Yessotoxins: history, existence, risk and warning

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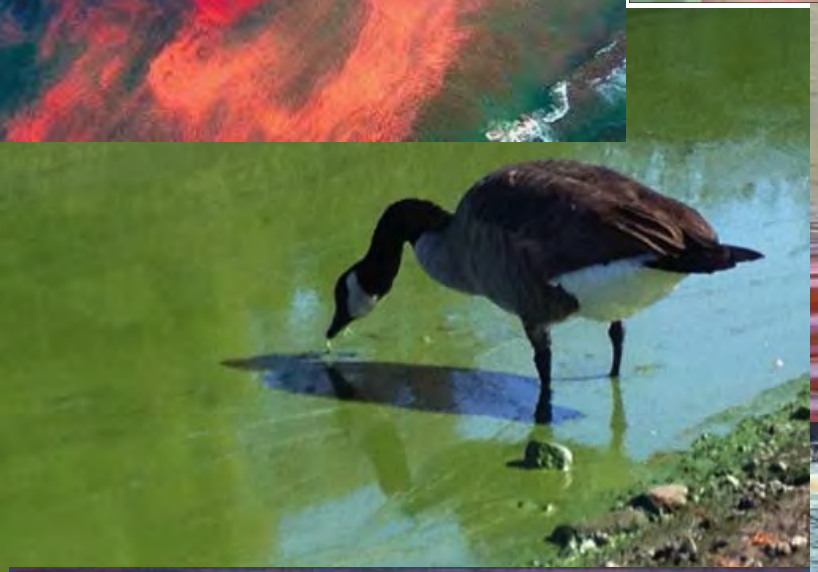
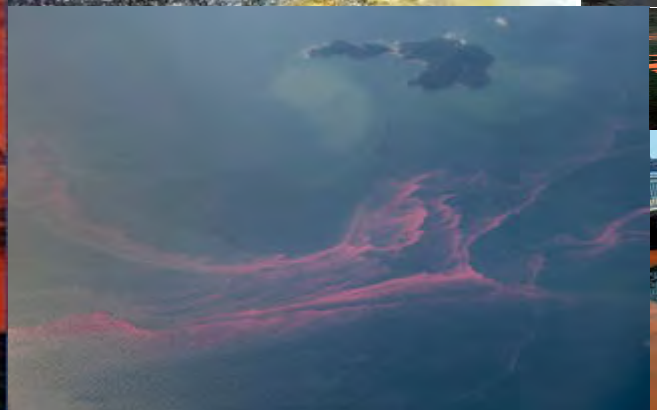
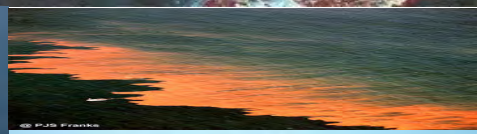
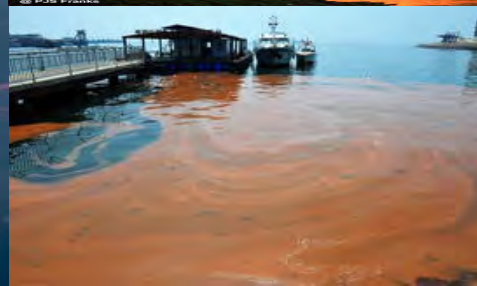
Harmful algae bloom(HAB)

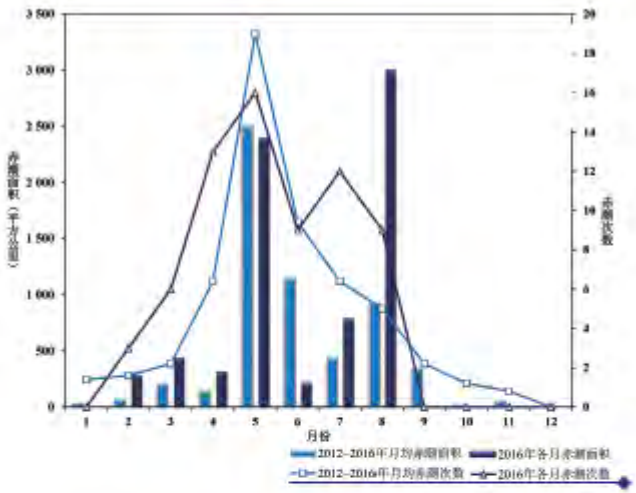




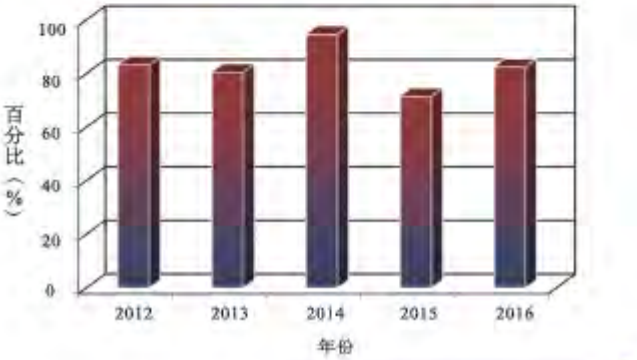




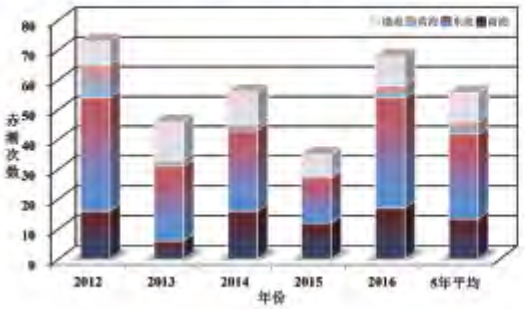
2012~2016年我国海域赤潮频次与面积的月际分布



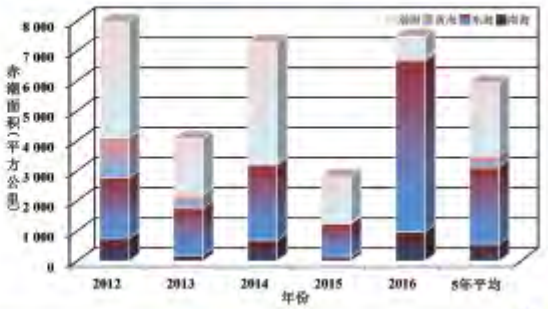
2012~2016年甲藻、着色鞭毛藻等引发的赤潮次数占当年总次数比例



2012~2016年我国海域发现的赤潮次数



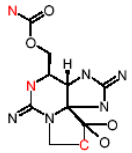
2012~2016年我国海域赤潮累计面积

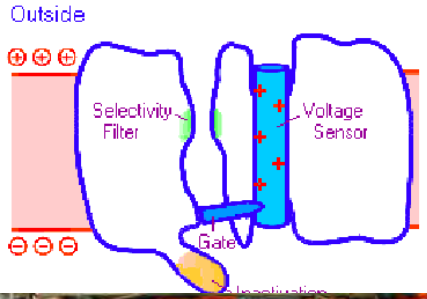


海区	赤潮发现次数Times	赤潮累计面积（平方公里）Area
Bohai 渤海	13	1880
Yelloe sea 黄海	2	450
East China Sea东海	25	1573
South China Sea南海	6	167
Total 合计	**46**	**4070**

海区	赤潮发现次数Times	赤潮累计面积（平方公里）Area
Bohai 渤海	10	740
Yelloe sea 黄海	4	62
East China Sea东海	37	5417
South China Sea南海	17	968
Total 合计	**68**	**7484**

