‘Namgis Land-Based Atlantic Salmon Recirculating Aquaculture System Pilot Project

Update re Production for the period October 1, 2015 to June 30, 2016

For Tides Canada Grant #GF04095

KUTERRA

SUSTAINABILITY HAS LANDED

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Executive Summary

The following report summarizes the performance of Atlantic salmon grown in the 'Namgis Land-Based Atlantic Salmon Recirculating Aquaculture System (RAS) Project up to June 30, 2016, with a focus on the period starting October 1, 2015. Detailed performance metrics reports for earlier periods can be found on the Tides Canada website at www.tidescanada.org/programs/salmon-aquaculture-innovation-fund.

This reporting period saw the completion of Cohorts 5 and 6, growth in Cohorts 7-9, and consolidation of findings to date based on research, development and data gathered at the facility. The final results of these cohorts were mixed, but offer significant information on husbandry and performance. The summary of findings consolidated in this period indicate progress and increased certainty in understanding the roles of temperature, salinity, water quality and density, as well as marketing achievements.

The final performances of Cohorts 5 and 6 were mixed. Of all cohorts grown to date, Cohort 5 grew most poorly, as a result of impacts of trialling various production parameters. The photoperiod for this cohort was twice changed in an investigation of light regimes. In both cases the photoperiod changes produced severe feeding crashes that impaired growth. The cohort was also subject to the impact of dramatically improved smolt survival, which led to higher densities that slowed late-stage growth. These factors were exacerbated by the facility's irregular smolt intake, which meant this cohort had a shorter growout time. Cohort 6 produced the most volume of any cohort so far (112mt live) but due to a number of issues did not perform as well as expected.

Cohort 7 also experienced some impacts of high density due to improved survival and irregular smolt intake. Cohorts 8 and 9 have had the benefit of improvements to the quarantine biofilter. The changes almost doubled the productivity of the quarantine system in terms of maximum densities and maximum daily feed loads before feeding began decreasing. This has confirmed the critical importance of a well functioning biofilter.

With the quarantine system serving as a trial/testing system, modifications to the growout biofilter were made in July 2016 in order to improve the rearing conditions and fish growth rates in the growout system. Results from the changes are pending. Based on average historic growth rates and the addition of a new production tank (former purge tank), the facility should be able to produce 370mt (live wt) of product per year. Full biomass was attained in the fall of 2015.

Flavour-changing compounds arose as a factor in November 2015, and the operations team focussed on identifying and implementing measures to reduce geosmin in the system. These strategies were incorporated into the design of two new purge tanks, which were completed and commissioned in July 2016. The new tanks and other changes have resolved the flavour issue. A summary of this work will be published in a report being prepared for another funder, Sustainable Development Technology Canada. That report, and all other reports, will be made available on Kuterra's website.

Despite production challenges with Cohorts 5 and 6, the facility is, on average, close to breaking even on production costs. Prices for Cohort 6 premium fish remained steady. Seventeen percent of the harvest was non-premium due to poor growth (13%) and early maturation (4%), which significantly decreased revenue. Monthly production costs have stabilized at approximately $213k/month, but the monthly unit cost of biomass added increased, due to the recent reduction in total production. Subsequent improvements are expected to result in more stable and positive cash flows. In particular, the following measures are expected to contribute significantly to improving profitability in 2016:

- Increased revenue and reduced smolt costs through improved survival;
- Increased revenue and reduced market risk due to two new harvest tanks and commencement of weekly deliveries in July 2016;
- Increased revenue through increased harvest size, reduced size downgrades and reduced smolt costs due to the conversion of the previous $250m^3$ purge tank to a growout tank;
- Increased revenue through mitigation of flavour-changing compounds in the main growout system and improved depuration systems via the construction of two new harvest tanks; and
- Improved unit costs once increased production is realized.

The additional growout results confirm the following:

- Survival rates have improved significantly. Access to saline water would likely eliminate fungus-related mortalities, and might have additional benefits in improved growth, reduced early maturation, reduced incidence of cataracts, and ensuring adequate water supply for purging;
- Growing smolts at 15^0C when they first arrive helps reduce the time needed to get them to 100% feeding and speeds their growth accordingly;
- Maximum rearing densities are likely determined by the ability of the growout system to deliver consistent water quality conditions across the tanks. Dramatically improved results with the quarantine system after modifying the biofilter indicate that improved results should be possible in Kuterra's growout system, if the growout biofilter performance is improved;
- Growth rates, at least at Kuterra, are currently slower than in open net-pens. This is extremely important information for bioplanning and facility design purposes.

The key remaining challenges and barriers to profitability at Kuterra are high rates of early maturation, slower than expected growth, and irregular and costly smolt supply. Various strategies have been implemented to address these challenges, including modifying the growout biofilter, conducting an overhead lighting trial, and adding two more harvest tanks, which enabled the conversion of the old harvest tank to a growout tank. These improvements were all completed by July 2016 and should improve the results of subsequent cohorts. Drilling a salt-water well, building a hatchery on site, and improving the cooling system would also help address these challenges and improve results.

A tremendous amount of data that will be useful to Atlantic salmon RAS developers has been generated and disseminated by the 'Namgis/Kuterra Project team. Some of the key findings:

- Properly designed land-based recirculating aquaculture systems are environmentally benign;
- Proper design and depuration protocols in recirculating aquaculture systems deliver a top quality product that commands a stable, premium price;
- Atlantic salmon RAS facilities are likely to benefit from access to saline water;
- In the short-term, it is possible to compensate for slow growth by adding tank space;
- Scale is of paramount importance in reducing both capital and operating costs;
- Once the challenge of early maturation has been overcome, RAS salmonid facilities at scale appear capable of producing investment grade returns.

Summary of Project Findings

Given that this is likely the final report prepared for Tides Canada, a list of the major findings from the Project follows.

1. Kuterra provided solid data that answers many questions and resolves many uncertainties that RAS proponents have grappled with. For example, Kuterra dispelled a number of myths regarding the amount of water use, energy use, and land use (footprint) regarding RAS facilities, and provided concrete operating cost data, water quality data, and descriptions of operational issues that will be invaluable to subsequent RAS developers/proponents.

2. Kuterra confirmed that fish eat more and grow faster at higher temperatures. However, more research is needed regarding determining the optimal temperatures for growing Atlantic salmon. The optimal temperature may vary depending on the various life stages of the fish, and will depend on the impact of temperature on early maturation, feed conversion rate, and the cost of building additional tank space to grow fish more slowly at lower temperatures. Ongoing research by UBC's inSEAS project and others will provide useful guidance.

3. Kuterra demonstrated that the ability to deliver consistent water quality conditions across the tank (CO_2, dissolved oxygen, etc.) is extremely important in terms of maximizing fish growth. However, additional research is required to determine what the optimum levels for each key water quality parameter are, and the optimal parameters may differ between soft and hard fresh water and saltwater. Improvements to fish growth from improving the water quality metrics must be balanced against the cost of providing those improvements. Ongoing research, and experience gained from the growing number of RAS producers, will provide useful guidance.

4. With regards to densities, the completed cohorts were reared under a variety of water conditions and rearing densities so the results are difficult to interpret. While it is known, based on other types of salmon production, that rearing salmon at "high" densities will negatively impact fish performance, this was not consistently observed at Kuterra. For example, in some situations fish reared at relatively high densities performed better than the same size fish reared at lower densities. However, when the results of individual cohorts were examined, impacts (slowing feed rates and growth) were correlated to the time when densities reached certain thresholds.

   The observations seem to suggest that the density that fish can be reared at in the Kuterra system is largely determined by how efficient the system is at removing metabolites, removing suspended solids, adding oxygen, etc., and maintaining optimal stable conditions across the tank. In other words, the ability to create consistent and optimal conditions across the rearing environment will likely have a large bearing on the threshold densities that can be achieved with Atlantic salmon grown in these kinds of systems. This may become an increasingly important design consideration as the size of the rearing tanks continues to increase markedly.

If uniform and optimal water quality could be provided, potential rearing density limits (related to fish behaviour/ space perception) may be much greater than the limits observed at Kuterra.

5. Kuterra demonstrated that growth in RAS systems is slower, on the basis of Thermal Growth Coefficients, than anticipated. This has been corroborated with other RAS producers. This fact is extremely important for RAS designers and bioplan developers in terms of ensuring that their production targets are realistic. Slow growth can be compensated for by adding more tank space, so this issue is easily overcome in the short term.

6. Kuterra demonstrated that a number of factors likely impact growth, and it will take more research and growout trials to determine which factors have the greatest impact (i.e. water quality, salinity, lowered early maturation, type of lighting, temperature, genetics) and ultimately, to determine what the optimal growth conditions are. A breeding program that invests in broodstock selectively raised and optimized for growing in RAS systems would likely, in the long term, result in salmon strains with significantly increased growth potential.

7. Kuterra's results and learnings indicate that future facilities built to grow Atlantic salmon should ensure that they have access to salt-water. Research from UBC's inSEAS project indicate that salinity of 10ppt may be optimal to maximize growth.

8. Kuterra's results also indicate that the characteristics of the fresh water (i.e. hard vs soft) and the resulting differences in mineralization in the water may impact fish growth, the incidence of cataracts, deformities, and other factors.

9. Kuterra demonstrated that excellent feed conversion rates (FCR) are possible.

10. Kuterra demonstrated that relatively low mortality rates are possible in a RAS system, especially if saline water is available to counter fungal infections.

11. Kuterra's results indicate that eliminating early maturation, or at least reducing it to <10%, is essential for growing Atlantic salmon profitably in RAS. New techniques hold promise, and ongoing research and more growout trials by producers (particularly in salt water), are encouraging.

12. Kuterra demonstrated that with some minor tweaking, standard feeds work well in RAS systems. In terms of an optimal formulation, there are many, sometimes conflicting, requirements for feed formulations used in RAS systems. These include considerations of: Fish production (FCR, growth rate, early maturation, fish health); market strategy (colour, ingredient sustainability, human health - GMO, animal products, fatty acid profile, etc.); system functioning (fecal stability); and direct cost. Given that the knowledge, priorities and costs of these are constantly changing, so will the formulations employed.

13. Kuterra confirmed that stable, premium pricing is obtainable for salmon that has been ranked as sustainable by Oceanwise and Seafood Watch. Because prices for commodity Atlantic salmon

fluctuate greatly and Kuterra's prices were very stable, the premium obtained (i.e. the difference between the two) varied from 10% - 100%.

14. Kuterra has shown that a properly designed RAS facility has the potential to produce a premium quality, extremely fresh product with a shelf life of up to 16 days. Albion Fisheries' quality control manager, Dr. Musleh Uddin, confirmed that the quality of Kuterra salmon was "10 out of 10." The excellent appearance and quality of the fish was also confirmed by the primary processors, Keltic Seafoods, and the texture and freshness confirmed by a number of chefs.

15. Kuterra demonstrated the importance of regular monitoring for the presence of flavour changing compounds in RAS systems and the importance of designing an effective purge system and associated processes to ensure that one's product will have excellent flavour.

16. Kuterra's results indicate that water use required for the purging of flavour changing compounds from the fish may be high, at least for systems such as Kuterra that use fresh water (Kuterra currently uses 2600 lpm for purging). This is a very important finding. Research is needed to determine what the levels of flavour changing compounds are in saltwater, or saltier, systems, and how much water would be needed for purging in those cases. The high purging water use may be another key reason why Atlantic salmon RAS facilities should be built with access to salt water.

17. Kuterra confirmed that the key Permits required for Land Based Salmon Operations in BC are as follows:

Government Agency		**Permit/ License**	**Facility Characterisitics**						
			Marine Intake	Ground water intake	Private lands	Crown lands	Ground effluent discharge	Marine effluent discharge	First Nation reserve lands
Federal	Dept. of Fisheries and Oceans Canada (DFO)	Aquaculture License	x	x	x	x	x	x	x
Prov	Ministry of Environment (MOE)	Waste discharge permit					x	x	
Prov	Ministry of Forests, Lands and Natural Resource Operations (FLNRO)	License of occupation or lease				x			
Federal	Introductions and trasnfer licence (ITC)	Fish or Egg Transfer permit	x	x	x	x	x	x	x
Prov	Ministry of Forests, Lands and Natural Resource Operations (FLNRO)	Water Use Approval		x	x	x			x
Federal	Timber removal permit					x			x

The permits required will vary by province, so new entrants should seek legal advice on the permit and/or regulatory requirements that are specific to their jurisdiction.

Kuterra helped DFO develop approval criteria for land based fish farms and those requirements continue to evolve.

18. The report by the Pacific Salmon Foundation's Independent Environmental Monitor confirmed that Kuterra's RAS facility is environmentally benign. This report is available at

http://tidescanada.org/programs/salmon-aquaculture-innovation-fund/ and will be made available on Kuterra's website.

19. Kuterra has confirmed that high construction/capital costs, particularly in North America are a major barrier to achieving investment grade returns from RAS salmonid farms. Some innovative designs that are currently being built in Switzerland and Norway are lowering capital costs significantly, but their ability to provide suitable rearing conditions and their operational efficiency are not yet known. Scale is a key driver of capital costs per kg of annual production.

    Opportunities to reduce capital costs are documented in the March 2013 report by Gary Robinson called Development costs of two operating facilities employing RAS, which is available at: http://tidescanada.org/programs/salmon-aquaculture-innovation-fund/

20. Kuterra generated a great deal of production and financial data and information that can be used to project results for scaled up facilities. These data elements include feed conversion rates (FCR), growth rates (TGC), power use (kwh/kg), water use (litres/kg feed), water treatment costs ($/kg), and processing and sales costs ($/kg). Kuterra has developed a detailed financial model of a 3000MT RAS Atlantic salmon facility and it shows that once early maturation has been addressed, a scaled up facility should generate investment grade returns, with operating costs equivalent to those of the ocean based industry.

In summary, while there are some remaining challenges regarding the economic production of Atlantic salmon in RAS facilities:

- New RAS facilities (if appropriately funded and utilizing current knowledge) should be capable of consistently producing premium quality products: Premium taste, premium size, and premium appearance.
- Increasing the production scale offers the opportunity to decrease both capital and operating unit costs to the point of generating investment grade returns.
- As knowledge continues to improve, the opportunity for reducing production costs, reducing capital costs and increasing revenues will continue to improve.
- There are several external trends that will also serve to improve the economic outlook for RAS salmon production. These include: Increasing demand for traceable, "free-from", sustainably produced seafood; increasing costs for open net pen salmon production; and increasing feed cost, which favours more efficient production methods.

BC Regional Needs

Kuterra operates in British Columbia (BC), and there are several factors that are unique to BC that impact the potential development of a strong salmonid RAS sector here. BC has several advantages compared to other regions with respect to RAS developments: Strong local markets for premium sustainable seafoods, existing aquaculture industry (feed mills, processors, equipment suppliers), proximity to the US market with a favourable exchange rate and abundant freshwater resources. However, there is much that could be done to help the BC RAS industry grow:

- Facilitating access to superior strains of salmon eggs from outside BC for RAS growout facilities. (trout eggs can be imported).*
- Tax incentives and/or loans with flexible terms need to be provided to offset the risk of building scaled up facilities.
- Support for RAS research and active promotion of the RAS industry.
- Support for collaboration and knowledge exchange with respect to RAS research and growout trials conducted elsewhere in the world. In particular, BC producers, suppliers and researchers need to be connected to the epicenters of RAS development in Denmark and Norway.
- Regulatory clarity over effluent discharge requirements for RAS projects.
- Support for the development of a multiuser, seafood industrial park: Creation of a site where start-up time, start-up costs and ongoing operating costs are significantly reduced due to shared resources and infrastructures.

*Facilitating access to eggs could take the form of establishing a local broodstock facility where imported strains (and/or all female stocks) could be reared in quarantine to Canadian "disease free" standards. Eggs from broodstock held at this facility would be sold to local producers.

Establishing a BC based broodstock facility with a program focused on genetic improvement could also be used to achieve these ends. However, these types of programs take many generations and a lot of investments to produce commercially significant results. The quickest path to improvement for the BC industry would be to make use of the superior strains available elsewhere today.

Canadian Needs

In Canada, perhaps due to the controversial nature of salmon farming (and ongoing negative media reporting on all sides), the investment community and governments seem to be much more cautious about getting involved with RAS compared with Europe. This is evident in the relative rate of applied RAS research being conducted, and new facilities being planned or under construction, particularly in Denmark and Norway compared with Canada and the US. (Note: Already two senior members of the Kuterra team are becoming involved in new developments in Europe.)

