The 2nd CEARAC expert meeting on Eutrophication Assessment in the NOWPAP Region

Eutrophication Assessment on Potential eutrophic zones in China: Qinghuangdao Coast

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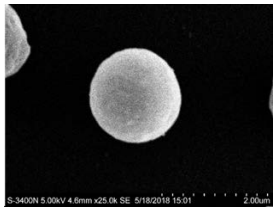
CONTENTS

CONTENTS

1.1 Selection of assessment area

- **Qinghuangdao City is located in the west of Bohai Sea, which is an import seaport in North China. Luanhe river, the biggest river in the area, flows into the sea with the fluxes of 4.6×10^9 m^3/y.**
- **Qinhuangdao City is also famous for its aquaculture (especially shellfish aquaculture)，tourism (Summer resort).**

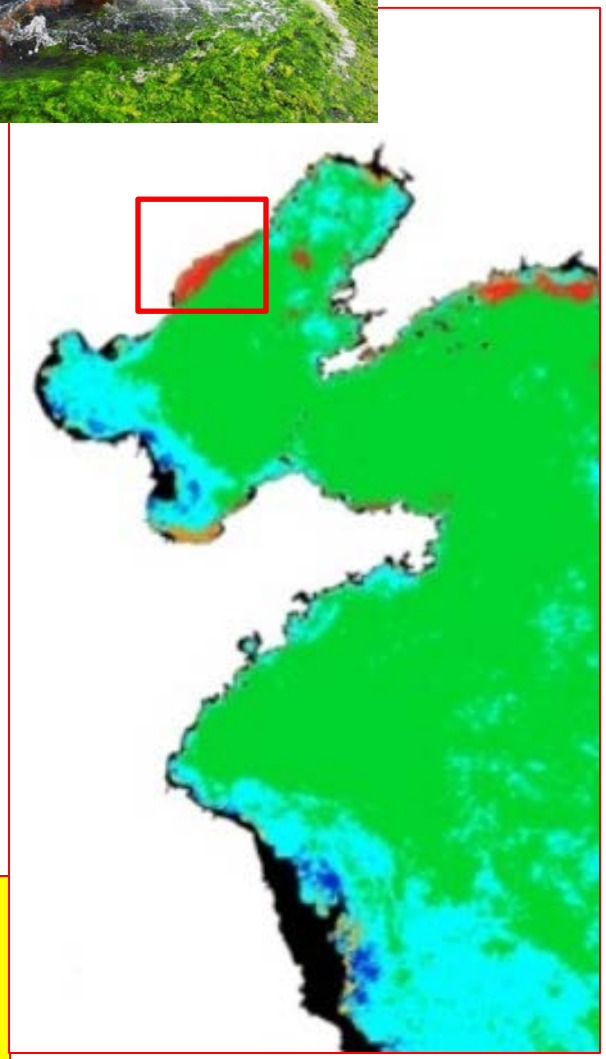
Since 2011, brown tide occurs with thousands of square kilometers and ~10^9 cells/L.



Green tide occurs frequently.

- **The population is about 3 million and the coast confronted with high pressure caused by human activity.**
- **There were red tide, brown tides and green tide recorded in recent years.**
- **The Qinhuangdao coast was recognized as potential eutrophic by satellite Chl-a from 1998 to 2015.**

Qinhuangdao coast is a typical water body of Bohai sea in China for coastal eutrophication assessment.



Satellite remote sensing from Zhang et al., 2013; Terauchi et al., 2019

1.2 No division of assessment area

The depth is about 10 m in most area and vertical exchange is sufficient. So sub-area was not divided in the assessment.

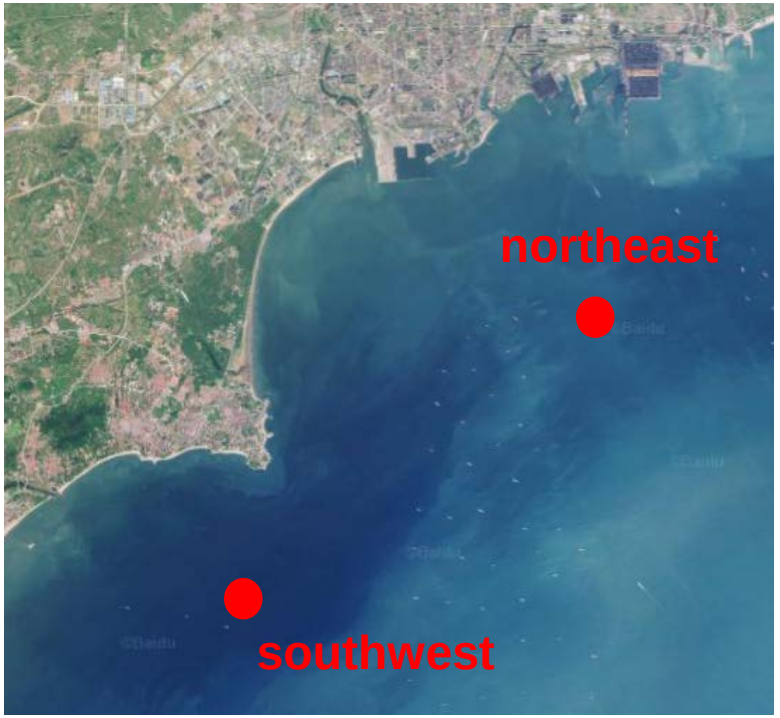
1.3 Collection of relevant information and data

Assessment data were mainly collected from following sources:

- **Qinhuangdao Marine Environment Monitoring Center**

10 year's monitoring data, including yearly average data of 3 seasonal cruses (May, Aug and Oct) and maximum data of this 3 seasons every year at 2 stations along Qinghuangdao coastline (One in northeast, one in southwest).

