A comparison of the health and performance of Chinook salmon reared in partial reuse circular tanks and flow-through raceways

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Outline

- Fish Rearing System Descriptions
- Study Overview
- Methodology
- Preliminary Results and Analysis
- Conclusions
Types of Water Use

- Flow Through Systems
  - Single Pass
- Serial Reuse Systems
  - Serial Flow Through
- Partial Reuse Systems
  - 70–80% Water Reuse
- Fully Recirculating Systems
  - >95% Water Reuse
Types of Water Use

- **Flow Through Systems**
  - Single Pass
- **Serial Reuse Systems**
  - Serial Flow Through
- **Partial Reuse Systems**
  - 70–80% Water Reuse
- **Fully Recirculating Systems**
  - >95% Water Reuse
Why Partial Water Reuse?

- Resource capacity and regulation
- Increased rearing capacity
- Proven technology creating quality fish
- Excellent water quality
- Waste flow concentration
# Reuse System Design Criteria

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Fish</td>
<td>118,000</td>
</tr>
<tr>
<td>Max Fish Size</td>
<td>16 g / 11 cm</td>
</tr>
<tr>
<td>Max Fish Density</td>
<td>8.7 kg/m³</td>
</tr>
<tr>
<td>Max Density Index</td>
<td>0.125 lb/ft³·in</td>
</tr>
<tr>
<td>Min Flow Index</td>
<td>0.75 lbs/gpm·in</td>
</tr>
</tbody>
</table>
Process Flow Drawing: Reuse

Fish Tank

Fish Tank

Discharge: 324 gpm

Return: 1295 gpm

Screen Filtration

Dissolved Gas Conditioning

Return: 971 gpm

Supply: 324 gpm
Reuse System Design by PRAqua
Magnitude of Water Reuse

- **Water reuse fraction, \( R \)**

\[
R = \frac{\left\{ \text{total reuse flowrate} - \text{makeup flowrate} \right\}}{\text{total reuse flowrate}} = \frac{Q - Q_{\text{new}}}{Q}
\]

- **Tank hydraulic retention time, HRT**

\[
HRT = \frac{\text{total system volume}}{\text{total reuse flowrate}} = \frac{V_{\text{system}}}{Q}
\]

- **Daily system exchange rate, % volume/day**

\[
\% \text{Exchange}_{\text{system}} = \frac{\text{system makeup flow}}{\text{total system volume}} \cdot 100 = \frac{Q_{\text{new}}}{V_{\text{system}}} \cdot 100
\]
Magnitude of Water Reuse

- Total reuse flow \( (Q) \) is 1,295 gpm
- Makeup flow \( (Q_{\text{new}}) \) is 324 gpm
- Total system volume \( (V_{\text{system}}) \) is 58,117 gallons

\[
R = \frac{(1295 - 324)}{1295} = 0.75
\]

\[
HRT = 58,117 \text{ gallons} \cdot \frac{\text{min}}{1,295 \text{ gallons}} = 45 \text{ minutes}
\]

\[
\% \text{Exchange}_{\text{system}} = \frac{324 \text{ gallons}}{58,117 \text{ gallons}} \cdot \frac{\text{exchange}}{\text{day}} \cdot 1,440 \text{ min} \cdot 100 \approx 800\% \text{ per day}
\]
Process Flow Drawing: Raceway

Supply: 603 gpm

Standard Raceway
100’ x 10’ by 4’

Discharge: 603 gpm
Magnitude of Water Use

- Total flow \((Q)\) is 603 gpm
- Makeup flow \((Q_{\text{new}})\) is 603 gpm
- Total system volume \((V_{\text{system}})\) is 28,125 gallons

\[
R = \frac{(603 - 603)}{603} = 0
\]

\[
HRT = 28,125 \text{ gallons} \cdot \frac{\text{min}}{603 \text{ gallons}} = 46.6 \text{ minutes}
\]

\[
\% \text{ Exchange}_{\text{system}} = \frac{603 \text{ gallons}}{\text{min}} \cdot \frac{\text{exchange}}{28,125 \text{ gallons}} \cdot \frac{1,440 \text{ min}}{\text{day}} \cdot 100 \approx 3,100\% \text{ per day}
\]
Study Overview

- **Objective:** Investigate fish health differences among raceways and partial reuse system cohorts
- **Hypothesis:** Fish growth and health will be equal or better in partial reuse environment vs. a raceway environment
Methodology

