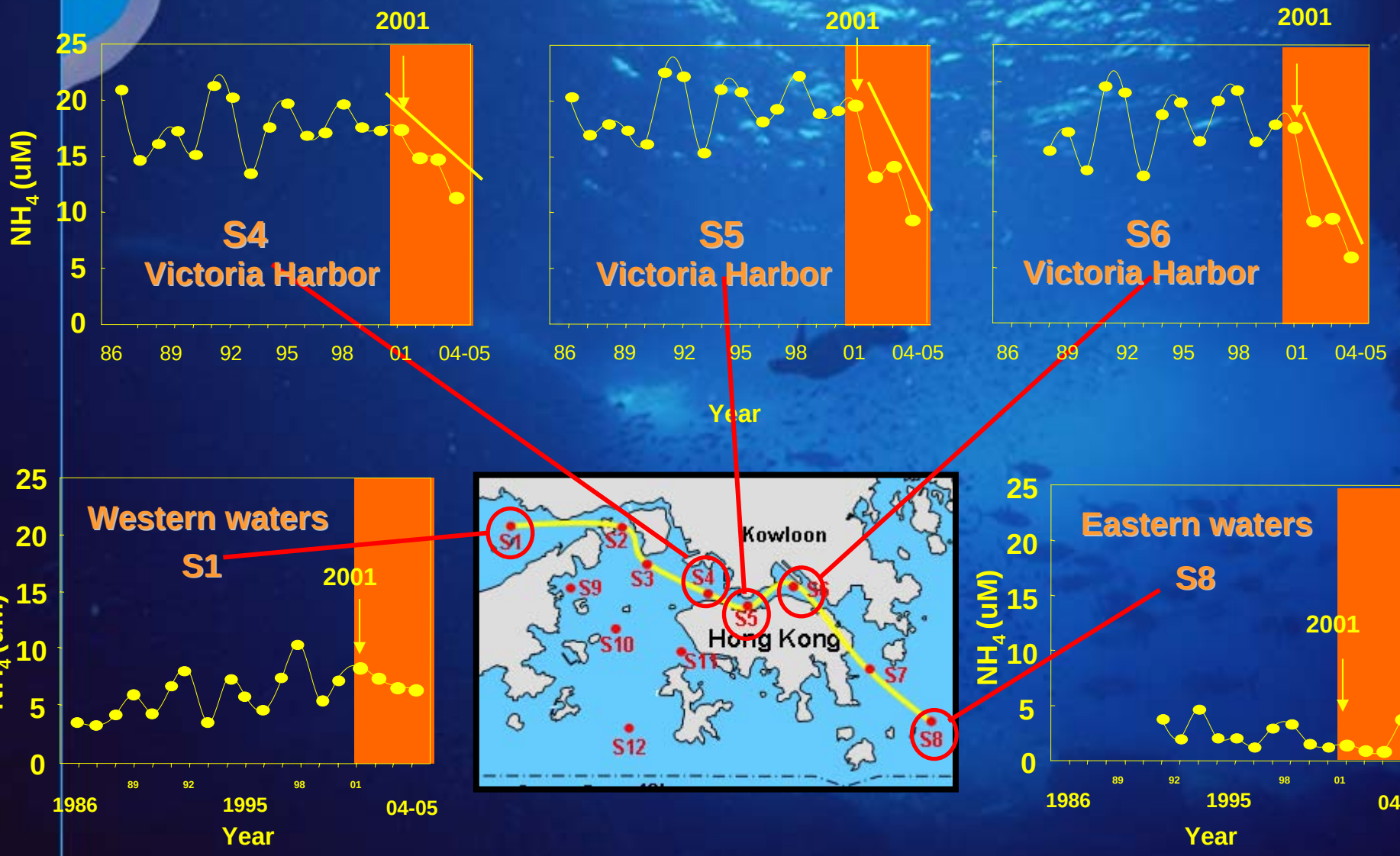

70% of the sewage receives primary treatment at SCI
青衣
TSING YI
九龍
KOWLOON
香港島
HONG KONG ISLAND
南丫島
LAMMA ISLAND
N
圖例 LEGEND :
第一期 (隧道)
STAGE I (TUNNELS)
第三/四期 (隧道)
STAGE III / IV (TUNNELS)
初級污水處理廠
Preliminary Treatment Works
昂船州污水處理廠
Stonecutters Island
Sewage Treatment Works
國際專家小組方案一
International Review Pane
Option 1
淨化海港計劃
Harbour Area
Treatment Scheme

