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Varieties in discharge of nutrient from land-based aquaculture freshwater facilities: Flow-through System vs Recirculating Aquaculture System

Vegard Øvstetun Flo
Master of Science in Aquaculture

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Vegard Øvstetun Flo

Department of Mathematical Science and Technology (IMT)

Norwegian University of Life Sciences

Abstract

Salmon farming is a large and still growing industry in Norway. Like all industries that utilize a country's natural resources, will lack of focus on the environmental impact potentially lead to negative consequences. To ensure sustainability and protect the environment, the Norwegian government use production licenses and emission permits to determine how large a salmon production can be, without adversely affecting the recipient water. There is restricted knowledge about the emission from land-based juvenile farms and about the difference between flow-through and a RAS in terms of emissions. In addition, are the licenses given by the county governor office, potentially leading to different practices between the different counties.

This master thesis asses this subject further by looking into two research questions:

- *Does the licensing system urge or stimulate to reduce the emissions from land-based salmon farms, both FTS and RAS?*
- *Is it possible to develop a better model for calculation of emissions from land-based salmon farms, both FTS and RAS?*

To answer these two questions the master is worked out in three parts:

1. Assessment of today's emission permits for land-based freshwater facilities, FTS and RAS
2. Development of a new model (VØF) for calculation of waste from land-based freshwater facilities, based on production system, production plan and mass balance estimates
3. Comparing VØF-model to the models used by the county governor's office for estimation of waste from land-based aquaculture freshwater facilities.

Today most of the emission permits demand a percentage purification of the total production without separating dissolved and particle waste and is more often given to RAS-facilities. This may lead to an incorrect assumption of the emissions from a facility because the tonnage waste produced and released is never actually specified. Secondly, will restrictions in terms of maximum feed usage, biomass, and the number of fish produced, give no room or motivation for self-improvement to reduce waste more effectively. If not tended to, this waste licensing system will certainly not improve the industries sustainability in the upcoming future.

Since the waste from fish farms is dependent on the feed, the feed content for different salmon life stages was mapped. In addition, literature shows that the salmon in average excrete following values of the total nutrient input: 18,33% of C, 52% of P and 15,40% of N as particulate waste, and 3% of C, 18% of P, and 44,40% of N as dissolved waste. The remaining C waste is discharged over the gills of the salmon in the form of 41% CO_2.

The new model (VØF-model) estimated waste with the mass balance principle with a literature background of distribution from a 100% feed input. In this thesis, the feed input to the model was based on six theoretical production plans with weekly calculations on biological needs in salmon production. The production plans simulated production of 100 000 salmon smolt for the sizes 100g, 300g, and 500g, in both FTS and RAS. The focus in the VØF-model is chosen to locate differences in nutrient content of C, P, and N in salmon waste from FTS and RAS.

The VØF-model showed that the total average feed content changed with the different compositions in fry, fingerling, and smolt feed. The model also showed the following overall average content in RAS feed, compared to FTS feed for production of the three fish sizes:

- 6,5 g/kg less C, 5,0 g/kg less N and 0,2 g/kg more P in a 100 g production,
- 7,2 g/kg less C, 3,4 g/kg less N and 1,3 g/kg more P in a 300g production,
- 6,8 g/kg less C, 3,2 g/kg less N and 1,4 g/kg more P in a 500g production,

This thesis demonstrated that both particle waste production and dissolved waste production from salmon, strongly correlates with the feed input, as a total and on a weekly basis, as well as the production plan. From this, it is clear that the water temperature, which is heavily affecting growth, is a crucial factor for waste production and is responsible for causing substantial waste differences between the FTS and RAS productions, but also between the 100g, 300g and 500g productions in general. Results showed that salmon waste produced under RAS conditions had following differences compared to salmon waste produced under FTS conditions:

- 0,85% less C, 6,29% less N and 1,42% more P in the 100g,
- 1% less C, 4,06% less N and 8,27% more P in the 300g,
- 1,53% less C, 4,44% less N and 8,72% more P in the 500g,

Results indicate that in land-based salmon farming, particle waste makes up 85,94% of C, 74,29% of P and 25,75% of N of the total waste produced. Theoretically, this part of the waste is simpler and more cost-effective for farmers to purify, compared to the remaining dissolved part.

When comparing the VØF-model to the government's newest estimation model, the highest percentage deviation in total waste from the VØF-model was, C + 11,13% (500g RAS), P +18,51% (500g FTS) and N – 6,13%. As the government's model calculated the amount of DW in sludge to increase with increasing fish size, this DW variation presumably lead to an inaccurate estimation according to the mass balance principle for salmon used in the VØF-model.

The new county governor model did not acknowledge the difference of C, P, and N content in the feed, the variations of these nutrients through the production cycle, and how this affected the overall production of waste. The sum of these factors results in a miscalculation of the dissolved waste produced when estimating with the new county governor model, compared to the VØF-model, with the highest percentage deviation being C +79,12% (500g RAS), P +71,97% (500g FTS) and N -8,26% (500g RAS).

Abbreviations

- BFCR (Biological Feed Conversion Rate)
- BOD (Biochemical Oxygen Demand)
- C (Carbon)
- Ca (Calcium)
- CO_2 (Carbon dioxide)
- COD (Chemical Oxygen Demand)
- DIN (Dissolved Inorganic Nitrogen)
- DIP (Dissolved Inorganic Phosphorous)
- DOC (Dissolved Organic Carbon)
- DW (Dry Weight)
- FCR (Feed Conversion Rate)
- Fe (Iron)
- FTS (Flow-Through System)
- FSD (Faeces Stability Difference)
- H_2S (Hydrogen Sulphide)
- K (Potassium)
- Mg (Magnesium)
- Mn (Manganese)
- MOM (Modellering - Overvking – Matfiskanlegg)
- N (Nitrogen)
- Na (Sodium)
- NCG-Model (New County Governor Model)
- NFE (Nitrogen Free Extract)
- OCG-Model (Old County Governor Model)
- P (Phosphorus)
- POC (Particulate Organic Carbon)
- PON (Particulate Organic Nitrogen)
- POP (Particulate Organic Phosphorus)
- PT (Production Time)
- RAS (Recirculating Aquaculture Systems)
- SGR (Specific Growth Rate)
- SS (Suspended Solids)
- TAN (Total Ammonium Nitrogen)
- TOC (Total Organic Carbon)
- VØF-Model (Vegard Øvstetun Flo Model)
- Zn (Zinc)

1. Introduction

1.1. Norwegian aquaculture production

Norway has a rich coastal history, and for centuries the Norwegian people harvested and fed on the goods that the sea provided. In the 60s and 70s a big scale fish production took form, by using well known agricultural techniques and general knowledge from fishers, the fish farming industry known today laid its foundation (Bjerkestrand. B, Bolstad. T og Hansen.S-J, 2013). Skip forward a couple of decades to 2018, and the Norwegian aquaculture industry had a landed value of 67,8 billion NOK. And of these numbers, the flagship for the Norwegian aquaculture industry was the Atlantic salmon (*Salmo Salar*), with a staggering 64,5 billion NOK in landed value (Sentralbyrå, 2019).

Today production of salmonids is modeled after the fish's natural life cycle, where early stages of the production take place in land-based facilities, e.g., flow-through systems (FTS), reuse systems, or recirculating aquaculture systems (RAS), and the other part in the sea (Bjerkestrand. B, Bolstad. T og Hansen.S-J, 2013). The land-based phase allows fish farmers to control the environmental aspects of the production, e.g., water flow, light, temperatures, feeding regime, and so on. Because of this, the land-based production has a unique opportunity to control what goes into the facility and what comes out (Aarhus I. J, Høy. E, Fredheim. A og Winther. U, 2011).

The Norwegian salmon production model is continuously evolving, from FTS, reuse, and RAS facilities on land, to open, semi-closed, and closed facilities in the sea. Salmon farmers are focusing on optimizing each production step concerning the salmon's natural life cycle (Figure 1). The salmon is an anadromous species and live their early life in freshwater, until they are ready to smoltify and then adjust themselves to a life in the seawater for growth (Ramenofsky.M and Hahn.T.P, 2018). In Norwegian aquaculture production, the freshwater stage represents a considerable part of the salmon production, where eggs, alevin, fry, fingerling/parr and smolt are produced in land-based facilities with freshwater. The breeding of new generations also takes place in freshwater, so in total 6, of 7 production stages happen in freshwater facilities.

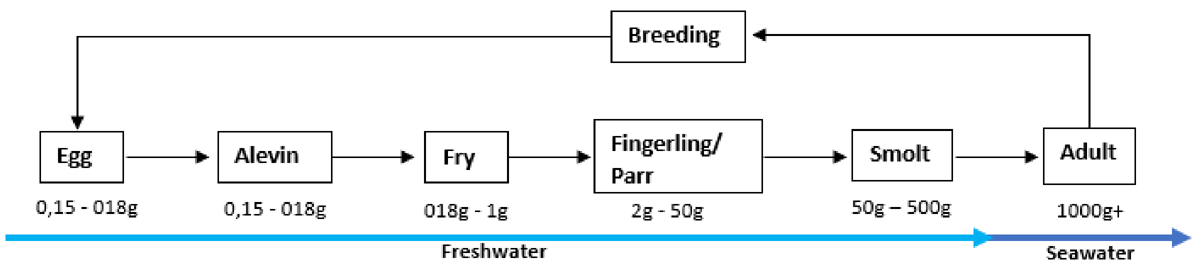

Figure 1: Simplified model of the lifecycle to Atlantic salmon (Salmo Salar). Blue arrows indicate the environmental changes salmon goes through as an anadromous creature.

One primary support for Norwegian salmon farmers are the country's biggest feed companies like Cargill, Skretting, Biomar and Mowi (Aas.T.S, Ytrestøyl.T and Åsgård.T, 2019) that specializes in optimizing different feed types for various productions, land-based or at sea, and in FTS or RAS facilities (Skretting, 2019). The same feed producers create different feed types that meet the salmon’s nutritional requirements at different life stages (Rongved.A.K.S, 2016).

The production from freshwater to seawater has earlier been divided into groups Norwegians refers to as “Settefisk” (freshwater production) and “Matfisk” (seawater production) production (Iversen.A, Hermansen.Ø, Nystøyl.R, Marthinussen.A og Garshol.L.D, 2018). But with today’s recycling technology and technical solutions on seawater supplement in freshwater facilities, the salmon farmers can produce post-smolt (smoltified salmon) up to one kg (Iversen.A, Hermansen.Ø, Nystøyl.R, Marthinussen.A og Garshol.L.D, 2018). Some farmers like Fredrikstad Seafood even produce salmon to slaughter (Lundberg.H, 2019), making the production stages more fluid and, therefore, harder to define. This continuous evolution also forces the government to improve its regulation and licensing of land-based aquaculture facilities.

1.2. Land-based aquaculture systems

Two of the most common Norwegian land-based aquaculture systems are the traditional FTS and the “newcomer” RAS.

The traditional FTS was the first type of land-based smolt facility built in Norway. The system is characterized by little to none water treatment of the inlet- and outlet water (Aarhus I. J, Høy. E, Fredheim. A og Winther. U, 2011). The system will, as the name implies, have the water flowing straight through it, and this also means that the system needs a big water reservoir as a buffer to meet the production demands. The layouts of the FTS often result in a more significant land usage than, e.g., RAS facilities (Aarhus I. J, Høy. E, Fredheim. A og Winther. U, 2011).
The water treatment process in these kinds of facilities are usually very straight forward (Figure 2).

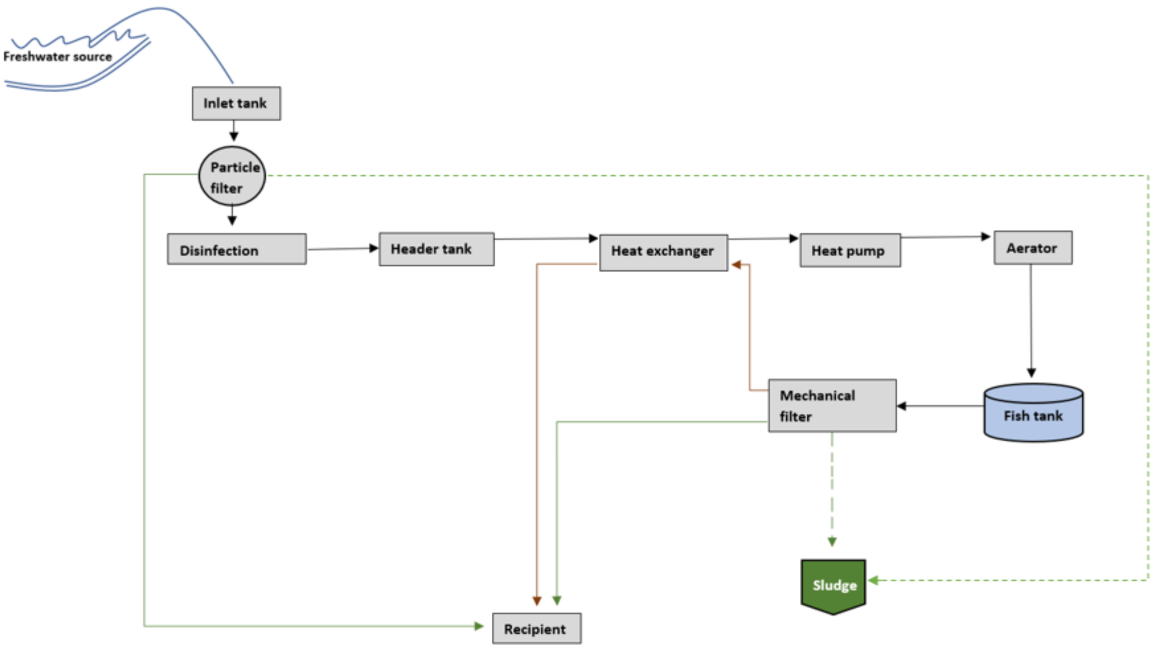

Figure 2: Simplified flowchart of possible water treatment steps in a flow-through system with an illustration of how sludge could be gathered in this type of system. Black arrows indicate inlet water, the brown arrows indicate effluent water, green arrows indicate sludge.

One of the newer production systems in Norway today is the RAS (Figure 3), which is an intensive aquaculture system that provides lots of advantages compared to the traditional FTS but also a lot of new challenges. A RAS may reduce the chances of fish escaping the facility because of its compact indoor production solutions. It can reduce the water usage necessary in production with 90%-99% (Timmons. M.B and Ebeling. J.M, 2010), and provide an opportunity of gathering sludge, which in turn will be beneficial for preserving the environment. Some RAS manufacturers today can deliver RAS with a 95% - 99% reuse of water (Akvagrouptm, 2020).

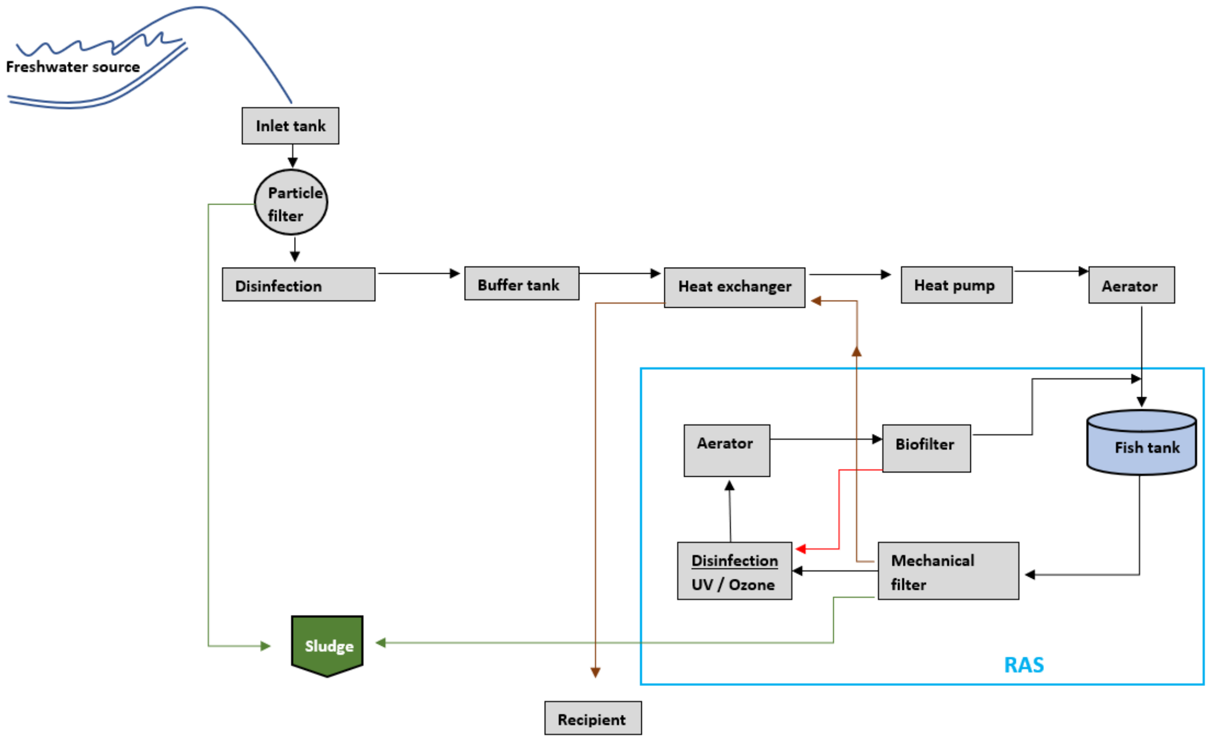

Figure 3: Simplified flowchart of possible water treatment steps in a RAS with gathering of sludge attached to the system. Black arrows indicate inlet water, the brown arrows indicate effluent water, green arrows indicate sludge.

RAS facilities can have differences when it comes to designs, and this will vary quite a bit between the suppliers. Still, all the RAS facilities have standard water treatment stages, even though the equipment may variate (Lekang, 2013).

Many believe that RAS is the future of land-based aquaculture fish farming because of its advantages when it comes to intensive fish production and environmental aspects. However, in Norway, the RAS still have some challenges to overcome. Hydrogen Sulphide (H_2S) is lethal to salmon, even in small concentrations and it has proven to be a real challenge, because it is created when particulate material accumulates, which can happen in pump sumps, tanks and pipes in a facility (Hilmarsen.Ø, Holte.E.A, Brendeløkken.H, Høyli.R og Hognes.E.S, 2019). Primarily, this is a challenge in post-smolt productions with brackish water (12 ‰) and other productions where farmers use saltwater as a buffer (2-3 ‰), because saltwater contains more particles than freshwater. Sulfur in seawater will under anaerobic conditions be reformed to H_2S by sulfur-reducing bacteria (Hilmarsen.Ø, Holte.E.A, Brendeløkken.H, Høyli.R og Hognes.E.S, 2019).

Accumulation of particle may also occur in FTS, but the reason it is more critical in RAS, is because of the recirculating process. All the water is not exchanged, and therefore the risk of H_2S increases. Other risks and challenges for RAS is, of course, over-saturation of nitrogen (N) and CO_2-poisoning (Hilmarsen.Ø, Holte.E.A, Brendeløkken.H, Høyli.R og Hognes.E.S, 2019). Some of these challenges are linked to faults in the RAS design, leading to still water, sedimentation of particles, and poor flow-through in the water supply system (Hilmarsen.Ø, Holte.E.A, Brendeløkken.H, Høyli.R og Hognes.E.S, 2019). Today there are many different opinions and speculations between farmers on how to operate a RAS optimally. Still, one thing they all agree on is the need for a competence enhancement among people working in and with RAS.

1.3. Licencing of land-based aquaculture facilities

In Norway, aquaculture is a permit-based industry, and by understanding how FTS and RAS works, the government or, more precisely, the county governor office, can license new salmon farms and provide production increase to existing ones. A county governor has only jurisdiction for his/her county in Norway (Figure 4). The licensing process is divided into two main parts. First, the directorate of fishery select which applicants should be granted permission for a permit. Then the county governor office processes the applications for clearance of a site for land-based aquaculture production (Fiskeridirektoratet, Fiskeridir.no, 2017).

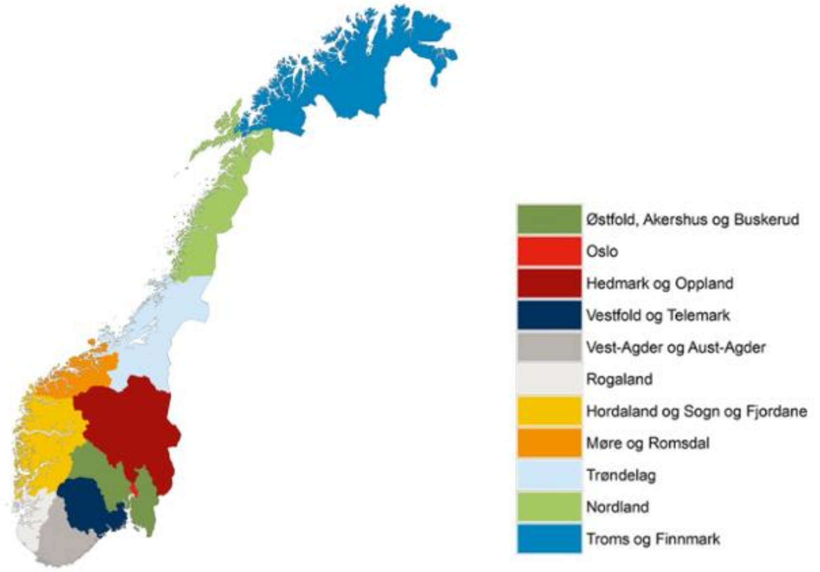

Figure 4: Color-coded overview of Norway and its 11 counties (Regjeringen.no, 2019).

But the licensing of land-based facilities in Norway is strictly monitored, and the licensing process fundamentally exists to preserve wildlife both on sea and land. Because of this, a production license for fish farming cannot be given if an aquaculture facility constitutes a pollution risk for marine life and ecosystems (Lovdata, Forskrift om tildeling, endring og bortfall av konsesjoner for oppdrett av andre arter enn laks, ørret og regnbueørret., 2005). After an application is sent for assessment at the county governor's office, it must go through a public hearing process. The application is also made available for the public to read, so that everyone that this may concern may get a grip around the situation that can affect them, and

provide comments on the application.
At last, it is up to the county governor office to make a decision, based on the public hearing, and other factors, whether to approve or decline the aquaculture application (Bjerkestrand. B, Bolstad. T og Hansen.S-J, 2013).

One of the main challenges for licensing land-based aquaculture facilities is the lack of proper estimation models for waste produced by salmon (Pedersen.T.N, Personal message, 2020). There are also variations between counties and county governors, about which requirements and estimations should be the foundation to approve a land-based aquaculture application (Johansen.M, 2020).
Today there are popping up new land-based facilities with huge variations in systems compared to the already established facilities. Is it correct to assume that the waste produced between the different facilities are generated in the same way and the same amount?

1.4. Aim of the thesis

The goal of this study is to increase the knowledge about waste from land-based salmon farms, both FTS and RAS, and propose how this knowledge can potentially make the production more environmentally sustainable.
This master thesis asses this subject further by looking into two research questions:

- *Does the licensing system urge or stimulate to reduce the emissions from land-based salmon farms, both FTS and RAS?*
- *Is it possible to develop a better model for calculation of emissions from land-based salmon farms, both FTS and RAS?*

To answer these two questions the master is worked out in three parts:

1. Assessment of today's emission permits for land-based freshwater facilities, FTS and RAS
2. Development of a new model (VØF) for calculation of waste from land-based freshwater facilities, based on production system, production plan and mass balance estimates
3. Comparing VØF-model to the models used by the county governor's office for estimation of waste from land-based aquaculture freshwater facilities.

One chapter is dedicated to each of the three steps above, dividing the thesis into three main parts.

2. Literature and theory

2.1. Waste production in salmon

Feed containing certain levels of nutrients gets introduced to the fish (Figure 5), and of these nutrients, some will be retained in the fish, while the rest will be excreted as waste (Reid.G.K, Liutkus.M, Robinson.S.M.C, Chopin.T.R, Blair.T, Lander.T, Mullen.J, Page.F and Moccia.R.D, 2009). Excreted waste is either in particulate form or dissolved form (Rohold.L, 2019). Land-based aquaculture farming of salmon will have a waste release consisting of C, N, and P in both organic and inorganic form, either particulate or dissolved. Particulate organic waste products of C, N, and P (POC, PON, and POP), as well as dissolved inorganic nitrogen and phosphorus (DIN and DIP), are released from the salmon farms in forms of salmon feces, urine and excessive feeding. Carbon dioxide (CO_2) and total ammonium nitrogen (TAN) is released over the salmon gills in the respiration cycle (Wang. X, Olsen. M.O, Reitan. K.I and Olsen. Y, 2012). From the organic waste, through leaks and breakage of feces and pellets, to particulate and molecular levels smaller than 0,2µm, dissolved organic waste of C, P and N (DOC, DOP and DON) are formed (Uglem.I, Järnegren.J og Bloecher.N, 2020).

