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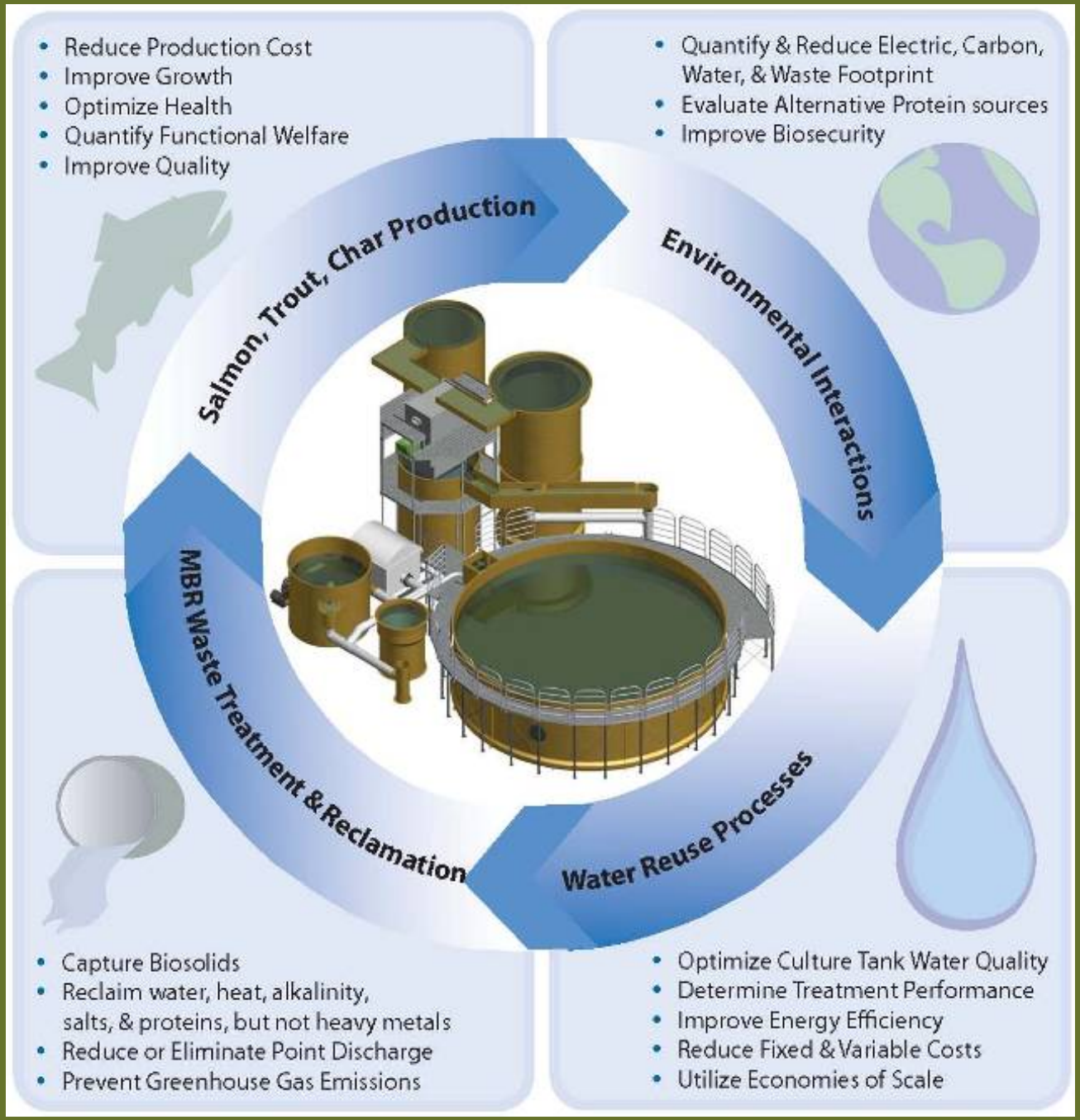
Effects of water exchange rate and biofiltration on circulating hormones in water recirculation aquaculture systems containing sexually maturing Atlantic salmon

