Physical Oceanic Conditions on Summer Time related with Harmful Algal Blooms around the Korean Peninsula

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15th PICES Annual Meeting
Yokohama, Japan

2006. 10. 18
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Introduction

- General

- Red tide is defined that red discoloration of marine waters caused by the presence of enormous numbers of certain microscopic algae with a long history (Halstead, 1965).

- Occurrences of red tide are clearly increased during last 20 years and threaten a human health and fisheries resource.

- The species of alga occurred red tides are known about 300 species in diatoms, dinoflagellates, silicoflagellates, prymnesiophytes and raphidophyte.

- In these species, 60~80 species called harmful bloom species by biotoxin, physical stress, hypoxia, decrease of luminous intensity and state of incongruent with nutrients. The 90% of harmful bloom species belong to the dinoflagellates (Smayda, 1997).

- The study about harmful bloom threatened a human health and occurred damage of fisheries has been globally and actively carried out (Watras et al., 1982; Yasumoto et al., 1993; Lefebvre et al., 2002).
Introduction

- In Korea Waters

♦ In Korea, the red tide was frequently occurred around some coastal area in 1980’s, though it was intermittently occurred in 1970’s.

♦ It, however, has been occurred not only inner bay and coastal area but also offshore for a long time after 1990’s.

♦ The species caused by red tide around the Korean Peninsula is mainly *Cochlodinium Polykrikoides* during last a few years. *Cochlodinium Polykrikoides* bloom greatly occurred around the South Sea and East Sea of Korea in 1995 with large damage of fisheries.

♦ These natural phenomena was extensively occurred year after year in summer and caused the enormous economic loss and the wastes of oceanic ecosystem since 1995 (NFRDI, 1997a, 1997b, 1999, 2000, 2002, 2004).

♦ The study about *Cochlodinium Polykrikoides* bloom started from 1996 and has been advanced about the occurrence mechanism, physiology and ecology of algae and mechanism of a fish mortality (Kim et al., 2000a, Kim et al., 2000b, Kim and Cho, 2000).
Introduction

- Research about the physical mechanism of HAB

- Frank and Anderson (1992) : the *Alexandrium tamarense* bloom related with the wind stress in the Gulf of Maine.
- Shaples (1997) : intrusion of offshore current by surface wind stress was closely related with dinoflagellate bloom off New Zealand.
- Steidinger *et al.* (1998) show the physical process such as wind and currents closely related with *Gymnodium breve* bloom in the Gulf of Mexico.
- Suh *et al.* (2000) and Suh *et al.* (2003) reported the relationship between sea surface temperature by NOAA satellite information and *Cochlodinium Polykrikoides* bloom and the spatio-temporal variation of *Cochlodinium Polykrikoides* bloom with oceanographic environment conditions around the Korean Peninsula.
- Yang et al. (2000) reported that when CDW appeared in the South Sea of Korea, a red tide occurred in summer 1997.
- Lee and Kang (2003) explained the physical environments and *Cochlodinium Polykrikoides* bloom by onshore transport due to wind stress around the Naro-Do.

In spite of these studies, the physical mechanism of HAB around the Korean Peninsula was not so clear yet.
Introduction

- In this study

♦ To clarify the relationship between the outbreak of Harmful Algal Bloom (HAB) and physical oceanic environmental factors in detail,

♦ From 1995 to 2006, the scale of HAB with
  - spatial distribution of temperature
  - vertical distribution of temperature
  - spatial distribution of nutrients
  - Kuroshio variation
  - pathway of Changjian Diluted Water and discharge of Changjian river

♦ It is needed to clarify significant relationship between oceanographic conditions and the outbreak of HAB for the early stage prediction about the scale of HAB.

♦ It is also important for the clarification about the mechanism related with outbreak of HAB in the Korean Waters.
- Monitoring of Red tide

Marine Harmful Organism Team in NFRDI has been carried out the monitoring for the outbreak of HAB with twice a month around the coastal area using R/V and helicopter during the red tide occurs every year. From these monitoring, they reported the spatial map about the outbreak of HAB.

# Data and Methods

## Monitoring of Red tide

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</tr>
</thead>
<tbody>
<tr>
<td><strong>First occur. Date</strong></td>
<td>8.29</td>
<td>9.4</td>
<td>8.24</td>
<td>8.30</td>
<td>8.11</td>
<td>8.22</td>
<td>8.14</td>
<td>8.2</td>
<td>8.13</td>
<td>8.5</td>
<td>7.19</td>
<td>8.7</td>
</tr>
<tr>
<td><strong>Duration (Days)</strong></td>
<td>55</td>
<td>28</td>
<td>27</td>
<td>34</td>
<td>54</td>
<td>29</td>
<td>41</td>
<td>57</td>
<td>62</td>
<td>30</td>
<td>58</td>
<td>23</td>
</tr>
<tr>
<td><strong>Maximum den. (10^3×inds./ml)</strong></td>
<td>30</td>
<td>23</td>
<td>20</td>
<td>22</td>
<td>44</td>
<td>15</td>
<td>32</td>
<td>30</td>
<td>48</td>
<td>5.8</td>
<td>25</td>
<td>23</td>
</tr>
<tr>
<td><strong>Amount of damage (100×million KRW)</strong></td>
<td>764</td>
<td>21</td>
<td>15</td>
<td>1.6</td>
<td>3.2</td>
<td>2.6</td>
<td>84</td>
<td>49</td>
<td>215</td>
<td>1.2</td>
<td>10</td>
<td>0.7</td>
</tr>
</tbody>
</table>


