Relative importance of oceanic, estuarine and riverine growth histories of the Japanese eel, *Anguilla japonica*, as revealed by otolith microchemistry analysis

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Reconsider the definition of catadromy

Discoveries of sea eels by otolith Sr/Ca ratios

Ref (e.g.)
1. Tzeng et al. (1997) MEPS 149:73-81
   Environmental history of eel
   Do all freshwater eel migrate?
   Semi-catadromous European eel

Source: Gross (1998)
Classification of life history patterns

Type I: Freshwater eel
Type II: Sea eel
Type III: Estuarine eel

Ref (e.g.)

Source: Tsukamoto & Arai (2001)
Diversity of the life history patterns of Japanese eels

Type I
Type III
Type II
Type III
Type III

Source: Tzeng et al. (2002)

M: Metamorphosis; E: Elver; Numerals: Annuli
Proportion of freshwater eels decreased with age

Frequency distributions, by age and migratory contingent, for female Japanese eels *Anguilla japonica* in the lower reach of the Kaoping River.

<table>
<thead>
<tr>
<th>Migratory contingents</th>
<th>Age 0-1</th>
<th>1-2</th>
<th>2-3</th>
<th>3-4</th>
<th>4-5</th>
<th>5-6</th>
<th>6-7</th>
<th>7-8</th>
<th>8-9</th>
<th>9-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>0</td>
<td>60.9</td>
<td>50</td>
<td>46.7</td>
<td>43.2</td>
<td>52.2</td>
<td>37.5</td>
<td>28.6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Type 2</td>
<td>19.6</td>
<td>15.2</td>
<td>10.9</td>
<td>20.0</td>
<td>24.3</td>
<td>21.7</td>
<td>25.0</td>
<td>28.6</td>
<td>50.0</td>
<td>0</td>
</tr>
<tr>
<td>Type 3</td>
<td>80.4</td>
<td>23.9</td>
<td>39.1</td>
<td>33.3</td>
<td>32.4</td>
<td>26.1</td>
<td>37.5</td>
<td>42.9</td>
<td>50.0</td>
<td>100</td>
</tr>
<tr>
<td>No. of fish</td>
<td>46</td>
<td>46</td>
<td>46</td>
<td>45</td>
<td>37</td>
<td>23</td>
<td>16</td>
<td>7</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Type I: Freshwater eel; Type II: Sea eel; Type III: Estuarine eel

Source: Tzeng et al. (2002)
Proportion of sea eels increased with latitude

<table>
<thead>
<tr>
<th>Country</th>
<th>Area</th>
<th>Salinity (0/00)</th>
<th>Maturational stage</th>
<th>Sample size</th>
<th>Composition of life history types (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>Mikawa Bay</td>
<td>Brackish (24.6-32.7) Freshwater and Brackish (0-32)</td>
<td>Silver</td>
<td>42</td>
<td>18.2 22.8 59.0</td>
</tr>
<tr>
<td>Japan</td>
<td>Shinjiko and Naka-umi</td>
<td>Brackish (0-32)</td>
<td>Silver</td>
<td>45</td>
<td>42.2 20.0 37.8</td>
</tr>
<tr>
<td>Taiwan</td>
<td>Kao-Ping River</td>
<td>Brackish (0-32)</td>
<td>Silver</td>
<td>60</td>
<td>31.7 8.3 60.0</td>
</tr>
</tbody>
</table>

Type I: Freshwater eel; Type II: Sea eel; Type III: Estuarine eel
Hypothesis of life history evolution (1): Productivity

Productivity is lower in freshwater than sea water in the high latitude (Gross, 1987)

Type I: Freshwater eel; Type II: Sea eel; Type III: Estuarine eel

Sources: Tzeng et al. (2003)
Freshwater growth habitat is limited in the Island countries, e.g. in Taiwan. This leads Japanese eel is dominated with estuarine-type eels.
Hypothesis of Life history evolution (3): Congeneric competitor

A. *marmorata* is a more ancestral species and has larger size than A. *japonica*, which may lead them can occupy upstream freshwater habitat and compel A. *japonica* to move to lower reaches of the river.

Subsequently A. *japonica* adaptively evolves into the present 3 types of life history.
**Competition for growth habitat between *A. japonica* and *A. marmorata***

<table>
<thead>
<tr>
<th>Composition of Life History Types</th>
<th><em>A. marmorata</em></th>
<th><em>A. japonica</em></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N</strong></td>
<td><strong>%</strong></td>
<td><strong>N</strong></td>
</tr>
<tr>
<td>Type I</td>
<td>60</td>
<td>69.8</td>
</tr>
<tr>
<td>Type II</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Type III</td>
<td>26</td>
<td>30.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>86</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

*Type I: Freshwater eel; Type II: Sea eel; Type III: Estuarine eel*
Implication of life history evolution to fisheries management

Relative abundance, growth rate and mortality rate (natural + fishing) may differ among FW, SW and estuarine eels, fishery management strategies of the eel needed to be considered respectively.

Conservation of the diversity of life history pattern is very important, because loss any one of the patterns may cause the eel population decline.
Acknowledgement

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