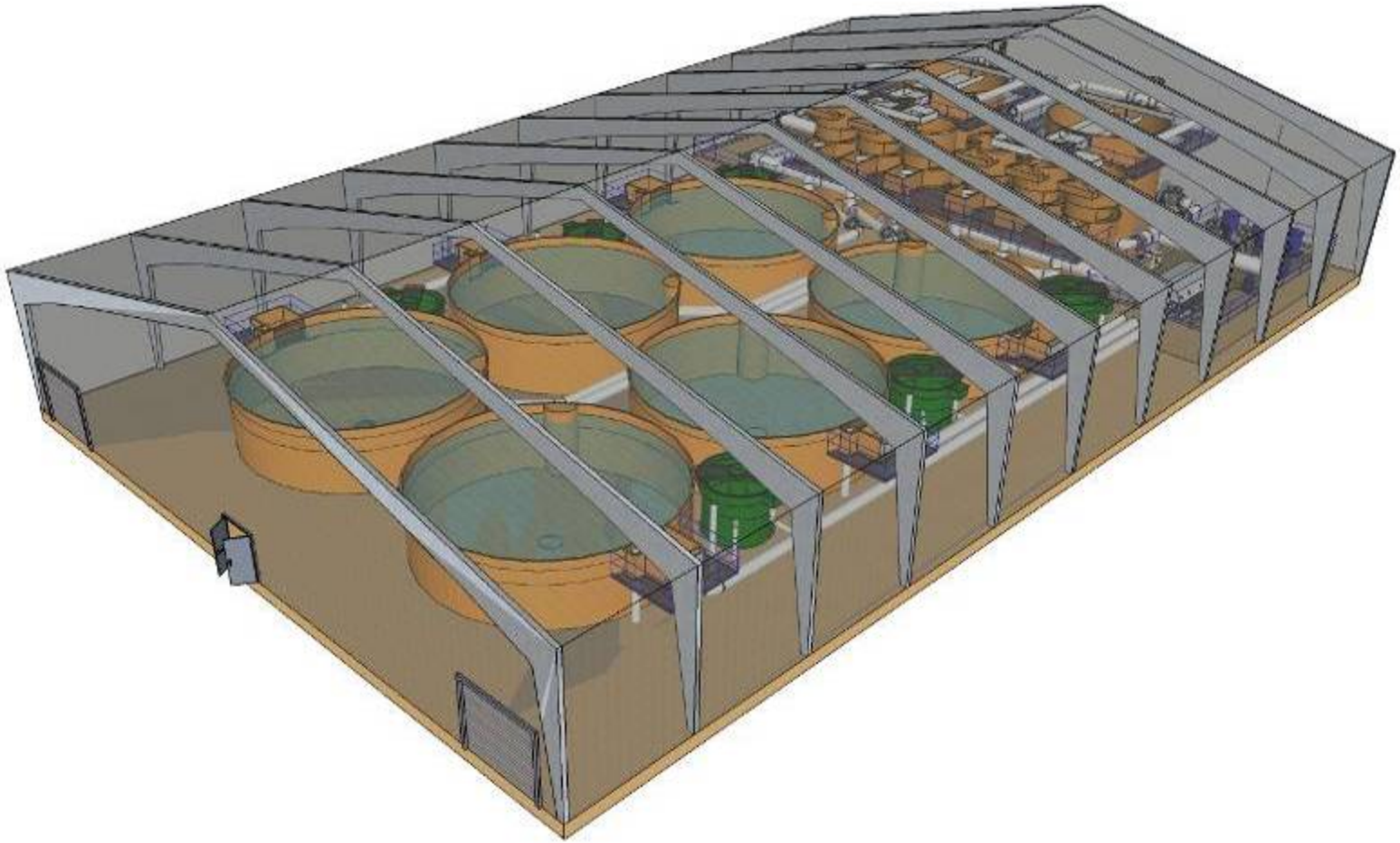
Good C, Davidson J, Earley R, Weber G, & Summerfelt S

Aquaculture Innovation Workshop #5
Shepherdstown WV - Sept 2013



Research at The Freshwater Institute

Closed Containment Facilities with Water Recirculation



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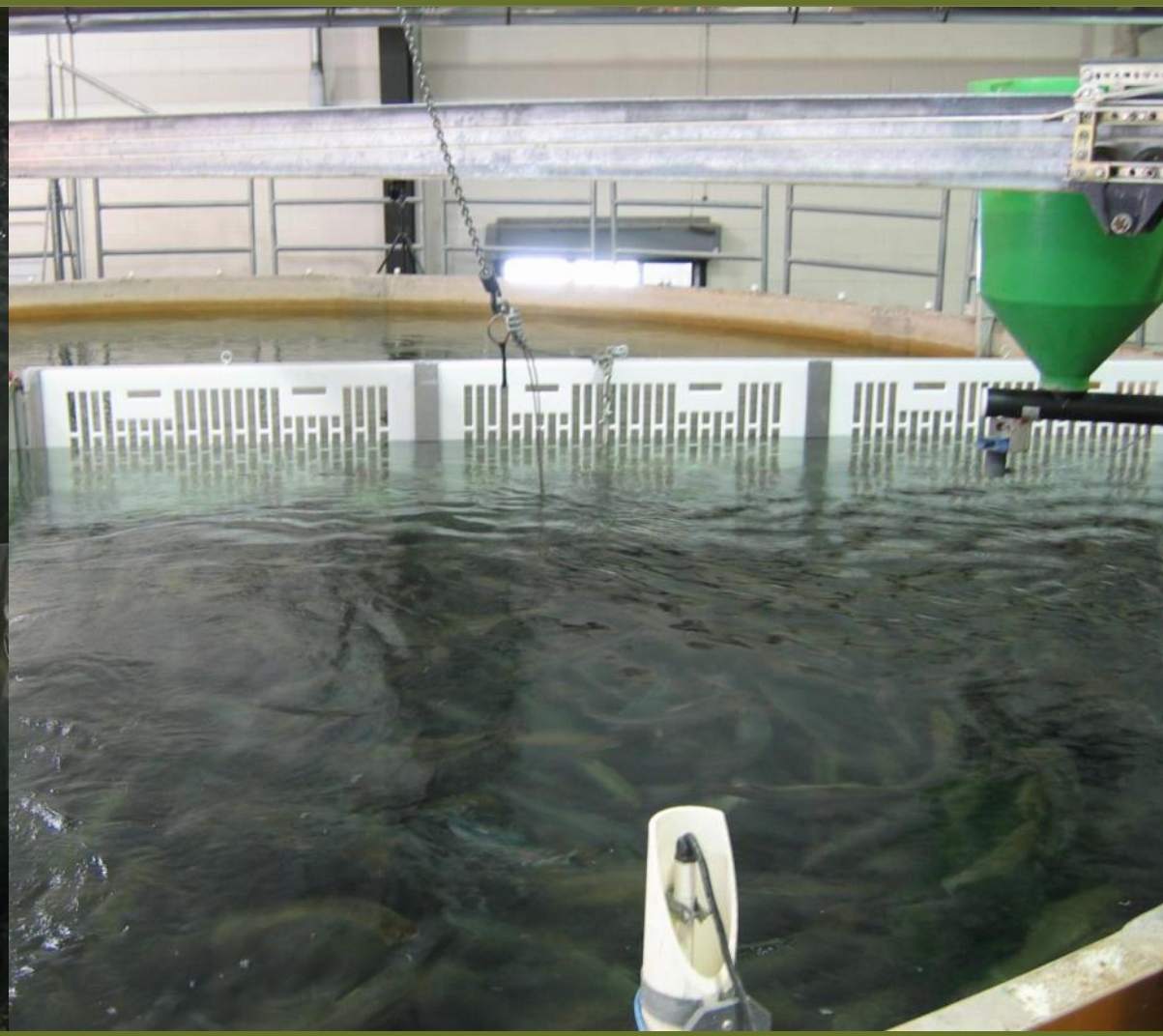
Background: Atlantic salmon growout trials