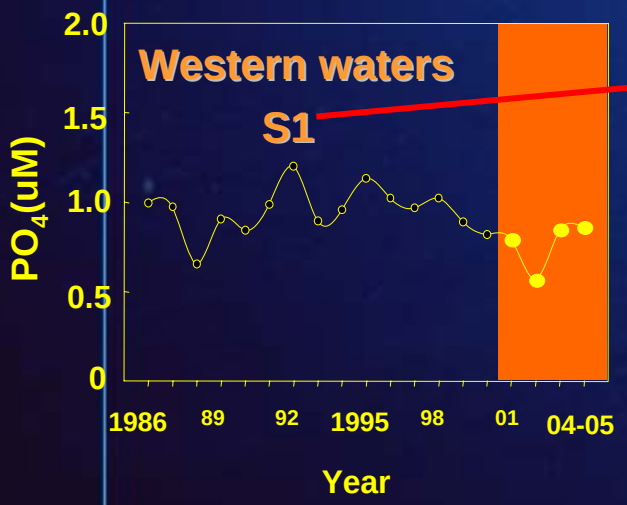
Transect 1: West → East

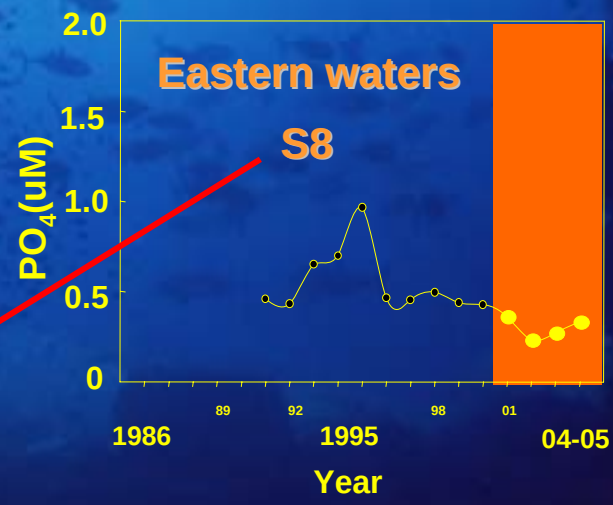
NH_4^+



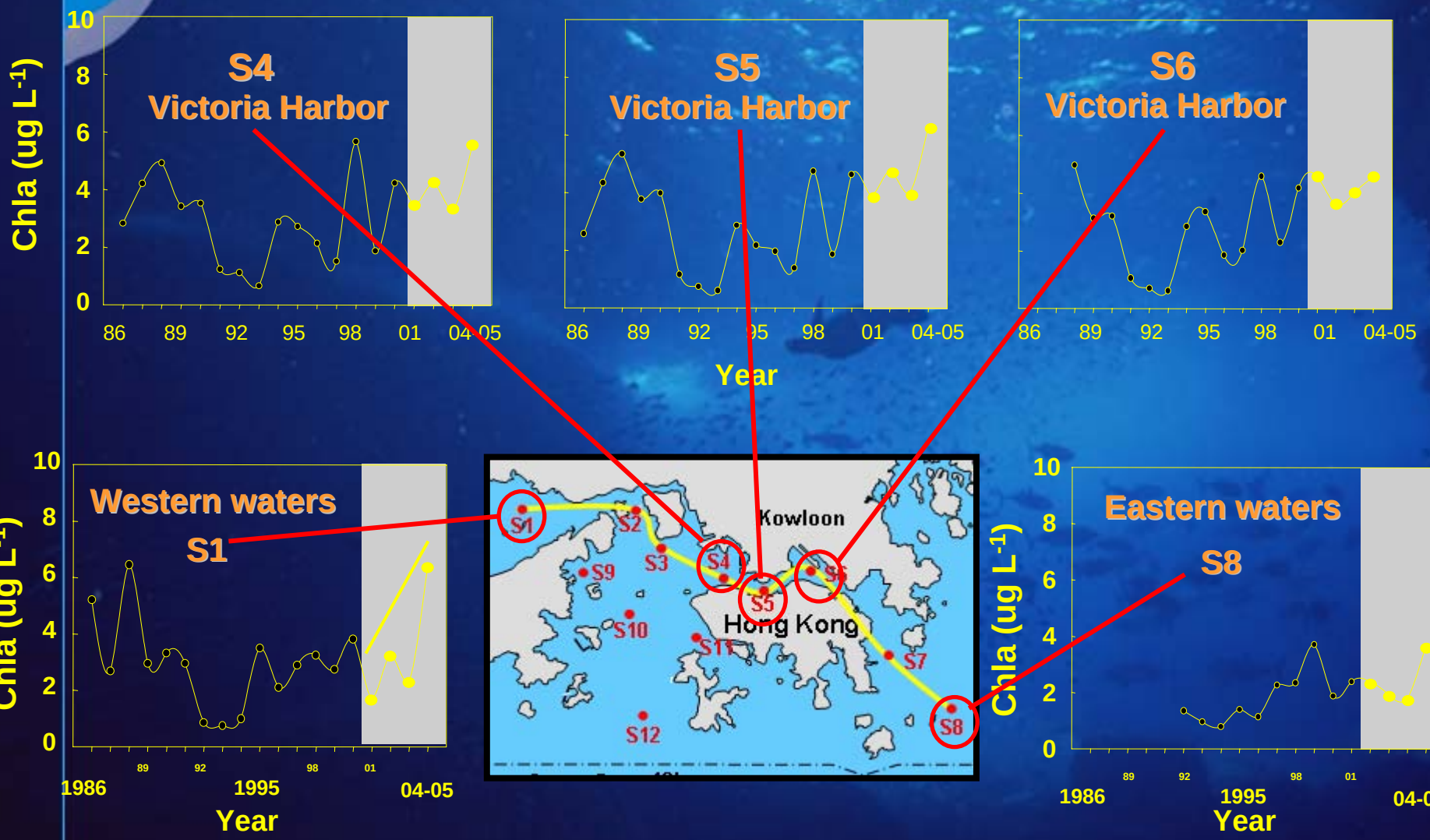
Transect 1: West → East

PO_4^{3-}

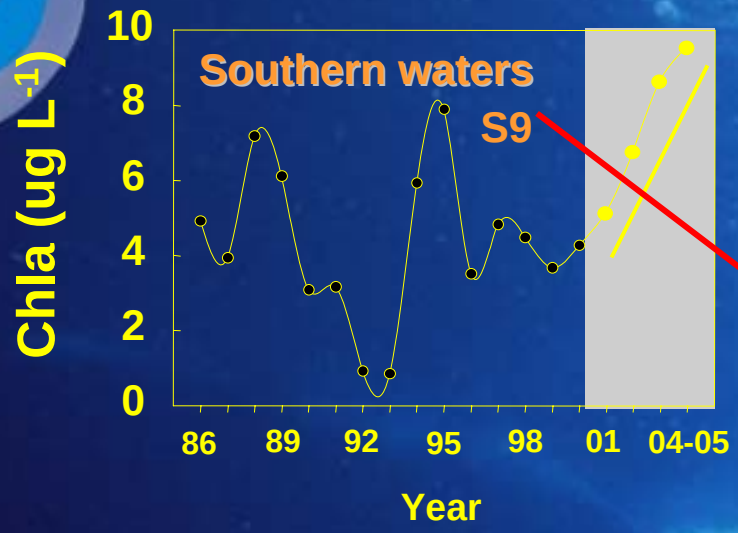


