Ecosystem Changes under multi-stressors in the Yellow Sea

Mingyuan Zhu, Ruixiang Li and Zongling Wang
First Institute of Oceanography, State Oceanic Administration

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I. Natural environment of Yellow Sea and East China Sea
II. Multi-stressors
III. Changes in pelagic and benthic community
IV. Disruptive response of ecosystem
V. Summary
I. Natural environment of Yellow Sea (including Bohai Sea, North East China Sea)
Yellow Sea and East China Sea are two of marginal and productive seas in North West Pacific Ocean.
Continental shelf is quite wide here.
Sediment here consists of sand, silt and clay mainly.
Water circulation of the YS and ECS (winter)
Water circulation of the YS & ECS (summer)
II. MultiStressors in Yellow Sea

- Temperature (Climate)
- Salinity (Climate & Water-Use)
- Nutrients
- Over-fishing
- Land Reclamation
Increasing SST trends over 1982-2006 in 59 out of 64 LMEs in the world.
Bohai SST (°C)

(Lin et al., 2001)
Reduced Freshwater to Bohai Sea
(Precipitation & Yellow River Discharge)

(Wang et al., 2006)
Other factors contributing to discharge reduction to Bohai
Increasing Salinity in Bohai Sea

Bohai SSS (psu)

(Lin et al., 2001)
World’s $\frac{1}{4}$ Nitrogen Use in China
(below optimal return)
Large Areas along Coast of China Eutrophicated (2008)
Major Pollutants

- DIN
- PO$_4^{3-}$
Large Changes of the N/P Ratio

Laizhou Bay (Cui & Tang, YSFRI unpublished data)
Large N/P as well in Jiaozhou Bay

(Li et al., 2005)
Nutrient concentration in Yangtze River Estuary

From B. Wang
Trends of atmospheric deposit pollutants in area of Yellow Sea (1997-2006)

<table>
<thead>
<tr>
<th>Areas</th>
<th>Fluxes of atmospheric deposit</th>
<th>Contents of pollutant in aerosol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TSP*  Cu  Pb  Cd</td>
<td>TSP+  Cu  Pb  Cd</td>
</tr>
<tr>
<td>near Dalian</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>near Qingdao</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Changjiang Estuary</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>All seas</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* TSP: Total suspended particles in atmosphere.
Change of content of pollutants in shellfish along coast of Yellow Sea (1997-2006)

<table>
<thead>
<tr>
<th>Coastal Area</th>
<th>Oil</th>
<th>THg</th>
<th>Cd</th>
<th>Pb</th>
<th>As</th>
<th>DDT</th>
<th>PCBs</th>
</tr>
</thead>
</table>

- **significantly increasing**
- **slightly increasing**
- **increasing**
- **decreasing**
- **slightly decreasing**
- **significantly decreasing**
- **no change**
- **no enough data**

From Q. Wen
Dust storms in China

VS<1000m

21-03-2002

21-03-2001
Chinese satellite image of dust storm
April 18, 2006

NOAA satellite image of dust storm
April 23, 2006
Dust storms in China
Dust storms in China

Dust storm durations 1961-2000
Mainly in spring (bloom season)
- Liu & Hao 2003

hours

100 days

40 days
High abundance of phytoplankton situated in the pass way of dust
Distribution of Global Atmospheric Nitrogen Deposition

Galloway et al., 2004
## Atmospheric nitrogen deposition

<table>
<thead>
<tr>
<th>Area</th>
<th>Deposition (Mmol m(^{-2})yr(^{-1}))</th>
<th>Deposition/Total (deposition+river)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>South North Sea</td>
<td>71</td>
<td>27%</td>
<td>Rendell et al., 1993</td>
</tr>
<tr>
<td>Delaware Bay</td>
<td>75</td>
<td>5%</td>
<td>Russell et al., 1998</td>
</tr>
<tr>
<td>Kattegat</td>
<td>69</td>
<td>30%</td>
<td>Asman et al., 1995</td>
</tr>
<tr>
<td>North Atlantic coast</td>
<td>23</td>
<td>20%</td>
<td>Galloway et al., 1996</td>
</tr>
<tr>
<td>Yellow Sea</td>
<td>90.5</td>
<td>42%</td>
<td>Bi, unpublished data</td>
</tr>
</tbody>
</table>

Note: The studies by Rendell et al. (1993) and Bi are the only ones to explicitly include ON. Cornell et al. (2003) suggest that organic nitrogen will enhance deposition total nitrogen by 10–20%, probably more in remote regions.
Atmospheric nitrogen deposition during China SOLAS cruise in YS in March 2005

TN   IN   ON
(\textit{mgN/m}^2/\text{mon})
Atmospheric nitrogen deposition during China SOLAS cruise in April 2006

TN                               IN                             ON

TN (mgN/m²/mon)
Overfishing & Over-Aquaculture

(Tang, 2005)
Overfishing: a fact since 1980’s

- Over the last 50 years, biodiversity and productivity of the Yellow Sea ecosystems have undergone large changes. For example, on the dominant species, the commercially important high-valued long-lived, high trophic level, piscivorous bottom fish have been replaced by low-valued short-lived, low trophic level, planktivorous pelagic fish.
Large-scale land reclamation

- During the last decades, China has lost ca. 1000 km² or 50% of total coastal wetlands to reclamation.