- **Bulletin of Marine Environmental Quality of North China Sea**
- **Bulletin of Marine Disaster of North China Sea**
- **Bulletin of Marine Environmental Quality of China and Hebei Province**
- **Bulletin of Marine Disaster of China and Hebei Province**
- **Published monograph and papers**



1.4 Selection of assessment parameters

Category	Parameters recommended by NOWPAP	Parameter in this study	Reason
I:Degree of nutrient enrichment	Riverine input (TN, TP)	Riverine input of **DIN, TP** of the biggest river (Luanhe River) in Qinhuangdao.	● Only DIN and TP data are available. ● Small rivers was not included because they only account for 1% nutrients of Luanhe (SOA, 2011)
	Total nitrogen/Total phosphorus (TN, TP)	×	**TN and TP** concentration data are unavailable
	Winter DIN, DIP concentration	Annual **maximum** DIN, DIP	DIN and DIP in winter (Feb) are unavailable and so maximum data in 3 seasonal cruses was used.
	Winter N/P ratio (DIN/DIP)	Annual **mean** DIN/DIP ratio	
II:Direct effects of nutrient enrichment	mean of Chlorophyll a concentration (field data)	√	
	Maximum of Chlorophyll a (field data)	√	
	red tide events (diatom species)	√	
	red tide events (flagellate species)	√	
	×	**Brown tide** events	*Aureococcus anophagefferens* is a HAB in this area.
	×	**Green tide**	Green tide events occurs frequently along Qinghuangdao coast in recent years.
III: Indirect effects of nutrient enrichment	Bottom Dissolved oxygen (DO)	√	DO of surface and bottom is almost the same.
	Fish kill incidents	×	No data collected
	Chemical oxygen demand (COD)	√	
IV: Other possible effects of nutrient enrichment	Red-tide events (*Noctiluca* sp.)	√	
	Shellfish poisoning incidents	√	

1.5 Final assessment parameters

Category	Assessment parameter	Timescale of parameters
Category I (degree of nutrient enrichment)	Riverine input of **DIN**	2005, 2013-2017
	Riverine input of **TP**	2013-2017
	Annual **maximum** DIN concentration	2008-2017
	Annual **maximum** DIP concentration	2008-2017
	Annual **mean** DIN/DIP ratio	2008-2017
Category II (Direct effects)	Annual mean of Chlorophyll a	2008-2017
	Annual maximum of Chlorophyll a	2008-2017
	Red tide events (diatom species)	2008-2017
	Red tide events (flagellate species)	2008-2017
	Brown tide events (*Aureococcus* sp.)	2008-2017
	Green tide events	2008-2017
Category III (Indirect effects)	Annual mean DO	2008-2017
	Annual mean COD	2008-2017
Category IV (other effects)	Red-tide events (Noctiluca sp.)	2008-2017
	Shell fish poisoning incidents	2008-2017

CONTENTS

All data was processed according to NOWPAP common procedure revised in 2015.

- **DIN concentration was the summation of ammonia, nitrite and nitrate (NH^{4+}, NO_2^- and NO_3^-).**
- **The annual values and maximum in the assessment were respectively the average and maximum of 3 seasonal cruses in the year.**
- **Comparison and occurrence were identified based on the data in recent 3 years.**
- **Trend was identified by non-parametric Mann-Kendall test (with the template provided by CEARAC).**

CONTENTS

3.1 Setting of identification criteria of the assessment data

Category	Assessment parameter	Units	Assessment value	Identification tools		
				Comparison	Occurrence	Trend
I	Riverine input of **DIN**	t/year	Annual total			√
	Riverine input of **TP**	t/year	Annual total			√
	DIN	mg/L	Annual maximum	√		√
	DIP	mg/L	Annual maximum	√		√
	DIN/DIP ratio	-	Annual mean	√		√
II	Maximum of Chl a	μg/L	Annual maximum	√		√
	Mean of Chl-a	μg/L	Annual mean	√		√
	Red tide events (diatom sp.)	Time/3 year	Annual occurrence		√	√
	Red tide events (flagellate sp.)	Time/3 year	Annual occurrence		√	√
	Brown tide events (*Aureococcus* sp.)	Time/3 year	Annual occurrence		√	√
	Green tide events	Time/3 year	Annual occurrence		√	√
III	DO	mg/L	Annual mean	√		√
	COD	mg/L	Annual mean	√		√
IV	Red-tide events(Noctiluca sp.)	Time/3 year	Annual occurrence		√	√
	Shellfish poisoning incidents	Time/3 year	Annual total		√	√

3.2 Setting of reference concentrations (Criteria)

Parameters	Classification of Chinese standard of national seawater quality			
	I	II	III	IV
DIN (mg l^{-1})	0.2	0.3	0.4	0.5
DIP (mg l^{-1})	0.015	0.03		0.045
COD (mg l^{-1})	2	3	4	5

- **Class II was set as the reference concentrations, which is criteria of seawater quality used for aquaculture and tourism in Chinese standard.**
- **Thresholds of DO and Chl-a were set according to relative research and international criteria (Yao et al., 2007; Xia et al., 2012; Bricker et al., 2003).**

Summation of assessment criteria

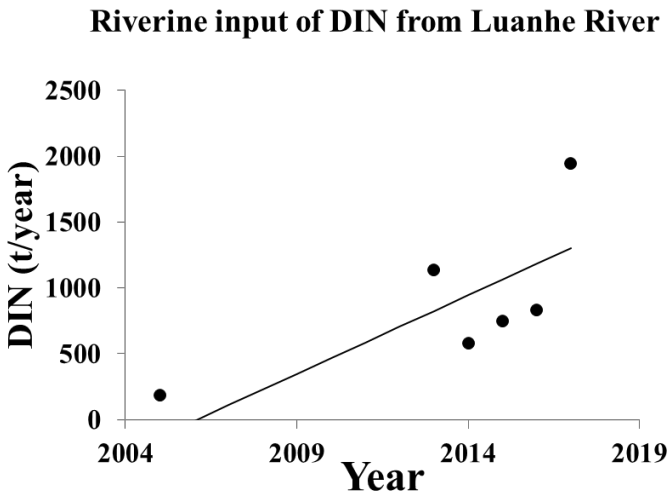
Category	Parameters	Reference concentrations	References
I	DIN	0.3 mg l^{-1} (21.4 **μM**)	NSQS Class II
	DIP	0.03 mg l^{-1} (**0.97μM**)	NSQS Class II
	DIN/DIP ratio	16	Redfield Value
II	Maximum of Chlorophyll a	**20μg l^{-1}**	Bricker et al., 2003
	Mean of Chl-a	5 **μg** l^{-1}	Yao et al., 2007; Xia et al., 2012
	Red tide (Diatom and flagellate species)	1 event/3 years	CEARAC Report 2011
	Brown tide events (*Aureococcus* sp.)	1 event/3 years	refer to red tide event
	Green tide events	1 event/3 years	Refer to red tide event
III	DO (bottom)	2 mg l^{-1}	Bricker et al., 2003
	COD	3 mg l^{-1}	NSQS Class II
IV	Red-tide events (*Noctiluca* sp.)	3 event/3 years	CEARAC Report 2011
	Shellfish poisoning incident	1 event/3 years	CEARAC Report 2011

