Phase II - Habituation
29 years of walleye habituation

Survival

- Bottleneck of the process.
  - Low survival.
  - Unpredictable.
  - Inefficient.
29 years of walleye habituation

Survival

• We gained control of the process.
  – Dark room environment, in-tank lights.
  – Quality habituation diet – Otohime.
  – Optimize fingerling size – 0.5 g.
Paradigm shift

As a result of research:

Plan for habituation success and not failure.

Scientific fish culture based on data.

89.5% Survival in three years.
Phase II - Habituation

Process of converting fingerlings from live prey to commercial diets.

Key developments:
• Fish size
• Environment
• Diets and feeding
• Disease management
Habituation Methods

Fish source: RFH one acre plastic lined ponds. Stocked into indoor raceways.

Raceway Density 2003: 185 fish/ ft³ (20,000/raceway).
2004: 139 fish/ ft³ (15,000/raceway).
2014: 125 fish/ ft³ (13,500/raceway)

Based on triplicate check weights (f/lb) of pond fng’s

Formerly: Fish confined to rear 2/3 (108 ft³) for 17 days.
Raceway volume 162 ft³ or 1,200 gallons
Habituation Methods

Daily Husbandry

Monitor dissolved oxygen levels.

Initial flow rates

Initially set at 15 gpm (0.75 exchanges/hr), increased to maintain effluent DO ≥ 5.0 mg/l.

Raceways cleaned with a broom daily, water lowered to remove waste.

Collect and evaluate mortalities:

Sick?... Starvation?...Cannibalism?...

Treat disease if necessary.

Fill feeders.

Leave them alone.
**Habituation Methods**

**Feeding regime:**

<table>
<thead>
<tr>
<th>Day</th>
<th>Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10</td>
<td>Habituation diet</td>
</tr>
<tr>
<td>11-17</td>
<td>Transition – blended diets</td>
</tr>
<tr>
<td>17-28</td>
<td>Walleye Grower 9206 1.0 mm.</td>
</tr>
</tbody>
</table>

**Frequency:** 5 minute intervals, 22 h/d

**Rate:** 10% body weight per day throughout study.

Feeders calibrated twice per week to reflect growth and mortality.
Phase II – Habituation: Influence of Fish size

In 2004-2005 larger fish had significantly higher survival during habituation.
Phase II – Habituation: Fish Size.

2005 study
Significant difference
Survival \(P<0.0001\)
- Mortality \(P<0.0001\)
- Cannibalism \(P<0.0038\)

<table>
<thead>
<tr>
<th>Initial</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish/lb</td>
<td>0.32</td>
<td>0.44</td>
<td>0.53</td>
</tr>
<tr>
<td>L (mm)</td>
<td>35.7</td>
<td>39.4</td>
<td>41.7</td>
</tr>
<tr>
<td>S.E. L</td>
<td>0.246</td>
<td>0.363</td>
<td>0.315</td>
</tr>
<tr>
<td>W (g)</td>
<td>0.32</td>
<td>0.42</td>
<td>0.53</td>
</tr>
</tbody>
</table>
Phase II – Habituation:
Pattern of mortality by size group

Average treatment mortality

Day of habituation
Why >0.56g?

800/lb = >42 mm; 1000/lb = 37 mm.

- Habituation of pond reared fingerlings best above 0.57 g. (about 42 mm). Johnson and Rudacille (2010).
- Scale development initiated at 24 mm complete at 45 mm.
  - Priege (1964)
- Mechanical damage allows entry of Columnaris.
  - Huissain and Summerfelt (1991)

Theory: fingerlings larger than 0.57 g are fully scaled and therefore more resilient to handling.
Habituation - Phase II

- Process of training fish to eat artificial diet.
- Habituation diet fed 10 days.
- The critical period in our production.

BioKyowa FFK C-1000 was our choice for fingerling habituation.

- Good survival, growth.
- Expensive, imported.

Search for a diet…

- **Palatability from marine ingredients (krill or other seafood).**
  - Krill hydrosylate coating on a commercial feed increased walleye growth 30% over uncoated feed (Kolkovski et al 2000).

