Cultivation and application of copepod and cladoceran for larval rearing in Japan: past, present and future

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Live food for larval fishes in aquaculture

Euryhaline rotifer *Brachionus*

- easy to culture (rotifer)
- easy to obtain (*Artemia*)
- optimum size for larval fishes to eat
- slow swimming for larval fishes to eat
What kind of food do larval fishes eat in nature?

<table>
<thead>
<tr>
<th>Category</th>
<th>Food Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copepod (nauplius, copepodide)</td>
<td>herring, Pacific sardine, northern anchovy, Japanese anchovy, cod, whiting, bib, walleye, jack-smelt, grunion, jack mackerel, horse mackerel, queenfish, white croaker, red sea bream, sand-eel, mackerel, yellow fin tuna, southern blue fin tuna, hairtail, marbled rock fish, sculpin, Japanese flounder, Atlantic flounder, dab, marbled sole, stone flounder, Australia flounder, sole, hookmouth sole (31 species)</td>
</tr>
<tr>
<td>Cladoceran</td>
<td>red sea bream, mackerel, yellow fin tuna, southern blue fin tuna, marbled rock fish, Japanese flounder, Australia flounder, hookmouth sole (8 species)</td>
</tr>
<tr>
<td>Protozoa</td>
<td>herring, whiting, bib, Atlantic flounder, dab (5 species)</td>
</tr>
</tbody>
</table>

(Ikewaki & Sawada, 1991)
Provision of copepod nauplii

- Increase survival
  red snapper (Doi et al., 1994)
grouper (Doi et al., 1997)
- Decrease malpigmentation
  halibut (MacEvoy et al., 1998)
- Increase stress resistance
  mahi-mahi (Kraul et al., 1993)

High lipid contents, and abundant DHA, EPA (Støttrup, 2003)
History of live feed for larval fishes in Japan

TL of red sea bream (mm)

- 0
- 10
- 20
- 30
- 40
- 50
- 10, 20, 30, 40 (days)

50s~

- (ciliate) Mollusk larva
- copepod nauplii, copepodide, barnacle larva
- Sea bream nauplii (wild zooplankton)
- fish meal

70s

- Mollusk larva
- rotifer
- copepod nauplii, copepodide
- fish meal

80s~

- rotifer
- Sea bream nauplii
- artificial diet

(Hino, 1994)
Feature of copepod and cladoceran culture in Japan

*Tigriopus japonicus*

**Tank (5~400m³)**

Fertilization
- chicken excrement
- rotifer + *N. oculata*

Fukusho (1980)

**Feeding**
- yeast
- *N. oculata*

**Inoculation**
- mono or mix w/rotifer

**Outdoor pond (fallow fields)**

Cladoceran
- *Moina, Daphnia, Diaphanosoma*

Fertilization
- chicken excrement

Feeding
- yeast
Cultivations of copepod and cladoceran (JASFA, 1981~93)

<table>
<thead>
<tr>
<th>Fertilization</th>
<th>feeds</th>
<th>Period (days)</th>
<th>Scale (m³)</th>
<th>mono or mix</th>
<th>Production (x10⁶ ind.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tigriopus japonicus</strong> (1981~89)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>chicken excrement</td>
<td>N. oculata yeast</td>
<td>44~49</td>
<td>7~200</td>
<td>mono</td>
<td>5.0~12.0</td>
</tr>
<tr>
<td>chicken excrement</td>
<td>N. oculata yeast</td>
<td>28~154</td>
<td>7~200</td>
<td>Mix /rotifer</td>
<td>0~5.1x10²</td>
</tr>
<tr>
<td>N. oculata + rotifer</td>
<td>N. oculata yeast</td>
<td>33~154</td>
<td>20~400</td>
<td>Mix /rotifer</td>
<td>0~4.0x10³</td>
</tr>
<tr>
<td><strong>Cladoceran</strong> (1981~1993)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Moina and/or Daphnia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>chicken excrement</td>
<td>yeast</td>
<td>7~418</td>
<td>2~450</td>
<td></td>
<td>0~6.3x10³</td>
</tr>
<tr>
<td><strong>Diaphanosoma</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. vulgaris yeast</td>
<td>16~85</td>
<td>6.5~200</td>
<td></td>
<td></td>
<td>0.8x10² ~2.9x10³</td>
</tr>
</tbody>
</table>
Feature of utilization of pelagic copepod in Japan

Tank (5~400m³)

Feeding

Outdoor pond (fallow fields)

Cultivation

Fertilization

Extensive culture
Use of pelagic copepod

Lighting & Pump up (1981~99)

<table>
<thead>
<tr>
<th>Location</th>
<th>Year</th>
<th>Daily production (x10^6 ind.)</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hakatajima</td>
<td>81~91</td>
<td>1.1~5.3</td>
<td>Acartia, Centrogages, Podon, Evadne, Calanus, Microstella, Corycaeus, Cladoceran, Crab larva, Barnacle larva</td>
</tr>
<tr>
<td>Kamiura</td>
<td>81~98</td>
<td>0.3~36.9</td>
<td>Acartia, Centrogages, Oithona, Paracalanus, Oncaea, Harpacticoida, Cladoceran, Crab zoea</td>
</tr>
<tr>
<td>Goto</td>
<td>82~91</td>
<td>6.6~2.8</td>
<td>Acartia, Oithona, Cladoceran</td>
</tr>
<tr>
<td>Notojima</td>
<td>83~99</td>
<td>0.7~5.7</td>
<td>Acartia, Centrogages, Podon, Evadne, Calanus, Oithona, Harpacticoida, Tigriopus, Mysid</td>
</tr>
</tbody>
</table>