**Medium scale**: 1997, 1999  
- Serial Oceanographic Investigation

- **Period**: 1921 ~ Present (Current investigation system started from 1961)

- **Items**: Temperature, Salinity, Dissolved Oxygen, Nutrients, Zoo- and Phyto Plankton, Transparency, Meteorological conditions and so on.

- **Frequency**: 6 times/year (Feb., Apr., Jun., Aug., Oct., Dec.)

- **Stations**: 164 stations (East Sea 58 stations, South sea 54 stations and Yellow Sea 52 stations)

In this study,

**Spatial and vertical distributions of temperature and nutrients on August in the South Sea** were mainly examined.
Data and Methods

- **Kuroshio Upstream Investigation**

  - **Period**: 1972 ~ Present (PN-line)
  - **Items**: Temperature, Salinity, Dissolved Oxygen, Nutrients, Chlorophyll-a, Current speed/direction and so on.
  - **Frequency**: 4 times/year
  - **Stations**: currently 16 stations
  - **Institute**: Nagasaki Marine Observatory
Data and Methods

- Behavior of Changjian Diluted Water

♦ Changjian River discharge from precipitation data using multi-regression
♦ Pathway of CDW by SEAWiFS Ocean color color image

Salinity (Wang et al., 2003) in August 1998

Relatively lower surface temperature related with the large scale outbreak of HAB.
Results

- Difference of surface and 30m depth temperature

Large and medium scale HAB: 3~7°C/30m
Small scale HAB: 7~13°C/30m (except 2004)

It is possible to occur the large scale outbreak of HAB related with weaken stratification
Results

- Spatial distribution of Nutrients (NO₃)

High concentration of NO₃ usually appeared during the large scale outbreak of HAB like 2002 and 2003.
Mean surface NO3 concentration near the Narodo on Aug. generally had an increase trend and large value appeared during the large scale outbreak of HAB except 1995.
Results

- Temporal variation of Kuroshio Volume Transport

Temporal variation of observed (red) and estimated (blue) Kuroshio volume transport by moving average with seasonal period (left panel) at Kuroshio upstream cross-section, PN-line (right) (e.g., Nagasaki Marine Observatory (2005)).

Since 1995, relatively large Kuroshio volume transport appeared in 1997~1998 and in 2001~2003. Except in 1995, tendency between the Kuroshio volume transport and the outbreak of HAB almost corresponded. That is, it could be considered that large volume transport in upstream of Kuroshio corresponded with the outbreak of large scale HAB.
Results

- Discharge of CDW


It could not found out direct relationship between discharge of Changjian river and the outbreak of HAB in the Korean Waters.
Results

- Behavior of CDW

<table>
<thead>
<tr>
<th>Year</th>
<th>Special Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001-2003</td>
<td>flow toward Jeju Island</td>
</tr>
<tr>
<td>1998</td>
<td>flow south of Jeju Island</td>
</tr>
<tr>
<td>1999</td>
<td>stay away from Jeju Island</td>
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(by J.-Y. Yang Ph.D. thesis paper)

During the large scale outbreak of HAB in the Korean Waters, CDW flowed toward Jeju Is. and South Sea. On the other hand, CDW stayed away from Jeju Is. or flowed to south of Jeju Is. during the small or medium scale outbreak of HAB in the Korean Waters.
Conclusions

To clarify available relationship between the oceanic condition and the scale of HAB, we examined the various physicochemical factors with the scale of HAB in the Korean Waters.

- Usually, the large scale outbreak of HAB appeared with negative SSTA around the southern coast of Korea.

- It is possible to occur the large scale outbreak of HAB with weaken stratification.

- It is also possible to occur the large scale outbreak of HAB with high concentration of NO3.

- Large Kuroshio volume transport seemed to related with the large scale outbreak of HAB in the Koran Waters.

- The large scale outbreak of HAB in the Koran Waters was more related with the behavior or pathway of CDW than the discharge of Changjian river.
In this study, we can found out some tendency the physical oceanographic conditions when the outbreak of HAB in the Korean Waters.

Exceptions, however, were existed and quantitative descriptions were insufficient.

In future study, we have a plan to research for the clarification of relationship between the outbreak of HAB and physical conditions like spatio-temporal variation of temperature and salinity structure, current pattern, wind stress, behavior of low saline water originated by Changjian river, precipitation and typhoon and so on in more detail.
Thank you for attention!