- **Prefer a domestic or readily importable.**
  - Most US diets are for catfish or salmonids.
  - EU prohibited the feeding of processed terrestrial animal protein to farmed animals.
Habituation Diet

Round 1 – Habituation diet trial:

- **BioVita FF #2** (BioOregon, Inc., Warrenton, OR).
  - Contains Krill. Made in US.
- **Nutra 2000 #2** (Skretting, Inc Vancouver, BC, Can.)
  - Contains Crustacean meal. Made in Canada.
- **Lansy CW 8/12** (INVE Aquaculture Inc, Ogden UT).
  - Contains Fish products. Made in Belgium.
- **Nutra HP 1.0** (Skretting, Inc)
  - Contains Crustacean meal. Made in France
- **EPAC CW 8/12** (INVE Aquaculture Inc)
  - Modification of Lansy CW.
- **Gemma 1.0** (Skretting, Inc)
  - Contains Crustacean meal. Made in France
Compare commercial feeds as a habituation diet for pond reared walleye fingerlings.

- Conducted at Rathbun Fish Hatchery
- Monitor survival (primary factor) and growth.
- 28-day production scale studies.
# Results

## 2003 Survival of walleye fingerlings after 28 days.

<table>
<thead>
<tr>
<th>Habituation diet</th>
<th>Survival (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BioVita FF</td>
<td>28.9 a</td>
</tr>
<tr>
<td>Nutra 2000</td>
<td>28.3 a</td>
</tr>
<tr>
<td>Nutra HP</td>
<td>47.3 b</td>
</tr>
<tr>
<td>Lansy CW</td>
<td>52.7 b</td>
</tr>
<tr>
<td><em>P</em>-value</td>
<td>0.0121</td>
</tr>
</tbody>
</table>

## 2004 Survival of walleye fingerlings after 28 days.

<table>
<thead>
<tr>
<th></th>
<th>Survival (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gemma</td>
<td>53.0 a</td>
</tr>
<tr>
<td>Nutra HP</td>
<td>44.0 a</td>
</tr>
<tr>
<td>EPAC CW</td>
<td>75.0 b</td>
</tr>
<tr>
<td><em>P</em>-value</td>
<td>0.0015</td>
</tr>
</tbody>
</table>
Results

Average daily mortality of walleye during habituation.

- **Habituation**
- **Transition**

**Average treatment mortality**
- BioVita FF
- Nutra 2000
- Nutra HP
- Lansy CW
Results

2004 - Initial size and condition of walleye

<table>
<thead>
<tr>
<th>Pond</th>
<th>L (mm)</th>
<th>W (g)</th>
<th>Wr</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>44.6</td>
<td>0.58</td>
<td>68.0</td>
</tr>
<tr>
<td>27</td>
<td>44.1</td>
<td>0.54</td>
<td>65.2</td>
</tr>
<tr>
<td>29</td>
<td>47.5</td>
<td>0.69</td>
<td>67.1</td>
</tr>
</tbody>
</table>
## Results

### 2003 Final length, weight, and growth rates.

<table>
<thead>
<tr>
<th>Diet</th>
<th>L (mm)</th>
<th>W (g)</th>
<th>Wr</th>
<th>mm/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>BioVita FF</td>
<td>69.5</td>
<td>3.3</td>
<td>96.7</td>
<td>1.06</td>
</tr>
<tr>
<td>Nutra 2000</td>
<td>71.2</td>
<td>3.0</td>
<td>98.9</td>
<td>1.12</td>
</tr>
<tr>
<td>Nutra HP</td>
<td>71.5</td>
<td>3.2</td>
<td>94.5</td>
<td>1.13</td>
</tr>
<tr>
<td>Lansy CW</td>
<td>71.8</td>
<td>3.4</td>
<td>92.5</td>
<td>1.14</td>
</tr>
<tr>
<td><em>P</em>-value</td>
<td>0.7504</td>
<td>0.7902</td>
<td>0.1504</td>
<td>0.7440</td>
</tr>
</tbody>
</table>

