Atlantic Salmon Growout in Freshwater Closed-Containment Systems at The Conservation Fund

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Acknowledgements



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Ctrl/QU/ SalmoBreed



Gordon and Betty

NDATION

Atlantic Salmon Federation

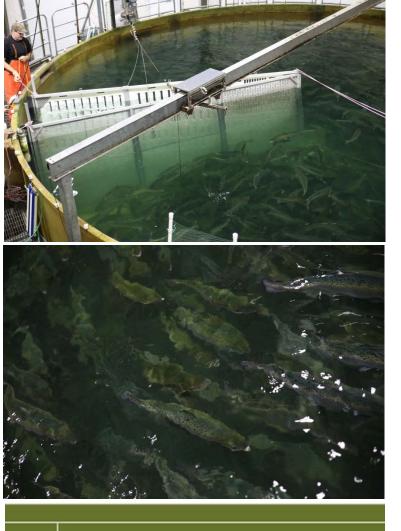


Growout Trials

• USDA ARS (finished in 2011)

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- Gaspe and St John River strain
- Atlantic Salmon Federation (finish 2012)
 - St John River strain salmon @ 40 kg/m3
- Gordon/Betty Moore Foundation (2013)
 - Cascade strain salmon @ 100 kg/m3
- **GBMF & ASF** (finished in 2014)
 - Cascade strain salmon @ 2 photoperiods and 120 kg/m3 biomass density
- **GBMF & Salmobreed** (finished in 2015)
 - Norwegian strain salmon @ 2 feed strategies and 95 kg/m3 density
- **GBMF**, **ASF**, **& Salmobreed** (to finish 2016)
 - Norwegian strain salmon @ 110 kg/m3 with custom sustainable feed formulation



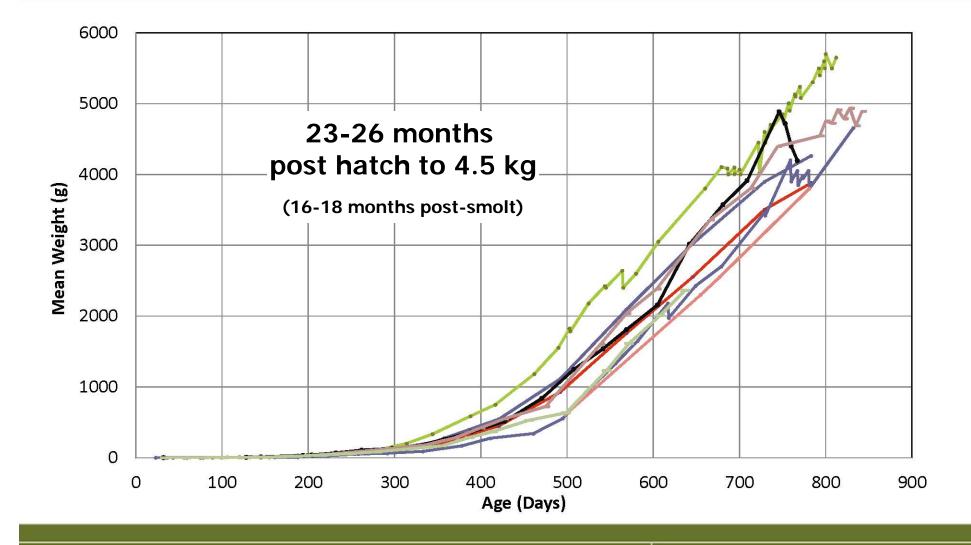


Closed-Containment System

- 145 m³ Culture Tank Volume
 - 4900 L/min recirc flow
 - 30 min HRT
- 260 m³ System Volume
 - 45 L/min mean makeup
 - 8 to 150 L/min makeup
 - 4 day HRT (1.2-23 day)
 - 99.8 to 96.9% flow
 reuse
 High flushing rate to keep