The summary in 2013(up）2016（down）





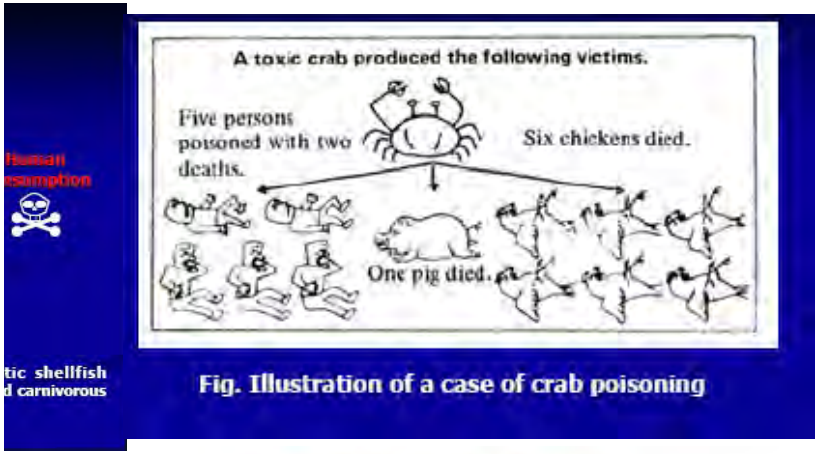


Fig. Illustration of a case of crab poisoning

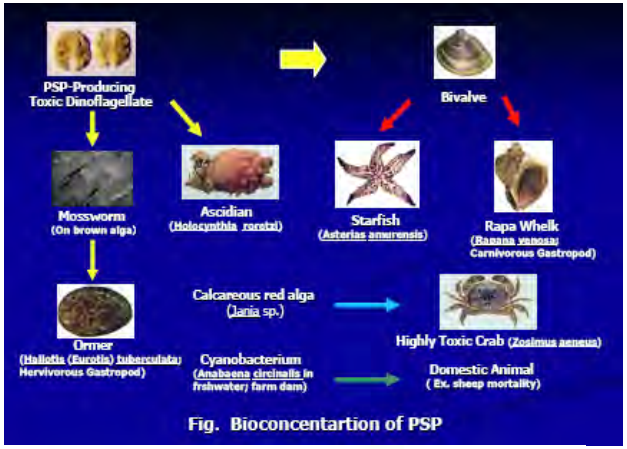


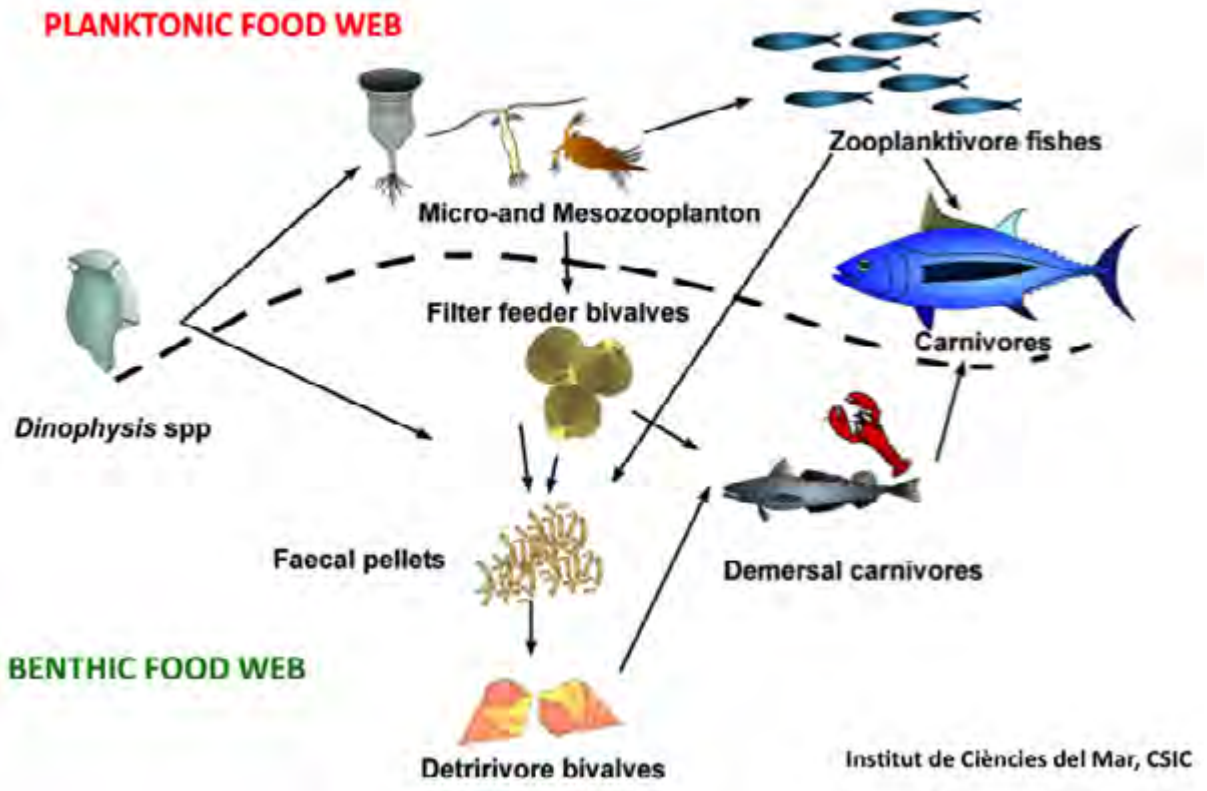
Fig. Bioconcentartion of PSP

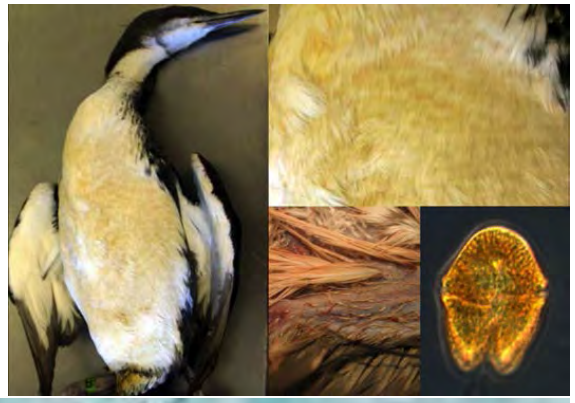
Mass mortality of flat-fish by a red tide of *Cochlodinium polykrikoides*

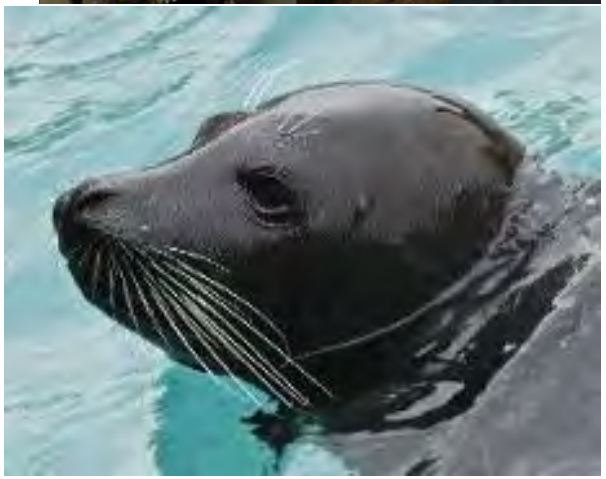
Flat-fish culture farms

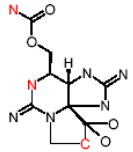
Photo by Mr. San Geun Lee of National Fisheries Reseach & Development Agency of Korea

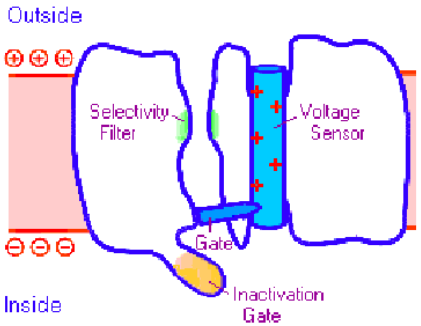
WESTPAC-HAB





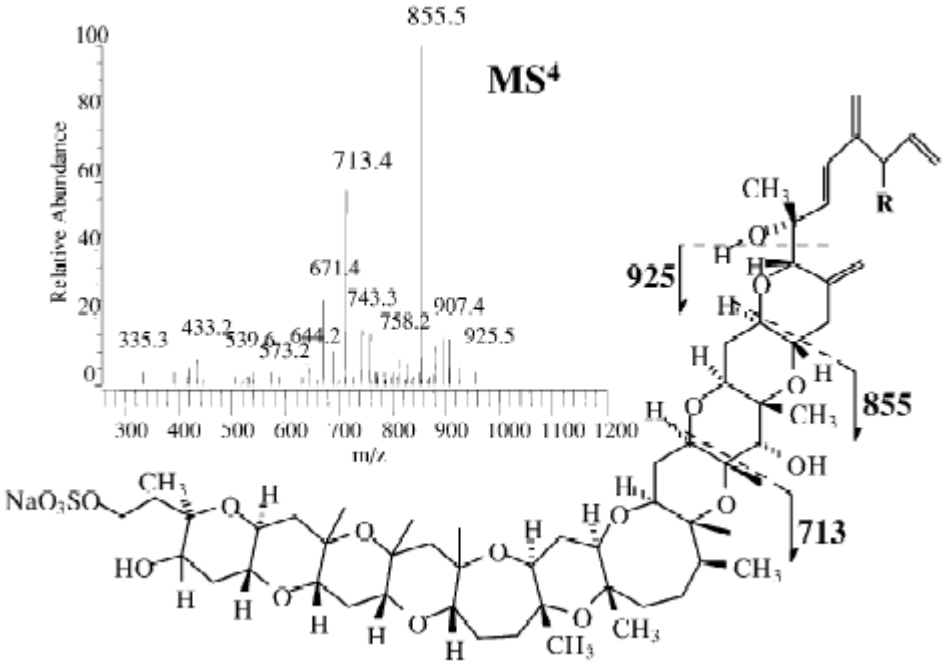


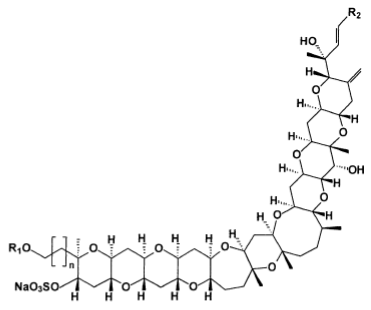




Massive mortalities of wild animals (turtles, dolphins, manatees, whales, birds) have also been linked to the microalgal toxins accumulating in food webs. **In the last few decades**, algal toxins were **responsible** for the death of 19 humpback whales off Cape Cod (USA), and probably of pygmy, dwarf sperm, and North Atlantic right whales. The US National Oceanic and Atmospheric Administration estimates that **more than 50% of all Unusual Mortality Events (UMEs) are due to algal biotoxins**. While not proven, HABs could also have been involved in Southern right whale mortalities in Peninsula Valdés (Argentina). In 2000, four captive penguins died in a zoo in Kentucky, USA (far from the ocean) after consuming herring and anchovies collected from Monterey Bay, CA (USA), a known hotspot for domoic acid (the cause of Amnesic Shellfish Poisoning).

Yessotoxins





Yessotoxin (YTX): **n=1; R_1= SO_3Na; R_2=**

45-HydroxyYTX: **n=1; R_1= SO_3Na; R_2=**

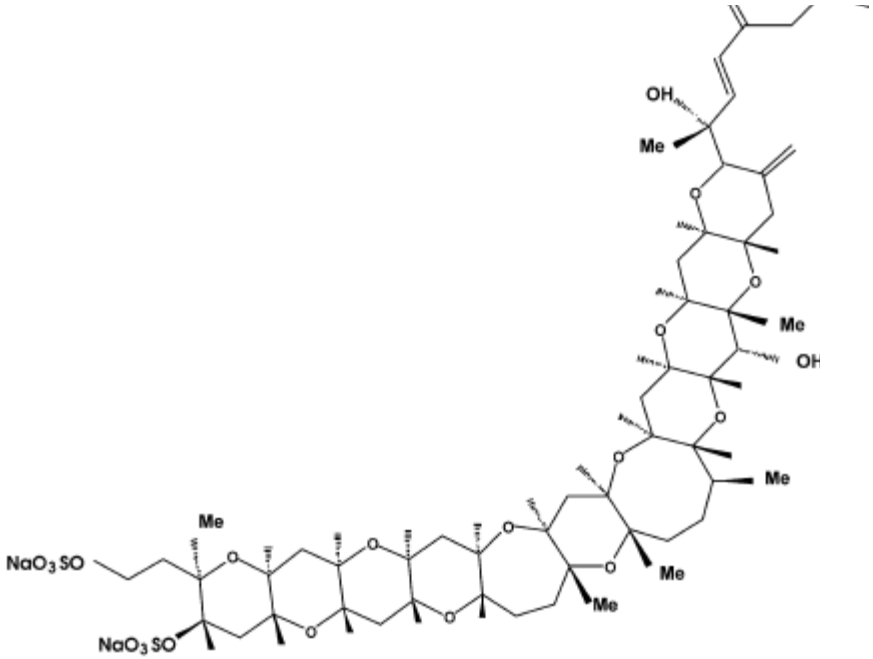
45,46,47-TrinorYTX: **n=1; R_1= SO_3Na; R_2=**