### 2004 Final length, weight, and growth rates.

<table>
<thead>
<tr>
<th>Diet</th>
<th>L (mm)</th>
<th>W (g)</th>
<th>Wr</th>
<th>mm/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gemma</td>
<td>84.4</td>
<td>5.16</td>
<td>95.1</td>
<td>1.39</td>
</tr>
<tr>
<td>Nutra HP</td>
<td>83.7</td>
<td>4.99</td>
<td>94.7</td>
<td>1.37</td>
</tr>
<tr>
<td>EPAC CW</td>
<td>83.4</td>
<td>4.99</td>
<td>95.5</td>
<td>1.36</td>
</tr>
<tr>
<td><em>P</em>-value</td>
<td>0.8236</td>
<td>0.8534</td>
<td>0.9342</td>
<td>0.7899</td>
</tr>
</tbody>
</table>
Habituation Diets:

- Highly attractive and palatable.
- Costly, but offered for a short period.
- Significant effect on survival and length.

<table>
<thead>
<tr>
<th></th>
<th>Otohime C2</th>
<th>EPAC CW 8/12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival (%)</td>
<td>88.3</td>
<td>73.5</td>
</tr>
<tr>
<td>Length (mm)</td>
<td>81.8</td>
<td>75.5</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>4.5</td>
<td>3.7</td>
</tr>
<tr>
<td>$/1000 walleye</td>
<td>$12.66</td>
<td>$6.71</td>
</tr>
</tbody>
</table>
# Habituation Diet

Survival (%) of walleye fingerlings to 28 days.

<table>
<thead>
<tr>
<th>Diets</th>
<th>2003</th>
<th>2004</th>
<th>2006</th>
<th>2011*</th>
</tr>
</thead>
<tbody>
<tr>
<td>BioVita FF</td>
<td>28.9 a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nutra 2000</td>
<td>28.3 a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nutra HP</td>
<td>47.3 b</td>
<td>44.0 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EPAC CW</td>
<td>52.7 b</td>
<td>75.0 b</td>
<td>73.5 a</td>
<td></td>
</tr>
<tr>
<td>Gemma</td>
<td></td>
<td></td>
<td>53.0 a</td>
<td></td>
</tr>
<tr>
<td>O.range</td>
<td></td>
<td></td>
<td></td>
<td>39.4a</td>
</tr>
<tr>
<td>Otohime</td>
<td></td>
<td>88.3 b</td>
<td></td>
<td>76.6b</td>
</tr>
</tbody>
</table>

2003, 2004 and 2006 studies conducted in hatchery tanks
*2011 Diet study conducted in research tanks
Sensitive to Light

- Eyes are very sensitive to light
- Seek to escape light or shadows

Dark Room Environment

- Eliminates shadows
- Fish attracted to feed around submerged light
Phase II - Habituation

Dark - room Environment

- No overhead lighting eliminates shadows
- Submerged lights further reduce shadows

<table>
<thead>
<tr>
<th></th>
<th>Overhead lighting</th>
<th>Dark Room - Submerged Lights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival</td>
<td>37.3</td>
<td>60.7</td>
</tr>
<tr>
<td>g/d</td>
<td>0.117</td>
<td>0.147</td>
</tr>
</tbody>
</table>

63% increase in survival

- Increased growth rates
- Five evaluations, all favorable.
- Production practice since 2003
Culture Environment references
- Walleye are preadapted to life in weak illumination (Moore 1944).
- Nagel (1996) 90% survival with CSL.

Conducted study in the CSL environment.
- 2003: Individual raceway covers
- 2004: Mass raceway covering
Environment

- 2001 – Researched covered tanks and submerged lights
- 2003 – First year with covered tanks and submerged lighting
- 2004 – Began dark room environment
  - All tanks now covered under one roof

Survival (%) 37.3 60.7 0.002
Growth (g/d) 0.117 0.147 0.038
Phase II

Keys to success:

- 0.57 g fingerling.
- Dark room environment, subm. light.
- Habituation feeding regime:
  - Day 1-10: Otohime C2.
  - Day 11-17: Mix of Otohime C2, Walleye Grower 1.0.
  - Day 18-35: WG 1.0 to 2.0.
Keys to success: Progress through research

Total Daily Mortalities

- 2004
- 2005
- 2006
- 2007

Days Post Stock
Phase II - Grading
Habituation History

2000-2007 Pivotal years
Research to improve culture techniques
• 2.4 fold increase in survival.
• Stability and Reliability.