water $\leq 17^{\circ}$ C in summer

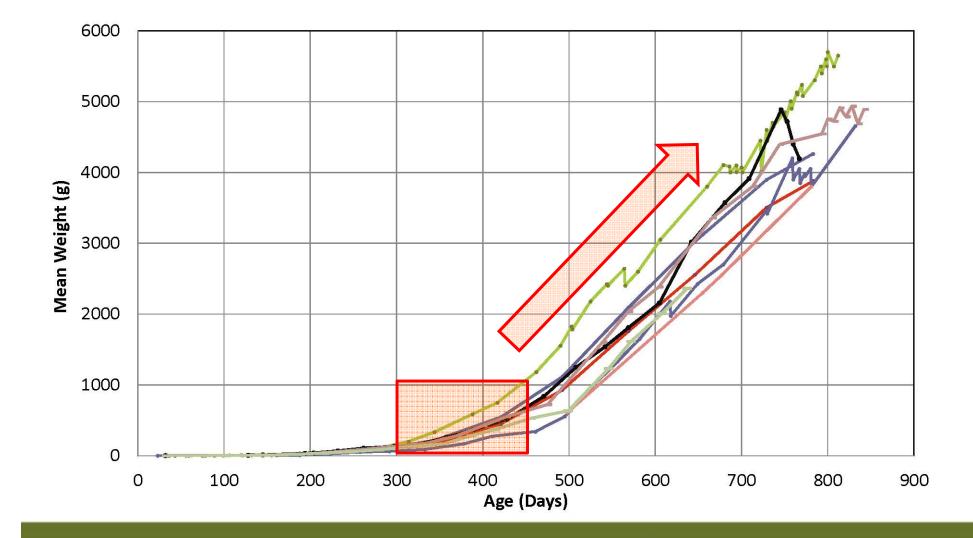
Freshwater Salmon Growout



Data from 8 cohorts at Freshwater Institute ²⁰¹⁵ A

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Freshwater Salmon Growout



Similar growth rate after 700 g

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Land-Based Salmon Growout

• Maximum Growout Density in freshwater

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	Trial #2	Trial #3	Trial #4	Trial #5
Strain	St John River	Cascade	Cascade	SalmoBreed
Density	36 kg/m ³	100 kg/m ³	118 kg/m ³	95

(Mean $CO_2 = 14 \text{ mg/L}$; Max $CO_2 < 20 \text{ mg/L}$ at highest density)



Atlantic Salmon Growout Trials

• Early Maturing Males

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	Trial #2	Trial #3	Trial #4	Trial #5
	St John River	Cascade	Cascade	SalmoBreed
Grilse harvest size, kg	2.7 & 3.7	2.6	2.1	2.2
Prevalence, %	36.6	38.5	17.1	18.3
Post-harvest use	Hot smoked	Cold smoked	Fresh fillets & smoked	Fresh fillets

High maturation: Post-smolt initially comingled with previous cohort that were maturing



Final Salmon Harvests

	Trial #2	Trial #3	Trial #4	Trial #5
Mean harvest size, kg	4.2 to 4.6	4.1 to 5.7	4.9 to 3.5	4.5 to 4.7
Total final harvests	<u>5,200 kg</u>	<u>13,382 kg</u>	<u>12,695 kg</u> Prem: 12,047 kg subPrem: 320 kg grilse: 328 kg	<u>12,453 kg</u> Prem: 12,107 kg subPrem: 117 kg grilse: 229 kg
All harvests	7,000 kg	19,496 kg	19,727 kg	15,754 kg
Post-harvest use	Food-banks	Albion Seafood	JJ McDonnell	JJ McDonnell

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Feed Conversion

• Overall feed/gain

	Trial #2	Trial #3	Trial #4	Trial #5
Strain	St John River	Cascade	Cascade	SalmoBreed
FCR	1.09	1.07	1.10	1.37

Trials 2-4, Growout RAS fed Ewos Dynamic Red (~44% protein & ~29% fat) Trial 5, Growout RAS fed Skretting Optiline RC (varies with size)



