Ecology and Recruitment of eels
*Anguilla japonica* in Korea

- Eel production
- Eel culture, catch and production
- Biology on glass eels, young and silver eels
- Research and management plan

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Eel Culture in Korea

Total number of eel farms and total area

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>216</td>
<td>270</td>
<td>269</td>
<td>468</td>
<td>521</td>
</tr>
<tr>
<td>Area (ha)</td>
<td>118</td>
<td>99</td>
<td>115</td>
<td>214</td>
<td>222</td>
</tr>
</tbody>
</table>

• Culture area increased sharply in early 2000 by increase of eel consumption because of foot-and-mouth disease, ‘mad-cow’ disease and bird flu.

• More than half of them did not culture eels in 2012 due to short supply of glass eels

• More than half of eel restaurants are changed into other items
In 2012 season
Total 8.3 mt
Import 7.00 mt
Domestic 1.3 mt

Catch and import of glass eels

Import: *A. japonica* 2.0 mt
*A. rostrata* 2.0 mt
Tropical eels 3.0 mt
### Consumption

#### Price of fully grown eels (February 2012) : KW/kg

<table>
<thead>
<tr>
<th></th>
<th>2p</th>
<th>3p</th>
<th>4p</th>
<th>5p</th>
</tr>
</thead>
<tbody>
<tr>
<td>49,000</td>
<td>52,000</td>
<td>57,000</td>
<td>60,000</td>
<td></td>
</tr>
</tbody>
</table>

Price will increase after the consumption of 2011 stock.

> Increase of eel restaurants changed into others, and……
Wild eel catch in Korea

- Habitat loss
- Overfishing
- Pollution of the habitat
- Global climate change
Upstream migration of glass eels

• Main season
  - Jeju: January to March
  - S. coasts: February to April
  - mid W coasts: March to May
  - N W coasts: April to June
Assessment of eel populations

• Monitoring the recruitment of glass eels
  Collection of daily catch data of glass eels in the 3 large river estuaries

• Ecology of yellow and silver eels
  - Biology such as sex ratio, age, growth, migration….
  using eel samples from the 3 large river estuaries
Eel trading system
- Collection of glass eel catch data

Collection of daily trade records from 2-3 glass eel fishermen from the estuaries in Han River (1993-), Geum River (2001-) and Nakdong River (2003-).
Fishing gears of glass eels

- **Jeju**: Scoop nets
  Few fishing since 1999
- **Main land**: scoop nets in some
  Weirs in the tidal channels
  Bag nets using tidal currents
• Using tidal currents in the western coastal waters.
Opened facing to the sea during the flood tide by sinking down the lower bar and collected the glass eels during the high tide.
Glass eels began to be caught from the end of February when water temperature raised over 15°C, to the end of May when the water temperature raised over 15°C.

However, the catch rates were low and fish season became later since 2010.
Relationship between catch rate in Geum River and total catch in Korea

- Similar annual catch rate among estuaries

![Graph showing the relationship between mean number of glass eels per boat per day (10^4) and total catch in Korea (mt). The equation is $y = 1.4289x - 1.0021$ with $R^2 = 0.8745$. The graph includes data points for the years 2006 and 2007.]

Total catch in Korea (mt)

Mean number of glass eels/boat/d ($10^4$)
Short term variation of catch rate of glass eels in Geum River estuary in 2003

Environment factors affecting to catch rate in 2003 by generalized additive model (GAM)

<table>
<thead>
<tr>
<th>Factor</th>
<th>edf</th>
<th>Chi-Square</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal range</td>
<td>1</td>
<td>12.9</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Temperature</td>
<td>4.2</td>
<td>248.4</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Salinity</td>
<td>1</td>
<td>4.2</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

R-sq.(adj) = 0.78, Deviance explained = 80.1%, n = 72

Temperature ranged from 4.5 to 15°C showing a peak at ca. 7°C
Factors affecting annual catch rate

- Time of peak catch, earlier, in early to mid March during the years of high catch, later, in mid April to early May during the years of low catch
- Since 2010, fishing season became later up to early June.
Sex ratios of silver eels

<table>
<thead>
<tr>
<th>Estuaries</th>
<th>F</th>
<th>M</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geum R.</td>
<td>117</td>
<td>6</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>ManG. R.</td>
<td>42</td>
<td>41</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Nakdong R.</td>
<td>126</td>
<td>27</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Sr/Ca ratios