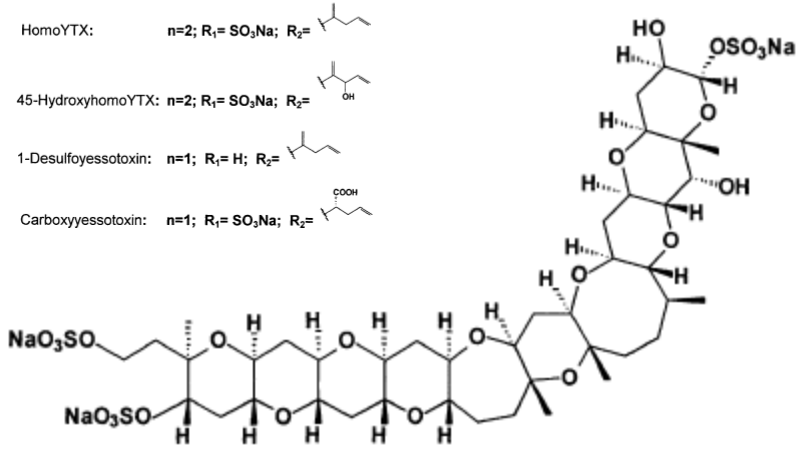
HomoYTX: **n=2; R_1= SO_3Na; R_2=**

45-HydroxyhomoYTX: **n=2; R_1= SO_3Na; R_2=**

1-Desulfoyessotoxin: **n=1; R_1= H; R_2=**

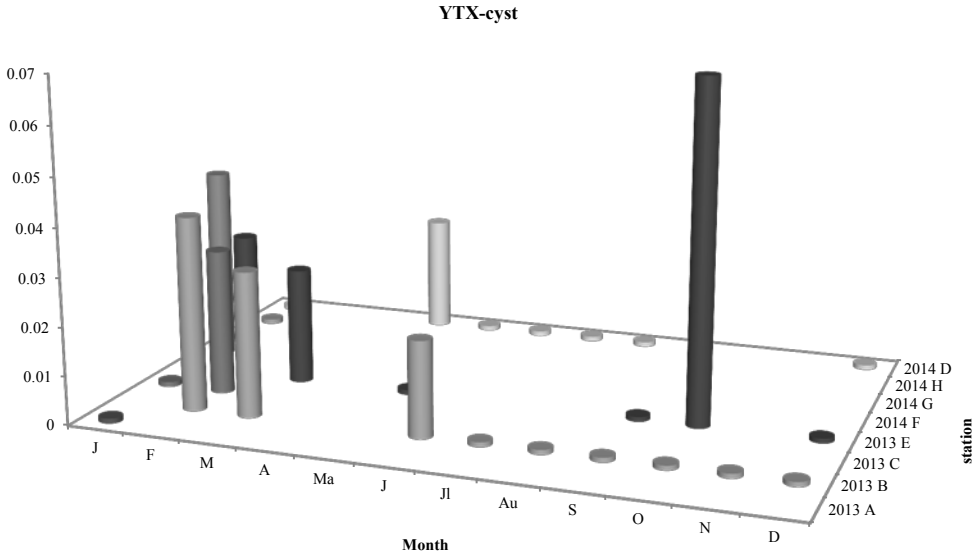
Carboxyyessotoxin: **n=1; R_1= SO_3Na; R_2=**

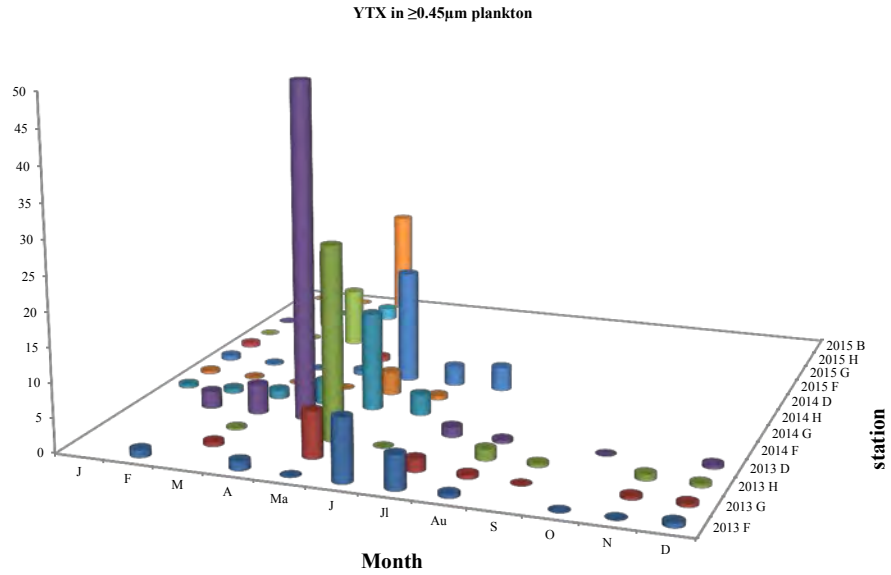


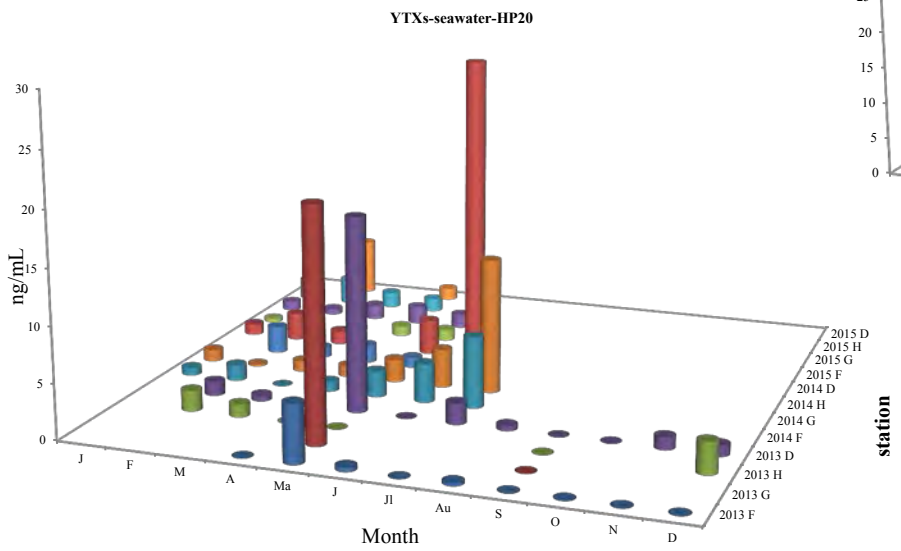


Adriatoxin (ATX)

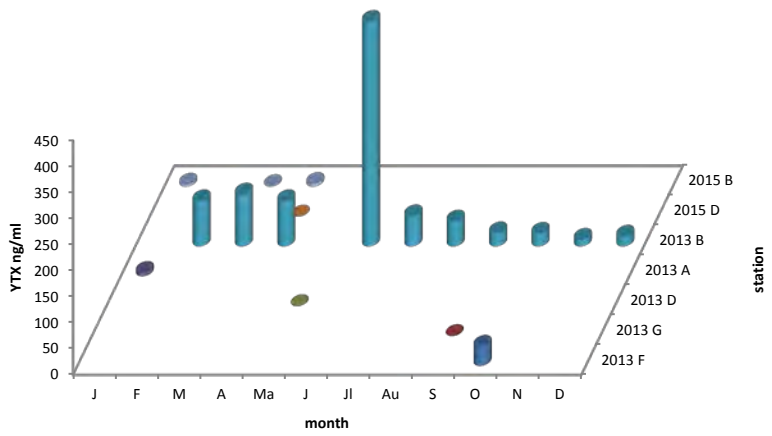
YTXs distribution


YTX-cyst
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
J
F
M
A
Ma
J
Jl
Au
S
O
N
D
Month
2014 D
2014 H
2014 G
2014 F
2013 E
2013 C
2013 B
2013 A
station

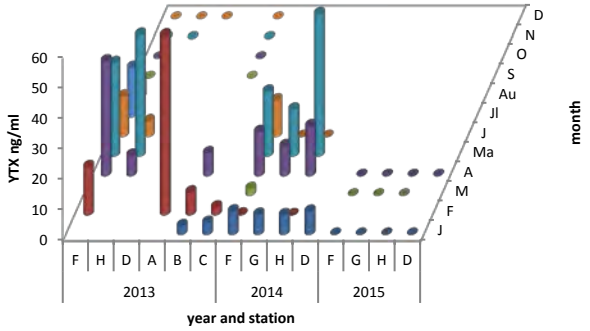

YTX in ≥0.45μm plankton
50
45
40
35
30
25
20
15
10
5
0
J
F
M
A
Ma
J
Jl
Au
S
O
N
D
Month
2015 B
2015 H
2015 G
2015 F
2014 D
2014 H
2014 G
2014 F
2013 D
2013 H
2013 G
2013 F
station


YTXs-seawater-HP20
ng/mL
30
25
20
15
10
5
0
J
F
M
A
Ma
J
Jl
Au
S
O
N
D
Month
2015 D
2015 H
2015 G
2015 F
2014 D
2014 H
2014 G
2014 F
2013 D
2013 H
2013 G
2013 F
station

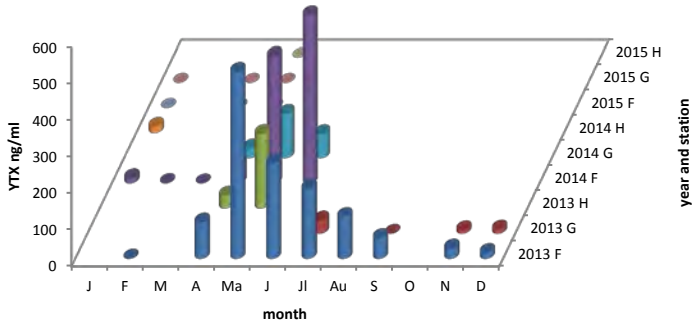
a: ZYB

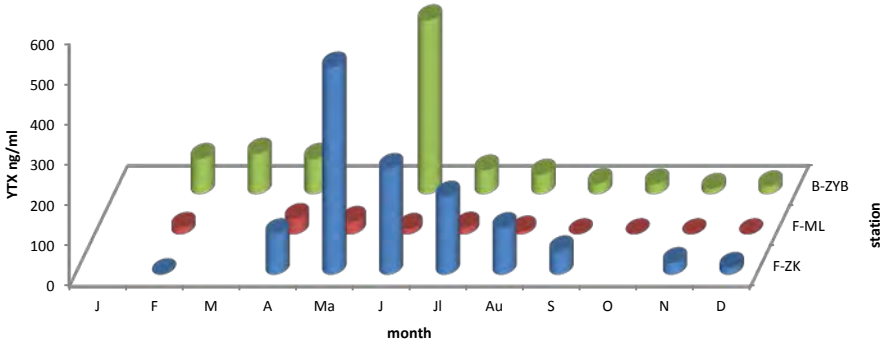

YTX ng/ml
450
400
350
300
250
200
150
100
50
0
J F M A Ma J Jl Au S O N D
month
2015 B
2015 D
2013 B
2013 A
2013 D
2013 G
2013 F
station

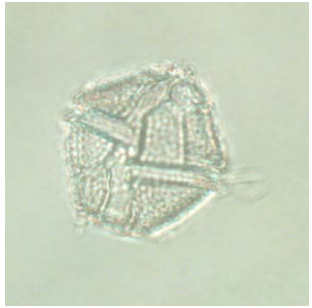
c: ML

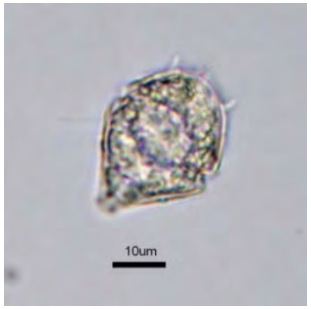

YTX ng/ml
60
50
40
30
20
10
0
F H D A B C F G H D F G H D
2013
2014
2015
year and station
D
N
O
S
Au
Jl
J
Ma
A
M
F
J
month