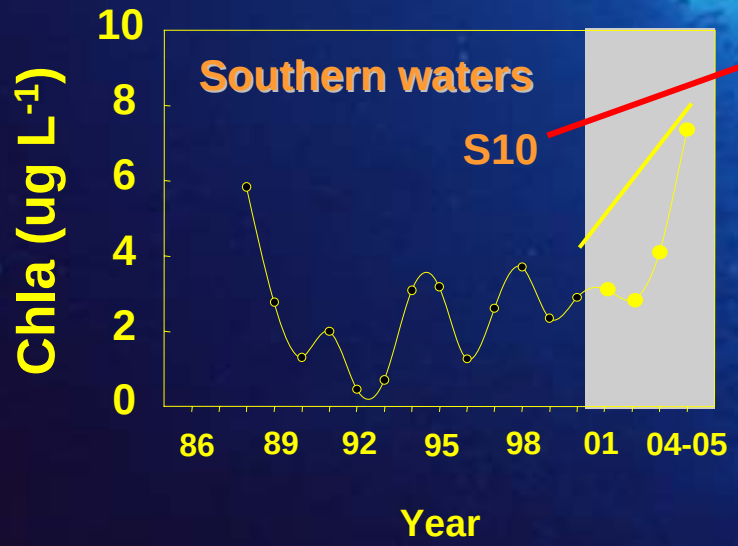


Transect 1: West → East



Chl in Southern Waters





Bottom DO

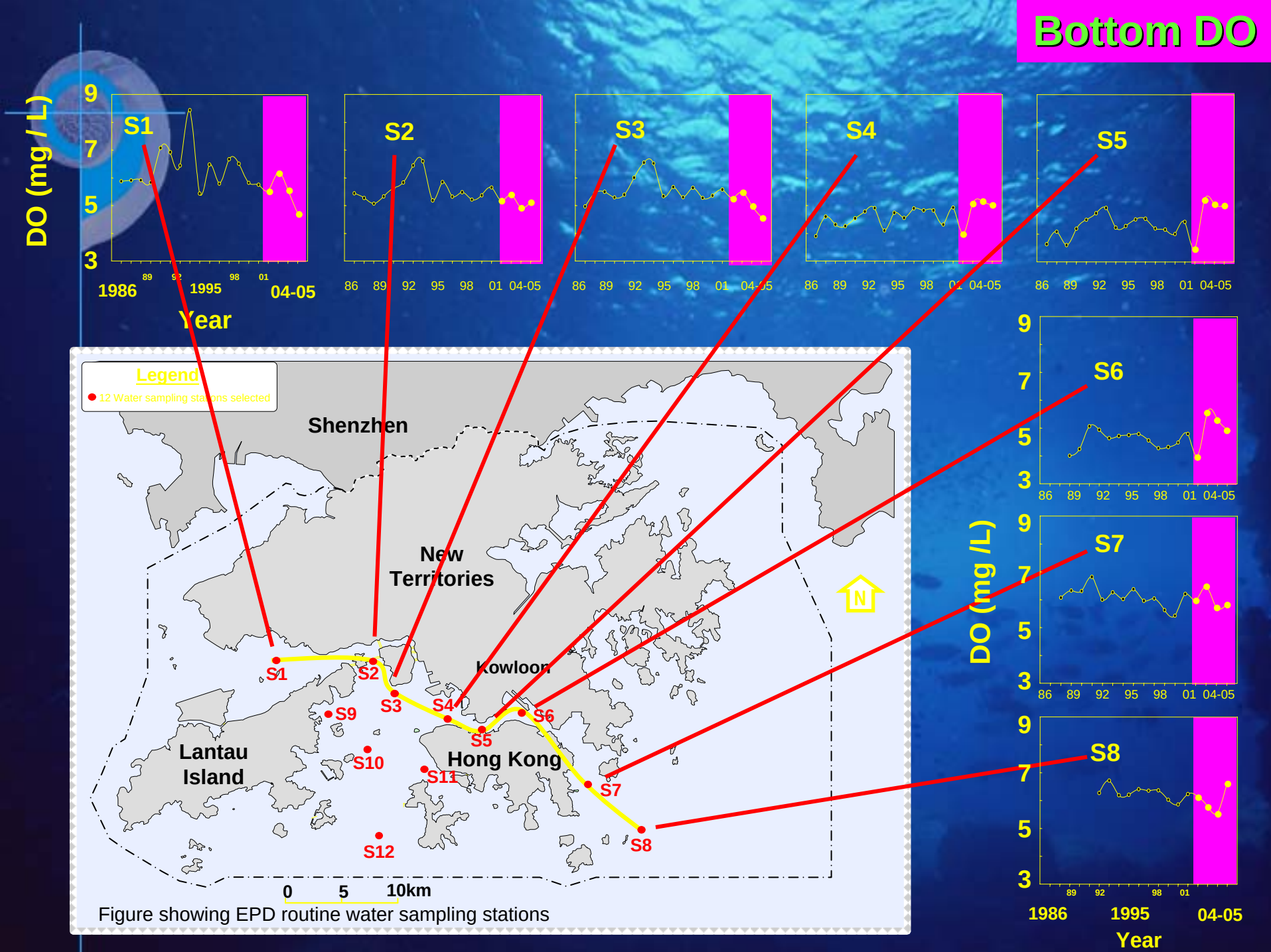
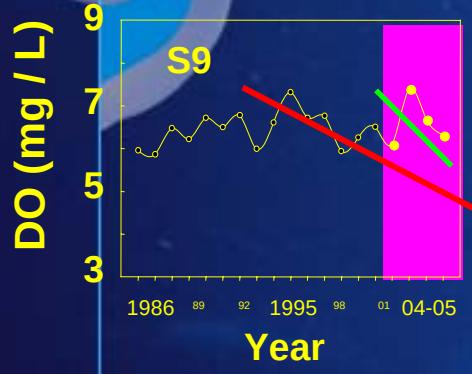
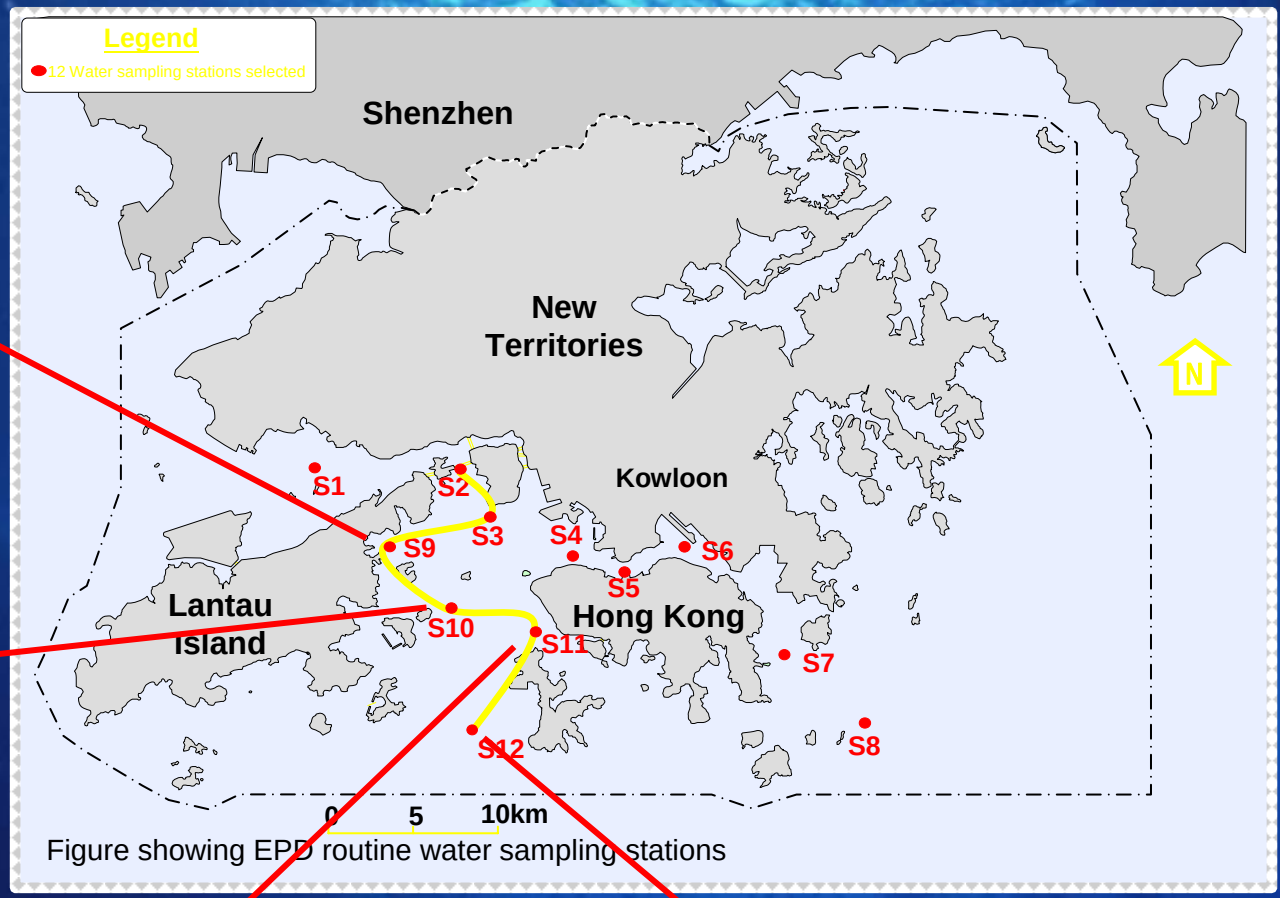