Therefore, in order for Canada to encourage the construction of more Canadian RAS facilities, some level of ongoing promotion and collaboration with global RAS industry developers will be required. This will help improve perceptions of the RAS industry, build investor confidence, and ensure that Canada benefits from what is being learned from elsewhere in the world.

It is not realistic for Canada to become leaders in RAS research and innovation, but by promoting the RAS industry and by helping Canadians stay abreast of global RAS developments, investment confidence in RAS systems will grow, and more Canadian RAS facilities will be built.

Research Needs

The following is a list of production related uncertainties that would benefit from research and that are prioritized according to their potential impact on commercial viability.

Early Maturation

Salinity vs Maturation: What is the impact of differing salinity levels on maturation to market size (4 -5 kg)?

Temperature vs Maturation: What is the impact of different temperatures on maturation to market size (4 - 5 kg)?

Performance of all female triploids: How well do they perform in RAS systems up to market size (4 - 5 kg)?

Performance of sterile fish produced by other means: (eg) What is the performance of fish sterilized by "Vivo" (dendrimeric oligoguanidine with a triazine core) to market size (4 -5 kg) in RAS systems?

Photoperiod: What are the optimum photoperiod regimes under RAS conditions?

Flavour

Purging rates: What are the rates of reducing flavour changing compounds (e.g. geosmin) in clean waters based on various factors, including water temperature, fish size, fish fat content, density, etc?

Flavour changing compound production in RAS systems: What are the factors (prioritize) that impact the production of flavour changing compounds in RAS systems (e.g. salinity, biofilter type, feed, temperature)?

Flavour changing compound removal technologies: What is the efficacy of the various technologies that could be used to remove flavour changing compounds from RAS systems?

Flavour changing compound testing: Is there a low cost method for the detection and quantification of flavour changing compounds in RAS systems and fish?

Growth

Impact of CO_2 and O_2: What is the impact of CO_2 and O_2 levels on growth to market size? Include impacts of exposure to hyper saturated oxygen levels (e.g. 260%).

Impact of high temperature rearing on growth: Determine impact of constant high temperature rearing (10 -15C) on growth to market size. Revise growth models.

Salinity vs Growth: What is the impact of differing salinity levels on growth to market size (4 -5 kg)?

Cataracts

Epidemiological study on potential causes.

Production Results

Cohort #5 (1014)

Summary of Cohort 1014 to week 61 (Completion)

Production		
FCRb	1.30	
FCRe	1.60	
TGC (lifecycle)	1.27	
SGR (lifecycle)	0.77%	
Average Condition	1.27	
Current Biomass (mt)	0.0	
Total Production (mt)	63.4	harvested+ current- smolt biomass
Smolts stocked (#)	45,163	
Current Inventory (#)	0	
Current or Max Size (kg live)	1.9	
Smolt Size (gm)	101	

Mortality & Fish Health				
	#	%		**Percent of start number**
Fungus	1,878	4.2%		
Other	494	1.1%		* See note below
Culls	117	0.3%		
NVM	608	1.3%		No Visible Marks
Adjust.	2,312	5.1%		Count adjustments
Mech	3	0.0%		
Total #	5,413	12.0%		
Total Losses		2.9%	1862 kg	**Percent of total production**
Treatments				No antibiotics, salt

Weekly Average Water Quality		Max	Min	Average	
Temperature	C	16.4	12.3	14.1	
TAN	mg/l	1.98	0.10	0.94	
Nitrite	mg/l	1.47	0.01	0.16	
Nitrate	mg/l	227	11	83	
Oxygen	mg/l	12	7	9	
CO2	mg/l	28	4	14	
Salinity		7.1	1.4	4.7	
Alkalinity		175	30	90	
Hardness					No samples
Density (kg/m3)		81		32	
Water Velocity (cm/s)					No samples
TSS					No samples
NTU		2.2	0.01	0.5	
ORP (mv)					No samples

Feed			
Skretting			
	Max	Min	Average
Pigment	80	80	80
Fat	25	25	25
Protein	45	45	45

Smolts	
Vaccines	Forte Micro, APEX IHN, Ermogen Vibrogen II
Source	Mainstream, Ocean Farms
Genetics	Mowi

* Other mortalities includes everything that does not fit into the main mortality categories including, for example: Fish that have jumped out of the tank, fish sucked into the bottom drain, fish removed for tissue samples, inventory adjustments when a tank is emptied.

Harvest		
	kg live	kg HOG
Total	67,801	57,631
Average Size	1.7	1.4

Growth

Cohort #5 was delivered at 98g average weight on October 27, 2014 from the same hatchery as Cohort #2. As experienced before with fish from this site, they tend to have excellent fin condition with few signs of fin erosion and low size disparity and this, when combined with the seasonal peak salinities in the source water at the time of entry (>6ppt), meant we had negligible mortalities (0.5%) for the entire period in quarantine.

This cohort experienced fewer commissioning issues than the previous cohorts but has not been able to avoid them entirely – the conditions experienced by this cohort in the quarantine system were the best of all the cohorts to date with an average turbidity in Q1 of 0.34 NTU but we did still have periods of murky water with turbidity elevated and peaking at 0.88 NTU. This was due to waste accumulating on the tank floor and also in the sump in the centre of the tank (confirmed by surges of extremely dirty water when the mort removal mechanism was activated and by operating a remotely operated vehicle in the tank with a camera attached) as well as problems with fluidization in the biofilter. Some of the impacts associated with this were reduced in the short term by using more exchange in the system as well as by removing the centre drain standpipe and by vigorous agitation of the sump in the tank until it was clear using the air from the mort removal mechanism. Despite these issues we were able to manage the situation such that these fish experienced good overall conditions for the majority of their time in Q1 which was helped further by the fact that this cohort spent a short duration in the quarantine system as they were delivered on October 27th but had to be removed again soon after to make way for the January entry.

Cohort #5 showed very good appetite and feed response in Q1 up until they reached a density of 40-50kg/m3 and a peak feed load of 170kg/day at which point feeding reduced and became more erratic. The change in the feeding behavior in Q1 was correlated with a change to 24 hour lighting. As mentioned earlier, typically after the light regime is changed the feeding is impacted for 3-4 weeks afterwards. In the case of this cohort, the change in photoperiod seemed to have a more severe response than we had experienced before resulting in the ration dropping from a peak of 170kg/day to an average of 60kg/day for three weeks before rapidly picking up again. This, of course, will affect the growth curve for this cohort. This cohort was subjected to another photoperiod change from the 8th of June using a newly devised strategy. This strategy took approximately 4 weeks to complete and involved 15 minute incremental changes each day until the desired photoperiod duration was attained. While the level of feeding actually increased throughout the implementation period, approximately two weeks after the changes was complete the feeding did reduce in both grades of this cohort.

The magnitude of the feed reduction showed a correlation with density – the most heavily stocked tank subjected to a change in photoperiod (>90kg/m3, Cohort #6) saw a reduction to about 40% ration as a result of the light regime change while the large grade of this cohort (65kg/m3) saw a drop in feeding to about 60% ration. In the small grade (stocked at 50kg/m3) the reduction was much lower initially (only a 7% reduction in feeding). However, the appetite for the small grade did continue to reduce over several weeks and eventually fell to a low of about 60% ration. Unlike observed previously, the reduction in appetite in this case lasted for an extended period of 7-8 weeks in the two heavier stocked tanks before it began to pick up again. This decline in feed rate combined with the reduction resulting from the first photoperiod change with this cohort greatly impacted the growth performance (by up to 40%). As a result, we have decided to discontinue this particular approach to photoperiod manipulation for the time being and will not change the regime midstream. We will, however, continue to test the impacts of different regimes on our fish going forward.

The timing of the crash in feeding levels is synchronized quite consistently only across the tanks affected by the light regime changes while those tanks where the photoperiod was not changed were unaffected. This has been observed quite consistently to date with all cohorts put through the system and would suggest that the change in photoperiod instigated the crash in feeding observed in this and preceding cohorts. However, there does appear to be some interplay with density. As mentioned above, the severity of the initial crash in feeding appears to be correlated with density, but all the cohorts up to this point did eventually show an improvement in feeding and an eventual return to 100% ration despite the densities continuing to increase in the tanks as the fish continued to grow. This would almost seem to diminish the role that increasing densities plays in hindering appetite or at least points to some degree of acclimatization since one would expect to see the feeding reduce further if increasing densities were adversely impacting the fish. However, we have also observed with this cohort that the return to full appetite may, in fact, also be influenced by density or some environmental parameters associated with density - the large grade of this cohort had to be harvested early as a result of space constraints due largely to the increase in survival rates at Kuterra and we noticed that the increase in appetite accelerated as fish were removed from the tank following each harvest period.

Feeds and Feeding

These fish were fed a transfer diet before and after entry and they achieved 100% appetite in less than 19 days post-delivery. Please see the section on Cohort #1 in previous reports for a complete description of the diet used.

Fish Health

As indicated above, the only significant losses to date were experienced over 8 weeks which coincided with falling salinities. Fungus mortalities started to appear at ≤ 3.7ppt and this was exacerbated by a 3 week shut down of our higher salinity 6” well due to a mechanical failure. In fact, the majority of mortalities (2.3%) in this cohort to date occurred throughout this 8 week period during which time the fish were acclimatizing to a change in the photoperiod regime, the density had increased beyond 45kg/m3 and the salinity dropped to as low as 1.4ppt.

While the density cannot be ruled out as a stressor especially for this size range of fish (350-600g), it is unlikely to be the main one or at the very least the fish may have the ability to acclimatize to such conditions. This is because approximately two weeks after the higher salinity 6” well was brought back online the salinity had increased from 1.2 to 5.4ppt and within three weeks the mortalities declined to very low numbers and the appetite of the fish improved despite the densities continuing to increase and eventually reaching 80kg/m3 prior to grading. It is likely that the change in photoperiod was the biggest stressor and if salinity could be maintained at >4.5ppt, then opportunistic fungal outbreaks would likely have not occurred to anywhere near the same extent.

Cataracts

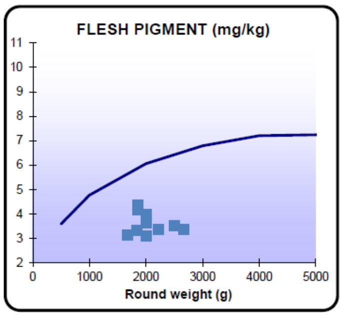
Final sampling of these fish indicated that 52.7% of the population in the large grade (1547g approx.) were recorded as having cataracts and these fish were 4.8% smaller than the average. Those with cataracts in both eyes (rather than just one eye) were 8.1% smaller than the average whereas those with cataracts in one eye only were 2.6% smaller. The small grade (1468g) had 26% with cataracts and they were 6.3% smaller than the average. Those with cataracts in both eyes were 8.3% smaller than the average whereas those with cataracts in one eye only were 5.9% smaller.

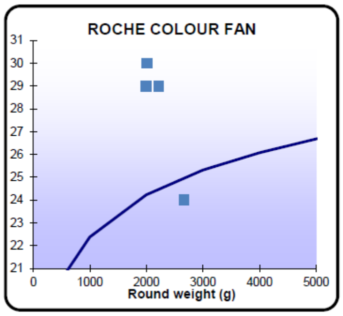
Flesh Quality Analysis

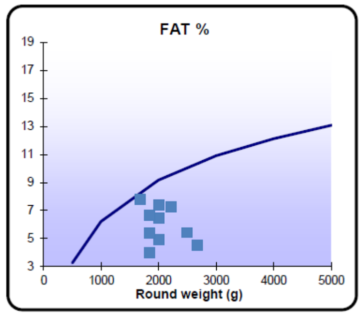
The results of NIR pigment analysis are shown below.

1014 – Large Grade

Fish no.	Round Weight (g)	Fish Length (cm)	Slaughter Loss %	Cond. factor (round)	Sex	Gonad Weight (g)	GSI %	Roche Colourfan score	Pigment NIR (NQC mg/kg)	EPA DHA (Total %)	Fat NIR (NQC %)
1	2000	51.0		1.51				29.0	3.1	5.1	4.92
2	2220	54.0		1.41				29.0	3.4	7.6	7.25
3	2010	53.0		1.35				30.0	4.0	6.8	6.45
4	1850	52.0		1.32				34.0	4.4	5.6	5.35
5*	1840	50.0		1.47				33.0	3.3	4.1	3.95
6	2670	60.0		1.24				24.0	3.4	4.7	4.54
7	2500	59.0		1.22				32.0	3.5	5.7	5.41
8	1680	50.0		1.34				32.0	3.1	8.1	7.81
9	1850	50.0		1.48				33.0	4.2	6.9	6.67
10	2000	53.0		1.34				32.0	3.6	7.7	7.41
Average	**2062.0**	**53.2**		**1.37**				**30.8**	**3.6**	**6.2**	**6.0**
St.dev.	313.0	3.6		0.10				2.9	0.4	1.4	1.3





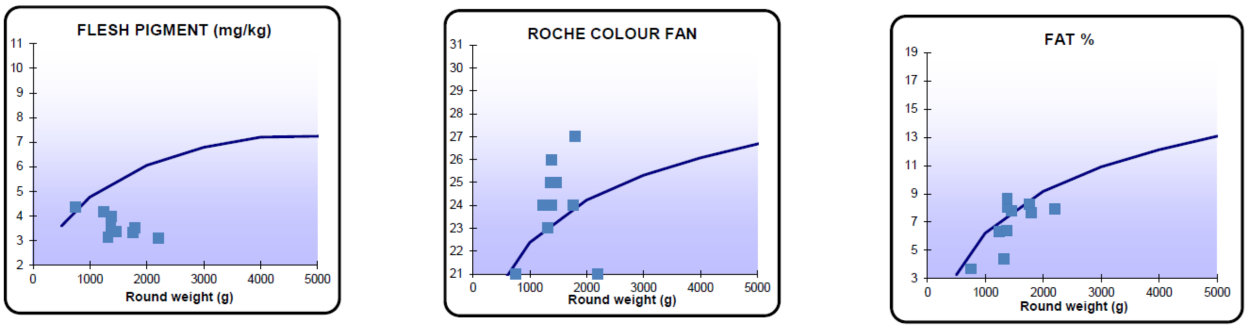


Flesh pigment levels are compared to historical results when feeding a 75, 65, 50, 40, 30 pigment regime.

Note: Fish 5 was flagged as an outlier by the NIR. The result is included in the above table but should be read with caution.

1014 – Small Grade

Fish no.	Round Weight (g)	Fish Length (cm)	Slaughter Loss %	Cond. factor (round)	Sex	Gonad Weight (g)	GSI %	Roche Colourfan score	Pigment NIR (NQC mg/kg)	EPA DHA (Total %)	Fat NIR (NQC %)
1	2200	53.0		1.48				21.0	3.1	8.3	7.94
2	1460	46.0		1.50				25.0	3.4	8.1	7.76
3	1380	46.0		1.42				26.0	4.0	8.4	8.07
4*	750	43.0		0.94				21.0	4.4	3.7	3.67
5	1760	48.0		1.59				24.0	3.3	8.6	8.23
6	1380	45.0		1.51				24.0	3.4	9.0	8.67
7	1800	51.0		1.36				27.0	3.5	7.9	7.63
8	1320	45.0		1.45				23.0	3.1	4.6	4.39
9	1240	44.0		1.46				24.0	4.2	6.6	6.31
10	1370	45.0		1.50				25.0	3.6	6.7	6.38
Average	**1466.0**	**46.6**		**1.42**				**24.0**	**3.6**	**7.2**	**6.9**
St.dev.	386.7	3.2		0.18				1.9	0.4	1.8	1.7



Flesh pigment levels are compared to historical results when feeding a 75, 65, 50, 40, 30 pigment regime.

Note: Fish 4 was flagged as an outlier by the NIR. The result is included in the above table but should be read with caution.

Maturation

GSI testing indicated that 12% of the population was maturing. This low number was supported by observations made during average weight sampling which on the most recent sample recorded only about 6% of the population as showing visible signs of maturation. Cohort #3 (0114) also displayed a relatively low rate of maturation (approximately 11% removed during a grilse harvest) and they were also subjected to the same photoperiod regime (which for both cohorts involved changing twice during the production cycle at Kuterra). It is possible, therefore, that the regime used may have contributed to the low rate of maturation.

Several more replicates (cohorts grown under the same conditions) would be needed to confirm this theory, but due to the detrimental impacts this regime had on growth of the fish it is unlikely to be tested again in the future. It should also be noted that we started harvesting these fish at a small size (1700g approx.) due to space constraints so it is unknown whether the maturation rate would have accelerated in the final stages of the production cycle which has often been the case with the other cohorts. There was no grilse harvest with this cohort because the fish had to be harvested early.