Cumulative Mortality

	Trial #2	Trial #3	Trial #4	Trial #5
Strain	St John River	Cascade	Cascade	SalmoBreed
Mortality	3.9%	2.7%	2.6%	2.6%
Culls (fungus- unthrifty)	5.6%	3.9%	1.3% in growout 3.6% @ harvest	0.4% growout 2.4% harvest
Jumpers	1.9%	0.4%	0.7%	0.4%
Total	11.4%	7.0%	8.2%	5.8%



town, WV 2015

Fish Health

- No major fish health events were noted at TCFFI – A little fungus, mostly during incubation & fry culture
- Tested **sixty** fish from each cohort
 - No sea lice or kudoa
 - **No** ISAV, IPNV, VHSV, OMV, SVCV, *A. salmonicida*, *R. salmoninarum*, *Y. ruckeri*, *M. cerebralis*, *C. Shasta*, or *K. thyrsites*
- No vaccination, antibiotics, formalin, or pesticides used at any time in over a decade
- No escapees

Current Growout Trial

- Current Atlantic salmon growout trial evaluating a sustainable formulation:
 - Fishmeal & GMO free

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- Zero Fish in: fish out (by Seafood Watch)
- North America sourced ingredients
- Natural pigment added (non-gmo phaffia yeast)
- Only fish oil (byproduct of processing residuals)
- Formulated by Barrows & Mann
- Produced by Ewos Canada

Conclusions

- Producing salmon in RAS is biologically and technically viable
 - Rapid growth
 - High survival
 - Good FCR

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- No sealice
- Good health & welfare
- Requires all-female
 germplasm
 - Available January 2016

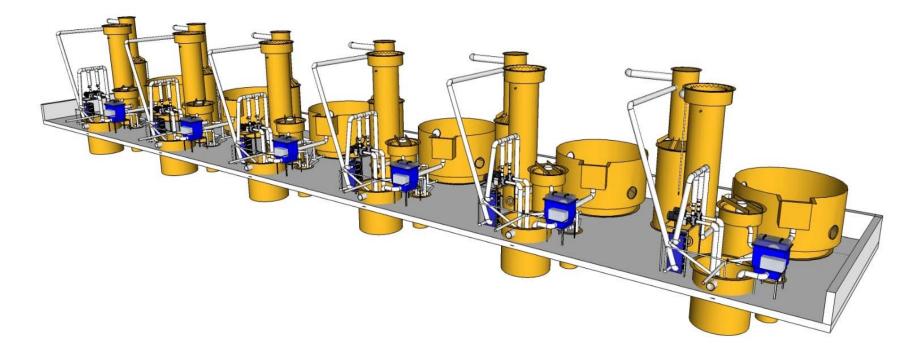


Comparing the effects of feeding a fishmeal-free vs. a fishmeal-based diet on Atlantic salmon performance, water quality, & waste production rates in low exchange recirculating aquaculture systems

John Davidson, Frederic Barrows, Christopher Good, Brett Kenney, and Steven Summerfelt

Methods

- 220 post-smolt Atlantic salmon (281 ± 5 g) stocked per RAS Salmon in 3 RAS fed a fishmeal-free diet
 - Salmon in 3 RAS fed a traditional fishmeal-based diet



Ingredient Composition (g/kg)

Parameter	FMF Diet	FM Diet
Mixed Nut Meal	320.0	-
Poultry Meal	295.0	160.0
Menhaden Meal	_	195.0
Wheat Flour	99.4	195.1
Soy Protein Concentrate	-	128.5
Blood Meal	-	70.5
Corn Protein Concentrate	35.6	-
Fish Oil Whiting Trimmings	182.0	-
Fish Oil Menhaden	-	157.4
Canola Oil	-	56.5
		Aquaculture Innovation Workshop NCTC, Shepherdstown, WV October 14- 15, 2015