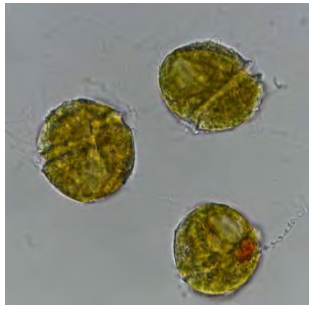
b: ZK


YTX ng/ml
600
500
400
300
200
100
0
J F M A Ma J Jl Au S O N D
month
2015 H
2015 G
2015 F
2014 H
2014 G
2014 F
2013 H
2013 G
2013 F
year and station

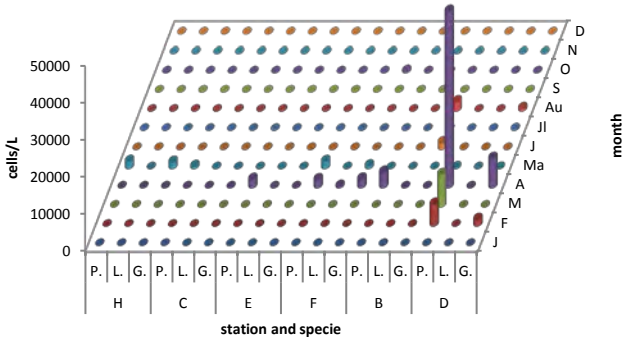

YTX ng/ml
600
500
400
300
200
100
0
J F M A Ma J Jl Au S O N D
month
B-ZYB
F-ML
F-ZK
station

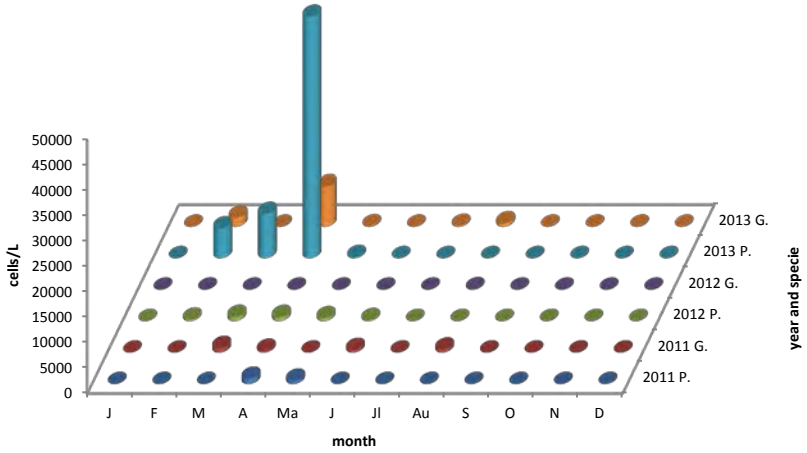


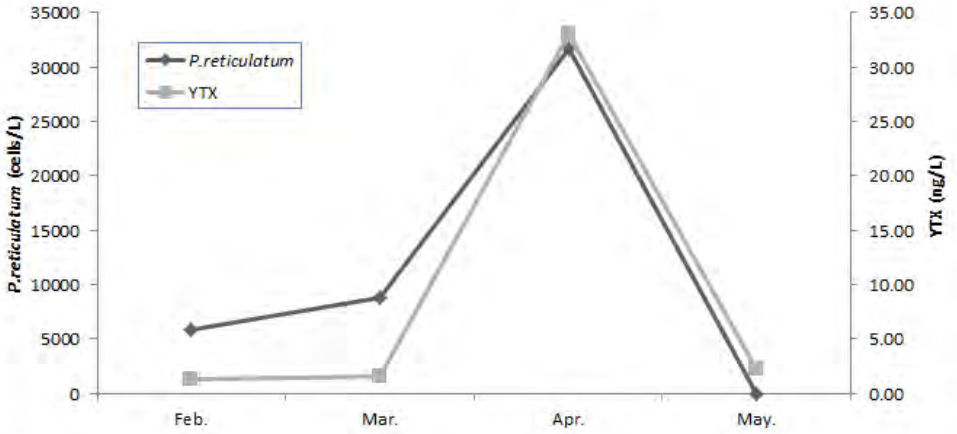


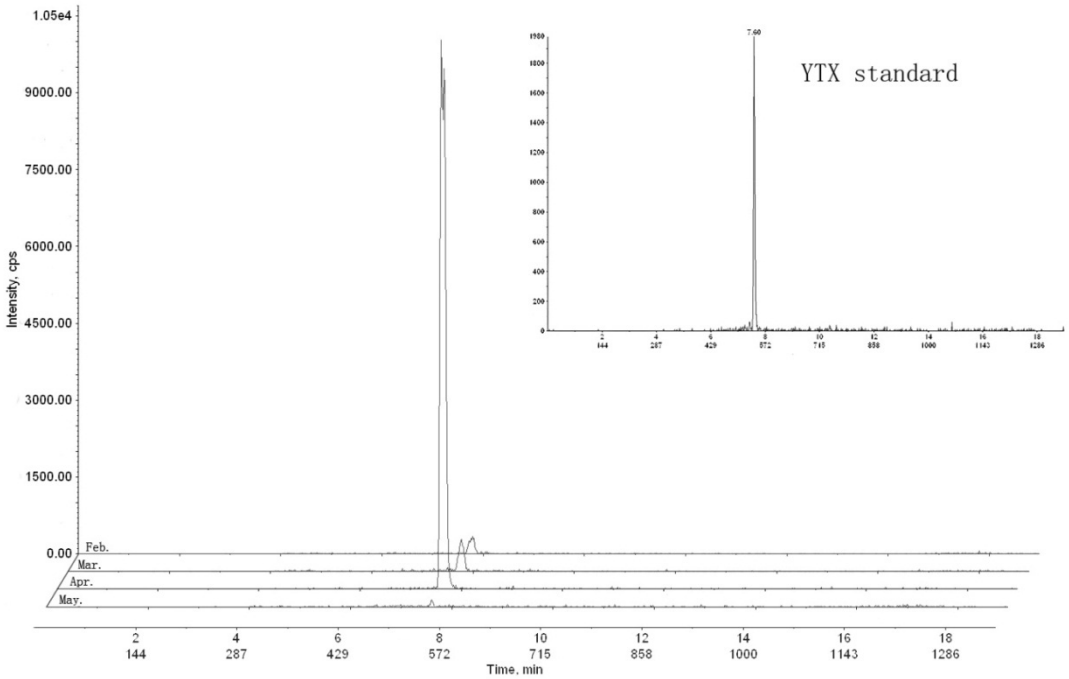


Lingulodinium polyedrum(left), *Gonyaulax spinifera* (middle), *Protoceratium reticulatum* (right)from the northern Yellow sea