Figure showing EPD routine water sampling stations

Bottom DO





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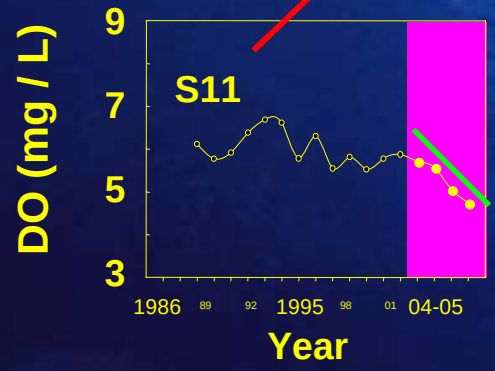
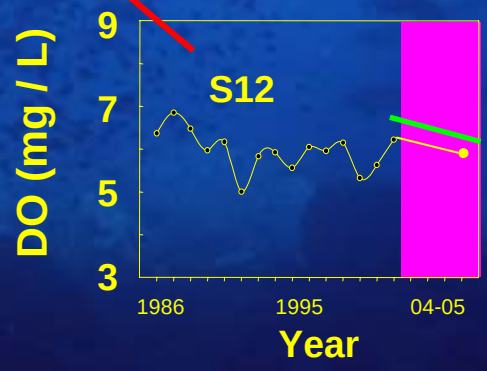