Problem solved?
## Unexpected problem

### Performance:

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Growout</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FCR</td>
<td>1.87</td>
<td>2.04</td>
</tr>
<tr>
<td>Cannibalism</td>
<td>3.5 %</td>
<td>15.0 %</td>
</tr>
<tr>
<td>Survival</td>
<td>92.7 %</td>
<td>83.8 %</td>
</tr>
</tbody>
</table>

### Habituation:

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cannibalism</td>
<td>19.2 %</td>
<td>4.4 %</td>
</tr>
<tr>
<td>Survival</td>
<td>47.0 %</td>
<td>67.6 %</td>
</tr>
</tbody>
</table>
Phase II success?

<table>
<thead>
<tr>
<th>Length Group (mm)</th>
<th>Percent Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;58</td>
<td>0%</td>
</tr>
<tr>
<td>58-60</td>
<td>0%</td>
</tr>
<tr>
<td>61-63</td>
<td>0%</td>
</tr>
<tr>
<td>64-66</td>
<td>0%</td>
</tr>
<tr>
<td>67-69</td>
<td>0%</td>
</tr>
<tr>
<td>70-72</td>
<td>0%</td>
</tr>
<tr>
<td>73-75</td>
<td>0%</td>
</tr>
<tr>
<td>76-78</td>
<td>0%</td>
</tr>
<tr>
<td>79-81</td>
<td>0%</td>
</tr>
<tr>
<td>82-84</td>
<td>0%</td>
</tr>
<tr>
<td>85-87</td>
<td>25%</td>
</tr>
<tr>
<td>88-90</td>
<td>58%</td>
</tr>
<tr>
<td>91-93</td>
<td>20%</td>
</tr>
<tr>
<td>94-96</td>
<td>10%</td>
</tr>
<tr>
<td>97-99</td>
<td>5%</td>
</tr>
<tr>
<td>100-102</td>
<td>0%</td>
</tr>
<tr>
<td>&gt;103</td>
<td>0%</td>
</tr>
</tbody>
</table>
Evaluate grading

- Grade between phase II and III.
- Comparison of Ungraded, Top 20% Grade, Pass through.
- Production scale – 10 outdoor tanks of 22,500 fish/tank.
## 2007 - Grading

Significant improvement of production.
- Reduced cannibalism by 62%.
- Survival increased 20%.
- Saved $0.10/fish.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Uniformity Graded</th>
<th>Pass-through</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival (%)</td>
<td>78.6</td>
<td>93.9*</td>
<td>82.5</td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>10.4</td>
<td>1.9</td>
<td>9.2</td>
</tr>
<tr>
<td>Cannibalism (%)</td>
<td>11.0</td>
<td>4.2*</td>
<td>8.3</td>
</tr>
<tr>
<td>Feed conversion ratio</td>
<td>1.8</td>
<td>1.5*</td>
<td>1.8</td>
</tr>
<tr>
<td>Feed &amp; Chemical Cost/Fish</td>
<td>$0.53</td>
<td>$0.43</td>
<td>$0.51</td>
</tr>
</tbody>
</table>
Grading Study - Results

<table>
<thead>
<tr>
<th>Final length</th>
<th>Control</th>
<th>Top Grade</th>
<th>Low Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.8 in.</td>
<td>9.9 in.</td>
<td>9.6 in.</td>
<td></td>
</tr>
</tbody>
</table>

Control Top Grade Low Grade

9.8 in. 9.9 in. 9.6 in.

Final length
2008 - Grading Plans

- 20% Grow a lot
- 60% Grow a little
- 20% Grow out
Grading was successful!

- Cannibalism was reduced, same as last year.
- Mortality reduced, but not as good as we expected. (!)