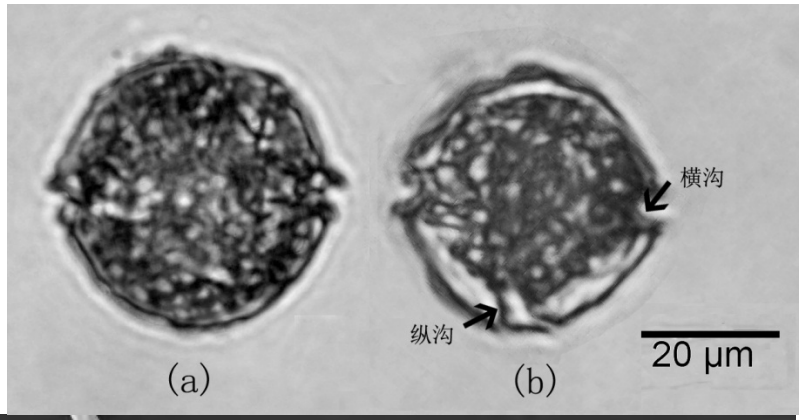


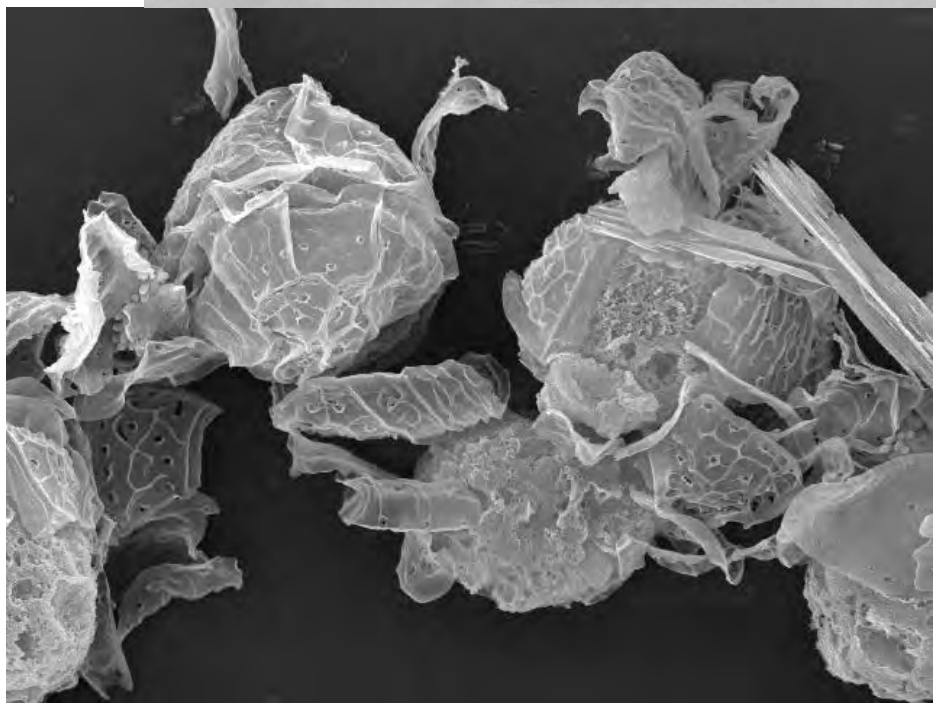


Protoceratium reticulatum （网状原角藻）

Protoceratium reticulatum

Cyst *of Protoceratium reticulatum*





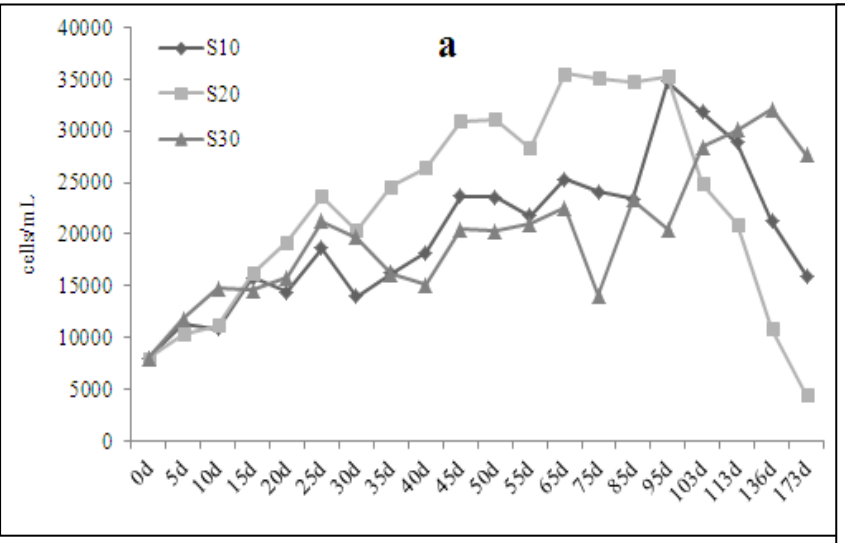
Protoceratium reticulatum （网状原角藻）

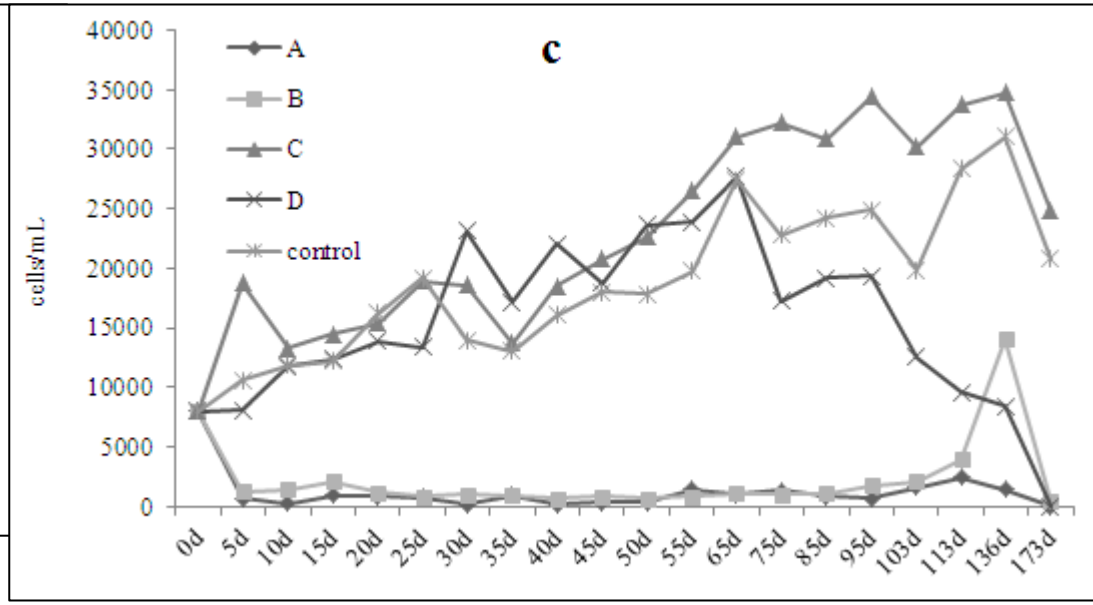
Summary

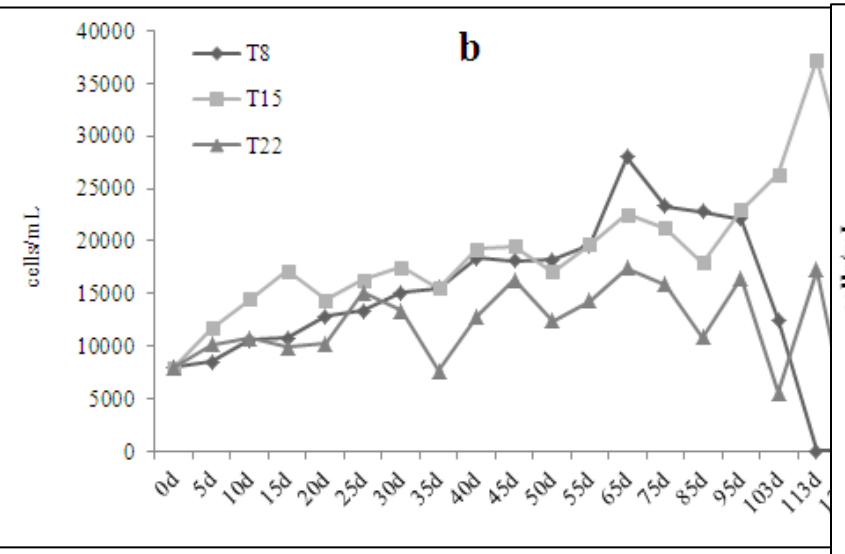
- The abundance changing of toxic dinoflagellates was same with the trend of YTXs in plankton.
- The peak time of YTXs in seawaters and shellfish slightly lags behind the highest abundance time of toxic dinoflagellates.
- The peak time of YTXs in cyst appeared in advance of the highest abundance time of toxic dinoflagellates.
- The YTXs varied according to the species of bivalve mollusk(oyster<*Patinopecten yessoensis*<*Chlamys farreri,*Mussel).

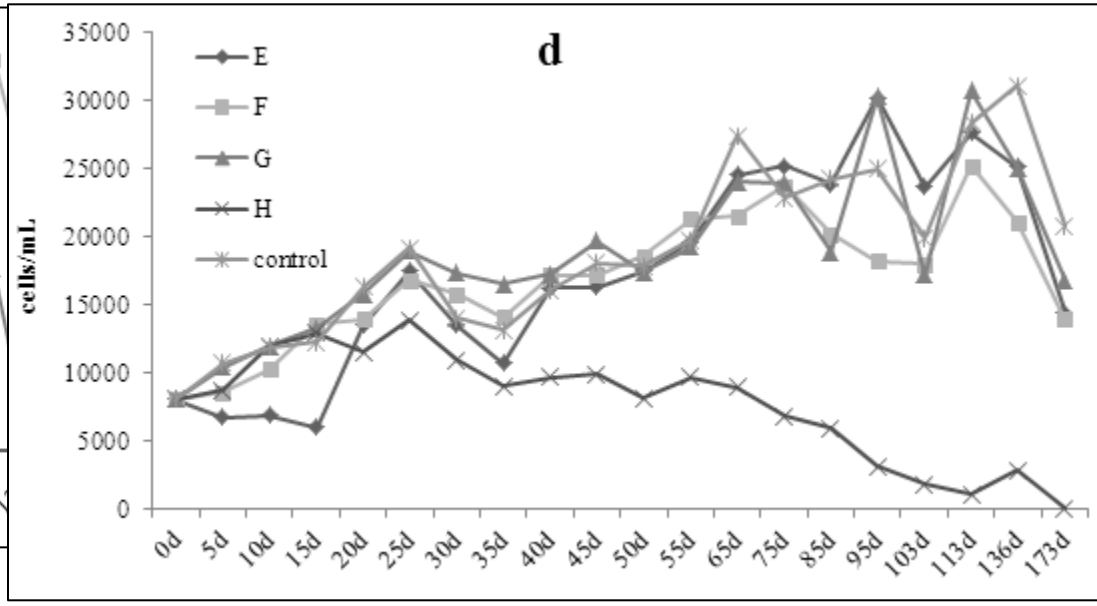
Protoceratium reticulatum cultured

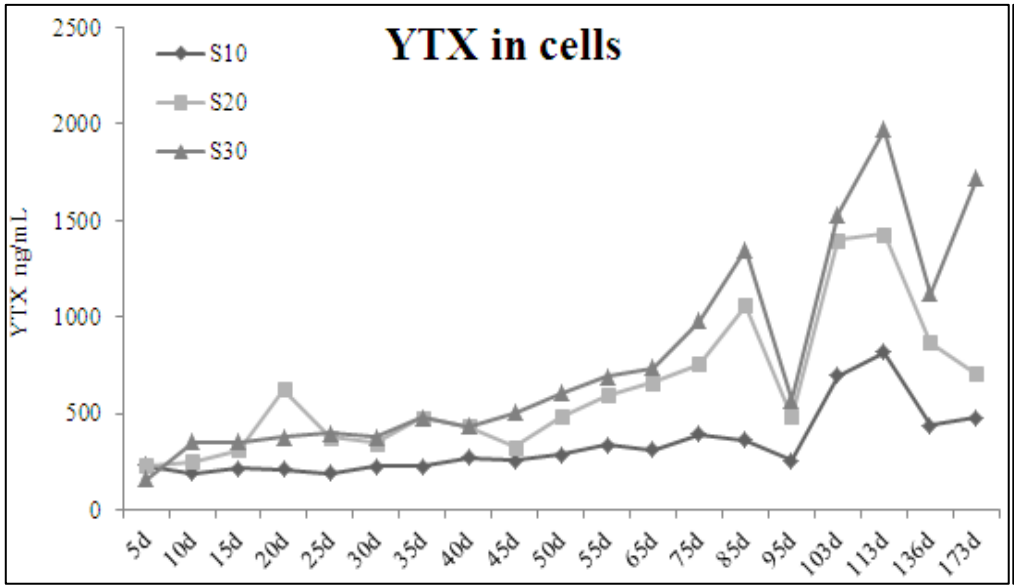
- different salinity of 10‰,20‰,30‰.
- different temperature of 8°C, 15°C and 22°C.
- different nitrogen source (**A**:NH_4Cl; **B**:NH_4NO_3; **C**:$(NH_2)_2CO$; **D**:no nitrogen; **control**:$NaNO_3$).
- different phosphorus sources [**E**: ATP($C_{10}H_{16}N_5O_{13}P_3$, adenosine triphosphate); **F**: $C_3H_7Na_2O_{10}P$, adenosine phosphate; **G**: $Ca(H_2PO_4)_2 \cdot H_2O$, triple superphosphate; **H**: without phosphorus sources; **control**: $NaH_2PO_4 \cdot H_2O$,sodium dihydrogen phosphate].
- *Patinopecten yessoensis, Mytilus galloprovincialis*, *Chlamys farreri*.

