

Performance of all-female Atlantic salmon in freshwater closed- containment systems

2017 AIW, Vancouver, Nov 29-30

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Land-Raised Salmon in Closed Containment Systems

Smolt production (freshwater)



Post-smolt production (fresh or brackish)



Market-size salmon production (fr or br)



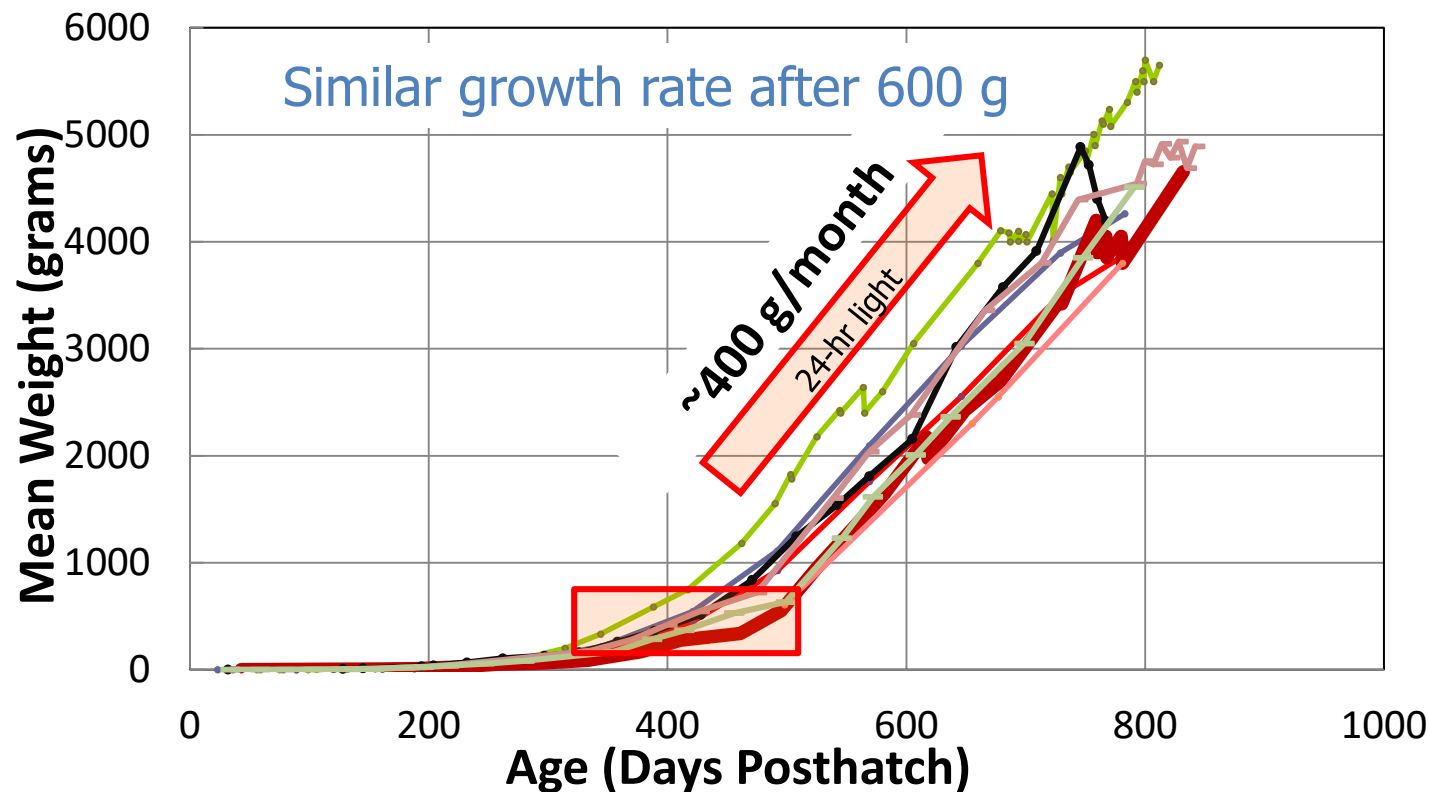
RAS Differences - Sea vs Freshwater

- Challenge: Seawater RAS require more flow, larger processes, & more \$\$, plus toxins/pathogens
 - O_2 saturation in seawater is **20% less** than freshwater
 - CO_2 removal effic. in seawater is **20% less** than fresh
 - Nitrification is **30-60% degraded** in seawater vs fresh
 - Low-dose O_3 can create **toxic bromine** in brackish-seawater RAS if not carefully dosed
 - High SO_4 in seawater can produce **toxic H_2S** in RAS
 - Pathogen risk in seawater intake (borehole vs surface)
 - Corrosion resistant materials are required