- Chinook salmon ponded June 11, 2008 at Eastbank hatchery:
  - Raceway ≈ 54,000
  - Partial reuse ≈ 63,000 per circular tank
- Fish reared until November 12, 2008
- Multiple health and welfare assessments
Methodology

- **Sampling at 0, 13, and 21 weeks post-ponding:**
  - Virology – 60 fish from each cohort sent to WADDL for cytopathogenic viruses
  - Histology – 10-30 fish from each cohort fixed in formalin and sent to WADDL for assessment of tissue health (all relevant organs)

- **4 and 21 weeks post-ponding:**
  - Fin indices for dorsal fin and dorsal and ventral poles of the caudal fin
  - Fin index: length of longest fin ray standardized to fish fork length
    - Common measure for fish welfare
Methodology

- Blood chemistry / blood gas measurements at 21 weeks post-ponding
  - Caudal venipuncture
  - i-Stat 1 portable analyzer
  - Statistical analysis to determine differences in measured parameters between the two cohorts

- Daily mortality and feed data, as well as monthly length and weight assessments for fish performance
## Fish Rearing Criteria Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Design Criteria</th>
<th>Reuse</th>
<th>Raceway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Fish</td>
<td>118,000</td>
<td>126,000</td>
<td>54,000</td>
</tr>
<tr>
<td>Max Fish Size</td>
<td>16 g / 11 cm</td>
<td>17 g / 11.4 cm</td>
<td>17.4 g / 11.1 cm</td>
</tr>
<tr>
<td>Max Fish Density</td>
<td>8.7 kg/m³</td>
<td>9.7 kg/m³</td>
<td>8.8 kg/m³</td>
</tr>
<tr>
<td>Max Density Index</td>
<td>0.125 lb/ft³·in</td>
<td>0.134 lb/ft³·in</td>
<td>0.126 lb/ft³·in</td>
</tr>
<tr>
<td>Min Flow Index</td>
<td>0.75 lbs/gpm·in</td>
<td>0.81 lbs/gpm·in</td>
<td>0.79 lbs/gpm·in</td>
</tr>
</tbody>
</table>
Comparison of average fish length between Chinook salmon reared in raceway and partial reuse environments up to 21-weeks post-ponding

* Statistically significant (p<0.05) difference between groups
## Overall performance at 21 weeks post-ponding

<table>
<thead>
<tr>
<th></th>
<th>Raceway</th>
<th>Reuse Tank 1</th>
<th>Reuse Tank 2</th>
<th>Average Reuse</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length (mm)</strong></td>
<td>110.7</td>
<td>115.1</td>
<td>113.1</td>
<td>114.1</td>
</tr>
<tr>
<td><strong>Weight (g)</strong></td>
<td>17.39</td>
<td>17.25</td>
<td>16.71</td>
<td>16.98</td>
</tr>
<tr>
<td><strong>Condition Factor</strong></td>
<td>1.28</td>
<td>1.13</td>
<td>1.16</td>
<td>1.15</td>
</tr>
<tr>
<td><strong>Coefficient of variation</strong></td>
<td>32.92</td>
<td>23.03</td>
<td>24.99</td>
<td>24.01</td>
</tr>
<tr>
<td><strong>Survival (%)</strong></td>
<td>99.0</td>
<td>99.3</td>
<td>99.3</td>
<td>99.3</td>
</tr>
</tbody>
</table>
Fin index assessments at 4 and 21 weeks post-ponding

4 weeks post-ponding

21 weeks post-ponding

* Statistically significant (p<0.05) difference between groups
Histopathology

- **At ponding:**
  - Normal tissues in all fish examined in each cohort

- **13 weeks post-ponding:**
  - Only consistent lesion noted:
    - "Gill – moderate, diffuse epithelial hypertrophy"
  - Prevalence of lesion:
    - Reuse: 4/10
    - Raceway: 1/10

- **21 weeks post-ponding:**
  - Results pending
Virology and Bacteriology

**Virology**

- At ponding, and at 13 weeks post-ponding:
  - No viruses detected in either cohort
- At 21 weeks post-ponding:
  - Results pending