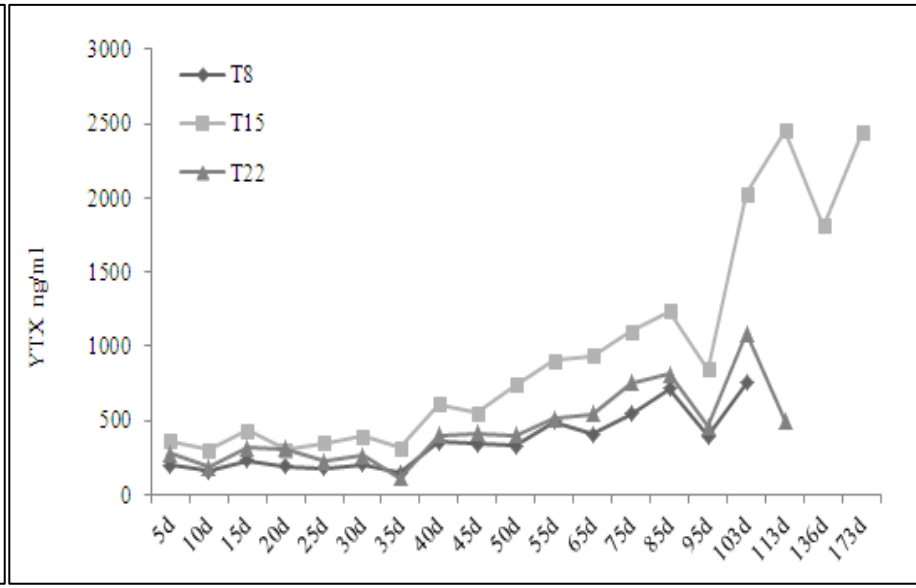

a
S10
S20
S30
cells/mL
40000
35000
30000
25000
20000
15000
10000
5000
0
0d 5d 10d 15d 20d 25d 30d 35d 40d 45d 50d 55d 65d 75d 85d 95d 103d 113d 136d 173d

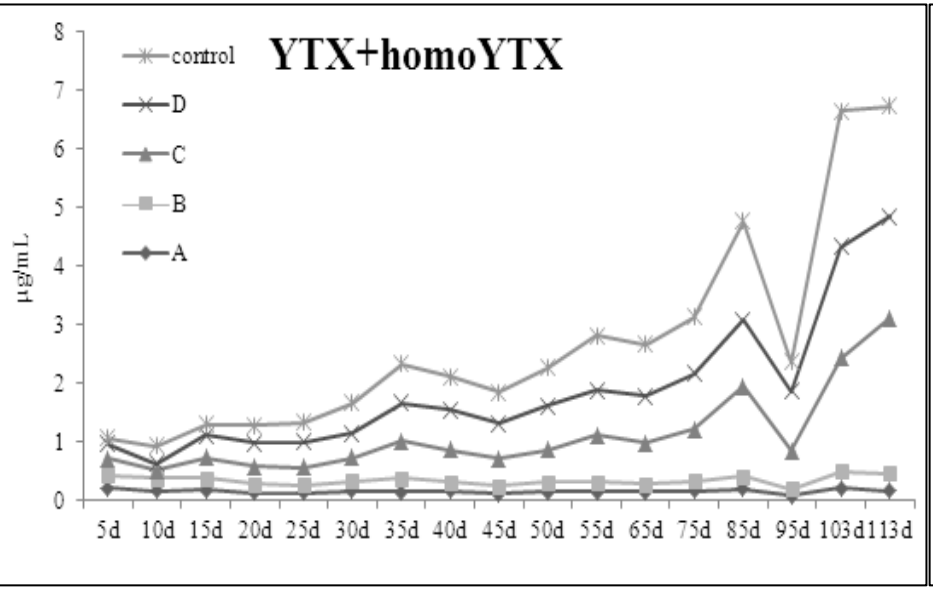

c
A
B
C
D
control
cells/mL
40000
35000
30000
25000
20000
15000
10000
5000
0
0d 5d 10d 15d 20d 25d 30d 35d 40d 45d 50d 55d 65d 75d 85d 95d 103d 113d 136d 173d

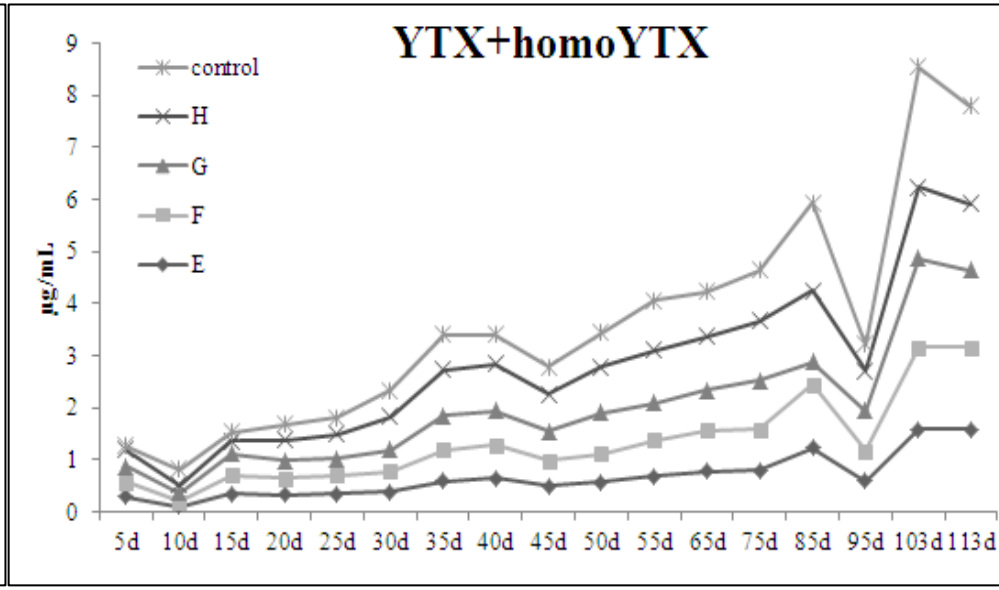

b
T8
T15
T22
cells/mL
40000
35000
30000
25000
20000
15000
10000
5000
0
0d 5d 10d 15d 20d 25d 30d 35d 40d 45d 50d 55d 65d 75d 85d 95d 103d 113d


d
E
F
G
H
control
cells/mL
35000
30000
25000
20000
15000
10000
5000
0
0d 5d 10d 15d 20d 25d 30d 35d 40d 45d 50d 55d 65d 75d 85d 95d 103d 113d 136d 173d


YTX in cells
S10
S20
S30
YTX ng/mL
2500
2000
1500
1000
500
0
5d
10d
15d
20d
25d
30d
35d
40d
45d
50d
55d
65d
75d
85d
95d
103d
113d
136d
173d

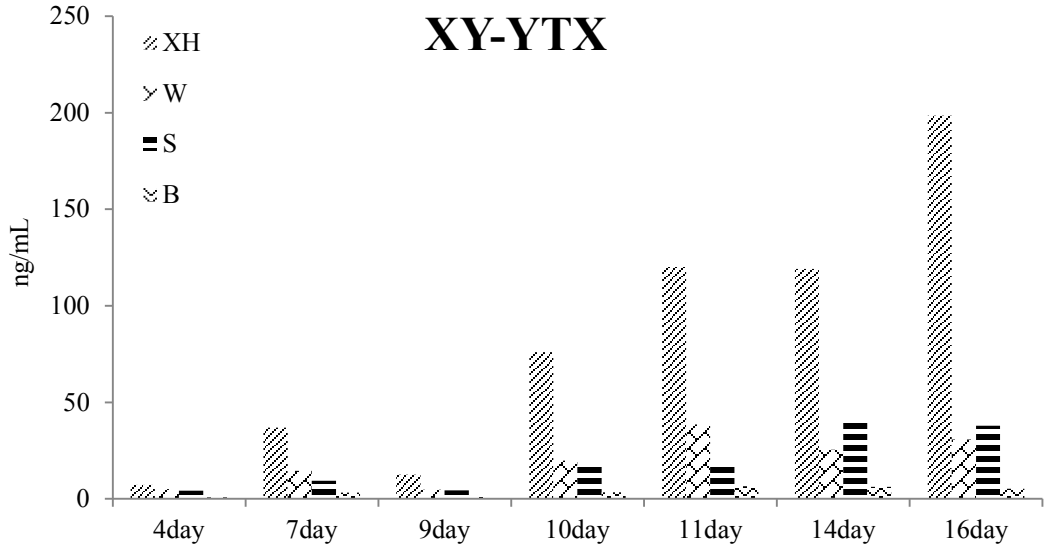

T8
T15
T22
YTX ng/ml
3000
2500
2000
1500
1000
500
0
5d
10d
15d
20d
25d
30d
35d
40d
45d
50d
55d
65d
75d
85d
95d
103d
113d
136d
173d

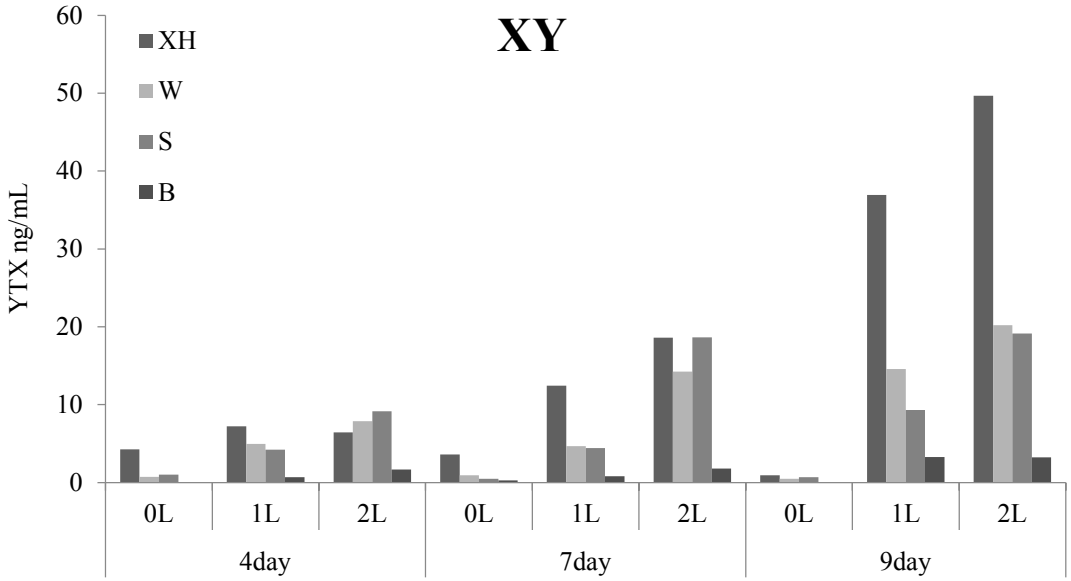

YTX+homoYTX
control
D
C
B
A
μg/mL
8
7
6
5
4
3
2
1
0
5d
10d
15d
20d
25d
30d
35d
40d
45d
50d
55d
65d
75d
85d
95d
103d
113d


YTX+homoYTX
control
H
G
F
E
μg/mL
9
8
7
6
5
4
3
2
1
0
5d
10d
15d
20d
25d
30d
35d
40d
45d
50d
55d
65d
75d
85d
95d
103d
113d