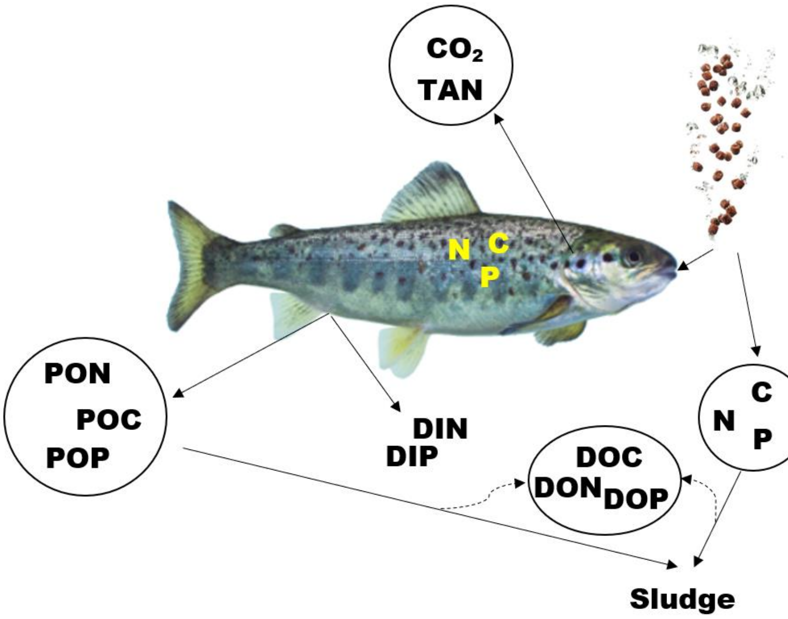

Figure 5: Nutrient flow model for Norwegian salmon, from the introduction of feed, retaining of nutrients (yellow) to the production of sludge.

The nutrient elements that create the most concern for intensive production of salmon is, therefore, C, N and P, because of the water pollution they create (Chatvijitkul.S, Boyd.C.E and Davis.D,A, 2018). Organic carbon and ammonia nitrogen contribute to higher oxygen demand along with P because of the degradation process of bacteria, which in turn leads to eutrophication in water bodies (Boyd.C.E and McNevin.A.A, 2015). Salmon farmers might quite simply produce an excess of nutrients, which in turn will be harmful to the ecosystem.

It is, therefore, necessary to calculate the levels of these nutrients in the intensive production of salmon farming, to truly understand what effect the waste has on the environment. Then, in particular, the nutrients that occur in a dissolved form, because these nutrients are harder and more expensive to reduce with purification.

The following calculations of C, P, and N in feed and salmon, is a continuation of the work done by Deyue Gu, from her master thesis at NMBU (Gu.D, 2019).

2.1.1. Chemical composition of salmon feed

The pellet used as feed for salmon is composed of several different raw materials. One variant from Mowi, the Alpheus 50 B5 contains, e.g., fish meal, fish oil, soy protein concentrate, rapeseed oil, vital wheat gluten, peas dehulled, maize gluten, wheat, minerals, vitamins, L-Histidine monohydrochloride, yeast, guar meal roasted, carotenoids and amino acids (Appendix 1). The feed formula varies according to the size and type of salmon (fry, fingerling/parr, smolt). In other words, the feed is customized to the size, biology, environment, and health of the salmon (Skretting, 2019). The composition of salmon feed and fish feed, in general, can be divided into six main parts; moisture, protein, fat, ash, crude fiber, and nitrogen-free extract (NFE) (Terpstra.A.H.M, 2015). By looking at salmon production today, the feed producers mainly focus on the compositions like protein, fat, ash, fiber, P, calcium, sodium (Appendix 2 - Appendix 6), NFE and Vitamin D, E, and C (Rongved.A.K.S, 2016).

According to literature (Table 1), feed content varies slightly between the different life stages of salmon. A decrease is seen in protein containment in the feed as the salmon grows, while fat containment increases as the salmon grows. Ash, fiber, NFE, and vitamin-D levels remains stable with salmon growth. Vitamin-E content decreases from fingerling feed to growth feed, and increases from growth to transfer feed. In contrast, vitamin-C contents increase only in the transfer feed, where the salmon adjusts itself to a life in seawater in a phase known as smoltification.

Table 1: Typical content in salmon feed for FTS and RAS

System	Feed type	Protein (%)	Lipid (%)	Ash (%)	Fibre (%)	Calcium (%)		Sodium (%)		Reference / Producer
FTS	Starter	53	18	10,5	0,5	2		0,5		Appendix 5
FTS	Starter	53	18	10,5	0,5	2		0,5		Appendix 6
FTS	Starter	58	15	11,8	0,4	2,31		1,15		Appendix 2
FTS	Starter	56	19	12,6	0,1	2,08		1,07		Appendix 3
FTS	Starter	57	18	12,9	0,4	1,95		1,24		Appendix 4
						NFE (%)	V-D (IU/kg)	V-E (mg/kg)	V-C (mg/kg)	
FTS	Starter	60	10	12,2	0,3	11				
FTS	Starter	60	10	12,2	0,3	11				
FTS	Starter	60	10	12,2	0,3	11				Appendix 7
FTS	Starter	58	15	12,4	0,2	6,2				Appendix 8
FTS	Starter	56	18	11,9	0,2	7,9				
FTS	Starter	56	18	12,0	0,3	8,4				
FTS	Fingerling	54	18	11,0	1,1	11				Appendix 9
FTS	Fingerling	47-50	24-27	7-9		9,1-15,1				Appendix 10
FTS	Grower	46-49	24-27	6,8-8,8		10,1-16,1				
FTS	Grower	44-47	23-26	6,8-8,8		12,2-18,2				Appendix 11
FTS	Grower	44-47	24-27	6,4-8,4		11,4-17,4				
FTS	Grower	38-41	33-36	5,3-7,3		10,7-16,7				
FTS	Grower	45-48	26-29	6,4-8,4		9-15				Appendix 12
FTS	Grower	40-43	30-33	4,7-6,7		11,7-17,7				
FTS	Fingerling	50-53	21	10-11	0,6-4,5	10-12	2200	300	200	
FTS	Fingerling	49-52	21	10-11	0,6-4,5	11-13	2200	200	200	(Rongved.A.K.S , 2016)
FTS	Grower	48-51	22	10-11	0,6-4,5	11-13	2200	200	200	
FTS	Grower	47-50	23	10-11	0,6-4,5	11-13	2200	200	200	
FTS	Grower	45-48	25	9-11	0,6-4,5	11-13	2200	200	200	
FTS	Transfer	49-50	21	10-13		10-13	2200	300	500	
FTS	Transfer	48-49	22	10-13		10-13	2200	300	500	(Rongved.A.K.S , 2016)
FTS	Transfer	45-46	24	10-13		10-13	2200	300	500	
RAS/FTS	Fingerling	50-54	21	9-11	0,6-4,5	10-12	2200	300	200	
RAS/FTS	Fingerling	49-52	21	9-11	0,6-4,5	11-13	2200	200	200	
RAS/FTS	Grower	48-51	22	9-11	0,6-4,5	11-13	2200	200	200	(Rongved.A.K.S , 2016)
RAS/FTS	Grower	47-50	23	9-11	0,6-4,5	11-13	2200	200	200	
RAS/FTS	Grower	45-48	25	9-11	0,6-4,5	11-13	2200	200	200	
RAS/FTS	Grower	39-42	28	3-5	0,6-4,5	16-18	1400	200	100	

AVERAGE

System	Feed type	Protein (%)	Lipid (%)	Ash (%)	Fibre (%)	Calcium (%)		Sodium (%)	
FTS	Starter	57	15,36	11,92	0,31	2,06		0,89	
						NFE (%)	V-D (IU/kg)	V-E (mg/kg)	V-C (mg/kg)
RAS/FTS	Fingerling	50,08	21,25	10	0,6-4,5	11,51	2200	250	200
RAS/FTS	Grower	45,80	25,92	8,26	0,6-4,5	13,23	2085,71	200	185,71
RAS/FTS	Transfer	47,83	22,33	11,5		11,5	2200	300	500
Total RAS/FTS	All	50,50	21,22	10,09	0,6-4,5	12,53	2142,85	235,71	257,14

If looking at a total average, protein is by far the most added component in feed for land-based aquaculture, with the average amount being around 50% (Figure 6).

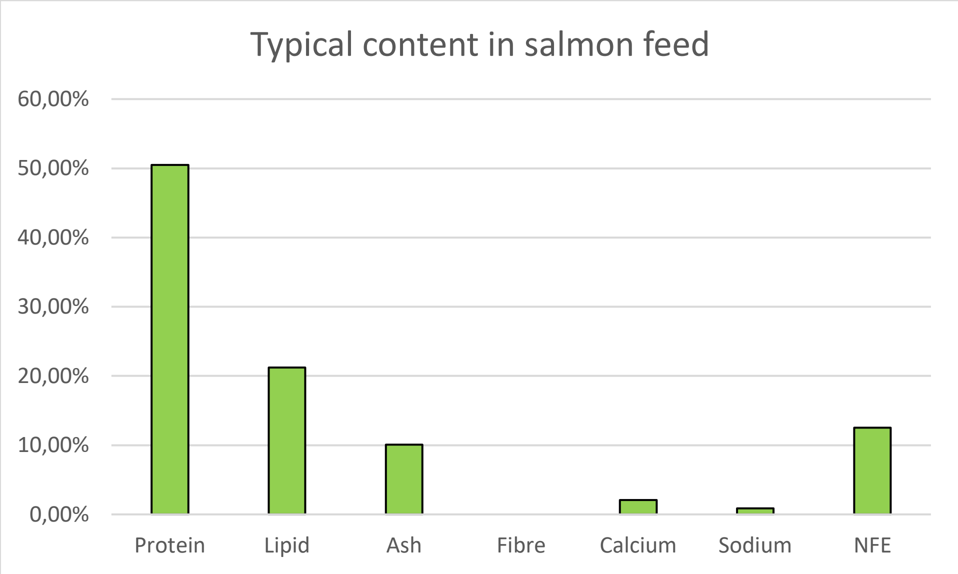

Figure 6: Graphical illustration of typical content in salmon feed

Furthermore, Cargill Aqua Nutrition's estimates (Skaar, 2020), Skretting's estimates (Tømmerås.S, 2019) and literature states that C, P and N concentrations in aquaculture feeds, varies between different life stages of salmon but also on different species of fish (Chatvijitkul.S, Boyd.C.E and Davis.D,A, 2018). For salmon, there are slight variations in C, P, and N between the total average of feed compositions for FTS and RAS. For FTS values of C, P and N in dry weight (DW) percentage where; 45,99%, 1,65% and 7,70%, for RAS DW percentage where; 45,25%, 1,70% and 7,44% (Table 2).

Table 2: Typical C, P, and N content in salmon feed.

System	Feed type	C (%DW)	P (%DW)	N (%DW)	References
FTS	Starter	44,32±0,294	1,62 ± 0,056	9,20 ± 0,211	(Chatvijitkul.S, Boyd.C.E and Davis.D,A, 2018)
FTS	Fingerling	47,43	1,36	7,25	
FTS	Grower	46,46±1,445	1,43 ±0,153	7,67 ±0,432	
FTS	Starter	42,68	2	8,8	(Skaar, 2020)
FTS	Starter	44,18	2	8,64	
FTS	Starter	44,91	1,8	8,48	
FTS	Fingerling	45,93	1,7	8,16	
FTS	Fingerling	47,06	1,7	7,84	
FTS	Grower	46,76	1,6	7,52	
FTS	Grower	45,88	1,6	7,52	
FTS	Transfer	46,32	1,6	7,52	
RAS	Starter	42,68	2	8,8	(Skaar, 2020)
RAS	Starter	44,18	2	8,64	
RAS	Starter	44,91	1,8	8,48	
RAS	Fingerling	43,92	1,7	6,72	
RAS	Fingerling	45,24	1,7	6,72	
RAS	Grower	45,9	1,6	6,72	
RAS	Grower	45,02	1,6	6,72	
RAS	Transfer	45,46	1,6	6,72	
FTS / RAS	Smolt feed	50	1,3	7,5	(Tømmerås.S, 2019)
FTS	Starter		1,6		Appendix 5
FTS	Starter		1,6		Appendix 6
FTS	Starter		2,08		Appendix 2
FTS	Starter		2,08		Appendix 3
FTS	Starter		1,95		Appendix 4
FTS	Starter		2,0		Appendix 7
FTS	Starter		2,0		
FTS	Starter		2,0		
FTS	Starter		2,0		Appendix 8
FTS	Starter		1,9		
FTS	Starter		1,9		
FTS	Fingerling		1,6		Appendix 9
FTS	Fingerling		1,6	7,8	Appendix 10
FTS	Grower		1,5	7,6	
FTS	Grower		1,2	7,3	Appendix 11
FTS	Grower		1,1	7,3	
FTS	Grower		1,0	6,3	
FTS	Grower		1,4	7,4	Appendix 12
FTS	Grower		1,0	6,6	
AVERAGE					
FTS tot	Starter	45,21	1,86	8,52	
FTS tot	Fingerling	47,60	1,54	7,71	
FTS tot	Grower	47,27	1,31	7,27	
FTS tot	Transfer	46,32	1,6	7,52	
RAS tot	Starter	45,45	1,77	8,35	
RAS tot	Fingerling	46,38	1,56	6,98	
RAS tot	Grower	46,97	1,50	6,98	
RAS tot	Transfer	45,46	1,6	6,72	
Total FTS	All	45,99	1,65	7,70	
Total RAS	All	45,25	1,70	7,44	

Even though there are slight variations in the total average feed content of C, P, and N, a more prominent difference can be seen in the average between different feed types (Figure 7). The RAS feed is designed to function optimally in interaction with the salmon as well as the RAS. Therefore in the formulation of these feed types, the focus is to generate a feed with high protein retention, lower N waste production to the water, and overall high technical quality of the pellet (Skaar, 2020).

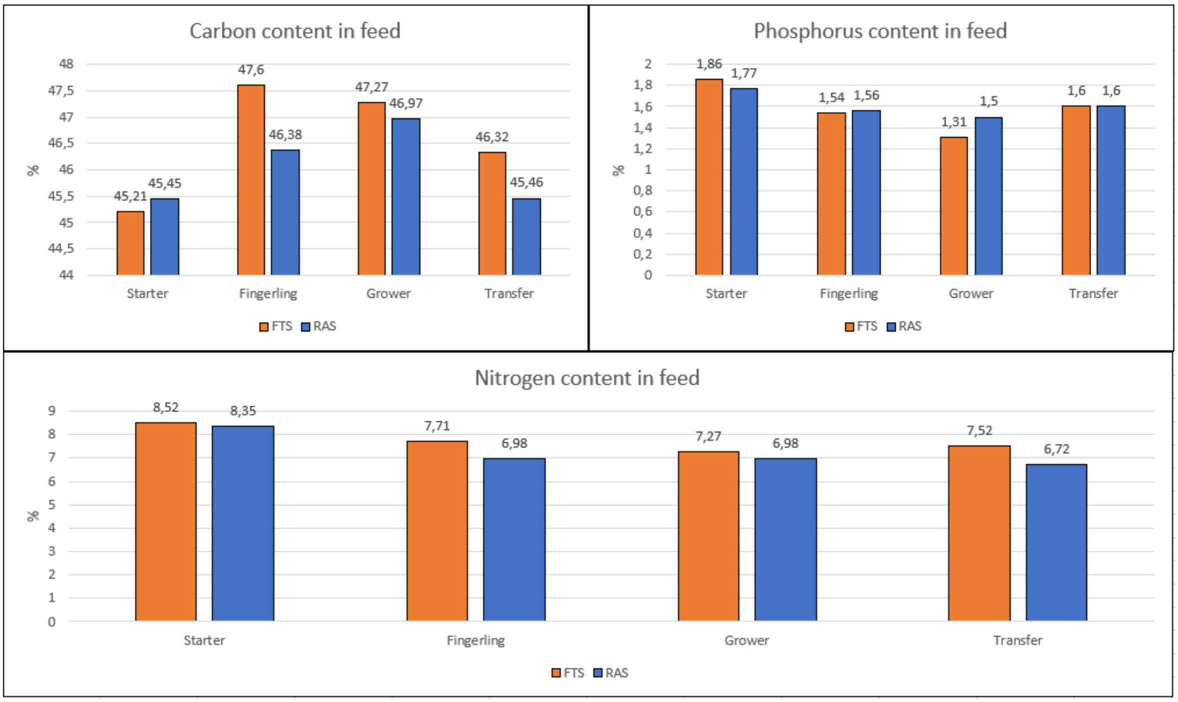

Figure 7: Average feed content and variations of C, P, and N for FTS and RAS in starter, fingerling, grower, and transfer feed.

2.1.2. Chemical composition of salmon

Literature shows that adult Norwegian salmon on a regular pellet based diet, consists of dry matter, ash, lipid and N; 31,64%, 2,14%, 11,76% and 2,70% (Aas.T.S, Ytrestøyl.T and Åsgård.T, 2019) (Aas.T.S og Åsgård.T, 2019), an amount of energy equal to 12,7 mJ/kg (Aas.T.S, Ytrestøyl.T and Åsgård.T, 2019) and different minerals i.e. P, iron (Fe), potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), sodium (Na) and zinc (Zn) (Aas.T.S, Ytrestøyl.T and Åsgård.T, 2019) (Aas.T.S og Åsgård.T, 2019). In dry and silage-based diets, the salmon's dry matter, ash, and lipid levels are reported to an average of; 34,92%, 1,82%, and 14,67% (Lie.Ø, Waagbø.R and Sandnes.K, 1988).

This gives salmon a combined composition of 31,1% dry matter, 2% ash, 13,05% lipid, and 2,7% N. The highest mineral concentrations are 4132 mg/kg of P, 3385 mg/kg of K and 4364 of Ca (Figure 8).

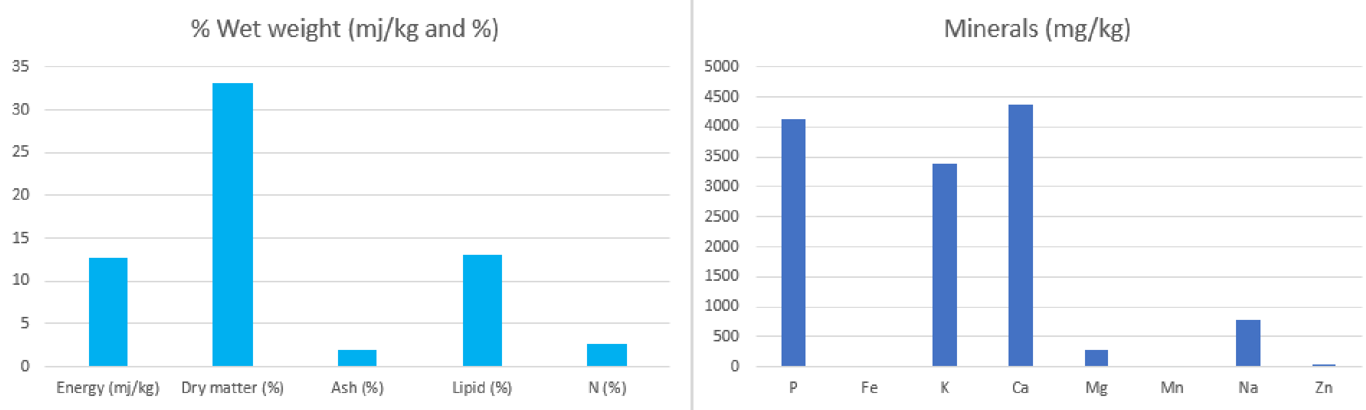

Figure 8: Typical content in adult Norwegian salmon, to the right (dark blue) is an overview of typical mineral content in salmon.

From the information gathered by earlier studies, it can be assumed that DW content of C, P, and N in salmon are; 50%, 0,40%, and 3% (Wang. X, Olsen. M.O, Reitan. K.I and Olsen. Y, 2012). P and N content levels in salmon (0,38% and 2,76%) are also supported in page 4 of Lerøy Sjøtroll department Bjørsvik's, emission permit (Pedersen.T.N, Utslippstillatelse, 2015) and the county governor of Vestland waste model (TOC: 20%, P:0,4% and N:2,72) (Pedersen.T.N, Personal message, 2020). By looking at the values gathered and taking into consideration that the salmon composition is changing according to feed composition, it is possible to say that this is a fair assumption.

From the feed given, the salmon will retain a certain amount of the components of the feed, while the rest will be excreted as waste. Literature states that an average of 37,66% C, 30% P, and 40,18 % N is retained in the salmon biomass (Table 3).

Table 3: Typical retention rate of C, P and N in salmon

Retention rate to biomass			
C (%)	**P (%)**	**N (%)**	**Reference**
30	30	38	(Wang. X, Olsen. M.O, Reitan. K.I and Olsen. Y, 2012)
38	24	43	(Wang.X, Andresen.K, Handå.A, Jensen.B, Reitan.K.J and Olsen.Y, 2013)
45	30	40	(Tømmerås.S, 2019)
	36	42	(Bergheim.A og Braaten.B, 2007)
		37,9	(Davies.I.M, 2000)
	30		(Ytrestøyl.T, Aas.T.S and Åsgård.T, 2014)
AVERAGE			
37,66	30	40,18	

2.1.3. Chemical composition of salmon feces

Salmon feces is produced as a waste product of digested salmon feed, meaning that the input value of feed, will have a direct correlation to the output values of the feces, on the respective feed composition. In other words, the C, P, and N content in feed minus the retention rate to biomass will decide the C, P, and N content in feces.

According to information from Cargill Aqua Nutrition, salmon, given a RAS diet, will have a higher stability in feces than salmon given a standard FTS diet (Skaar, 2020). With a RAS diet, the salmon will, therefore, produce feces that is firmer and does not get particle-breakage as quickly as feces produced from an FTS diet (Figure 9). This is an essential quality in a RAS, because the nitrification efficiency of the biofilter is negatively correlated to particulate organic matter concentration in the water (Chen. S, Ling. J and Blancheton. J-P, 2006).

Figure 9: Differences in feces stability between faces produced on a RAS-diet (left) contra feces produced on an FTS-diet (right) (Skaar, 2020).

From the information given by Cargill Aqua Nutrition, a FTS diet will, on average, provide around 6% less feces stability (Skaar, 2020), possibly making for less collection of particles in the mechanical filters compared to the RAS diet.
The data was collected from an experiment done by Cargill Aqua Nutrition, where they put feces in a mechanical filter, and registered number of particles before and after the filter had been operating for 5 minutes (Figure 10).

The results showed a decreasing particle concentration in the filter with increasing time, so when the particle count was low in the filter, it means that some particles have passed through. Results showed that the stability of feces produced on an FTS diet always was lower than the stability of feces produced on a RAS diet, with an increasing difference over time. The first measurement showed a feces stability difference (FSD) of ca. 3% less stability in the FTS diet feces compared to the RAS diet feces. The middle measurement showed an FSD of ca. 6% less stability in the FTS diet feces compared to the RAS diet feces. The last measurement showed an FSD on ca. 8% less stability in the FTS diet feces compared to the RAS diet feces (Skaar, 2020).

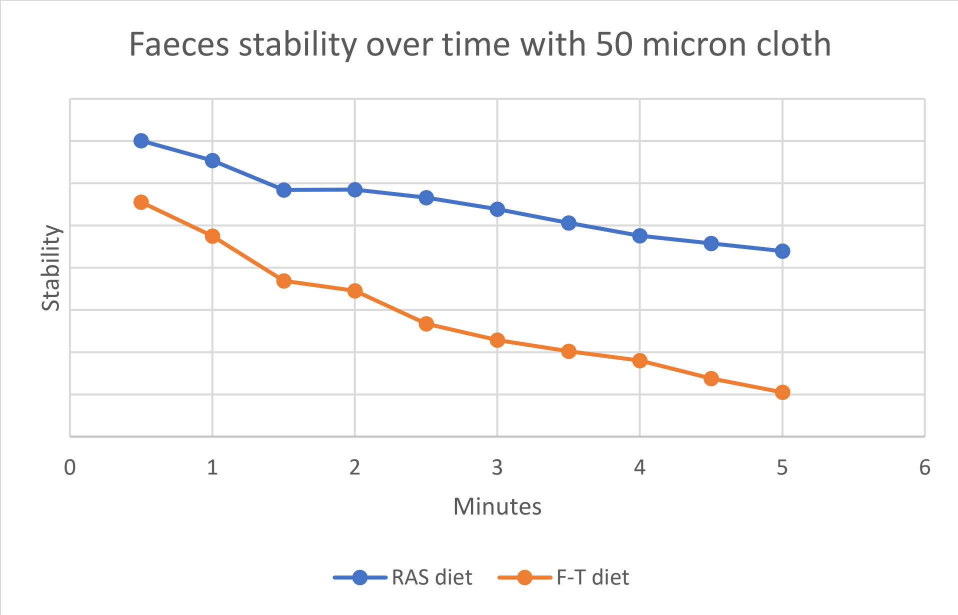

Figure 10: Cargill Aqua Nutrition data on difference in feces stability between RAS diet and an FTS diet, over 5 minutes in a filter with a 50-micron cloth

The average from these data gave a 6% less feces stability in feces produced on an FTS diet compared to feces produced on a RAS diet.