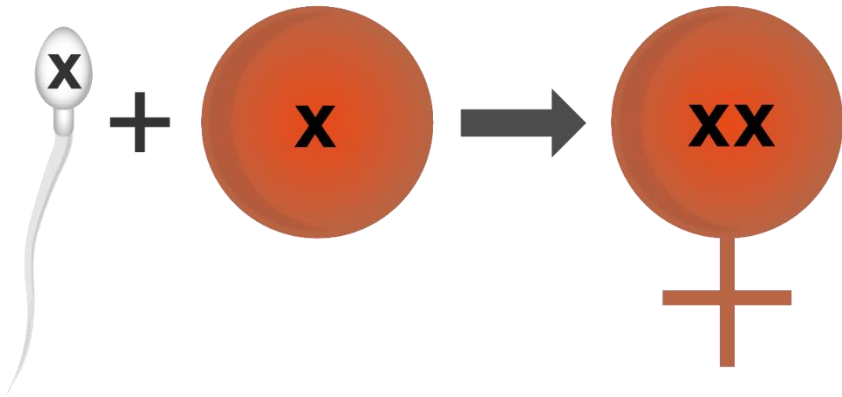


RAS Differences - Sea vs Freshwater

- Challenge: Post-smolt *salar* in **freshwater** RAS
 - slow and inconsistent growth from 100-500 g
 - **increased male maturation @ $\geq 13^{\circ}\text{C}$**



Hypothesis: All-female germplasm can reduce maturation; it eliminates male maturation



Atlantic Salmon Study #1

(2009-2010)

Materials and Methods

2x2 Factorial Study: Strain x photoperiod

- Two Atlantic salmon strains:
 1. St. John River from Cooke (**mixed sex**, diploids)
 2. Gaspe from Troutlodge (**all female**, diploids)
- Two early rearing light regimes:
 1. Continuous light (No S_0 winter)
 2. Continuous light with S_0 winter
 - 12h:12h light:dark for six weeks, then to continuous light

