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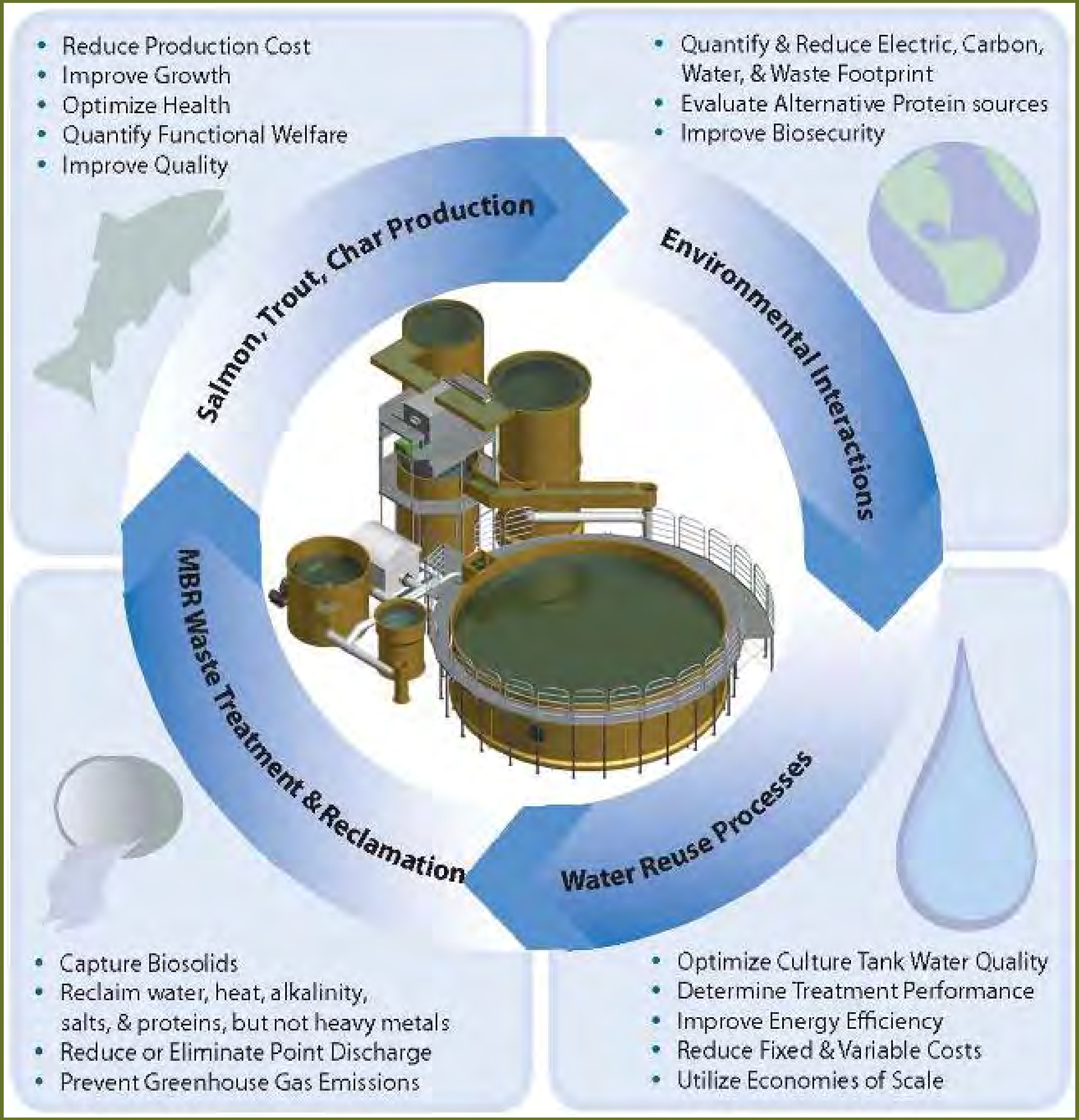
# Recent Research on the Effects of $NO_3$-N, $CO_2$, $O_2$ x Swimming Speed, and Strain x Photoperiod on Salmonid Performance, Health, and Welfare

