

How can we avoid early sexual maturation in RAS?



 **Tides Canada**

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GORDON AND BETTY
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ARS

 Atlantic Salmon Federation
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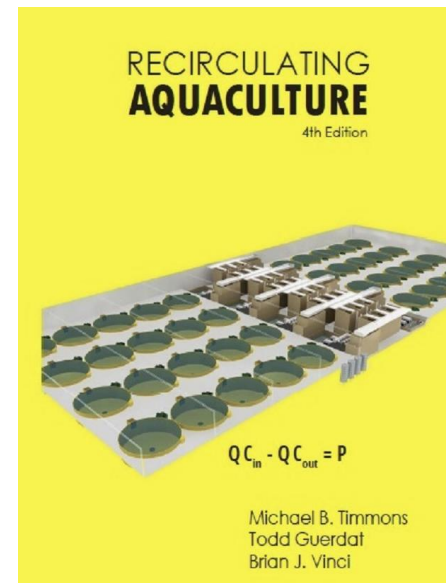
 **Nofima**
Ctrl**AQUA**

- Interdisciplinary team (M.S., PhD) providing practical research for > 30 years in support of the growing aquaculture industry

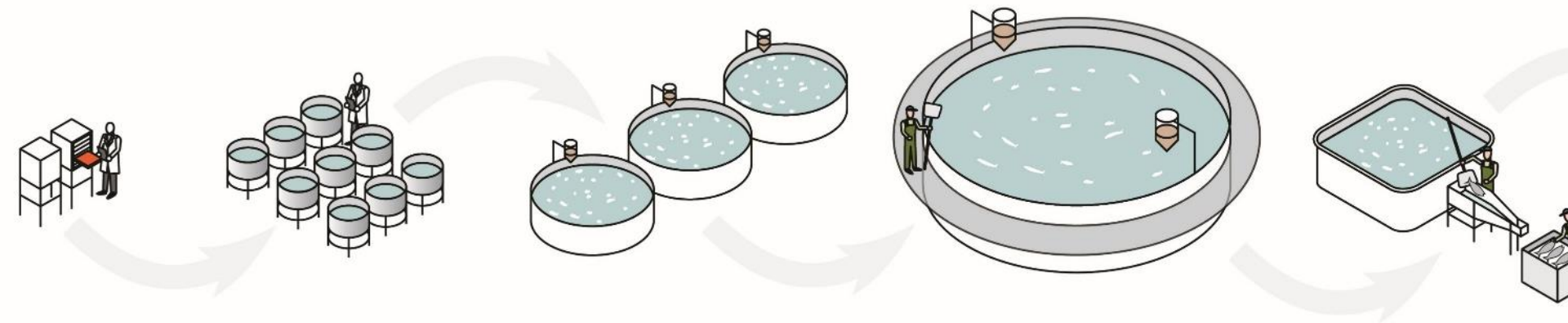
- Engineers
- Biologists
- Researchers
- Water Chemists
- Veterinarian
- Fish Production
- Administrative
- Operations



- Research & development of recirculating aquaculture systems
 - Hundreds of peer-review and trade press articles
 - Engineers have contributed to four book iterations
 - Collaborate with domestic & international research partners



- Heath tray egg incubation system (8 °C)
- Flow-through fry system (11-14 °C)
 - 12:12 LD Photoperiod at ~40 g
- Partial reuse system (12.5-14.5 °C)
- RAS grow-out to 4 kg (12-17 °C)
- Depuration system (13.5-15 °C)



➤ Demonstrated success

- 12 years of Atlantic salmon production in RAS
- 4+ kg market size
- 22 to 26-month cycle
- High survival rates
- Excellent fish welfare
- Optimized water quality





Contents lists available at [ScienceDirect](#)

Aquacultural Engineering

journal homepage: www.elsevier.com/locate/aqua-online



Production of market-size North American strain Atlantic salmon *Salmo salar* in a land-based recirculation aquaculture system using freshwater

John Davidson^a, Travis May^a, Christopher Good^a, Thomas Waldrop^b, Brett Kenney^c, Bendik Fyhn Terjesen^d, Steven Summerfelt^{a,*}