**Bacteriology**

- At 21 weeks post-ponding:
  - Results pending
## Blood Chemistry – 21 weeks

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Raceway</th>
<th>Reuse</th>
<th>Mean</th>
<th>St. Error</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>nmol/L</td>
<td>147.94</td>
<td>146.13</td>
<td>0.6777</td>
<td>1.1026</td>
<td>0.2442</td>
</tr>
<tr>
<td>Potassium</td>
<td>nmol/L</td>
<td>4.1063</td>
<td>4.2438</td>
<td>0.1702</td>
<td>0.1441</td>
<td>0.5421</td>
</tr>
<tr>
<td>Chloride</td>
<td>nmol/L</td>
<td>129.88</td>
<td>127.88</td>
<td>0.9569</td>
<td>1.1026</td>
<td>0.1809</td>
</tr>
<tr>
<td>Calcium</td>
<td>nmol/L</td>
<td>1.6219</td>
<td>1.6375</td>
<td>0.0258</td>
<td>0.0252</td>
<td>0.6622</td>
</tr>
<tr>
<td>Glucose</td>
<td>mg/dL</td>
<td>65.588</td>
<td>75.286</td>
<td>2.7158</td>
<td>3.0191</td>
<td>0.0236</td>
</tr>
<tr>
<td>Creatinine</td>
<td>mg/dL</td>
<td>1.0273</td>
<td>1.7231</td>
<td>0.2598</td>
<td>0.3853</td>
<td>0.2637</td>
</tr>
<tr>
<td>Hematocrit</td>
<td>%PCV</td>
<td>30.882</td>
<td>31.938</td>
<td>0.7616</td>
<td>0.6087</td>
<td>0.2912</td>
</tr>
<tr>
<td>Hemoglobin</td>
<td>g/dL</td>
<td>10.494</td>
<td>10.856</td>
<td>0.2583</td>
<td>0.2086</td>
<td>0.2873</td>
</tr>
<tr>
<td>Anion gap</td>
<td>mmol/L</td>
<td>16.357</td>
<td>14.769</td>
<td>0.5893</td>
<td>0.4408</td>
<td>0.0431</td>
</tr>
</tbody>
</table>
# Blood Gas – 21 weeks

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Raceway</th>
<th>Mean</th>
<th>St. Error</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td></td>
<td></td>
<td>7.0246</td>
<td>0.0231</td>
<td>0.0209</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reuse</td>
<td>7.1083</td>
<td>0.0192</td>
<td></td>
</tr>
<tr>
<td>pCO2</td>
<td>mmHg</td>
<td>Raceway</td>
<td>28.255</td>
<td>1.2614</td>
<td>0.1925</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reuse</td>
<td>30.692</td>
<td>0.8603</td>
<td></td>
</tr>
<tr>
<td>pO2</td>
<td>mmHg</td>
<td>Raceway</td>
<td>12.692</td>
<td>1.3463</td>
<td>0.1098</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reuse</td>
<td>9.5</td>
<td>1.0177</td>
<td></td>
</tr>
<tr>
<td>Base excess</td>
<td>mmol/L</td>
<td>Raceway</td>
<td>-23.364</td>
<td>0.8126</td>
<td>0.0055</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reuse</td>
<td>-19.833</td>
<td>0.5752</td>
<td></td>
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<tr>
<td>HCO3</td>
<td>mmol/L</td>
<td>Raceway</td>
<td>7.5545</td>
<td>0.4829</td>
<td>0.0166</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reuse</td>
<td>9.7</td>
<td>0.2879</td>
<td></td>
</tr>
<tr>
<td>Total CO2</td>
<td>mmol/L</td>
<td>Raceway</td>
<td>8.5714</td>
<td>0.4709</td>
<td>0.0019</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reuse</td>
<td>10.833</td>
<td>0.2973</td>
<td></td>
</tr>
<tr>
<td>O2 Saturation</td>
<td>%</td>
<td>Raceway</td>
<td>8.3077</td>
<td>1.2163</td>
<td>0.4049</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reuse</td>
<td>6.75</td>
<td>1.3195</td>
<td></td>
</tr>
<tr>
<td>Lactate</td>
<td>mmol/L</td>
<td>Raceway</td>
<td>9.6742</td>
<td>0.3458</td>
<td>0.2431</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reuse</td>
<td>8.71</td>
<td>0.9331</td>
<td></td>
</tr>
</tbody>
</table>
Conclusions

- Comparable performance between raceway and reuse cohorts over the entire study period
- Excellent survival in both cohorts
- Final results from WADDL still pending, will aid in blood chemistry / gas interpretation
- Study provides evidence for the viability of partial reuse systems for raising juvenile Chinook salmon
Acknowledgements

- Washington Department of Fish & Wildlife
  - Eastbank Hatchery Staff
  - Bob Rodgers
- PRAqua
- Chelan County PUD
  - Ian Adams
- Grant County PUD
- The Conservation Fund