Dispersal pathways of Japanese glass eel in the East Asian continental shelf and its sustainable use

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Outline

1. Dispersal pathways of Japanese glass eel in the East Asian continental shelf

2. Sustainable use of the eel resource
19 *Anguilla* eels in the world

- **North America**: A. rostrata
- **Europe**: A. anguilla
- **Asia**: A. japonica, A. bicolor, A. interioris, A. obscura, A. marmorata, A. megastoma, A. luzonensis, A. borneensis, A. celebesensis
- **Africa**: A. bicolor, A. marmorata, A. nebulosa, A. mossambica
- **Oceania**: A. australis, A. dieffenbachii

**Catadromous fishes**
An eel species distribute over countries

> International management and conservation are essential

**Figure:** Dr. Kuroki
Eel life cycle

Leptocephalus → Glass eel → Silver eel → Catch for food → Egg → Spawning

Catch for aquaculture

Ocean

Continental

Yellow eel

Catch for food
Important factors of eel biogeography

1. Spawning location
2. Length of larval duration
3. Spawning time
4. Temperature preference
5. Oceanic current availability
If spawning ground overlapped & larval duration comparable
A. japonica %

A. marmorata %

Han et al. 2012 PLoS ONE
Spawning site and dispersal range

- A. japonica
- A. luzonensis
- A. marmorata

Taiwan
Luzon
12.5°N
Mindanao

Kuroshio
NEC

Spawning latitude

Han et al. 2016 MEPS
Important factors of eel biogeography

1. Spawning location

2. Length of larval duration

3. Spawning time

4. Temperature preference

5. Oceanic current availability
Segregation of American and European eel

A. rostrata

6-8 month

A. anguilla

> 1 year

Spawning
Distribution ranges of 3 eel species

- A. japonica
- A. luzonensis
- A. marmorata

NEC
# Eel otolith age

## Table 1 Sampling and age information of *Anguilla japonica* and *Anguilla marmorata* specimens analyzed in this study

<table>
<thead>
<tr>
<th>Species</th>
<th>Sampling site</th>
<th>Sampling date</th>
<th>Number</th>
<th>Total length (mm)</th>
<th>$T_m$</th>
<th>$T_l$</th>
<th>$T_{l-m}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>A. japonica</em></td>
<td>Tungkang River, Taiwan</td>
<td>30 December 1992</td>
<td>30 (16)</td>
<td>57.0 ± 2.0</td>
<td>138.7 ± 14.3</td>
<td>177.7 ± 17.8</td>
<td>39.0 ± 11.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 March 93</td>
<td>30 (14)</td>
<td>56.1 ± 2.4</td>
<td>134.0 ± 14.1</td>
<td>174.4 ± 17.9</td>
<td>40.4 ± 11.0</td>
</tr>
<tr>
<td></td>
<td>Shuangshi River, Taiwan</td>
<td>20 December 92</td>
<td>30 (12)</td>
<td>56.8 ± 2.3</td>
<td>135.7 ± 16.6</td>
<td>175.0 ± 20.9</td>
<td>39.5 ± 9.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17 February 93</td>
<td>30 (13)</td>
<td>55.9 ± 2.2</td>
<td>128.9 ± 14.6</td>
<td>174.4 ± 17.7</td>
<td>45.5 ± 13.4</td>
</tr>
<tr>
<td></td>
<td>Mingchiang River, China</td>
<td>1 March 93</td>
<td>30 (20)</td>
<td>55.1 ± 1.9</td>
<td>139.6 ± 10.1</td>
<td>172.1 ± 14.1</td>
<td>32.5 ± 7.7</td>
</tr>
<tr>
<td></td>
<td>Chyantang River, China</td>
<td>17 February 93</td>
<td>30 (23)</td>
<td>55.6 ± 1.9</td>
<td>148.1 ± 14.7</td>
<td>194.9 ± 18.6</td>
<td>46.8 ± 8.9</td>
</tr>
<tr>
<td></td>
<td>Yalu River, China</td>
<td>3 May 93</td>
<td>30 (23)</td>
<td>58.3 ± 1.8</td>
<td>157.4 ± 16.1</td>
<td>199.3 ± 15.6</td>
<td>41.9 ± 3.9</td>
</tr>
<tr>
<td></td>
<td>Ichinomiya River, Japan</td>
<td>10 January 94</td>
<td>30 (10)</td>
<td>57.4 ± 2.3</td>
<td>143.3 ± 7.9</td>
<td>186.6 ± 7.0</td>
<td>43.3 ± 5.2</td>
</tr>
<tr>
<td>Overall ($\mu_1$)</td>
<td></td>
<td>240 (131)</td>
<td></td>
<td>56.5 ± 2.1</td>
<td>140.7 ± 13.6</td>
<td>181.8 ± 16.2</td>
<td>41.1 ± 8.8</td>
</tr>
<tr>
<td><em>A. marmorata</em></td>
<td>Cagayan River, the Philippines</td>
<td>19 May 08</td>
<td>45 (13)</td>
<td>49.5 ± 1.5</td>
<td>110.4 ± 12.8</td>
<td>144.8 ± 14.2</td>
<td>34.3 ± 7.9</td>
</tr>
<tr>
<td></td>
<td>Hsiukuluan River, Taiwan</td>
<td>20 May 08</td>
<td>86 (13)</td>
<td>51.6 ± 1.6</td>
<td>112.4 ± 12.3</td>
<td>134.0 ± 15.4</td>
<td>22.6 ± 6.6</td>
</tr>
<tr>
<td></td>
<td>Kurio River, Japan</td>
<td>6 June 96</td>
<td>37 (15)</td>
<td>46.7 ± 1.7</td>
<td>117.7 ± 16.8</td>
<td>145.0 ± 17.8</td>
<td>27.3 ± 8.9</td>
</tr>
<tr>
<td>Overall ($\mu_2$)</td>
<td></td>
<td>168 (41)</td>
<td></td>
<td>49.3 ± 1.6</td>
<td>113.5 ± 13.0</td>
<td>141.6 ± 15.8</td>
<td>28.1 ± 7.8</td>
</tr>
<tr>
<td>Difference ($\mu_1 - \mu_2$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7.2</td>
<td>27.2</td>
<td>40.2</td>
</tr>
<tr>
<td>Significance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>113.5 ± 13.0</td>
<td>141.6 ± 15.8</td>
<td>28.1 ± 7.8</td>
</tr>
</tbody>
</table>