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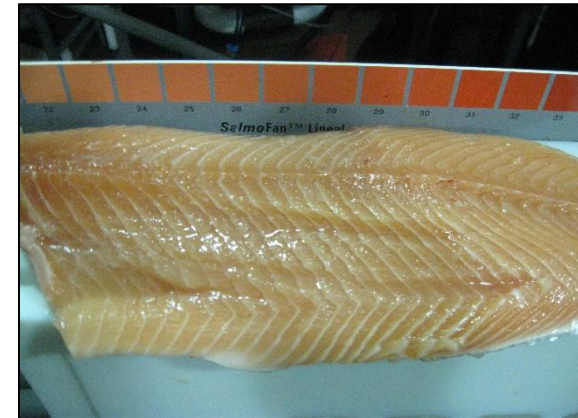


Production of market-size European strain Atlantic salmon (*Salmo salar*) in land-based freshwater closed containment aquaculture systems

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The Conservation Fund Freshwater Institute, 1096 Turner Road, Shepherdstown, WV, 25443, USA





Many Contributing Factors

- Photoperiod
- Genetics
- Nutritional State
- Hormones
- Exercise
- Temperature

Product Downgrades & Disadvantages

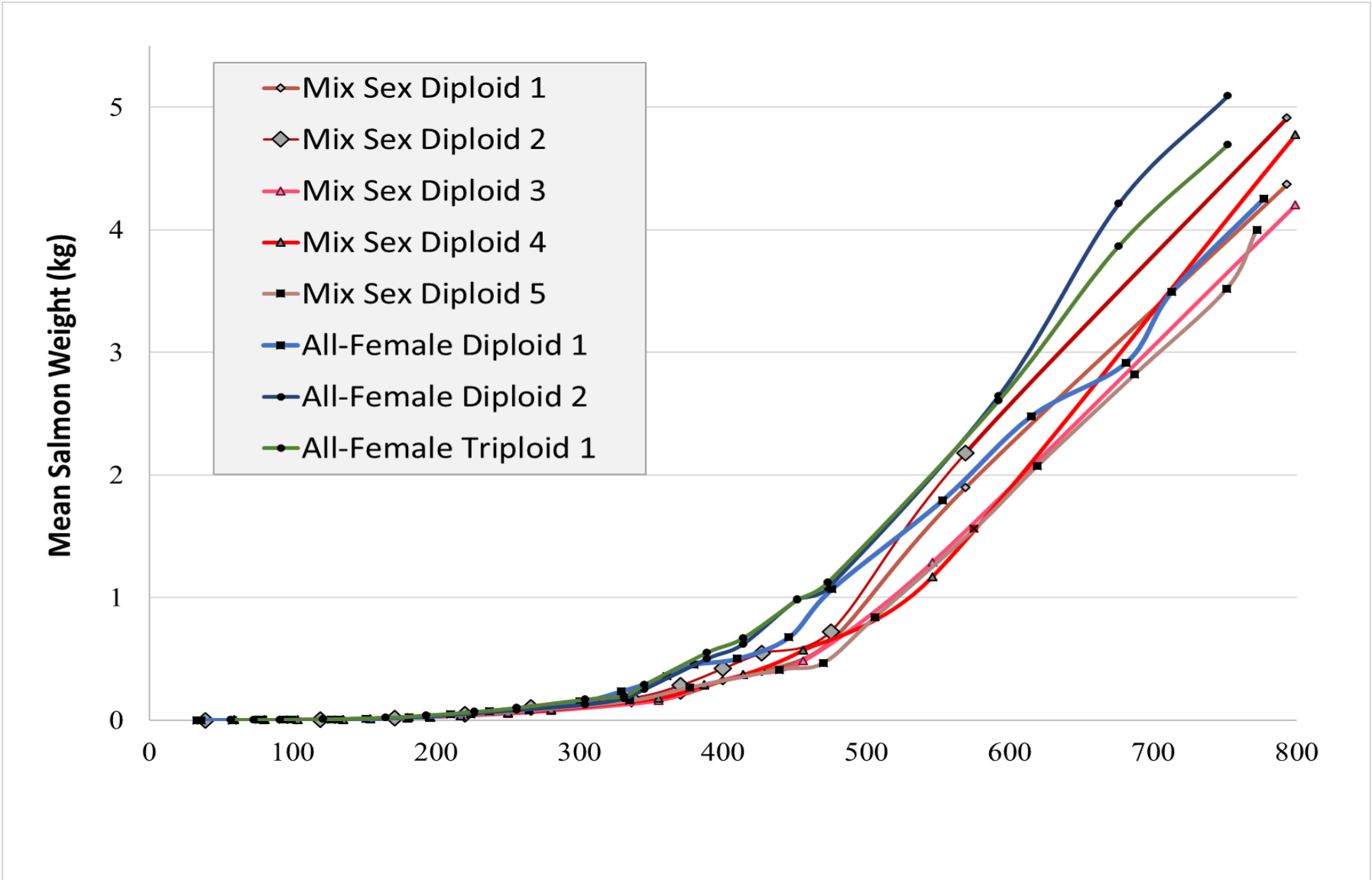
- Poor flesh color
- Softer fillet texture
- Reduced fillet yield and thickness
- Aggressive behavior
- Slower growth performance
- 17-47% maturity - mixed-sex groups

