Closing the tap in Recirculating Aquaculture Systems

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Fish consumption

? 

Fish from fisheries
Challenges facing aquaculture

Sustainable Intensification?

Production  Environment
Recirculating Aquaculture Systems (RAS)

Figure 1 – Example of a conventional RAS.
Conventional RAS: build up of Nitrate

- Water nitrate-N (mg/L)
  - 0
  - 20
  - 40
  - 60
  - 80
  - 100
  - 120
  - 140
  - 160
  - 180

- Time (week)
  - 0
  - 1
  - 2
  - 3
  - 4

- Low RAS
- High RAS
- 150 L/kg feed/day
- 1500 L/kg feed/day

Warm-water species: 90mg/L (EPA)

Long term exposure to sub-toxic levels?
RAS needs innovations: possible to close the tap?
Denitrification reactors (USB)

Org. compound (soluble) + Nitrate + Ammonium

Biomass + Nitrogen gas
+ Alkalinity + Carbon
dioxide + Water + Energy
Conventional vs USB-RAS

- Reduce the make-up water volume necessary for NO$_3^-$ control
- Reduce energy consumption
- Concentrate and reduce the drum filter solids flow - reducing fees for discharge
- Increase alkalinity
Conventional vs USB-RAS

- Reduce in waste discharge:
  - 81% for nitrogen (N)
  - 59% for chemical oxygen demand (COD)
  - 61% for total oxygen demand (TOD)
  - 58% for total dissolved solids (TDS)
RAS with denitrification

Fish ? Environment
Closing the tap: fish?

↓ water exchange rates (from 1500 to 30 L/kg feed)
Closing the tap: fish?

- Stress hormone (cortisol)
- Bacteria & bacteria Metabolites
- Alarm cues
- Heavy metals
- Nutrients
- Humic acids
- Sexual steroids
- Pheromones
# Closing the tap: water quality

<table>
<thead>
<tr>
<th>Water quality parameter</th>
<th>High accumulation</th>
<th>Low accumulation</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>24.0 ± 0.0</td>
<td>24.0 ± 0.0</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>pH</td>
<td>7.2–7.3</td>
<td>8.5–8.6</td>
<td>0.00</td>
</tr>
<tr>
<td>Conductivity (µS/cm)</td>
<td>1304.2 ± 10.1</td>
<td>586.9 ± 9.6</td>
<td>0.00</td>
</tr>
<tr>
<td>Dissolved oxygen (mg/L)</td>
<td>8.5 ± 0.0</td>
<td>8.5 ± 0.0</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>TAN (mg/L)</td>
<td>0.15 ± 0.04</td>
<td>0.02 ± 0.01</td>
<td>0.09</td>
</tr>
<tr>
<td>NH₃–N (mg/L)</td>
<td>0.001 ± 0.0</td>
<td>0.004 ± 0.002</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>NO₂–N (mg/L)</td>
<td>0.1 ± 0.0</td>
<td>0.0 ± 0.0</td>
<td>0.01</td>
</tr>
<tr>
<td>NO₃–N (mg/L)</td>
<td>65.3 ± 1.0</td>
<td>14.8 ± 0.1</td>
<td>0.00</td>
</tr>
<tr>
<td>Ortho-phosphate-P (mg/L)</td>
<td>19.5 ± 1.0</td>
<td>0.51 ± 0.0</td>
<td>0.00</td>
</tr>
<tr>
<td>Total bicarbonate (mg/L)</td>
<td>18.5 ± 1.8</td>
<td>169.4 ± 1.5</td>
<td>0.00</td>
</tr>
</tbody>
</table>

30 L/kg feed/day

1500 L/kg feed/day
Closing the tap: heavy metals

<table>
<thead>
<tr>
<th>µg/L (min-max)</th>
<th>30 L/kg feed</th>
<th>1500 L/kg feed</th>
<th>CMC (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>As 17.3 - 22.0</td>
<td>6.0 - 9.3</td>
<td>340</td>
<td></td>
</tr>
<tr>
<td>Cd 0.0 - 0.6</td>
<td>0.0 - 0.3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Cu 11.0 - 18.3</td>
<td>5.2 - 15.3</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Ni 6.9 - 11.7</td>
<td>0.8 - 2.5</td>
<td>850</td>
<td></td>
</tr>
<tr>
<td>Zn 29.6 - 206.9</td>
<td>3.3 - 13.0</td>
<td>215</td>
<td></td>
</tr>
</tbody>
</table>

CMC = Critical Maximum Concentration for freshwater aquatic life (EPA)

✓ Copper and Zinc concentrations may become toxic

(Martins et al., 2009a, 2010)
Closing the tap: heavy metals

Where do they come from?

Copper (Cu)

Zinc (Zn)

(Martins et al., 2010)
Closing the tap: egg and larvae develop.

Water from RAS (30 L/kg feed/d) affects egg and larvae development

(Martins et al., 2009 a)
Closing the tap: fish growth

Growth retardation = size dependent?

(Martins et al., 2009b)
Closing the tap: fish growth

17% growth retardation  (Deviller et al., 2005)

European sea bass  
*Dicentrarchus labrax*

11% growth retardation  (Mota et al., submitted)

Nile tilapia  
*Oreochromis niloticus*
Closing the tap & upscaling

- More fish
- More feed
- More water exchange

Water exchange (closing the tap) needs to be proportional to Upscalling
RAS & Upscaling: Challenges!

Economics of scale vs difficulties from:
1) Distributing flow
   • Good mixing conditions?
   • Good removal of faecal and feed waste from the tank?
   • Dead zones?
   • Tank shape?
   • Design of discharge channels?

2) Stratification of water quality
3) Removal efficiencies of the treatment units
4) Grading & harvesting
5) Removing mortalities
6) How to monitor welfare?
Conclusion

The challenge of feeding 9 billion people!

Sustainable intensification/up-scaling

RAS

Technological and ecological innovations

Interaction Fish-RAS