- In 2002~2007, the wetland loss rate increased from 20 km²/yr to 134 km²/yr
Reclamation in the Yellow Sea

Jiangsu Province

- Presently, over 5000 km$^2$ coastal wetlands, about one-fourth of China’s total.
- Over 1300 km$^2$ coastal wetlands reclaimed over the past 15 years
- Plans to reclaim another 1800 km$^2$ by 2020
Coastal erosion of Yellow Sea.

- erosion coast; ~siltation coast; ::: sandy coast
- * embayment coast; ▽ delta coast

Coastal erosion of Yellow Sea.
III. Change in planktonic and benthic community
1. Phytoplankton

There was a decrease in species number of phytoplankton in last century

Number of phytoplankton species identified in Yellow Sea in different years

<table>
<thead>
<tr>
<th></th>
<th>spring</th>
<th>summer</th>
<th>autumn</th>
<th>winter</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacillariophyta</td>
<td>78</td>
<td>22</td>
<td>99</td>
<td>85</td>
<td>42</td>
</tr>
<tr>
<td>Pyrrophyta</td>
<td>17</td>
<td>8</td>
<td>16</td>
<td>28</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>168</td>
<td>160</td>
<td>55</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
phytoplankton abundance

a significant decrease in phytoplankton abundance from 1959 through 1985 to 1998.

The seasonal and interannual variation of phytoplankton abundance
Since 2001, the abundance of phytoplankton in spring became much higher than that in earlier years. It may attribute to the acceleration of eutrophication process and global warming.

Table 3. The cell abundance of phytoplankton in Yellow Sea
In different years (×10^4 cells/m^3)

<table>
<thead>
<tr>
<th>Year</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
<th>Winter</th>
<th>Mean</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1959</td>
<td>77.29</td>
<td>354.90</td>
<td>20.40</td>
<td>441.53</td>
<td>223.53</td>
<td>[1]</td>
</tr>
<tr>
<td>1984-1985</td>
<td>27.6</td>
<td>254.0</td>
<td>109.4</td>
<td>577</td>
<td>242</td>
<td>[9, 11]</td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9.54</td>
<td>FIO</td>
</tr>
<tr>
<td>2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FIO</td>
</tr>
<tr>
<td>March 2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FIO</td>
</tr>
<tr>
<td>May 2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.59</td>
<td>FIO</td>
</tr>
<tr>
<td>April 2006</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2027.66</td>
<td>FIO</td>
</tr>
</tbody>
</table>
Ratio of diatom to dinoflagellates

Figure 1. Ratio of diatoms/(diatoms+dinoflagellates) species number from Chinese surveys. Redrawn using the data from the Chinese report.

(From Sinjae Yoo)
Chlorophyll a (chl-a) and primary productivity

Chlorophyll-a concentrations in the surface water of the Yellow Sea in spring and autumn were in the range of 0.426~17.425 mg/m³ in Korean report.

The mean concentration of chl-a in Yellow sea in 1992
2. Zooplankton
Figure 7. Long-term change in relative composition of four major zooplankton groups during 1978~2000 (KEWG, 2006). A net with a mesh size of 330 μm was used to sample zooplankton.
Seasonal variation of zooplankton biomass shows a double peak type. In general, the peaks occur in spring and autumn. But there is a winter peak in 1984-85. From results of these 3 surveys, there was a trend of decrease of zooplankton biomass.
Long-term variation of zooplankton biomass
(from Korean data)

Figure 8. Long-term change in zooplankton biomass in wet weight in
the Yellow Sea (KEWG, 2006).
3. Macrobenthos
Relative composition of major benthic groups in the Yellow Sea (from D. Kang)

Relative composition of the major benthic groups in the Yellow Sea in September 1992 (data from KEWG(2006)).

Relative composition of the major benthic groups in the Yellow Sea in 1998~2001 (data from CEWG(2006)).
Trophic level continuously lowering

(Zhang & Tang, 2004)
Species feeding habits in Yellow Sea changing over the past 20 years

- **Spanish mackerel**
  - FH: nektivorous
  - TL: 4.9
  - 1982

- **Large head hairtail**
  - FH: nektivorous
  - TL: 4.9
  - 1985

- **Bombay duck**
  - FH: nektivorous
  - TL: 4.5
  - 1985

- **Trichiurus muticus**
  - FH: nektivorous
  - TL: 4.4
  - 1985

- FH: omnivorous
  - TL: 3.81
  - 2000

- FH: omnivorous
  - TL: 3.89
  - 1992

- FH: omnivorous
  - TL: 3.55
  - 2000

- FH: Planktivorous
  - TL: 3.55
  - 2000

(Zhen & Tang, 2007)
Community Structure Changes in Yellow Sea

(Based on biomass yield data, YSFRI)
Shift of dominant species with climate
(Tang, 2003)