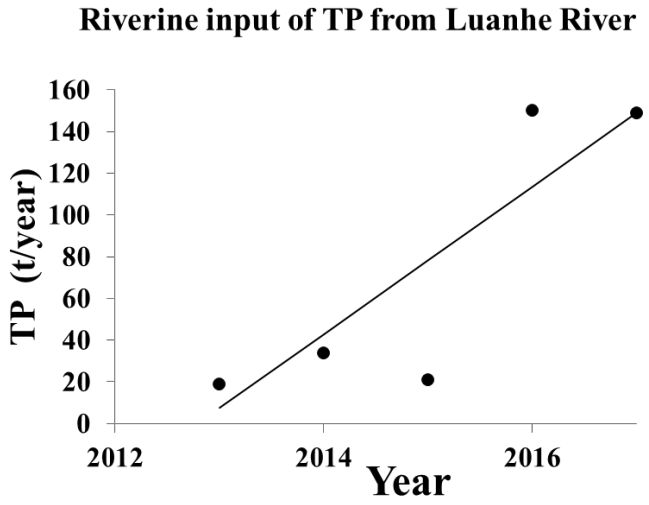
CONTENTS

4.1 Assessment of Category I

- Riverine input of DIN, TP
- DIN and DIP concentration
- DIN/DIP ratio

(1) Riverine input of DIN, TP from Luanhe river.



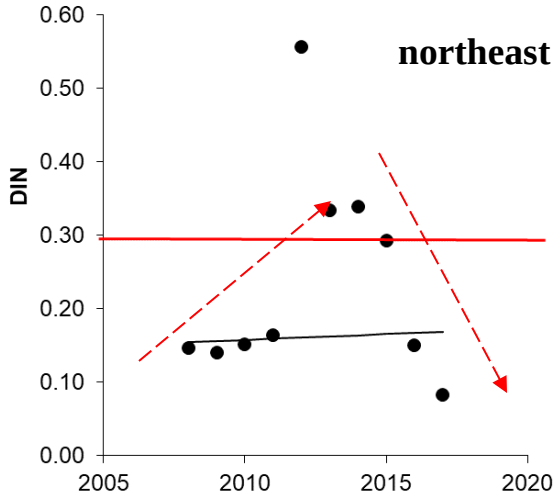


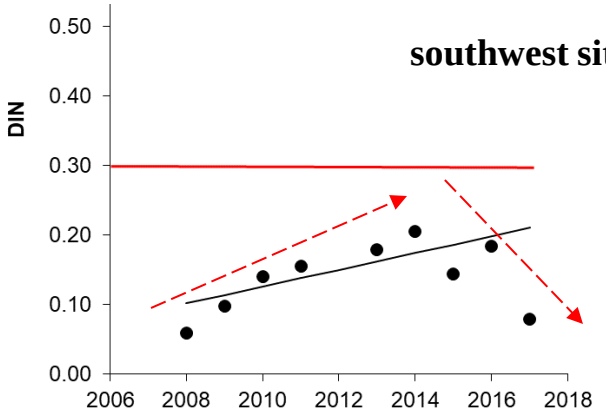
Trends of DIN and TP : Both of Increasing

by non-parametric Mann-Kendall analysis.

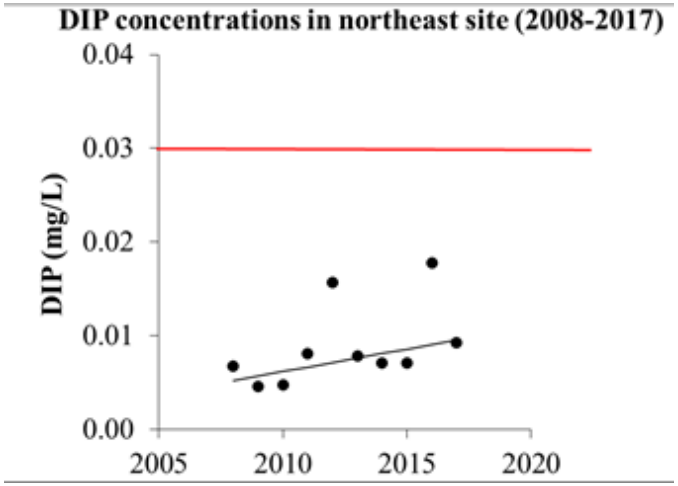
(2) Annual maximum of DIN and DIP concentration