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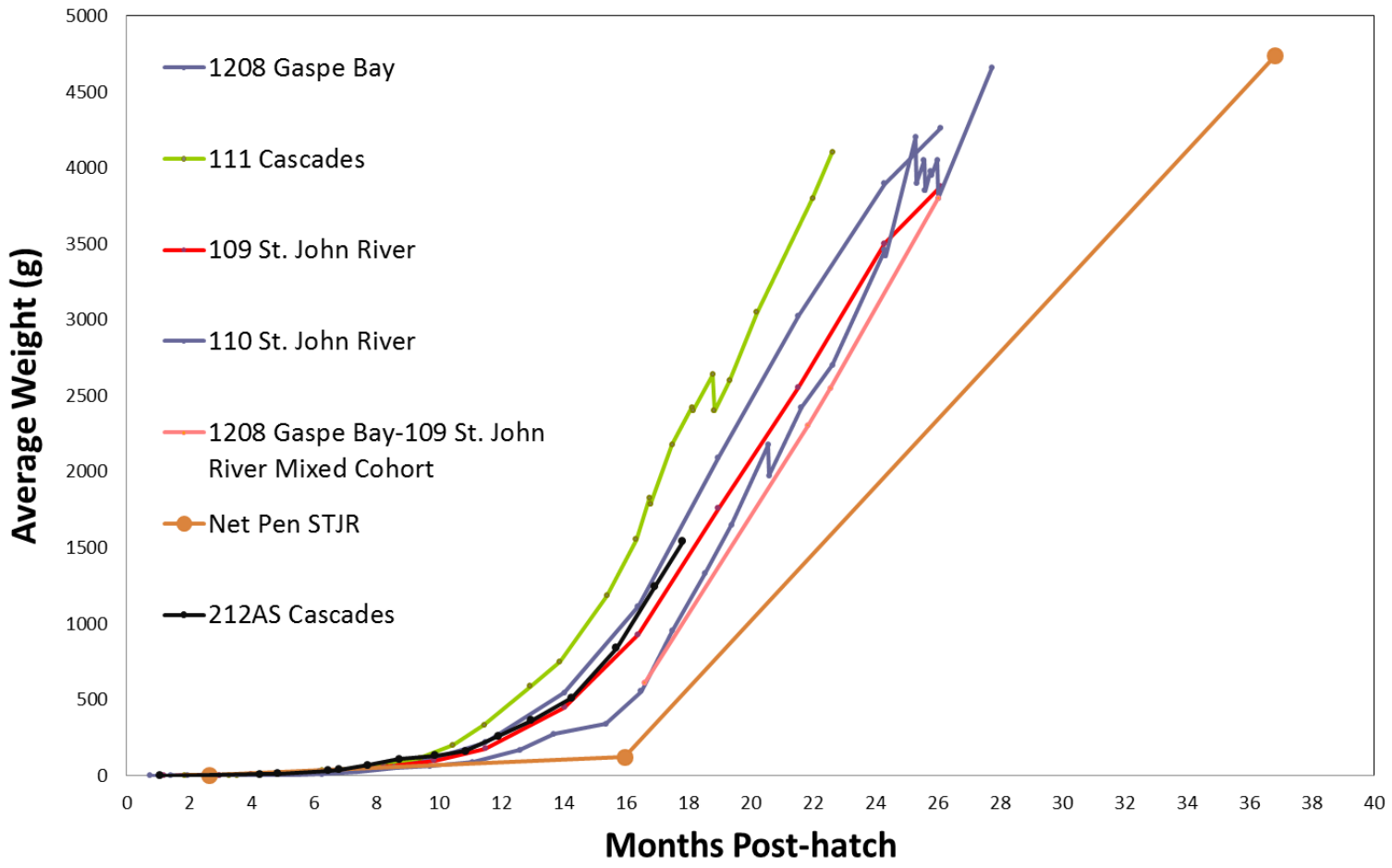