2.1.4. Waste loss to recipient, particulate and dissolved

When the retention rate of C, P, and N to salmon biomass are mapped, it is possible to estimate how much of the same nutrients that have been lost to the recipient. Literature and feed manufacturers calculations (Tømmerås.S, 2019) states that an average of 62,33% C, 70% P and 59,82% N, is lost to the recipient as waste products from the salmon. Calculated feed not eaten of the input, is at 5% (Table 4).

Table 4: Typical loss to recipient of C, P, and N from Salmon production.

Feed not eaten	**Waste production (Loss to recipient)**			
%	**C (%)**	**P (%)**	**N (%)**	**Reference**
3	70	70	62	(Wang. X, Olsen. M.O, Reitan. K.I and Olsen. Y, 2012)
3	62	76	57	(Wang.X, Andresen.K, Handå.A, Jensen.B, Reitan.K.J and Olsen.Y, 2013)
	55	70	60	(Tømmerås.S, 2019)
9		64	58	(Bergheim.A og Braaten.B, 2007)
			62,1	(Davies.I.M, 2000)
		70		(Ytrestøyl.T, Aas.T.S and Åsgård.T, 2014)
AVERAGE				
5	62,33	70	59,82	

The estimates from Skretting (Tømmerås.S, 2019) did not directly mention how much C where respired as CO_2, therefore it was assumed that the dissolved part of C was equal to calculations from Wang.X 2012 and 2013. Therefore dissolved C values were estimated at 3%, leaving 35% to be respired as CO_2 (Table 5).
By looking at the total waste loss from the salmon, it is possible to divide between the amount of particulate waste and dissolved waste (Table 5). For C, the emission ratio between particulate and dissolved was p18,33%/d3%, with 41% being respired as CO_2. The emission ratio between particulate and dissolved for P and N was p52%/d18% and p15,4%/d44,4.

Table 5: Emission ratio between particulate and dissolved waste of C, P, and N from salmon production.

Particulate C%	Dissolved C%	Respired CO_2 %	Particulate P%	Dissolved P%	Particulate N%	Dissolved N%	Reference
19	3	48	52	18	15	47	(Wang. X, Olsen. M.O, Reitan. K.I and Olsen. Y, 2012)
19	3	40	44	32	15	42	(Wang.X, Andresen.K, Handå.A, Jensen.B, Reitan.K.J and Olsen.Y, 2013)
17	3	35	58	12	13	47	(Tømmerås.S, 2019)
			54	10	19	39	(Bergheim.A og Braaten.B, 2007)
					15	47	(Davies.I.M, 2000)
AVERAGE							
18,33	3	41	52	18	15,4	44,4	

2.2. Environmental monitoring of salmon waste

As mentioned earlier, from the waste that is produced from land-based salmon farming, only some of the particulate waste is possible to remove from the production water physically. In contrast, the dissolved waste is usually released to the recipient, because it is hard and expensive to purify. All salmon productions, therefore, need some sort of waste calculation methods as well as some sort of surveillance.

The county governor office is responsible for the regulation of salmon farms in the different Norwegian counties. When it comes to estimating waste from land-based aquaculture facilities, they do so with the help of a "recipe" (Ekli.M, Personal message, 2018).
The county governor office uses a model (OCG-model) to estimate how much waste that can be produced from a given salmon farming facility, before approving an application and granting a production license with an emission permit. The model used by the county governor to estimate waste produced, have prerequisites with an FCR of 1,0 and both feed and salmons N and P values, as well as estimation methods for TOC (Ekli.M, Personal message, 2018).

With the estimation model, the county governor calculates the expected waste from a specific production of salmon. They assume that everything not retained in biomass in the salmon, dead salmon included, are to be considered waste (Ekli.M, Personal message, 2018).
From February 01.2020, the county governor in Vestland has developed a new model (NCG-model) to better estimate waste generated in land-based aquaculture facilities (Pedersen.T.N,

Personal message, 2020). Theoretical calculations for both the OCG-model and the NCG-model are specified later in part 3 of this thesis.

All aquaculture facilities have specific demands for environmental surveillance of the recipient in their respective production areas (Pedersen.T.N, Personal message, 2020), and this demand has been in place since the law of aquaculture was decided in Norway in 2005 (Fiskeridirektoratet, Fiskeridir.no, 2018). Feces and feed residue from salmon production, e.g., is a source of H_2S gas, created as a bi-product in the decomposition process of organic material (Hilmarsen.Ø, Holte.E.A, Brendeløkken.H, Høyli.R og Hognes.E.S, 2019). This gas is extremely poisonous for marine life, and therefore the aquaculture facilities should avoid an accumulation of organic material, as mentioned earlier in chapter 1.2.

Environmental surveillance of the recipient is done by conducting a "Modellering - Overvking - Matfiskanlegg" or a MOM investigation. The MOM investigation is used to assess the bottom conditions of an aquaculture facility. It is divided into three different types of inquiry, A-, B-, and C-investigation, performed over three different areal zones from a farm (Lekang, 2013). The local impact zone stretches from 5m -15m, the intermediate zone stretches from 50m -150m, and the regional zone extends in an area of over 150m from the facility. For the local zone, A-, B- and C-investigation are conducted at different intervals and periods. The A-Investigation categorizes as a light examination, while the C-Investigation categorizes as a thorough examination, regarding environmental conditions. For the intermediate and regional zone, only the C-investigation is usually conducted (Lekang, 2013).

The MOM investigations are modeled for cage salmon at sea and are therefore not genuinely representable for the assessment of a land-based aquaculture recipient. Today it is practiced by the county governor's office, that a simple investigation of the discharge point in the form of a modified B-Investigation, is accepted as an environmental surveillance method (Pedersen.T.N, Personal message, 2020). To assess the environmental impact as correct as possible, the county governor's office distinguishes between surveillance of discharge point and surveillance of recipient (Pedersen.T.N, Personal message, 2020).
Literature shows that waste from salmon farms has a higher impact close to the farms, and as the distance increases, the environmental impact decreases (Kutti.T, Ervik.A and Hansen.P.K, 2006). Surveillance of the discharge point can, therefore, show a high degree of ecological effect from the land-based aquaculture facility. In contrast, oversight from the recipient may paint another picture.

2.2.1. Measuring methods of sludge/waste from land-based salmon farms

The waste from land-based aquaculture production of salmon (as seen in chapter 2.1) consists of a variety of different particulate and dissolved substances. Some land-based facilities have purification demands included in the production licenses, where they must measure the amount of given substances released to the environment (Aune.E, 2009).
According to literature and emission permits, the facilities that purify water, measures solid contents which exist in particulate and suspended form (SS). Also, the organic content of the wastewater is measured using oxygen demand methods like chemical oxygen demand(COD) or biological oxygen demand (BOD), or using total organic carbon (TOC), N, and P (González.J.F, 2006).

2.2.1.1. Suspended solids

Suspended solids (SS) is defined as the constant movement of particles in water, where the particles will remain in suspension in water (or movement in water) because of the motion in water or because the density of the particle is lighter or equal to the density in the water (Grundfos, 2020). In the Norwegian aquaculture production licenses, in the sections containing the emission permit, SS are defined as particles > 0,45μm (Aune.E, 2009) (Lorvik.M og Ekli.M, 2012).

SS poses an environmental concern because when they are flushed out of the land-based facilities, they may float in the water masses, creating a cloud that reduces the amount of sunlight shining through the water and directly affecting the ecosystem. If these suspended solids settle in the recipient, they may also affect the bottom flora (González.J.F, 2006). Another concern with SS is that they can carry pathogens on the surface of the particles (Grundfos, 2020) and therefore be a contamination risk to the aquatic life, if not reduced or removed.

2.2.1.2. Biochemical oxygen demand and chemical oxygen demand

BOD and COD estimate the amount of oxygen needed to stabilize organic content in effluent water.
BOD estimates the contamination degree of samples by measuring how much oxygen microorganisms requires to oxidize organic material with their aerobic metabolism (González.J.F, 2006). In the land-based facilities, the salmon will be provided with additional oxygen and ways to transport away organic waste that consumes oxygen effectively. If the organic waste from the facilities reach the recipient in excessive amounts, it will rob other aquatic organisms of their required oxygen to live, and it can affect the ecosystem.

These BOD tests of wastewater from land-based aquaculture facilities usually takes some time to conduct, because a test like this is dependant of the microorganism to provide the result by decomposing the organic material over 5 or 7 days minimum (González.J.F, 2006). Therefore COD analyses, by the dichromate method is the other option to BOD, because the number of compounds that can be chemically oxidized is more significant than the compounds that can be degraded biologically, and it can be done in a shorter period (González.J.F, 2006).

2.2.1.3. Total organic carbon

TOC is a measure for the amount of C, which is bound in organic compounds in water (elgalabwater.com, 2020). In other words, TOC is the amount of POC and DOC waste produced by a salmon, meaning that the inorganic compounds (carbonate, bicarbonate and dissolved carbon dioxide) is not represented in the TOC. TOC emitted from land-based facilities will show how impacted a recipient is. Studies show that the values of TOC in sediments are high close to the discharge area, and decreasing with increasing distance (Carroll.M.L, Cochrane.S, Fieler.R, Velvin.R and White.P, 2003).

2.2.2. Emission permits

When an aquaculture facility application is approved, it will be given a production license. In the production license, there is an incorporated emission permit that reflects on the application, in terms of applied emissions, demands on amount proportionality, focus on the recipient, and a demand for environmental surveillance (Pedersen.T.N, Personal message, 2020). These emissions permits are all modeled after the Norwegian pollution laws, in terms of purification (Lovdata, Lov om vern mot forurensinger og om avfall - forurensingsloven, 1983). The permits are recipient oriented because of the lack of accurate modelling tools to predict environmental impact (Pedersen.T.N, Personal message, 2020). With the sum of these factors, the aquaculture facilities are required to report environmental status to the county governor's office, giving the county governor's office experience data as a foundation to update and upgrade the licenses (Pedersen.T.N, Personal message, 2020).

2.3. Water treatment in land-based aquaculture

Understanding how salmon retain and excrete waste nutrients (C, P, and N) is essential, but understanding how the different land-based aquaculture systems function and how the waste nutrients can be removed, before ending up in the recipient, is equally important.

All water used in land-based aquaculture production, usually goes through some sort of treatment, depending on the water quality of the intake source. One usual water treatment model contains six different steps of treatment (Lekang, 2013) plus the "handling" of the water in the tank and the biofiltration necessary for RAS.

1. Particle removal
2. Disinfection
3. pH adjustment
4. Heating/cooling
5. Aeration
6. Oxygen addition
7. Tank
8. Biofilter

The different water treatment steps are in place to remove unwanted elements and add desired features to salmon production, while stabilizing and securing a reliable water source to the land-based aquaculture facility.

2.3.1. Particle removal

Water is extracted from a freshwater source and passes through a particle filter for the removal of solids from the freshwater source. The particles are removed by using a filter, e.g., mechanical filters separates particles from the water in a straining pile. Particles from the water will not pass through the filter and will gradually accumulate in the filter itself (Lekang, 2013). What size of particles to be removed is decided by the size of the filter cloth. A filter with a size of 40µm will remove a larger number of particles than a filter of 60µm. These mechanical filters, with self-cleaning mechanisms, are common filters used in FTS facilities and extensive RAS production (Lekang, 2013) for the removal of particles.

It is imperative to remove these particles, because a high particle concentration in the water increases the possibilities for gill-infections and parasites (Lekang, 2013). Some of the larger parasites can be removed from the water with the use of a particle filter. The inlet water is, if possible, not pumped from the source to the facility, because with a gentle treatment of the water, particle breakage can be avoided. This careful handling is done because filters that remove the particles are more effective in removing large particles as opposed to small ones (Lekang, 2013). Because of this, the filter needs to be placed as close to the water source as possible to function optimally.

After the water has been used in the fish tanks, it exits the tanks through the outlet pipe. This effluent water contains feed residues and other pollutants. The water again needs to be cleaned for particles, so it is treated in a different particle filter than the inlet water, but the theory is the same.

By removing particles from the water, other water treatment equipment may function better than if the particles are not removed. It is especially important that all the equipment in the RAS, that reuse water, has a good effect, otherwise the salmon may get less than optimal environmental conditions. Water with an excessive number of particles may cause a carbon overload in the biofilter (Lekang, 2013).
From the filters used for effluent water, sludge can be extracted and processed further, which will reduce the environmental damage to the recipient.

2.3.2. Disinfection

All land-based facilities have demands to control the effects the facilities have on the environment around them, as well as controlling input values to the facility itself, e.g., freshwater source.
If the facilities inlet water is home to species that are at risk of contaminating the farmed fish, or if the inlet water is a breeding ground for anadromous fish, then the facility is required to disinfect their inlet water.

After the particles in the water are removed, the water needs to be disinfected to prevent diseases spreading through the water, e.g., Infectious pancreas necrosis (IPN) or heart and skeletal muscle inflammation (HSMI). UV filters is a physical method of eliminating or inactivating parasites, bacteria, and viruses from the water stream through photochemical damage by using UV radiation (Acuaculture Consultansy and Engenering, 2018).

Opposed to the physical method for disinfection of water with the use of a UV system, chemical methods for the disinfection of water may be an alternative to use, e.g., ozone treatment of water. Ozone is a strong oxidizing agent, which is extremely toxic for all lifeforms. This toxicity makes ozone a handy tool for the removal of bacteria, viruses, fungi, protozoa, and algae by destroying their cellular membrane (Lekang, 2013).
Ozone concentrations of 0,0093 mg/l has proven to be deadly for rainbow trout in freshwater (Litved.H og Vogelsand. C, 2011), but in, e.g., RAS, the ozone treatment takes place in separate systems so that the fish is never exposed to any danger. Ozone’s extremely short reaction time also makes it safer to use as a disinfectant in intensive salmon production compared to other chemical substances, e.g., chlorine (Litved.H og Vogelsand. C, 2011), if it is used correctly.

One of the advantages with the usage of ozone and its strong oxidizing abilities, is the clarifying of water by removal of coloration (Lekang, 2013).

2.3.3. pH adjustment

Water used in the production of salmon will need a pH adjustment, if the pH values are outside the recommended range from 6.5 – 7.0 (Lekang, 2013). Through respiration, the salmon will produce CO_2, which is easily soluble in water to carbon acid (H_2CO^3), and the solubility will variate with temperature and pressure (Haraldsen.H og Pedersen.B, 2019). E.g., with an atmospheric pressure of 1 at 15°C, 1 liter of water dissolves 1 liter of CO_2, if the temperature drops to 0°C, one liter of water dissolves 1,7 liter of CO_2 (Haraldsen.H og Pedersen.B, 2019). In facilities with an FTS, the adjustment rate of pH depends on the conditions of the water source. For the RAS facilities, a certain amount of reuse water will also affect the pH variations in the system, and therefore also the adjustment rate (Lekang, 2013).

Water has a specific capacity to neutralize acids, with the carbonate system representing the major part of the alkalinity. Since the salmon help lowering the pH in the production water, making it more "acid-rich," then the adjustment of pH is done by removing H^+ ions.
In RAS facilities, it is a tendency of decreasing pH where bacteria produce acids, and CO_2 is generated by the salmon and the biofilter (Masser.M.P, Rakocy.J and Losordo.T.M, 1992). To adjust the pH, salmon farmers can either add hydroxides (OH-) or carbonate compounds like magnesium carbonate (MgCO3) or calcium carbonate (CaCO3).

In the water treatment process, the adjustment of pH takes place before the water reaches the salmon. In FTS, it can often be by treating the water source directly, and in RAS, it can be done with an independent treatment tank (Billund, 2020). Seawater in levels of 2% - 4% can also be used to increase pH because of its buffering capacity. Seawater naturally contains carbonate ions (CO_3^{-2}) and bicarbonate ions (HCO_3^-) and is, therefore, a possible pH buffer (Lekang, 2013). If seawater is to be used, pathogenic microorganisms and poisonous algae must be considered (Lekang, 2013) as well as H_2S arising to a larger degree from the decomposition of the organic matter in seawater as mentioned earlier in chapter 1.2.

2.3.4. Heating and cooling

Heat exchangers are commonly used in all land-based aquaculture facilities. They are economically beneficial to have in these facilities, as they offer a solution where heat or cold can be transferred between inlet and outlet water (Lekang, 2013).
The heat exchangers could be used directly before the tanks or in combination with heat pumps, to save costs on heating of the water (Lekang, 2013).

The energy or heat is transferred from the liquid with the highest temperature to the transfer plate, then trough this transfer plate, and to the liquid with the lowest temperature. With this type of equipment, fish farmers can manipulate the temperature of the water by changing the flow pattern through the heat exchanger. (Lekang, 2013)

Land-based intensive aquaculture requires stable temperatures for the fish to grow optimally. Heat pumps are used to obtain these stable temperatures.

The heat pump can be compared to a refrigerator. A refrigerator is used to remove energy from a media, to keep a cold temperature, a heat pump is used to add energy to a media and increase the temperature (Can also be used for cooling). The energy required to heat water is determined by the specific heat capacity (kJ/kg°C) of the water, e.g., to heat 1 kg of freshwater 1°C, you need 4,2 kJ/kg°C energy (Lekang, 2013).

2.3.5. Aeration

When water is heated, the solubility of gases decreases, which can lead to an oversaturation in the water. An oversaturation can be extremely lethal for fish, and land-based fish production must remove these excess gasses like, for instance, N and CO_2. CO_2 is a substance that possibly can, in excessive amounts in the production water for salmon, hurt the salmon's performance and welfare. Excessive amounts of CO_2 can reduce the oxygen uptake of the salmon, lead to low pH values, lead to nephrocalcinosis (kidney stone), and deformation in the salmon skeleton (Bjerkestrand. B, Bolstad. T og Hansen.S-J, 2013). CO_2 in inlet water for Norwegian land-based aquaculture is usually not a problem, since the Norwegian freshwater does have low concentrations of CO_2, unless the facilities are located near areas with high lime concentrations (Bjerkestrand. B, Bolstad. T og Hansen.S-J, 2013).

To remove these excess gasses, different methods and equipment can be used, e.g., diffuser, surface agitators, and pressurized or non-pressurized columns (Losordo. T.M, Masser. M.P and Rakocy. J, 1998). The main principle of aeration is to create irregularities in the water so that the gas exchange between water and air gets more effective. One very common way to aerate the production water is aeration by columns (Bjerkestrand. B, Bolstad. T og Hansen.S-J, 2013).

In RAS facilities where the water is reused, there is an increased possibility for CO_2 build up. CO_2 is naturally added to the production water with decay of feed and feces (Wang. X, Olsen. M.O, Reitan. K.I and Olsen. Y, 2012), respiration of fish and through gas exchange with water and air (Bjerkestrand. B, Bolstad. T og Hansen.S-J, 2013).
Because of this, RAS facilities usually need to adjust the CO_2-concentration in the production water, and this is mostly done by adding strong bases that don't contain carbon. The addition of this may lead to a failure to remove dissolved inorganic carbon (DIC) from the water, and therefore there needs to be a gas exchange between water and air (Noble.C, 2018). The CO_2-aerator can provide effective removal of CO_2 and N (Akvagrouptm, 2020).

2.3.6. Oxygen addition

There are many different reasons for adding oxygen (O_2) to the salmon's production water, first and foremost because the salmon reduces the levels of dissolved oxygen in the water through respiration which in turn leads to an increase in CO_2 and also ammonia (NH_3) in RAS (Noble.C.A and Summerfelt.S.T, 1996). In intensive aquaculture production, the addition of pure O_2 can increase the salmon production without increasing the quantity of water necessary and, at the same time, reduce the required water flow and pumping costs (Lekang, 2013). For the RAS facilities addition of pure O_2 may also reduce the new water necessary to uphold optimal production (Lekang, 2013).

The theory behind adding pure O_2 to the salmon's production water, is to increase the O_2 saturation in the water, up towards 100%. Studies have stated that 70% O_2 saturation in production water for Atlantic salmon, at water temperatures of 16°C, will set limitations in appetite, and affect growth negatively (Remen.M, 2012). When O_2 saturation reaches 60% and downwards to 30%, farmers will register adverse effects on production performance and welfare (Remen.M, 2012).

Today many land-based aquacultures facilities inject pure O_2 directly in the inlet pipes to the different departments and through oxygenation equipment in the tank itself. The oxygenation equipment is usually connected to some sort of alarm and monitoring system, so that it can be injected in the case of an emergency.

2.3.7. Tanks and wastewater pipe

Tanks used in land-based aquaculture facility, can vary in terms of shapes, sizes, and materials, but the principal of the tanks are about the same. It consists of the three main components, water inlet, production unit, and water outlet. Optimally, the fish should be distributed evenly in the tank, and the tank itself should possess god self-cleaning capacity, to ensure that feces and feed residue are transported out of the production unit (Lekang, 2013). It is the tank that houses the fish during its time in the facility, and therefore the tank must contribute to optimize the water quality.

For FTS facilities with demands on the purification of effluent water, and especially for RAS that collects sludge and reuse water, the length and conditions in the waste pipe from the tanks, play a secondary independent role in the water treatment steps for the facility. Feces and feed residue are transported from the tanks through the wastewater pipe and to the filters where particulate waste can be collected and extracted. The length of the pipe, combined with the transport speed and turbidity inside the pipe influences breakages of the feces, before it reaches the filter (Lekang, 2013). If the transport length of the pipe is long and rough, it can be assumed that more feces break into smaller particles that will pass through the filter and be lost to the recipient (Figure 11).

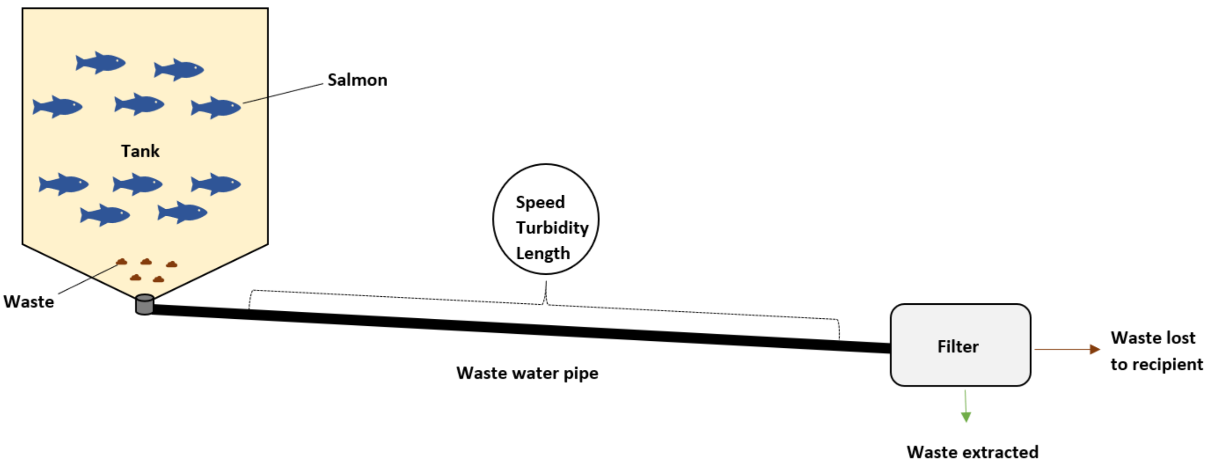

Figure 11: Wastewater pipe connecting the salmon tank to filter, showing how the conditions in this pipe may affect the transported material, in terms of what is possible to gather and what will be lost to the recipient.