<table>
<thead>
<tr>
<th></th>
<th>Top grade</th>
<th>Mid grade</th>
<th>Pass-through</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival (%)</td>
<td>91.2</td>
<td>87.9</td>
<td>88.9</td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>5.5</td>
<td>8.1</td>
<td>7.2</td>
</tr>
<tr>
<td>Cannibalism (%)</td>
<td>3.4</td>
<td>4.1</td>
<td>3.9</td>
</tr>
<tr>
<td>Feed conversion ratio</td>
<td>1.76</td>
<td>1.60</td>
<td>2.00</td>
</tr>
<tr>
<td>Final L (mm)</td>
<td>230</td>
<td>229</td>
<td>223*</td>
</tr>
</tbody>
</table>
Blind Walleye

• Causes: Mechanical damage (handling or rough tanks), disease, gas saturation, sunburn??
• Solutions can be implemented when a cause is defined.
  – Reduce handling, fix saturation columns, etc.
Grading Study

- **Other Important Observations:**

<table>
<thead>
<tr>
<th>Eye blindness</th>
<th>Control</th>
<th>Top grade</th>
<th>Low grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilateral</td>
<td>5.71%</td>
<td>8.13%</td>
<td>7.17%</td>
</tr>
<tr>
<td>Bilateral</td>
<td>0.0%</td>
<td>0.52%</td>
<td>0.82%</td>
</tr>
<tr>
<td>All above (total)</td>
<td>5.71%</td>
<td>8.65%</td>
<td>7.99%</td>
</tr>
</tbody>
</table>

- No significant difference in rate of blindness.

- 2006 (before grading was implemented)
  observation 30% blind eyes in one production tank.
Phase III – Growout
Keys to Success

Phase I
- Pond stocking density results in 600-800 fish/lb harvest size.
- Fertilization regime.

Phase II
- Dark Room Submerged Light Environment
- Habituation diet – Otohime C2

Phase III
- Size grading
- Feed rates
- Control costs
Phase III

Growth period – July – October

3.75 in. to 9-10 inches

Culture System:

- 10 outdoor circular tanks
- 45,000 gallon, (170 m$^3$) concrete tanks.
- Flow rate 0.45 exchanges/hour
- Single-pass, surface water.
- Final density 0.15 lb/gal
Phase III Stocking

Fish from Phase II are transferred after:

- trained to formulated diet, WG 9206
- graded for size
- 90 mm in length
- Stocking rate = 21,500 fish / tank (126 fish/ m³ ).
Phase III - Husbandry

Monitor Dissolved Oxygen
Collect mortality, examine.
Treat disease if necessary
Fill feeders
Calibrate feeders
Leave them alone.

Weekly – sample 5 fish for Ich infestation
Biweekly – sample 25-50 fish Length & Weight
Phase III - Growout

Growout to 9 inches:
- 75% of fish cost incurred.
  - Feed; FCR = 2.0.
  - Therapeutants; Formalin $32,000.

How can we improve efficiency?
Improve FCR

<table>
<thead>
<tr>
<th>Year</th>
<th>Research Project</th>
<th>FCR</th>
<th>$ Savings/tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>Phase II grading</td>
<td>1.6</td>
<td>$1780</td>
</tr>
<tr>
<td>2009</td>
<td>Measure fish, Feed the gain</td>
<td>1.4</td>
<td>$700</td>
</tr>
</tbody>
</table>
Growth rates

23.9 – 25.5°C Optimal Growth Temperature

- **Fry**
  - Pond Culture: 1.2 mm/d
  - Intensive Fry culture: 1.0 mm/d 18.3°C
- **Fingerlings**: 45 to 90 mm
  - 1.75 to 2.0 mm/d
- **Fingerlings**: 90 to 230 mm
  - 1.5 to 1.75 mm/d
Growth Rates

- **Phase I** – Fry to 45 mm
  - Pond Culture: 1.2 mm/d
- **Phase II** – 45 to 90 mm
  - 1.75 to 2.0 mm/d
- **Phase III** 90 to 225 mm
  - 1.5 to 1.75 mm/d

24-25°C Optimal Growth Temperature
Northern Climates

Rathbun 9-10” in 5 months (73.8°F)
Spirit Lake 6-7.5” in 4.5 months.
Commercial production in heated and enclosed systems.
Challenges to Efficiency