	Mixed-Sex Diploid								AF Diploid		AF Triploid
	Cas1	Cas2	SJR	Euro1	Euro2	Euro3	Euro4	Euro5	Euro All-Fem. Dip. 1	Euro All-Fem. Dip. 2	Euro All-Fem. Trip
Maternity	39%	17%	37%	19%	26%	47%	41%	36%	67%	13%	0%
Temp. °C	15.6	15.2	15.6	15.1	15.1	14.8	14.8	14.9	14.4	13.3	13.3



- Most males in mixed-sex cohorts began to mature at 1-2 kg
- All-female diploid maturation still occurred in freshwater RAS and was variable
- Maturation did not occur in all-female triploids, but there was a trade-off for increased deformities
 - Production methods were not specific to triploid requirements

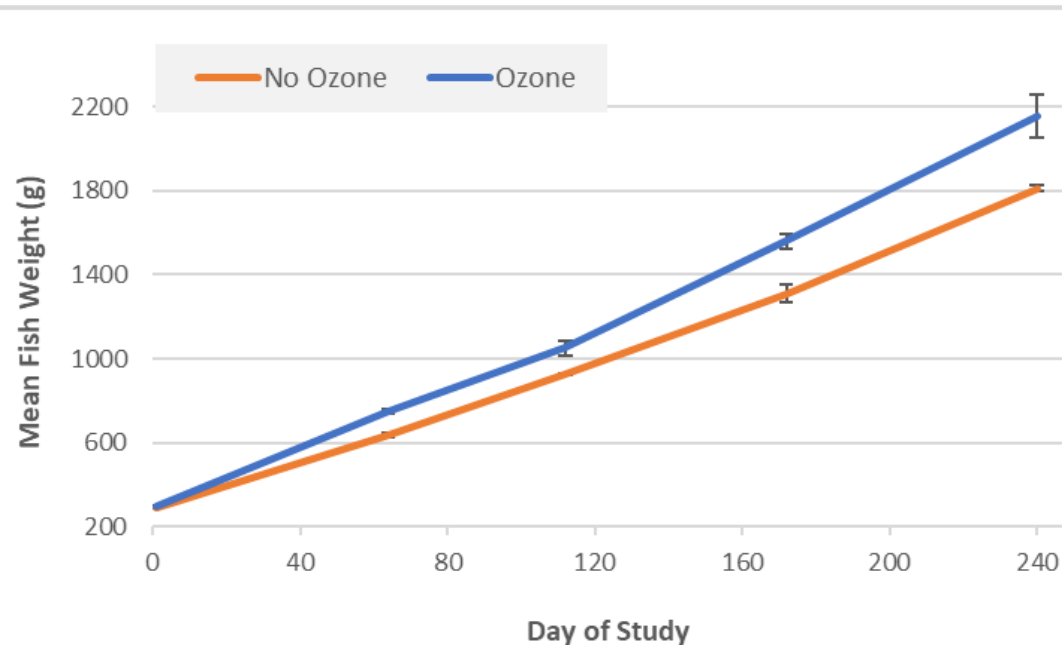
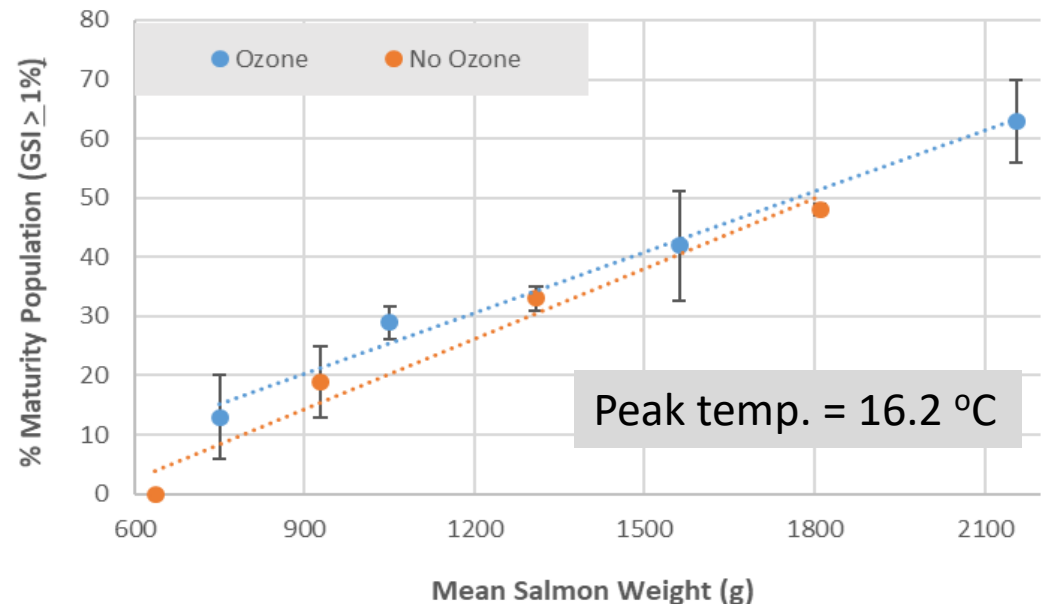
➤ Fastest growing group was an all-female cohort from European supplier. All-female triploids performed well and were close behind.