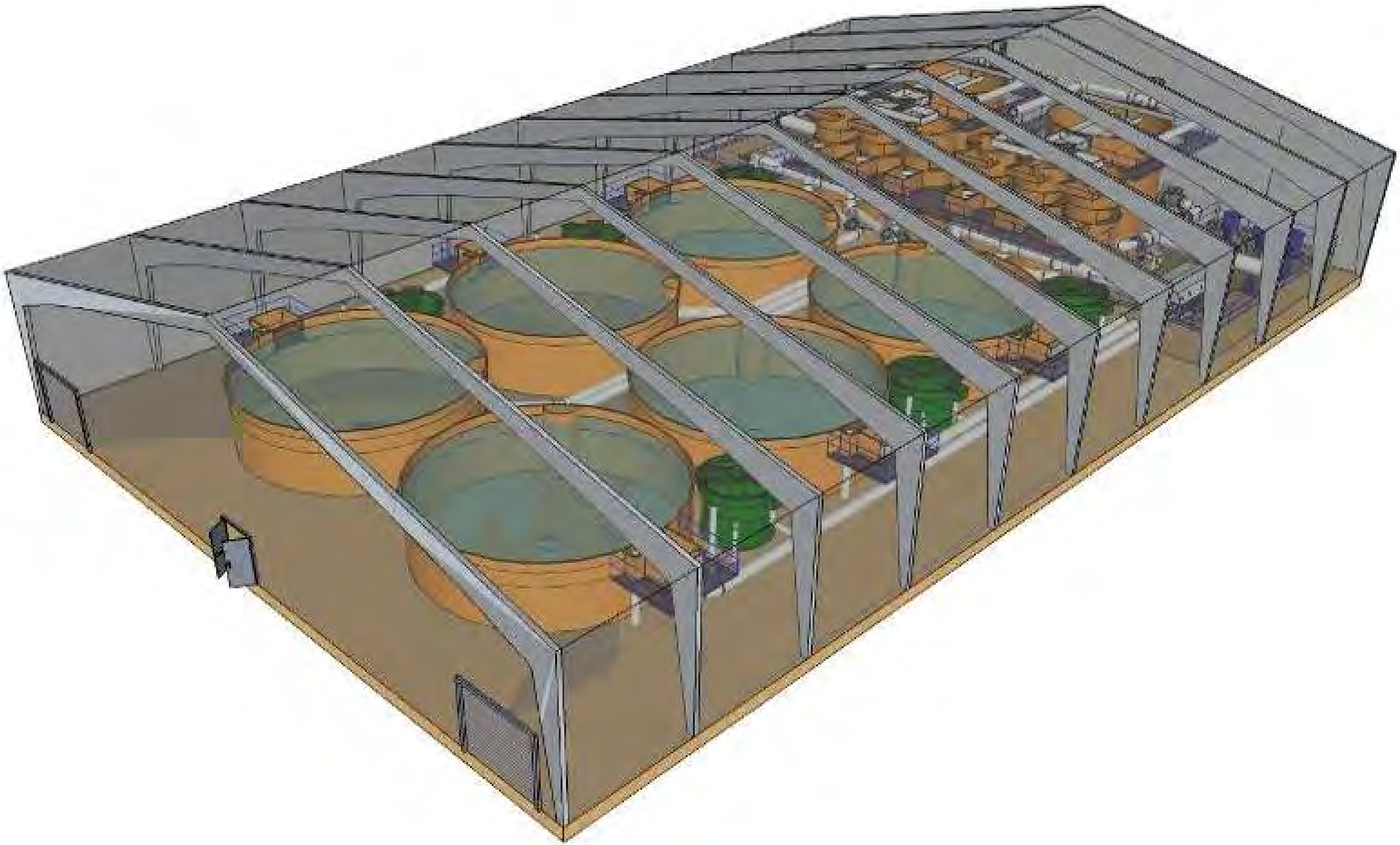
**Good, C., Davidson, J., Waldrop, T., Welsh, C., Snekvik, K., Terjesen, B., Summerfelt, S.**

Aquaculture Innovation Workshop, Campbell River, BC
Sept 26-27, 2011




# Research at The Freshwater Institute

# Closed Containment Facilities with Water Recirculation



# Recent Research at The Freshwater Institute

**Atlantic salmon *Salmo salar* growout in freshwater closed-containment systems:**

**(1) effects of strain and photoperiod manipulation**

**(2) effects of high and low dissolved carbon dioxide**

**(3) effects of swimming speed and dissolved oxygen**

# Rainbow trout *Oncorhynchus mykiss* in freshwater closed-containment systems:

# Effects of high vs. low $NO_3$-N

# STUDY 1

## Effects of strain and photoperiod manipulation on Atlantic salmon

# Objectives

- Determine how Atlantic salmon strain and photoperiod manipulation (to produce smoltification) influence growth, processing attributes, and sexual maturity to 26 months post-hatch in freshwater RAS.

# Materials and Methods

- 2X2 Factorial study
- Two Atlantic salmon strains:
  1. St. John's
  2. Gaspe
- Two early rearing light regimes:
  1. Continuous light
  2. Continuous light with $S_0$ winter
     - 12h light, 12h dark for six weeks, then return to constant light

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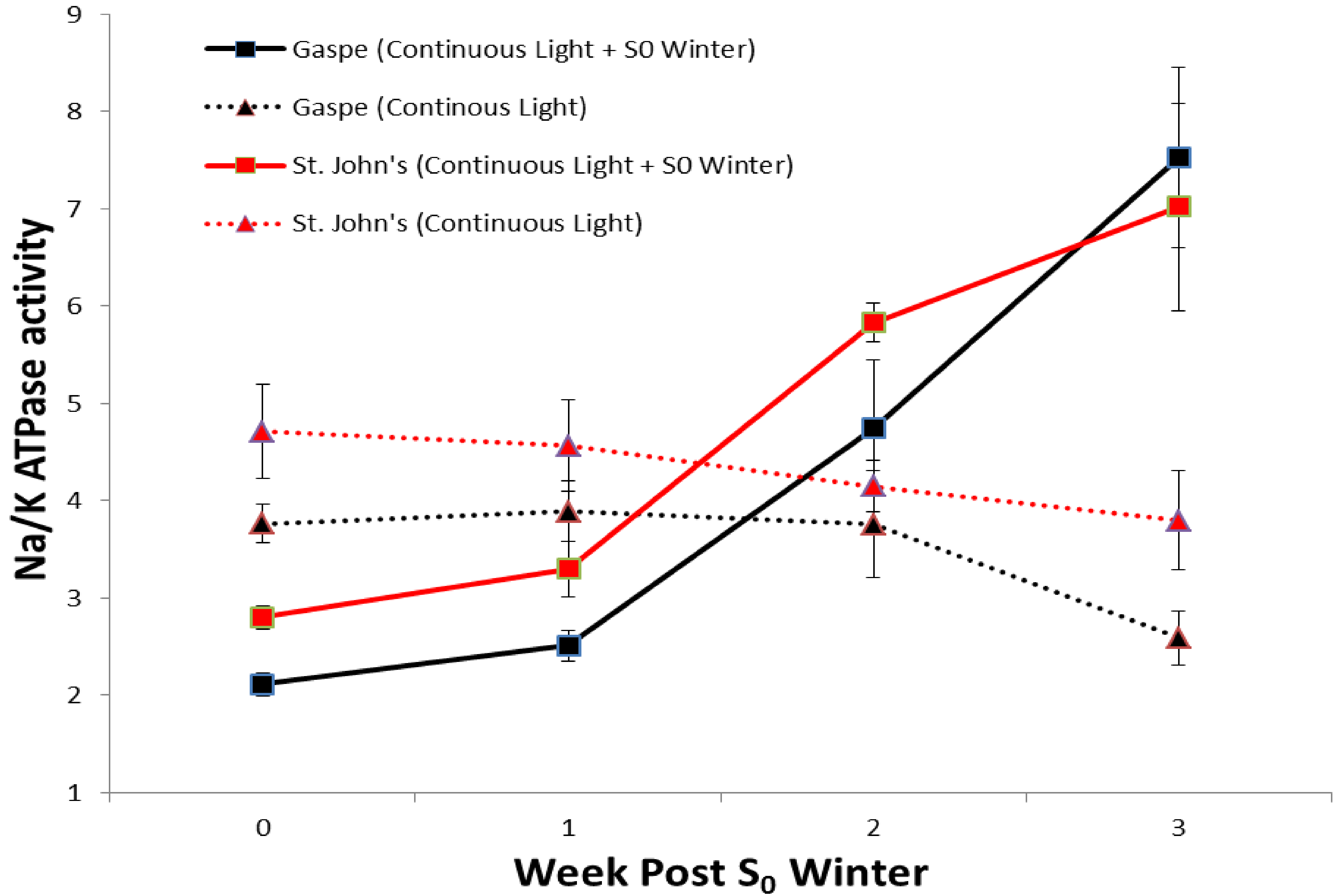
# Seawater Challenge Post-Photoperiod Manipulation



