The development of Life Cycle Assessment for the Evaluation of Rainbow Trout Farming in France

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Total global farmed terrestrial and aquatic meat production

**(HOG/PIG MEAT)**
- (APR 3.1%)

**(POULTRY MEAT)**
- (APR 5.1%)

**(BEEF & VEAL)**
- (APR 1.2%)

**(AQUATIC MEAT)**
- (APR 9.4%)

**(MUTTON & LAMB)**
- (APR 1.0%)
Aquaculture production is increasing at a fast pace…but so do the environmental concerns associated with it.

Contribution of aquaculture to total world fisheries landings 1970-2001

Total aquaculture production in 2001 was 48.4 mmt or 34.1% of total world fisheries landings of 142.1 mmt (FAOSTAT, 2003)
Aquaculture production in France by major species for the year 2001

Total production 62677 tonnes

Rainbow trout 42037 tonnes (67%)

Common carp 5649 tonnes

European sea bass 2721 tonnes

Roach 2508 tonnes

Other 9762 tonnes

Chart: 2001; France

FAO, 2001
There are two major trout producing regions: Aquitaine and Bretagne

Decrease in farms: environmental and economic constraints
Goal and Scope

• To develop and apply the LCA methodology for the evaluation of the environmental impacts of trout farming in France

• To assess the potential of using LCA as a tool for the identification and demonstration of the potential variability in the environmental impacts due to different choices in farm management
LCA of trout production in France

Production of eggs, fingerlings, market size fish

Inputs
- Fertilisers, Pesticides,...
- Agriculture
- Ships...
- Fishery
- Feed ingredients
- Feeds

Transformation, distribution, consumption

Chemical treatments
- Veterinary treatments
- Infrastructure
- Equipment

Oxygen

Raw material
- Energy resources

Transport

Disposal

Functional unit:
1 ton of trout live weight
Choice of farms objectives

- Commercial farms - intensive freshwater raceway type system
- Main producing regions (cover >50%)
- Variation in production capacity (cover >80%)
- Variation in market sizes (cover 100%)
- Variation on technological sophistication (types of equipment use)
- Construction of production scenarios
- Availability of and willingness to share data
Production scenario construction

Production process A

Production process B

Production process C

Broodstock/Eggs

Juveniles/Portion

Large/Very large

Scenario I

Scenario II
### Description of farms used for the inventory analysis stage

<table>
<thead>
<tr>
<th>Farm No</th>
<th>Region</th>
<th>Starting size</th>
<th>Product type</th>
<th>Production capacity</th>
<th>Average weight at market size</th>
<th>TS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aquitaine</td>
<td>broodstock/eggs</td>
<td>eggs</td>
<td>45 million</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>2</td>
<td>Aquitaine</td>
<td>eggs</td>
<td>juveniles-portion</td>
<td>393 tonnes</td>
<td>220</td>
<td>18</td>
</tr>
<tr>
<td>3</td>
<td>Bretagne</td>
<td>eggs</td>
<td>juveniles-portion</td>
<td>38 tonnes</td>
<td>250</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>Bretagne</td>
<td>juveniles</td>
<td>portion-very large</td>
<td>231 tonnes</td>
<td>925</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>Aquitaine</td>
<td>juveniles</td>
<td>portion-very large</td>
<td>100 tonnes</td>
<td>984</td>
<td>13</td>
</tr>
<tr>
<td>6</td>
<td>Aquitaine</td>
<td>juveniles</td>
<td>portion-very large</td>
<td>230 tonnes</td>
<td>1410</td>
<td>16</td>
</tr>
<tr>
<td>7</td>
<td>Aquitaine</td>
<td>juveniles</td>
<td>portion-very large</td>
<td>330 tonnes</td>
<td>2062</td>
<td>22</td>
</tr>
<tr>
<td>8</td>
<td>Aquitaine</td>
<td>juveniles</td>
<td>portion-very large</td>
<td>192 tonnes</td>
<td>2189</td>
<td>13</td>
</tr>
</tbody>
</table>
## Impact categories and emissions

<table>
<thead>
<tr>
<th>Impact Categories</th>
<th>Resources and Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy use</td>
<td>Coal, oil, gas, uranium, lignite</td>
</tr>
<tr>
<td>NPP use</td>
<td>Biotic resources (direct use)</td>
</tr>
<tr>
<td>Climate Change Potential</td>
<td>CO$_2$, N$_2$O, CH$_4$</td>
</tr>
<tr>
<td>Acidification Potential</td>
<td>NH$_3$, NO$_2$, NO$_x$, SO$_2$</td>
</tr>
<tr>
<td>Eutrophication Potential</td>
<td>N, NH$_3$, NO$_3$, NO$_2$, NO$_x$, P, PO$_4$, COD, ThOD</td>
</tr>
</tbody>
</table>
Hypotheses

• Trout Farm Inputs-Outputs: producers records
  – Eutrophying emissions, energy use and emissions related to non-renewable energy use

• Production of feed: extended assessment (Papatryphon et al., in press)
  – All emissions, energy and biotic resource use during agricultural/fishery phase