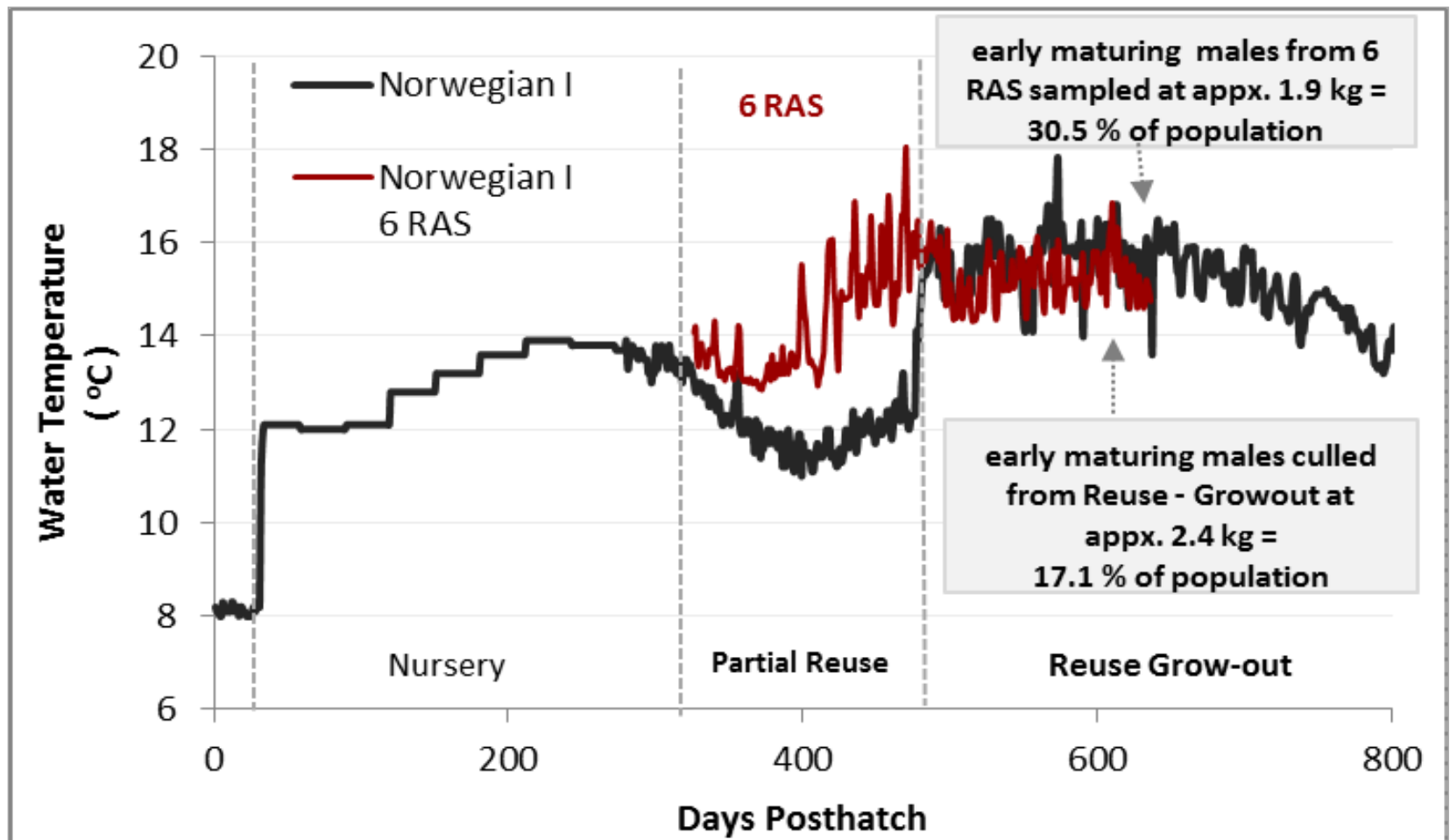
- Mota et al. (2014) found that sex steroids accumulate in RAS
- Good et al. (2017) reported that hormones accumulate in RAS stocked with maturing Atlantic salmon
 - Ozone reduced estradiol, testosterone, and 11-KT
- Followed with study to determine if low-dose ozone can limit early maturation when applied in RAS stocked with immature salmon (mean weight - 296 g) – Davidson et al. (2021)