- Three 10 $m^3$ culture tanks in one freshwater reuse system
- Both strains and photoperiod treatment fish co-mingled within each tank for n=3 replication

# Results

- Good overall feed conversion throughout study – 1.05 with 40:30 diet
- Overall survival >95%
- No vaccinations or treatments necessary, aside from occasional salt to control fungus
- Gaspe strain outperformed St. John's at 26 months post-hatch

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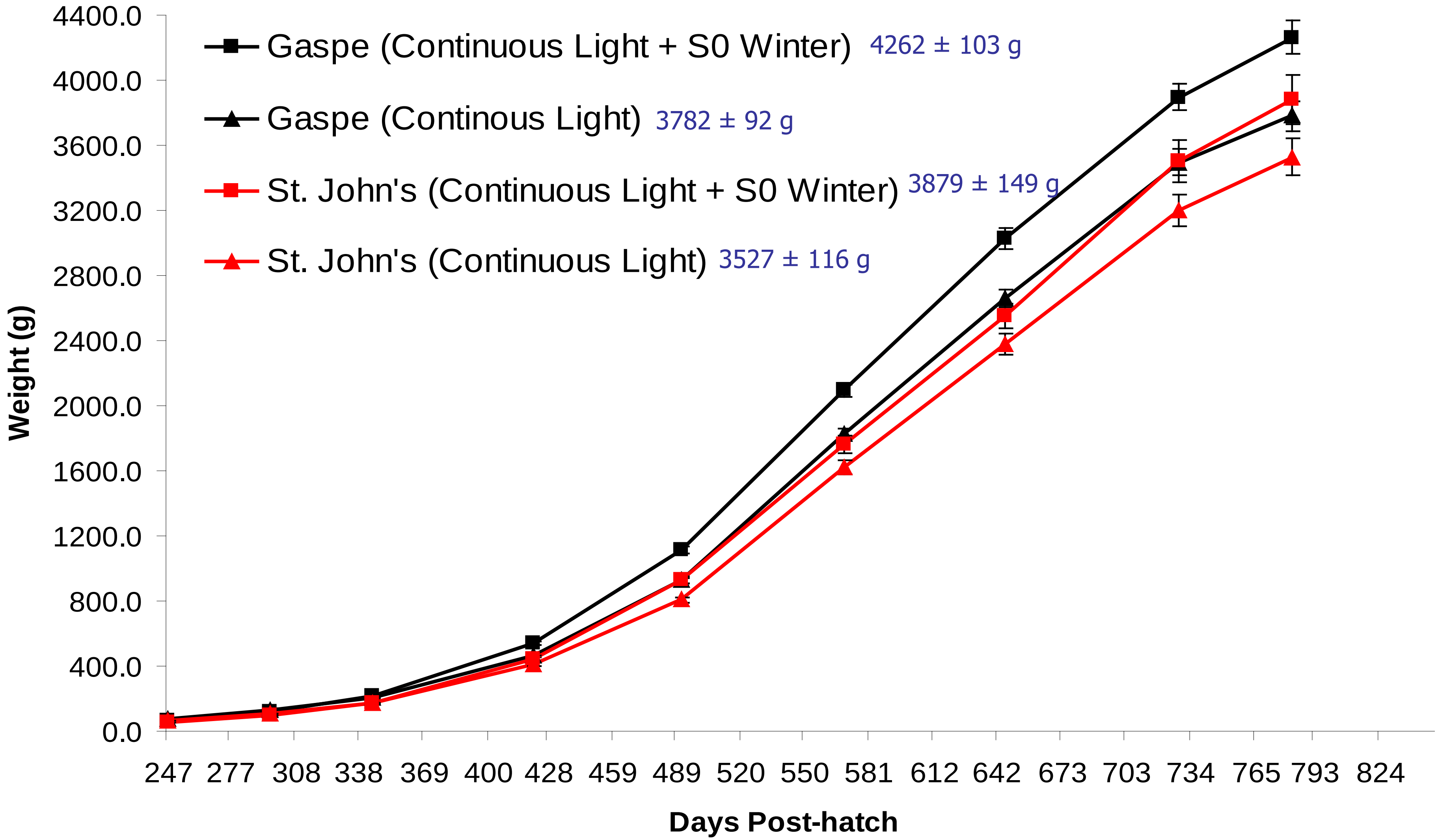
# Mean Fish Weight to 26 months



| Variable | Gaspe S0 Winter | Gaspe Constant | St. John's S0 Winter | St. John's Constant |
|---|---|---|---|---|
| Weight (g) *** | 4262 ± 103 | 3782 ± 91.8 | 3879 ± 149 | 3527 ± 116 |
| Head-on Gutted Yield (%)† | 89.8 ± 0.4 | 88.5 ± 0.3 | 87.8 ± 0.5 | 88.3 ± 0.5 |
| Fillet Moisture (%)† | 62.7 ± 0.7 | 62.2 ± 0.7 | 67.1 ± 0.7 | 64.9 ± 0.7 |
| Fillet Fat (%)*** | 17.2 ± 0.8 | 17.8 ± 0.9 | 11.7 ± 0.8 | 14.4 ± 0.8 |
| Fillet Protein (%) *** | 19.7 ± 0.1 | 19.7 ± 0.2 | 20.9 ± 0.2 | 20.2 ± 0.2 |
| Fillet Ash (%) | 1.38 ± 0.06 | 1.40 ± 0.03 | 1.46 ± 0.03 | 1.40 ± 0.05 |
| Viscera Index (%) | 8.72 ± 0.6 | 9.51 ± 0.3 | 8.42 ± 0.7 | 8.43 ± 0.5 |