Species Shift

- Small yellow croaker, Hairtail (temperate species)
- Herring, Chub mackerel (cold water species)
- Anchovy (warm water species)
Warm water tunicate moving north

*Doliolum denticulatum*: a warm water species

- In 1958/59, distribution limited to 32 °N.
- In 2007, becoming the dominant species in the Northern Yellow Sea (38-39 °N).
IV. Disruptive response of ecosystem

1. HAB
2. Jellyfish bloom
3. Hypoxia
4.1 HAB events

From Chinese report, there is an increase of HAB events in Yellow Sea. During 2000-2005 the HAB events accounted for about 50% of total records. Although there were only two HAB events in 2006, this does not suggest that the environmental quality of Yellow Sea is being improved.
4.1 HAB events

Figure 2. The trend in the purported HAB incidences from Korean side of the Yellow Sea. Here, identification of HABs was based on cell density (1,000 cells ml$^{-1}$).
Records of red tides in the East China Sea

- Red tides dominated by diatoms
- Red tides dominated by dinoflagellates
Main dinoflagellates species for large scale HAB in East China Sea

- *Prorocentrum donghaiense*
- *Karenia mikimotoi*
- *Alexandrium tamarense/catenatum*
浙江近海赤潮卫遥感影像图

MODIS AQUA 2004 05 10 13 39(250 米)

国家海洋环境监测中心
863 模块化赤潮卫星遥感监测技术项目（2001AA636020）
Bloom of Prorocentrum donghaiense in East China Sea during 2002-2006
succession of HAB species:
“diatom → dinoflagellate → diatom”

Bloom of diatom

2002—2004:
End of March
early April

Increase of Dino.

2005:
Early April

Bloom of dino.

Large scale bloom of Prorocentrum
Early May-June

Large scale bloom of Proro. & Karenia
End of May to end of June
1. In March, Nutrients concentration are high, diatom bloom occurs;

2. As decrease of nutrients, large scale dinoflagellate bloom occurs;

3. When NO$_3$-N concentration is lower than 1 $\mu$mol/L (some station lower than 0.1 $\mu$mol/L), HAB dispersed
Jellyfish Bloom

In recent years, bloom of *Cyanea nozakii* and *Stomolophus nomurai* occurred in Yellow Sea and East China Sea.

Jellyfish bloom in coastal water of China
Jellyfish bloom in Yellow Sea and East China Sea in 2006

(From Song Sun)
Jellyfish abundance in Yellow Sea and East China Sea during 1999-2004

(F. Ding et al., 2005)
Dynamics of jellyfish biomass in the East China Sea

Changes of jellyfish biomass in the main jellyfish distribution area in summer
Stations jellyfish founded in summer of 2006
Biomass of jellyfish at summer cruise in 2006

<table>
<thead>
<tr>
<th>Total number of statins</th>
<th>0kg</th>
<th>&lt;10kg</th>
<th>&lt;100kg</th>
<th>&lt;1000kg</th>
<th>&gt;1000kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>11</td>
</tr>
</tbody>
</table>
Hypoxia area in the coastal water of the world

(From Z. Zhu)
Hypoxia in Estuary of Changjiang River
Variation of the minimum level of dissolved oxygen (DO) in the bottom layer in sea area off the Changjiang River Estuary
The Macroalgae Blooms in Yellow Sea in 2008
The green tides in the Yellow Sea

From end of May to August 2008, a large scale of green tides (macro algae blooms) broke out in the middle of Yellow Sea.

31 May, the first time of finding the green tides at the middle of Yellow Sea by flight monitoring.

14 June, the green tides reached Qingdao coast and began to accumulate in seashore.

The affected area of the green tides is about 20,000 km², with a covering area about 400 km².
Bloom in Coastal water of Qingdao City

From www.davegoblog.wordpress.com
The remote sensing results on development of green tide in Yellow Sea

The green tide in Qingdao coastal area is from southwest Yellow Sea, floated at sea surface, and accumulated in the coastal area of Qingdao.

The left sketch map shows the development of the green tides based on remote sensing image.
The bloom species is *Enteromorpha prolifera*

The bloom species is identified as *Enteromorpha prolifera*, but there are still some different opinions on taxonomy. Some people think that the dominant species should be *Enteromorpha linza*.

*Cultivated strain of Enteromorpha prolifera in lab*
The development of green tide on July 1, 2009

漂浮藻生物量约 262000t
The development of green tide in 2009 during early April to early July.
Sea Star Bloom

Empty shells of abalone and clam
Summary:

Multi-Stressors on Ecosystems of China Seas from both the climate change & anthropogenic activities are increasingly severe.

There are clear ecosystem changes, as evidenced in loss of biodiversity, decline in living marine resources, increasing HABs/Green Tides/Jellyfish blooms etc.

Further studies and management actions to reduce environment stresses are urgently needed.
Thank You