2.3.8. Biofilter

One essential step when recirculating water in intensive salmon production, is the biological filtration of NH_3. In aquaculture, NH_3 occurs naturally trough the ammonification process, when organic N from fish feed, feces, and dead fish is decomposed by microbes. This NH_3 gas is extremely deadly for the fish and needs to be removed from the recycled water (Terjesen. B. F og Rosseland. B. O, Retrived 01.03.2020). The biofilter gives the RAS a possibility to reform the dissolved waste produced in salmon production, thus separating the RAS from the FTS further because this is a purification step that is not possible in FTS today.

Biofilters takes advantage of microbes that naturally breaks down NH_3 in the nitrogen cycle. NH_3 is converted to nitrite (NO_2^-), which is consumed by other microbes and converted further to nitrate (NO_3-) (Rosten. T. W, Ulgenes. Y, Henriksen. K, Terjesen. B. F, Biering. E og Winther. U, 2011).

To remove the NO_3- from the environment, the microbes conduct a denitrification process, where the denitrifying bacteria converts NO_3- to oxygen (O_2) and to free nitrogen (N_2), like so: $NO_3- \rightarrow N_2 + 3O_2$ (Oslo, 2019).

To make this process optimal, the biofilter needs to provide the necessary environmental factors for the microbes to thrive. The biofilter can consist of different types of bio-bodies on which microbes can form biofilms, the filter is usually kept at stable pH-levels for the microbes, and the filters are supplied with O_2 and NH_3 trough wastewater from the fish tanks, which of course is “food” for the microbes (Lekang, 2013).

As mentioned earlier, RAS facilities vary in designs depending on the suppliers, and this is also the case for what kind of biofilter that should be used in the different RAS facilities. The two main biofilters that are commonly used are moving bed solutions and still bed solutions. The still bed solutions consist of a larger bio-body plate that wastewater physically must pass through, while the moving bed solutions consist of multiple tiny bio-bodies that swirls around in a water treatment tank (Lekang, 2013).

2.4. Feed distribution system

In salmon farming and farming in general, feed equals growth. What is special about feeding strategies for salmon farming, is that the environment in a tank is hugely different from the situation on land, and this sets specific requirements to the salmon feed, feed system (Cho.C.Y, 1992), and the internal feed transport system of various facilities.

Internal feed transport is a standard process in a land-based aquaculture facility, and there are many different solutions from transporting the feed from point A to point B.

The goal for the feed distribution system is to transport the feed from the storing tanks out to the different salmon tanks in the facilities various departments. The most important part of the feed distribution system is to transport the feed without destroying or damaging it (Skaar, 2020). A damage feed pellet will break or reform into dust. If the feed pellet breakages and dust forming is too high, the salmon will not eat these particles because they are too small, and the feed will ultimately go to waste (Skaar, 2020).

When feed manufacturers produce a specific type of pellet, the dust and breakage of the pellet can be as little as 0,03% (Skaar, 2020). Depending on the delivery method, from feed production facility to the aquaculture facility, the breakage and dust percentage can increase to some degree. Numbers from Cargill indicates 0,38% breakage and dust with deliverance from bulk truck (Skaar, 2020).

Research from Cargill shows that increasing internal feed transport length and numbers of twists and turns in the feed transport system in land-based aquaculture facilities, correlate with increasing dust and breakage percentage. The data is collected from research done in a RAS facility with a chain transport system for feed distribution to the individual departments of the facility. Results from this test shows an average of 2,51% dust and breakage created from internal transport in these two different feed transport systems (Skaar, 2020).

2.5. Sludge treatment

Sludge treatment is an additional but separate step in RAS. It has become more and more relevant now that the government is starting to tighten up its licensing policy on the collection and further processing of sludge from land-based fish farming facilities (Pedersen.T.N, Personal message, 2020). These changes in the licensing process is a result of a knowledge increase within the aquaculture field, for both participants, inspectors and controllers, as well as public awareness of environmental challenges connected to the aquaculture industry.

Sludge from closed fish farms mostly consist of feces and feed waste, that is naturally occurring in intensive fish production, but can be kept to a minimum with low feed waste while feeding the fish (Aas.T.S, Ytrestøyl.T og Berge.G.M, 2016). The amount of sludge produced will vary with the selected production models, e.g., the more fish produced, the more sludge produced. Since sludge mostly originates from the feed, it has the potential of becoming a useful bi-product if handled correctly. Sludge is a good source of N and P (Table 6), and P is a limited resource that is also one of the essential components of fertilizer. This makes sludge treatment one very important subject in aquaculture production today (Aarhus I. J, Høy. E, Fredheim. A og Winther. U, 2011).

Table 6: Average content of sludge from different aquaculture facilities

Content in sludge from various facilities		**Source**
Ash (% of DW)	15 – 22	(Hagemann.A, 2020)
Protein (% of DW)	13 – 25	
N (% of DW)	3 – 12	
C (% of DW)	29 – 41	
Lipid (% of DW)	8 – 20	
Fatty acids (% of DW)	2 – 5	
P (% of DW)	2 – 3	

3. Part 1: Review of Norwegian land-based aquaculture emission permits

3.1. Material and method

Production licenses with embedded emission permits were retrieved from the web site "norskeutslipp.no," which is a web site that, among other things, gathers and shares production licenses from different fish farming companies that's been made available to the public.

To get a good overview of the emission permits in all of Norway, 15 production licenses were gathered from three of Norway's most significant fish farming counties (Vestland, Trøndelag, and Troms), five licenses from each county. Norway is a long country, and by dividing the country into three focus areas, a good overview was obtained. Because FTS per now is more common in Norway than RAS, it was gathered nine permits from FTS, five permits from RAS, and one combination permit from FTS and RAS.

3.2. Results

The facility's different locations and environmental status, affected the formulation of an applicant's size and purification requirements of their discharge.

The results showed a variation in licensing terms and purification demands (Table 7). Prominent differences were seen in restrictions for maximum allowed biomass, feed used, and number of salmon set in sea per year, and also in purification demand and measurement method.

Common for all the emission permits was that the licenses sat a requirement that every facility must do their best to obtain the lowest possible FCR in the facility and make sure the equipment function in the best way possible, given the circumstances.

Table 7: Overview of production licenses in three different production counties in Norway.

County	Facilities	License			System	Purification							Ref.
		Biomass (ton/year)	Feed (ton/year)	Number of fish (mill)			COD	BOD	TOC	SS	N	P	
Vestland (Hordaland / Sogn og Fjordane)	Alvøen	110	110	1,1	FTS	No							(Myksvoll.S, 2002)
	Nesfossen	2000	2400	2,5	FTS	50%							(Pedersen.T.N , Utslippstillatelse, 2014)
	Sagvåg	570	680	5	RAS		50%	50%	50%	70%			(Aune.E, 2009)
	Sævareid	4300	4300	20	RAS and FTS				140 t/yr.		130 t/yr.	14 t/yr.	(Pedersen.T.N , Utslippstillatelse, 2015)
	Femangerlaks	100	100	1	FTS	No							(Ekli.M, Utslippstillatelse, 2002)
Trøndelag	Belsvik	1120		14	RAS			60%		65%			(Lorvik.M og Ekli.M, 2012)
	Bessaker			2,5	FTS	No							(Bretten.A, 98)
	Sagelva			2	FTS	No							(Espedal.T, 2008)
	Statland		650	7,5	FTS	No							(Gorseth.M.B.M, Utslippstillatelse, 2013)
	Røyklibotn		400	5	RAS		20%	20%	20%	50%			(Gorseth.M.B.M, Utslippstillatelse, 2014)
Troms	Sandøra	1800	1972	12	RAS				70%		20%	60%	(Krogstad.P.K , Utslippstillatelse, 2018)
	Storelva		270	2,5	FTS	No							(Krogstad.P.K , Utslippstillatelse, 2012)
	Salangsverket	1547,7	1553	6	FTS	No							(Krogstad.P.K , Utslippstillatelse, 2016)
	Jøvik	1557	1500	15	RAS						47 t/yr.	3,2 t/yr.	(Krogstad.P.K , Utslippstillatelse, 2014)
	Foldvik	210		3	FTS	No							(Krogstad.P.K , Utslippstillatelse, 2013)

One in ten of FTS facilities had requirements for 50 % purification of wastewater, but it was not specified what substance to reduce by 50% (Figure 12). Eight in ten had no demands for purification. Six in ten had emission permits based on production as a maximum allowed biomass (ton/year) and seven in ten as feed (ton/year).
All ten FTS facilities had restrictions in production defined as the maximum number of fish

set in sea per year. Of these, two in ten of the FTS facilities had no other restrictions in the production than the number of fish set in sea pr. Year.

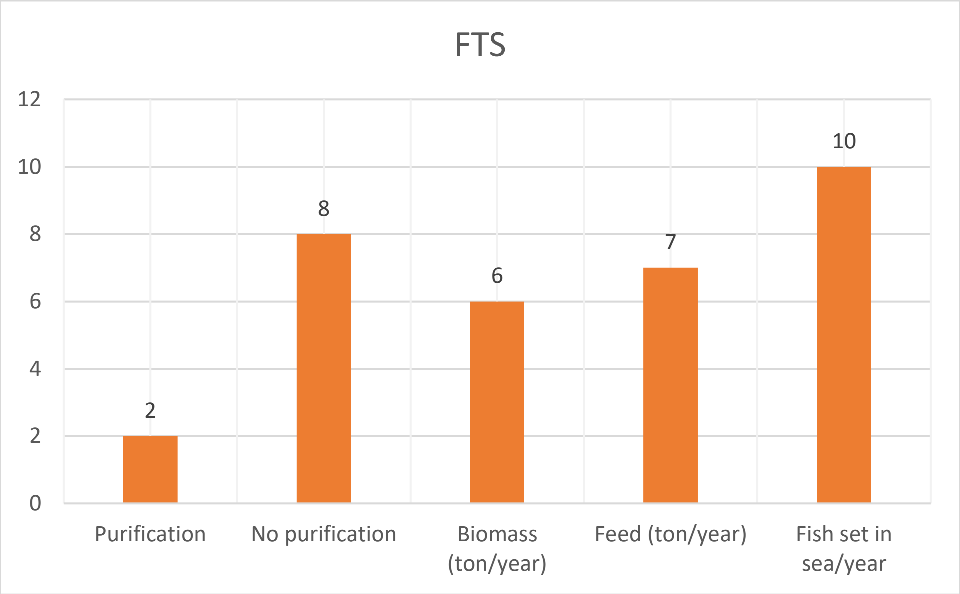

Figure 12: Requirements set in emission permits for Norwegian FTS.

Furthermore, the emission permits show that all the facilities with RAS require purification of the effluent water (*Figure 13*). Two in six RAS facilities got emission permits based on purification of COD, BOD, TOC and SS, two in six RAS facilities on TOC, N and P with different methods of measuring TOC either percent or ton, one in six RAS facilities were only required to measure on BOD and SS, and one in six RAS facilities was only measuring on N and P in ton per year (Table 7). All RAS facilities had restrictions in production defined as the maximum number of fish set in sea per year, along with limitations in feed usage per year and/or maximum biomass production per year (*Figure 13*).

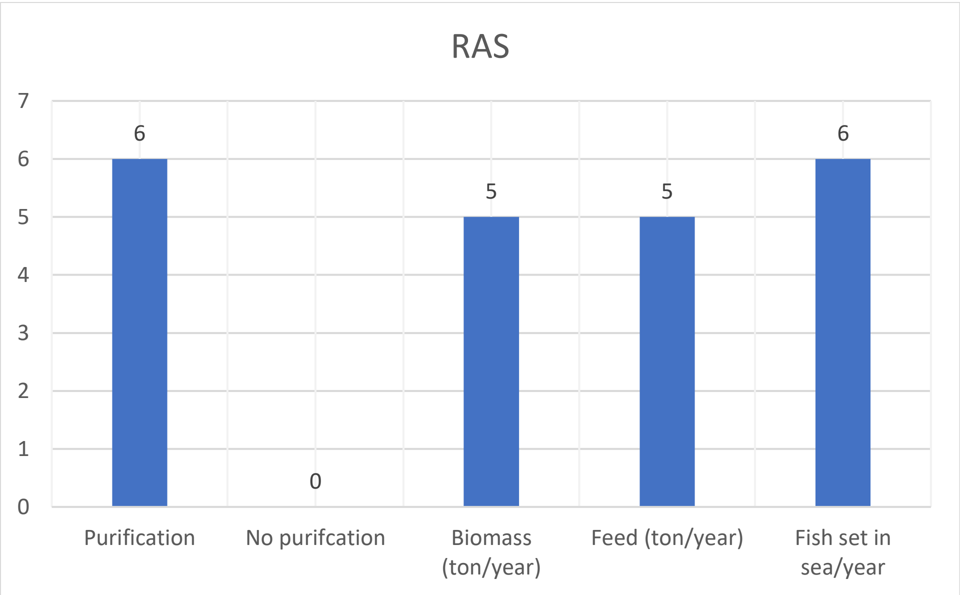

Figure 13: Requirements set in emission permits for Norwegian RAS facilities.

3.3. Discussion and conclusion

Most of the purification demands in the emission permits were given for production in RAS, where four permits demanded percentage purification of the total production. This may lead to an incorrect assumption of the emissions from a facility, because the tonnage waste produced and released is never specified. For one of the FTS listed, a purification demand was given at a 50% reduction of waste. Still, the emission permit lacked specifications of what substance or even nutrient that should be reduced in the waste. One concern is that none of the licenses listed, separated particulate waste from dissolved waste, giving little control to actual nutrient release from the salmon farms.

The emission permits also differed on measurement method of COD, BOD, TOC, SS, N, and P and only the newest emission permits (from 2014) sat purification requirements on N and P. I do not see any reason for why there is not a common standard for these measurement methods and purification demands? It seems to give more control on a higher level, if the whole country relates to a common standard. It may also increase our knowledge of waste production and system functionality in land-based salmon farms, if every facility operates from a common standard, measuring the same nutrient release. An interesting observation was that the emission permits see N and P as a whole, both particulate and dissolved, while C is only estimated in TOC, which is the sum of POC and DOC, leaving a small part of DIC and CO_2 out of its equation.

Two production licenses that caused concern regarding environmental impact were Bessaker and Sagelva, which sat no purification demands, and only limited production with the number of fish set in sea per year. What control does this provide if waste production variates between production of 100g, 300g and 500g of salmon?
There is, to some degree, a form of control if the licenses specify that this is a smolt producing facility. But if this is exaggerated to emphasize a point, if a license does not specify that it is smolt production and a facility suddenly has the possibility to produce 5 kg salmon, there are no restrictions stopping them from doing so, and their waste production would possibly increase significantly.

By restricting production with maximum feed usage, maximum biomass, and maximum number of fish produced, the licenses and permits gives no room for self-improvement to reduce waste more effectively amongst the production facilities. If not tended to, this waste licensing system will certainly not improve the industries sustainability in the upcoming future. E.g., with all these restrictions, there is no reason for salmon farmers to search for solutions to reduce their emissions of waste. If a feed producer, for instance, can offer a feed that reduces the particle waste produced by 6%, and a filter manufacturer can deliver a filter that reduces the particle waste amount by 10%, the salmon farm can now reduce the total particle waste produced by 16%. For the salmon farm, this will, of course, include a substantial investment cost with the increase in the feed budget and the cost of buying and installing the new filter. However, because of the restrictions set in the license and the emission permits, the facility still can only produce a certain amount of salmon to a certain amount of biomass each year.

If licenses and emission permits, on the other hand, operated from specific values of certain nutrient waste produced in the duration of a year, farmers could produce as much fish as they want to, as long as they do not exceed the emission permits. From this, the motivation to work on reducing waste production may come, if the farmers see some sort of personal gain.

It can be concluded that the production licenses and emission permits listed above gives little to no control of waste produced and released to the environment and respective recipient. At the same time, there is no standard for purification demand, equal for the entire country. Even though the emission permits are poorly formulated, they all require an effort of optimal feeding, meaning that every salmon farmer should try their best to keep FCR as low as possible, around 1. By doing this, salmon farmers that purify waste does remove the particle waste and not just excessive feed pellets.

4. Part 2: Waste model development and comparison of waste from FTS and RAS conditions

4.1. Material and method

It was chosen to develop a mathematical model for waste estimation, to calculate the differences between the FTS and RAS. The model should estimate waste with the mass balance principle of distribution from an input, how much of C, P and N were retained, respired, dissolved and particulate, separated in and from the salmon (chapter 2.1). To obtain and increase the accuracy of the waste model, it was chosen to calculated waste with input values from a production plan, with weekly calculations on biological needs in salmon production. Weekly estimates in the production plans were determined because this would generate sufficient data to uncover possible differences between the two systems. The model formed by developing a mathematical waste model from a production plan became what is referred to as the "VØF-model."

To test the VØF-model, and study differences in the nutrient content of waste from FTS and RAS, three theoretical production plans of 100g, 300g, and 500g salmon were simulated for the FTS and RAS. Different facilities commonly produce salmon from 100g up to 500g +, and these salmon sizes roughly represent the various productions of 0-year-old, 1-year-old, and post-smolt production, that are commonly seen in Norway today. It was chosen to simulate productions of 100 000 salmon smolts for each system, and look at the total waste produced and the percentage variation between the production models. In the production plan, some factors that did not have a direct link to the discharge of nutrients, e.g., oxygen demand, water demand, etc., were added. The intension was to see if these kinds of factors would correlate with the discharge of nutrients.

The approach for the mathematical calculations, along with production estimates for each 100g, 300g, and 500g production plan, is presented together. These will naturally be woven into one another for the different steps. Se appendix 13A – 13G for production plan and emission model (Appendix 13).

4.1.1. Specific growth rate, individual weight and biomass

One main factor affecting waste production is as mentioned the size of the salmon, because bigger salmon need more feed. Therefore, they will probably produce more waste than smaller salmon. The production plans had to provide a realistic assumption of salmon growth in Norwegian land-based salmon farms.

Specific growth rate or SGR addresses the growth of the salmon at different temperatures and different weights (size). SGR is expressing the daily growth rate of the salmon body in percentage:

$$SGR\left(\frac{\%body\ wt.gain}{day}\right) = \frac{(Log\text{n}\ Final\ fish\ wt. - Logn\ Initial\ fish\ wt.)}{Time\ interval} * \ 100\%$$

Since the SGR would change according to the water temperature and size of the salmon, a table from Skretting was used to estimate these variations. This table is also used in MOWI estimates (Tørrisen.A, 2020). <u>NB! The yellow lines and the helplines above were added for calculation purposes</u> (Table 8).

Table 8: SGR% per day Atlantic Salmon (Salmo salar) – Skretting ClubN (Tørrisen.A, 2020)

Fish Weight (g)

Temperature in freshwater	0,20	0,50	1,00	2,00	3,00	4,00	5,00	10,00	15,00	20,00	25,00	30,00	35,00
	2,00	3,00	4,00	5,00	6,00	7,00	8,00	9,00	10,00	11,00	12,00	13,00	14,00
1	1,83	1,41	1,16	0,95	0,85	0,78	0,73	0,60	0,54	0,50	0,47	0,45	0,43
2,0	1,83	1,41	1,16	0,95	0,85	0,78	0,73	0,60	0,54	0,50	0,47	0,45	0,43
3,0	2,34	1,82	1,50	1,24	1,11	1,03	0,97	0,80	0,72	0,67	0,63	0,60	0,58
4,0	2,85	2,23	1,85	1,54	1,38	1,28	1,21	1,01	0,91	0,84	0,80	0,76	0,73
5,0	3,36	2,64	2,20	1,83	1,65	1,53	1,44	1,21	1,09	1,01	0,96	0,92	0,88
6,0	3,86	3,05	2,55	2,13	1,92	1,78	1,68	1,41	1,27	1,19	1,12	1,07	1,04
7,0	4,37	3,46	2,89	2,42	2,19	2,03	1,92	1,61	1,46	1,36	1,29	1,23	1,19
8,0	4,88	3,86	3,24	2,72	2,45	2,28	2,16	1,81	1,64	1,53	1,45	1,39	1,34
9,0	5,39	4,27	3,59	3,01	2,72	2,53	2,39	2,02	1,83	1,70	1,61	1,55	1,49
10,0	5,90	4,68	3,94	3,31	2,99	2,78	2,63	2,22	2,01	1,87	1,78	1,70	1,64
11,0	6,41	5,09	4,28	3,60	3,26	3,03	2,87	2,42	2,19	2,05	1,94	1,86	1,79
12,0	6,91	5,50	4,63	3,90	3,53	3,28	3,11	2,62	2,38	2,22	2,11	2,02	1,95
13,0	7,42	5,91	4,98	4,19	3,79	3,53	3,35	2,82	2,56	2,39	2,27	2,17	2,10
14,0	7,93	6,32	5,33	4,49	4,06	3,78	3,58	3,03	2,75	2,56	2,43	2,33	2,25
15,0	8,44	6,73	5,67	4,78	4,33	4,03	3,82	3,23	2,93	2,74	2,60	2,49	2,40
16,0	7,94	6,29	5,27	4,43	3,99	3,72	3,51	2,95	2,67	2,49	2,36	2,26	2,18

Fish Weight (g)

Temperature in freshwater

40,00	45,00	50,00	60,00	70,00	80,00	90,00	100,00	125,00	150,00	175,00	200,00	225,00	250,00	300,00
15,00	16,00	17,00	18,00	19,00	20,00	21,00	22,00	23,00	24,00	25,00	26,00	27,00	28,00	29,00
0,41	0,40	0,39	0,37	0,36	0,35	0,34	0,33	0,31	0,30	0,29	0,29	0,28	0,28	0,27
0,41	0,40	0,39	0,37	0,36	0,35	0,34	0,33	0,31	0,30	0,29	0,29	0,28	0,28	0,27
0,56	0,54	0,53	0,51	0,49	0,48	0,46	0,45	0,43	0,42	0,40	0,39	0,39	0,38	0,37
0,71	0,69	0,67	0,64	0,62	0,60	0,59	0,57	0,55	0,53	0,52	0,50	0,49	0,49	0,48
0,86	0,83	0,81	0,78	0,75	0,73	0,71	0,70	0,67	0,64	0,63	0,61	0,60	0,59	0,58
1,00	0,98	0,95	0,91	0,88	0,86	0,84	0,82	0,78	0,76	0,74	0,72	0,71	0,70	0,68
1,15	1,12	1,09	1,05	1,01	0,99	0,96	0,94	0,90	0,87	0,85	0,83	0,82	0,81	0,79
1,30	1,26	1,23	1,18	1,15	1,11	1,09	1,06	1,02	0,99	0,96	0,94	0,92	0,91	0,89
1,45	1,41	1,37	1,32	1,28	1,24	1,21	1,19	1,14	1,10	1,07	1,05	1,03	1,02	1,00
1,59	1,55	1,52	1,46	1,41	1,37	1,34	1,31	1,25	1,21	1,18	1,16	1,14	1,12	1,10
1,74	1,70	1,66	1,59	1,54	1,50	1,46	1,43	1,37	1,33	1,29	1,27	1,25	1,23	1,20
1,89	1,84	1,80	1,73	1,67	1,62	1,59	1,55	1,49	1,44	1,41	1,38	1,35	1,34	1,31
2,04	1,98	1,94	1,86	1,80	1,75	1,71	1,68	1,61	1,56	1,52	1,49	1,46	1,44	1,41
2,18	2,13	2,08	2,00	1,93	1,88	1,84	1,80	1,72	1,67	1,63	1,60	1,57	1,55	1,52
2,33	2,27	2,22	2,13	2,06	2,01	1,96	1,92	1,84	1,78	1,74	1,70	1,68	1,65	1,62
2,11	2,06	2,01	1,93	1,86	1,81	1,77	1,73	1,66	1,60	1,56	1,53	1,50	1,48	1,45

In theory, the SGR shows achievable growth for the salmon. Still, due to the handling of salmon in fish farms, e.g., vaccination, grading, or moving of salmon between departments, stress levels in the salmon will increase, which in turn will affect the growth (Tørrisen.A, 2020). Ahead of these operations, the salmon will also be starved. These factors were taken into consideration when setting up the production plan, and experience numbers from MOWI facilities were used for these estimations (Table 9).

Table 9: Corrected SGR values of different types for different work operations with handling of salmon

Week	**Work operation 1.**	**Cor. SGR**	**Work operation 2.**	**Cor. SGR**	**Reference**
1	**Grading**	**0,5**		**0,3**	(Tørrisen.A, 2020)
2			**Vaccination**	**0,5**	
3				**0,9**	
4				**0,9**	

The individual weight of the fish was calculated weekly to get a good overview of production differences between FTS and RAS:

$$V1 = V0 * \left(1 + \frac{d}{100}\right)^{t}$$

V1 shows the final weight of the salmon after a certain amount of time (t) (in this thesis 7 days), V0 represents the initial weight, d equals SGR. From the individual weight and number of salmons per production plan (100g, 300g, or 500g) per week, the biomass was calculated. Biomass represents the total weight of all the salmon in the respective production plan (Bjerkestrand. B, Bolstad. T og Hansen.S-J, 2013):

$$Biomass = \text{Number} * \text{Average weight(Individual weight)}$$

4.1.2. Feed demand and Feed Conversion Rate

The feed calculations for each of the salmon production models were formed on the same design. This is because the feed demand is modeled after the size and weight (SGR) of the salmon. As mentioned earlier, bigger salmon are assumed to need more feed to grow and, therefore, will presumably produce more sludge.