† Significantly ($p<0.05$) different between strains

*** Significantly ($p<0.05$) different between both strain and photoperiod treatment

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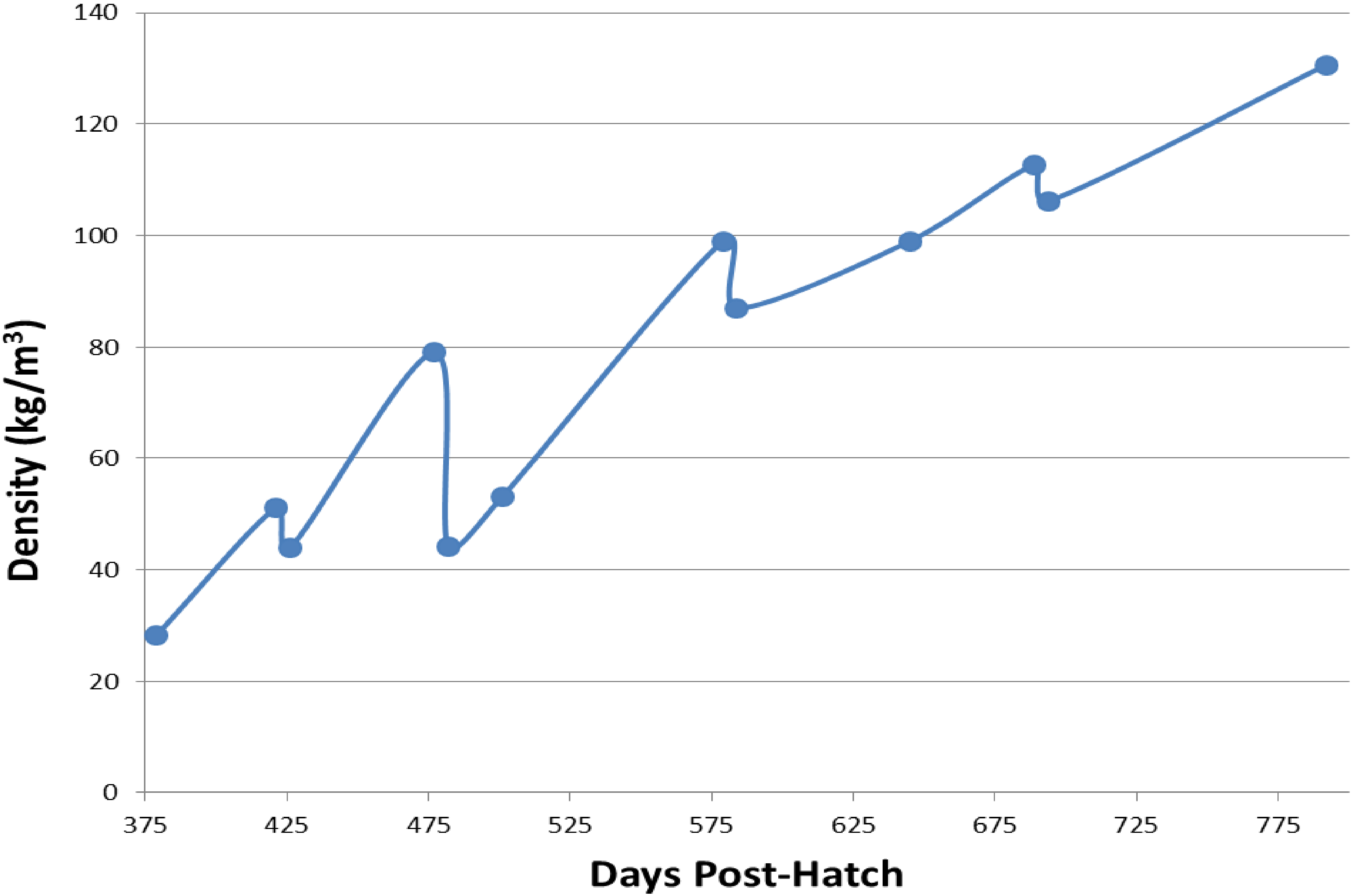
# Mean Density to 26 months



# STUDY 2

Long-term effects of
high (**20 mg/L**) vs. low (**10 mg/L**) $CO_2$
exposure on Atlantic salmon

# Background: Dissolved $CO_2$

- Salmonids produce 0.96 – 1.10 g $CO_2$ per gram of $O_2$ consumed
- Inverse relationship of $CO_2$ with pH
- Long-term exposure to elevated $CO_2$
  - Decreased hemoglobin oxygen binding capacity (Bohr effect)
    - Increased ventilation, elevated blood pressure
  - Reduced growth rate
  - Higher FCR
  - Nephrocalcinosis
- Also, increased solubility of toxic metals at lower water pH

# Background: Dissolved $CO_2$

- Growth of salmonids significantly reduced at ≥30 mg $CO_2$ / L
- Maximum limit < 20 mg $CO_2$ / L
  - Recent review suggests 10 mg $CO_2$ / L max for Atlantic salmon