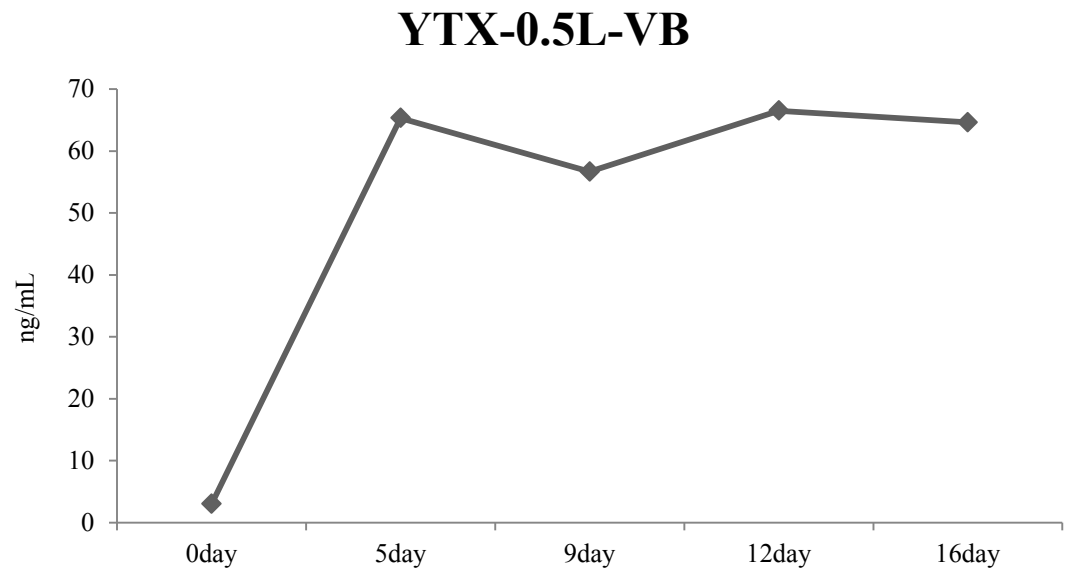
Protoceratium reticulatum

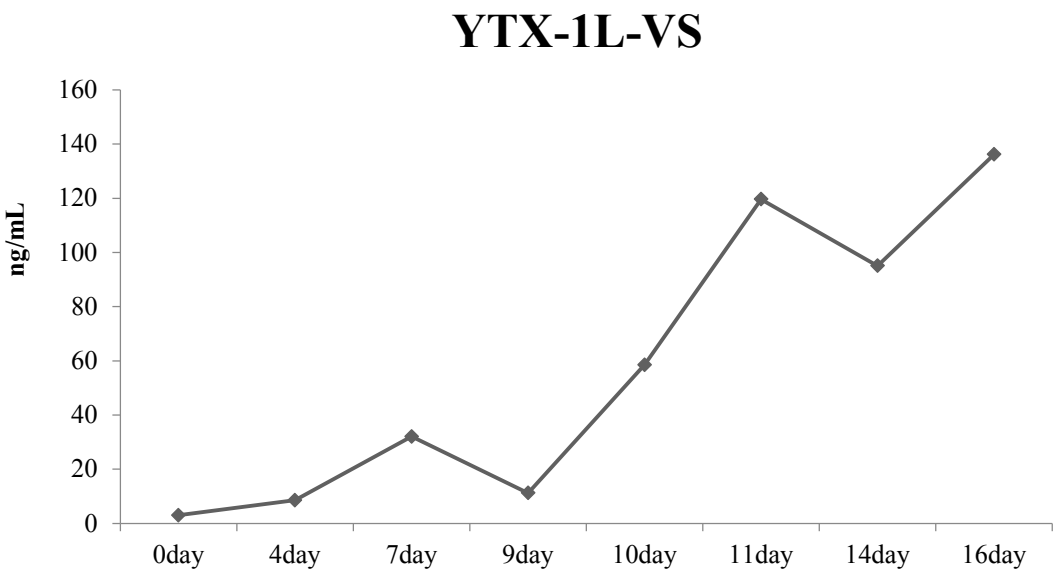
- Growth: 20‰ salinity, 15°C temperature, organic nitrogen (urea $(NH_2)_2CO$), any phosphorus sources
- Production of YTXs: 30‰ salinity, 15°C temperature, inorganic nitrogen source, inorganic phosphorus source(sodium dihydrogen phosphate＞without phosphorus ＞triple superphosphate＞adenosine phosphate＞ATP)

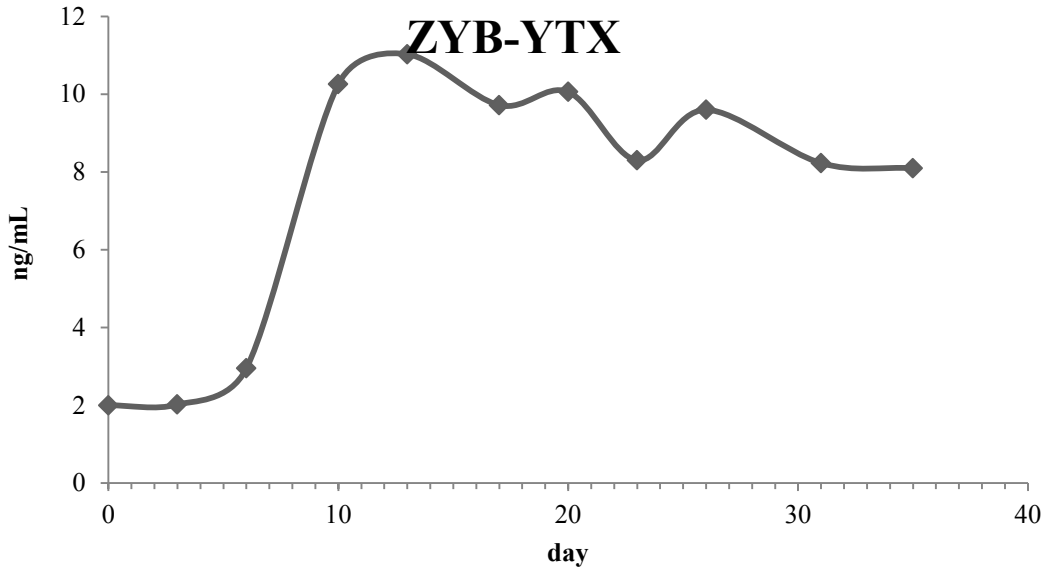




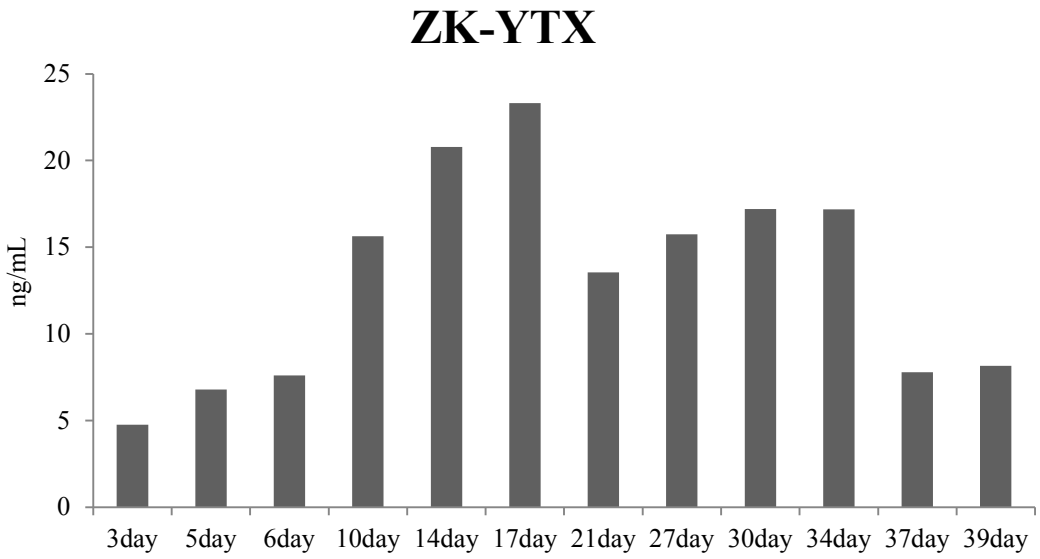
XH:digestive gland
W:mantle
S:gill
B: adductor muscle


YTX-0.5L-VB
ng/mL
70
60
50
40
30
20
10
0
0day
5day
9day
12day
16day

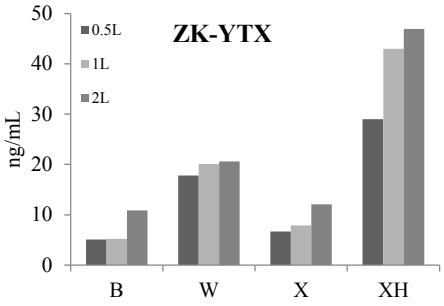

YTX-1L-VS
ng/mL
160
140
120
100
80
60
40
20
0
0day
4day
7day
9day
10day
11day
14day
16day



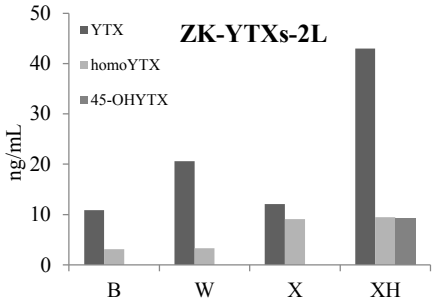
The YTXs accumulated and eliminated in mussels



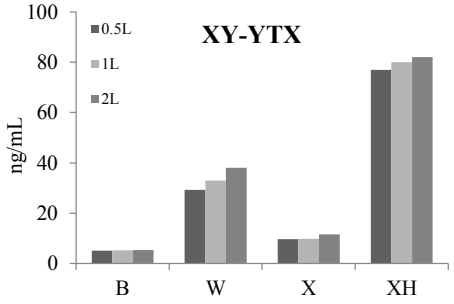
The accumulation and elimination of YTXs in *Chlamys farreri*



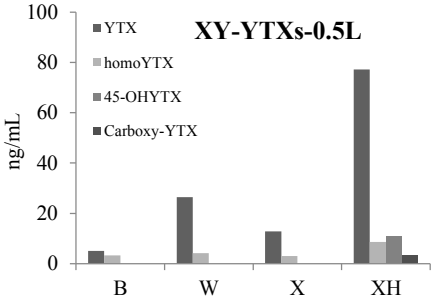
YTX in different parts of *Chlamys farreri*