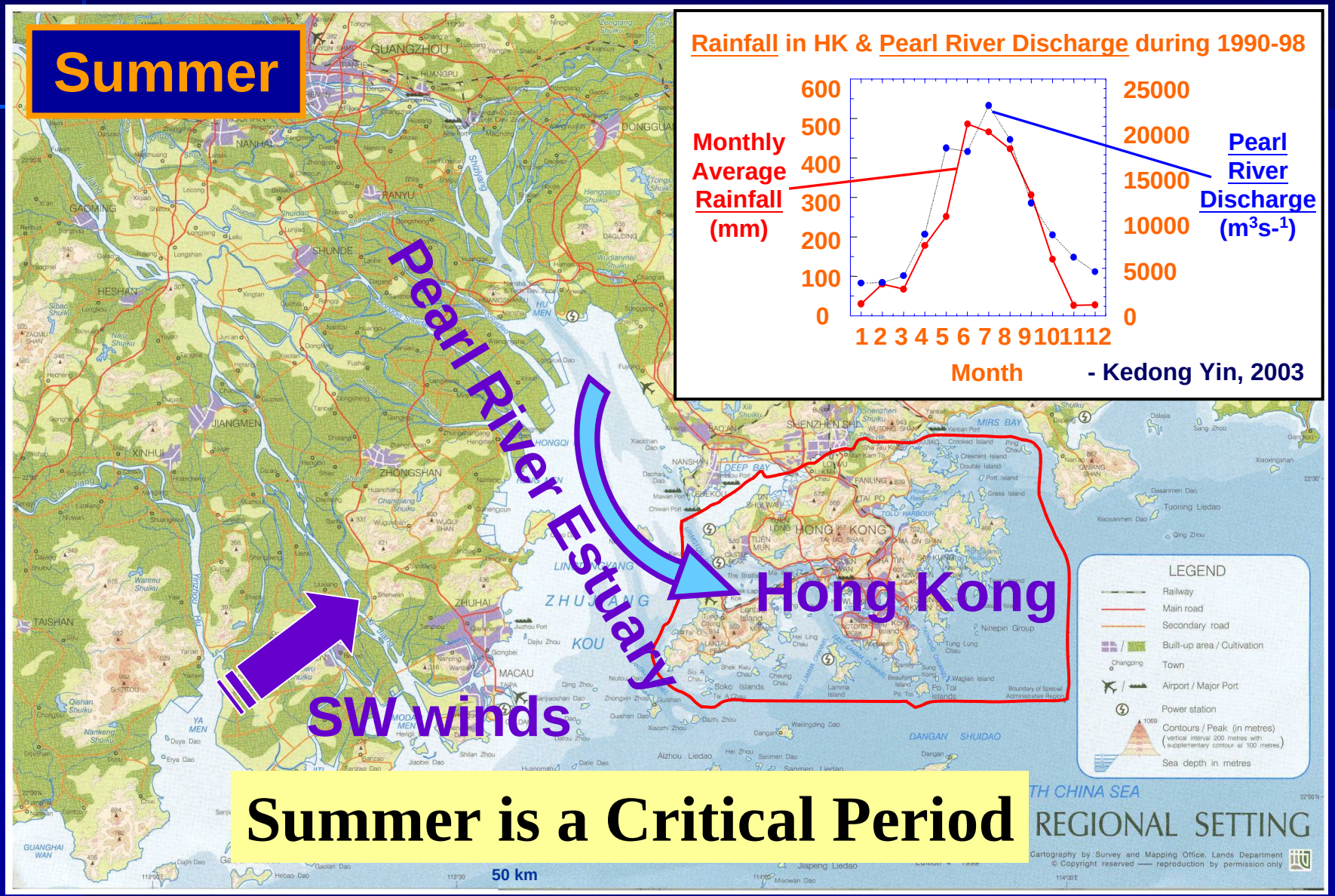
Cross-border Influence

(Watershed contribution)

- Pearl River discharge
- Rainfall

Guangdong Province & Pearl River Region (satellite image courtesy of Pearl River Water Resources Commission, 1998)

HK Nutrient Source 1: Pearl River Estuary



Nutrient Sources

1) Anthropogenic Sources

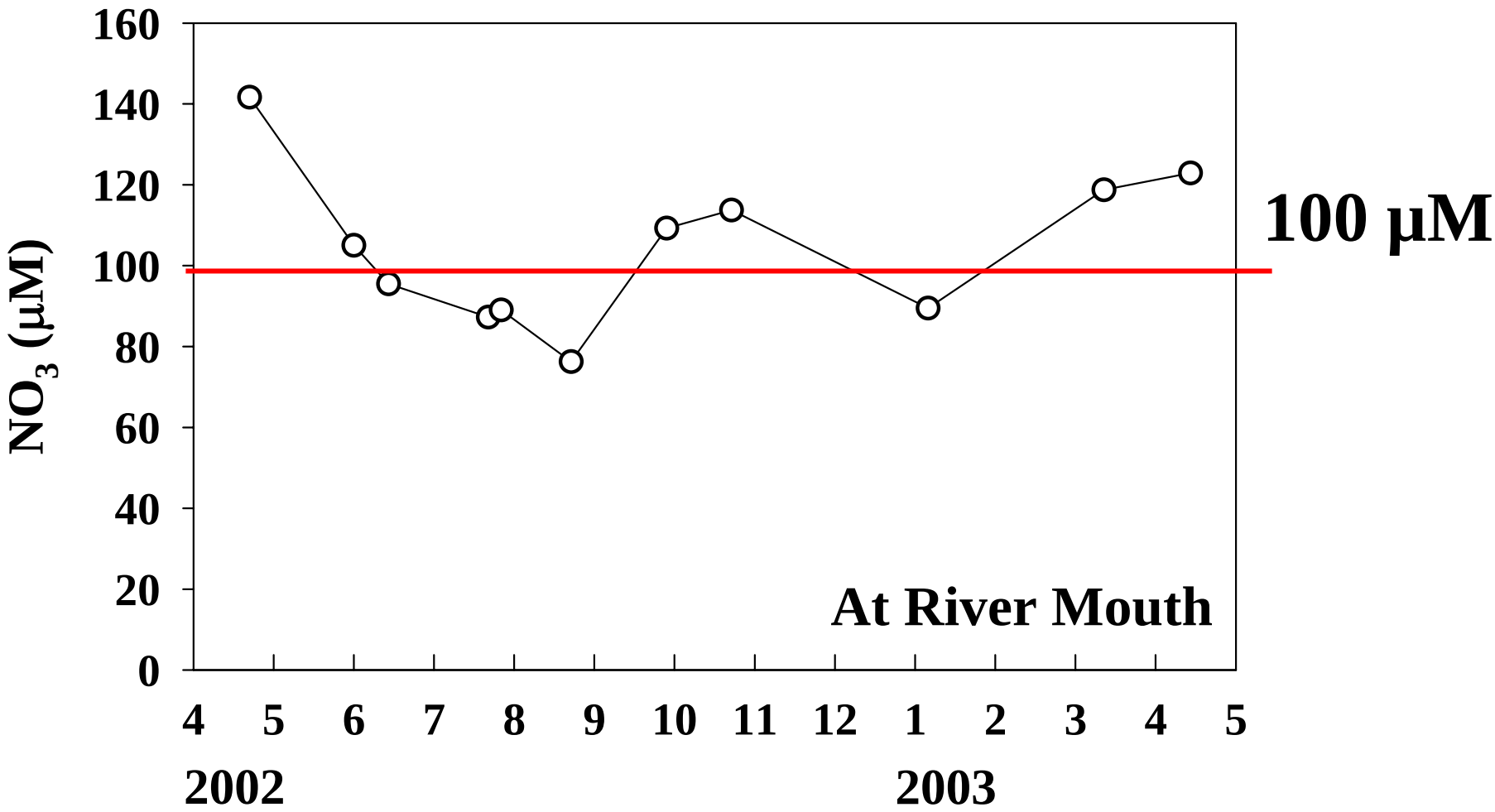
- **Sewage N:P = 8:1**
- **Rain N:P = 50:1**
- **River N:P > 100:1**