Leander et al. 2013 ZS

*ZS* indicates a significant difference.
## Eel otolith age

<table>
<thead>
<tr>
<th>Locations</th>
<th>Sampling date</th>
<th>n</th>
<th>Age*</th>
<th>Presumed birth month</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. marmorata</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baler, Philippines</td>
<td>Sep. 2013</td>
<td>10</td>
<td>$110.1 \pm 6.0^a$</td>
<td>May/Jun.</td>
</tr>
<tr>
<td>Cagayan, Philippines</td>
<td>May 2008</td>
<td>13</td>
<td>$143.0 \pm 11.1^b$</td>
<td>Dec.</td>
</tr>
<tr>
<td>Gen. San., Philippines</td>
<td>Sep. 2013</td>
<td>15</td>
<td>$140.7 \pm 6.6^b$</td>
<td>Apr./May</td>
</tr>
<tr>
<td>Siouguluan River, Taiwan</td>
<td>May 2008</td>
<td>12</td>
<td>$146.1 \pm 14.1^b$</td>
<td>Dec.</td>
</tr>
<tr>
<td><strong>A. luzonensis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baler, Philippines</td>
<td>Sep. 2013</td>
<td>20</td>
<td>$116.2 \pm 6.4^a$</td>
<td>May</td>
</tr>
<tr>
<td>Cagayan, Philippines</td>
<td>Sep. 2009</td>
<td>15</td>
<td>$127.2 \pm 7.5^b$</td>
<td>Apr./May</td>
</tr>
<tr>
<td>Gen. San., Philippines</td>
<td>Jul. 2013</td>
<td>13</td>
<td>$137.9 \pm 10.7^b$</td>
<td>Feb./Mar.</td>
</tr>
<tr>
<td>Siouguluan River, Taiwan</td>
<td>Oct. 2010</td>
<td>16</td>
<td>$137.0 \pm 8.3^b$</td>
<td>May/Jun.</td>
</tr>
</tbody>
</table>

*The 9 d of the preleptocephalus stage were added to the total age.*
Eel larval duration and distribution

Mean larval duration:
A. japonica > A. marmorata > A. luzonensis
Outline

1. Dispersal pathways of Japanese glass eel in the East Asian continental shelf

2. Sustainable use of the eel resource
Japanese glass eel recruitment time
The farther dispersal distance, the longer larval duration
## Estimated age and otolith age of Japanese glass eel