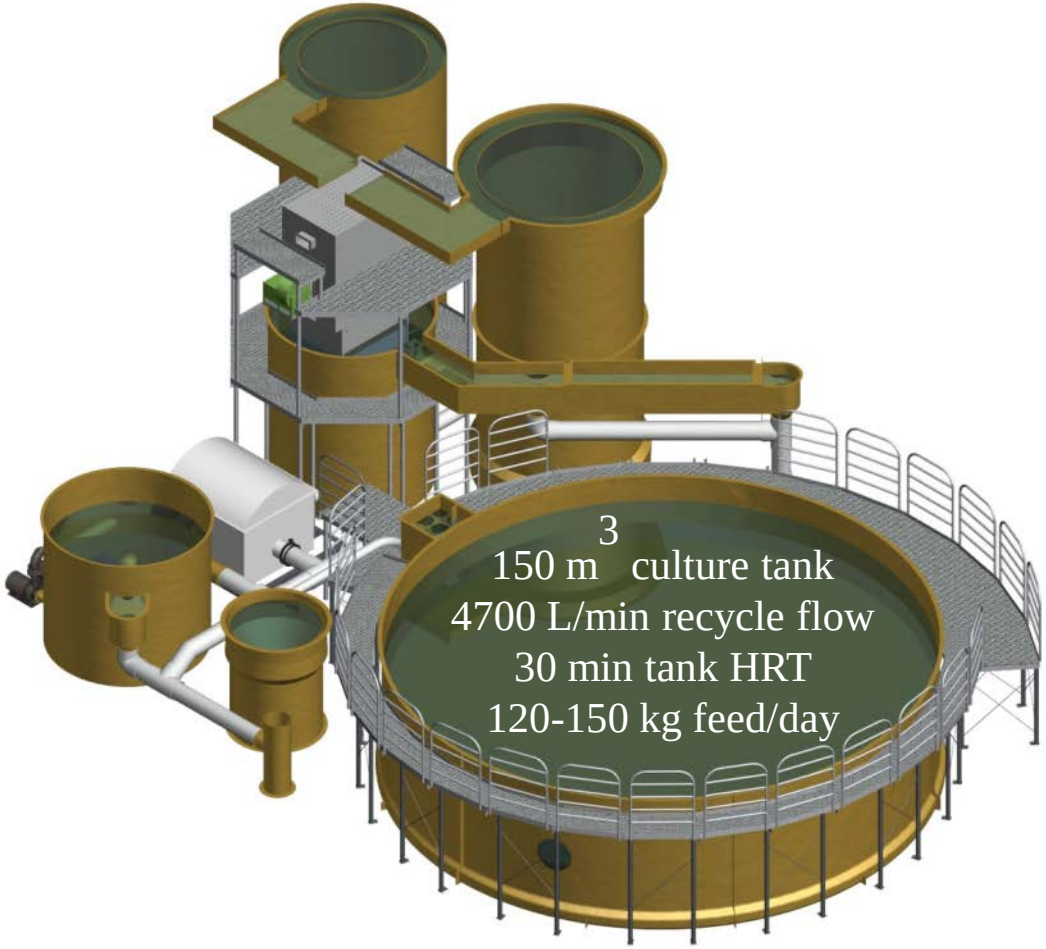
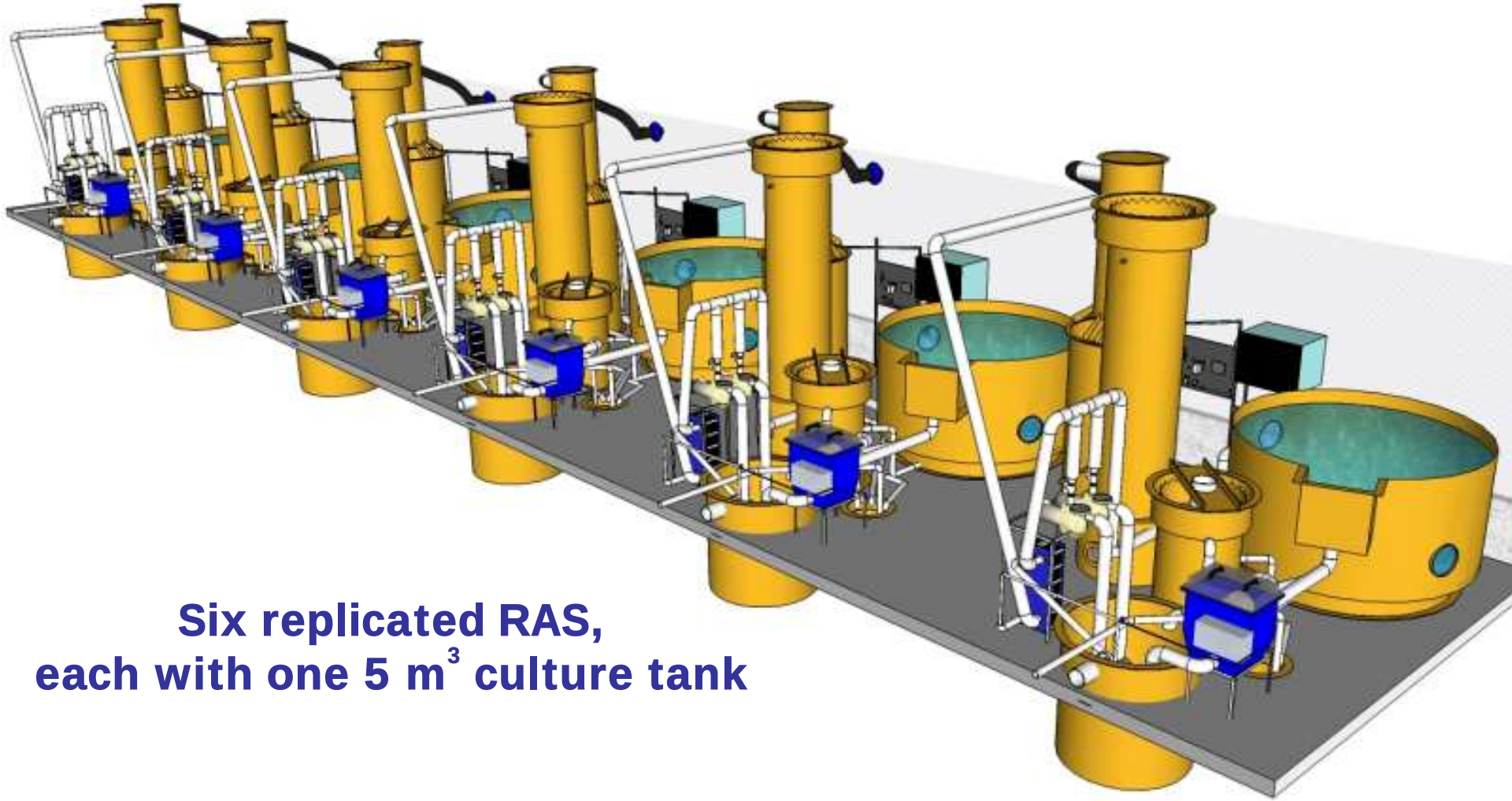