The feed consumption is calculated weekly, with the principle of the standard formula:

$$\frac{Biomass\ at\ end\ of\ period - Biomass\ at\ start\ of\ period}{Number\ of\ days} x\ Feed\ conversion\ rate$$

However, for the production plans, a modified version was used:

$$\left(\frac{Biomass\ at\ end\ of\ period - Biomass\ at\ start\ of\ period}{Number\ of\ days} x\ Feed\ conversion\ rate\right) x\ Cor.SGR$$

The nutritional variations in feed, are directly correlated to the different nutritional demands of the salmon at certain life stages. The salmon will also utilize different feed types differently as it grows (Table 10). Therefore the biological feed conversion rate (BFCR) would be variating (Lomnes.B.S, Senneset.A og Tevasvold.G, 2019). To make this thesis relevant for the farmers, the calculations took into consideration the feed loss that came from feed not eaten by the salmon in the tanks. It is important to understand that the salmon is fed by appetite, and this can vary, so in reality, farmers must adjust the feed amount on their intuition. With this method, faults can occur. Therefore the calculations were done with a 5% excessive feeding (Table 4, chapter 2.1.4) plus 2,51% dust and breakage (Chapter 2.4), which was ultimately not consumed by the salmon. This gave a total estimate of 7,51% feed not eaten by salmon, which was added to the waste model as an addition to the overall feed usage per production.

Table 10: Average biological feed conversion rate stated by feed producers (Lomnes.B.S, Senneset.A og Tevasvold.G, 2019).

Fish weight (gram)	BFCR
0-50	0,77
50-200	0,82
200-500	0,87
500-1000	0,97

To meet the nutritional and biological demands of the salmon at different life stages, the feed given to the salmon would variate in pellet size and content (Skaar, 2020). Therefore, to calculate the average amount of C, P, and N inputs in the different productions and systems, the feed given would variate with the salmon's growth (Table 11). A total of C, P, and N for both systems combined would also be calculated for a comparison. Values used in these calculations were average C, P, and N in FTS and RAS feed gathered from literature (Chapter 2.1.1).

Table 11: Feed variations of C, P, and N, correlating to salmon growth, and a total. Based on average in (Table 2: Typical C, P, and N content in salmon feed.).

System	Feed type	Pellet Size (mm)	Fish size (grams)	C (%DW)	P (%DW)	N (%DW)
FTS	Starter	0,6-1,3	0,15 – 4,9	45,21	1,86	8,52
	Fingerling	1,5-2,2	5 – 39,9	47,60	1,54	7,71
	Grower	3,0-6,0	40+	47,27	1,31	7,27
	Transfer			46,32	1,6	7,52
RAS	Starter	0,6 – 1,3	0,15 – 4,9	45,45	1,77	8,35
	Fingerling	1,5 – 2,2	5 – 39,9	46,38	1,56	6,98
	Grower	3,0 – 6,0	40+	46,97	1,50	6,98
	Transfer			45,46	1,6	6,72
FTS/RAS	All		All	45,46	1,72	7,78

For comparison, an independent feed value for C, P, and N at 45,62% DW, 1,67% DW, and 7,57% DW, was also added. The independent value was not specified to any production and was a total average of C, P, and N content in the feed, based on information collected from the literature (Table 2). This was done to see how the content in feed changed with production models.

4.1.3. Mortality

The mortality variates through the different life stages of the salmon, with the highest occurrence of mortality being in the early life stages of the salmon (Lekang, 2013). The difference from literature and experience numbers from salmon farmers are substantial when it comes to mortality, where literature states a total survival of 50-80% and experience numbers from salmon farmers states a total survival of 95% (Tørrisen.A, 2020). The mortality was therefore set as an average of these two sources giving a calculated mortality from eye eggs to end of start feeding at 2,62%. Throughout the on-growing stage, the mortality was set to 0,05% (Table 12).

For grading and vaccination, experience numbers from salmon farmers indicated a 2,54% mortality in connection to grading and a 1,27% mortality over three days connected to vaccination (Tørrisen.A, 2020). This mortality is partially due to the separation and destruction of salmon with deformities and small salmons. Some salmons may also die in conjunction with the vaccination process and maybe even the vaccine itself (Tørrisen.A, 2020).

Since the mortality alters the number of salmon from week to week, the grading and vaccination mortality was calculated by subtracting the percentage from the end survival value. For 100 000 salmon, this gave a mortality with grading to 2540 salmons and 1270 salmons over three days of vaccination (total of 3810 salmon assumed dead by association to vaccination).

Table 12: Mortality (%) of Atlantic salmon gathered from literature and experience from MOWI facilities.

	Mortality (%) in literature	**Mortality (%) experience from MOWI – facility**	**Average (%)**
Eye eggs	5-15	0,25	2,62-7,62
Hatching	5	0,25	2,62
Start feeding	5-15	0,25	2,62-7,62
Ongrowing including sea water stage (%per month)	0,1-1	0,01	0,05-0,50
Grading (%)		2,54	2,54
Vaccination (% per 3 days)		1,27	1,27
Total survival (%)	50-80	95	

The low mortality percentage from the MOWI experience numbers was caused because these numbers only estimated salmon mortality (Tørrisen.A, 2020) and did not incorporate average salmon destruction numbers, as the literature mortality did (Lekang, 2013). By using average mortality percentage from both these sources while also adding salmon destruction to the production plan, the estimations were believed to become more precise.

4.1.4. Water and oxygen demand

When calculating the amount of water usage to land-based facilities, it was differentiated between the production models specific water demand (SWD) and the specific water usage (SWU), all based on the salmon's biological need, in consideration of size and temperatures. The SWU per salmon was found by using a table (Table 13) for these calculations.

Table 13: Freshwater requirements of fish over a range of fish weights and water temperatures, given in l/kg fish/min (95% saturation of intake water) Kittelsen og Fjoera, 1993. (Lekang, 2013)

		Fish weight (gram)									
Temperature (°C)		0,2	1	5	10	50	100	500	1000	2500	5000
	1	0,51	0,37	0,27	0,24	0,17	0,15	0,15	0,13	0,11	0,10
	2	0,51	0,37	0,27	0,24	0,17	0,15	0,15	0,13	0,11	0,10
	4	0,78	0,57	0,42	0,36	0,27	0,23	0,23	0,20	0,17	0,14
	6	1,14	0,83	0,61	0,53	0,39	0,34	0,33	0,29	0,24	0,21
	8	1,68	1,23	0,90	0,79	0,58	0,50	0,49	0,43	0,36	0,32
	10	2,48	1,82	1,33	1,16	0,85	0,74	0,72	0,63	0,53	0,43
	12	3,21	2,35	1,72	1,50	1,10	0,96	0,94	0,82	0,68	0,60
	14	4,19	3,07	2,24	1,96	1,43	1,26	1,22	1,70	0,09	0,79
	16	5,53	4,05	2,96	2,59	1,90	1,66	1,62	1,42	1,18	1,03
	18		5,72	4,18	3,66	2,68	2,34	2,28	2,00	1,67	1,46

When the SWU per salmon was determined, the SWD for the production models could be estimated, using the formula:

$$\text{SWD}\ (\frac{\text{m3}}{\text{min}}) = \frac{Biomass * SWU}{1000}$$

Water will contain more oxygen at lower temperatures than at high temperatures. When the temperature rises, the requirement for oxygen will increase because the salmon's metabolism increases. Because the water then contains less oxygen and salmon requires more oxygen, the water demand will usually increase. Just like water usage, the calculation of oxygen demand for salmon is variating with the weight of the salmon and temperatures (Table 14).

Table 14: Oxygen demand in mg/kg live weight/min with varying water temperature and fish weight. Kittelsen og Fjoera (Lekang, 2013)

		Fish weight (gram)									
		0,2	1	5	10	50	100	500	1000	2500	5000
Temperature (°C)	1	3,09	2,27	1,66	1,44	1,06	0,93	0,90	0,80	0,66	0,58
	2	3,09	2,27	1,66	1,44	1,06	0,93	0,90	0,80	0,66	0,58
	4	4,22	3,08	2,26	1,97	1,44	1,26	1,23	1,08	0,90	0,78
	6	5,58	4,08	2,99	2,61	1,91	1,67	1,63	1,42	1,19	1,04
	8	7,23	5,28	3,87	3,38	2,48	2,16	2,11	1,84	1,55	1,36
	10	9,18	6,72	4,91	4,29	3,14	2,75	2,68	2,34	1,96	1,72
	12	10,59	7,74	5,67	4,95	3,63	3,17	3,09	2,70	2,26	1,98
	14	12,15	8,90	6,51	5,69	4,16	3,65	3,55	3,10	2,60	2,28
	16	12,15	8,90	6,51	5,69	4,16	3,65	3,55	3,10	2,60	2,28
	18		11,43	8,36	7,31	5,35	4,68	4,56	4,00	3,34	2,92

4.1.5. Temperature regime FTS

In FTS, the production is, to some extent, bound to temperature changes. From the knowledge gained in chapter one, about facilities with FTS, the water is primarily being heated in two steps. The first step is by exchanging heat from wastewater to the inlet stream, and the second step is by running the inlet water through a heat pump. It is commonly known to salmon farmers that smaller fish are more fragile to temperature changes than large fish, because of the low water demand of small salmon it is also both practical and economical to heat water in the early stages of the salmon's life cycle.

To make this thesis relevant for today's salmon production, the temperature regime in the FTS variated in temperature. The input values were experience numbers from an anonyms MOWI-facility located in the middle of Norway (Tørrisen.A, 2020). The temperature variations in the FTS productions was also chosen because it showed the differences that can occur between an FTS and a RAS.
At the egg stage of the production, the temperature was kept at a stable 8°C. When the start feeding began in week 11, the temperature was manually increased to around 14°C, and this was done to simulate optimal temperature for salmon growth. Around May, in week 18-19, the salmon went through its first grading, which means the temperature got adjusted down in preparation of normal environmentally regulated temperatures for the salmon, from this stage on. From the middle of May, the temperature regime of the salmon was being regulated naturally by environmental changes (Figure 14).

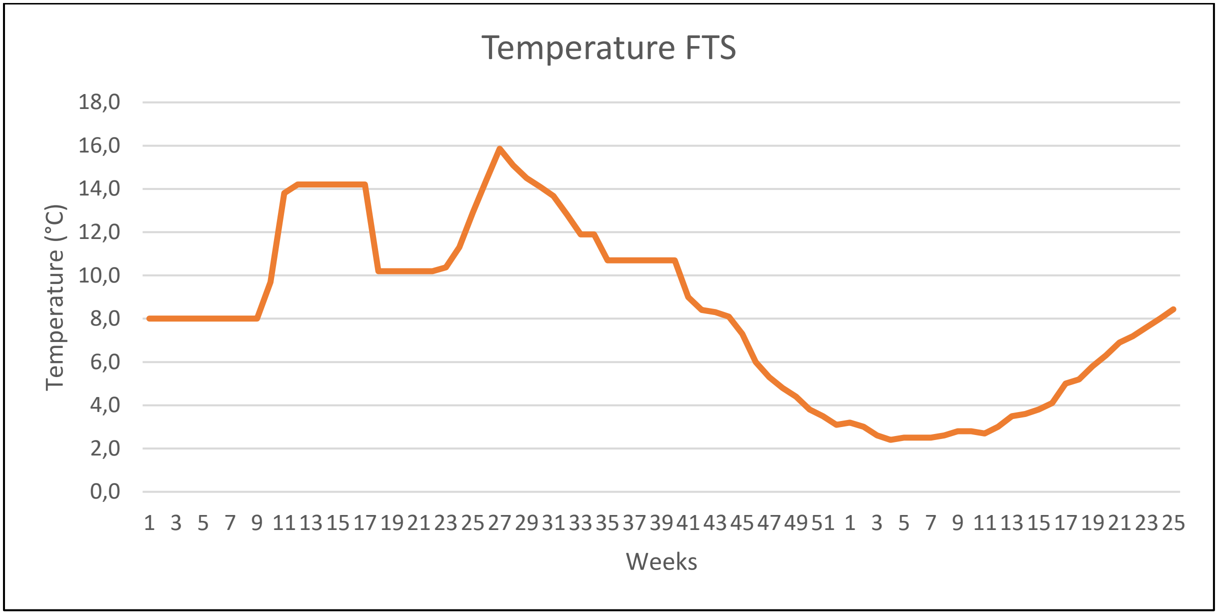

Figure 14: Illustration of temperature regime in FTS for three different productions of Norwegian Salmo Salar.

4.1.6. Temperature regime RAS

Because of the recirculation steps in the RAS facilities, these types of facilities are not bound to temperature to the same extent as the FTS facilities. This is because of the water exchange, or more precisely, the amount of new water in. FTS needs 100% new water after usage, while RAS needs 1%-10% new water after usage (Timmons. M.B and Ebeling. J.M, 2010), so, both practically and economically, the RAS facilities have a unique opportunity to produce salmon on higher stable temperatures.

This means that many of the RAS facilities today produce salmon on stable high temperatures. Therefore the temperature values in this thesis were chosen, with a background in this (Figure 15).

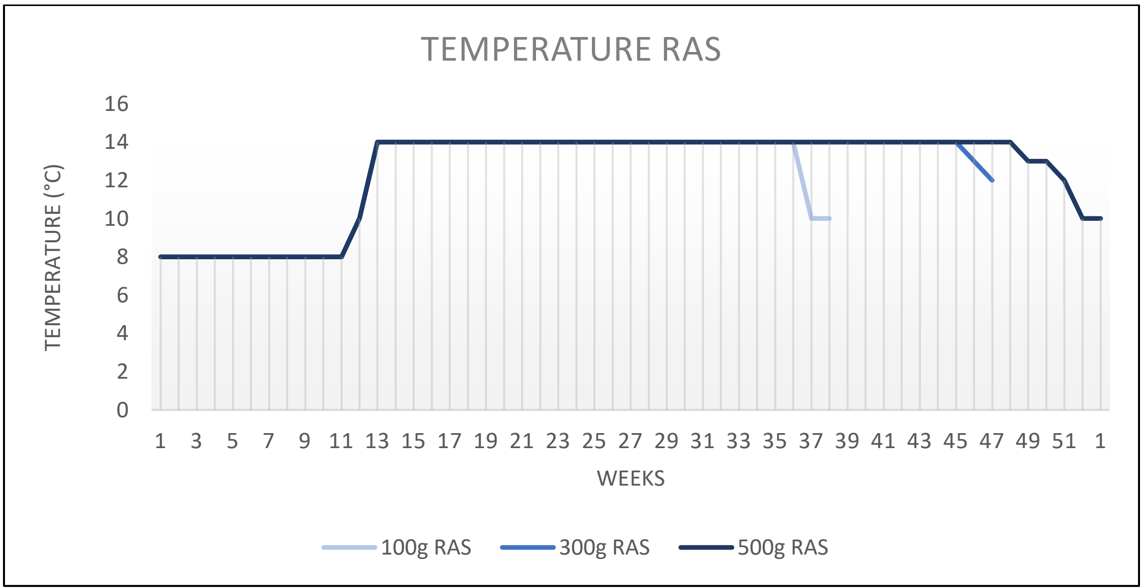

Figure 15: Illustration of temperature regime in RAS for three different productions of Norwegian Salmo Salar.

The egg stage of the production would be the same as in the FTS, with a stable temperature at 8°C, up to start feeding in week 11. From week 11, the temperature was manually increased to 14°C, and was kept at this temperature throughout the production.
In this thesis, each of the production models for RAS had a fall in temperature for the last three weeks of production. This is irregular behavior in a production plan, but to get similar end values in size (100g, 300g and 500g), compared to the FTS, this temperature drop was added.

4.1.7. Day degrees

Because of the different temperatures in the RAS and FTS, day degrees (d°) were calculated. Day degrees show the total temperature variation the salmon has gone through over a certain amount of time, and it was added in the production plans to spot differences between the different production models. It was calculated using the following formula:

$$d° = number\ of\ days * water\ temperature$$

In this thesis, it was assumed that eggs were put in the hatchery at 220 d° and hatched at 500 d° (Lekang, 2013). The starter feed was used as recommended by feed producers (Table 11), the end of start feed was, therefore, around 1500 d°, which was close to earlier assumptions found in the literature (Table 15).

Table 15: Expected day degrees for the early life stages of Atlantic salmon (Lekang, 2013).

Stage	Atlantic Salmon Day Degrees
Eye egg	220 – 223
Hatching	450 – 520
End of Start Feeding	1200 – 1400

4.1.8. Mass balance estimates of C, P, and N

Mass balance calculations show how much of the feed input is retained in the salmon and how much is excreted as waste (chapter 2.1.2 and chapter 2.1.4). For an input value of 100% (from the feed), the mass-balance will show how this 100 % is divided between retained biomass, particle waste, and dissolved waste.
In the waste model, the total C, P, and N production will be equal to 100%, and it is calculated as such:

$$Total\ C, P\ and\ N\ production = \text{Feed usage per production (per ton)}\ x\ C, P\ and\ N\ content\ per\ ton\ salmon\ feed$$

From the total C, P, and N produced, the estimated percentage for particle waste, dissolved waste, respired CO_2, and retention to biomass was subtracted to calculate each of the values towards their respective productions (100g, 300g and 500g, RAS and FTS).

4.1.9. Sludge calculation

DW in sludge was estimated from the total feed usage per production and a calculation key with the amount of dry weight in sludge taken out per kg salmon feed.

$$DW\ in\ sludge = \text{feed usage per production (per ton)} * Amount\ of\ dry\ weight\ taken\ out\ per\ kilo\ salmon\ feed$$

The calculation key used in this thesis were gathered from a Nofima report (Aas.T.S, Ytrestøyl.T og Berge.G.M, 2016), with an assumed dry weight of 0,285kg per ton salmon feed.
The difference in feces stability of 6% less feces stability in FTS was added to the calculations for DW in sludge (chapter 2.1.3).

By dividing the sludge amount on the total particle amount for C, P, and N, it was possible to calculate how much of the DW in sludge, that was consisting of the different nutrients.
The reason it was divided by the particle waste was because this was the only part of the waste that could easily be gathered with standard filters.

To estimate how much of the C, N, and P that could theoretically be purified, the particle waste was subtracted from the total, to estimate how large percentage of the C, P, and N were possible to easily remove from the water or purify.

4.2. Results

4.2.1. Production time

Production time (PT) showed the following for the different productions:

- 100g FTS: 40 weeks
- 100g RAS: 38 weeks
- 300g FTS: 66 weeks
- 300g RAS: 47 weeks
- 500g FTS: 77 weeks
- 500g RAS: 52 weeks

The variations seen in the PT correlated with the temperature regimes in the FTS (Figure 14) and RAS (Figure 15) conditioned productions. The RAS conditioned productions, with stable high water temperatures, had a shorter production length when compared to their respective FTS conditioned productions, with variating high and low water temperatures.

4.2.2. Correlations in the productions

The results showed a positive correlation between SGR, percentage biomass gain, and oxygen demand for salmon. As illustrated (Figure 16), the SGR values were higher at the beginning of the start feeding period, with 5,90 for FTS and 4,88 for RAS. The SGR for both FTS and RAS were decreasing over time.

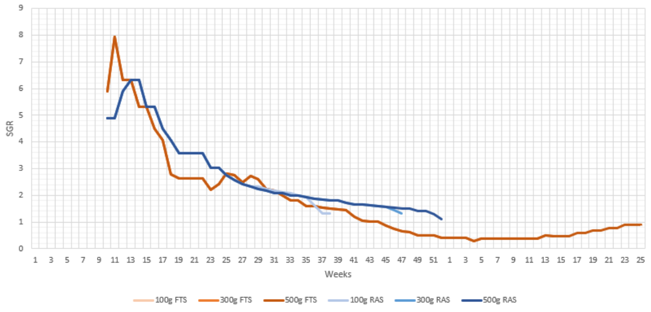

Figure 16: SGR variations per production

The gain in biomass (Figure 17) was high for both FTS and RAS productions in the start feeding period, with a peak gain in biomass at 41,38% for FTS and 34,88% for RAS. The gain in biomass for both FTS and RAS were decreasing over time, with two major drops in percentage biomass gain for both productions. These drops were expected, where the first drop represents grading, and the second drop represents vaccination.

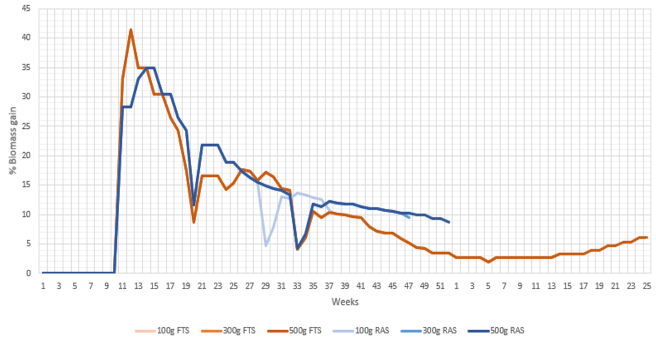

Figure 17: Percentage biomass gain per production

Oxygens values (Figure 18) were corresponding with temperature variations and the size of the salmon. The oxygen demand was higher at the beginning of the start feeding period, positively correlating to percentage biomass gain and SGR values, indicating that a smaller salmon with a high increase in biomass, demands a higher oxygen level in this growth period.

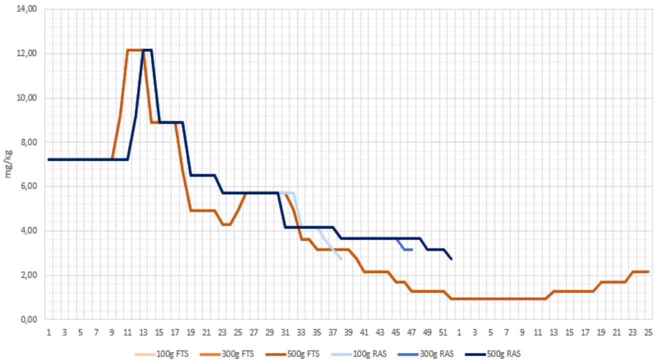

Figure 18: Oxygen demand variations per production

The graphical illustrations of the production results also showed a positive correlation between individual weight gained and feed demand, meaning that the salmons feed demand was increasing with the increasing size and weight.

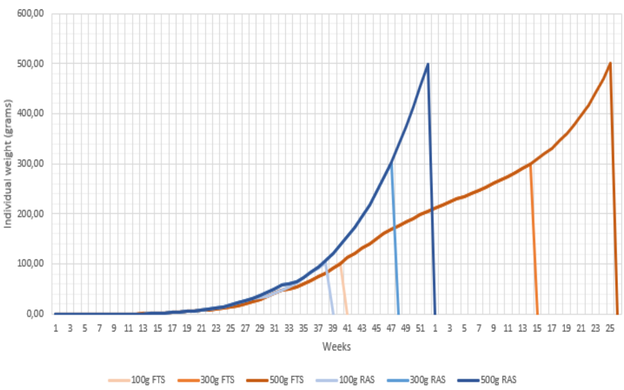

Figure 19: Individual weight per production

Individual weight (Figure 19) for both FTS and RAS were estimated to grow smoothly from the point of start feeding at week 11 through their maximum weight at 100g, 300g, and 500g. By looking at the PT from 300g to 500g salmon, the RAS production had a 5-week gap, and the FTS production had an 11-week gap.

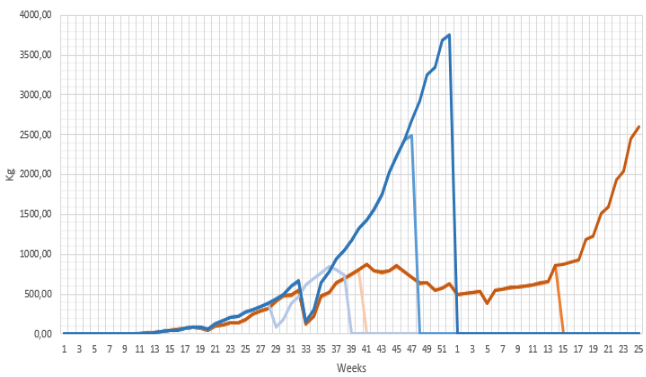

Figure 20: Feed demand per week per production

The feed demand per week (Figure 20) was shown to be strongly correlating with the temperature and size of the salmon. The RAS productions also gave a higher feed demand at a shorter period, compared to the FTS productions. The drops in feed demand were expected because of a loss in appetite connected to grading and vaccination handling.