Cohort #6 (0115)

Summary of Cohort 0115 to week 72 (Completion)

Production		
FCRb	1.15	
FCRe	1.20	
TGC (lifecycle)	1.39	
SGR (lifecycle)	0.69%	
Average Condition		no samples
Current Biomass (mt)	0.0	
Total Production (mt)	112.0	harvested+ current- smolt biomass
Smolts stocked (#)	45,340	
Current Inventory (#)	0	
Current Size (kg live)	0.00	
Smolt Size (gm)	106	

Mortality & Fish Health				
	#	%		Percent of start number
Fungus	151	0.3%		
Other	2,387	5.3%		* See note below
Culls	975	2.2%		
NVM	668	1.5%		No Visible Marks
Adjust.	1,849	4.1%		Count adjustments
Pre	2	0.0%		
Mech	76	0.2%		Mechanical Damage
Total #	6,108	13.5%		Percent of total production
Total Losses		7.5%	8360 kg	No antibiotics, salt
Treatments				

Weekly Average Water Quality					
		Max	Min	Average	
Temperature	C	16.4	11.8	14.6	
TAN	mg/l	1.98	0.10	1.02	
Nitrite	mg/l	1.47	0.02	0.16	
Nitrate	mg/l	201	18	77	
Oxygen	mg/l	11	7	9	
CO2	mg/l	28	7	14	Peak daily was 10mg/l
Salinity		9.7	1.4	4.7	
Alkalinity		175	30	96	
Hardness					No samples
Density (kg/m3)		114	19	51	
Water Velocity (cm/s)					No samples
TSS					No samples
NTU		2.2	0.00	0.5	
ORP (mv)					No samples

Feed			
Skretting			
	Max	Min	Average
Pigment	80	80	80
Fat	25	25	25
Protein	45	45	45

Smolts	
Vaccines	Forte Micro, APEX IHN, Ermogen Vibrogen II
Source	Mainstream, Ocean Farms
Genetics	Mowi

Harvest		
	kg live	kg HOG
Total	125,128	106,359
Average Size	2.8	2.4
% Complete	100%	

* Other mortalities includes everything that does not fit into the main mortality categories including, for example: Fish that have jumped out of the tank, fish sucked into the bottom drain, fish removed for tissue samples, inventory adjustments when a tank is emptied.

Growth

Cohort 0115 was transferred to the facility at 106g average weight on January 16, 2015. This cohort experienced generally good water quality conditions during their time in Q1. At the start, however, we were still experiencing problems with waste accumulation in the tank and in the tank sump which caused turbidity to rise at times peaking at 1.20 NTU. After approximately 5 weeks, we were largely able to eliminate the problem of waste collecting in the sump. This was achieved by increasing the flow to the tank, by diverting it from the biofilter, and by installing a modified inlet manifold in the tank that directed more flow towards the centre. These changes, combined with ozone injection, allowed us to achieve an average turbidity of about 0.43 NTU (for comparison, Cohort #3 experienced an average of 4.37 NTU during it's time spent in Q1).

Note, however, that just like all the other cohorts in the Q1 system these fish also hit a bottleneck where the feeding crashed, in this case when the fish were at a density of 42kg/m3 and a feed load of 168kg feed/day. At that point it was becoming increasingly difficult to maintain the desired turbidity levels (peaking at 1.79 NTU) despite using increasing volumes of ozone and exchange and this reduction in feeding would have undoubtedly impacted the growth performance of the fish.

The water quality started to deteriorate at about the same time as the reduction in feeding which was traced, at least in part, to insufficient fluidization in the biofilter. It was believed at the time that this was a result of the flow being diverted to the tank to improve its self-cleaning capacity. This tactic was reversed to some extent by returning the flow back to the biofilter and attempting to find a balance whereby waste does not accumulate in the tank sump as it did previously and at the same time the biofilter is sufficiently fluidized. This approach did not result in improved turbidity during the remainder of their time in Q1.

It should also be noted that a problem with solid waste accumulation in the CO2 stripper sump was discovered a few months earlier when Cohort #5 was removed and we emptied the system of water to do a repair. It was thereby felt that this particular issue may have been contributing to the murky water (e.g. a leachate or solids emanating from the material collecting in the CO2 stripper sump at a certain feed load or bacterial proliferation as a result of the waste accumulation). As such, once we had a window of opportunity (when Cohort #6 was removed), the water in the sump was drained to carry out these changes to the manifolds in the base of the sump to prevent this waste from accumulating.

Another potential factor we considered is that there may be significant volumes of waste sitting on the floor of the tank despite increasing the flow and changing the inlet manifold. This would result in nutrients dissolving into the water and can contribute to bacterial propagation. To minimize this risk, the mort screen in the base of the tank was removed and additional holes drilled to facilitate movement of waste solids toward the sump and effluent. Subsequent filming with a submerged camera indicated that this approach, along with the changes mentioned above, was successful in preventing this buildup of solids on the floor of the quarantine tank.

The issue with murky water persisted, however, until we were able to establish that the biggest problem was down to the biofilter not functioning correctly – we removed the sand from the filter once Cohort #7 was removed and discovered that a large number of holes had not been drilled in critical locations which led to insufficient fluidization and build-up of sand on the edges (up to 2 feet in places). Once this was rectified we were able to achieve record feeding levels in Q1 (>300kg/day) with subsequent cohorts while maintaining excellent water quality conditions and consistently attaining densities of 90kg/m3 before fish started to slow down on the feeding. However, for Cohort #6, all of the issues just described would have impacted their growth curve.

Another point to mention in relation to growth is that it took more than twice as long to get these fish on to a full ration (see notes below on "Feed and Feeding") than previous cohorts. Any growth gains or losses with small fish are important as they tend to be maintained throughout the production cycle so taking longer to get to 100% ration will have some negative impact on their growth curve.

While in the GO system, similar to Cohort #5 these fish were subjected to a photoperiod change from the 8th of June using a newly devised strategy explained in the Early Maturation Strategy section of this document. This strategy took approximately 4 weeks to complete and while the level of feeding actually increased throughout the implementation period, approximately two weeks after the changes were complete the feeding did crash in this tank. The severity of the change on fish appetite was greater in this tank than that of the other tanks which, as indicated earlier, could be correlated with density and the fact that this tank was more heavily stocked than the others (>90kg/m3 versus 65 & 50kg/m3 in the other two tanks subjected to the same photoperiod change).

Unfortunately, with several cohorts including this one, inconsistencies in the timing of smolt deliveries (as we do not have a hatchery) means that we are not always able to grade and split the fish when we would like to. Combined with the fact that we have greatly increased the survival rates of the fish, this means that the stocking densities have been increasing and at times would gradually climb to undesirable numbers for these relatively small fish before a tank becomes available for grading. In the case of this cohort the fish reached a stocking density of 114kg/m3 @ approximately 1200g average weight before they could be graded and it was clear from the reduction in appetite that they simply did not like it. In fact, between 75-80kg/m3 we noticed a disruption in the feeding behavior with the daily ration fed becoming more erratic. The ration gradually reduced over 9 weeks and in the final week before grading they were only feeding approximately 50% of the recommended daily ration. This would undoubtedly have further impacted their growth curve.

This trend was to repeat itself again later and with subsequent cohorts and essentially was indicating that Atlantic salmon grown in the Kuterra GO culture system were being adversely effected by the tank environment created when the fish were in the 75-80kg/m3 stocking range and beyond. In fact, we conducted a trial with this particular cohort where we removed 21.5T of fish from one tank and placed them in to an empty tank for almost 4 weeks to test the outcome. This dropped the density in that tank from >100kg/m3 down to 58kg/m3 while the receiving tank had a density of 43kg/m3. It took approximately 12 days for these large fish to recover from the transfer but at that point the ration rapidly increased and by the end of the trial had gone from about 65% ration to approximately 110% in the more heavily stocked tank and approximately 114% in the other tank (and it was still rising at the end of the trial).

It should be noted, however, that in no way is it being suggested that these are the upper density limits for this species grown in RAS. Atlantic salmon are a schooling species and we know nowadays that, within reason, the density you can grow these fish without inducing stress is greatly influenced by how well your system is able to perform and how efficiently it is at removing solids and metabolites, adding oxygen, removing CO2 and providing all of the other conditions that the fish need to stay happy and healthy and others such as the Fresh Water Institute in West Virginia have grown Atlantic salmon to 120kg/m3 with little observed negative impacts.

What we later observed with Cohort #7 was that the improvements made to the quarantine system allowed us to attain 90kg/m3 in the 250m3 Q1 tank but when this population of fish were transferred to a 500m3 GO tank they were only able to achieve a density of 75kg/m3 before the appetite started to reduce. This was unexpected considering that these were the very same fish except that they were even bigger (950g approx. versus 500g when we grew them to 90kg/m3) which from previous experience at Kuterra one would expect them to be even more tolerant of density than at a smaller size.

But upon reflection we can point to some fundamental differences between the GO tank and the Q1 tank which can explain this discrepancy - we installed a centrifugal pump on Q1 to boost the flow which meant that the turnover rate in that tank was only 23 – 30 minutes in comparison to 45 minutes in the GO tank. Also, the aeration device installed in Q1 was the same size unit as on the GO tanks even though the Q1 tank is half the volume. Consequently the Q1 tank environment was more homogenous due to better mixing of the water, had lower CO2 levels (≤9mg/l versus up to 20mg/l in the GO tank) and higher and more stable oxygen levels across the tank than the GO tank experienced. And this same growth pattern was repeated again with Cohort #9 (Cohort #8 were moved early due to a smolt intake) where we achieved >90kg/m3 in the Q1 tank but saw the appetite consistently reduce from 75kg/m3 onwards with the same fish in a GO tank.

As such, this data supports the finding that the larger GO tanks are not as efficient at creating optimal growing conditions for the fish as the smaller tank and that this is having a large bearing on the threshold densities that can be achieved with Atlantic salmon grown in these bigger round tanks. While it is possible to minimize the impacts somewhat with more optimized stocking plans and addition of more culture space for the fish, this phenomenon observed in the larger tanks may become an increasingly important design consideration as the size of standard rearing tanks continues to increase markedly.

Feeds and Feeding

We have noticed that the prophylactic treatment used for this cohort to prevent fungal mortalities appeared to impact the time taken to get the smolts to 100% ration. For example, it can be seen from the table below that it took this cohort 40 days to reach 100% ration when operating in the range of 9.7ppt to 3.7ppt (average 7.5ppt & 13.1C) whereas with Cohort #5 they were on 100% ration in just 19 days when operating in the range of 6.6ppt to 5.8ppt (average 6.3ppt & 12.9C).

Time Taken to Reach 100% Ration Following Delivery to Site

Cohort	Days	Temp (C^{o})	Average Salinity (ppt)	Min Salinity (ppt)	Max Salinity (ppt)	Standard Deviation	Diet
0313	25	11.1	5	3.1	8.4	3.7	Standard
1013	38	11	3.8	2.9	4.9	1.4	Standard
0114	28	13.7	5.5	5	5.8	0.6	Standard
0514	17	13.7	2.2	2	2.4	0.3	Supreme
1014	19	12.9	6.3	5.8	6.6	0.6	Supreme
0115	40	13.1	7.5	3.7	9.7	4.2	Supreme

Both cohorts received the Skretting Supreme transfer diet before and after transfer and so it is speculated that the higher salinity at the start may have been the cause for the delay. There could also be a correlation with how stable the salinity is during this time period. So operating at a reduced salinity of 6ppt and maintaining that salinity as consistently as possible may both be important factors in influencing the time to 100% ration which is a theory we tested with Cohort #7 (see "Feeds and Feeding" section below for that cohort).

Fish Health

As indicated above, fungal outbreaks with fish from one supplier during the first 6-8 weeks in Q1 resulted in heavy mortalities especially when the salinity levels in the production wells are low (<4.5ppt). For this cohort we implemented a new strategy whereby we raised the salinity of the Q1 system to 9.5ppt and allowed it to fall very gradually to 3.7ppt over 5 weeks (average of 7.5ppt over that period). This prophylactic treatment has proven extremely successful as instead of experiencing up to 17% mortalities in the first 6 weeks, this cohort went through this high risk period with just 1% total mortalities - 0.3% due to fungus.

Cataracts

Final sampling of these fish indicated that 45% of the population in the large grade (2256g approx.) were recorded as having cataracts and these fish were 5% smaller than the average. Those with cataracts in both eyes were 6% smaller than the average whereas those with cataracts in one eye only were 3.5% smaller. The small grade when last sampled (2454g) had 55% with cataracts and they were also 5%

smaller than the average. Those with cataracts in both eyes were 5% smaller than the average whereas those with cataracts in one eye only were 4% smaller.

The addition of an extra mineral pack in the diet does not appear to be lowering the prevalence (although it is unknown whether the mineral pack is benefiting the fish in other ways such as in the magnitude of the size differentiation between those effected and those that are not). We also did an independent analysis of the feed to confirm "actual" nutrient levels. The nutrients that are stipulated to influence cataracts were generally in excess. The only one that was a little lower than specified was histidine which acts as an antioxidant and buffer in the lens, stabilizing biological membranes. But it was still higher (9g/kg) than the recommended levels (>7g/kg). According to Breck *et al.* 2005, Remo *et al.* 2014, supplementation with dietary histidine at 14.4 g / kg feed or greater minimizes the risk of cataract development but having inquired about this, the primary source of histidine in Canada comes from blood meal as in Canada you are not allowed to use crystalline histidine. To increase the level of histidine to 14g/kg would add something in the region of ~ $200/MT. We have more recently increased the zinc levels in our diet but it is too early to say if this is having an impact.

CO_2 levels, which have been implicated in cataracts development, have been greatly reduced in the Kuterra system, although we do sometimes still hit levels approaching 20mg/l when space constraints mean we are unable to grade and split a tank of fish.

There is some evidence that the cause is physical, including the suggestion that fish handling may be a factor. In our case we do not handle our fish a lot until they are ready for harvest but we still see a steady increase in cataracts over time. However, while routinely observing the fish in the tanks when they are being fed, I have noticed that fish in heavily stocked tanks (75kg/m3 and upwards) compete for pellets sometimes in such a way that they will brush off each other as several attempt to go for the one pellet. This includes when the fish are being fed the appropriate amount of ration and appears to relate somewhat to how pellets are distributed in large tanks. The fish also constantly leap out of the water and, again in tanks with high stocking density, sometimes rub off each other as they dive back in to the water. So physical damage to the lens is plausible, but research is required to validate this potential method of cataracts development.

We are also starting a trial at Kuterra over the summer period with Cohort #8 where we are going to use overhead lights on this cohort rather than submerged lights to rule this out as a factor. Some other factors associated with cataract formation are fluctuations in water temperature, rapid growth, fluctuations in the water salinity and strain of fish grown - all of which could not be ruled out at Kuterra.

Maturation

This cohort had a GSI of 43% and the average number removed during a grilse grade was 17%. While this is a lower rate than some preceding cohorts, it is still high enough that it would have impacted growth rates and feed conversion rates.

Cohort #7 (0415)

Summary of Cohort 0415 to week 63

Production		
FCRb	1.31	
FCRe	1.50	
TGC (lifecycle)	1.41	
SGR (lifecycle)	0.73%	
Average Condition		no samples
Current Biomass (mt)	65.5	
Total Production (mt)	87.2	harvested+ current- smolt biomass
Smolts stocked (#)	39,840	
Current Inventory (#)	22,114	
Current Size (kg live)	2.96	
Smolt Size (gm)	125	

Mortality & Fish Health				
	#	%		Percent of start number
Fungus	580	1.5%		
Other	2,519	6.3%		* See note below
Culls	965	2.4%		
NVM	730	1.8%		No Visible Marks
Adjust.	2,456	6.2%		Count adjustments
Pre	2	0.0%		
Mech	2	0.0%		Mechanical damage
Samples	124	0.3%		
Total #	7,378	18.5%		
Total Losses		8.2%	7130 kg	Percent of total production
Treatments				No antibiotics, salt

Weekly Average Water Quality					
		Max	Min	Average	
Temperature	C	16.4	12.0	14.9	
TAN	mg/l	7.34	0.26	1.33	
Nitrite	mg/l	1.47	0.03	0.24	
Nitrate	mg/l	202	1	75	
Oxygen	mg/l	11	7	9	
CO2	mg/l	23	9	15	
Salinity		7.3	1.4	4.7	
Alkalinity		175	30	109	
Hardness					No samples
Density (kg/m3)		102	20	61	
Water Velocity (cm/s)					No samples
TSS					No samples
NTU					
ORP (mv)					No samples

Feed			
Skretting			
	Max	Min	Average
Pigment	80	80	80
Fat	25	25	25
Protein	45	45	45

Smolts	
Vaccines	Forte Micro, APEX IHN, Renogen
Source	Marine Harvest, Big Tree Creek
Genetics	Mowi

Harvest		
	kg live	kg HOG
Total	26,716	22,709
Average Size	2.8	2.4
% Complete	28%	

* Other mortalities includes everything that does not fit into the main mortality categories including, for example: Fish that have jumped out of the tank, fish sucked into the bottom drain, fish removed for tissue samples, inventory adjustments when a tank is emptied.