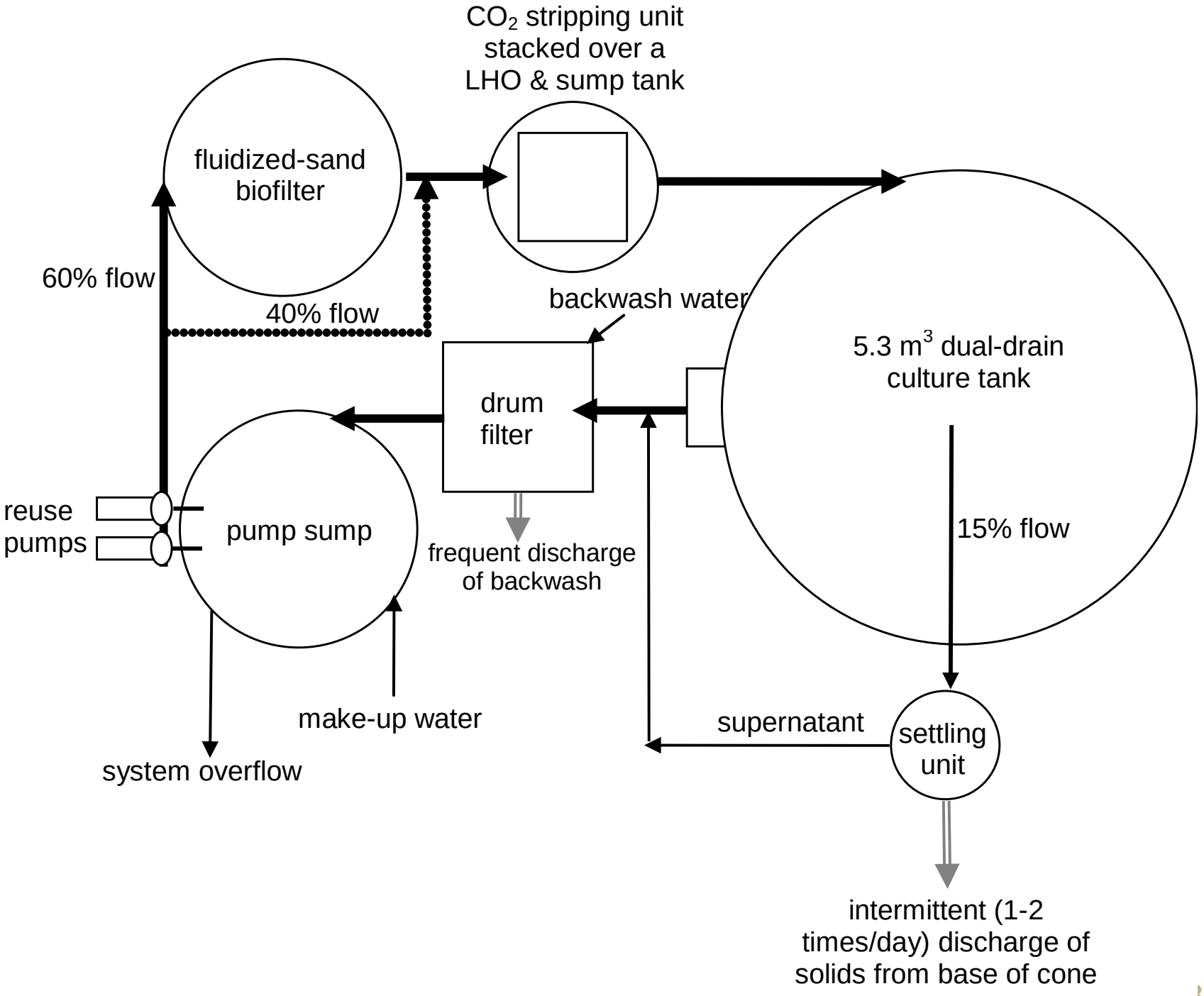
Main Reuse System Freshwater Institute



Replicated RAS



Six replicated RAS,
each with one 5 m^3 culture tank


CO_2 stripping unit
stacked over a
LHO & sump tank
fluidized-sand
biofilter
60% flow
40% flow
backwash water
5.3 m^3 dual-drain
culture tank
drum
filter
reuse
pumps
pump sump
frequent discharge
of backwash
15% flow
make-up water
supernatant
settling
unit
system overflow
intermittent (1-2
times/day) discharge of
solids from base of cone

Background: Atlantic salmon growout trials

Precocious maturation

- 80% of male salmon matured early
- 40% of all fish removed as early maturing males
- approximately half at 2 kg and half at 3.5 kg

Maturation in Atlantic salmon

Sexual maturation in *S. salar*:

A highly flexible process, influenced by

- Photoperiod
- Water temperature
- Feed intake
- Nutrition
- Lipid reserves
- Growth rate
- Stock genetics
- Etc.