YTXs profile in different parts of *Chlamys farreri*

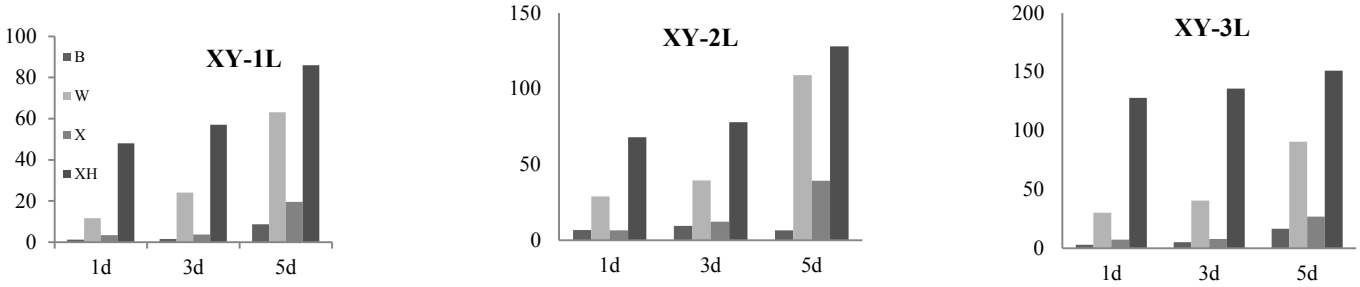


YTX in different parts of *Patinopecten yessoensis*



YTXs structure in different parts of *Patinopecten yessoensis*

（XH:digestive gland; W:mantle; X:sex gland;B:adductor muscle）

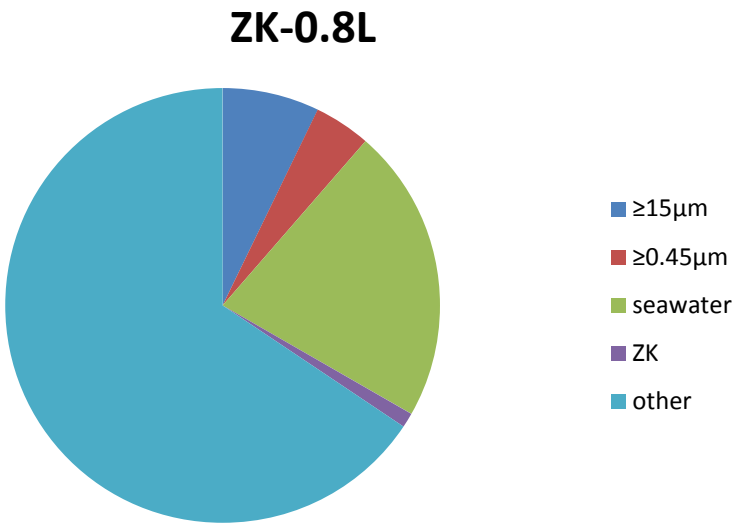


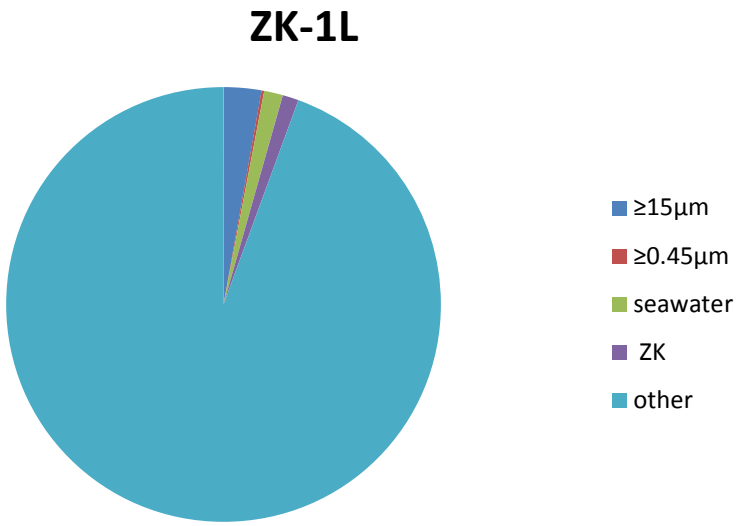
YTX in *Patinopecten yessoensis* fed different volumn of *Protoceratium reticulatum*

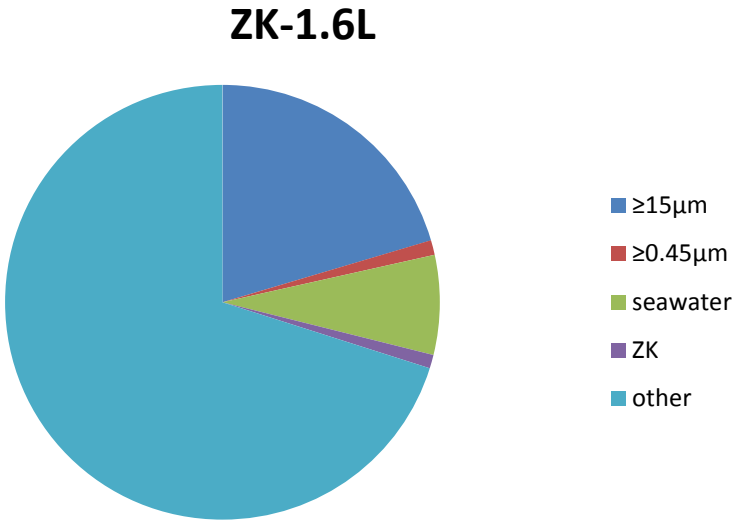
YTX in *Chlamys farreri* fed different volumn of *Protoceratium reticulatum*

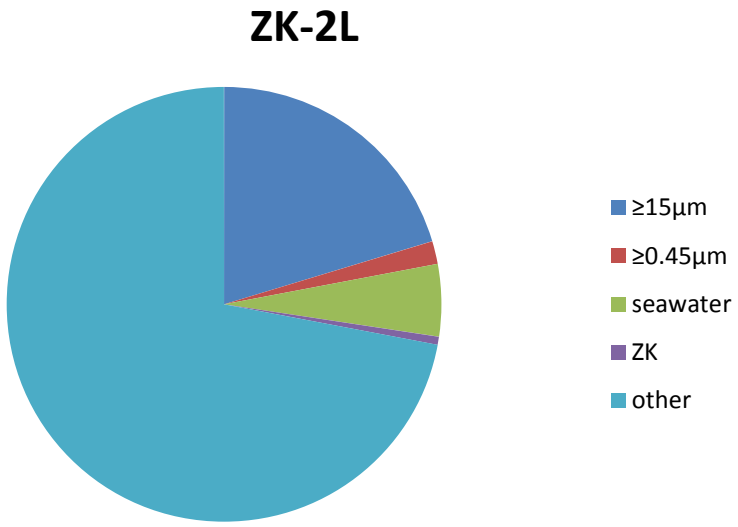
Relationship: *Protoceratium reticulatum* and shellfish

- The more *Protoceratium reticulatum,* and the more YTXs in shellfish(*Patinopecten yessoensis* and *Chlamys farreri*)
- The elimination of YTX in shellfish is slower
- The YTXs structures transformed was diversified and complex in the digestive gland

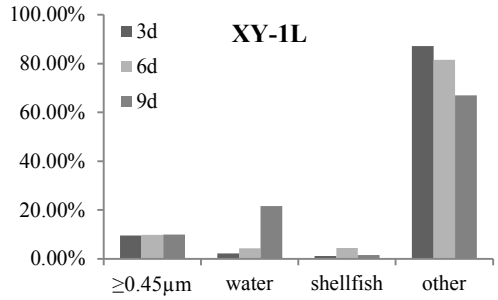


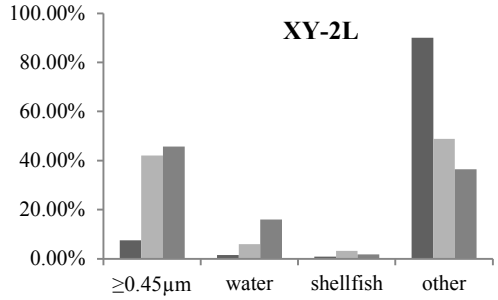




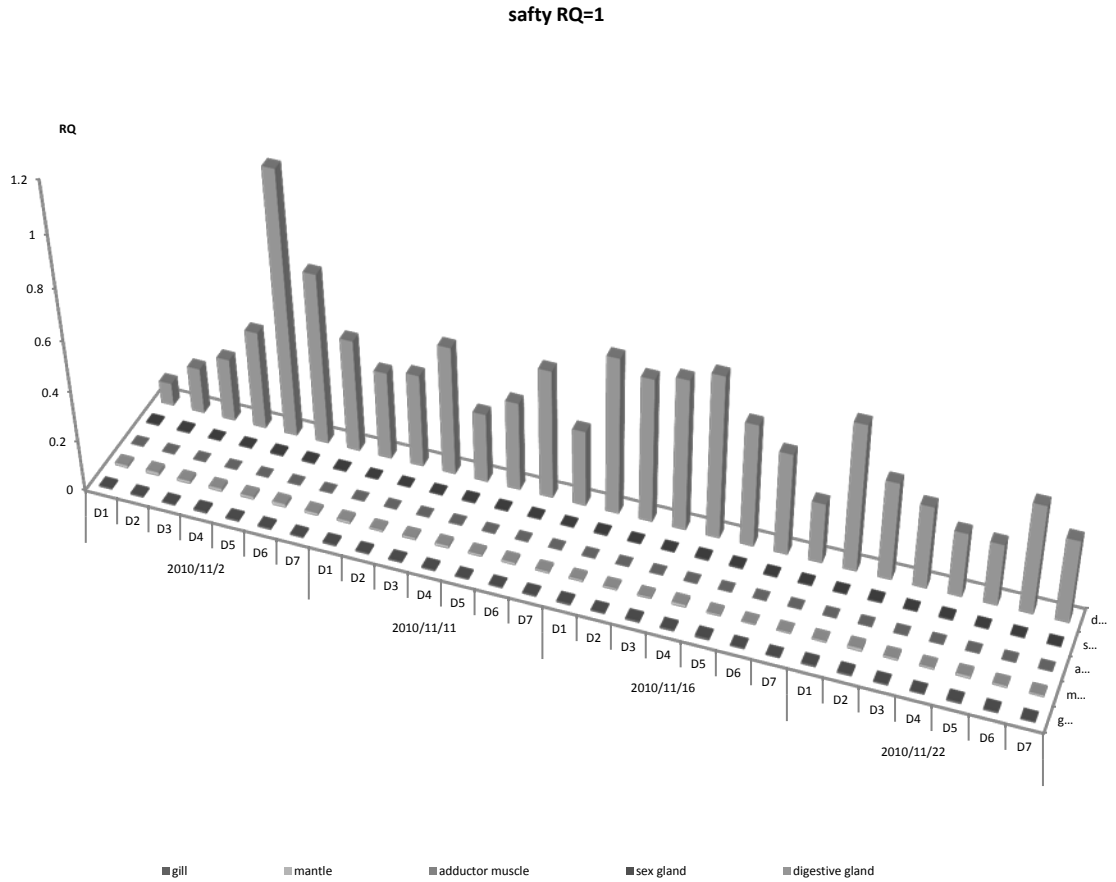


The distribution of YTXs in each midium of the system which *Chlamys farreri* fed using *Protoceratium reticulatum*(3days).





YTX percentage in *Patinopecten yessoensis* cultured in different *Protoceratium reticulatum*



YTXs in the ecosystem(simulated)

- Most YTXs toxins exist in particular matters and seawaters
- The YTX in the shellfish is very little, only 1%
- The digestive gland is the highest risk for eating
- Fast trasformation of structures of YTXs toxin happen in the ecosystem

conclusion

- *Protoceratium reticulatum* is one of the major producers for YTXs in the Northern Yellow Sea of China. (The abundance change of toxic dinoflagellates was same with the trend of YTXs in plankton)
- The peak time of YTXs in seawaters and shellfish slightly lags behind the highest abundance time of toxic dinoflagellates.
- The peak time of YTXs in cyst appeared in advance of the highest abundance time of toxic dinoflagellates.

- It support *Protoceratium reticulatum* was a bloom forming spices in there.
- In the marine ecosystem of the northern Yellow Sea of China, for YTXs of *Protoceratium reticulatum*, a significant amount may exist in particulate matters and also seawater, only a little in shellfishes.
- The toxicity of different structure is different (hYTX ＞ YTX).
- There is synergistic effect,existing more than two kinds of toxins.
- There is higher toxicity to young.
- What is its potential damage and threats to whole ecosystem which must be paid attention.

warning

- Potential damage to the whole ecosystem
- Safe regulation for the ecosystem
- Synergestic toxicity (new regulation)

Thanks for your attention!

Lingulodinium polyedrum（多边舌甲藻）