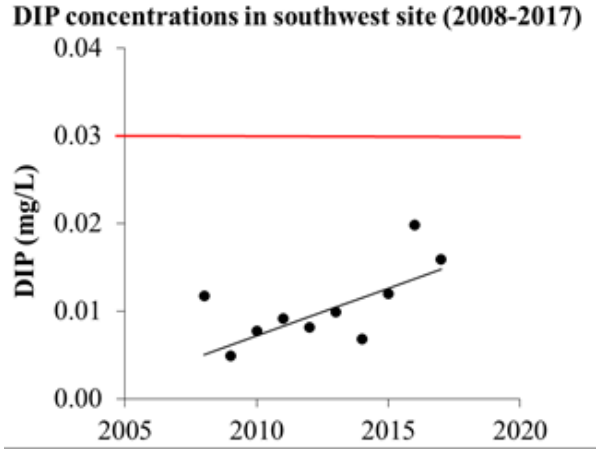
DIN





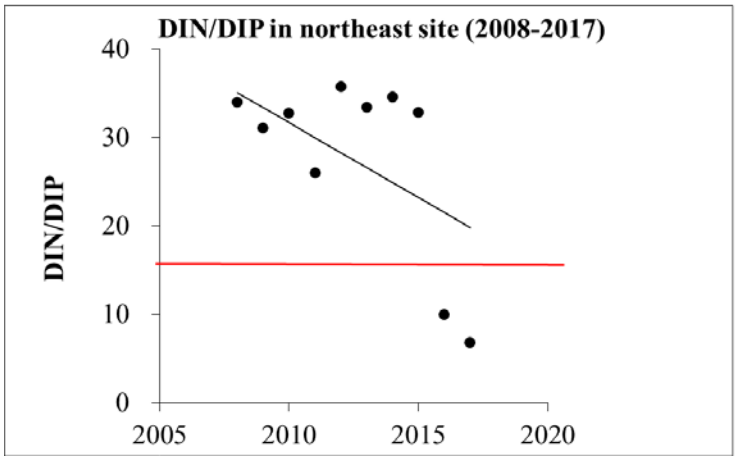
DIP

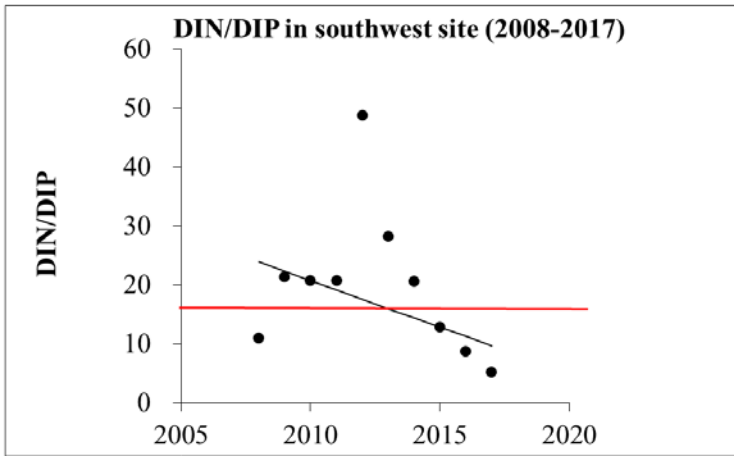




- Lower than criteria in recent 3 years
- Increasing trend

DIN/DIP

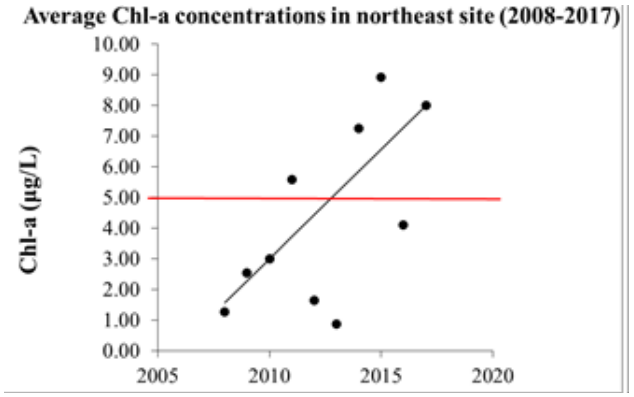


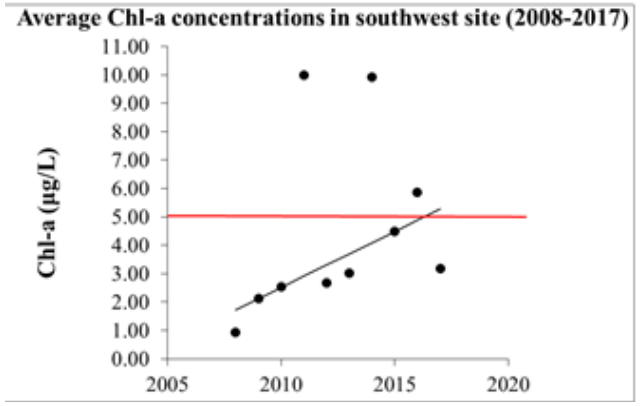


- Decreasing trend
- Lower than criteria in the recent 3 years

4.2 Assessment of Category II: **Chlorophyll a and Red tide events**

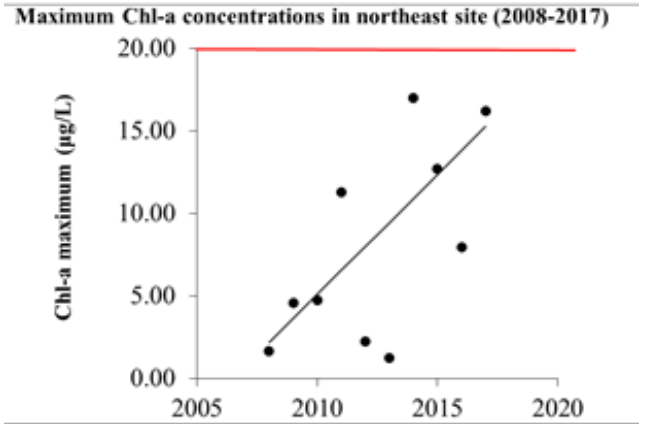
(1) Mean of Chl-a

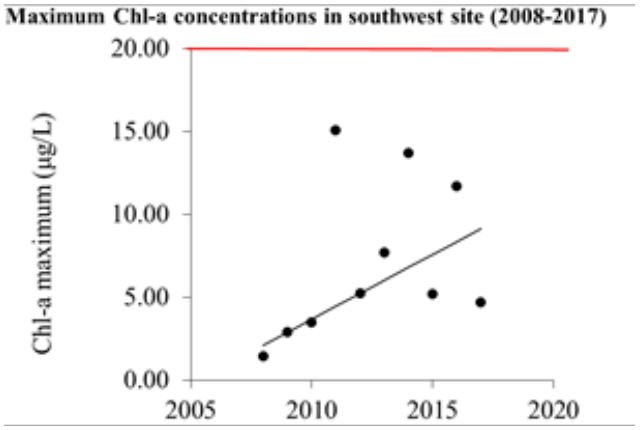




- Higher than criteria mostly in recent 3 years
- Increasing trend

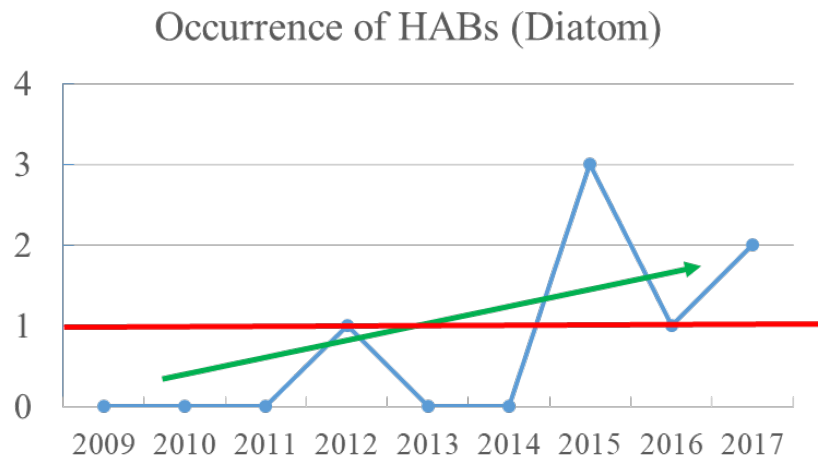
(2) Maximum of Chl-a





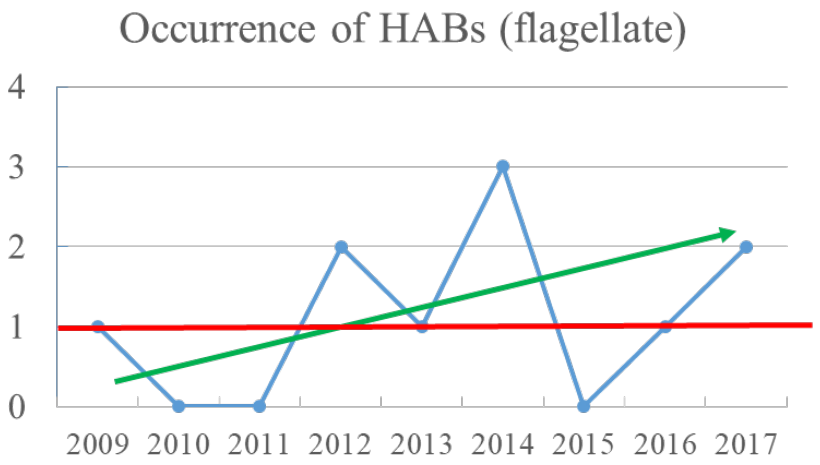
- Lower than criteria
- Increasing trend