Atlantic Salmon Study #1

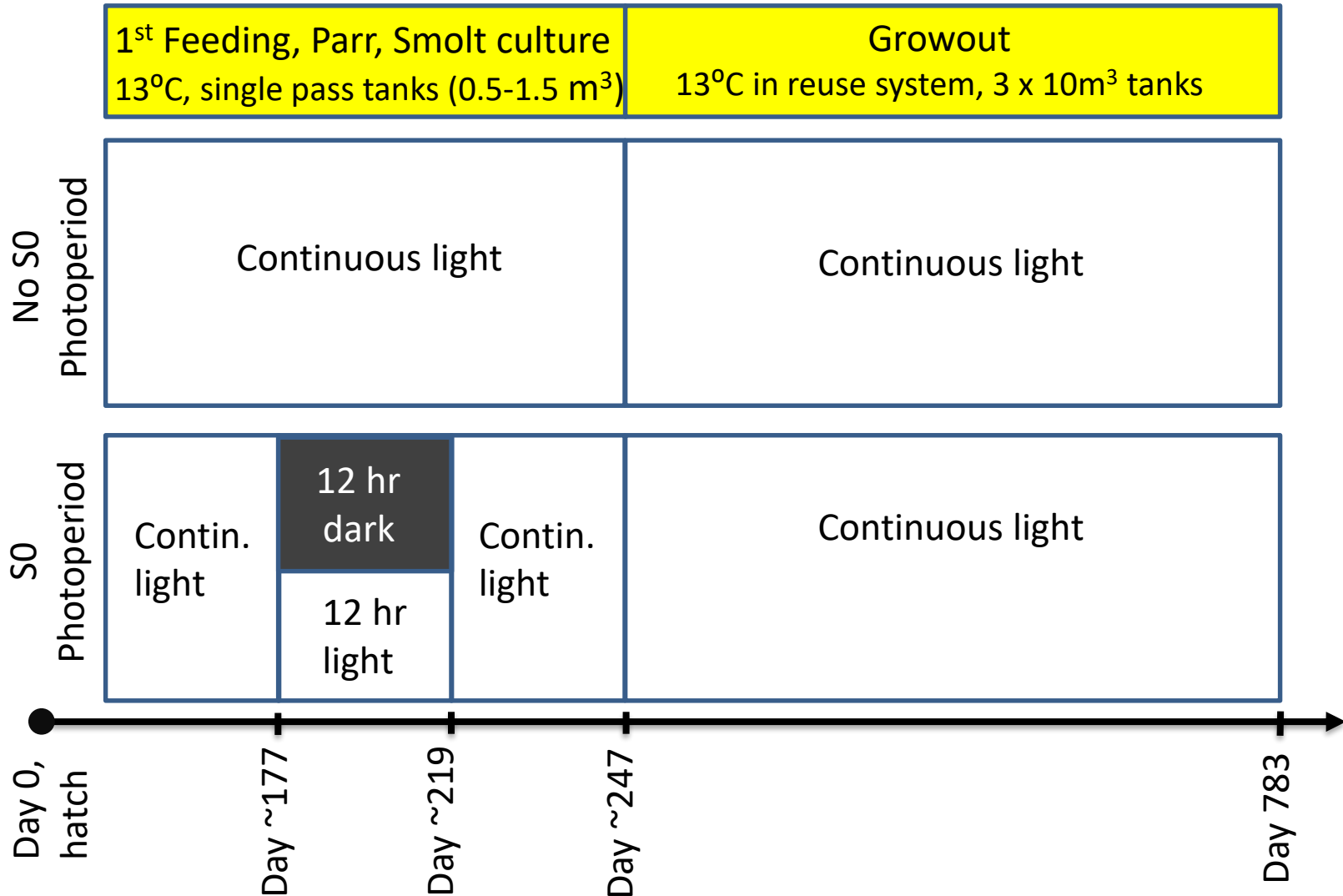
Growout

- Co-Mingled 4 trts in three 10 m³ tanks (n=3)
 1. 300 PIT tagged fish per strain
 2. Continuous light using metal halide high-bay fixtures
 1. 4000K color, 400 Watt fixtures (Metalarc Pro-Tech, Sylvania)
 3. Biomass density maintained at ~ 40-80 kg/m³
 4. Sampled at 25 months post-l
 1. Size, g
 2. GSI
 3. Head-on gutted (HOG)
 1. fillet attributes