Growth

Cohort #7 was transferred to the facility from a new source on April 20, 2015 at an average weight of 125g. Work had been carried out on the CO2 stripper sump in the quarantine (Q1) prior to the delivery in an attempt to reduce the accumulation of sludge previously observed in this part of the system. This involved strategically drilling holes in the pipe manifold at the bottom of the CO2 stripper sump and required that the biofilter be taken off line (no fluidization) for approximately 8 hours. This was not the first time we had completely emptied the sump to carry out maintenance but the extended period of downtime on this occasion meant that when we brought the biofilter back online, biofloc persistently emanated from the biofilter. This continued for many weeks afterwards causing murky water conditions (max of 4.1NTU).

Upon closer examination of the biofilter in Q1 we found that there were a number of areas at the bottom where sand was not fluidized and was gathering in mounds rising toward the walls to a depth of approximately 2 feet. An analysis of the flow rates on each of the biofilter laterals (all valves 100% open) using a flow meter found that the laterals where sand was most inclined to accumulate had an average flow rate of only 284lpm compared to an average of 475lpm for the others. Several attempts were made to correct this using the valves as well as by diverting flow from the tank to the biofilter to increase fluidization but there was a limit to how much could be diverted from the tank due to the accumulation of waste in the Q1 tank sump as previously noted.

Each time we made an adjustment or change like this we noticed that the quantity of biofloc leaving the biofilter increased, almost certainly due to the change in the flow dynamics of the fluidized sand created each time we made a change in flow to the biofilter cell. Repeated failed attempts to prevent dead areas of sand using the flow from the tank led to the decision to increase the overall flow to the system by bringing online a centrifugal pump that had been installed in Q1 in the beginning of the project when we were contending with faulty pumps in the quarantine system. We also directed all of our surplus heat from the mechanical room into the Q1 unit and vented a greater proportion of the CO2 stripped air back inside the Q1 building in order to maximize the heat load such that the maximum possible water exchange (which, at 10C, would strive to lower the system temperature) could be used to alleviate the murky conditions without lowering the temperature below the 15C optimum (maximized feeding at this temperature was also contributing to the heat load).

These tactics along with the use of increased flow capacity, the install of drop-down pipes to the remaining trouble areas in the biofilter (1" pipes directing flow toward the remaining areas of dead sand), a lengthening of the siphon pipe to improve removal efficiency of old biofloc, an increase in the depth of the Q1 tank to reduce waste accumulation in the tank sump, increased tank turnover and the use of higher ozone flows, over a period of weeks contributed to the stabilization of the biofilter and a gradual improvement to excellent water quality conditions. The consequent optimization of the fishes rearing environment for a longer period than achieved previously in Q1 and the fact that we decided not to change the photoperiod (continuous light) meant that we were able to attain record feed loads (272kg/day when previously 160-170kg feed/day was the max we could achieve in Q1 before a marked slowdown in performance) and record stocking densities.

Indeed, even beyond a density of 80kg/m3 the water clarity continued to improve (0.4NTU @ 250kg/day) as did the appetite of the fish and it is only when the density approached 90kg/m3, the turbidity started to increase again, ammonia and nitrite levels were increasing and it was getting increasingly difficult to maintain steady oxygen levels across the tank, that we saw a reduction in the appetite of the fish. **This observation and the fact that better water quality conditions this time in Q1 meant that we were able to attain much higher densities before we detected any adverse effects would suggest that the density that you can grow the fish at (within reason) in this system is largely determined by how efficient the system is at removing metabolites, removing suspended solids, adding oxygen, etc., and maintaining optimal stable conditions across the tank.**

We also observed that when this cohort of fish was moved from Q1 to one 500m3 GO tank that they were only able to achieve a density of 75kg/m3 before the appetite started to reduce which, as mentioned in the discussion on Cohort #6 above, can largely be explained by the inability of the larger GO tanks to maintain the same optimal rearing conditions that could be achieved in the smaller Q1 tank. **As such, this would seem to suggest that having the ability to create consistent and optimal conditions across the rearing environment will likely have a large bearing on the threshold densities that can be achieved with Atlantic salmon grown in these kinds of systems and this may become an increasingly important design consideration as the size of the rearing tanks continues to increase markedly.**

This problem was compounded by the fact that the irregular stocking of smolts in the system meant that these fish had to endure many weeks at undesirable densities in the GO tank before an empty tank became available to grade and split them. And this pattern repeated itself again later in the cycle with the small grade in particular where they again exceeded 75kg/m3 and growth has been impacted for many weeks now while they approach a size large enough for harvest. In fact, the growth has been impacted to the extent that they are taking longer than modelled to reach harvest size which further compounds the problem (as they have to spend longer at suboptimal conditions) which not only has thrown this cohort completely off the excellent growth trajectory they had displayed initially but will also likely adversely impact revenue due to a larger number of fish being downgraded due to small size.

Going forward, however, Kuterra expects to see improved results due to the following factors:

1. Vastly improved survival means that the latest cohorts have been stocked at lower numbers. This will reduce the higher stocking densities in the GO tanks and their associated negative impacts.
2. The construction of two new purge tanks in July 2016 and the conversion of the original 250m3 purge tank in to a grower tank in July will provide more space and will create the option to greatly alleviate stocking bottlenecks at key parts of the production cycle.
3. The very significant improvements in water quality and fish performance obtained in the quarantine due to the modifications to the Q biofilter point to the opportunity for similar gains in the GO facility by modifying the biofilter in the GO. The GO modifications were completed in June 2016.

These improvements could be further enhanced in the future with the construction of a hatchery to allow control over the timing of smolt supplies.

Feeds and Feeding

As noted above, these fish were transferred from a new location and the husbandry conditions experienced by the fish were, in some respects, quite different to what they experienced when they arrived at Kuterra. For example, the source hatchery used a stationary feeder that dropped the feed in one location of the tank whereas at Kuterra we use a spreader which spins and distributes feed over the entire circumference of the tank. This was observed to startle the fish for the first couple of weeks until they got used to it.

Another example is that the lights used at Kuterra are submerged lights whereas the source hatchery used overhead lights. They are also coming from a tank where the fish are very much sheltered from surrounding activity by a canopy that completely encloses the tank, plus there is virtually no noise. In the Q1 system the fish are more exposed to activities outside the tank and noise levels from the pumps, blowers and other equipment are higher than they were accustomed to at the source site. All of these are just some examples of conditions the fish need to acclimatize to when they are first delivered to the Kuterra site and thereby influence the time to 100% ration.

Despite these challenges, it can be seen from the table below that it took this cohort just 25 days to reach 100% ration. This was achieved while operating in a narrow salinity range (6.5 ± 0.6 ppt) and average temperature of 13.2C. This is a vast improvement on Cohort #6 which took 40 days to get to 100% ration at the same temperature (and also using a transfer diet) but with a much greater salinity range (±4.2ppt). This would suggest that, along with the use of the transfer diet, maintaining stable salinity conditions during the first 3-4 weeks is an important factor in reducing the time to 100% ration. This, in turn, has positively impacted the growth curve of this cohort and helped to put them on a trajectory that far surpasses all of the other cohorts put through the quarantine system to date. This can be further improved upon in the future once the facility has an onsite hatchery linked to the smolt tank such that the smolts are exposed to the same conditions they have experienced all their lives while providing the operator with the ability to gradually change key parameters in that tank as appropriate (e.g. salinity).

Time Taken to 100% Ration Following Delivery to the Site

Cohort	Days	Temp (C^o)	Average Salinity (ppt)	Min Salinity (ppt)	Max Salinity (ppt)	Standard Deviation	Diet
0313	25	11.1	5	3.1	8.4	3.7	Standard
1013	38	11	3.8	2.9	4.9	1.4	Standard
0114	28	13.7	5.5	5	5.8	0.6	Standard
0514	17	13.7	2.2	2	2.4	0.3	Supreme
1014	19	12.9	6.3	5.8	6.6	0.6	Supreme
0115	40	13.1	7.5	3.7	9.7	4.2	Supreme
0415	25	13.2	6.5	5.9	6.8	0.6	Supreme

It is also expected that operating at 15C with future cohorts in Q1 rather than 13C as soon as possible after delivery of the smolts (while carefully monitoring fungus which is more prolific at higher temperatures) should significantly reduce this time and so maximize growth performance further. In fact, following the first three weeks, and with clear indications that the strategies undertaken to attain higher salinities were successful at subduing fungus, it was decided to take the temperature from its average up to that point of 13C and increase it such that they would be grown at 15C thereafter. This significantly enhanced the appetite of the fish and this combined with the improvements made to optimize water quality conditions and the fact that we did not change the photoperiod, have all contributed to the superior growth shown by this cohort in the early stages compared to all the cohorts put through the system to date.

Building on the lessons learned regarding the GO system constraints and the opportunities to mitigate them (lower stocking numbers due to better survival, an additional 250m3 of growing space as a result of the conversion of the purge tank to a grower tank, greater control over smolt supply to make tanks available according to the optimized bioplan, stocking of all-females to alleviate the problem of early maturation, continued refinement of the design and the system components such as to maximize their performance e.g. the restructuring of the biofilters), the potential exists to greatly improve on the performance achieved by this cohort in the future.

Fish Health

For this cohort we were again able to maintain salinity at a level that gave excellent control over fungal mortalities (1.3% fungal mortalities by the time they were through the high risk period in Q1). We also had the use on this occasion of well water from the higher salinity 6" well rather than continually adding industrial salt to artificially raise the salinity. This has obvious cost saving implications but more importantly for Kuterra, which has a generally soft water supply, raising the salinity in this way allows for an increase in key minerals and trace elements that play an important role in fish physiology (e.g. calcium) and which may be low under very low salinity conditions at the Kuterra site or not present to the same extent when using industrial salt. This could also be playing an important role allowing us to sustain a strong appetite in Q1 with this cohort and thereby feeding at record levels. This strategy of managing salinity and applying higher levels where needed has proven highly successful with both cohort 6 & 7 (and also cohort #8, #9 and #10) so it is expected that fungal mortalities will represent a greatly diminished challenge for the Kuterra facility going forward.

As noted above, salinity plays several roles regarding fish health. Recent studies both at UBC's INseas project and at NOFIMA indicate that optimal salinity for fish growth is likely around 10ppt. It may also play a significant role in reducing early maturation, although the evidence to date is strictly anecdotal. For all of these reasons, the addition of a saltier well is being evaluated.

Cataracts

Final sampling of these fish indicated that 17.3% of the population (ungraded average of 1131g approx.) were recorded as having cataracts and these fish were 16.6% smaller than the average. Those with cataracts in both eyes (rather than just one eye) were 24.8% smaller than the average whereas those with cataracts in one eye only were 9.6% smaller. While all the other cohorts monitored have generally shown a marked increase in the prevalence of cataracts over time, the last two data sets for this cohort have shown fairly stable values (16% prevalence recorded in the previous sample for this cohort). The incidence of cataracts is also low by comparison to others e.g. Cohort #6 had 39% cataracts at a similar size, which may be an indication that the strategies implemented to mitigate the condition (reduced CO2 levels, higher salinity improving the availability of key minerals and trace elements and the inclusion of a supplementary mineral pack in the diet) may be having a positive impact. But it is too early at this point and the fish too small to speculate on the final outcome of this cohort and several replicates will be required thereafter to confirm the consistency of any significant improvements achieved as a result of these strategies.

Maturation

With this cohort fish were top-graded out of the small grade to alleviate to some extent the problem of over-crowding in the GO tanks which was reducing the appetite of the fish. As generally speaking the largest fish are often the maturing males this was considered a grilse grade of sorts. However, since those fish could not be put to the purge tank at that time but were instead transferred directly to a tank containing Cohort #6 fish, it is difficult to make an accurate assessment of the true number of maturing individuals. These fish were the first cohort grown with 24 hour light from the start and visual observations and sampling during weighing indicated a low rate not exceeding 7%. This would seem to indicate that the use of continuous light did not exacerbate maturation beyond what has been experienced to date but the cohort needs to be complete before this can be confirmed (currently about 50% have been harvested).

Cohort #8 (1015)

Summary of Cohort 1015 to week 37

Production			
FCRb	0.88		
FCRe	1.23		
TGC (lifecycle)	1.38		
SGR (lifecycle)	0.88%		
Average Condition			no samples
Current Biomass (mt)	41.6		
Total Production (mt)	37.9		harvested+ current- smolt biomass
Smolts stocked (#)	39,840		
Current Inventory (#)	40,136		
Current Size (kg live)	1.17		
Smolt Size (gm)	94		

Mortality & Fish Health				
	#	%		Percent of start number
Fungus	793	2.0%		
Other	1,201	3.0%		* See note below
Culls	1,777	4.4%		
NVM	556	1.4%		No Visible Marks
Adjust.	0	0.0%		Count adjustments
Pre	4	0.0%		Precocial male
Mech	208	0.5%		Mechancial Damage
Samples	44	0.1%		
Total #	4,583	11.3%		
Total Losses		10.4%	3948 kg	Percent of total production
Treatments				No antibiotics, salt

Weekly Average Water Quality					
		Max	Min	Average	
Temperature	C	16.4	12.2	15.1	
TAN	mg/l	8.40	0.28	2.52	
Nitrite	mg/l	7.00	0.02	0.76	
Nitrate	mg/l	136	0	52	
Oxygen	mg/l	10	8	9	
CO2	mg/l	21	8	14	
Salinity		7.2	1.4	4.3	
Alkalinity		175	70	106	
Hardness					No samples
Density (kg/m3)		89		18	
Water Velocity (cm/s)					No samples
TSS					No samples
Turbidity		5.1	0.10	1.3	
ORP (mv)					No samples

Feed			
Skretting			
	Max	Min	Average
Pigment	80	80	80
Fat	25	25	25
Protein	50	45	50

Smolts	
Vaccines	Forte Micro, APEX IHN, Renogen
Source	Marine Harvest, Big Tree Creek
Genetics	Mowi

Harvest			
	kg live	kg HOG	
Total	0	0	Harvesting not started
Average Size			
% Complete	0%		

* Other mortalities includes everything that does not fit into the main mortality categories including, for example: Fish that have jumped out of the tank, fish sucked into the bottom drain, fish removed for tissue samples, inventory adjustments when a tank is emptied.

Growth

Cohort #8 was transferred to the facility on October 19, 2015 at an average weight of 94g. They spent 11 weeks in Q1 reaching a density of only 40kg/m3 as they had to be removed at that point to make way for Cohort #9. Their growth curve was similar to Cohort #6 until they reached about 885g at which point the density in the GO tank increased beyond 75kg/m3 as there was not a free tank available to split and grade them. In fact, it would be 6 weeks later that a tank would become available so similar to many of the previous cohorts, this constraint meant that the growth performance of the fish was greatly impacted as a result. At the time of writing this cohort was 1000-1400g (small and large grade respectively) and while a significant amount of growth has been lost at this point, this cohort is likely to be the first to benefit from the availability of an extra 250m3 of space (due to the conversion of the old purge to a grower tank). So there will be the opportunity to avoid excessive densities with the small and large grade tanks later on and so improve on performance somewhat. In fact, converting the old purge to a grower tank will allow 5-6 weeks of extra growth which allows 1.5lbs of extra growth (20-25% more) with a consequent 20-25% reduction in the smolt numbers required. So not only should growth be enhanced but at the same time smolt costs should be reduced and revenue increase as there will be less size downgrades.

Feeds and Feeding

Please see the section on Cohort #1 in previous reports for a complete description of the diet used.