(3) Red tide events (Diatom)



- Increasing trend in recent 9 years
- High (6 events in recent 3 years)

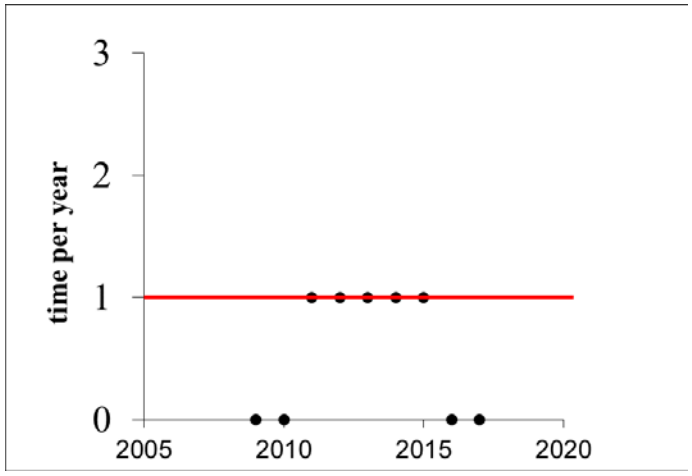
(4) Red tide events (flagellate)



- Increasing trend in recent 9 years
- High (3 events in recent 3 years)

species	2009	2012	2013	2014	2015	2016	2017
Diatom		*Chaetoceros sp*			*Skeletonema costatum* (2 times); *Cylindrotheca sp.*	*Chattonella sp.*	*Cylindrotheca sp.; Ceratium furca*
flagellate	*Cochlodinium sp.*	*Prorocentrum micans; Gonyaulax polygramma*	*Prorocentrum minimum*	*Prorocentrum minimum; Karenia mikimotoi; Scrippsiellat rochoidea*		*Alexandrium tamarense*	

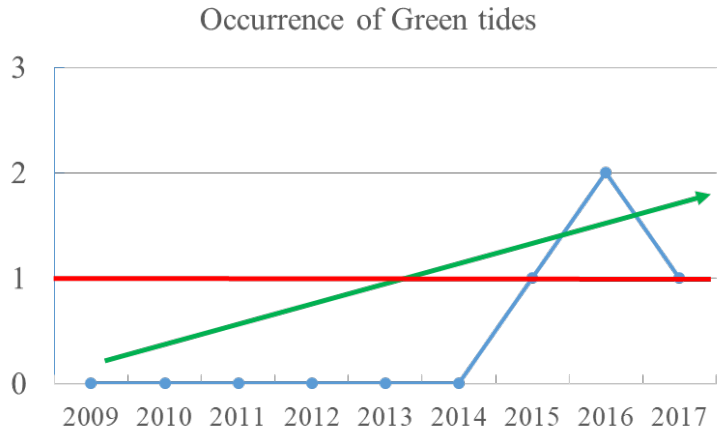
(5) Brown tide events (*Aureococcus* sp.)



1 events in recent 3 year

- High occurrence
- No trend

(6) Green tide events



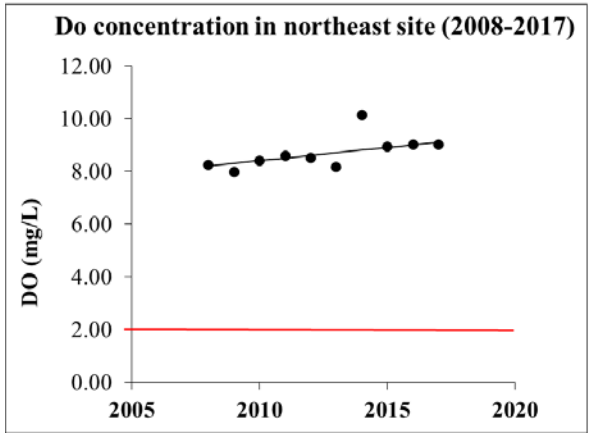
4 events in recent 3 year

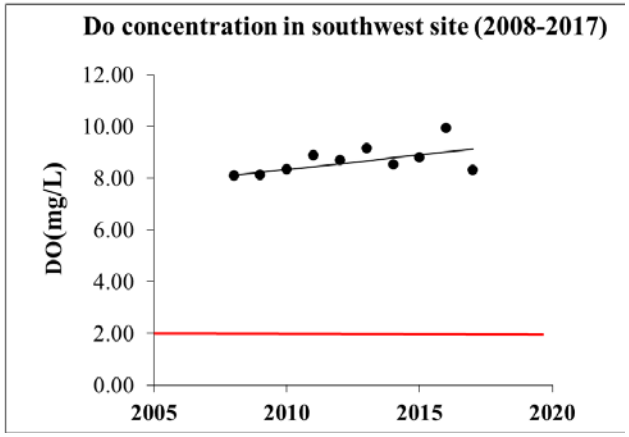
- High occurrence
- Increasing trend

4.3 Assessment of Category III: DO and COD

(1) DO

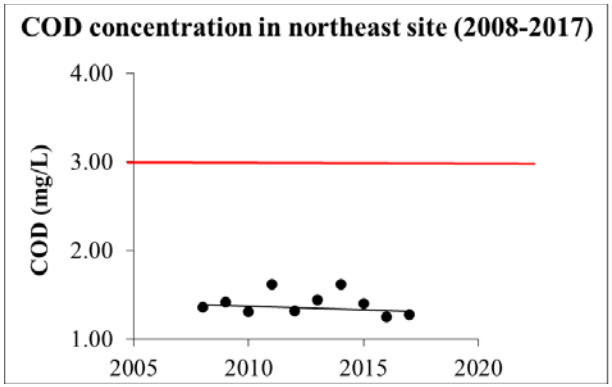
- Increasing trend
- Higher than criteria