The feed demand also showed how the feed input was changing throughout the different productions. Because of small variations in the final weight to meet the actual production at 100g, 300g, and 500g, the total amount of feed was slightly variating between the systems (Table 16).

Table 16: Feed usage variations in kg, between 100g, 300g and 500g salmon produced in FTS and RAS

Production model	Number of salmon	Feed usage pr. Production (kg)	Variation (kg)
100g FTS	100 000	8 107	45
100g RAS	100 000	8152	
300g FTS	100 000	24 907	138
300g RAS	100 000	25 045	
500 FTS	100 000	42 275	-20
500g RAS	100 000	42 255	

The mortality of the salmon increased with increasing production time. The FTS productions had a longer production time compared to their similar productions in the RAS (chapter 4.2). Compared to the RAS productions the 100g, 300g and 500g FTS productions had 142, 1268 and 1674 more dead salmons, which equals around +0,349%, +2,990% and +3,880% higher mortality (Figure 21).

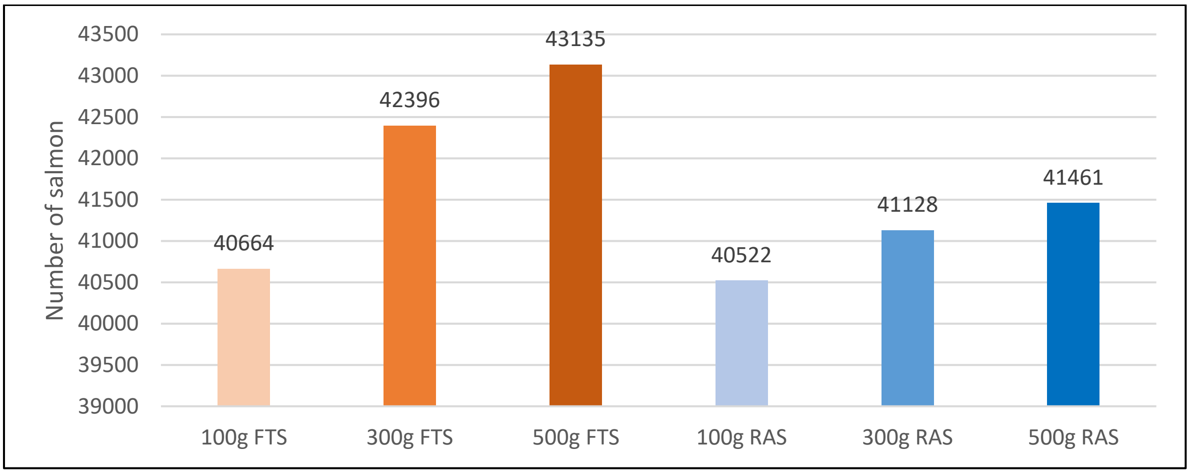

Figure 21: Total mortality per 100g, 300g and 500g FTS and RAS conditioned productions.

What was interesting with these results was the negative correlation that the individual weight and feed demand had with SGR values, percentage biomass gain, and oxygen demand.

4.2.3. Feed content variations of C, P, and N

Carbon content in feed input, modeled after different productions, showed a steady increase of carbon DW percentage in the feed, as the salmon grew in 100g, 300g and 500g productions (Figure 22). Both productions with FTS and RAS conditions had a steeper increase from 100g to 300g production than from 300g to 500g production.
For productions with FTS conditions, the 100g to 300g increased with 0,6% while 300g to 500g increased with 0,11%.
For productions with RAS conditions, the 100g to 300g increased with 0,45% while 300g to 500g increased with 0,19%.

The total average of RAS feed showed a content of 6,5 g/kg less carbon in the 100g production, 7,2 g/kg less carbon in the 300g production, and 6,8 g/kg less carbon in the 500g production, compared to the FTS productions.

The independent carbon value not specified to a particular production, were overall lower than the other values, with the feeds 45,62% carbon DW content. From the highest production feed content (500g FTS) compared to the independent production feed content for C, the difference was equivalent to 13,38 grams carbon per kg salmon feed.

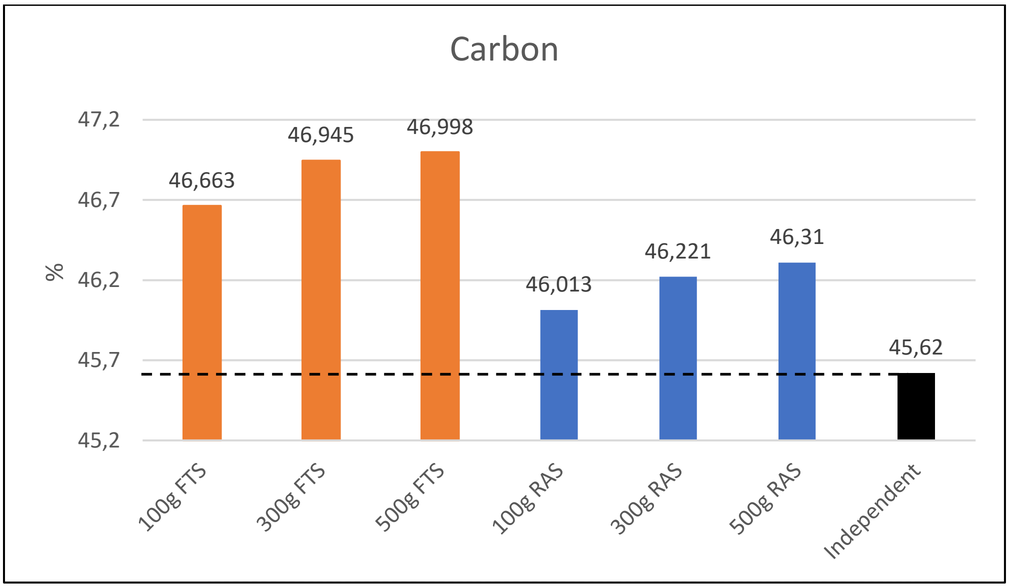

Figure 22: Average C content in feed used specifically for the production of 100g, 300g and 500g salmon in FTS and RAS compared to the total average of C content in the feed.

Phosphorus values in feed input, model after different productions, showed a decrease of phosphorus DW percentage as the salmon grows in 100g, 300g and 500g (Figure 23). The productions with FTS conditions, had a steeper decrease from 100g to 300g production than from 300g to 500g production. The productions with RAS conditions also decreased, but more smoothly.
For the productions with FTS conditions, the 100g to 300g decreased with 9%, while 300g to 500g decreased with 1,8%.
For the productions with RAS conditions, the100g to 300g decreased with 1,8%, while 300g to 500g decreased with 0,6%.

The total average of RAS feed showed a content of 0,2 g/kg more phosphorus in the 100g production, 1,3 g/kg more phosphorus in the 300g production, and 1,4 g/kg more phosphorus in the 500g production, compared to the FTS productions.

The independent phosphorus value not specified to a particular production, were overall higher than the other values, with the feeds 1,675% phosphorus DW content. The 500g production with FTS conditions had the highest average phosphorus content variation, compared to the independent production feed content for phosphorus, with a different equivalent to 2,32 grams phosphorus per kg salmon feed.

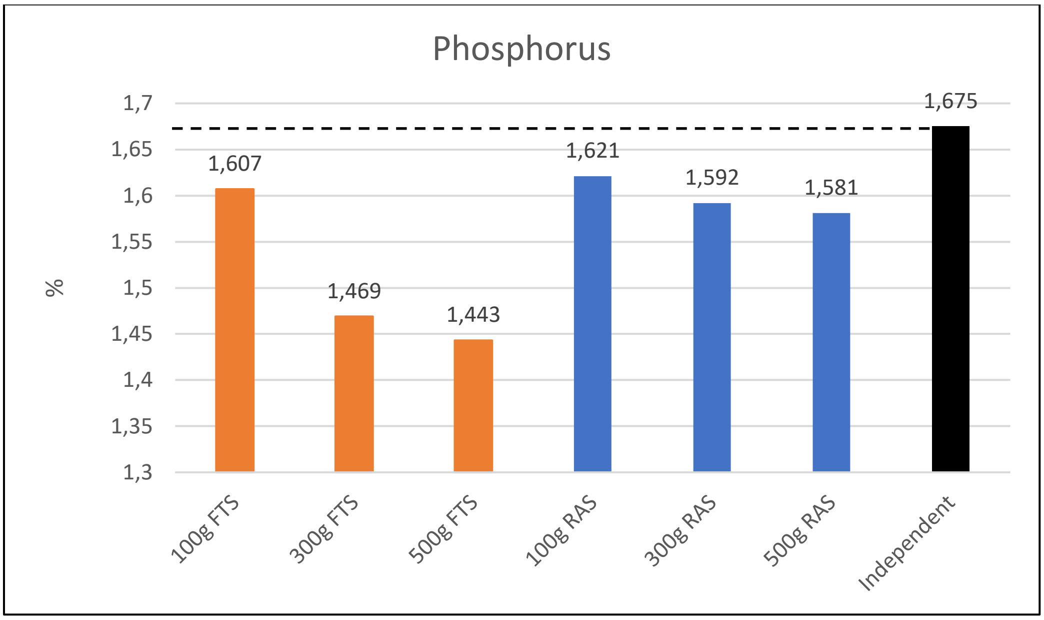

Figure 23: Average P content in feed used specifically for the production of 100g, 300g and 500g salmon in FTS and RAS compared to the total average of P content in the feed.

Nitrogen values in feed input, model after different productions, showed a decrease of nitrogen DW percentage as the salmon grows in 100g, 300g and 500g productions (Figure 24). The productions with the FTS conditions, had a steeper decrease from 100g to 300g production, than from 300g to 500g production. The productions with RAS conditions, also decreased, but more smoothly.
For productions with FTS conditions, the 100g to 300g decreased with 3,4%, while 300g to 500g decreased with 0,66%.
For productions with RAS conditions, the 100g to 300g decreased with 1,25%, while 300g to 500g decreased with 0,41%.

The total average of RAS feed showed a content of 5,0 g/kg less nitrogen in the 100g production, 3,4 g/kg less nitrogen in the 300g production, and 3,2 g/kg less nitrogen in the 500g production, compared to the FTS productions.

The independent nitrogen value not specified to a particular production, were lower than RAS productions and FTS 300g and 500g production, with the feeds 17,57% nitrogen DW content. The 500g production with RAS conditions, had the highest average nitrogen content variation, differentiating with 3,66 grams nitrogen per kg salmon feed, when compared to the independent nitrogen value.

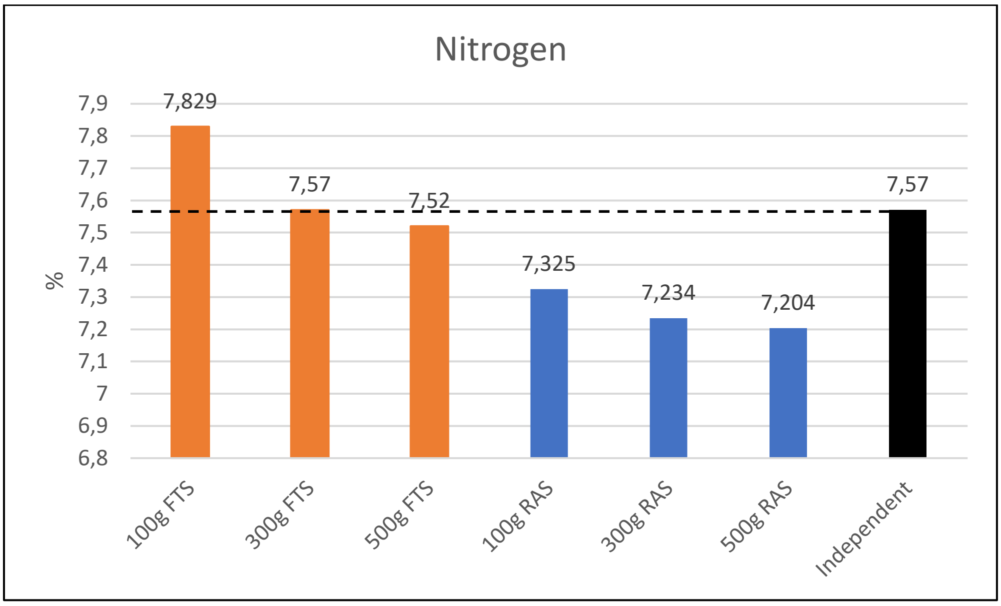

Figure 24: Average N content in feed used specifically for the production of 100g, 300g and 500g salmon in FTS and RAS compared to the total average of N content in the feed.

The variations in feed content seemed to be directly linked to the PT for the different systems, in other words, how many weeks the salmon was given a specific type of feed designed for a certain weight span. Apart from 100g productions, the results showed that it was mainly the content of the grower feed that affected the average content of C, P, and N in feed (Table 17).

Table 17: Weekly feed type variations in productions with FTS and RAS conditions

System	Feed type	Pellet Size (mm)	Fish size (grams)	100g production	Variation (weeks)	300g production	Variation (weeks)	500g production
FTS	Starter	0,6-1,3	0,15 – 4,9	8 weeks	+ 0 -	8 weeks	+ 0 -	8 weeks
	Fingerling	1,5-2,2	5 – 39,9	12 weeks	+ 0 -	12 weeks	+ 0 -	12 weeks
	Grower	3,0-6,0	40+	4 weeks	+ 26 -	30 weeks	+ 11 -	41 weeks
	Transfer			6 weeks	+ 0 -	6 weeks	+ 0 -	6 weeks
RAS	Starter	0,6 – 1,3	0,15 – 4,9	8 weeks	+ 0 -	8 weeks	+ 0 -	8 weeks
	Fingerling	1,5 – 2,2	5 – 39,9	12 weeks	-1 +	11 weeks	+ 0 -	11 weeks
	Grower	3,0 – 6,0	40+	3 weeks	+ 9 -	12 weeks	+ 5 -	17 weeks
	Transfer			6 weeks	+ 0 -	6 weeks	+ 0 -	6 weeks

4.2.4. Total Mass balance of C, P, and N in the FTS and RAS productions (VØF-model)

Results from the mass balance calculations show the amount of C, P and N produced and how they differentiated between the productions of 100 000 salmon smolts. The uneven tops between the respective 100g, 300g and 500g FTS and RAS productions came from the variations in total feed demand. 45kg for the 100g productions, 138kg for the 300g productions, and 20kg for the 500g productions.

Mass balance of C (Figure 25) showed that for each production, most of the C was retained in the salmon, while the waste released, was mainly released as particles. For production of 100g, 300g and 500g salmon, estimates showed a particle release of around 690kg, 2130kg and 3600kg for the three productions in both FTS and RAS. Dissolved waste values were the lowest, but this was expected with only a 3% input value.

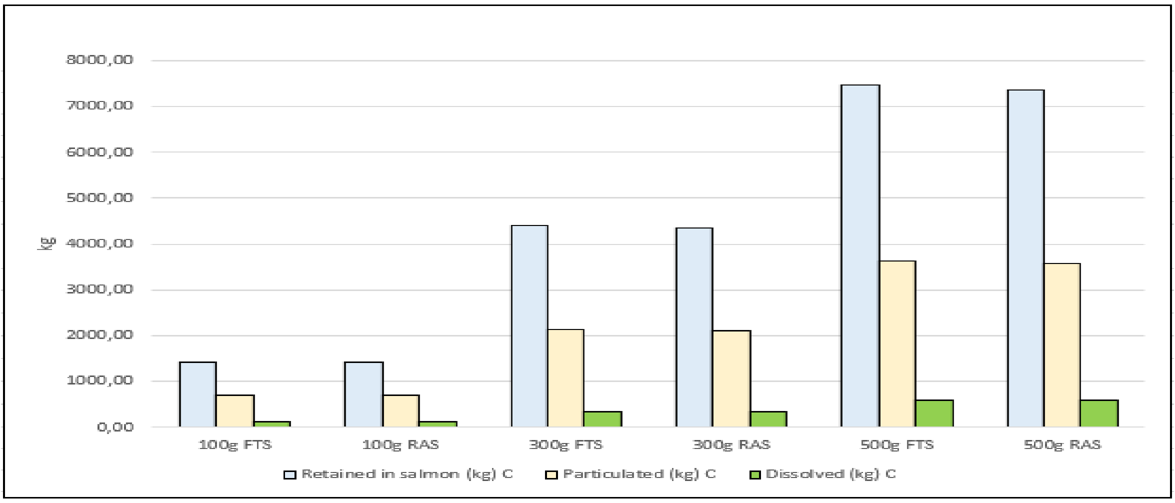

Figure 25: Mass balance overview of C in 100g, 300g and 500g FTS and RAS productions of salmon

These results showed that salmon waste produced under RAS conditions contained 5,85 kg less particulate C and 0,96kg less dissolved C in the 100g production, 21,31 kg less particulate C and 3,49 kg less dissolved C in the 300g production, 54,96 kg less particulate C and 9 kg less dissolved C in the 500g production, compared to salmon waste produced under FTS conditions.

Mass balance of P (Figure 26) showed that most of the P, added in the diet, was released as particle waste, while only 18% of P were released as dissolved waste. For production of 100g, 300g and 500g salmon, estimates showed a particle release of around 67kg, 200kg and 330kg. The dissolved waste from the same forecast was about 23kg, 68kg, 115kg.

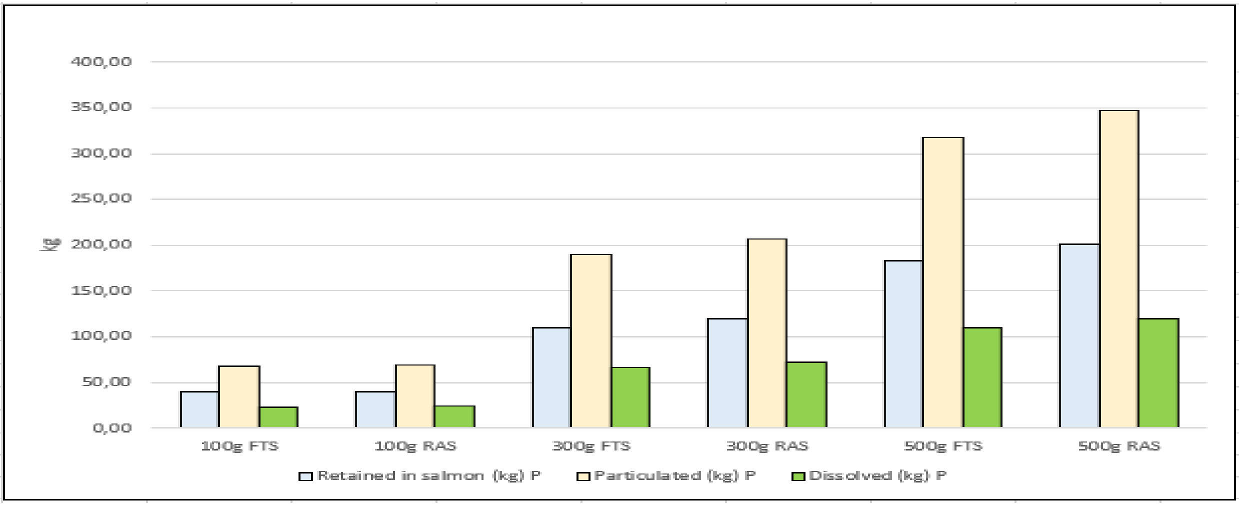

Figure 26: Mass balance overview of P in 100g, 300g and 500g FTS and RAS productions of salmon

These results showed that salmon waste produced under RAS conditions contained 0,98 kg more particulate P and 0,33 kg more dissolved P in the 100g production, 17,14 kg more particulate P and 5,93 kg more dissolved P in the 300g production, 30,30 kg more particulate P and 10,49 kg more dissolved P in the 500g production, compared to salmon waste produced under FTS conditions.

Mass balance of N (Figure 27) showed that most of the N added in the diet was released as dissolved waste while a substantial amount was retained in the salmon. For production of 100g, 300g, and 500g salmon, estimates showed a dissolved waste release of around 273kg, 820kg, and 1390kg with a particle waste release of about 95kg, 284kg and 475kg.

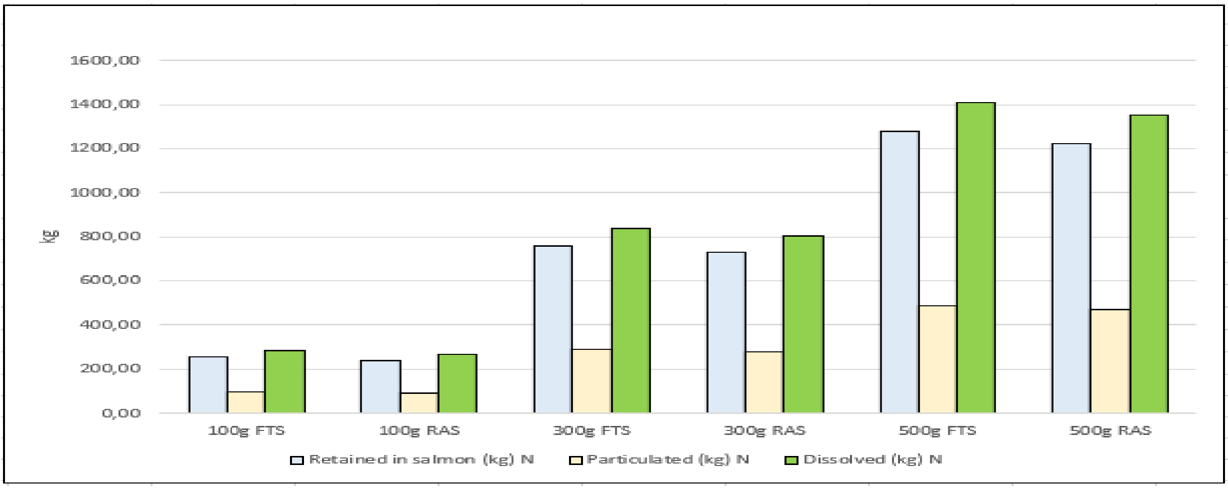

Figure 27: Mass balance overview of N in 100g, 300g and 500g FTS and RAS productions of salmon

These results indicated that salmon waste produced under RAS conditions contained 5,79 kg less particulate N and 16,68 kg less dissolved N in the 100g production, 11,33 kg less particulate N and 32,67 kg less dissolved N in the 300g production, 20,84 kg less particulate N and 60,06 kg less dissolved N in the 500g production, compared to salmon waste produced under FTS conditions.

Calculated from total waste, the purification degree where equal for all productions of 100 000 salmon smolt in 100g, 300g and 500g FTS and RAS (Table 18). It was not excepted to see differences here because the estimations were calculated from the total waste produced in each production and system individually, with the same input values on particle waste at 18,33% for C, 52% for P and 15,40% for N.

Table 18: Possible purification degree of C, P and N in land-based FTS and RAS facilities

C	P	N
%	%	%
85,94	74,29	25,75

The total percentage waste difference, on the other hand, showed that salmon waste produced under RAS conditions had:

- 0,85% less C, 6,29% less N and 1,42% more P in the 100g,
- 1% less C, 4,06% less N and 8,27% more P in the 300g,
- 1,53% less C, 4,44% less N and 8,72% more P in the 500g,

compared to salmon waste produced under FTS conditions (Figure 28).