> All RAS operated with relatively "low" water exchange rates

- No continuous flushing, water exchange via backwash only
- Enough flushing to maintain NO_3 -N \leq 75 mg/L
- Average system HRT approximately 20 days
- Feed delivered via automated feeders
 - 24 equally spaced feedings, around-the-clock
 - Feed adjusted per RAS based on observations of wasted feed and feeding response
 - Average feed loading rate = 3.2 kg feed/ m³ makeup water



Growth Performance and Survival

Atlantic salmon mean weight at study's end

FM Diet - 1.72 ± 0.06 kg FMF Diet - 1.72 ± 0.07 kg

Condition factor

THE

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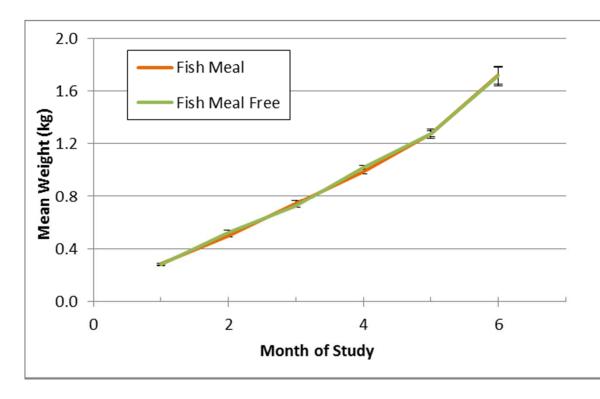
FM Diet - 1.28 ± 0.02 FMF Diet - 1.25 ± 0.01

≻ <u>FCR</u>

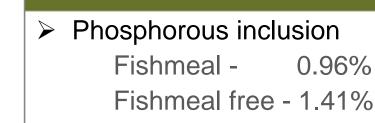
FM Diet - 0.87 ± 0.03 FMF Diet - 0.90 ± 0.06

Survival

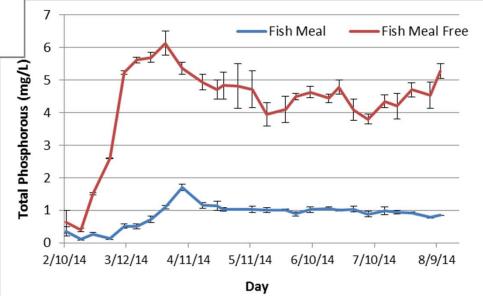
FM Diet - 99.7 ± 0.3 % FMF Diet - 99.8 ± 0.2 %



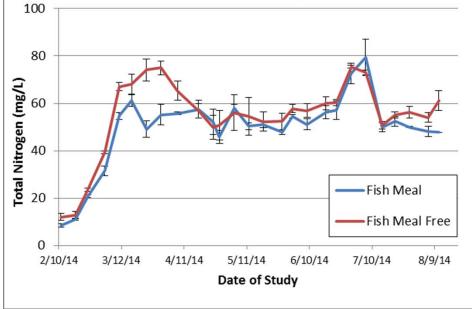
Nitrogen and Phosphorous



FMF supplemented with extra dicalcium phosphate due to lower ADC of mixed-nut meal



Aquaculture Innovation Workshop NCTC, Shepherdstown, WV October 14- 15, 2015



- Total nitrogen similar between diets over study duration
- Protein inclusion
 Fishmeal 42.3%

Fishmeal-free - 42.1%

Waste Production per kg Feed

	Month 2		Mor	Month 4		Month 6	
	FM	FMF	FM	FMF	FM	FMF	
TSS	0.164 ± 0.019	0.231 ± 0.020	0.250 ± 0.029	0.349 ± 0.012	0.287 ± 0.052	0.322 ± 0.057	
TP	0.006 ± 0.001	0.008 ± 0.000	0.006 ± 0.001	0.010 ± 0.000	0.007 ± 0.001	0.009 ± 0.001	
TN	0.016 ± 0.002	0.018 ± 0.002	0.023 ± 0.001	0.025 ± 0.003	0.022 ± 0.004	0.024 ± 0.001	
BOD	0.055 ± 0.006	0.076 ± 0.005	0.054 ± 0.005	0.082 ± 0.005	0.065 ± 0.003	0.080 ± 0.007	
					Aquaculture Innovat NCTC, Shepherd October 14- 1	stown, WV	