(a) Geum River estuary
(b) Mangyeong River estuary
(c) Nakdong River estuary
### Age and Size of silver eels

<table>
<thead>
<tr>
<th>Estuaries</th>
<th>Sex</th>
<th>Age±SD (range)</th>
<th>TL±SD cm (range)</th>
<th>BW±SD g (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geum R.</td>
<td>F</td>
<td>6.3±2.5 (3-17)</td>
<td>65.6±6.9 (47.0-85.7)</td>
<td>463.7±186.1 (140-1029)</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>7.3±1.5 (4-8)</td>
<td>51.9±3.5 (48.7-58.5)</td>
<td>180.8±29.1 (141-221)</td>
</tr>
<tr>
<td>Mangyeong R.</td>
<td>F</td>
<td>6.9±1.8 (4-11)</td>
<td>62.2±8.7 (48.3-87.5)</td>
<td>418.5±206.5 (148-1040)</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>5.4±0.9 (4-7)</td>
<td>52.2±4.9 (43.2-62.3)</td>
<td>231.0±76.3 (115-458)</td>
</tr>
<tr>
<td>Nakdong R.</td>
<td>F</td>
<td>7.0±1.0 (5-9)</td>
<td>64.9±5.7 (52.2-81.5)</td>
<td>454.2±135.3 (163-909)</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>6.4±0.8 (5-8)</td>
<td>58.2±4.8 (50.0-66.9)</td>
<td>317.8±77.4 (187-530)</td>
</tr>
</tbody>
</table>
Growth in total length (female)

Geum R.

ManG R.

Nakdong R.

Lee phenomena
Management of eel resources

Short-term
- Development of culture techniques of foreign eels

Mid-term
- Release of young eels
- Construction eel pass
- Regulation of fishery on glass eels and yellow/silver eels

Long-term
- Artificial mass production of glass eels
- Amelioration of habitat environment
• Culture techniques of foreign eels
  such as *A. rostrata*, *A. bicolor*, and others.....
  >> Cooperative research of NFRDI, Eel Culture cooperative and
  Fishery institute of Cheonnam Province

• Eel larvae culture
  - Eel research teams, NFRDI
    >> cultured *leptocephali* up to 250 d (metamorphosing stage)

• Release of young eels
  - Young eels have been released by local governments having dams
    in the upper reaches of the rivers
    >> The species were checked before release,
    but any monitoring researches after release have not yet been done.
Reseaches on eel resource to date

• Monitoring the recruitment of glass eels
  - Data of daily catch are available in some estuaries, and can be collected from the glass eel fishermen on daily trade amount

• Biology and ecology of yellow and silver eels
  - Basic biology such as sex ratio, age, growth, and habitat use has been studied in some rivers.
  - More data have to be collected for assessment of eel populations such as geographic distribution of eel density, age composition ....
Technical approach

• Dam effect and eel pass/eel ladders
  - Upstream migration of eels blocked by river mouth dams, and urgent need to construct/modify eel specific pass/ladders
    cf) Dams in Japan: in the upper reaches of the rivers, Taiwan and China ???
  - Downstream migration of silver eels:
    > They can migrate during the gate opening after autumn rains
    cf) In Europe, the downstream silver eels were injured by the turbines in the electric power stations or mills

• Fishery management
  - Reducing the fishing efforts on glass eels and silver eels
Inter-governmental organization

• Annual EASEC meetings since 1998

• Meetings among eel industry peoples
  - Present status of eel culture
  - Assessment and management of eel populations

Declarations by the NGOs are only an agreement, but has no restriction.

• Urgent need of the supports from the governments
  - Mid- and long-term research fund for assessment and management plan of eel populations
  - Convention and rules for the management of international fish
    cf) - North Pacific Anadromous Fish Commission (Korea, Japan, U.S.A, Canada and Russia)
      - International Whaling Commission (IWC)
      - Western and Central Pacific Fisheries Commission (WCPFC)
      - European Eel WG in ICES/EIFAC
  ➢ Government supports the scientific committee for
    - data collection for stock assessment
    - meeting for data exchange and establishment of action plan for management

East Asia Eel Resource Consortium > East Asia Eel Resource Commission