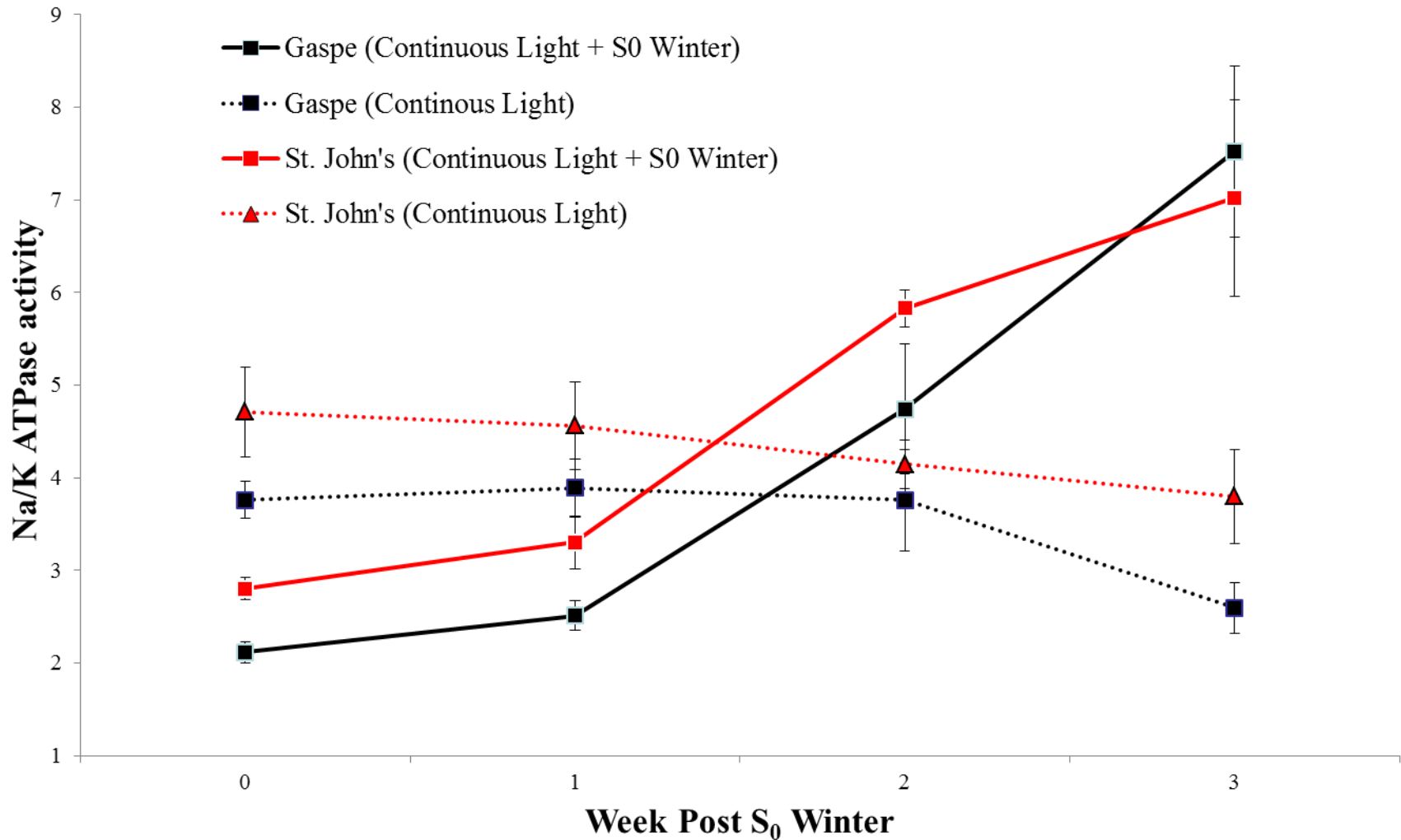


Atlantic Salmon Study #1

- Culture system and photoperiod timeline



Gill ATPase Post-S₀ Winter



Results: Maturation

- Mean Gonadal Somatic Index (GSI): % (min, max)

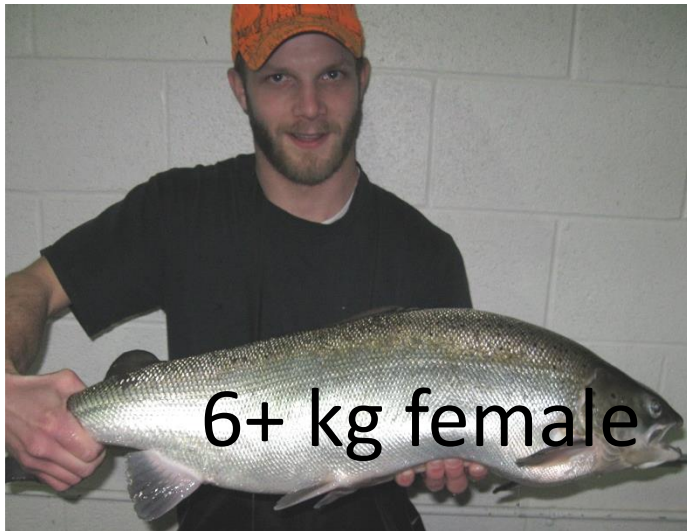
Strain		<u>Photoperiod</u>	
		S ₀	No S ₀
Gaspe (all female)		0.41 (0.23 – 0.91)	0.38 (0.08 – 1.15)
St John River	Females	0.31 (0.24 – 0.36)	0.29 (0.02 – 0.54)
	Males	2.88 (0.09 – 8.32)	4.03 (0.14 – 7.25)