Excess nitrogen in Summer

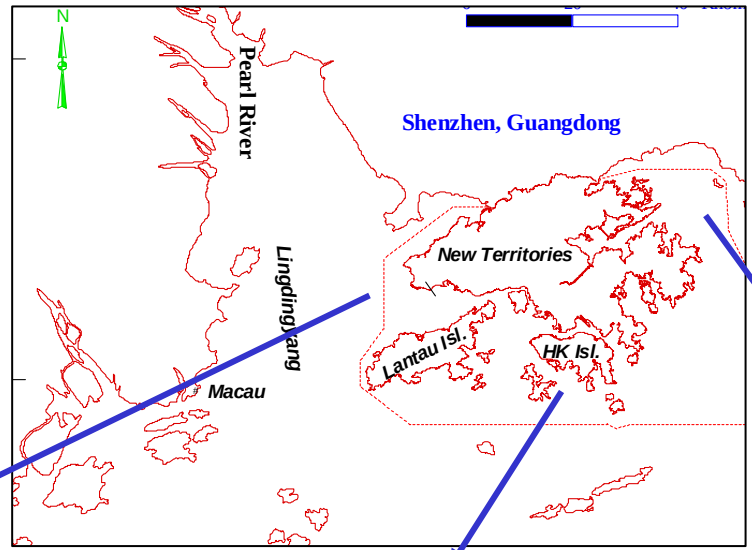
2) Natural Sources (N:P <16:1) from coast - South China Sea

Algae need N:P = 16:1

NO_3 at Humen (a river mouth of the Pearl River)



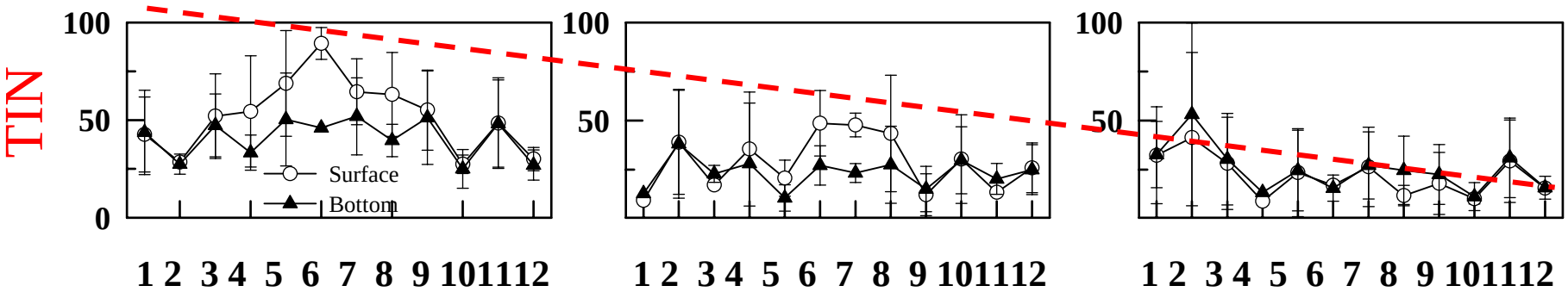
Monthly Average of total inorganic nitrogen during 1991-2000 (Yin 2002)