Accumulation of steroid hormones?

High Makeup H_2O Exchange (2.6%)

Low Makeup H_2O Exchange (0.26%)

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Atlantic salmon growout – High vs. Low Exchange RAS

- Recirculating System (9.5 m^3)
- 5.3 m^3 Dual-drain tank
- Radial flow settler
- Drum filter (60 µm screens)
- Pump sump
- 1-HP centrifugal pump
- Heat Exchanger
- Fluidized Sand Biofilter
- Low Head Oxygenator (LHO)
- CO_2 Stripping Column

Atlantic salmon growout – High vs. Low Exchange RAS

- High vs. Low Water Exchange Rates – 3 RAS per treatment

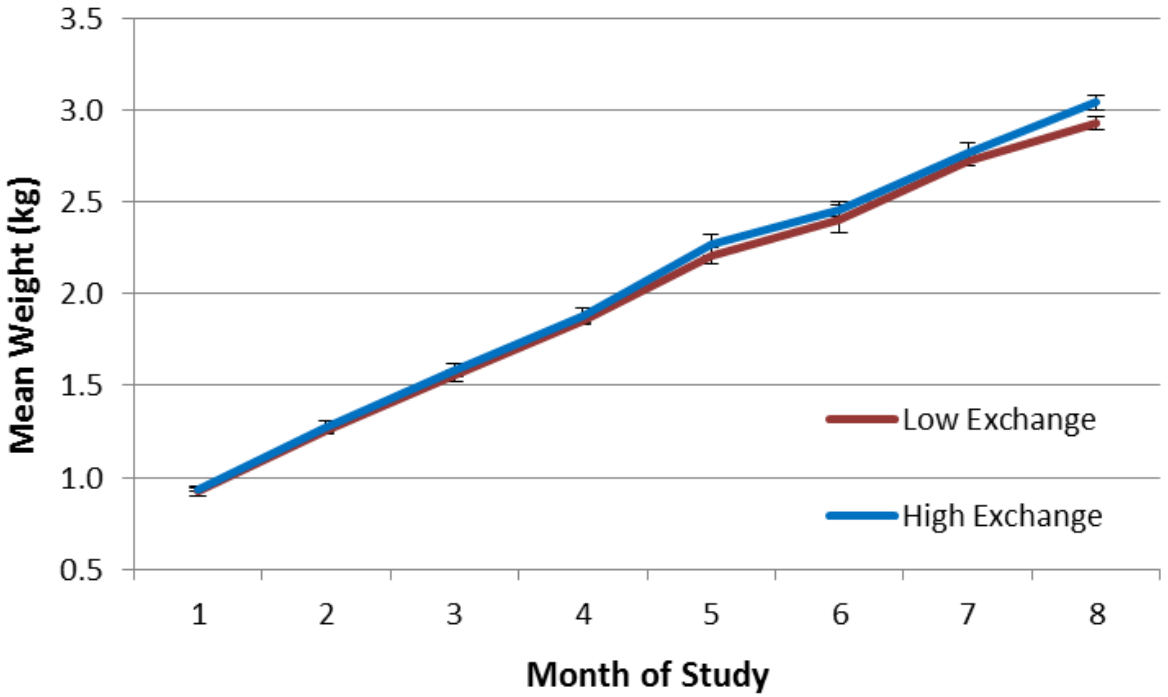
	Low Water Exchange	High Water Exchange
Flushing Rates (% of Recycled Flow)	0.25	2.60
Feed Loading Rate (kg feed/m^3 makeup water/ day)	1.3	0.13
Hydraulic Retention Time (days)	7.0	0.7

Atlantic salmon growout – High vs. Low Exchange RAS

Parameter (mg/L)	High Exchange	Low Exchange
Temperature °C	15.0 ± 0.0	14.9 ± 0.0
Dissolved Oxygen	10.3 ± 0.1	10.3 ± 0.0
Carbon Dioxide	9 ± 1	9 ± 1

Atlantic salmon growout – High vs. Low Exchange RAS

- Atlantic salmon were stocked at 0.93 ± 0.01 kg to begin
- No significant difference in mean weight throughout the study
- Slight separation in growth curves but difference not statistical
- End Mean weight
  - High Exchange 3.04 ± 0.04 kg
  - Low Exchange 2.93 ± 0.04 kg



Atlantic salmon growout – High vs. Low Exchange RAS

Parameter (mg/L)	High Exchange	Low Exchange
Thermal Growth Coefficient	1.45 ± 0.02	1.40 ± 0.02
FCR	1.03 ± 0.02	1.16 ± 0.13
Survival	> 99%	>99%