- % Population Mature

Strain		GSI	<u>Photoperiod</u>	
			S ₀	No S ₀
Gaspe (all female)		>2.0	0.0	0.0
		>1.0	0.0	5.5
St John River	Females	>2.0	0.0	0.0
		>1.0	0.0	0.0
	Males	>0.5	53.8	71.4

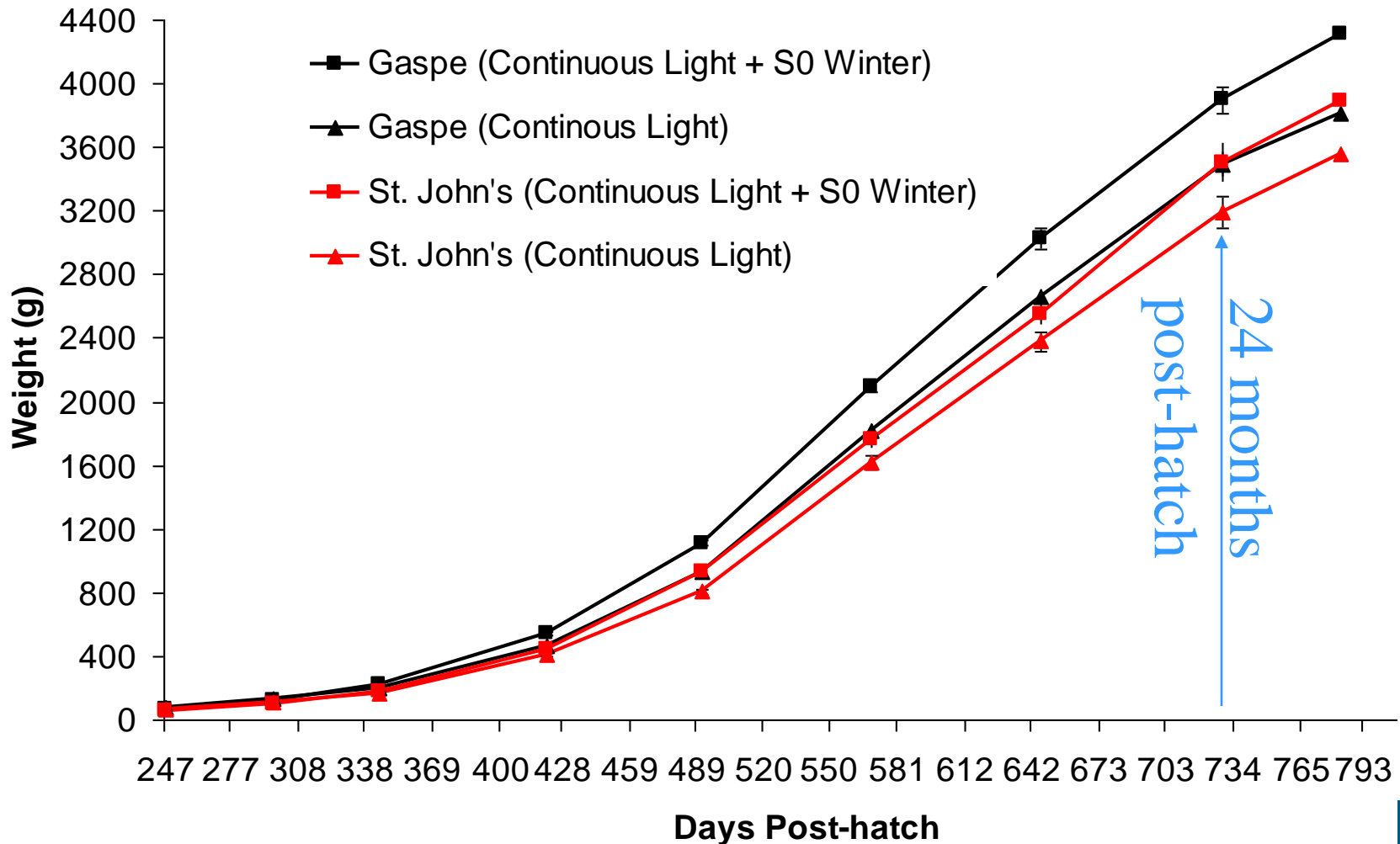
Atlantic Salmon Study #1

- No females sexually matured (e.g., $GSI > 1.2$)
- over 50% of male St John River strain salmon were sexually mature