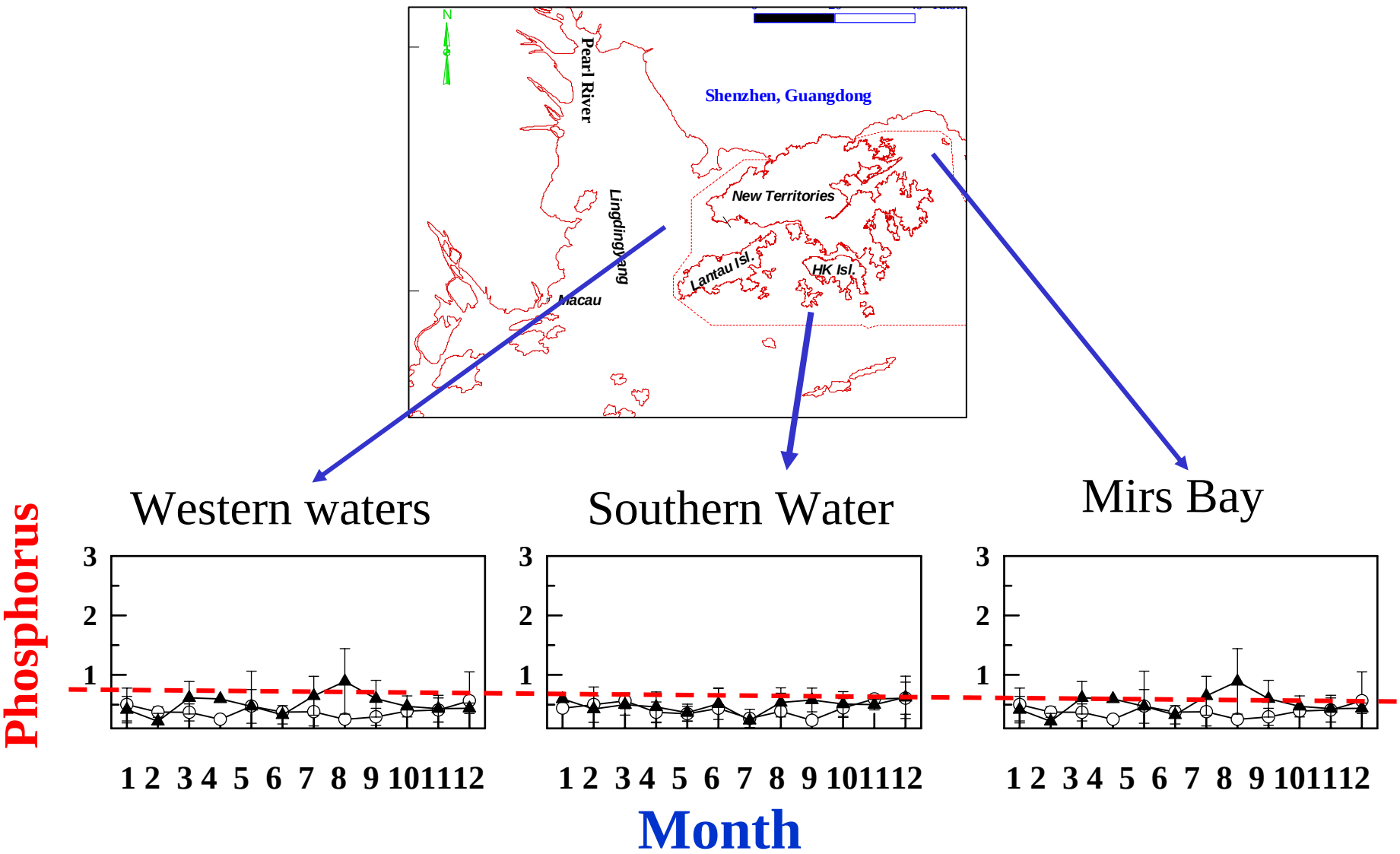
Western waters

Southern Water

Mirs Bay

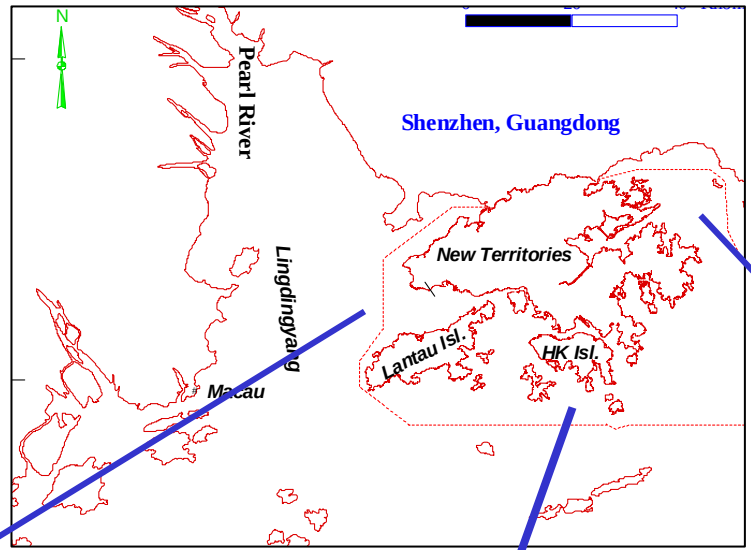


Monthly Average of phosphate during 1991-2000 (Yin 2002)



Monthly Average of Molar N:P ratio during 1991-2000

(Yin 2002)