A number of investigators have reported that Phosphorous concentration correlates with geosmin concentration (Saadoun et al. 2001, Robertson et al. 2006, Robin et al. 2006, Dzialowski et al. 2009) and a study conducted by Sarker *et al*, 2014 showed that the concentration of geosmin levels was approximately 50% lower in fish that received a low P diet compared to the high P diet. Since the majority of P released by aquaculture operations is ultimately from dietary origin, effective management of waste outputs can be achieved through management of the nutrient composition of feeds. As such we have reduced our phosphorous levels in the feed as of March 2016. The below table shows the previous and current total P levels in the main diets used at Kuterra:

	4mm, OPTILINE RC VIC 100 MB	6mm, OPTILINE RC VIC 400 MB	9mm, OPTILINE RC VIC 1000 MB
TPHOS (Before)	1.37%	1.32%	1.13%
TPHOS (Now)	1.37%	1.10%	1.00%
Reduction (indigestible P)	0%	27%	20%

Reducing the P level results in a reduction in the addition of poultry meal and an increase in the level of both fish meal and feather meal. It was decided not to alter the P level in the Optiline 100 diet as it is a very nutrient dense diet and the cost of reducing the phosphorous levels in that particular diet would be prohibitively expensive and it only accounts for a small portion of the overall feed fed anyway.

Sarker *et al*, (2014) found that zinc levels were lower in a treatment group fed a high P diet compared to a low P diet. Significantly lower concentrations of zinc in tank water of fish fed a high P diet could stimulate the secondary metabolism of bacteria and permit greater geosmin production, as has been reported previously (Weinberg 1989).
The lowest level measured in the Sarker study was about 4ppm while in our system we are as low as 0.02ppm. As such we have doubled the zinc in the diet from 75ppm to 150ppm as of March 2016.

Fish Health

While in Q1 mortalities were <2% and overall mortalities at the time of writing were 11.3%, which includes 4.4% culls.

Cataracts

Latest sampling of these fish indicated that 15% of the population in the large grade (1087g approx.) were recorded as having cataracts. Interestingly, these fish were actually 1.6% larger than the average without cataracts. Those with cataracts in both eyes were 13.7% smaller than the average whereas those with cataracts in one eye only were 1.6% larger. The small grade when last sampled (798g) had 29.5% with cataracts and they were 6.8% smaller than the average. Those with cataracts in both eyes were 1.8% larger than the average whereas those with cataracts in one eye only were 9.2% smaller.

The submerged lights in the tank containing the large grade were removed and replaced with overhead lights on the last week of June, 2016. It has been suggested that the submerged lights are too bright for the fish and that the direction of light (due to being positioned in the water column) is very unlike that which they would experience in the natural environment. It can also be observed that the fish actively avoid the 6 x lights in each tank which further suggests that they do not like them, while also resulting in less efficient utilization of the available tank space. It has also been suggested that the brightness and location of the lights make it difficult for the fish to see feed pellets that fall within close proximity of the lights and that they are hesitant to enter that portion of the water column in any case. This will be a useful trial therefore, to observe impacts on feeding behaviour and to determine whether the intensity of the submerged lights is contributing to the development of cataracts in the lens.

Maturation

N/A – not yet large enough to sample.

Cohort #9 (0116)

Summary of Cohort 0415 to week 25

Production			
FCRb	0.86		
FCRe	0.88		
TGC (lifecycle)	1.67		
SGR (lifecycle)	1.04%		
Average Condition			no samples
Current Biomass (mt)	39.9		
Total Production (mt)	34.8		harvested+ current- smolt biomass
Smolts stocked (#)	40,456		
Current Inventory (#)	39,104		
Current Size (kg live)	1.02		
Smolt Size (gm)	127		

Mortality & Fish Health				
	#	%		Percent of start number
Fungus	73	0.2%		
Other	802	2.0%		* See note below
Culls	48	0.1%		
NVM	169	0.4%		No Visible Marks
Adjust.	0	0.0%		Count adjustments
Pre	0	0.00%		Precocial male
Mech	260	0.6%		Mechancial Damage
Samples	0	0.0%		
Total #	1,352	3.3%		
Total Losses		1.9%	645 kg	Percent of total production
Treatments				No antibiotics, salt

Weekly Average Water Quality		Max	Min	Average	
Temperature	C	16.1	12.2	15.1	
TAN	mg/l	6.84	0.66	1.95	
Nitrite	mg/l	7.00	0.02	0.79	
Nitrate	mg/l	136	0	48	
Oxygen	mg/l	11	8	9	
CO2	mg/l	18	7	11	
Salinity		7.9	1.4	5.0	
Alkalinity		175	70	109	
Hardness					No samples
Density (kg/m3)		92		55	
Water Velocity (cm/s)					No samples
TSS					No samples
Turbidity		3.1	0.13	0.8	
ORP (mv)					No samples

Feed			
Skretting			
	Max	Min	Average
Pigment	80	80	80
Fat	25	25	25
Protein	50	45	50

Smolts	
Vaccines	Forte Micro, APEX IHN, Renogen
Source	Marine Harvest, Big Tree Creek
Genetics	Mowi

Harvest			
	kg live	kg HOG	
Total	0	0	Harvesting not started
Average Size			
% Complete	0%		

* Other mortalities includes everything that does not fit into the main mortality categories including, for example: Fish that have jumped out of the tank, fish sucked into the bottom drain, fish removed for tissue samples, inventory adjustments when a tank is emptied.

Growth
Cohort #9 was transferred to the facility on January 13, 2016 at an average weight of 127g. They spent 15 weeks in Q1 reaching a density of 92kg/m3 and it was only at that point that we started to see a slowdown in the feeding. As a result of the repairs made to the biofilter the water quality was excellent throughout their time spent in Q1 even at a new record feed load of 291kg/day and this was instrumental in permitting the fish to attain this new upper density threshold and a TGC of 2.2. As a result of the improved conditions created in Q1 this cohort (and future cohorts) will have a better start to their growth curve, which combined with the opportunity to avoid excessive densities later on (as a result of more space created with the conversion of the old purge tank) has the potential to surpass the best growth achieved at the facility to date.

Feeds and Feeding
Please see the section on Cohort #1 in previous reports as well as Cohort #8 for a complete description of the diet used.

Fish Health
This cohort is currently 1kg average weight and mortalities to date have been very low at 3.3%

Cataracts
These fish were last sampled for cataracts at about 800g at which point 1.4% of the population had cataracts and these were 16% smaller than the average without cataracts (it should be noted however,

that only 4 fish were recorded with cataracts out of 150 fish sampled so this will likely skew the percentage).

Maturation

N/A – not yet large enough to sample.

Production Summary

Cohort (month/Year) =>	**0313**	**1013**	**0114**	**0514**	**1014**	**0115**	**0415**	**1015**	**0116**	**0516**	**Totals/Averages**	
Cohort #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	Completed Cohorts	All Groups
Length of Cycle weeks	76	64	68	71	61	72					69	
Production												
FCRb	1.25	1.12	1.08	1.03	1.30	1.15	1.29	0.89	0.86	0.86	1.16	1.08
FCRe	1.43	1.17	1.32	1.15	1.60	1.20	1.38	1.22	0.88	0.86	1.31	1.22
TGC (lifecycle)	1.5	1.5	1.6	1.7	1.3	1.4	1.5	1.4	1.7	1.7	1.49	1.53
SGR (lifecycle, %bw/d)	0.7%	0.7%	0.7%	0.8%	0.8%	0.7%	0.7%	0.9%	1.0%	1.3%	0.01	0.01
Average Condition	1.23	1.18	1.20	1.25	1.27						1.23	1.23
Current Biomass (mt live)	0	0	0	0	0	0	67	44	40	16	0	166
Total Production (mt live)	58	72	80	102	63	112	96	40	35	11	488	670
Smolts stocked (#)	23,503	33,723	40,210	41,387	45,163	45,340	39,840	40,136	40,456	37,536	36,797	44,186
Current Inventory (#)	0	0	0	0	0	0	19,839	35,553	39,104	37,311	0	131,807
Density Average	36	39	47	55	36	51	61	43	55	40	44	
Maximum	67	69	94	96	81	114	102	89	92	61	87	
Mortality & Fish Health (% of start number)												
Fungus	9.7%	2.6%	18.5%	17.5%	4.2%	0.3%	1.5%	2.0%	0.2%	0.0%	8.8%	5.6%
Other	6.2%	1.1%	2.4%	1.8%	1.1%	5.3%	6.3%	3.0%	2.0%	0.2%	3.0%	2.9%
Culls	3.3%	3.0%	1.5%	1.2%	0.3%	2.2%	2.4%	4.4%	0.1%	0.1%	1.9%	1.8%
NVM	3.9%	3.1%	4.2%	2.0%	1.3%	1.5%	1.8%	1.4%	0.4%	0.0%	2.7%	2.0%
Adjust.	1.2%	2.9%	1.9%	1.8%	5.1%	4.1%	6.2%	0.0%	0.0%	0.0%	2.8%	2.3%
Mechanical							0.01%	0.52%	0.64%	0.28%		
Samples							0.31%	0.11%	0.00%	0.00%		
Precocial							0.01%	0.01%	0.00%	0.00%		
Total Number	24.1%	12.7%	28.5%	24.3%	12.0%	13.5%	18.5%	11.4%	3.3%	0.6%	19.2%	14.9%
Mort Biomass (mt)	8.8	4.7	14.7	6.2	1.9	8.4	7.1	3.9	0.6	0.03	44.7	56.4
(% of prod.)	15%	7%	18%	6%	3%	7%	7%	10%	2%	0.3%	9%	8%
Early Maturation	100%	41%	*42%*									
Harvest												
Total (kg HOG)	50,071	62,550	71,545	89,961	57,631	106,359	29,424	0	0	0	438,115	467,539
Average Size (kg HOG)	2.7	2.1	*2.8*	3.4	1.4	2.4	2.5	0.0	0.0	0.0	2.5	2.5
Total Feed (kg)	83,305	84,650	105,777	116,903	101,127	134,533	132,512	49,216	30,641	9,278	390,635	808,023
Water Quality												
Temperature	14.3	13.9	14.0	13.7	14.1	14.6	14.9	15.1	15.1	14.9	14.1	14.5
CO2 (mg/l average)	15.0	14.0	16.0	14.0	13.7	14.0	15.1	14.2	11.5	5.0	14.4	13
Salinity (ppt average))	3.0	2.0	4.0	3.6	4.7	4.7	4.7	4.3	5.0	4.1	3.7	4.0
Total Ammonia -N (mg/l average)	0.6	0.7	0.8	0.8	0.9	1.1	1.3	2.5	2.3	0.6	0.8	1.2
Nitrate-N (mg/l average)	58	115	122	126	83	77	75	52	48	64	97	82
Nitrite-N (mg/l average)	0.46	0.26	0.21	0.11	0.16	0.16	0.24	0.76	0.79	0.10	0.23	0.3
Alkalinity (mg/l average)	29	52	54	64	90	96	109	106	109	85	64	79

NVM = No Visible Marks

Flavour

Due to the use of biofilters and the build-up of bacterial colonies on all culture surfaces (including pipe works), RAS systems will always harbour some flavour changing bacteria and therefore produce some flavour changing compounds. Flavour changing compounds like geosmin and MIB typically cause the fish to taste mossy or muddy. People's palates vary greatly in their ability to detect flavour changing compounds in fish, and the levels of these compounds in different fish from the same harvest will vary. While methods to remove or reduce the prevalence of these compounds in growout systems are being developed, purging salmon that have accumulated flavour changing compounds will continue to be required, prior to the fish being harvested.

Flavour changing compounds were detected at Kuterra in November 2015, likely due to the system maturing in terms of biofilm growth over time and as feed levels and biomass increased. It became necessary to increase the purge times in order to achieve the desired fish flavour. Increased purge times delayed the harvest, slowed cash flow, and impacted production and the bioplan.

The change in flavour was traced to an increase in geosmin in the system and so in November the focus shifted to identifying and implementing strategies that would:

1. Increase the efficiency of the purge system and purge process; and
2. Reduce the level of geosmin in the growout system, thereby lowering the amount of geosmin in the fish.

The first strategy was to improve the efficiency of the purge system and process.

Since the last report, two new harvest tanks have been completed, and the first fish were transferred into the first of the new tanks on July 4th. The new 100m3 harvest/purge tanks incorporate many changes that were tested in the old 250m3 purge tank. Two granulated activated charcoal (GAC) filters have been installed on each new tank to remove geosmin from the water as the fish emit it, in order to maintain a delta that is as large as possible between the geosmin in the fish and the geosmin in the purge water.

The new purge tanks.

The new purge tanks also have a much higher exchange rate than the old purge tank in order to improve the flushing of geosmin from the tank as the fish emit it. Factoring in the GAC filters, the new tanks flush the equivalent of 25.6 times per day, compared to the previous 12.6 tank exchanges per day. This was achieved by activating an 8” well for additional water, and by building a purge water effluent channel to handle the additional, very clean, purge effluent.

The elimination of CO_2 stripping equipment and a much simplified piping design has reduced the surface area of the new purge system in order to minimize the growth of biofilm and to make it easier to clean. All of these factors have improved the efficiency of the purge system. An ancillary benefit is that the new fish transfer system is much smoother and more gentle on the fish. There were no mortalities when the first 3MT of fish were pumped into the first new purge tank. With the old system, on average there would be two mortalities per tonne of fish pumped.

The second strategy was to reduce the level of geosmin in the growout system, in order to reduce the geosmin loading in the fish.

Three things have been done to reduce geosmin in the growout system.

A. The sand was pumped from three of the four growout biofilter cells and additional holes were drilled in the lateral pipes in each cell to improve the sand fluidization. In addition, one biofilter cell has been shut down. This increases the amount of flow that is available to the rest of the system and other cells. It is hoped that these changes will improve the functioning of the biofilter to the same extent that the modifications to the quarantine biofilter have improved its operation and effectiveness.

   Geosmin testing prior to the changes showed that geosmin was highest in the biofilters. Subsequent testing showed that geosmin levels in the growout dropped from 250ng/l to their lowest levels (27ng/l) immediately after the cells were modified in June.

B. In July the inside of the remaining pipes in the growout system were cleaned. Very little algae/growth appeared to be removed by the cleaning, so the pipes are likely not a major source of geosmin creation.

C. In May and June a company agreed to create a mix of bacteria that should destroy geosmin producing bacteria. This mixture arrived in July and as is currently being trialed.

Geosmin levels in the growout are tested weekly so that the impact of these various interventions can be measured. As at time of writing, Albion’s quality control staff have confirmed that the flavour of KUTERRA salmon is back to its previous premium standard.

Looking ahead, it is clear that having an effective purge system and purge process is critically important to ensure that one’s fish meet the desired low levels of flavour changing compounds and meet the taste requirements to be sold as a premium product. One idea for new designs is to allow for the fish to be held in a tank (just prior to being transferred to the final purge tank) in which they can be flushed at a very high rate (I.e. partial flow through) while still being fed. Once the geosmin or other flavour changing compounds in them is low enough, they could then be transferred for just a few days into the final purge tank. This approach:

- Would reduce the risk of fish not meeting the desired flavour profile, no matter the level of flavour changing compounds in the system;

- Would reduce shrinkage due to extended purge times, during which the fish are not fed; and
- Would address the concern that purge time limits may be established by governments or animal welfare advocates.

Having an adequate supply of water is key to this strategy, therefore access to salt water is strongly advised and should be a key design/site criteria. The incremental costs of incorporating this strategy into a new design and into the operations have not been calculated.

Pipes (laterals) at the bottom of a biofilter cell.

Additional holes were drilled in the pipes, especially at the corners/elbows.