<table>
<thead>
<tr>
<th>Sampling Sites (code)</th>
<th>Estimated Age (day)</th>
<th>Counted Otolith Age * (day)</th>
<th>Time Difference (day)</th>
<th>Body Weight (Pieces per Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-Lan (宜蘭)</td>
<td>180</td>
<td>188.6 ± 9.3</td>
<td>0–10</td>
<td>5000–5500</td>
</tr>
<tr>
<td>Ping-Tung (屏東)</td>
<td>190</td>
<td>190.4 ± 12.4</td>
<td>0–10</td>
<td>5000–5500</td>
</tr>
<tr>
<td>Tanegashima Island (種子島)</td>
<td>200</td>
<td>207.7 ± 6.9</td>
<td>0–10</td>
<td>5000–5500</td>
</tr>
<tr>
<td>Mikawa Bay (三河灣)</td>
<td>210</td>
<td>209.0 ± 6.2</td>
<td>0–10</td>
<td>5500–6000</td>
</tr>
<tr>
<td>Min River (閩江)</td>
<td>210</td>
<td>206.1 ± 10.9</td>
<td>0–10</td>
<td>5500–6000</td>
</tr>
<tr>
<td>Sagami River (相模川)</td>
<td>220</td>
<td>215.4 ± 6.5</td>
<td>0–10</td>
<td>5500–6000</td>
</tr>
<tr>
<td>Ichinomiya River (一宮川)</td>
<td>220</td>
<td>216.7 ± 5.3</td>
<td>0–10</td>
<td>5500–6000</td>
</tr>
<tr>
<td>Wen-Zhou (溫州)</td>
<td>220</td>
<td>215.4 ± 13.9</td>
<td>0–10</td>
<td>6000–6500</td>
</tr>
<tr>
<td>Xiang-Shan (廣東象山)</td>
<td>220</td>
<td>209.4 ± 14.3</td>
<td>10–20</td>
<td>6500–7000</td>
</tr>
<tr>
<td>Je-Ju Island (濟州島)</td>
<td>220</td>
<td>211.5 ± 4.9</td>
<td>0–10</td>
<td>6000–6500</td>
</tr>
<tr>
<td>Shang-Hai (上海)</td>
<td>260</td>
<td>223.2 ± 19.4</td>
<td>30–40</td>
<td>6500–7000</td>
</tr>
<tr>
<td>Ning-Bo (寧波)</td>
<td>260</td>
<td>209.8 ± 8.0</td>
<td>50–60</td>
<td>6500–7000</td>
</tr>
<tr>
<td>Geum River (錦江)</td>
<td>270</td>
<td>241.8 ± 7.0</td>
<td>20–30</td>
<td>7000–7500</td>
</tr>
<tr>
<td>Yalu River (鴨綠江)</td>
<td>330</td>
<td>240.0 ± 11.2</td>
<td>90–100</td>
<td>8000–9000</td>
</tr>
</tbody>
</table>

* Unit: Mean ± SD
The increment rings in glass eel zone are usually obscure and may stop formation under low temperature.
Particle tracing for glass eel dispersal
Dispersal pathways of Japanese glass eel in the East Asian continental shelf
Outline

1. Dispersal pathways of Japanese glass eel in the East Asian continental shelf

2. Sustainable use of the eel resource
Resource decline in 3 temperate eel species

Eel abundance index (% of 1960-1970s)

Year


Japanese eel

American eel

European eel

Dekker 2004
Japanese glass eel catch in East Asia

Data source: Nihon Aquaculture News

Non-Quantitative data

\[ Y = -2.74x + 5579.2 \]
\[ R^2 = 0.3, P < 0.001 \]

Data source: Nihon Aquaculture News
Japanese eel listed in IUCN 2014 Red List

Main aquaculture eel species in the world
Why does eel resource decline?

- Habitat destruction
- Overfishing
- Global climate change
Eel habitat now

Modified from Mochioka
Dams and coastal reclamations

- Geum River mouth dam: 1.2 km
- Saemangeum barrier: 33.9 km
- Additional feature: >33 km
Satellite remote analysis of eel habitat loss in East Asia

USGS

Chronological Landsat image analysis
Eel habitat in danger

Impact of long-term habitat loss on the Japanese eel *Anguilla japonica*

Jian-Ze Chen a, Shiang-Lin Huang b, Yu-San Han a, *贵

a Institute of Fisheries Science, College of Life Science, National Taiwan University, Taipei, Taiwan
b The Swire Institute of Marine Science, School of Biological Sciences, The University of Hong Kong, Cape d'Aguilar, Shek O, Hong Kong

East Asia long-term eel river habitat quality decline > 75%
Long term trend of eel HQI in Taiwan rivers

Long term changes of Habitat Quality Index

<table>
<thead>
<tr>
<th>Year</th>
<th>HQI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>106.94</td>
</tr>
<tr>
<td>1970</td>
<td>40.74</td>
</tr>
<tr>
<td>1980</td>
<td>31.13</td>
</tr>
<tr>
<td>1990</td>
<td>28.71</td>
</tr>
<tr>
<td>2000</td>
<td>38.14</td>
</tr>
<tr>
<td>2010</td>
<td>43.56</td>
</tr>
</tbody>
</table>

Han, unpublished
Fate of the Japanese eel resource

Eel abundance

1970s 1990s 2010s Year

Before Habitat destroy Now Overfishing Future Global Warming

???
Conservation or Economy?
Which should be protected with priority?

- Glass eel: 10,000
- Adult eel: 100
- Spawner: 2
- Egg: 1,000,000

Mortality:
- Glass eel: 99%
- Adult eel: 98%
- Spawner: 99%
- Egg: 99%
Benefit estimation

Catch one pair of spawners, you get only
2 individuals * 50 USD/kg = 100 USD

V.S.

Release one pair of spawners, you may get
2% * 1 million eggs * 1% survival rate
* 5 USD/glass eel = 1,000 USD
Suggested eel conservation plan

- **Estuary**
  - Spawning
  - 20-40%
  - Eel aquaculture
  - 60-80%
- **River**
  - Stock releasing
  - No fishing
- **For food**
Better Conservation
Better Future Life

Thank You