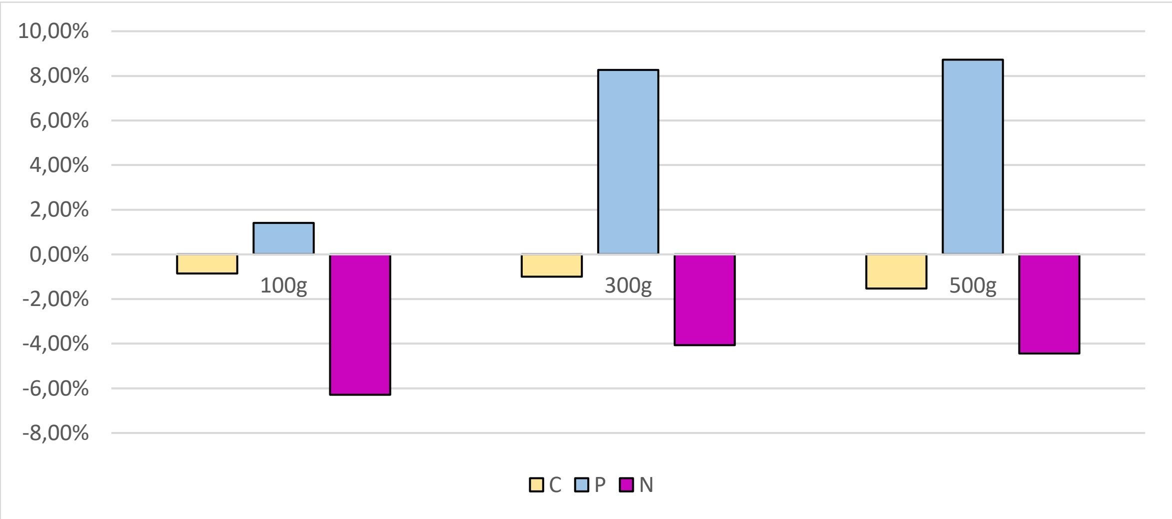

Figure 28: Waste differences of C, P and N in 100g, 300g and 500g RAS productions of salmon compared to FTS productions of salmon

4.2.5. Waste production of C, P, and N

By presenting the same results (Chapter 4.2.4) of particulate and dissolved waste produced in the FTS and RAS for the different production of 100 000 salmon smolts, weekly, it could be shown that the feed demand or feed input correlated strongly with the waste production. The graphical illustration also shows that C was dominating the particulate waste while the dissolved waste was dominated by N (Figure 29).

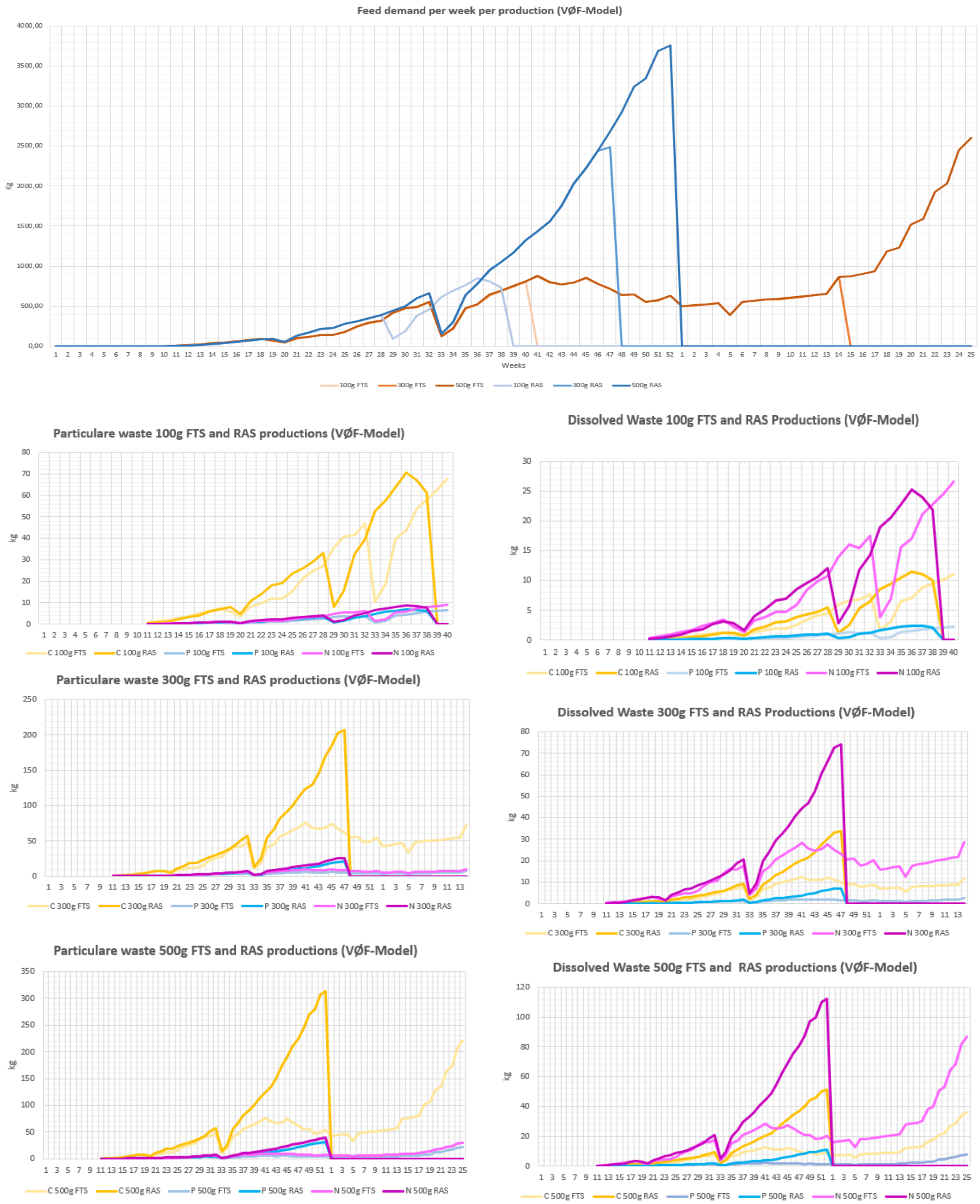

Figure 29: Weekly production of particulate and dissolved waste produced in 100g, 300g and 500g FTS and RAS, compared to weekly feed demand

4.2.6. Sludge generated per production in FTS and RAS

The total DW amount in sludge produced (Figure 30), increased steadily from the smallest production of 100g salmon to the more massive 300g and 500g productions. The only variations between the FTS and the RAS were the difference inflicted by the 6% variation in feces quality. Results shows that bigger salmon produced more DW in sludge, and overall more waste than smaller salmon.

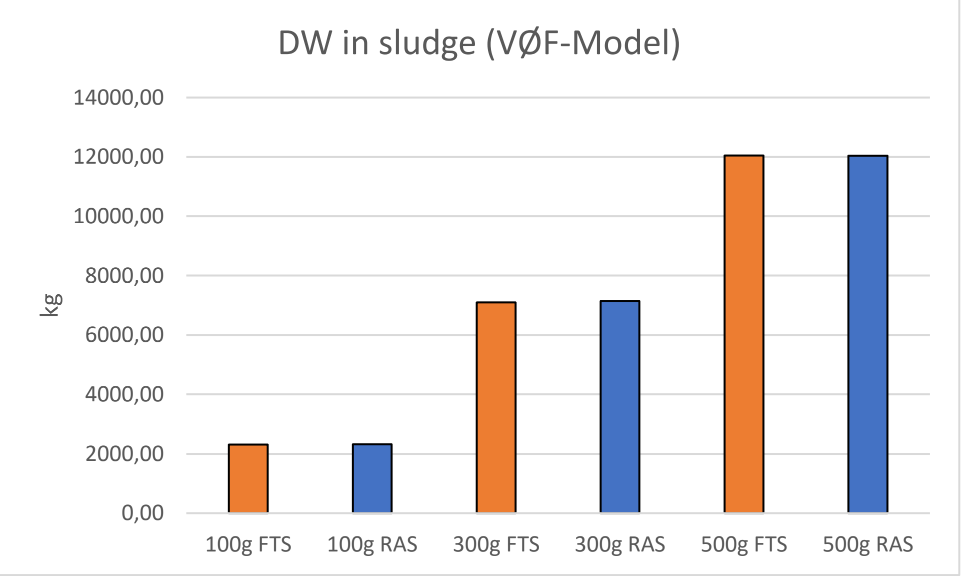

Figure 30: DW amount in sludge (VØF-Model)

Estimations of sludge content showed no significant variations between the different productions, and the total DW% in sludge showed average values of 30% C, 3%P and 4% N (Figure 31).

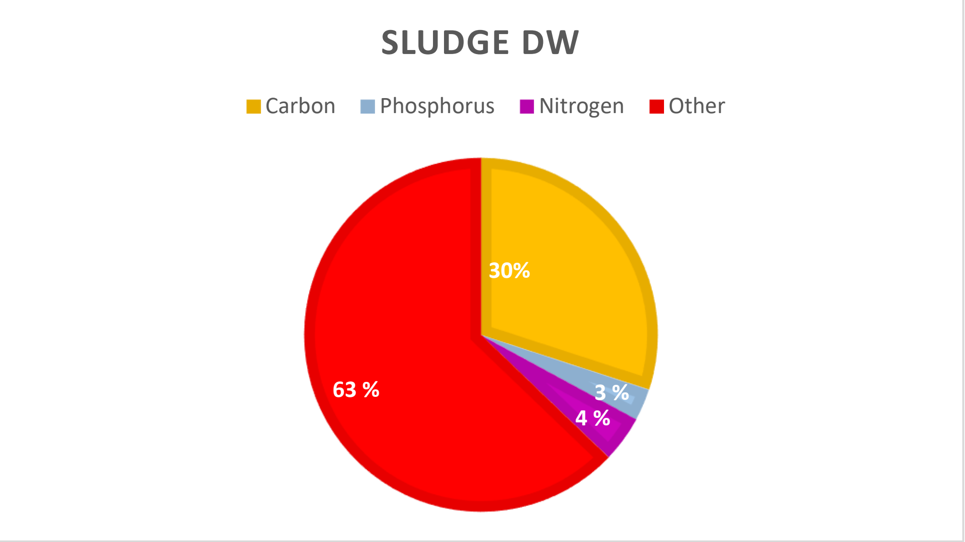

Figure 31: Percentage content of C, P and N in Sludge (VØF-Model)

4.3. Discussion and conclusion

The results showed that both particle waste and dissolved waste correlated strongly with the salmons feed demand and/or feed usage, both as a total and on a weekly basis.
In intensive aquaculture production, the salmon is not continuously fed by hand, and the feed is handled numerous times with delivery, storing, and internal transport before even reaching the salmon. Because of this, the technical quality of the feed would be affected differently in different farms and also with different technical equipment (Skaar, 2020). It is basically impossible to set an average value for dust and breakage of feed that ultimately will not be eaten by the salmon and go straight through the system as waste, also affecting the FCR and the amount of particle waste produced (Pedersen.T.N, Personal message, 2020).

The results showed that the salmon fry utilizes the feed for growth, more efficiently than fingerling and smolt, like many other animals, humans included, the newborn salmon (0,15g – 0,8g), often have a higher growth rate compared to adults (Austreng.E, Storebakken.T and Åsgård.T, 1986). With this fast growth, the small salmon required protein as building blocks, and it was shown that the feed contained more protein and less fat, than feed for a bigger salmon (Table 1). By putting more protein in the feed for smaller salmon, the N values of the waste seemed to become larger. So, by producing a 100g salmon, the salmon gets a more protein-filled diet to meet its biological protein demands, than compared to a 300g or 500g salmon. Because of this, a production of smaller salmon would have a lower total waste production than an equivalent production of larger salmon, but the composition of the waste would be different with, for instance, more N compounds and less P and C compounds (Figure 28). In retrospect it would have been interesting to incorporate the protein retention rate of salmon, in the calculations, which would have increased according to growth (Storebakken.T and Austreng.E, 1986), and possibly affecting the N emission.

When looking at differences between FTS and RAS, the feed content for each production showed a percentage three-decimal difference (0,123%) between the different systems.
If the percentage difference for C, P, and N were calculated to g/kg, the difference did show variations between FTS and RAS of around 0-7 g/kg feed, indicating that the actual waste produced could be differing with a substantial amount when estimating larger salmon productions of, e.g., 20 million salmon produced. But the question is, if this is an actual difference or an acceptable standard deviation in feed production?
The difference was not greater than +- 5%, and it is therefore uncertain if it could be concluded that there were actual differences. There could be seen prominent waste differences, both particulate and dissolved, between RAS and FTS. Because of the standard deviation question, it can not be claimed that the difference occurs because the C, P, and N values were estimated every week, thus creating different levels of C, P, and N in the salmon feed, but in these results, this actually does have an effect and shows the difference.

Feed was definitely one of the main factors affecting waste production from salmon (Broch.O.J og Ellingsen.I, 2020), but there were several factors affecting feed usage and demand. The production plan estimated biomass and the number of salmon produced, which again affects the feed demand of the salmon. Mortality of different productions affects the start number of salmon, and the mortality can variate regarding sickness, vaccination, and the number of gradings. The PT did affect the amount of feed used with specific content levels of C, P, and N, which ultimately affected the result. Since the results showed that the PT was mainly determined by water temperature variation, it is safe to assume that the water

temperature regime used in a facility ultimately impacts the waste content.
Previous studies support the claim that there are many factors (both biotic and abiotic) affecting the feed demand and feed usage of the salmon (Cho.C.Y, 1992), and the thesis illustrates that it is a culmination of all the different aspects that determines the waste produced from salmon.

An important fact to be aware of, is that the calculations in the VØF-model (chapter 4), only estimated waste produced by salmon in a tank, before waste were transported through the sieve and further through water treatment steps and waste pipes. The results showed (Table 18) that from waste in the tank 85,94% of C, 74,29% of P and 25,75% of N consisted of particles and could, in theory, easily be removed from the production system through filtration.
The only calculations that affected waste after it had left the tank was done through the feces stability numbers from Cargill, which was assumed to affect the DW content in sludge, with a 6% difference. At the beginning of the assignment, I did not realize the complexity of the treatment steps of wastewater and what effect this would cause on the feces and feed residue. If I could have done anything different, I would have gathered information from equipment suppliers and RAS suppliers on how much particle waste that could be removed from systems, and used this in the VØF-model to estimate the actual purification effect from the theoretical purification effect (Table 18).

It can not be claimed that the VØF-model that has been developed is 100% accurate, but results from this thesis showed that the estimated sludge consisted of 30% C, 3% P, 4% N, and 63% other components, which matches estimates gathered from literature (Table 6).
This gives a pointer that the VØF-model estimates correct waste values to some degree.
The model is also created from literature and studies of mass balance trials (Table 5), and by looking at the biology of the salmon and how nutrients are handled, the estimates may be correct to some extent (Figure 5). There are also studies that support that the interpretation of particle and dissolved waste done in this thesis is correct (Etter.S.A, Andresen.K, Leiknes.Ø, Wang.X og Olsen.Y, 2014). There was a lack of mass balance studies done specifically on land-based salmon. All were done on cage salmon in the sea. It must, therefore, be assumed that there could be deviations between land-based and sea-based, mass balance calculations for salmon. What can be claimed is that with the input values in the thesis, the VØF-model estimates retained nutrients, as well as particulate waste and dissolved waste with high accuracy. The County governor office of Vestland has also confirmed that the calculations done with the VØF-model matches registrations of C, P, and N levels in sludge from numerous salmon farming facilities in the region (Pedersen.T.N, Personal message, 2020).

From the results in this study, it can be concluded that the total amount of waste produced does not variate between FTS and RAS facilities because the salmon need a specific amount of feed to grow to given sizes. While the total waste amount did not show differences, there were apparent differences in the weekly waste production and the content of the waste produced in FTS and RAS facilities. The difference seen occurred as a combination of several factors like feed nutrients in the pellet, feces stability, and production models used (water temperature, salmon size, etc.). Another factor that may have had an effect on waste released to the recipient, were the different technical aspects in the facilities and systems (Length of waste pipe, filter cloth size, drum filter placement, etc.), but further studies are needed to make a final conclusion surrounding this.

5. Part 3: Evaluation and comparison of VØF-model and todays waste models

As mentioned in chapter 2.2, there are mainly two different models that the county governor office uses to estimate waste production of C, P, and N from land-based aquaculture salmon farms, the old OCG-model, and the new NCG-model. Apart from these models, the county governor office, for the different counties, sets individual requirements of purification demands based on estimations and/or recipient samples (Johansen.M, 2020).

Concerning the sub-goal of this thesis, I have worked closely with senior advisor Tom Pedersen at the county governor office in Vestland. The intent was to uncover possible "weaknesses" of the OCG-model and, more importantly, the NCG-model, and help build a solid theoretical foundation for the development of a new and possibly better licensing policy for land-based aquaculture salmon farms.

The estimation techniques for the OCG-model were shared from the county governor office in Trøndelag (Ekli.M, Personal message, 2018), and the NCG-model, with descriptive estimations, were shared through Tom Pedersen, at the county governor office in Vestland.

5.1. Material and methods

The NCG-model is designed to be as easy and user friendly as possible (Table 19). It is relying on input information on feed usage, fish production, production of sludge, and DW in sludge. Constant key numbers for content of TOC, P, and N in feed and fish are used as estimation tools for waste production. The constant key numbers are total average values of TOC, P, and N, gathered form different feed manufacturers and salmon farmers by the environmental directorate in Norway and the county governor office (Pedersen.T.N, Personal message, 2020).

The model estimates Gross waste and Net waste, which is equal to total waste and dissolved waste in the VØF-model. The reason the Net waste was equivalent to dissolved waste in this trial, was because the particulate waste is presumably the only substance that ultimately can be removed from the equation. What the VØF-model defines as particulate waste, is in the NCG-model equal to:

$$Gross\ waste - Net\ waste = Particulate\ waste$$

Table 19: Waste calculation model (NCG-model), used by the county governor office in Vestland (Pedersen.T.N, Personal message, 2020)

Calculation example, emission estimates					**Unit**	BFCR
Feed usage	**1 900**		Produksjon av fisk	**2 000**	kg	0,95
Production of sludge	**2 000**			200	kg Dry matter (DW)	
DW in sludge (%)	10,0					
Keynumbers, content in		**N**	**P**	**TOC**		
feed, values from feed supplier		7,21	1,37	45	% of the feed	
fish, standard		2,72	0,4	20	% of the fish	
sludge, measured by farmers		**7,3**	**2**	**28**	% of DW	
Calculation of waste		**N**	**P**	**TOC**		
Gross waste, before purification		83	18	228	kg	
Net waste, after purification		68	14	172	kg	
Specifc waste (with purification)		**34**	**7**	**86**	**kg/ton biomass**	
Purification effect		**17,7**	**22,7**	**24**	%	
Purification effect defined as (net waste)/(gross waste)*100						
TOC is corrected for 50% loss through respiration and waste of CO2						
NB! This is only example numbers, it must be generated qualified keynumbers						

To correctly compare the models to each other, the total waste production of C, P, and N had to be estimated in kg waste produced for each of the productions, both in the FTS and the RAS conditioned productions. Since, in reality, there are production variates between different salmon farms and facilities, the percentage variation for each of the waste nutrients in the various productions, had to be calculated from the total waste produced. The goal was to see if the county governor office models differentiated from the VØF-model, so the values in the VØF-model had to be set as a mean, and the values from the OCG and NCG model showed the percentage deviation from this mean.

Because both the NCG and VØF-model separates particulate from dissolved waste, these were also compared to each other. The different estimation methods for particulate and dissolved waste between the models, were compared on each level, to trace any possible deviation back to a source of origin.

5.1.1. Experimental setup

Mathematical calculations of waste estimation models

To compare the OCG-model and NCG-model to the VØF-model, and also to each other, the same theoretical productions of 100g, 300g and 500g under RAS and FTS conditions had to be used, to understand how they differentiate from one another (chapter 4).

To compare the county governor office models to the VØF-model accurately, some adjustments had to be made in the input values. Still, it is curial to note that the theoretical methods and thinking of the county governor office were implemented in the experimental comparison (Table 19). Therefore, the input model used by the county governor office, was used as a template, and adjustments where made as such:

OCG-model

For the old model, it was only calculated total waste, because the model did not differentiate between dissolved and particle waste. The calculation methods for TOC, P, and N, were supplied by the county governor office in Trøndelag (Ekli.M, Personal message, 2018).

$$TOC = \text{Feed usage} * 0{,}8 * 0{,}15$$

$$N = (Feed\ usage * N\ in\ feed) - (Salmon\ biomass * N\ in\ salmon)$$

$$P = (Feed\ usage * P\ in\ feed) - (Salmon\ biomass * P\ in\ salmon)$$

NCG-model

In the new model, Gross TOC / total particle C, P, and N content in salmon, was set to 20%, 0,4% and 2,72% like the calculation method of the county governor (Table 19). The TOC value in the NCG-model was adjusted with a 50% loss of CO_2 through respiration (Pedersen.T.N, Personal message, 2020).

$$Waste\ production = \left(Feed\ usage * \frac{TOC, P\ or\ N\ value\ in\ feed}{100}\right) - \left(\frac{Biomass\ of\ fish * TOC, P\ or\ N\ value\ in\ fish}{100}\right)$$

The net TOC, P and N waste were estimated from Gross waste:

$$Net\ waste = (Gross\ waste - (kg\ DW\ in\ sludge * C, P\ or\ N\ content\ pr\ KG\ DW)$$

Where the kg DW in sludge was estimated as:

$$kg\ DW\ in\ sludge = Sludge\ production * \frac{DW\ percentage\ in\ sludge}{100}$$

To estimate how much of the waste that could be purified, the NCG-model subtracts gross waste from net waste.

Similar for both the OCG-model and NCG-model

For the C, P, and N feed content variation, the independent value of C, P, and N was used in all the productions. This is the method that is practiced by the county governor office of Vestland, when estimating waste production from salmon. The independent value was not specified to any production and was a total average of C, P, and N content in the feed, based on information collected from the literature (Table 2).

The BFCR in both models was set equal to the VØF-model. This was done to match the input values as much as possible.

5.2. Results

5.2.1. Total C, P and N production in the OCG-model and NCG-model compared to the VØF-model

When comparing the total C waste produced in the VØF-model with the TOC waste produced in the OCG-model and NCG-model (Figure 32), results showed that both the OCG-model and NCG-model estimated a higher total C waste produced than the VØF-model. The OCG-model had the most significant variations, while the NCG-model had smaller differences when compared to the VØF-model. The OCG-model estimated the highest TOC waste produced in the 500g FTS production with 5072,9 kg.

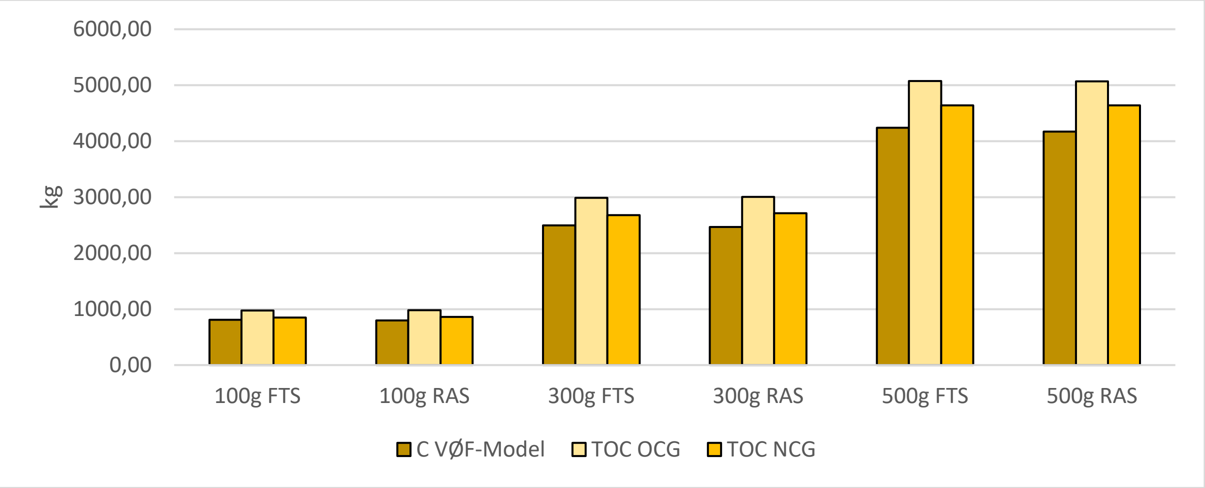

Figure 32: Total carbon waste estimation in kg for the OCG, NCG and VØF-model

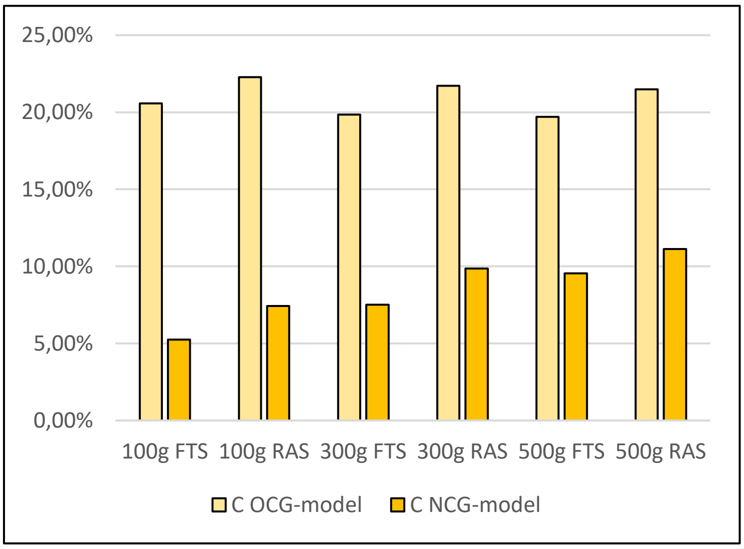

Figure 33: Percentage carbon waste deviation of the county governor office models from the VØF-model

The NCG-model showed the highest percentage deviation from the VØF-model in the 500g RAS production, where it estimated +11,13% more C waste produced (Figure 33). The OCG-model estimated +22,27% more C waste produced than the VØF-Model in the 100g RAS production.