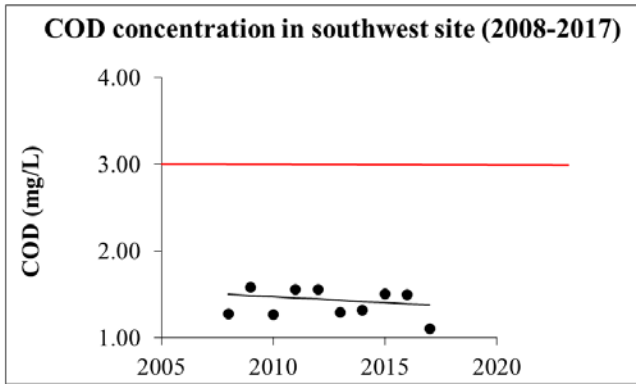




(2) COD

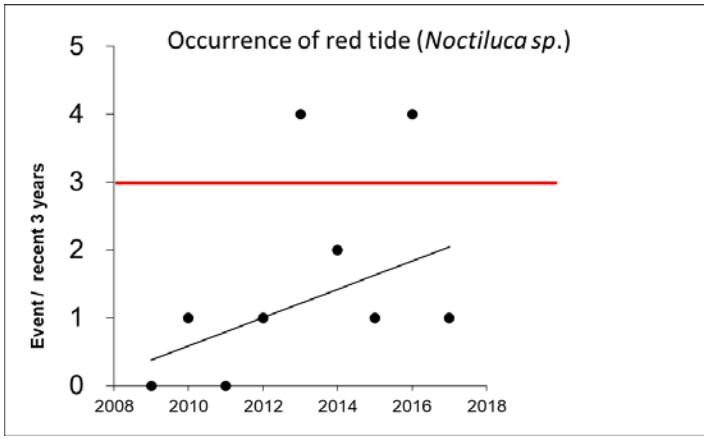
- Decreasing trend
- Lower than criteria





4.4 Assessment of Category IV: Red-tide (*Noctiluca* sp.) and shellfish poisoning incidents

(1) Red-tide of *Noctiluca* sp.



6 events in recent 3 year

- High occurrence
- Increasing trend

(2) Shellfish poisoning incidents

There were one records for shellfish poisoning incidents in 2016, which is the first record in the city.

- High Occurrence
- No trend

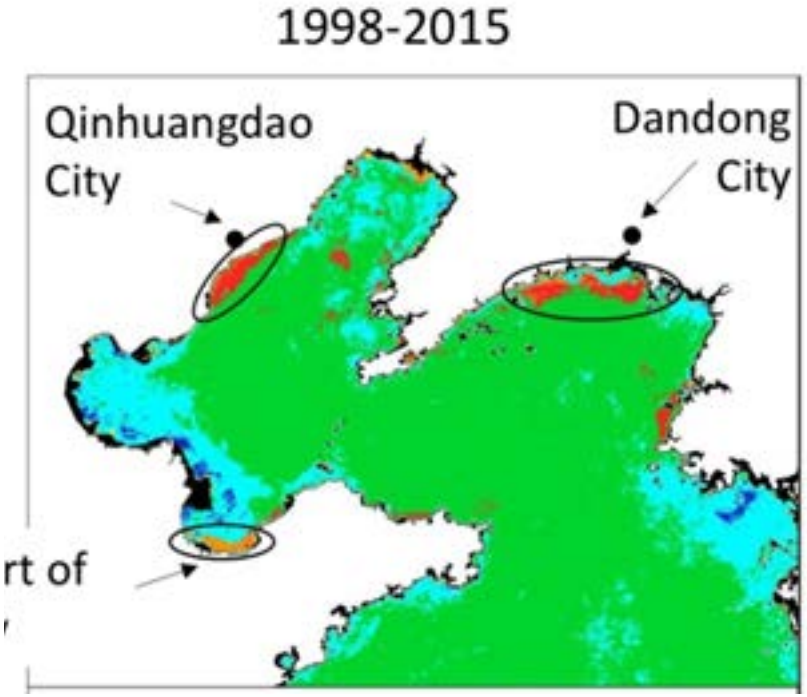
CONTENTS

5.1 Assessment summary for Qinhuangdao coast

Category	Assessment parameter	Comparison	Occurrence	Trend	Parameter identification	Category identification
I	Riverine **DIN**	×	×	I	I	LI
	Riverine **TP**	×	×	I	I	
	DIN	L	×	I	LI	
	DIP	L	×	I	LI	
	DIN/DIP ratio	L	×	D	LD	
II	Maximum of Chl-a	L	×	I	LI	HI
	Mean of Chl-a	H	×	I	HI	
	Red tide events (Diatom)	×	H	I	HI	
	Red tide events (flagellate)	×	H	I	HI	
	Brown tide (*Aureococcus* sp.)	×	H	N	HN	
	Green tide events	×	H	I	HI	
III	DO	L	×	D	LD	LD
	COD	L	×	D	LD	
IV	Red-tide events (*Noctiluca sp*)	×	H	I	HI	HI/HN
	Shell fish poisoning incidents	×	H	N	HN	

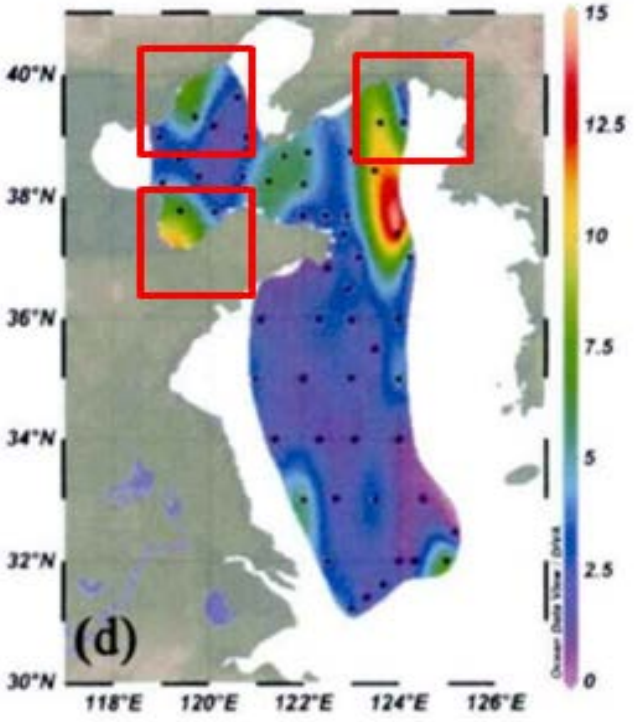
CONTENTS

Comparison of Chl.a distribution between satellite remote sensing and the field observation