- Low-dose ozone reduced hormones, but did not inhibit early maturation
- Maturation occurred sooner and was greater in ozonated RAS, but maturity rate was similar when normalized with fish growth
- Low-dose ozone resulted in significantly faster post-smolt Atlantic salmon growth

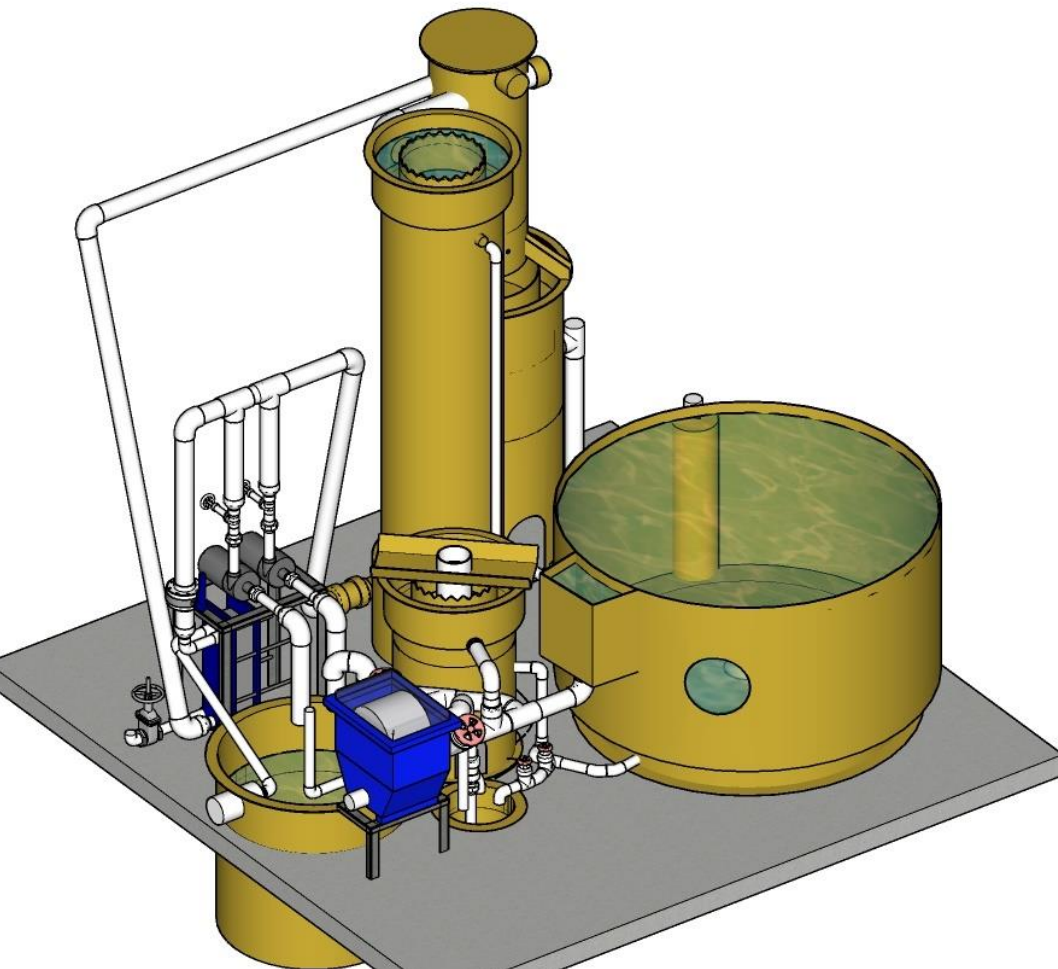


- Observations of relationship between temperature and early maturation in 2015
- Without chillers, we are subject to inherent, seasonal temperatures
 - 12 – 14 °C spring water
 - Increasingly warmer water in low exchange RAS



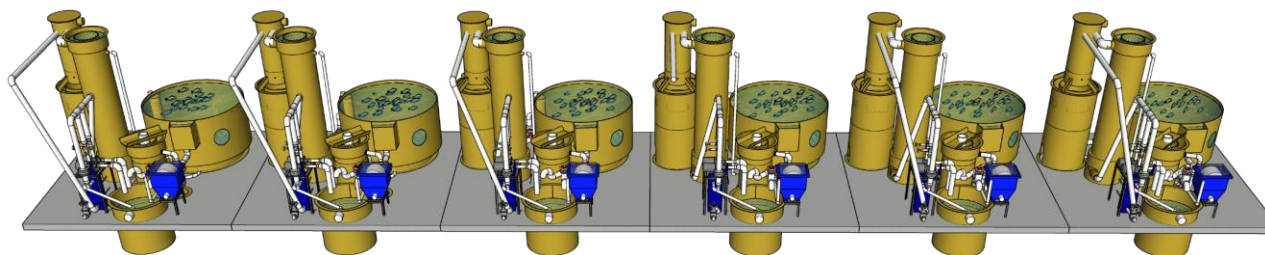
➤ Six identical RAS (9.5 m³ total volume) now equipped with chillers

- 3 RAS at 12 °C v. 3 RAS at 14 °C
- Early-life stages maintained on 24-h photoperiod at 11-12 °C
- Mixed-sex diploids from Benchmark Genetics stocked at 51 g
- Cultured for 8 months to ~1.3 kg