# Background: Dissolved $CO_2$

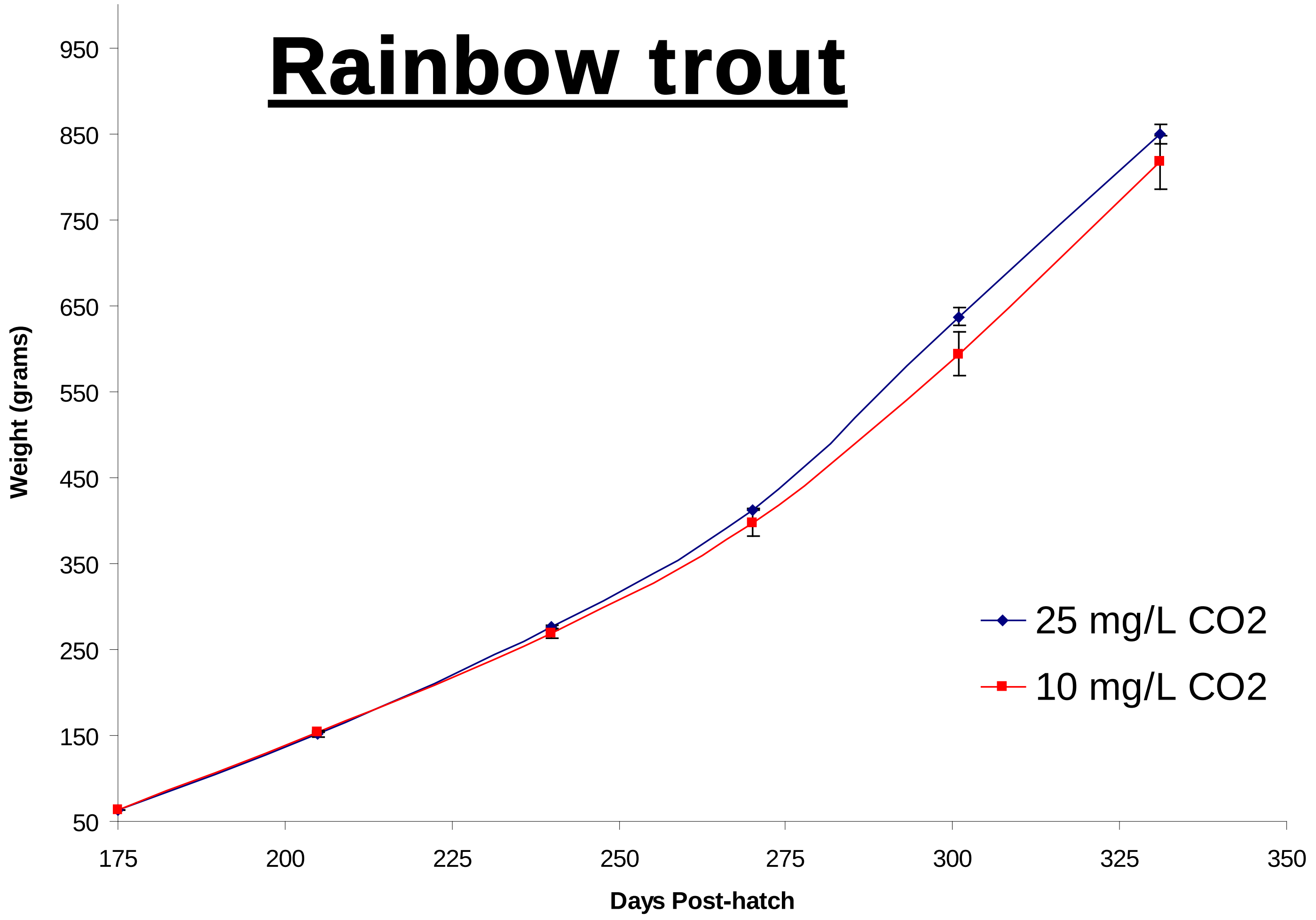
Aside from fish health implications….

## Economic Considerations

- Decreasing tank $CO_2$ concentrations requires pumping more water flow & installing a larger stripping unit (cascade column or aerated basin)
  - increases fixed costs
  - increases variable costs to pump water