Atlantic Salmon Study #1

- Rapid Atlantic salmon growth (4 kg in best trt) in **freshwater** to 24-month post-hatch at 13°C



Atlantic Salmon Study #1

- Gaspe strain (all females) grew faster than St John strain (mixed sex)
- Providing an S0 winter decreased time to harvest size, increased growth

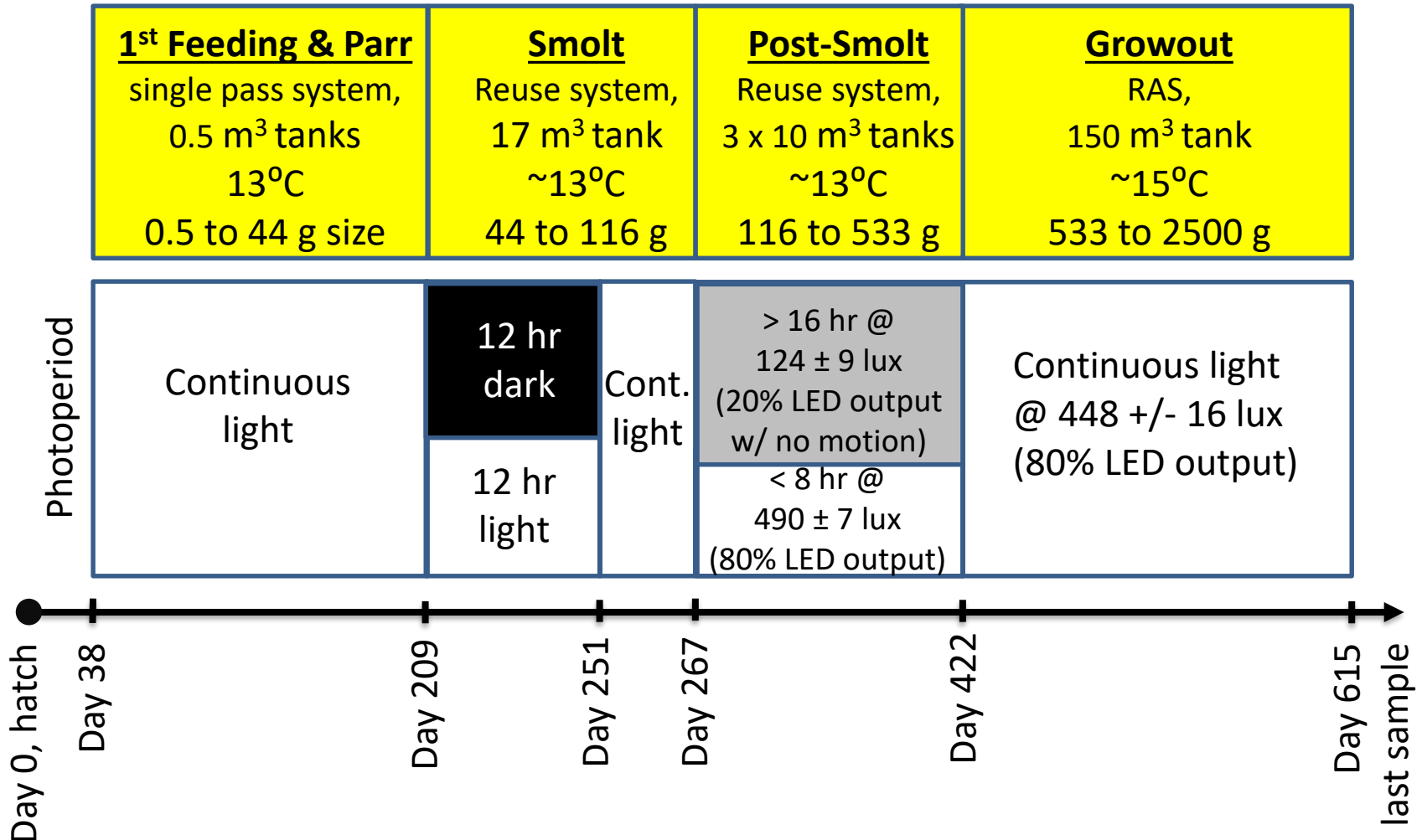
Atlantic Salmon Study #2

(2016-2017)