1. Cannibalism
   • Grading in Phase II – evaluated in Phase III.

2. Poor feed conversion ratio
   • Monitor growth rates
   • Feed the gain

3. Formalin use for *Ich* treatment
   • Monitor *Ich* population
   • Treat according to need
Challenge 1. Cannibalism

As Phase II survival increased

- Phase III cannibalism losses increased ($R^2=0.94$)
2007 Grading Research

- Production scale – 3 outdoor ponds of 22,500 fish/treatment
  - Graded between phases II and III
  - Comparison of uniformity graded and control
2007 Grading Research

Grading significantly improved walleye production efficiency

- Reduced cannibalism by 80%
- Survival increased 15%

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Graded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival (%)</td>
<td>78.6</td>
<td>93.9</td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>11.0</td>
<td>4.2</td>
</tr>
<tr>
<td>Cannibalism (Unaccounted %)</td>
<td>10.4</td>
<td>1.9</td>
</tr>
<tr>
<td>Feed conversion ratio</td>
<td>1.8</td>
<td>1.5</td>
</tr>
<tr>
<td>Total Feed and Chemical Cost/Fish</td>
<td>$0.53</td>
<td>$0.43</td>
</tr>
</tbody>
</table>

Grading is now part of our walleye production process
Feed Rates

How much to feed? No standardized rates....
2007 Grading – 1.5 FCR.
Can we do better?
• 1.2 FCR optimum for maximum growth of RbT.

Methods:
Known growth and mortality rates.
Westers feed equation.
Accurate feeders?
Challenge 2. Feeding

Prior to 2008 – FCR was often 2.0, fish were fed based on projected growth

2008 plan to improve feeding efficiency by:

• Sample fish and measure growth rates
• Developing a feed rate calculation spreadsheet using Westers’ equation
• Target a 1.2 FCR
Walleye Growth

Daily Growth (mm/d) vs. Temperature (F)

FCR = 1.2
FCR = 1.5
Temp F

17-Jul, 31-Jul, 14-Aug, 27-Aug, 10-Sep, 24-Sep, 6-Oct, Overall
Sampling fish every 2 weeks gave excellent growth data and did not harm the fish.

Feed rate calculation spreadsheet was developed.

Did not achieve goal of 1.2 FCR but made improvement.

<table>
<thead>
<tr>
<th></th>
<th>1.2 FCR</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual feed conversion ratio</td>
<td>1.44*</td>
<td>1.90</td>
</tr>
<tr>
<td>Survival (%)</td>
<td>89.0</td>
<td>89.8</td>
</tr>
<tr>
<td>Final L</td>
<td>229</td>
<td>226</td>
</tr>
<tr>
<td>Daily growth (mm/d)</td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Improved FCR resulted in $0.07 savings per fish.
Develop a formula to “Feed the gain”:

- Sample for length gain
- Translate length gain to weight gain via relative weight (Wr) equation
- Feed 1.2 X calculated biomass gain.
- Research compared 1.2 and 1.5 FCR

### 2009 Research

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>T</th>
<th>U</th>
<th>V</th>
<th>W</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
<th>AA</th>
<th>AB</th>
<th>AC Predicted</th>
<th>AD</th>
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<tbody>
<tr>
<td>3</td>
<td>DATE</td>
<td>Length</td>
<td>Weight</td>
<td>Daily Gain Length</td>
<td>Predicted</td>
<td>Weight</td>
<td>Weight Gain/fish</td>
<td>Biomass Gain (g)</td>
<td>FCR</td>
<td>Daily Feed (g)</td>
<td>Daily Feed (lb)</td>
<td>% BW/d</td>
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<tr>
<td>37</td>
<td>7/26</td>
<td>131.4</td>
<td>18.787</td>
<td>1.50</td>
<td>100.0</td>
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<td>15383.9</td>
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<td>23.379</td>
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<td>39</td>
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<td>139.1</td>
<td>23.379</td>
<td>1.75</td>
<td>105.6</td>
<td>24.233</td>
<td>0.854</td>
<td>17581</td>
<td>1.2</td>
<td>21097.7</td>
<td>46.5</td>
<td>4.38</td>
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<tr>
<td>40</td>
<td>7/29</td>
<td>140.8</td>
<td>24.233</td>
<td>1.75</td>
<td>105.6</td>
<td>25.107</td>
<td>0.874</td>
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<td>41</td>
<td>7/30</td>
<td>142.6</td>
<td>25.107</td>
<td>1.75</td>
<td>105.6</td>
<td>26.001</td>
<td>0.894</td>
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<td>22077.2</td>
<td>48.6</td>
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<tr>
<td>42</td>
<td>7/31</td>
<td>144.9</td>
<td>26.894</td>
<td>1.75</td>
<td>105.6</td>
<td>26.845</td>
<td>0.815</td>
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<td>22576.6</td>
<td>49.7</td>
<td>4.19</td>
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## 2009 Results