- Conclusions
- One of few studies to show that post-smolt Atlantic salmon performance is not compromised when feeding a diet without fishmeal
- The fishmeal-free diet qualifies this product as having a 0:1 wild fisheries-in : farmed fish-out ratio
- The diet produced excess phosphorous & slightly greater TSS and BOD per kg feed
- Increased waste loads could be problematic for compliance with local discharge regulations but could be advantageous for aquaponics operations



Comparing the effects of high versus low nitrate on post-smolt Atlantic salmon performance and physiology in RAS

John Davidson, Christopher Good, Christina Russell, and Steven Summerfelt

- Establishing a nitrate threshold for Atlantic salmon production is becoming more important
 - 1. An increasing number of smolt producers are shifting to RAS

Bergheim et al., 2009, Production of Atlantic salmon smolts in Europe – Current characteristics and future trends. Aquacult. Eng. 41, 46-52.

2. Use of RAS to culture Atlantic salmon through entire production cycle to market-size is an emerging trend

Summerfelt & Christianson, 2014. Fish farming in land-based closed containment systems. World Aquaculture Magazine. March 2014, 18-21.



Methods

> 3 RAS with 100 mg/L NO₃-N – "high"

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- Sodium nitrate continuously dosed
- > 3 RAS with 10 mg/L NO₃-N "low"
 - Sodium sulfate dosed to balance conductivity



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Equal numbers of post-smolt Atlantic salmon stocked per RAS

- 6-week, 12-h light: 12-h dark S₀ winter photoperiod starting at 38 g
- Returned to 24-h light thereafter, 80 g
- Study began when salmon were 102 g

Equal flushing rates used for each RAS

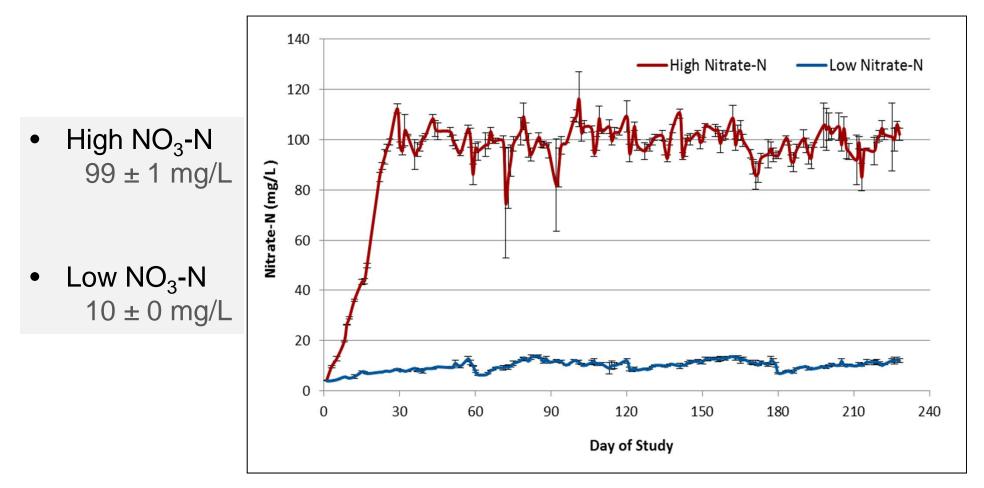
- 3.7 L/min water continuously flushed
- 1.7 day HRT
- Relatively high flushing to limit other accumulating water quality