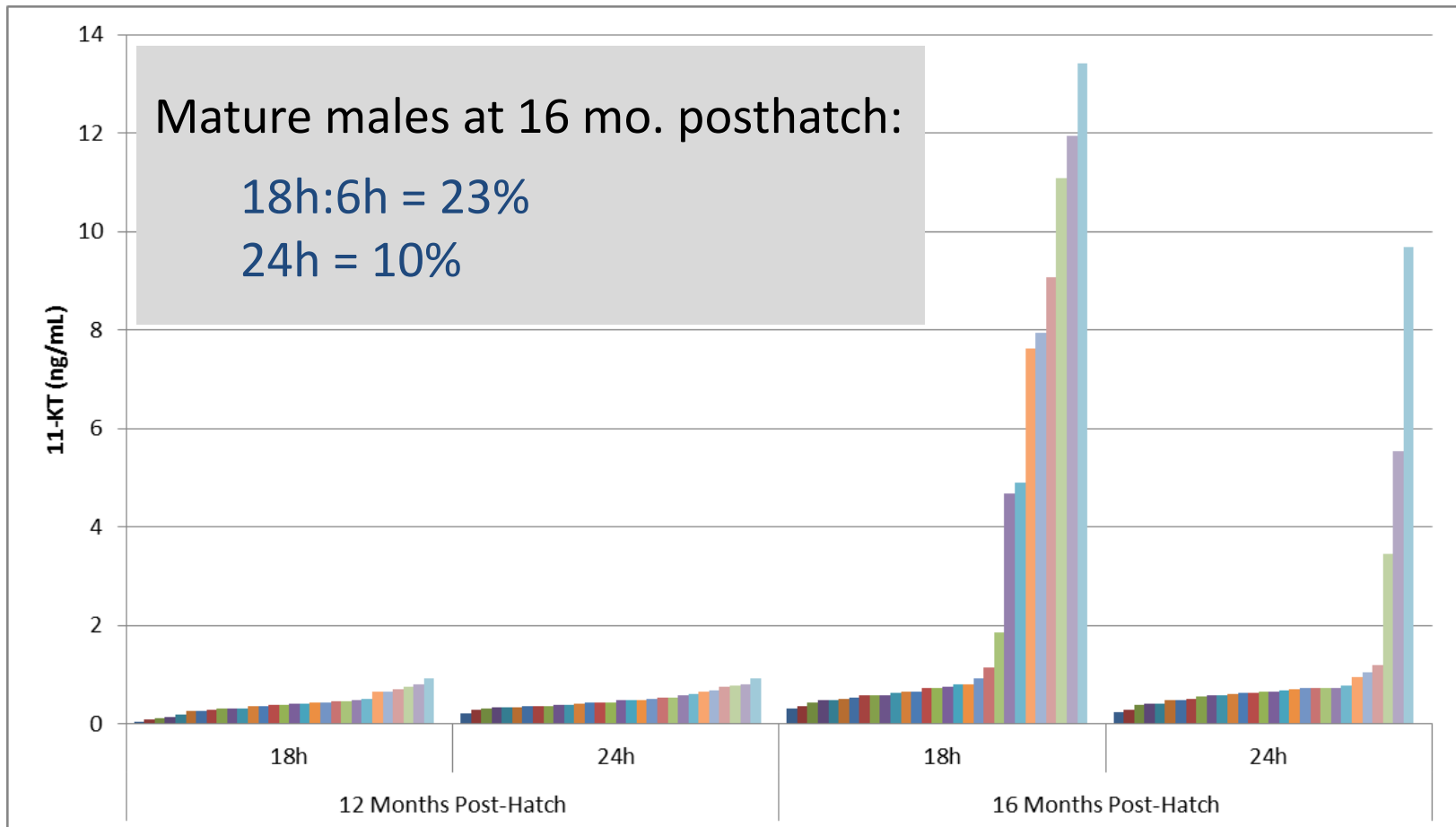


Study	Temp. (°C)	Maturity (% of pop.)	Maturity Assessment Method	Thermal Growth Coefficient	End Fish Weight
Crouse et al. 2022	12	20.4%	GSI >0.3%	2.45	1,292 ± 25 g
Crouse et al. 2022	14	32.1%	GSI >0.3%	2.18	1,355 ± 31 g
Davidson et al. 2017	14.3	39%	Visual Assessment	1.74 (100 mg/L NO ₃ N) 1.76 (100 mg/L NO ₃ N)	1,148 ± 22 g 1,174 ± 8 g
Davidson et al. 2021	14.7	42%; 63% 33%; 48%	GSI >1.0%	1.6 (Ozone) 1.3 (No Ozone)	1,561 ± 35 g 1,309 ± 43 g

- Temperature from previous studies without chillers had maximums ≥ 16 °C
- Maturation at 12 °C ~40-50% less than 14 °C and previous studies in same RAS
- Continued growth to 5+ kg with little additional maturation



- We've carried out several photoperiod studies with differing results
- Good et al. (2016) found that a reduced photoperiod caused greater maturation than 24-h light
 - Mean early rearing temperature = 13.7 ± 0.3 °C
 - Mixed sex diploids from North American supplier



- Reduced temperature (12 °C) limits early maturation but does not fully eliminate maturity in mixed-sex cohorts in freshwater RAS
 - Maintenance of stable temperature at early life stages also has benefits
- All-female salmon typically used for full life cycle production in RAS, but maturation can still occur in freshwater RAS
- Future research with all-female triploid salmon while using specific culture requirements and diets could be useful
- Similar research evaluating influence of temperature and ozone with all-female diploids and triploids
- Evaluating sterile salmon performance and culture requirements in RAS



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- All experimental protocols complied with the Animal Welfare Act (9CFR) and approved by the Freshwater Institute's Animal Care and Use Committee.
- The Conservation Fund and its partners are equal opportunity employers and providers.
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<https://www.conservationfund.org/our-work/freshwater-institute>