Atlantic salmon growout – High vs. Low Exchange RAS

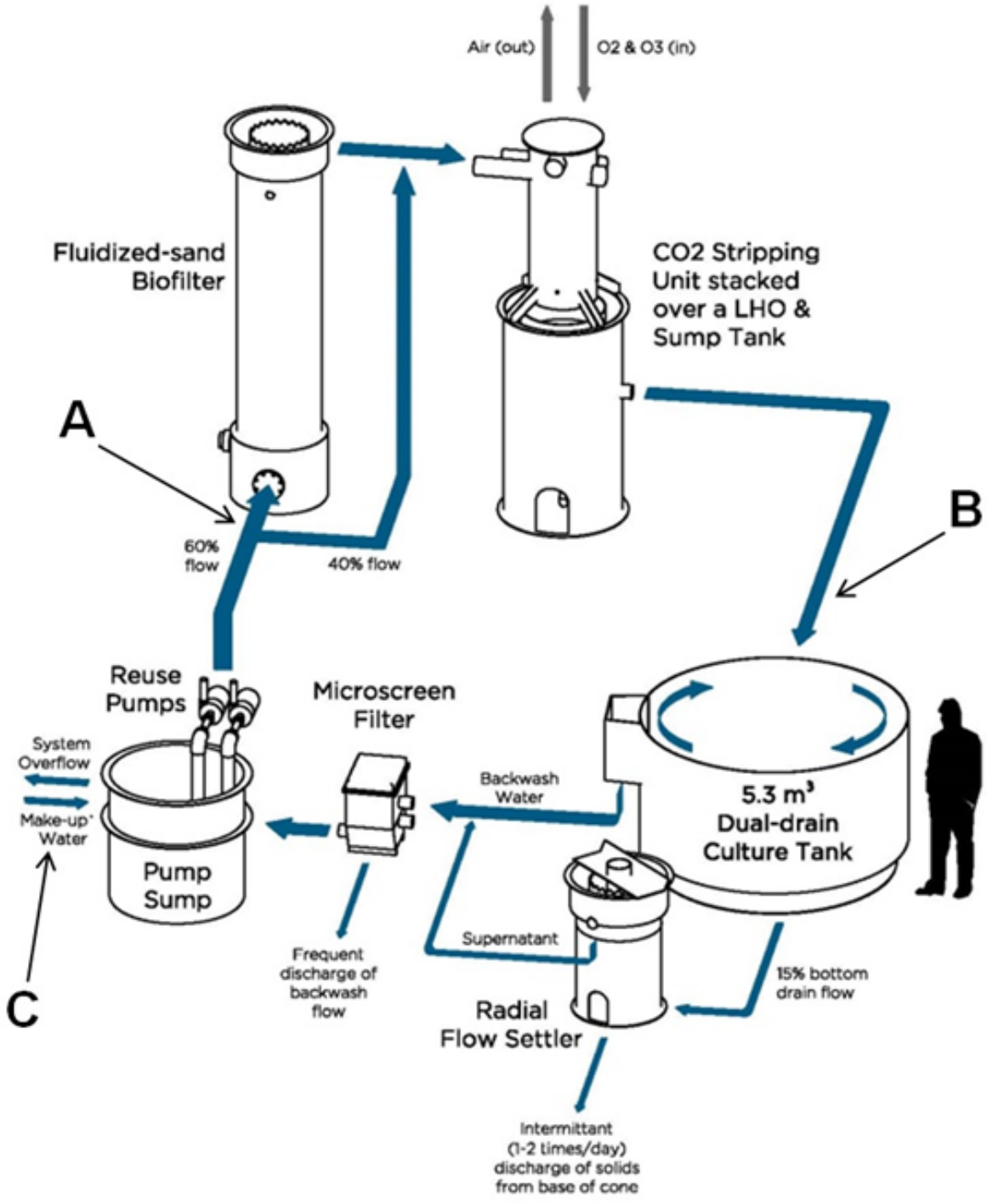
Very high prevalence of apparently mature males and females by study's end (24-months post-hatch)

Atlantic salmon growout – High vs. Low Exchange RAS

- Photoperiod?
- Rapid growth?
- Water temperature?
- Freshwater environment?
- Accumulating steroid hormones? - testable

Separate Study: Hormone measurements from water samples

- **Objectives:**
  - Determine whether important hormones accumulate in RAS relative to exchange rate, and whether this is associated with increased early maturation
  - Determine the effects of treatment processes on hormone concentrations
- Target hormones: **testosterone, 11-KT, estradiol, progesterone, cortisol**



Triplicate water samples collected from each RAS:

A – pre-water treatment processes
B – post-water treatment processes
C – makeup water influent

EIA quantification

Results

		Water sample location		
Hormone	Exchange rate	Pre-Treatment (A)	Post-Treatment (B)	Makeup influent (C)
Testosterone	High	518.7 ± 118.0 ^{ab}	443.7 ± 86.32 ^{a}	123.7 ± 7.313 ^{c}
	Low	768.4 ± 88.88 ^{d}	758.5 ± 155.5 ^{bd}	124.0 ± 45.24 ^{c}
11-KT	High	194.5 ± 21.19 ^{a}	127.9 ± 11.08 ^{b}	4.783 ± 0.390 ^{c}
	Low	183.0 ± 17.73 ^{a}	124.7 ± 11.90 ^{b}	4.526 ± 1.008 ^{c}
Estradiol	High	168.7 ± 61.80 ^{a}	168.8 ± 66.25 ^{a}	39.55 ± 6.341 ^{b}
	Low	223.5 ± 28.53 ^{a}	239.8 ± 20.69 ^{a}	38.92 ± 25.06 ^{b}

No differences in measured concentration for cortisol or progesterone

Results

		RAS	
	Sex	High exchange	Low exchange
Visual signs of maturity (%) (n=357)	M	75.6 ± 13.7 [a]	67.8 ± 8.07 [a]
	F	11.3 ± 3.27 [a]	3.23 ± 1.47 [b]
Gonadosomatic index (n=24)	M	6.79 ± 0.30 [a]	5.94 ± 0.79 [a]
	F	3.06 ± 1.38 [a]	5.24 ± 4.97 [a]