(JASFA Annual Report, 1981~99)
Application of copepod and cladoceran for aquaculture

Red sea bream
- Mollusk larva
- rotifer
- copepod nauplii, copepodide
- fish meal

Japanese flounder
- rotifer
- Artemia nauplii
- Tigriopus
- Moina
- fish larva
- mysid

Yellowtail
- rotifer
- Artemia nauplii
- Copepod
- fish larva
- Cladoceran

(days)
Extensive culture

- Increase the survival
- Decrease the deformity
- Increase stress resistance

**Tigriopus**, cladoceran, wild zooplankton

- Increase the survival
- Decrease the deformity and malpigmentation
- Increase stress resistance

Establish of larval rearing of Yellowtail fed on *Moina* sp.
(JASFA, 1979)

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50 mm over 20 ind./m²

(Ohno, 2001)
• Need much labor to culture
• High cost for labor, fertilization and land
• Difficult to control the culture
• Fluctuation of the harvest

Difficult to apply them for practical aquaculture

• Development of rotifer culture method
• Large amount of production of *Artemia* eggs

Methods of nutritional enrichment

Nearly all hatcheries use rotifer and *Artemia* as live feed.
Frozen & dry copepod

Establishment cladoceran culture system

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Rise in the price of *Artemia* eggs → Low production ?

Deformity and malpigmentation → Nutrition supplements ?

High cost, low productivity in hatcheries

Copepod and cladoceran

Intensive culture method

Issues

• No need to enrich artificially ? → Diet

• Deficiency of DHA & EPA

• Next sheet
<table>
<thead>
<tr>
<th>(mg/100g)</th>
<th>cultured A. tsuensis</th>
<th>Wild copepod</th>
<th>enriched rotifer</th>
<th>enriched Artemia</th>
</tr>
</thead>
<tbody>
<tr>
<td>C14:0</td>
<td>32.1</td>
<td>25.0</td>
<td>32.0</td>
<td>24.2</td>
</tr>
<tr>
<td>C14:1</td>
<td>2.7</td>
<td>0</td>
<td>3.4</td>
<td>11.4</td>
</tr>
<tr>
<td>C16:0</td>
<td>39.7</td>
<td>144.0</td>
<td>180.4</td>
<td>189.5</td>
</tr>
<tr>
<td>C16:1</td>
<td>16.4</td>
<td>11.6</td>
<td>36.5</td>
<td>247.9</td>
</tr>
<tr>
<td>C16:2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C16:3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C18:0</td>
<td>11.2</td>
<td>30.6</td>
<td>37.7</td>
<td>67.0</td>
</tr>
<tr>
<td>C18:1</td>
<td>26.7</td>
<td>10.8</td>
<td>54.8</td>
<td>341.9</td>
</tr>
<tr>
<td>C18:2</td>
<td>11.5</td>
<td>11.6</td>
<td>177.0</td>
<td>64.1</td>
</tr>
<tr>
<td>C18:3</td>
<td>11.5</td>
<td>8.3</td>
<td>99.3</td>
<td>44.2</td>
</tr>
<tr>
<td>C20:0</td>
<td>2.4</td>
<td>0</td>
<td>2.3</td>
<td>2.8</td>
</tr>
<tr>
<td>C20:1</td>
<td>0.6</td>
<td>2.0</td>
<td>22.8</td>
<td>10.0</td>
</tr>
<tr>
<td>C20:4</td>
<td>1.5</td>
<td>2.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>C20:5</strong></td>
<td><strong>14.2</strong></td>
<td><strong>180.5</strong></td>
<td><strong>65.1</strong></td>
<td><strong>199.4</strong></td>
</tr>
<tr>
<td>C22:0</td>
<td>1.8</td>
<td>3.0</td>
<td>2.3</td>
<td>7.1</td>
</tr>
<tr>
<td>C22:1</td>
<td>1.8</td>
<td>4.2</td>
<td>17.1</td>
<td>8.5</td>
</tr>
<tr>
<td>C22:5</td>
<td>0.9</td>
<td>8.5</td>
<td>30.8</td>
<td>2.8</td>
</tr>
<tr>
<td><strong>C22:6</strong></td>
<td><strong>26.1</strong></td>
<td><strong>199.9</strong></td>
<td><strong>82.2</strong></td>
<td><strong>25.6</strong></td>
</tr>
<tr>
<td>C24:0</td>
<td>7.3</td>
<td>0.4</td>
<td>10.3</td>
<td>4.3</td>
</tr>
<tr>
<td>C24:1</td>
<td>5.5</td>
<td>18.6</td>
<td>6.9</td>
<td>2.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>303.0</strong></td>
<td><strong>708.8</strong></td>
<td><strong>1141.8</strong></td>
<td><strong>1424.5</strong></td>
</tr>
</tbody>
</table>

A. tsuensis was fed on 100x10³ cells /mL of Chaetoceros gracilis and 200x10³ cells /mL of Isochrysis sp.
Problem on copepod and cladoceran

How maintain the water quality?

No water exchange  Every 3 days all exchange  Everyday 1/3 exchange

![Graphs showing the number of individuals/mL and hatched individuals over time for different water exchange strategies.]

- **Nauplius**
- **Copepodide + adult**
- **Nauplius hatched from egg**
Future

Live feed to be abundant nutritionally
Alternative feed to Artemia

Copepod and Cladoceran

Stable supply and High nutritional value

What kind of micro algae is optimum as feed for copepod and cladoceran?

Large amount of micro algae (Diatom?) Concentrated micro algae

How to maintain the water quality
water exchange closed circulation system?

Use of dormant egg
Large intensive or extensive culture