Monthly mean of Chl-a during 1998-2015 from satellite remote sensing

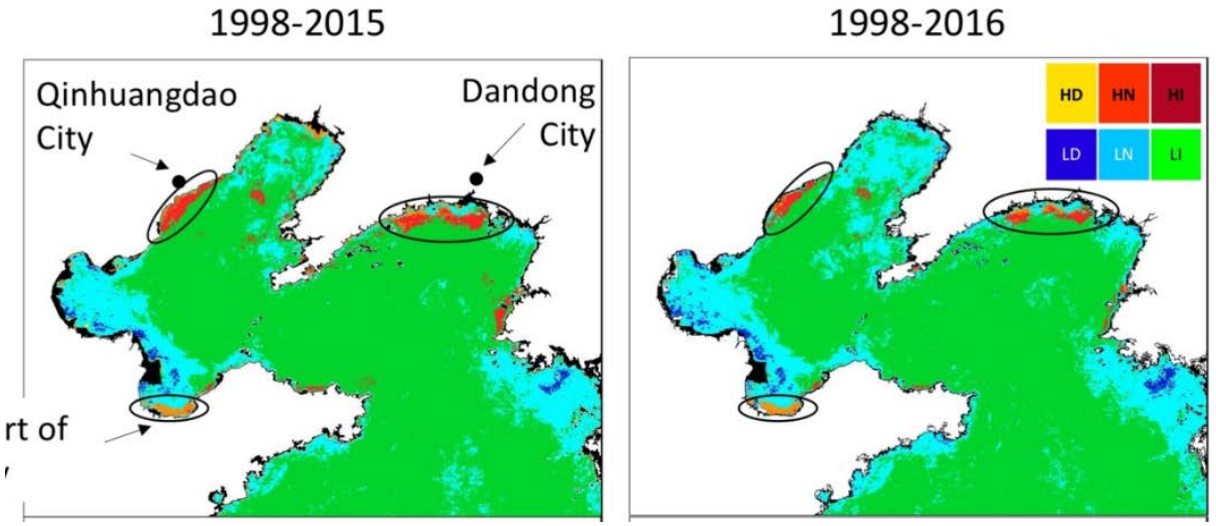
-- CEARAC



Chl-a at DCM in spring 2014 from field observation

-- Leng. 2016

Comparison of assessment on Chl-a between satellite remote sensing and the Comprehensive Procedure

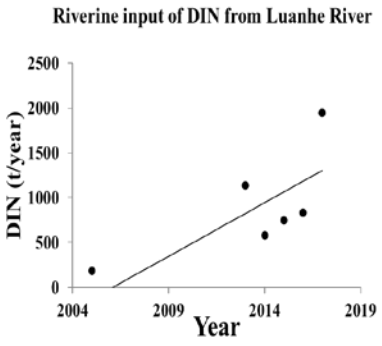


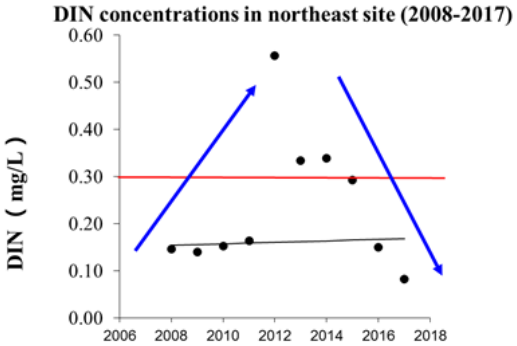
- **The Satellite Chl-a method recognized the Qinhuangdao coast as HN/HI, which is similar with the result in comprehensive procedure (HI).**

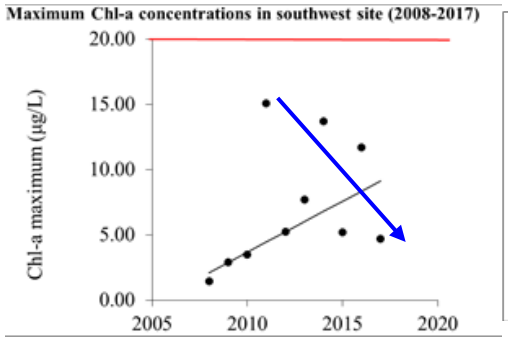
CONTENTS

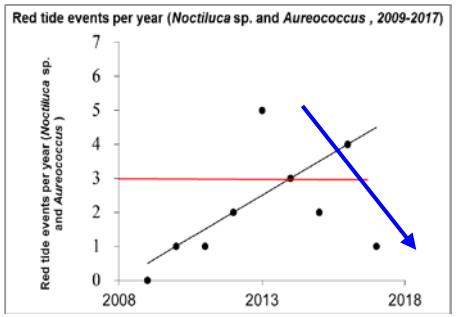
Conclusions

- **Riverine nutrients showed an increasing trend in Qinhuangdao coast, however, DIN in the coastal waters showed decrease in recent years. It indicate that Luanhe river may not be the major factor to affect the coastal water quality.**
- **HABs are the major sign of eutrophication in the area. But recent years also showed decreasing trend.**
- **Assessment results by Satellite Chl-a method and by comprehensive procedure showed consistency to a certain extent.**









Suggestion

- **Red tide events in category II should be merged into “HABs”, in which green tide, brown tide etc. should be included.**
- **CEARAC reference or criteria for eutrophication assessment should be recommended and set up in order to compare each other in different areas.**

Category	Assessment parameter	Comparison	Occurrence	Trend	Parameter identification	Category identification
II	Maximum of Chl-a	L	×	I	LI	HI
	Mean of Chl-a	H	×	I	HI	
	Red tide events (Diatom)	×	H	I	HI	
	Red tide events (flagellate)	×	H	I	HI	
	Brown tide events (*Aureococcus* sp.)	×	H	N	HN	
	Green tide events	×	H	I	HI	
IV	Red-tide events (*Noctiluca sp*)	×	H	I	HI	HI/HN
	Shell fish poisoning incidents	×	H	N	HN	


Thank You !