<table>
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<tr>
<th></th>
<th>1.2 FCR</th>
<th>1.5 FCR</th>
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</thead>
<tbody>
<tr>
<td>Feed conversion ratio</td>
<td>1.38</td>
<td>1.59</td>
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<tr>
<td>Survival (%)</td>
<td>83.2</td>
<td>85.5</td>
</tr>
<tr>
<td>Final L</td>
<td>230</td>
<td>232</td>
</tr>
<tr>
<td>Daily growth (mm/d)</td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

- We currently “feed the gain” at 1.2 FCR.
- Savings - $700 of feed per grow-out pond (1.2 vs 1.5 FCR)
Improved feed efficiency

- **2008** – Grading
  - Improved survival, FCR
  - $900/tank saved

- **2009** – Feed calculations
  - Improved FCR
  - $700/tank saved
Production Costs

Phase III Costly

Expenses:
Formalin therapy –
Feed: increased fish size –
Avoidable losses:
Cannibalism loss – 9% (4% - 15%).
Feed Conversion – 1.9 (1.6 – 2.4)
Production costs have more than doubled in the past 6 years.

- 2003: $0.51/fish
- 2008: $1.08/fish

Why the increase?
Input cost increases 55%
Larger fish are produced
- More feed and stocking trips!
### Rathbun Survival (%) by Culture Phase

<table>
<thead>
<tr>
<th>Year</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>Fry to fall fingerling</th>
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<tbody>
<tr>
<td>2001</td>
<td>71.5</td>
<td>28.9</td>
<td>88.7</td>
<td>46.6</td>
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<tr>
<td>2002</td>
<td>89.6</td>
<td>26.0</td>
<td>90.8</td>
<td>59.7</td>
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<tr>
<td>2003</td>
<td>84.6</td>
<td>33.1</td>
<td>97.4</td>
<td>60.5</td>
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<td>2004</td>
<td>81.7</td>
<td>46.9</td>
<td>92.7</td>
<td>35.5</td>
</tr>
<tr>
<td>2005</td>
<td>99.6</td>
<td>52.9</td>
<td>83.0</td>
<td>60.7</td>
</tr>
<tr>
<td>2006</td>
<td>87.7</td>
<td>67.3</td>
<td>82.8</td>
<td>48.8</td>
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<tr>
<td>2007</td>
<td>95.0</td>
<td>91.8</td>
<td>85.5</td>
<td>74.4</td>
</tr>
<tr>
<td>2008</td>
<td>85.0</td>
<td>89.1</td>
<td>88.7</td>
<td>67.2</td>
</tr>
<tr>
<td>2009</td>
<td>100.9</td>
<td>87.5</td>
<td>85.6</td>
<td>74.9</td>
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<tr>
<td>2010</td>
<td>92.9</td>
<td>84.0</td>
<td>94.1</td>
<td>73.4</td>
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<tr>
<td>2011</td>
<td>90.7</td>
<td>85.1</td>
<td>82.8</td>
<td>63.9</td>
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<tr>
<td>2012</td>
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<td>61.0</td>
<td>82.9</td>
<td>45.0</td>
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<td>2013</td>
<td>89.8</td>
<td>71.4</td>
<td>80.2</td>
<td>51.4</td>
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<td>2014</td>
<td>89.6</td>
<td>71.0</td>
<td>80.1</td>
<td>50.9</td>
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</tbody>
</table>
Disease and therapeutants
Rathbun Fish Hatchery

Annual production:

- 200,000 walleye fingerlings (200 mm).
- 250,000 catfish fingerlings (175 mm)

Exposure to many stressors:

- Disease outbreaks result:
  - External bacteria: Columnaris disease, Bacteria gill disease
  - External protozoa’s: Ichthyopthirius

Therapeutants to control mortality are essential.