• O₂ production and transport: industry-expert data (Air Liquide)
  – Energy use and emissions related to non-renewable energy use

• Equipment production and transport: industry-expert data (Faivre)
  – Energy use and emissions related to non-renewable energy use

• Farm infrastructure: farm measurements and data
  – Energy use and emissions related to non-renewable energy use
Hypotheses

• All other processes: only energy use and emissions related to non-renewable energy use is taken into account
• Allocation: economic for feed production, mass for oxygen production, none for fish production, none for manure production.
• Manure management: accounting of airborne emissions during agricultural application, no penalty for soil/water emissions as it is assumed to replace chemical fertiliser use.
Results
Production Scenarios: total calculated impacts between 2 trout production scenarios for the production of 1 ton of rainbow trout live weight

**Eutrophication**

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>74</td>
<td>70</td>
</tr>
<tr>
<td>Min</td>
<td>40</td>
<td>54</td>
</tr>
<tr>
<td>Moy.</td>
<td>58</td>
<td>54</td>
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</tbody>
</table>

**Global Warming**

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>2400</td>
<td>2300</td>
</tr>
<tr>
<td>Min</td>
<td>1500</td>
<td>1700</td>
</tr>
<tr>
<td>Moy.</td>
<td>1900</td>
<td>1800</td>
</tr>
</tbody>
</table>

**Acidification**

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>16.5</td>
<td>15.5</td>
</tr>
<tr>
<td>Min</td>
<td>10.5</td>
<td>11.5</td>
</tr>
<tr>
<td>Moy.</td>
<td>14.5</td>
<td>13.5</td>
</tr>
</tbody>
</table>

**Energy Use**

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>75000</td>
<td>65000</td>
</tr>
<tr>
<td>Min</td>
<td>25000</td>
<td>35000</td>
</tr>
<tr>
<td>Moy.</td>
<td>45000</td>
<td>35000</td>
</tr>
</tbody>
</table>

**NPP Use**

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
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</thead>
<tbody>
<tr>
<td>Max</td>
<td>62000</td>
<td>58000</td>
</tr>
<tr>
<td>Min</td>
<td>38000</td>
<td>42000</td>
</tr>
<tr>
<td>Moy.</td>
<td>50000</td>
<td>46000</td>
</tr>
</tbody>
</table>
Production Scenarios: process contribution analysis

Scenario I: Portion trout

Scenario II: Larger sizes
**Farm variability:** Total calculated impacts among 7 trout farms for the production of 1 ton of rainbow trout live weight

- **Eutrophication:**
  - Range: 46.5-74.1

- **Global Warming:**
  - Range: 1540-2410

- **Acidification:**
  - Range: 10.6-16.5

- **Energy Use:**
  - Range: 30500-73000

- **NPP Use:**
  - Range: 39200-59300
Farm variability: process contribution analysis

![Diagram showing various components of farm variability and their contributions to EP, GWP, AP, Energy, and NPP.](Image)

- **EP**: Energy Potential
- **GWP**: Global Warming Potential
- **AP**: Acidification Potential
- **Energy**: Energy consumption
- **NPP**: Net Primary Production

Components:
- **Diesel-farm**
- **Electricity-farm**
- **Oxygen-farm**
- **Equipment**
- **Infrastructure**
- **Feed**
- **Trout production**
Farm variability:
Eutrophication and NPP use

Eutrophication

R = 0.85; R^2 = 0.73; p<0.01

Regression equations

NPP Use

R = 0.99; R^2 = 0.99; p<0.00

Predictions
Farm variability: Energy use

Rm = 0.82; $R^2 = 0.67$; $p < 0.11$
Farm variability:
Global warming and Acidification

Global Warming

Acidification

Rm = 0.93; R^2 = 0.87; p < 0.02
R = 0.92; R^2 = 0.86; p < 0.02
Conclusions

• The present assessment is an estimate representing the range of potential impacts of trout farming in France

• The last stage in the production chain of trout farming is by far the most important in terms of environmental concern

• In general terms, the potential environmental impacts of trout production increase with final product size

• Feed is the largest single contributor to all environmental impacts associated with trout production

• The metrics “feed : gain“ and “feed : fresh water use“ explain the majority of variation regarding the environmental impacts of trout production (as considered in this assessment)
Conclusions

Improvements in environmental impacts could be brought about by:

• *On farm improvements in*
  – *feed: gain ratio - All impacts*
    • shifting to smaller sized product
    • improving feed composition and management
    • genetic selection for better feed efficiency
  – *feed:water use - Energy use, Global warming, Acidification*
    • assuring adequacy of fresh water flow
    • using most environmentally-friendly technology for water treatment (aeration, oxygenation, recycling)
    • reducing production capacity under current feed:gain
  – *waste treatment technology - Eutrophication*

• *Improvements in agriculture/fishery stages of ingredient production*
  – *Energy use, NPP use, Global warming, Acidification*
Perspectives

• The methodology is now in place: inclusion of more farms, simulations for alternative systems, seek means of improvement, seek better metrics

• The results from a detailed LCA assessment may be used for the identification of metrics which could serve as simple indicators for the evaluation of farming systems