Flavour Summary

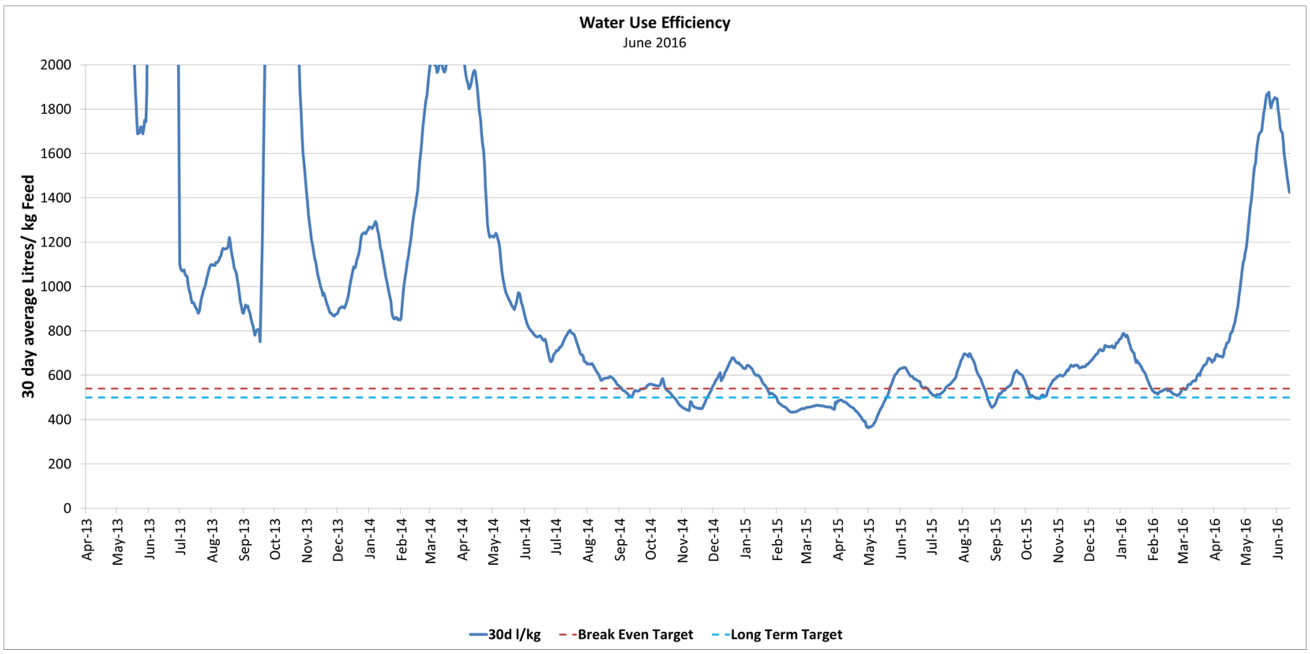
The strategies to improve the effectiveness of the purge process have been completed with the completion and commissioning of the new purge tanks. The new tanks and increased flushing have been effective at removing flavour changing compounds. The impact of the changes to the biofilter should be fully known by September, once the biofilter cells have fully stabilized. The effectiveness or impact of the new bacteria that will be added to the growout system should also be known by September.

New design ideas have been generated in order to address the issue of flavour changing compounds in new facilities, but the new ideas and strategies have not yet been costed out and/or implemented.

Engineering and Environment

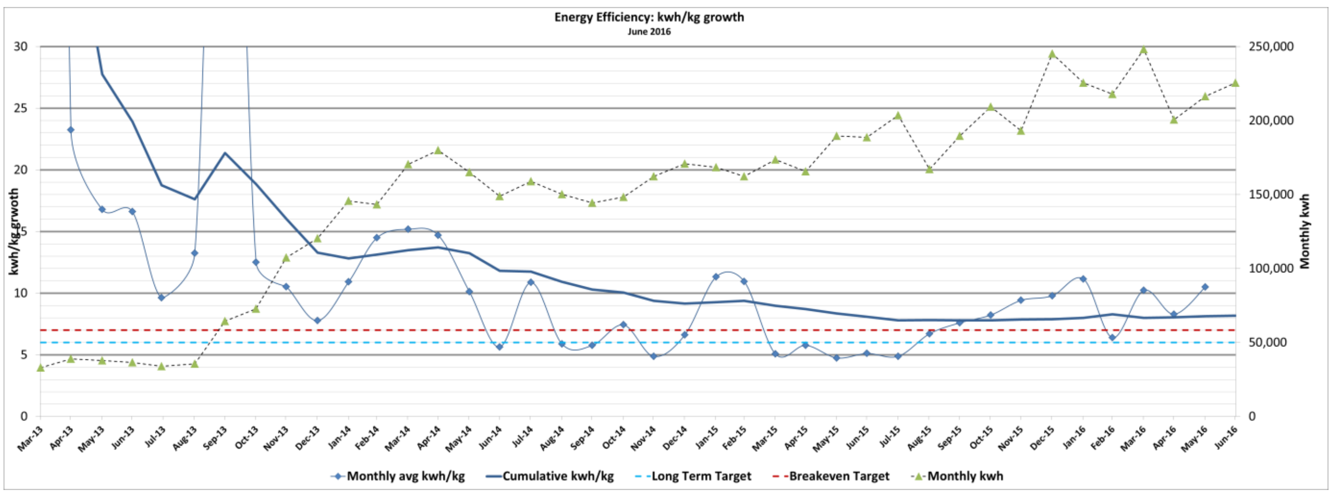
The following presents a summary of water and power use metrics since start up.

Water Use- Production Facility	Max	Min	Average	Total/pd	
Total (m3/day)	2,881	602	2,030	369,452	Includes purge overflow
Total (lpm)	2,001	418	1,410	256,564	Includes purge overflow
Recirculating flow (lps)			1946		Average in Grow out and Quarantine
Exchange (% wate reuse /cycle)			99.39%		Excludes purge
Exchange (% replacement /day)			29%		Excludes purge
Exchange (minutes/tank exchange)			25		Excludes purge
Litres/kg feed- Production Only			1,531		Excludes purge overflow
Average/day (m3/day)- Production Only			861		Excludes purge overflow
Litres/kg feed- Purge Overflow Only			1,214		Excess of culture needs
Average/day (m3/day)- Purge Overflow Only			1,180		Excess of culture needs



The average power use has stabilized at approximately 8kwh/kg of production.

Energy- Electricity	Jan 1/2016 - June 30/ 2016						
Energy Cost:	**$0.077**	/kwh	Blended cost of all charges				
	%	kwh	kwh/kg	kwh/tfp	Cost/kg	kg= biological production (not net prod.)	
Growout RAS	33%	447,388	3.2	3,155	$0.24		
Oxygen generation	7%	89,427	0.6	631	$0.05		
Quarantine RAS	6%	80,172	0.6	565	$0.04		
Heat/Cool	26%	350,648	2.5	2,473	$0.19	Includes geothermal wells	
Purge	1%	15,778	0.1	111	$0.01		
Other	27%	360,587	2.5	2,543	$0.20	Supply wells, UV, feeders, general lighting, office heat	
Total Current	**100%**	**1,344,000**	**9.5**	**9,478**	**$0.73**		



Sales and Revenue

For the period January 1 – June 30, 2015 (Q1 & Q2, 2016) the harvest and processing results were primarily represented by Cohort #6 which was harvested over the period January 18 to June 13, 2016. These fish were slightly smaller compared to fish harvested during the same period in 2015. The smaller size was a major factor in the higher percent of downgrades for the period compared to the same period in 2015.

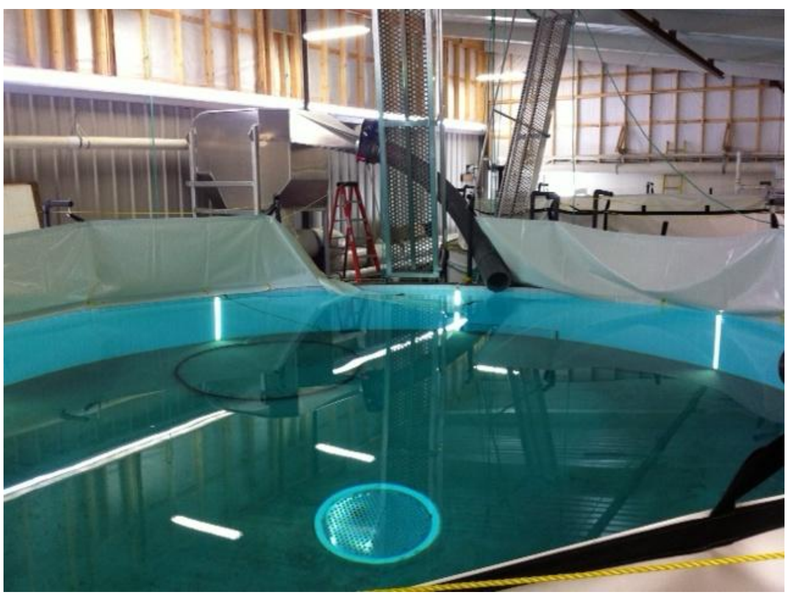
Prices for all products continue to remain stable despite challenges to maintaining a high percentage of premium quality products.

Customers have clearly indicated a need to have fresh fish delivered weekly, so as to ensure that they have adequate shelf life when they receive them. This is particularly important with the food services sector. As a result, two new 100m3 purge tanks were designed and built. The first fish were transferred into the new tanks in July 2016. The tanks replace the old 250m3 purge tank and enable the old tank to be converted to a growout tank, which will extend the production cycle by roughly one month. It is expected that the move to weekly harvesting (possible with the new purge tanks) will open up new market possibilities and further stabilize prices.

Total Processing and Sales Summary

Calendar Years >>		2014				2015				2016		Total/
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Average
Average Size (kg HOG)		**1.6**	**2.2**	**2.8**	**2.0**	**2.4**	**2.7**	**3.1**	**1.4**	**1.7**	**2.5**	**2.2**
Harvest Volume	kg HOG	792	28,847	19,831	40,698	63,848	47,335	74,346	47,033	63,284	61,851	445,968
Sales Volume	Kg HOG equiv.		21,147	16,496	17,711	58,054	47,002	62,126	41,045	56,516	59,340	377,499
	lbs HOG equiv.		46,621	36,368	39,045	127,985	103,620	136,963	90,487	124,594	130,821	832,235
Unsold Inventory (kg HOG equiv*)			7,847	13,729	29,542	36,979	38,450	49,488	51,775	53,209	51,730	29,339
Quality (% Premium)			**85%**	**66%**	**77%**	**81%**	**85%**	**64%**	**42%**	**65%**	**83%**	**72%**
Processing Yields												
Round to HOG			88%	87%	89%	90%	90%	91%	91%	91%	91%	90%
HOG to Fillet (all trims)			65%	57%	64%	63%	64%	64%	63%	64%	63%	63%
Round to Fillet			57%	51%	61%	57%	58%	58%	57%	58%	57%	57%
Fillet to Portion (all sizes)						74%	59%	78%	69%	44%	0%	65%
Live to Round (estimated)			94%	94%	94%	94%	94%	94%	94%	94%	94%	94%

* Fresh and Frozen



New purge tank ready to receive fish.

Financial Update

The following financial summaries have been updated based on the information provided by the growout, harvest, and sale of Cohorts 1 - 6.

Overall, the business remains close to the breakeven level with respect to production costs. As improvements continue to be made it is expected that more stable and positive cash flows will result. Early maturation, slow growth, irregular timing of smolt intakes, and recently, flavour changes, continue to be the major impediments to improving financial success.

While costs and production processes continue to improve, the poor growth in recent cohorts (decrease in total production) has had a significant impact on the unit costs. See graph and chart of unit costs of added biomass (Production Cost) below.

At present, there is no clear explanation for this trend in growth. However, after examination of the various factors that may be correlated to changes in growth rates, the following offers a potential explanation and pathway for improvement:

It appears that changes in growth patterns correlate strongly with changes in rearing density. However, density per se (e.g. behavioural response to density) may only be a correlate and not the causative factor in growth rate changes observed. For example, one or more water quality elements such as CO_2 or oxygen may be the actual limiting factors. As density increases, the ability of the systems to maintain good water quality throughout each tank is challenged, particularly now that maximum biomass has been reached.

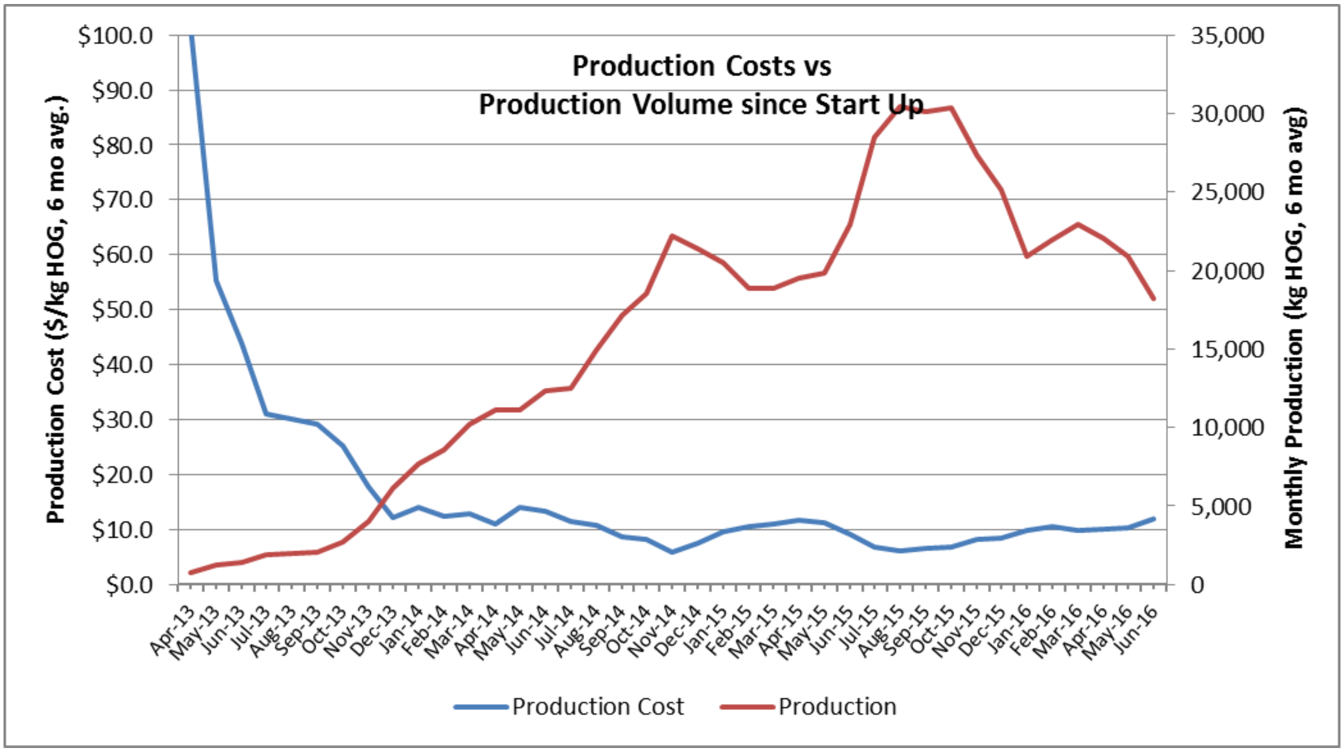
It may be that the assumptions for what are safe limits for controlled parameters, such as CO_2 and oxygen, may be incorrect for the specific water conditions at Kuterra. For example, Atlantics reared in warm, soft, slightly saline freshwater (such as at Kuterra) probably have different requirements for CO_2 and oxygen than Atlantics reared in "hard " non-saline freshwater (i.e. as at the Freshwater Institute) or in saline waters, such as is used by several other RAS Atlantic salmon producers. So the "safe" limits that were derived through trials at the Freshwater Institute, and which we are using at Kuterra, may not be accurate or safe at Kuterra, because Kuterra's soft, slightly saline water is very different from the Freshwater Institute's non-saline, hard, freshwater.

Therefore with respect to Kuterra, since internal oxygen and CO_2 requirements are related to the metabolic rate of the fish, which is temperature dependent, and are limited by the rate exchange processes in the gills, rearing the fish at lower temperatures may offer a pathway to improving biological efficiency and growth, as well as reducing early maturation rates.

For new facilities, water treatment systems should be designed to maintain conservative water quality parameters unless fish performance and safe water quality limits have been established for the same background/influent water (e.g. water with a similar ionic / mineral composition). Rearing Atlantics in saltwater may offer a safer pathway in this respect because:

1. It is the same type of water that Atlantics have evolved to spend their adult life in; and
2. There is more available information about water quality requirements for rearing Adult Atlantics in saltwater than for raising them in freshwater.

In July 2016 a new, two tank purge facility was put into operation. This will allow weekly harvesting, which will greatly improve marketing options for all products and reduce market risk. In addition, it will allow the existing 250m3 purge tank to be used for production. This in turn will allow for a lengthening of the overall production cycle by 4-5 weeks, which will result in an increase in average fish size at harvest.