# Background: Dissolved $CO_2$

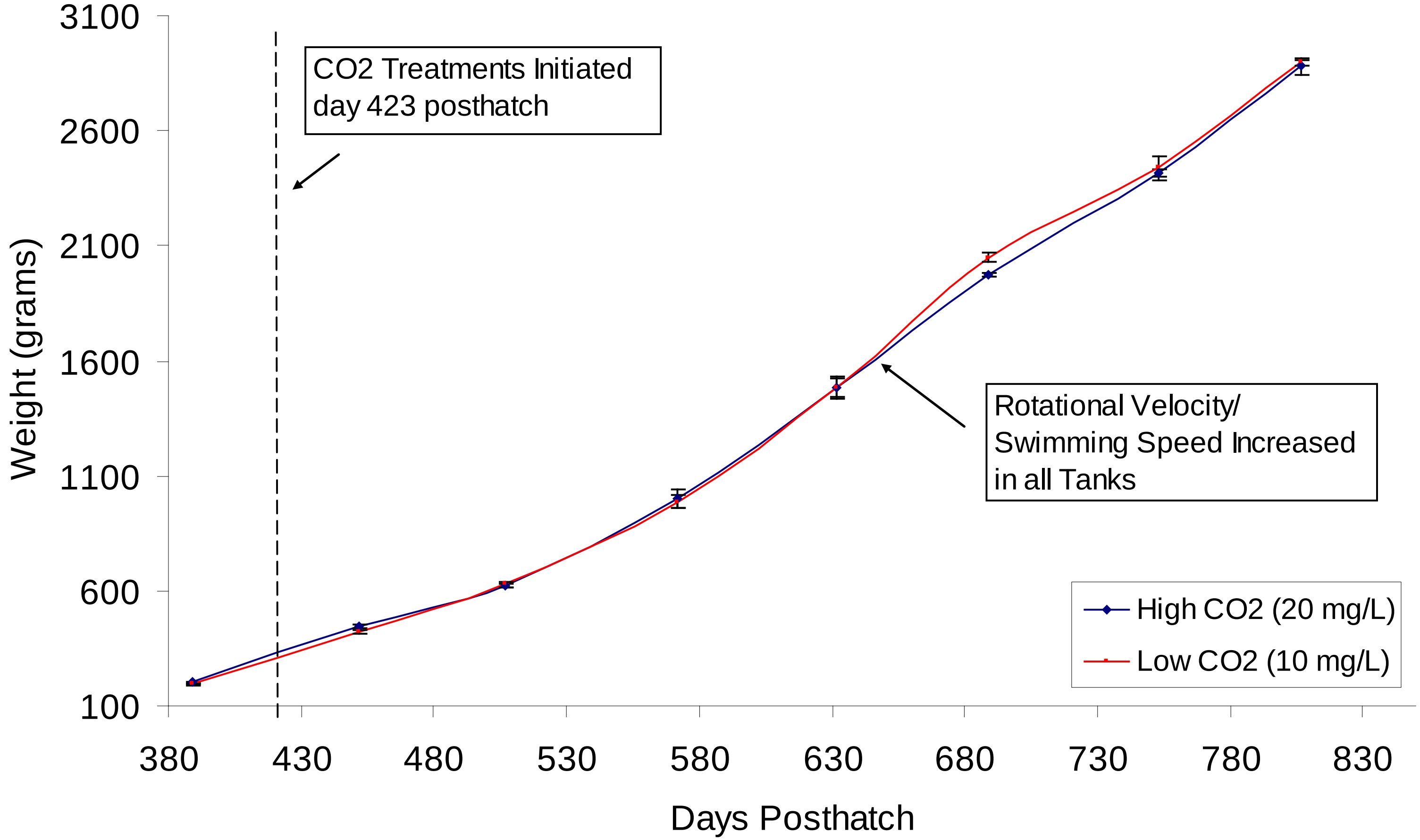
Similar study completed with rainbow trout (Good et al. 2010 *Aquacultural Engineering*)



## Atlantic salmon growout in freshwater:

- Six replicated RAS
- 3 with 20 mg/L $CO_2$
- 3 with 10 mg/L $CO_2$
- Alkalinity >200 mg/L
- 100% DO saturation

# Equal salmon growth at 10 and 20 mg/L of $CO_2$



**Final weight (g)**
**@ 807 days post-hatch**

High $CO_2$:
**2879** ± 35

Low $CO_2$:
**2896** ± 12

**Mean survival (%)**
High $CO_2$: 99.2 ± 0.3
Low $CO_2$: 99.1 ± 0.3

**Culls due to fungus (%)**
High $CO_2$: 3.75 ± 1.05
Low $CO_2$: 3.41 ± 1.27
* approx. 3400 lbs of salt added to each system during study to control fungus

**Feed conversion ratio**
High $CO_2$: 1.02 ± 0.03
Low $CO_2$: 1.03 ± 0.02

## **Whole blood analyses**

- High $CO_2$ group:
  - Higher $pCO_2$, $HCO_3^-$, pH
  - No change in $pO_2$, $sO_2$, or cardiosomatic indices
- No nephrocalcinosis observed

# STUDY 3

## Effects of
## *swimming speed*
## (2 BL/s vs. 0.5 BL/s)
## and *dissolved oxygen*
## (100% vs. 70% saturation)
## on Atlantic salmon

# Swimming Speed

- Published research on salmonids suggests prolonged exercise leads to:

- Increased growth
- Better feed conversion
- Less size variation at harvest
- Improved disease resistance
- Reduced aggressive behavior
- Improved flesh texture
- **Increased oxygen consumption**

# Dissolved Oxygen

- Can become limiting as production levels, feeding, and biomass increases
- Low dissolved oxygen can lead to:
  - Slower growth
  - Poor feed conversion
  - Increased disease
  - Decreased swimming fitness

# Swimming Speed X Dissolved Oxygen

- Recommended for salmonid aquaculture:
  - **0.5-2.0 Body-lengths/s swimming speed**
  - **100% oxygen saturation**
- Difficult to achieve in raceways; relatively straightforward in circular tanks
- Plenty of research on exercise and DO, but little work in assessing these parameters in combination

# 2X2 Factorial Study Design

## Two swimming speeds:

<0.5 (BL/s)

1.5-2 (BL/s)