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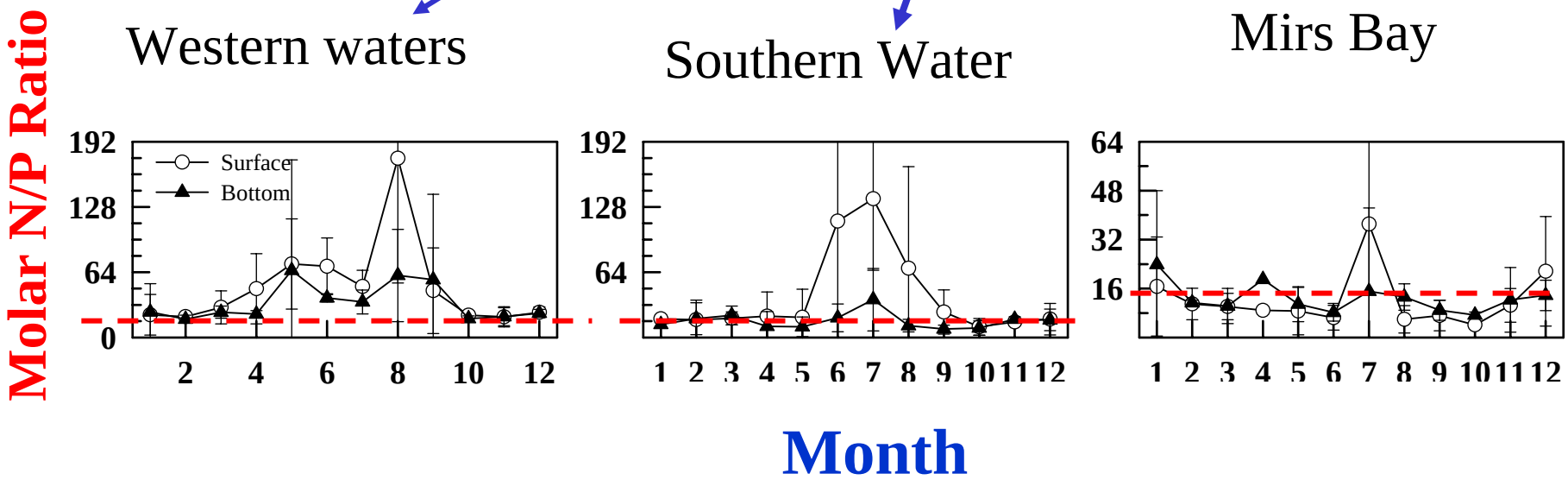
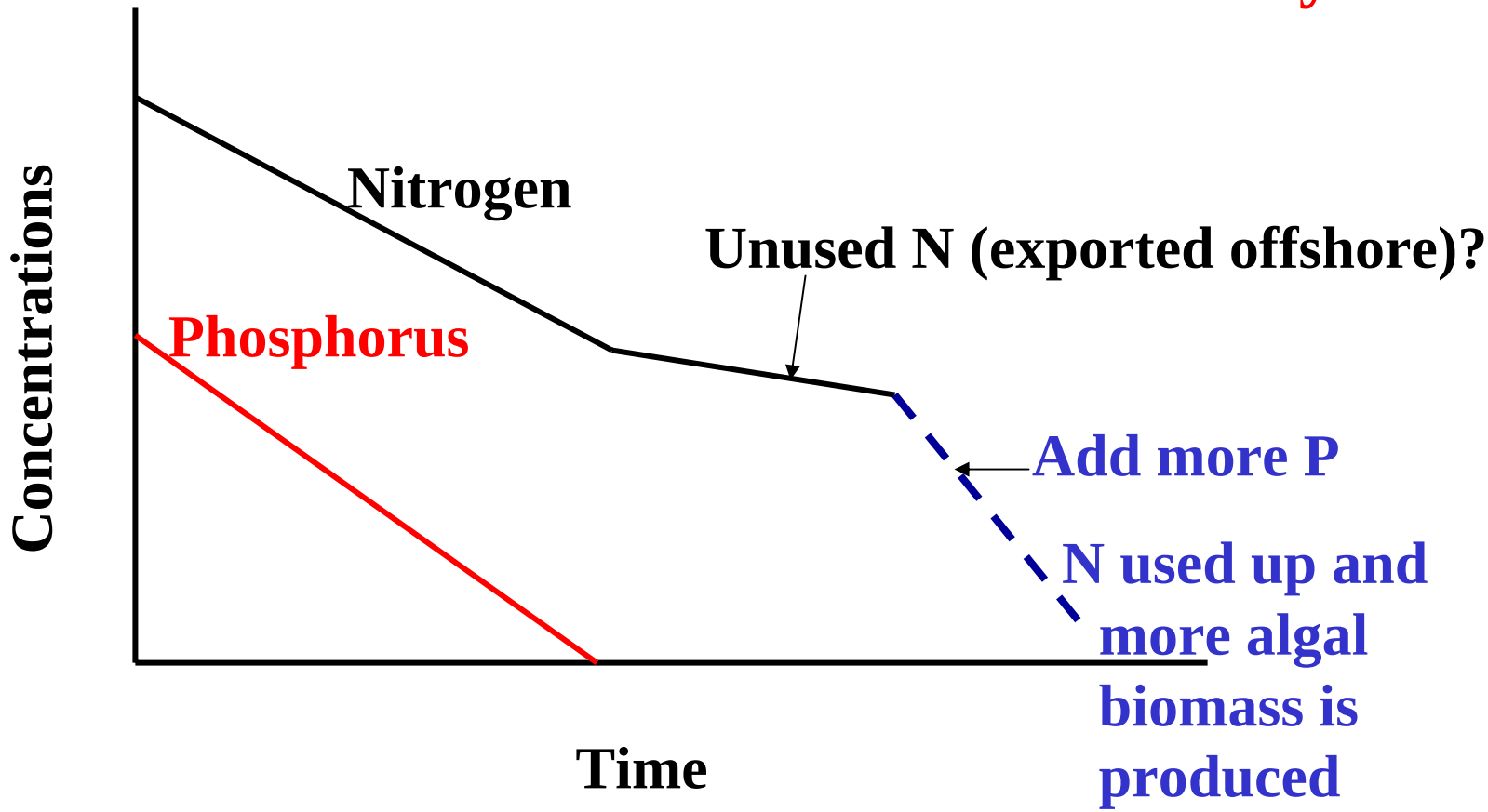
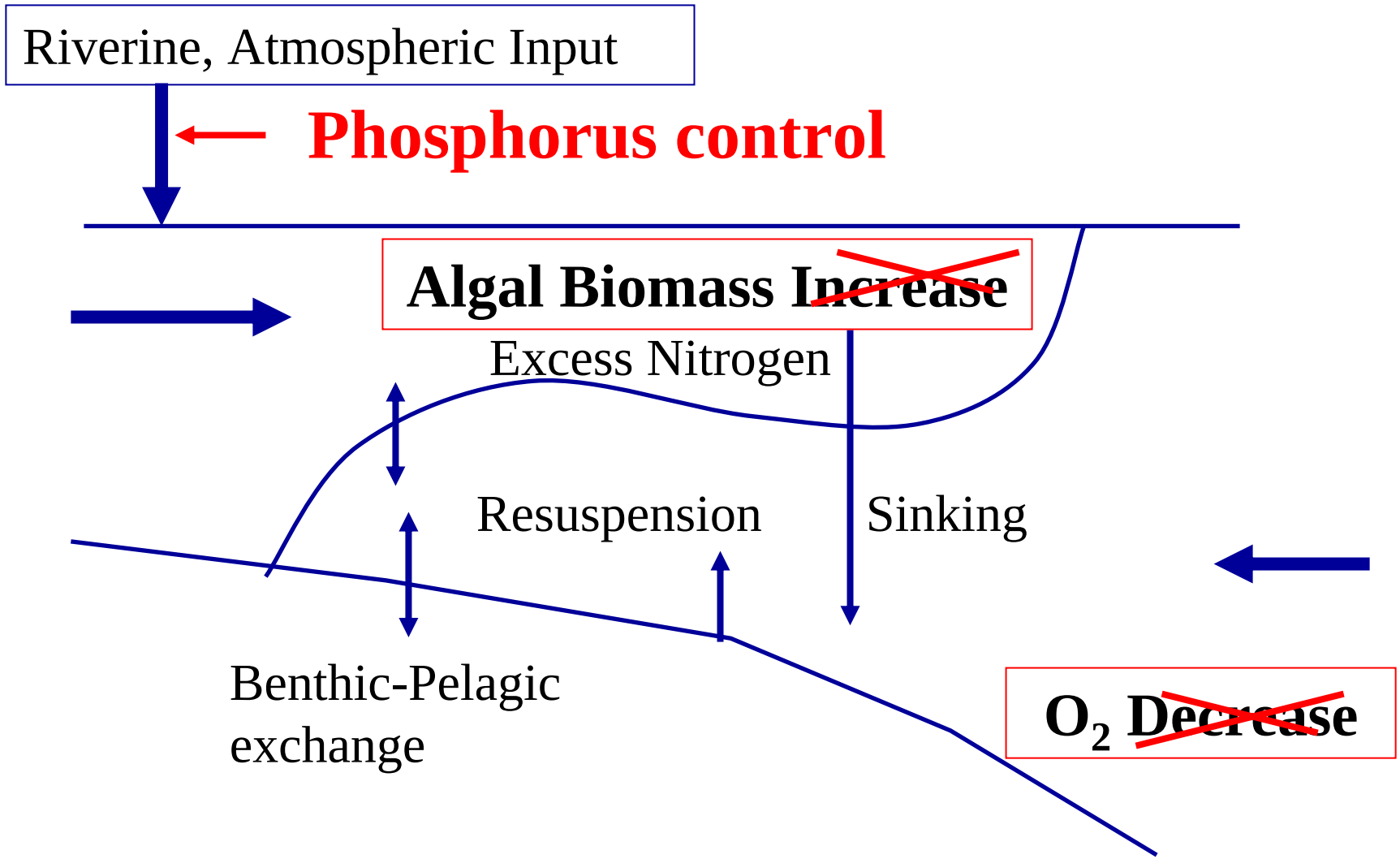


Unused Nitrogen in Summer in Western and Southern waters

Potential P limitation in summer near estuary



Ecosystem Responses to Input of Nutrients



Only Episodic Low O_2 Events – Late Summer

- **Good Physics**

  – wind and tidal mixing and tidal currents dilute the algal biomass.

  - Shallow water depth

- **Good Chemistry**

  - low phosphorus compared to some rivers

Summary

- **Excess nitrogen in summer in western and southern waters.**
- **P is potentially the most limiting nutrient since N/P ratios are high in the estuarine influenced western waters in summer.**
- **At the present, removal of P would more likely control algal biomass production.**
- **Improving conditions in Victoria Harbor due to sewage abatement.**