Rathbun Fish Culture Research Facility

- Involved in efficacy trials, cooperators in drug approvals.
- Evaluate therapeutants and treatment regimes for Hatchery.

Handling:

- Dietary changes
- Environment
- Aggression and cannibalism.
Overview

Efficacy trials 2006
- Catfish – Columnaris – Aquaflor™
- Walleye – Columnaris – Chloramine-T

Theraputant comparison:
- Walleye columnaris
- Diquat, Chloramine-T, Hydrogen Peroxide

Theraputant regime modifications:
- Walleye Ich infections
- Compared formalin treatment regimes
Columnaris infections

Net handling – skin abrasions

Saddlebacks

Diagnosis: *Flavobacter columnare*
Phase II Diseases

Common diseases:
- Columnaris
- Bacterial gill disease

Disease management:
1. Monitor
2. Identify
3. Treat – Diquat or Chloramine-T
Objective: Compare bath therapeutants for columnaris disease during habituation.

- Diquat
- Hydrogen Peroxide
- Chloramine-T

Therapeutant use:
1. Diagnose columnaris.
2. Apply therapeutant.
3. Monitor post treatment mortality, re-infection.
Fish – Walleye fingerlings.
- Pond reared fingerlings.
- Initial size: 45 mm, 0.65 g
- 3,500 fish/raceway, triplicate raceways.

Standard habituation practices
- Study duration: 27 days.

Theraputant application –
- Started on day two.
- Day one: 0.5% salt for all tanks.
### Columnaris therapeutant comparisons

<table>
<thead>
<tr>
<th>Therapeutants</th>
<th>Treatment Rate</th>
<th>Duration</th>
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</thead>
<tbody>
<tr>
<td>Diquat</td>
<td>12 to 18 mg/l</td>
<td>2 h</td>
</tr>
<tr>
<td>Perox-aide</td>
<td>First treatment: 25 mg/L</td>
<td>30 m</td>
</tr>
<tr>
<td></td>
<td>Thereafter: 50 mg/L</td>
<td>up to 1 h</td>
</tr>
<tr>
<td>Chloramine-T</td>
<td>15 to 20 mg/L</td>
<td>1 hr</td>
</tr>
<tr>
<td>Control (1 tank)</td>
<td>None</td>
<td>-</td>
</tr>
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</table>
Number of Applications

Theraputant

<table>
<thead>
<tr>
<th>Theraputant</th>
<th>Diquat</th>
<th>Chloramine-T</th>
<th>HP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14</td>
<td>16 *</td>
<td>12</td>
</tr>
</tbody>
</table>

*Chloramine –T was applied more often than others (P=0.004)
2005 Cumulative mortality curves

2006 Cumulative mortality curves

Year comparison

Cumulative Mortality vs. Day of habituation for Diquat, Chloramine-T, Hydrogen Peroxide, and Control.
Challenge 3. Ich Treatment

Parasite-S (formalin) applied July – October

- Prior to 2008 prophylactic treatment regime:
  - Daily 9 hour flowing water treatment
  - 45 mg/l formalin via metering pump
- $30,000 – $35,000 annually
2009 Ich Research

Treatment - Daily 24-h formalin treatment until eradicated.

- “Action levels”
  - If Ich > 15 cells/gill arch – begin daily treatments

Results

• 1. Threshold count of 15 cells/gill arch was adequate
• 2. Infestations can be controlled with consecutive daily treatments.
• 3. Seven days of continuous treatment required to eradicate Ich if temperatures are above 21°C