## Two dissolved oxygen levels:

**High:** 100% saturation

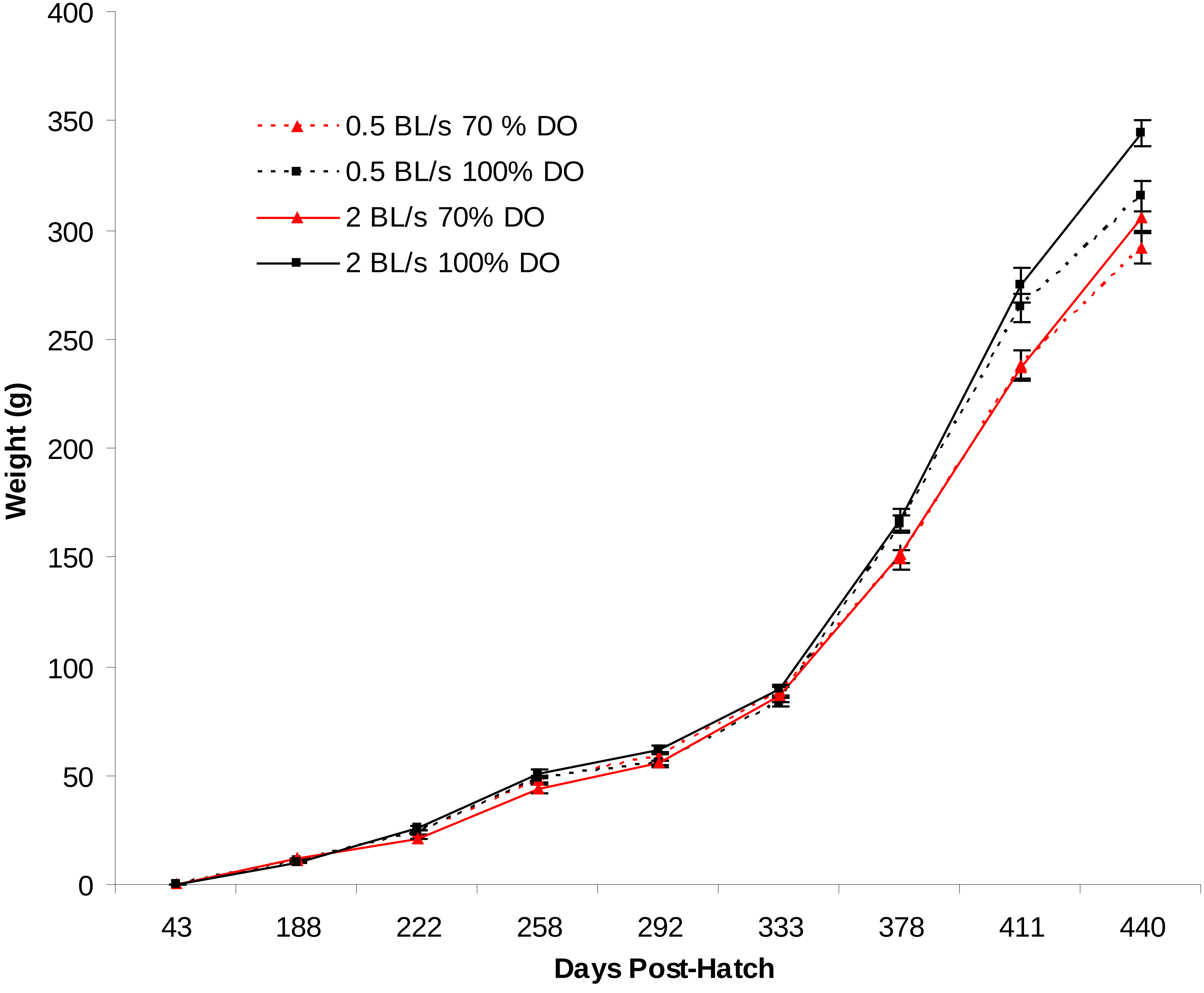
**Low:** 70% saturation

# Materials and Methods

**Identical Flow-Through Circular Tanks**

**<u>12 tanks total:</u>**
3 replicates of each
Swimming speed /DO combination (random)

# Performance



| | DO 100% saturation | | DO 70% saturation | |
|---|---|---|---|---|
| | 2 BL/s | 0.5 BL/s | 2 BL/s | 0.5 BL/s |
| Weight (g) | 344.3 ± 6.3 | 315.8 ± 7.5 | 306.0 ± 6.87 | 292.2 ± 6.9 |

| Treatment | df | F | p-value |
|---|---|---|---|
| Swimming speed | 1 | 9.86 | 0.0018 |
| Dissolved oxygen | 1 | 18.95 | <0.0001 |
| Swimming speed X dissolved oxygen | 1 | 1.35 | 0.2451 |

**Precocious Males:**
2 BL/sec : **6.4%**
< 0.5 BL/sec: **11.5%**

**Logistic regression model reporting odds ratios for the probability of precocious males within each treatment group:**

| Treatment | Odds ratio | (95% conf. int.) | p-value |
|---|---|---|---|
| 0.5 BL/s | 1.896 | (1.121, 3.208) | 0.017 |
| 70% DO | 0.945 | (0.546, 1.636) | 0.839 |

Additional assessments:

- Cardiosomatic index higher in high DO group ($p=0.059$)
- No difference in visceral index

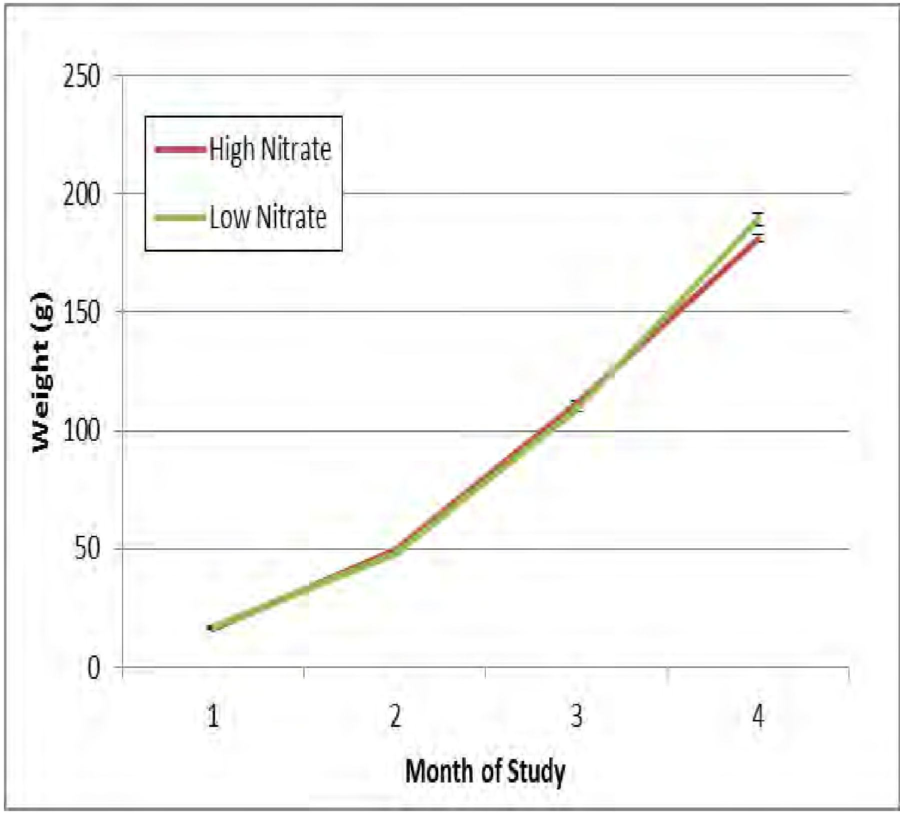
# Current Research at The Freshwater Institute

