The giant jellyfish (*Nemopilema nomurai*) bloom in East Asian seas: causes, consequences and countermeasures

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Transport of Nemopilema to Japanese waters

Seeding/nursery ground of Nemopilema

They all die in winter, i.e. expatriated population

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Consequences of *Nemoplema* plague
Nuisance to fisheries, in particular to net fisheries

- Clogging and bursting fishing nets
- Decrease of fish catch
- Killing and spoiling fish
- Stinging fishermen
- Increase of time and labor to remove medusae from the nets
- Increase of capsizing of trawl boats

In 2005, >100,000 complaints and reports on damage in fishery
Estimated monetary loss:
ca. 30 billion Japanese yen (ca. 300 million US$)
Causes: Environmental and ecosystem changes in Chinese coastal waters

**Overfishing**
(Korean fish catch in YS)

**Eutrophication**
(In Changjiang river water)

**Global warming**
(1.7°C/25 years)

**Harmful algal bloom**

(Wang, 2006)

(Lin et al., 2005)

(Wang, 2006)
Jellyfish spiral

Human forcing
1) global warming
2) eutrophication
3) overfishing
4) marine construction
5) others

Jellyfish dominated ecosystem

Fish dominated ecosystem

The more jellyfish prevail, the more fish would be eradicated
Environmental factors cannot explain a year-to-year difference in the occurrence of Nemoplema

Big bloom in 2009 (as of Oct. 29)

No bloom in 2010 (as of Oct. 28)
Biological factors: resting/excystment of podocysts

Colonized polyps and podocysts

Podocysts can rest for at least 5 years

2 mm

100 μm

100 μm
## Induction of podocyst excystment

**An excysted polyp**

**Podocysts**

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Salinity</th>
<th>Excystment (%) for 80 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>33</td>
<td>39</td>
</tr>
<tr>
<td>27</td>
<td>33</td>
<td>55</td>
</tr>
<tr>
<td>23</td>
<td>33</td>
<td>4</td>
</tr>
<tr>
<td>19 (control)</td>
<td>33</td>
<td>1</td>
</tr>
<tr>
<td>15-5</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>19</td>
<td>24</td>
<td>7</td>
</tr>
<tr>
<td>19</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>19 (in mud)</td>
<td>33</td>
<td>44</td>
</tr>
</tbody>
</table>

- Extremely high temp.
- Extremely low sal.
- Deoxygenation
Hypothetic scheme to cause a bloom year or non-bloom year

Non-bloom year

- Strobilation and ephyra release
- Excystment

Bloom year

- Spawning
- Encystment
- Strobilation and ephyra release
- Excystment
Forecast of *Nemopilema* bloom intensity by ferry-on-deck sighting survey
Ferry survey during 6-10 June, 2009

- Green: 6 June 14:00-18:30
- Blue: 7 June 07:00-14:30
- Red: 9 June 06:00-18:30
- Yellow: 8 June 07:10-19:00
- Purple: 10 June 15:50-19:00

Abundance (medusae 100 m)
Ferry survey during 20-24 June, 2009

Bloom warning

- Blue: 21 June 06:00-13:30
- Red: 23 June 06:00-18:30
- Yellow: 22 June 07:00-16:40
- Purple: 24 June 09:00-19:45
Ferry survey during 4-8 July, 2009

Orange: 4 July 06:00-18:00
Yellow: 5 July 07:00-11:00
Green: 4 July 13:30-19:30
Blue: 5 July 06:00-13:00
Red: 7 July 06:00-19:00
Purple: 8 July 09:00-19:00
Seasonal change in average density of *Nemopilema* in the Yellow Sea in 2009

- Apr.: 0.71
- May: 0.54
- Jun.: 2.29
- Jul.: 0.55
- Aug.: 0.20
- Sep.: 0.20
- Oct.: 0.20
- Nov.: 0.006
Ferry survey during 3-7 July, 2010

Orange: 3 July 6:00-18:00
Yellow: 4 July 6:00-10:30

Green: 3 July 14:00-19:00
Blue: 4 July 6:00-14:30
Red: 6 July 6:00-18:50

Purple: 6 July 17:30-19:30
Pink: 7 July 6:00-15:00
Year-to-year difference of the average density of *Nemopilema* in the Yellow Sea in July

- **Mass occurrence in Japanese waters**
- **No damage in fisheries**

<table>
<thead>
<tr>
<th>Year</th>
<th>Average density (medusae 100 m$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>2.17</td>
</tr>
<tr>
<td>2007</td>
<td>3.32</td>
</tr>
<tr>
<td>2008</td>
<td>0.02</td>
</tr>
<tr>
<td>2009</td>
<td>2.29</td>
</tr>
<tr>
<td>2010</td>
<td>0.0006</td>
</tr>
</tbody>
</table>
The simulation model can forecast the date of arrival of Nemopilema
Countermeasures in set-net fishery

Number of set-nets along *Nemopilema* affected coast

- **Large-scale:** 6
  - **Salmon:** 204
  - **Small-scale:** 352

- **Large-scale:** 154
  - **Small-scale:** 815

- **Large-scale:** 74
  - **Small-scale:** 320
Structure of a large-scale set-net

- Trapping nets: 300-600 m in length
- Leading net: 2-5 km to the shore
Structure of a large-scale set-net

Fish play ground

1st trapping net

2nd trapping net (Harvest net)

Leading net
Modification of set-net to reduce the damage

1) Enlargement of the mesh size of the leading net → Medusae pass through the leading net
2) Installment of bypass nets → Entrapped medusae are removed outside the net
3) Installment of a partition net → Entrapped medusae are separated from fish and removed outside the net

Total investment: 5-10 million JPY (ca. 50-100 thousand USD)
Ecological impact of *Nemopilema* bloom: population biomass in July and September, 2009

**In July**
- Total abundance: 23 billion medusae
- Average wet weight: 1.8 kg
- Total wet weight: 41.3 million ton

**Distribution in July**
- Yellow Sea: Average density 68,700 km⁻²
- Northern East China Sea: Average density 38,100 km⁻²

**In September**
- Total abundance: 20.7 billion medusae
- Average wet weight: 15.9 kg
- Total wet weight: 329 million ton

**Distribution in September**
- Japan Sea: Average density 40,000 km⁻²

(Annual fish catch: 0.5 million ton)
Conclusion

Causes of the bloom
Human-induced environmental/ecosystem changes in Chinese coastal waters are primary responsible, but some biological factors (e.g. podocyst dormancy) may also be important.

Forecast of the bloom
Year-to-year bloom intensity can be forecasted by ferry sighting survey in early summer. Dispersal pathways and approximate arrival date of medusae to each location can be predicted by numerical models. These forecasts enable fishermen to prepare well in advance for possible jellyfish attacks.

Countermeasures of the bloom
Modification of set-nets is effective to alleviate the damage by entrapped medusae. Such a modification is essential to keep operating set-net fisheries under currently recurrent bloom conditions.