- **All-Female** Atlantic salmon diploids
 - Eyed-eggs arrived January 29, 2016
 - Stofnfiskur (Iceland)
- Ewos/Cargill feed
 - Parr/Smolt/Post-Smolt
 - “Transfer diet”, 48:24
 - Growout
 - “Conserve FMF”, 42:28, natural astaxanthin (Panaford)
- Intended light regime
 - Continuous light with S0 winter
 - 12h light, 12h dark for six weeks, then continuous light
 - LED high-bay fixtures
 - 5000K color temperature, **dimnable, programmable motion-detection activation**
 - Digital Lumens (Boston, MA)

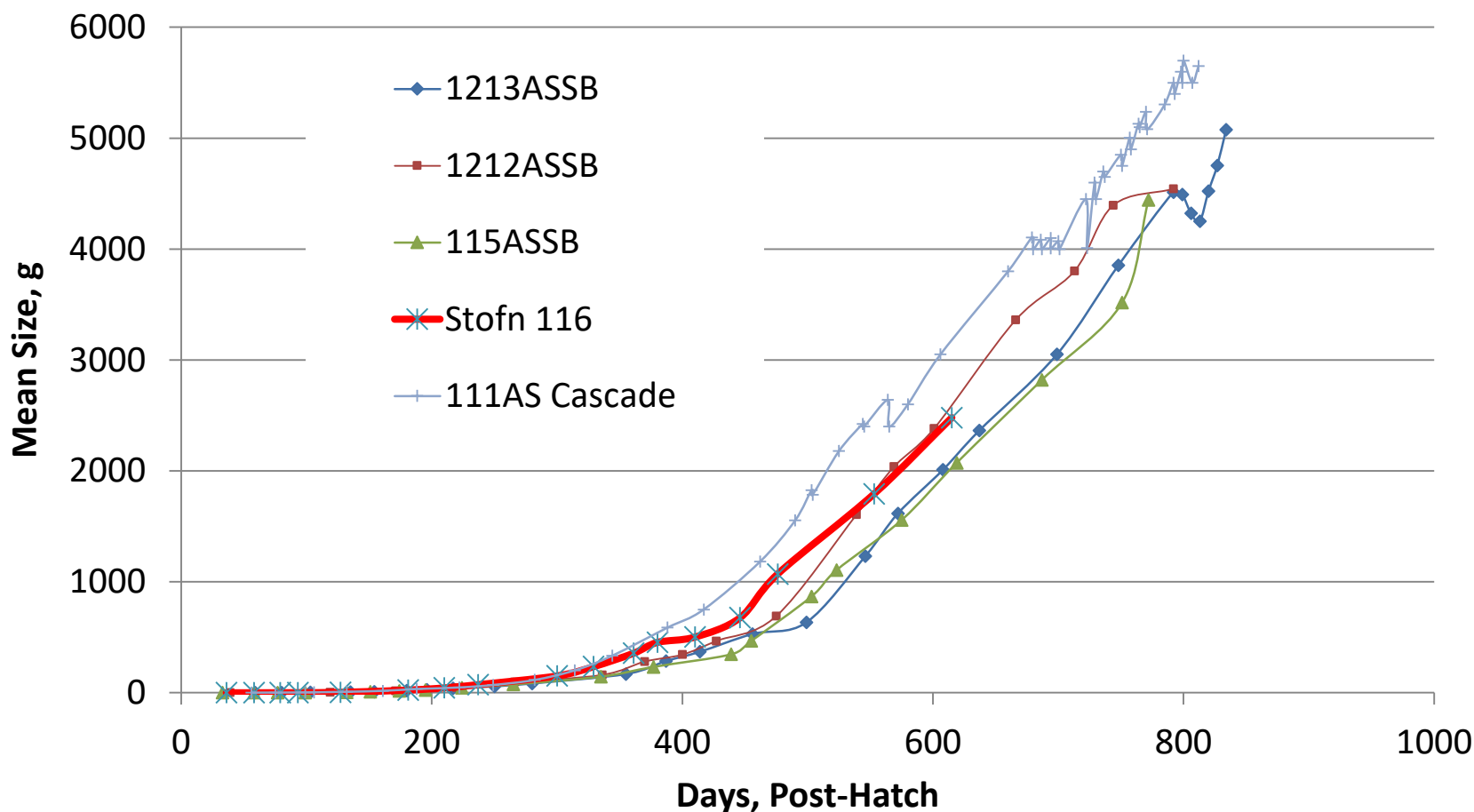
Atlantic Salmon Study #2

- Culture system and photoperiod timeline



Atlantic Salmon Study #2

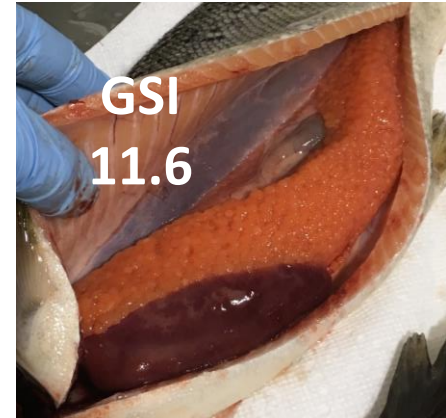
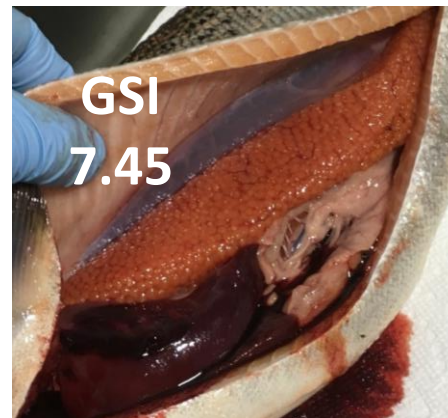
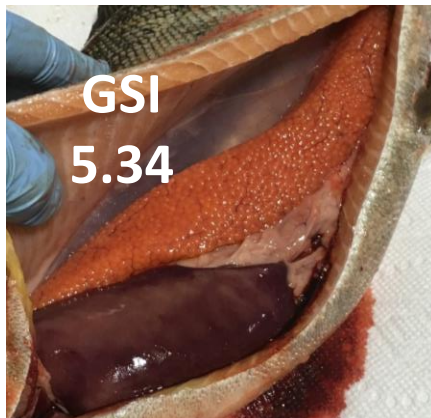
Growth



Results: Female Maturation

Egg Arrival	Dec 12	Dec 13	Jan 15	Jan 16
Cohort Harvest	2015	2016	2017	2018
Strain	SalmoBreed	SalmoBreed	SalmoBreed	Stofnfisk.
Mature Females, % of pop	1.6	4.7	14	52

(Programmable high-bay LED lights replaced metal halide lights in 2014)



Gonads *In Situ* All-female Atlantic salmon, ~2-3 kg



Differences in Studies 1 & 2

- Photoperiod cue
 - Study #2 may have provided two winter photoperiod cues
- Different strain of Atlantic salmon
 - Gaspe may be less susceptible to maturation than Stofinfskur strain in freshwater (??)
- Water temperature
 - Study #1 was at near constant 13°C through life-cycle
 - Study #2 moved post-smolt from 13°C to 15°C for growout
- Water quality
 - Study #1 used a partial reuse system with less opportunity for hormone accumulation
 - Study #2, used a RAS for growout with biofilters & ozone

Conclusion

- Uncertain why female salmon maturation occurred in recent study, but not in previous study.
 - In freshwater, Atlantic salmon maturation is sensitive to environmental conditions, e.g., photoperiod & temp
 - Hypothesis: two winter photoperiods were created that triggered high maturation
- Future studies:
 - Sterile (i.e., Wong & Zohar approach) Atlantic salmon or all-female triploid salmon performance in freshwater RAS
 - Use of bright:dim photoperiods to trigger smoltification or other endocrine signal, allowing for 24/7 feed & consist. water quality

Acknowledgements

USDA



*Cargill*TM



StofnFiskur