8-month trial

- To evaluate long-term effect
- Freitag et al., 2015. Aquaculture 436, 8-12
 - Evaluated short term effect of nitrate on Atlantic salmon pre-smolts

Nitrate-N - Study Duration

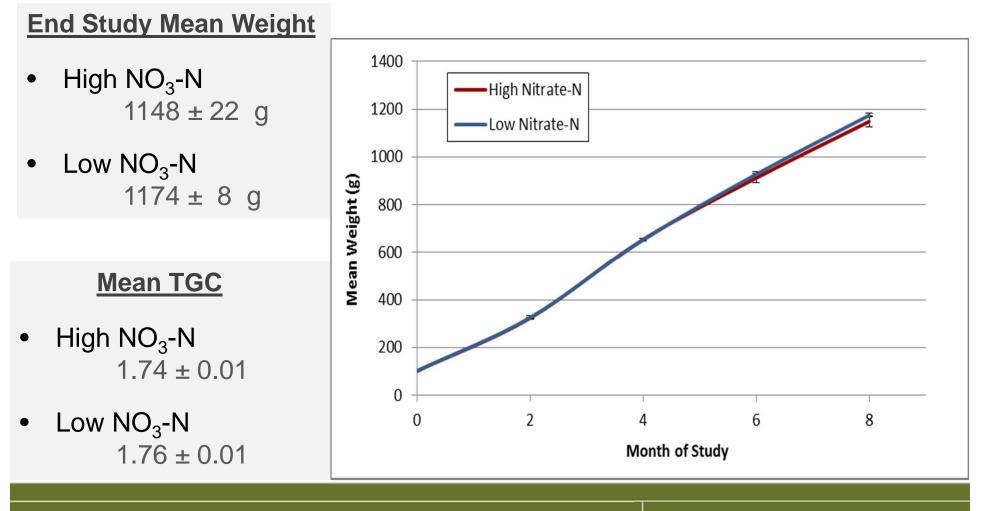
One month of gradual nitrate increase to begin



Conservation Fund	Controlled Water Quality			
Parameter (mg/L)	"High" NO ₃ -N	"Low" NO ₃ -N		
Alkalinity	239 ± 2	242 ± 2		
Carbon Dioxide	5 ± 0	3 ± 0		
Conductivity	1322 ± 8	1320 ± 10		
Dissolved Oxygen	9.5 ± 0.1	9.6 ± 0.1		
рH	8.1 ± 0.1	8.1 ± 0.1		
Temperature ° C	14.3 ± 0.0	14.3 ± 0.0		
		Aquaculture Innovation Workshop NCTC, Shepherdstown, WV October 14- 15, 2015		

Atlantic Salmon Growth

No significant effect on growth performance



Conservation Fund	Health and Performance Metrics		
Parameter (mg/L)	"High" NO ₃ -N	"Low" NO ₃ -N	
FCR	1.00 ± 0.03	0.99 ± 0.01	
Condition Factor	1.27 ± 0.01	1.29 ± 0.02	
Cumulative Survival (%)	99.4 ± 0.5	99.2 ± 0.2	

Fins were assessed using 3-pt scale (Good, Medium, Poor)

- Initial analysis indicates no differences between treatment
- Average dorsal and caudal fin scores were 1.5 for both treatments
- > Cataracts were observed in approximately 13% of fish for each treatment
- > No unusual swimming behavior observed

- Conclusions
- Post-smolt Atlantic salmon can be safely cultured in land-based RAS at nitrate-nitrogen levels up to 100 mg/L under conditions similar to those of the present study



- Additional research should evaluate the effects of higher NO₃-N levels in order to establish the upper threshold for Atlantic salmon grow-out in RAS
- Increasing the RAS design threshold for nitrate could result in:
 - Use of less makeup water
 - Subsequently reduced discharge flow that requires treatment
 - Increased heat retention of the culture water
 - Energy/cost savings relative to pumping/ heat retention
 - No requirement for denitrification technologies

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