Conclusions

- **Testosterone** the only measured hormone significantly accumulating in RAS relative to exchange rate
- **11-KT** the only measured hormone to be significantly reduced across the water treatment processes
- **Testosterone**, **11-KT**, and **estradiol** sig. higher in RAS compared to makeup water
- Mature male % unrelated to exchange rate

Further Research

- Controlled studies incorporating:
  - Water sampling at multiple time points
  - More sampling locations throughout the RAS
  - Plasma hormones assessments for water sampling validation
  - Increased GSI sampling
  - Other physiological assessments in parallel, e.g. vitellogenin, MIH, etc.

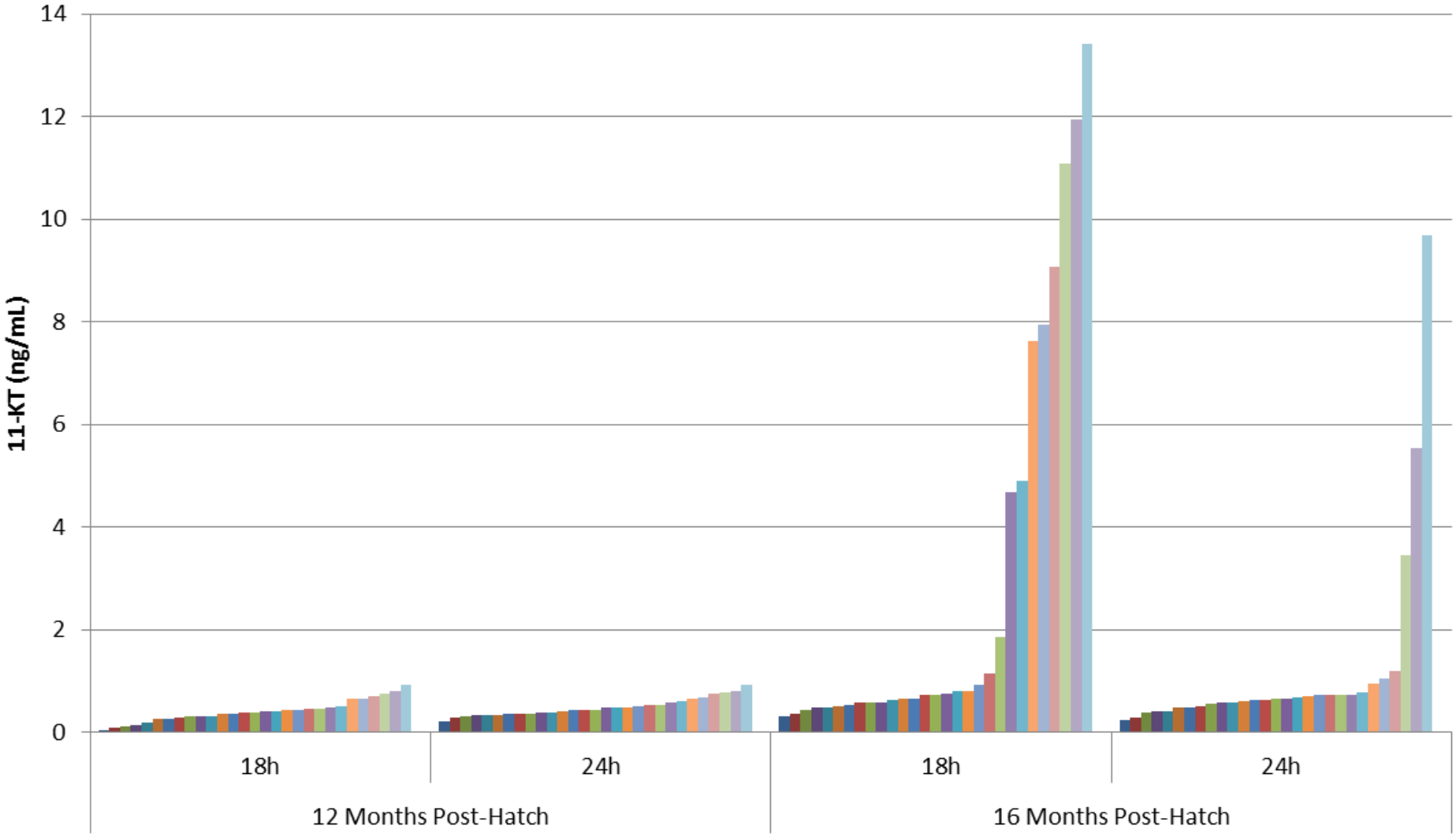
2013 Maturation Assessments

Photoperiod effect?

Two treatment groups:

- 24-hour photoperiod
- 18h:6h photoperiod

2013 Maturation Assessments



2013 Maturation Assessments

- Mature males at 16 months:
  - 18h:6h = 23%
  - 24h = 10%
- GSI vs 11-KT:
  - 18h:6h correlation coefficient = 0.1808 (p=0.3538)
  - 24h correlation coefficient = 0.4613 (p=0.0103)

Conclusions

- No evidence that 18h:6h photoperiod reduces early male maturation
- Further sampling at ~2.5 kg and final harvest (4-6 kg)

Acknowledgements

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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 were in compliance with Animal Welfare Act (9CFR) and have been approved by the Freshwater Institute Animal Care and Use Committee.

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