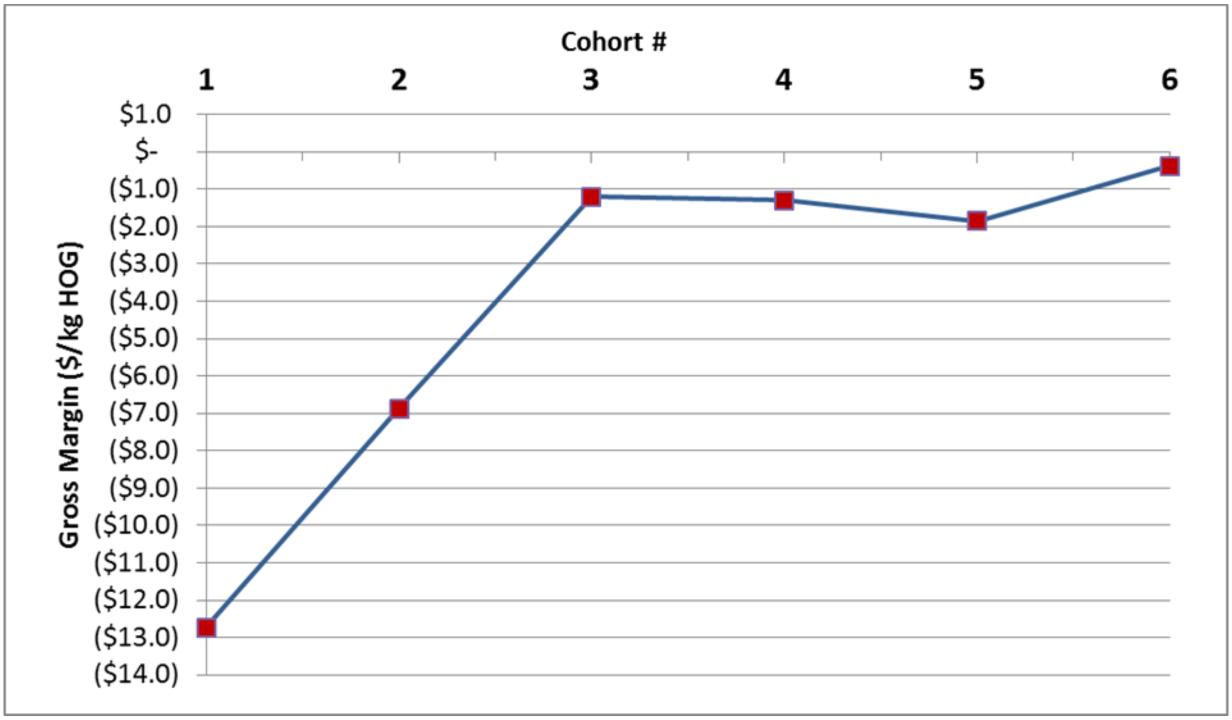


Production Costs and Returns Summary

Production Costs and Returns	2014 Q1	2014 Q2	2014 Q3	2014 Q4	2015 Q1	2015 Q2	2015 Q3	2015 Q4	2016 Q1	2016 Q2	Totals / Avg.	ST Targets
Production (kg HOG)	26,681	36,446	51,065	58,165	38,000	79,116	74,481	54,047	62,945	30,163	511,108	292,000
Current Production Costs ($/kg HOG) (Marginal cost of biomass added *)												
Feed	$2.67	$3.13	$2.41	$2.36	$3.81	$2.59	$2.87	$3.83	$2.99	$5.61	$3.08	$2.69
Smolts	$5.22	$3.80	$0.00	$2.63	$3.80	$1.68	$0.00	$2.41	$2.45	$4.82	$2.23	$1.28
Labour	$3.35	$3.50	$1.32	$1.59	$3.28	$1.12	$1.45	$2.10	$1.61	$3.21	$1.98	$1.48
Power	$2.17	$0.83	$0.93	$0.94	$1.79	$0.42	$0.74	$0.76	$0.81	$2.22	$0.99	$0.45
Water Treatment	$0.38	$0.58	$0.21	$0.57	$0.26	$0.34	$0.25	$0.70	$0.43	$0.83	$0.43	$0.17
Insurance	$0.55	$0.46	$0.32	$0.29	$0.29	$0.22	$0.23	$0.33	$0.29	$0.62	$0.32	$0.09
Maintenance	$0.44	$0.26	$0.10	$0.37	$1.20	$0.22	$0.33	$0.39	$0.26	$0.43	$0.36	$0.27
Other- Variable	$1.27	$0.46	$0.72	$0.55	$0.95	$0.31	$0.67	$1.20	$0.53	$0.46	$0.67	$0.25
- Fixed	$2.36	$0.86	$1.34	$1.03	$1.38	$0.79	$1.37	$1.15	$1.09	$3.15	$1.30	$1.17
Total Cost	$18.42	$13.88	$7.36	$10.34	$16.76	$7.68	$7.92	$12.89	$10.45	$21.35	**$11.36**	**$7.85**
Sales												
Harvest volume (kg HOG)	803	29,268	20,355	40,514	64,022	47,523	74,346	47,033	63,283	61,851	448,999	
Sales volume (kg HOG)	17	21,215	16,742	17,631	58,212	47,002	62,126	41,045	56,516	59,340	379,845	
Net back to farm revenue($/kg HOG)	-$1.9	$9.4	$6.7	$9.7	$8.9	$10.0	$8.1	$7.3	$8.6	$8.2	**$8.5**	**$8.59**
Gross Margins*												
On Production Costs	-$20.4	-$4.5	-$0.7	-$0.7	-$7.9	$2.3	$0.1	-$5.6	-$1.9	-$13.1	**-$2.8**	**$0.7**
On Variable Production Costs	-$18.0	-$3.6	$0.7	$0.4	-$6.5	$3.1	$1.5	-$4.4	-$0.8	-$10.0	-$1.5	

Cohort Margin Analysis

Cohort # 6 had a slightly better gross margin that previous cohorts based on this analysis. This was a result of slightly better sales price (product quality) and slightly lower unit costs. Note: The Production Costs in the previous chart represents the cost of biomass added today (= Future costs of fish to be sold/ Forward looking analysis). Conversely the cohort margin analysis represents costs that were accumulated and allocated to each cohort since they were stocked (Backward looking analysis).



Cohort	**0313**	**1013**	**0114**	**0514**	**1014**	**0115**
	1	2	3	4	5	6
Production						
Size/ harvest size (kg HOG)	2.8	2.1	2.4	2.9	1.4	2.4
Harvest to date (kg HOG)	50,341	51,954	81,336	86,331	71,026	107,398
Cost ($'000)						
Total cost of fish harvested	952	626	797	821	661	964
Fixed Costs re Fish harvested	106	77	85	83	71	113
Variable (direct) re Fish Harvested	846	549	712	738	590	851
Revenue ($'000)						
Sales*	312	269	699	711	529	923
Margins ($'000)						
On Total Costs	(640.9)	(357.4)	(98.5)	(110.1)	(131.6)	(41.3)
On Variable Costs	(534.4)	(280.7)	(13.4)	(27.2)	(60.9)	72.0
Unit Returns ($/kg HOG)						
Total Cost	$ 18.92	$ 12.05	$ 9.80	$ 9.51	$ 9.30	$ 8.97
Total Revenue	$ 6.19	$ 5.17	$ 8.59	$ 8.20	$ 7.45	$ 8.59
Gross Margin on Total Cost	($ 12.73)	($ 6.88)	($ 1.21)	($ 1.31)	($ 1.85)	($ 0.38)
Margin on Variable Costs	($ 10.62)	($ 5.40)	($ 0.16)	($ 0.35)	($ 0.86)	$ 0.67

Notes:

- Costs do not include: Interest, Depreciation or Corporate Overheads .
- Revenue does not include the value of harvested but unsold fish (eg frozen inventory).
- Costs were allocated to each cohort on the basis of relative biomass except for smolts which were allocated based on actual costs.

Acknowledgements

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The Project was made possible thanks to vision and support of the 'Namgis First Nation, SOS Marine Conservation Foundation, Tides Canada, Sustainable Development Technology Canada, Department of Fisheries and Oceans, Aboriginal Affairs Canada, the Ritchie Foundation, and a number of other funders and collaborators.

On behalf of wild salmon, the 'Namgis, and the Kuterra team – thank you all.

Appendix

Weekly Data Summaries

Cohort #5 (1014)

Week	Size	TGC	Condition	Morts	Feed	Density	TAN	TSS	Nitrite	Nitrate	Ph	CO2	Salinity	Alkalinity	Hardness	Turbidity	Harvest	Biomass	Inventory	Pigment	Fat	Protein	Photo-
1	99	103		5	14	17	0.38				7		6.2	60		0.4		4450	45139	80	25	45	11
2	103	117		1	37	18	0.48		0.01	63		4	6.5	70		0.4		4655	45121	80	25	45	11
3	111	132		2	58	20	0.62		0.01	11			6.1	60		0.4		4992	45114	80	25	45	11
4	123	147		0	83	22	0.95		0.10	26			5.7	60		0.3		5530	45107	80	25	45	11
5	152	164	1.2	1	105	27	0.94		0.02	102		9	5.5	125		0.4		6863	45101	80	25	45	11
6	182	182		1	99	32	0.93		0.07	113		8	5.2	115		0.3		8186	45095				11
7	198	202		2	109	35	0.88						4.9			0.5		8937	45084				11
8	219	222		3	124	39	0.93			35		15	4.9			0.3		9846	45062				11
9	241	244		3	141	43	0.92			61	7	11	4.9			0.2		10860	45048				24
10	278	268	1.5	6	142	49	0.83			227			4.9			0.3		12513	45009				24
11	374	293		5	127	66	0.34			67		15	4.9			0.3		16833	44969				24
12	338	319		3	41	48	0.24		0.03	84	8		4.6			0.3		15183	44933	80	25	50	21
13	306	346		4	42	28	0.81	5.5	0.02	77	7	19	3.7	70		0.4		13761	44913	80	25	50	24
14	303	375		4	65	27	0.22		0.02	76	7	23	3.3	70		0.8		13604	44886	80	25	50	24
15	285	406	1.1	4	108	26							3.0			0.6		12767	44854	80	25	50	24
16	305	439		5	149	27	0.78	5.3					2.6			0.8		13654	44814	80	25	50	24
17	332	473		4	164	30	0.88						2.5			1.0		14867	44794	80	25	50	24
18	361	508		9	175	32	0.84		0.06	97			2.4			0.7		16169	44753	80	25	50	24
19	392	549		18	183	35	0.83		0.08	139			1.7	90		0.6		17524	44678	80	25	50	24
20	474	592		36	182	42							1.5			0.5		21066	44459	80	25	50	24
21	506	637		82	194	45			0.07	44			1.7			0.3		22297	44050	80	25	50	24
22	538	684		68	210	47	0.92			31			3.6			0.3		23411	43485				24
23	574	734		30	231	50	0.95						5.1			0.3		24763	43169				24
24	627	776		7	232	54	0.58			113		23	5.3			0.2		26988	43053				24
25	685	813		4	253	59	1.10				7	19	4.8			0.4		29485	43015				24
26	726	852		2	259	62	1.93			128			5.1			0.4		31228	42998				24
27	753	892		3	239	65	1.19			164			5.0			0.4		32383	42981				24
28	772	933		3	299	66	1.47			79			5.4			0.3		33177	42962				24
29	824	979		1	346	71	1.32		1.47	39	7	10	4.5	83		0.3		35391	42950				24
30	883	1025		4	342	76	1.15		0.05		7	11	3.8			0.6		37919	42934				24
31	808	1075	1.2	25	139	37							3.7			0.6		34627	42852	80	31	41	24
32	853	1125		2	313	22	0.95		0.08				3.5			0.8		36437	42741	80	31	41	24
33	901	1182		2	353	24	1.14				7		3.6	30		0.7		38488	42725	80	31	41	
34	957	1240		3	381	25	0.98					10	3.5			0.7		40868	42707	80	31	41	
35	1019	1297		2	431	26	1.21		0.33	64			3.8	60		0.4		43506	42692	80	31	41	
36	1088	1357		2	479	28	1.04		0.08	29			3.1			0.4		46437	42684	80	31	41	
37	1168	1416	1.2	1	456	29												49832	42671	80	31	41	
38	1242	1476		3	582	31	0.70						3.1			0.5		52988	42653	80	31	41	
39	1326	1542		7	567	33	1.23						3.0			0.5		56492	42604	80	31	41	
40	1391	1607	1.4	3	369	34							3.0			0.4		59233	42586	80	31	41	
41	1419	1673		5	436	34	1.03		0.07		7		3.2			0.3		60401	42565	80	31	41	
42	1474	1742		2	345	35	0.83		0.06				3.0			0.5		62693	42534	80	31	41	
43	1527	1817		6	406	36							3.3			0.5		64898	42511	80	31	41	
44	1581	1894		3	376	37							3.8			0.5		67138	42469	80	31	41	
45	1581	1968	1.3	7	464	37	1.32		0.07	68	8		4.7	120		0.5		67085	42423	80	31	41	
46	1620	2050		4	398	38	1.84		0.07	29			5.1			0.4		68672	42398	80	31	41	
47	1672	2140		6	301	39							5.8			0.4		70819	42365	80	31	41	
48	1714	2231		5	332	40	1.20		0.07				6.4			0.6		72527	42319	80	31	41	
49	1640	2325		4	283	20	1.24		0.11	31			6.9			0.8		57747	35138	80	31	41	
50	1625	2420	1.3	3	245	17	0.96		0.06	38			6.8			0.8		55114	33919	80	31	41	
51	1645	2517		3	294	17							6.9			0.3		55757	33897	80	31	41	
52	1643	2615		4	241	6	0.94		0.13	31			6.9			0.7		45818	27887	80	31	41	
53	1701	2710		3	269	6	1.43		0.20	116	7		6.6	145		0.6		47397	27857	80	31	41	
54	1716	2811		146	169	2	1.35		0.25	130	7		6.3			0.9		39078	22778				
55	1737	2916	1.3	4	202	0	0.70		0.21				6.6			#DIV/0!		36356	20928				
56	1672	3014		3	203	0	1.05		0.08	120	7					#DIV/0!		29091	17228				
57	1657	3083		3	191	0	1.18		0.09	108	7		6.5	130		0.7		23921	14440				
58	1737	3147		2	202	0	1.20		0.15				6.4			0.5		25060	14428				
59	1744	3202		2	134	0	1.37			122			6.1	75		0.6		15196	8689				
60	1821	3257		0	117	0	1.19		0.08	31			6.1			0.6		14081	7732				
61	#DIV/0!	3293		657	64								6.1			0.6		6013	3209				

Cohort #6 (0115)