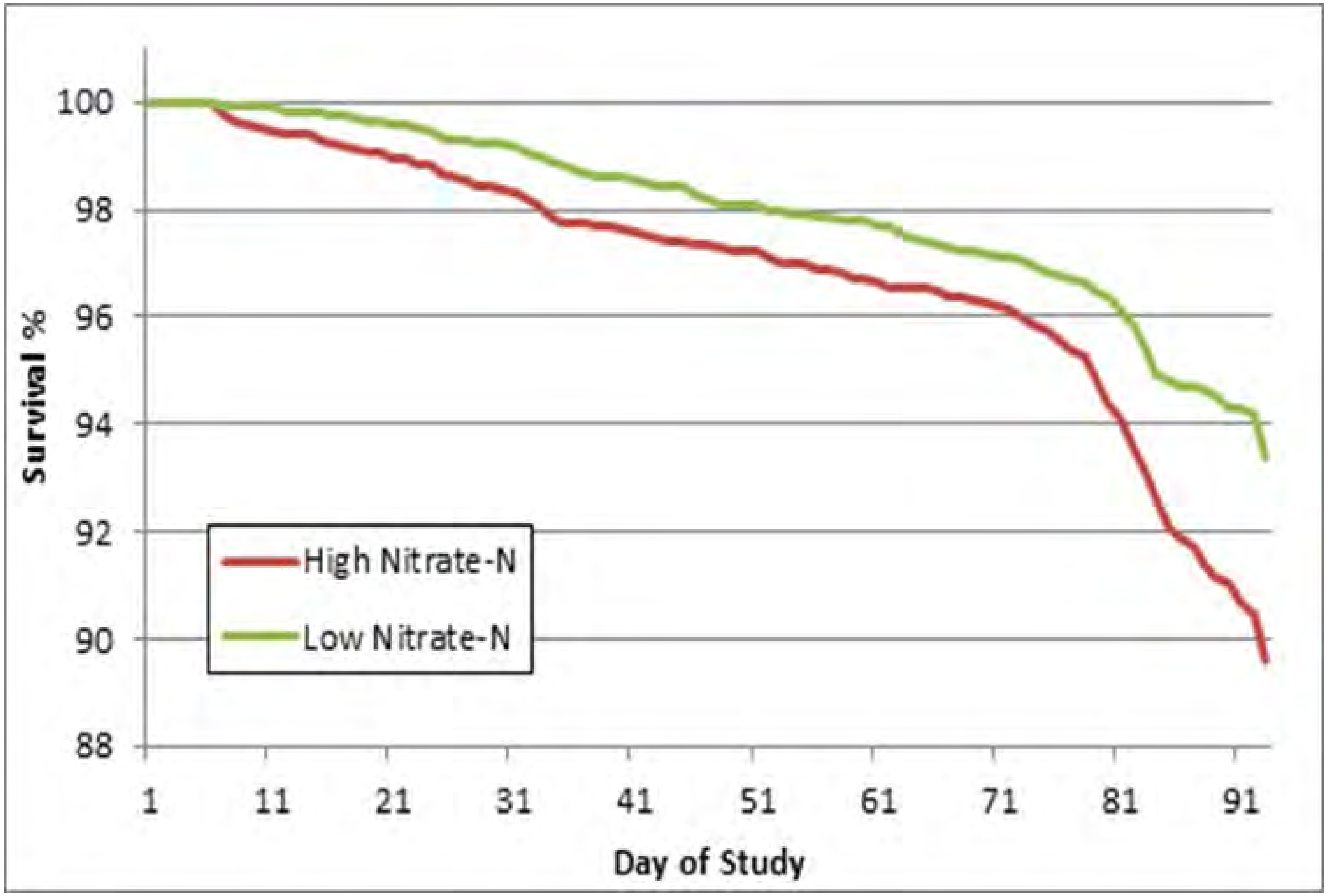
<u>**Rainbow Trout**</u>

**Effects of High vs. Low $NO_3$-N**



| | High Nitrate | Low Nitrate |
|---|---|---|
| TAN | 0.38 ± 0.02 | 0.35 ± 0.00 |
| $NH_3$ | 0.003 ± 0.000 | 0.003 ± 0.000 |
| $NO_2$-N | 0.08 ± 0.01 | 0.02 ± 0.00 |
| $NO_3$-N | 89 ± 0 | 29 ± 0 |
| Alkalinity | 195 ± 0 | 195 ± 0 |
| pH | 7.58 ± 0.01 | 7.59 ± 0.01 |
| Hardness | 307 ± 2 | 306 ± 1 |
| $CO_2$ | 13 ± 0 | 13 ± 0 |
| $cBOD_5$ | 4.6 ± 0.9 | 3.2 ± 0.2 |
| True Color | 25 ± 1 | 22 ± 0 |
| UV Transm. (%) | 77 ± 1 | 81 ± 0 |
| Sulfate | 36 ± 0 | 257 ± 2 |
| TSS | 6.2 ± 1.1 | 4.0 ± 0.6 |
| Temperature (°C) | 15.4 ± 0.0 | 15.3 ± 0.0 |
| DO | 10.1 ± 0.0 | 10.1 ± 0.0 |
| Conductivity | 1184 ± 7 | 1176 ± 5 |






<u>Side swimmers</u>

High Nitrate
11.5% ± 1.1

Low Nitrate
3.8% ± 0.7

# Acknowledgements

Nick Zacharias, Phil Backover, Lauren Jescovitch, Tre Kidwell

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*Opinions, conclusions, and recommendations are of the authors and do not necessarily reflect the view of the USDA.*

*All experimental protocols involving live animals were in compliance with Animal Welfare Act (9CFR) and have been approved by the Freshwater Institute Animal Care and Use Committee.*