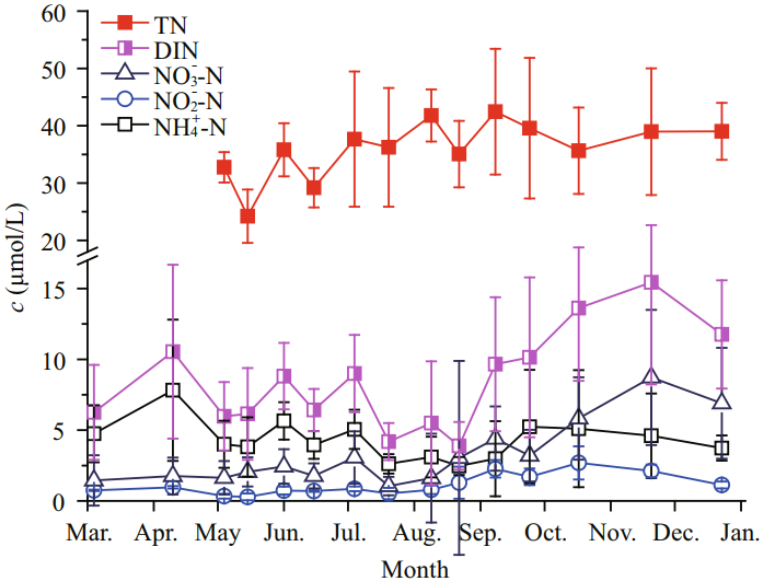


Fig.6 Annual variation in different forms of nitrogen in upper layer seawaters of Qinhuangdao

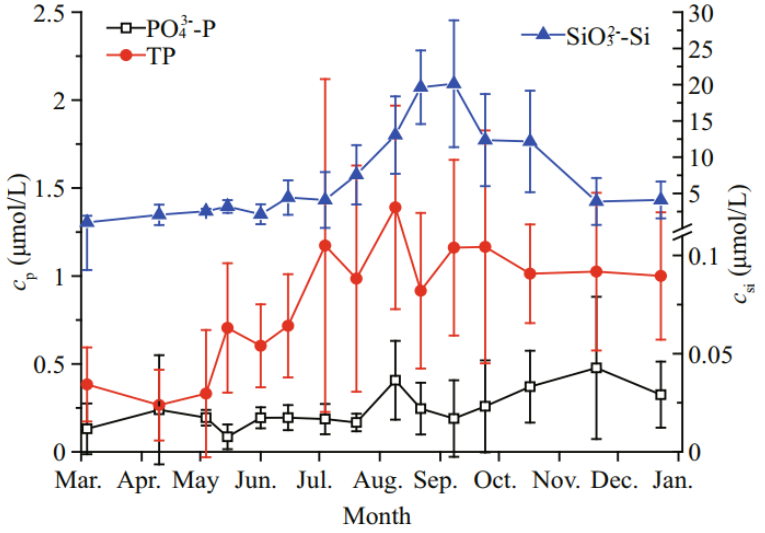


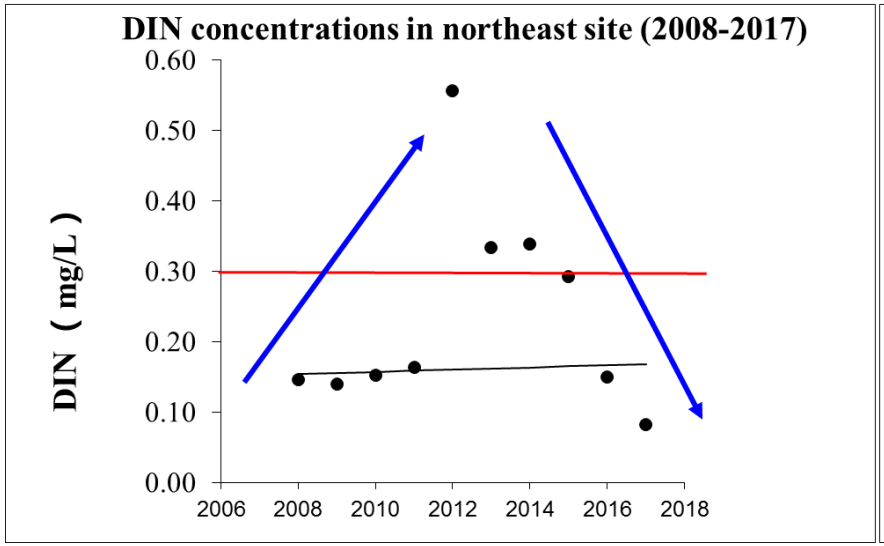
Fig.7 Annual variation in different forms of phosphorus and silicate in upper layer seawaters of Qinhuangdao

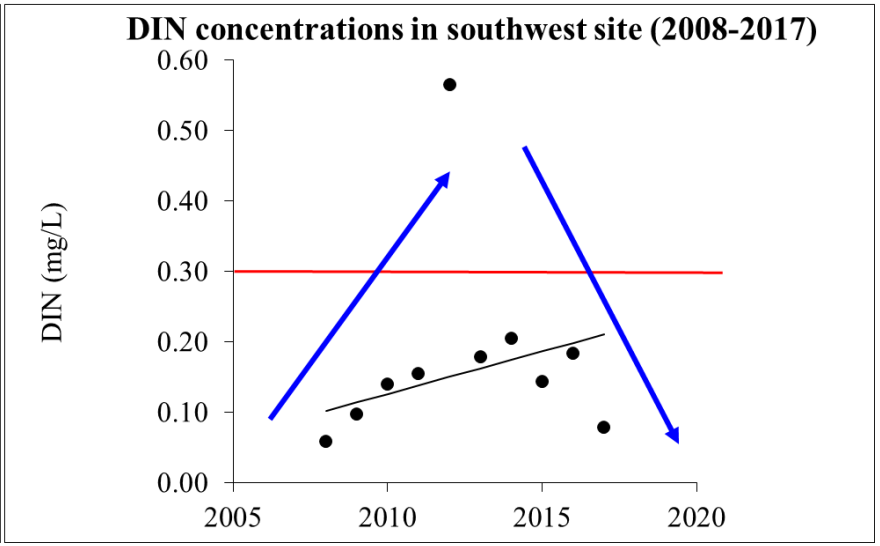
Data are averages of samples from nine sites in one cruise and represent characteristics of the whole area surveyed.

- **DIN was highest in Nov. and Dec., while DIP was highest in Aug. and Sep.(not in winter, Cao et al., 2018), so we used maximum data of DIN and DIP in a year to substitute winter DIN and DIP data, since no winter data was collected .**

(2) Annual maximum of DIN and DIP concentration

DIN





- Lower than criteria in recent 3 years for both sites.
- Increasing trend was determined by Mann-Kendall test with minor positive statistic Z values.
- The concentrations of DIN increased firstly then decreased, with 0.56 mg/L in the year 2012 as a peak value.
- But if data since 2012 to 2017 was considered, Decreasing trend was observed.