Week	Size	TGC	Morts	Feed	Density	TAN	TSS	Nitrite	Nitrate	Ph	CO2	Salinity	Alkalinity	Turbidity	Harvest	Biomass	Inventory	Pigment	Fat	Protein	Photo-
1	107	111	13	12	19	0.22		0.03	50	8	#DIV/0!	8		0.5		4825	45290	80	25	45	24
2	109	125	9	18	19	0.23	5.0	0.11	30	7	14	9	75	0.9		4937	45204	80	25	45	24
3	113	141	1	25	20	0.29		0.04	81	7	7	9	95	0.5		5102	45178	80	25	45	24
4	118	158	3	30	21		7.5					8		0.6		5314	45164	80	25	45	17
5	122	177	0	37	22	0.49			74			6		0.5		5494	45156	80	25	45	0
6	130	196	1	74	23					7		4		0.2		5888	45149	80	25	45	0
7	146	216	2	110	26	0.68		0.09	83	7		3	120	0.3		6600	45141	80	25	45	0
8	174	238	1	127	31							2		0.2		7866	45130	80	25	45	0
9	216	262	3	144	38							2		0.2		9750	45117				0
10	243	287	3	164	43	0.53	5.3	0.10	46	7	16	2		0.3		10961	45098				0
11	271	314	2	161	48	0.93		1.08		7		5		0.4		12218	45082				0
12	300	342	1	173	53							8		0.8		13501	45069				0
13	295	370	13	107	30	0.81		0.02	77	7		4		0.4		13276	44994	80	25	50	21
14	315	401	2	160	28	0.22		0.02	76	7	23	3	70	0.8		14155	44967	80	25	50	24
15	345	433	1	199	31							3		0.6		15505	44961	80	25	50	24
16	382	467	1	237	34		5.3					3		0.8		17189	44956	80	25	50	24
17	442	502	0	258	40	0.88						2		1.0		19853	44950	80	25	50	24
18	489	542	1	294	44	0.84	5.3	0.06	97	7		2		0.7		21994	44945	80	25	50	24
19	537	585	1	291	48	0.83		0.08	139	7		2	90	0.6		24133	44939	80	25	50	24
20	579	629	2	269	52							2		0.5		26017	44929	80	25	50	24
21	637	671	2	293	57			0.07	44	7		2		0.3		28615	44914	80	25	50	24
22	705	712	3	365	63	0.92			31	7		4		0.3		31634	44897				
23	761	754	4	361	68	0.95		0.98		7	19	5		0.3		34168	44874				
24	818	797	5	380	73							5		0.2		36702	44844				
25	874	840	3	357	78	1.10				7		5		0.4		39187	44814				
26	933	884	3	369	84	1.93		0.20	128			5		0.4		41806	44792				
27	994	931	5	436	89	1.19		0.07	164	7		5		0.4		44507	44759				
28	1047	980	5	268	94							5		0.3		46845	44737				
29	1075	1029	11	147	96	1.32		1.47	39	7	10	4		0.3		48006	44667				
30	1099	1079	6	184	98	1.15		0.05		7	11	4		0.6		49038	44609	80	29	45	
31	1158	1133	2	139	103					7	9	4		0.6		51630	44580	80	29	45	
32	1203	1192	13	92	107	0.95		0.08	37			4		0.8		53564	44531	80	29	45	
33	1216	1249	6	194	108	1.14		0.09	41	7	14	4		0.7		54073	44460	80	29	45	
34	1216	1307	6	276	108	0.98					10	4		0.7		54003	44422	80	29	45	
35	1254	1366	9	263	111	1.21		0.33	64		8	4		0.4		55621	44370	80	29	45	
36	1330	1427	62	98	86	1.04		0.08	29			3		0.4		58775	44189	80	29	45	
37	1415	1489	6	327	26			0.09	18			3		0.3		62093	43874	80	29	45	
38	1460	1553	3	376	27	0.70						3		0.5		64032	43852	80	29	45	
39	1534	1617	4	437	31	1.23						3		0.5		67209	43824	80	29	45	
40	1597	1683	5	476	32							3		0.4		69948	43800	80	29	45	
41	1668	1753	6	564	34	1.03		0.07		7		3		0.3		73000	43757	80	29	45	
42	1744	1824	4	518	35	0.83		0.06				3		0.5		76217	43711	80	29	45	
43	1825	1896	33	458	37							3		0.5		79643	43632				
44	1920	1969	6	650	39							4		0.5		83425	43457				
45	2012	2047	9	679	41	1.32		0.07	68	8		5		0.5		87315	43402				
46	2105	2131	10	653	43	1.84		0.07	29			5		0.4		91229	43345				
47	2189	2219	4	565	45							6		0.4		94764	43288				
48	2261	2311	4	529	47	1.20		0.07				6		0.6		97831	43264				
49	2333	2404	5	528	48	1.24		0.11	31			7		0.8		100884	43236				
50	2391	2500	51	285	48	0.96		0.06	38			7		0.8		99747	41732				
51	2440	2596	2	294	39							7		0.3		87333	35796				
52	2497	2696	4	440	39	0.94		0.13	31			7		0.7		89321	35772				
53	2525	2798	13	316	42	1.43		0.20	116	7		7		0.6		87782	34739				
54	2479	2897	7	315	46	1.35		0.25	130			6		0.9		80045	32296				
55	2540	2995	7	340	47	0.70		0.21				7				80424	31675				
56	2612	3055	5	390	55	1.05		0.08	120							73695	28216				
57	2694	3110	6	419	56	1.18		0.09	108	7		7		0.7		75922	28181				
58	2763	3166	10	337	61	1.20		0.15				6		0.5		74349	26905				
59	2802	3223	4	338	69	1.37			122	7		6		0.6		66805	23846				
60	2867	3279	5	294	75	1.19		0.08	31			6		0.6		64971	22657				
61	2916	3338	5	195	84							6		0.6		59967	20544				
62	3006	3403	284	154	75	1.45		0.08	101			6		0.2		62532	20808				
63	3168	3471	7	161	34	0.81		0.05	24			6		0.0		54717	17270				
64	3199	3533	8	155	28	1.15		0.06	49			6		0.3		51006	15929				
65	3197	3611	6	167	12							5		0.2		40370	12629				
66	3013	3709	11	212	35	0.38		0.10				6		0.2		37931	12478				
67	2780	3800	2	173	53	1.20		0.07	68	7		6		0.2		26651	9586				
68	2884	3890	8	144	48							4		0.2		23894	8305				
69	2991	3990	1	86	33	1.16		0.08	71			4		0.3		16339	5459				
70	3098	4071	8	82	33	1.10		0.12	22			4		0.5		16412	5327				
71	3251	4136	2	37	19							4		0.4		9620	2959				
72		4189	134	16				0.11	38	7		3		0.4		7711	2328				

Cohort #7 (0415)

Week	Size	TGC	Morts	Feed	Density	TAN	Nitrite	Nitrate	Ph	CO2	Salinity	Alkalinity	Hardness	Turbidity	TDS	Water	Harvest	Biomass	Inventory	Pigment	Fat	Protein	Photo-
1	126	131	36	11	20	0.3	0.06	42	7.0		5.9			3.9				5012	39718	80	25	45	24
2	128	147	77	14	20		0.04	6	7.0		6.5			2.2				5029	39275	80	25	45	24
3	134	163	19	45	20		0.06	26	7.1	9	6.5			0.6				5216	39016	80	25	45	24
4	145	183	6	74	22		1.22	126	7.0		6.3	140		0.8				5646	38939	80	25	45	24
5	162	204	3	100	25		0.20	1	7.1	9	6.1	130		1.4				6318	38906	80	25	45	24
6	184	226	3	113	28		0.20		7.0		5.7			2.9				7136	38883				24
7	226	250	3	122	34	0.8	0.32			8	5.2			3.6				8764	38863				24
8	275	275	3	133	42	0.9	0.37	23			4.7			2.6				10670	38840				24
9	304	302	6	162	46	1.3	0.45	14	7.2	10	4.0	145		2.4				11801	38818				24
10	337	330	2	163	51	1.1	0.57	32			3.0	120		1.5				13073	38788				24
11	370	359	3	176	56	1.2	0.82	40			3.1			1.2				14357	38763				24
12	411	391	2	192	63													15943	38746				24
13	459	423	1	182	70													17760	38732				24
14	499	458	1	222	76													19317	38725				24
15	540	495	1	223	82						3.6			0.6				20900	38719				24
16	582	536	2	247	88	0.5		74			6.1			0.5				22541	38710				24
17	628	584	5	160	88						4.1			0.4				24282	38683	80	28	46	21
18	652	628	3	185	50	0.8	0.06	97	7.0		2.4			0.7				25200	38657	80	25	50	24
19	689	670	1	255	53	0.8	0.08	139	7.0		1.7	90		0.6				26621	38643				24
20	740	720	5	323	57						1.5			0.5				28564	38623				24
21	854	771	6	364	66		0.07	44	7.1		1.7			0.3				32960	38587				24
22	932	814	2	403	72	0.9		31	7.1		3.6			0.3				35947	38562				10
23	1003	858	1	368	77	1.0	0.98		6.9	19	5.1			0.3				38676	38547				
24	1060	903	2	333	82	0.6	0.10	113	7.0	23	5.3			0.2				40828	38534				
25	1109	950	6	291	85	1.1			7.1	19	4.8			0.4				42695	38505				
26	1159	998	4	356	89	1.9	0.20	128			5.1			0.4				44589	38466				
27	1215	1047	4	355	93	1.2	0.07	164	7.0		5.0			0.4				46718	38445				
28	1271	1100	7	296	98	1.5		79		12	5.4			0.3				48791	38403				
29	1306	1153	3	158	100	1.3	1.47	39	7.1	10	4.5	83		0.3				50104	38370				
30	1304	1208	484	106	70	1.2	0.05		7.1	11	3.8			0.6				47674	36540				
31	1269	1263	2	261	0				7.1	9	3.7			0.6				44825	35315				
32	1329	1321	3	389	0	0.9	0.08	37			3.5			0.8				46900	35295				
33	1401	1380	5	434	0	1.1	0.09	41	6.5	14	3.6	30		0.7				49414	35266				
34	1479	1441	3	485	0	1.0				10	3.5			0.7				52105	35240				
35	1559	1502	1	515	0	1.2	0.33	64		8	3.8	60		0.4				54934	35227				
36	1608	1565	4	468	0	1.0	0.08	29			3.1			0.4				56621	35211				
37	1687	1630	3	457	0		0.09	18			3.1			0.3				59372	35183				
38	1756	1697	4	384	0	0.7					3.1			0.5				61740	35157				
39	1821	1764	8	405	0	1.2					3.0			0.5				63981	35127				
40	1849	1835	176	370	0						3.0			0.4				63232	34207				
41	1919	1913	9	441	0	1.0	0.07		7.2		3.2			0.3				64878	33815				
42	1994	1988	3	382	0	0.8	0.06				3.0			0.5				67350	33784				
43	2072	2070	3	547	0						3.3			0.5				69968	33764				
44	2166	2159	4	499	0						3.8			0.5				73101	33743				
45	2240	2252	5	425	0	1.3	0.07	68	7.5		4.7	120		0.5				75504	33705				
46	2303	2345	5	367	0	1.8	0.07	29			5.1			0.4				77575	33680				
47	2371	2440	2	441	0						5.8			0.4				79812	33655				
48	2383	2538	7	317	0	1.2	0.07				6.4			0.6				77281	32394				
49	2362	2635	4	374	0	1.2	0.11	31			6.9			0.8				72526	30710				
50	2450	2733	6	375	0	1.0	0.06	38			6.8			0.8				75146	30676				
51	2532	2835	6	326	0						6.9			0.3				77575	30633				
52	2590	2933	5	330	0	0.9	0.13	31			6.9			0.7				78106	30160				
53	2651	3029	6	403	0	1.4	0.20	116	7.2		6.6	145		0.6				78289	29536				
54	2729	3108	8	397	0	1.4	0.25	130	7.0		6.3			0.9				80470	29492				
55	2797	3191	2	299	0	0.7	0.21				6.6							82386	29453				
56	2862	3281	5	233	0	1.1	0.08	120	6.9									81872	28611				
57	2927	3372	18	325	0	1.2	0.09	108	7.1	10	6.5	130		0.7				79147	27036				
58	2989	3439	7	213	0	1.2	0.15				6.4			0.5				80588	26962				
59	3034	3496	4	259	0	1.4		122	7.3		6.1	75		0.6				81682	26923				
60	3102	3574	7	361	0	1.2	0.08	31			6.1			0.6				83374	26880				
61	3064	3667	7	306	0						6.2			0.6				79883	26003				
62	2825	3757	12	343	0	1.4	0.08	101			6.4	175		0.2				67440	23877				
63	2926	3820	7	304	0	0.8	0.05	24			6.4			0.0				67474	23076				

Cohort #8 (1015)

Week	Size	TGC	Morts	Feed	Density	TAN	Nitrite	Nitrate	Ph	CO2	Salinity	Alkalinity	Hardness	Turbidity	TDS	Water	Harvest	Biomass	Inventory	Pigment	Fat	Protein	Photo-
1	126	131	36	11	20	0.3	0.06	42	7.0		5.9			3.9				5012	39718	80	25	45	24
2	128	147	77	14	20		0.04	6	7.0		6.5			2.2				5029	39275	80	25	45	24
3	134	163	19	45	20		0.06	26	7.1	9	6.5			0.6				5216	39016	80	25	45	24
4	145	183	6	74	22		1.22	126	7.0		6.3	140		0.8				5646	38939	80	25	45	24
5	162	204	3	100	25		0.20	1	7.1	9	6.1	130		1.4				6318	38906	80	25	45	24
6	184	226	3	113	28		0.20		7.0		5.7			2.9				7136	38883				24
7	226	250	3	122	34	0.8	0.32			8	5.2			3.6				8764	38863				24
8	275	275	3	133	42	0.9	0.37	23			4.7			2.6				10670	38840				24
9	304	302	6	162	46	1.3	0.45	14	7.2	10	4.0	145		2.4				11801	38818				24
10	337	330	2	163	51	1.1	0.57	32			3.0	120		1.5				13073	38788				24
11	370	359	3	176	56	1.2	0.82	40			3.1			1.2				14357	38763				24
12	411	391	2	192	63													15943	38746				24
13	459	423	1	182	70													17760	38732				24
14	499	458	1	222	76													19317	38725				24
15	540	495	1	223	82						3.6			0.6				20900	38719				24
16	582	536	2	247	88	0		74			6.1			0.5				22541	38710				24
17	628	584	5	160	88						4.1			0.4				24282	38683	80	28	46	21
18	652	628	3	185	50	1	0.06	97	7		2.4			0.7				25200	38657	80	25	50	24
19	689	670	1	255	53	0.8	0.08	139	7		1.7	90		0.6				26621	38643				24
20	740	720	5	323	57						1.5			0.5				28564	38623				24
21	854	771	6	364	66		0.07	44	7		1.7			0.3				32960	38587				24
22	932	814	2	403	72	1		31	7		3.6			0.3				35947	38562				10
23	1003	858	1	368	77	1.0	0.98		7	19	5.1			0.3				38676	38547				0
24	1060	903	2	333	82	1	0.10	113	7	23	5.3			0.2				40828	38534				0
25	1109	950	6	291	85	1.1			7	19	4.8			0.4				42695	38505				0
26	1159	998	4	356	89	2	0.20	128			5.1			0.4				44589	38466				0
27	1215	1047	4	355	93	1.2	0.07	164	7		5.0			0.4				46718	38445				0
28	1271	1100	7	296	98	1		79		12	5.4			0.3				48791	38403				0
29	1306	1153	3	158	100	1.3	1.47	39	7	10	4.5	83		0.3				50104	38370				0
30	1304	1208	484	106	70	1	0.05		7	11	3.8			0.6				47674	36540				0
31	1269	1263	2	261	0				7	9	3.7			0.6				44825	35315				0
32	1329	1321	3	389	0	1	0.08	37			3.5			0.8				46900	35295				0
33	1401	1380	5	434	0	1.1	0.09	41	7	14	3.6	30		0.7				49414	35266				0
34	1479	1441	3	485	0	1				10	3.5			0.7				52105	35240				0
35	1559	1502	1	515	0	1.2	0.33	64		8	3.8	60		0.4				54934	35227				0
36	1608	1565	4	468	0	1	0.08	29			3.1			0.4				56621	35211				0
37	1687	1630	3	457	0		0.09	18			3.1			0.3				59372	35183				0
38	1756	1697	4	384	0	1					3.1			0.5				61740	35157				0

Cohort #9 (0116)

Week	Size	TGC	Morts	Feed	Density	TAN	Nitrite	Nitrate	Ph	CO2	Salinity	Alkalinity	Hardness	Turbidity	TDS	Water	Harvest	Biomass	Inventory	Pigment	Fat	Protein	Photo-
1	126	131	36	11	20	0.3	0.06	42	7.0		5.9			3.9				5012	39718	80	25	45	24
2	128	147	77	14	20		0.04	6	7.0		6.5			2.2				5029	39275	80	25	45	24
3	134	163	19	45	20		0.06	26	7.1	9	6.5			0.6				5216	39016	80	25	45	24
4	145	183	6	74	22		1.22	126	7.0		6.3	140		0.8				5646	38939	80	25	45	24
5	162	204	3	100	25		0.20	1	7.1	9	6.1	130		1.4				6318	38906	80	25	45	24
6	184	226	3	113	28		0.20		7.0		5.7			2.9				7136	38883				24
7	226	250	3	122	34	0.8	0.32			8	5.2			3.6				8764	38863				24
8	275	275	3	133	42	0.9	0.37	23			4.7			2.6				10670	38840				24
9	304	302	6	162	46	1.3	0.45	14	7.2	10	4.0	145		2.4				11801	38818				24
10	337	330	2	163	51	1.1	0.57	32			3.0	120		1.5				13073	38788				24
11	370	359	3	176	56	1.2	0.82	40			3.1			1.2				14357	38763				24
12	411	391	2	192	63													15943	38746				24
13	459	423	1	182	70													17760	38732				24
14	499	458	1	222	76													19317	38725				24
15	540	495	1	223	82						3.6			0.6				20900	38719				24
16	582	536	2	247	88	0		74			6.1			0.5				22541	38710				24
17	628	584	5	160	88						4.1			0.4				24282	38683	80	28	46	21
18	652	628	3	185	50	1	0.06	97	7		2.4			0.7				25200	38657	80	25	50	24
19	689	670	1	255	53	0.8	0.08	139	7		1.7	90		0.6				26621	38643				24
20	740	720	5	323	57						1.5			0.5				28564	38623				24
21	854	771	6	364	66		0.07	44	7		1.7			0.3				32960	38587				24
22	932	814	2	403	72	1		31	7		3.6			0.3				35947	38562				10
23	1003	858	1	368	77	1.0	0.98		7	19	5.1			0.3				38676	38547				0
24	1060	903	2	333	82	1	0.10	113	7	23	5.3			0.2				40828	38534				0
25	1109	950	6	291	85	1.1			7	19	4.8			0.4				42695	38505				0