Blooms and non-blooms of the giant jellyfish *Nemopilema nomurai* in the East Asian Marginal Seas: 12-year monitoring using ships of opportunity

Shin-ichi Uye¹, Hideki Ikeda¹, Mariko Takao¹, Hiroko Okawachi¹, Miwa Hayashi¹, Manabu Shimizu², Takashi Setou² (¹ Hiroshima University, ² National Research Institute of Fisheries Science, Japan)
Extensive horizontal transportation of *Nemopilema* to Japanese waters

- March-May: Sea of Japan
- June: CLSWM
- July: Tsushima C
- August: Pacific Ocean
- September-October: Yellow Sea
- October-November: Sea of Japan
Nemopilema outbreaks cause serious damage in net-fisheries

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

Monetary loss in 2005: ca. 30 billion JPY (270 million USD)
Forecast of Nemopilema outbreak like typhoon forecast
Forecast of *Nemopilema* bloom intensity using ships of opportunity
Nemopilema occurrence: 6-10 June, 2009

Yellow Sea

East China Sea

Green: 6 June 14:00-18:30
Blue: 7 June 07:00-14:30
Red: 9 June 6:00-18:30
Yellow: 8 June 07:10-19:00
Purple: 10 June 15:50-19:00
Nemopilema occurrence: 20-24 June, 2009

- Green: 20 June 14:00-18:30
- 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
Nemopilema occurrence: 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 *Nemopilema* density in the Yellow Sea

<table>
<thead>
<tr>
<th>Year</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
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<tbody>
<tr>
<td>2006</td>
<td></td>
<td></td>
<td></td>
<td>6.57</td>
<td>0.02</td>
<td>2.29</td>
<td>0.32</td>
<td>0.38</td>
<td>0.11</td>
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<td>2007</td>
<td>0.02</td>
<td>0.02</td>
<td>0.32</td>
<td>0.71</td>
<td>0.55</td>
<td>6.22</td>
<td>0.01</td>
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<tr>
<td>2008</td>
<td>0.01</td>
<td>0.00</td>
<td>0.07</td>
<td>0.03</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
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<tr>
<td>2009</td>
<td>0.01</td>
<td>0.00</td>
<td>0.07</td>
<td>0.03</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
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<tr>
<td>2010</td>
<td>0.01</td>
<td>0.00</td>
<td>0.07</td>
<td>0.03</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
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<tr>
<td>2011</td>
<td>0.01</td>
<td>0.00</td>
<td>0.07</td>
<td>0.03</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
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</tbody>
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Annual peak density (medusae 100 m$^{-2}$)
Average density of *Nemopilema* in the Yellow Sea in July from 2006 to 2017
Average annual by-catch of *Nemopilema* in set-nets along Japan

30 set-nets in 6 prefectures (Japan Fisheries Information Service Center)
A relationship between the ferry survey data and the bloom intensity in Japanese waters

Graph showing the annual bycatch of medusae in set net (medusae net\(^{-1}\) year\(^{-1}\)) against the average medusa density in July in the Yellow Sea (ind. 100 m\(^{-2}\)). The graph is divided into three regions: Safety, Advisory, and Warning, indicating the level of bloom intensity. The years 2006, 2007, 2009, 2012, 2013, 2016, and 2017 are marked on the graph, with different symbols and colors indicating their respective levels of intensity.
Which physical variables can explain *Nemopilema* density in the Yellow Sea in July?: Correlation analysis

**Objective variables**

- Average maximum density in July in the Yellow Sea (medusa 100 m²)

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<tbody>
<tr>
<td>Density</td>
<td>1.97</td>
<td>3.17</td>
<td>2.29</td>
<td>0.02</td>
<td>0.0006</td>
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</tr>
</tbody>
</table>

**Explanatory variables:**

- SST,
- U-wind (west-wind),
- V-wind (south-wind),
- Precipitation,
- Shortwave radiation

(Japan Meteorol. Agency)

**Correlation maps between SST and *Nemopilema* density**

- Higher SST in early spring ➔ Higher density in July
**Multiple regression model**

\[
(Nemopilema \text{ density in July}) = 0.56 \cdot (\text{SST in Feb.}) + 0.37 \cdot (U\text{-wind in May}) + 0.20 \cdot (V\text{-wind in June}) - 2.59 \quad (R^2=0.81)
\]

- **SST in Feb.**
  - Higher strobilation,
  - Higher survival of ephyrae

- **U-wind in May**
  - Offshore transport of young medusae from inshore area

- **V-wind in June**
  - Offshore transport of young medusae
Nemopilema bloom forecast: transmitted nation-wide from scientists to fishermen

- Monitoring of:
  1. SST in February
  2. U-wind in May
  3. V-wind in June
  4. Jellyfish density by sighting in May-July

- Forecast of bloom intensity (e.g. safety, advisory, warning) by July

- Nation-wide transmission of information through Fisheries Agency network

- Fishermen can prepare well in advance (i.e. 1-3 months prior to jellyfish arrival) for countermeasures
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