For the P estimations, the OCG-model and NCG-model (Figure 34), estimated a higher total waste than the VØF-model. The total P waste produced was increasing between the different production models. For RAS and FTS, the OCG and NCG-model did not differ in total waste generated, while the VØF-model showed apparent variations between RAS and FTS productions. Both county governor office models estimated the highest P waste produced in the 500g FTS production with 505,99 kg.

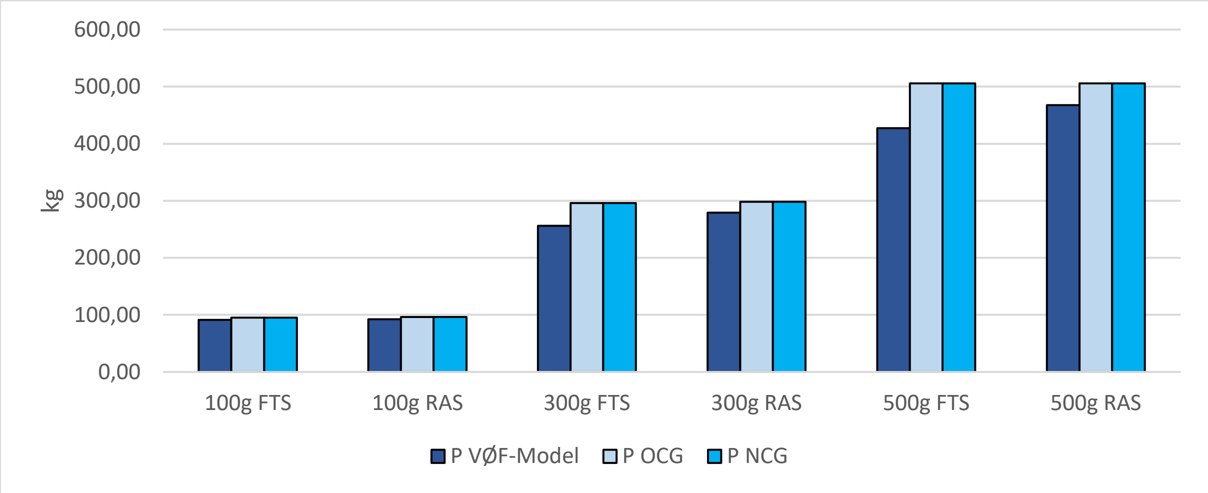

Figure 34: Total phosphorus waste estimation in kg for the OCG, NCG and VØF-model

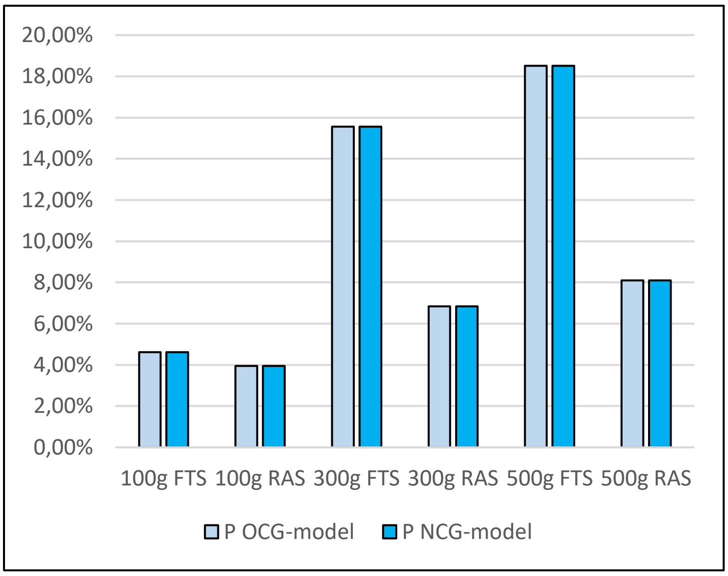

Figure 35: Percentage phosphorus waste deviation of the county governor office models from the VØF-model

The variations between the two different county governor models compared to the VØF-model (Figure 35), showed that both the OCG-model and the NCG-model had the highest percentage deviation from the VØF-model in the 500g FTS production, where they both estimated +18,51% more P waste produced. For P, the OCG-model and NCG-model estimated the same amount of waste produced by salmon.

For the N estimations, the OCG-model and NCG-model (Figure 36), estimated a higher total of N waste produced in the 100g, 300g, 500g RAS and 500g FTS productions than the VØF-model. For the 100g and 300g FTS, the VØF model estimated a higher total N waste produced than the OCG-model and the NCG-model. The total N waste produced was increasing between the different production models. Both county governor office models estimated the highest N waste produced in the 500g FTS production with 1916,3 kg.

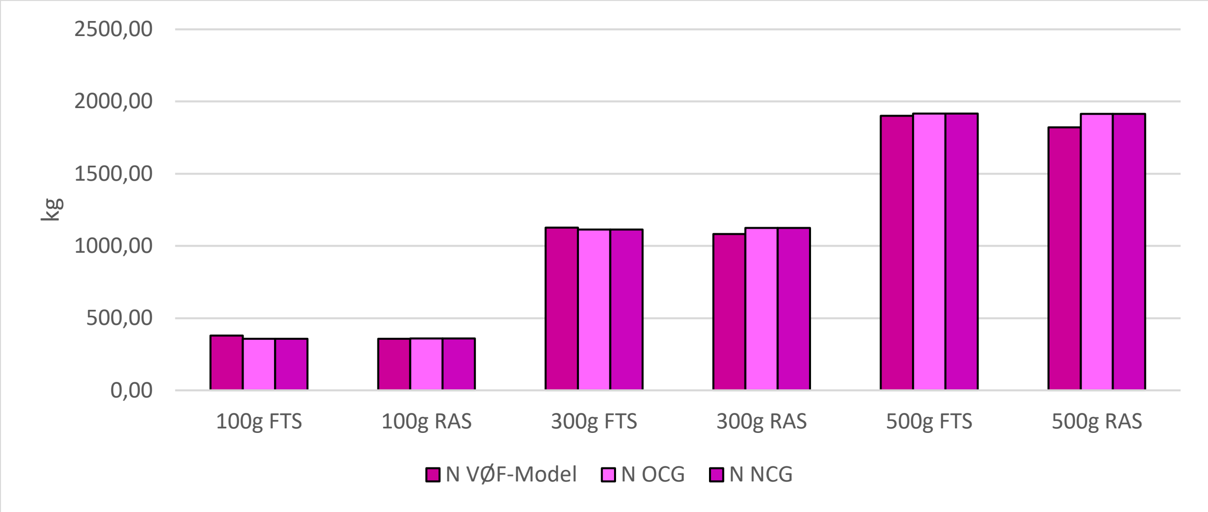

Figure 36: Total nitrogen waste estimation in kg for the OCG, NCG and VØF-model

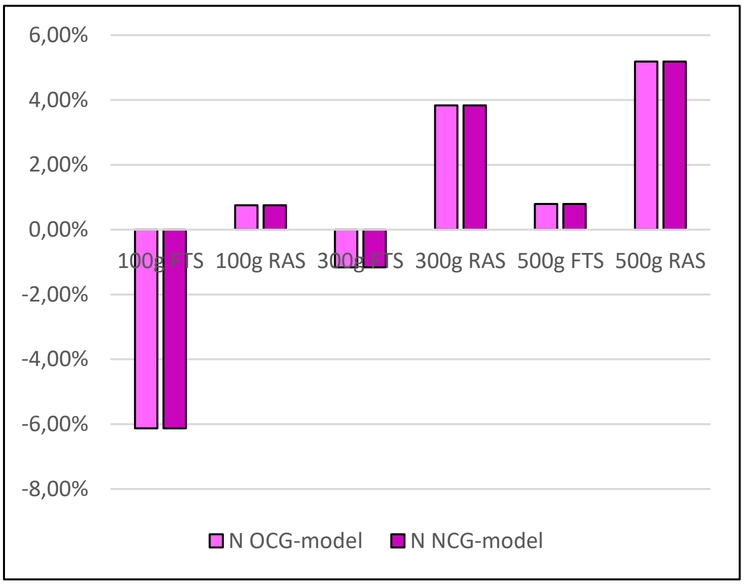

Figure 37: Percentage nitrogen waste deviation of the county governor office models from the VØF-model

The variations between the two different county governor models compared to the VØF-model (Figure 37), showed that both the OCG-model and the NCG-model had the highest percentage deviation from the VØF-model in the 100g FTS production, where they both estimated -6,13% less N waste produced compared to the OCG-model and NCG-model. For the 500g RAS production, the models estimated +5,19% more N produced than the VØF-model.

5.2.2. Purified (particle) and not purified (dissolved) waste in VØF-model compared to NCG-model

The NCG-model estimated Net waste produced as waste not purified, and therefore released to the environment. The Net waste in the NCG-model was the equivalent to the dissolved waste in the VØF-model.

The dissolved waste (Figure 38) was variating in the same pattern as the total waste from chapter 5.2.1, indicating that variations in the dissolved waste caused the difference between the VØF-model and NCG-model. In the VØF-model, the variations between FTS and RAS productions, clarified in chapter 4.2.4, were also observable.

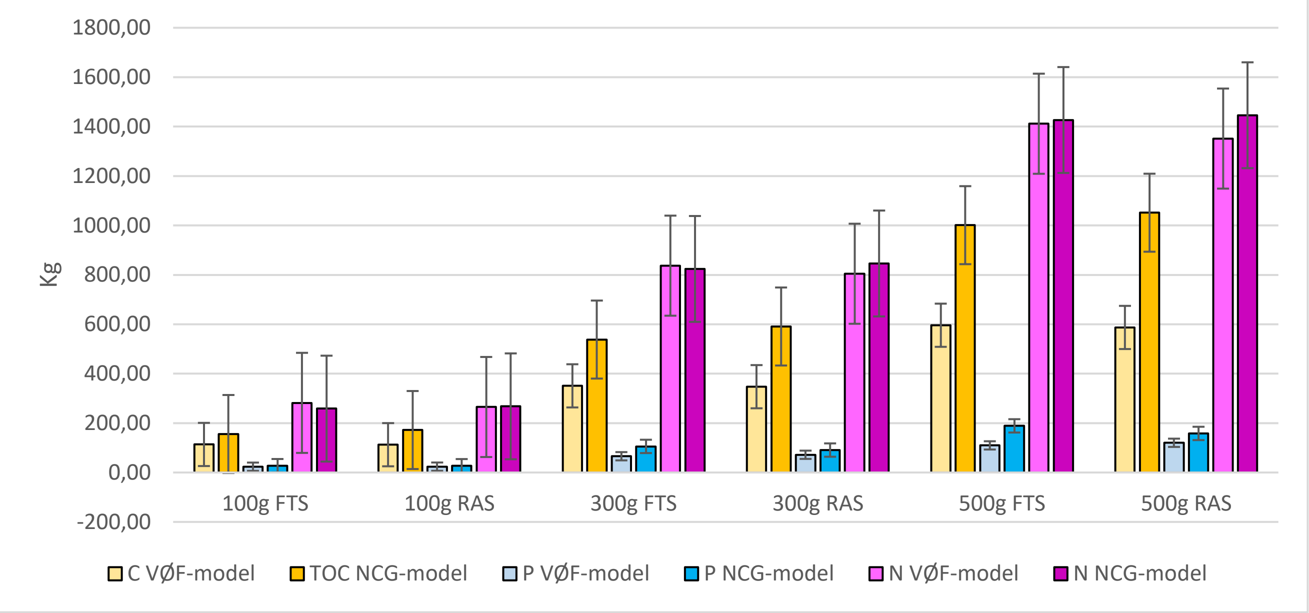

Figure 38: Dissolved waste production of C, P and N in 100g, 300g and 500g FTS and RAS production, NCG-model compared to VØF-model

By calculating the percentage dissolved waste amount from the actual dissolved waste amount (Figure 38), the VØF-model showed no variations in percentage between the different FTS and RAS productions, estimating that 14,06% of C, 25,71% of P and 74,25% of N in each production was released to the environment. The NCG-model showed a variation in percentage dissolved waste between both FTS and RAS, but also between the different production models. The NCG-model estimated that by producing smaller salmon (100g FTS production= C 18,35%, P 28,99% and N 72,57%), there would be a reduction in dissolved waste produced compared to a production of larger salmon (500g RAS production = C 22,67%, P 31,28% and N 75,52%).

By setting the VØF-model as a baseline, the percentage deviations of the NCG-model was clearly illustrated (Figure 39).

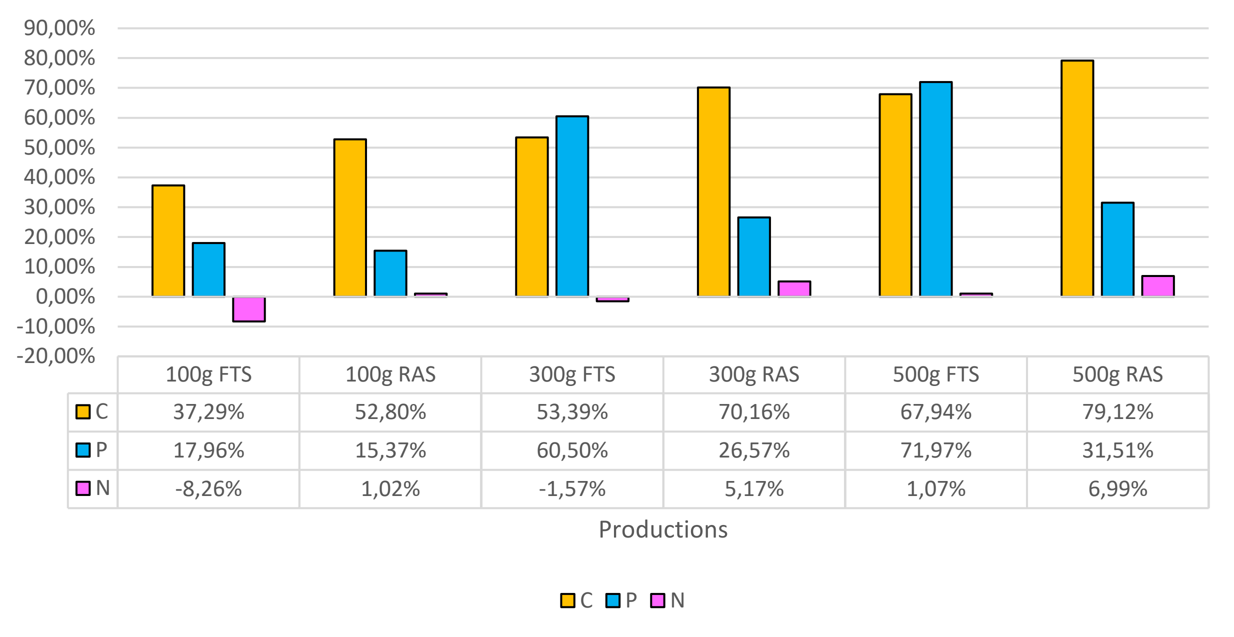

Figure 39: Percentage deviation of dissolved waste in the NCG-model from the VØF-model

The variations caused in the dissolved waste produced in the NCG-model, impacted the theoretical purification (removal of particles) that was possible to achieve for C, P, and N waste in the NCG-model (Figure 40). Showing that production of a smaller salmon generated more particle waste (100g FTS production = C 81,65%, P 71,01% and N 27,43%) than the production of a larger salmon (500g RAS production = C 77,33%, P 68,72% and N 24,48%) when comparing in percent, in actual kg the larger salmon generated more particle waste.

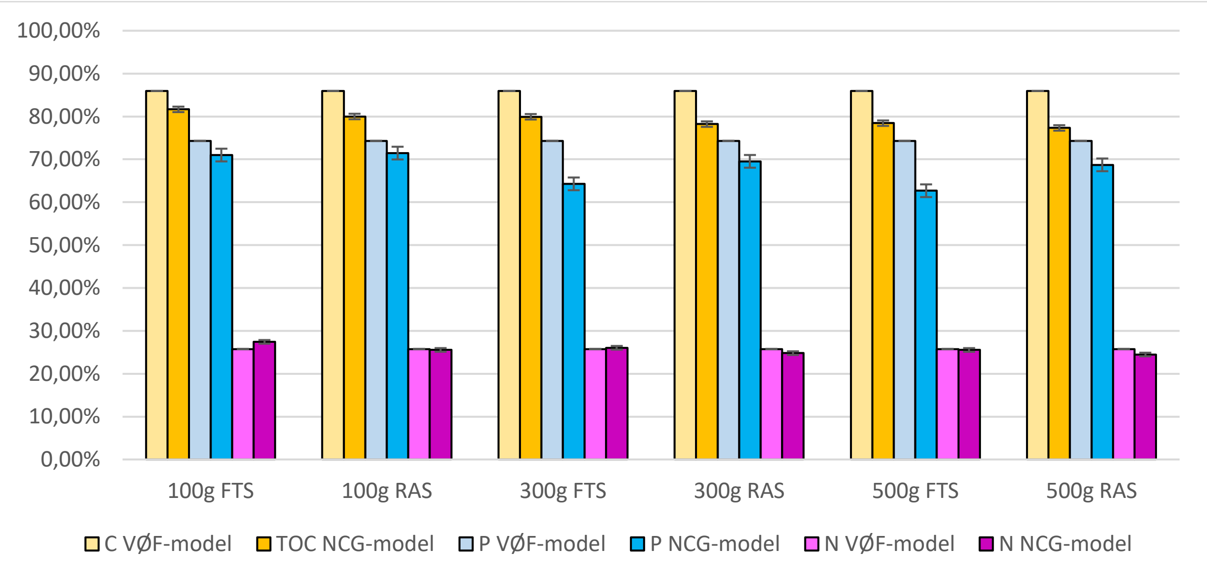

Figure 40: Theoretical purified (particle) waste in the VØF-model compared to the NCG-model

Because the net waste was estimated with:

$$Net\ waste = (Gross\ waste - (kg\ DW\ in\ sludge * C, P\ or\ N\ content\ pr\ KG\ DW)$$

The amount of particulate waste estimated in the NCG-model would be equal to the amount of particle waste estimated in the VØF-model (Figure 41) because the sludge was by these estimations consisting of around 30% C, 3% P, and 4% N.

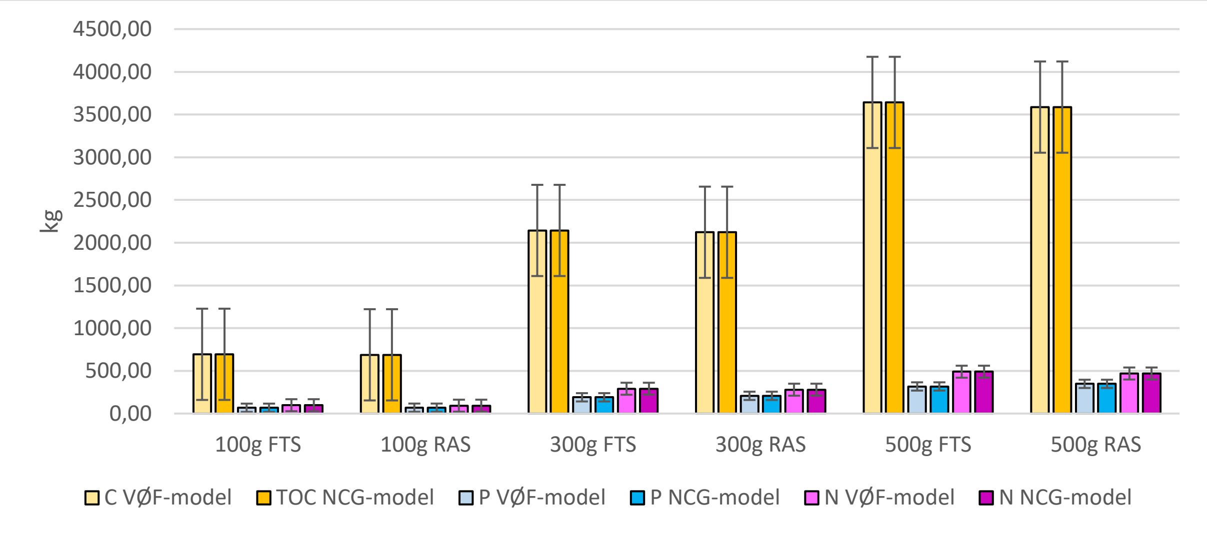

Figure 41: Particle waste production of C, P and N in 100g, 300g and 500g FTS and RAS production, NCG-model compared to VØF-model

5.3. Discussion and conclusion

The result on waste produced both total, particle, and dissolved seemed to correlate with the results in the NCG-model, but there were apparent differences. The VØF-model utilized input values based on mass balance from previous studies, combined with mathematical theories surrounding input numbers in the production plans, based on experience numbers from actual land-based salmon farms (Tørrisen.A, 2020) combined with literary studies.
This structuring of the VØF-model gave a very detailed estimate on waste produced, opposed to the county governor models that gave a less accurate estimate because the input values were done with total averages in productions and not specific averages in different production plans (Pedersen.T.N, Personal message, 2020).

The NCG-model and OCG-model estimated C content in waste as TOC and not as total C as it did with P, and N. TOC consists of DOC and POC where dissolved waste is defined as particles smaller than 0,2 µm (Uglem.I, Järnegren.J og Bloecher.N, 2020). The VØF-model, on the other hand, estimated total C, P, and N, as well as the dissolved inorganic part of C that is not respired as CO_2, giving a more accurate and even estimation compared to the NCG-model.

Regarding sludge calculation, the NCG-model estimated that DW content in sludge changed with increased size in salmon produced, which may be questionable. The VØF-model estimates that DW in sludge is equal for all salmon sizes produced (Aas.T.S, Ytrestøyl.T og Berge.G.M, 2016), thus differentiating itself from the NCG-model. However, I am uncertain if this is an incorrect or correct assumption, but with the mass balance method used in the VØF-model, the sludge components of C, P, and N match earlier studies (Hagemann.A, 2020).

The real strength of the VØF-model, however, was its ability to estimate the variations in waste production between FTS and RAS. By acknowledging the fact that there are differences between FTS and RAS, the VØF-model can be a more environmental considerate estimation tool, than the OCG-model and NCG-model. One main support for this claim is the amount of water discharged from the FTS and RAS facilities. From the current emission permits, and the comparison done between the dissolved waste in the VØF-model and Net waste in the NCG-model (Chapter 5.2.2), the thesis leans towards an assumption that all dissolved waste components are released to the environment (Krogstad.P.K, Utslippstillatelse, 2018).
With the RAS high reuse capacity, there can, therefore be as little as 5%-1% effluent water discharged from these types of facilities (Akvagrouptm, 2020). As shown in this thesis, the RAS waste will, therefore, occur at shorter intervals than FTS waste and consist of higher concentrations of C, P, and N components, which may be harmful to the local impact zone (Figure 29).

A weakness for all models included the VØF-model, was that they only estimated what was theoretically possible to purify, which means that the models estimated that a facility could remove 100% of particle waste produced. This is near impossible because of particle breakage, waste pipe conditions, filter cloth size, and so on. Also, all models failed to specify particle removal efficiency and the collaboration between feces stability and placement of filter in connection to the biofilter. Further, they did not specify how different feces handles different transport lengths and how much of the nutrients that are assumed lost in connection to transport length with different feces qualities. There is also a question surrounding fouling in the tanks, and if this somehow contributes to an increased amount of waste produced. Because of high temperatures and biological production in the tanks, fouling occurs in these tanks throughout the entire production. This fouling is cleaned regularly and will follow the wastewater as an emission, either particle and/or dissolved.

One of the most prominent strengths of the VØF-model was that it showed how feed producers could impact the feces produced, but unfortunately, along with the other models it did not tell how all the different factors in a facility affected the feces stability, e.g., particle removal rate for, different types of filter (belt, drum, etc.), different filter-cloth sizes, different types of biofilters in RAS (Moving bed, fixed bed) and so on.

All of the information and mathematical methods used in the county governor office models, were given from county governor employees both in Trøndelag and Vestland. Unfortunately, it was not specified where they had received this information or their references around the estimation models. Because of this, it was not possible to trace the exact estimation choices back to its origin, to approve or disapprove the sources and definitions of, e.g., gross waste and net waste.

To conclude, by altering DW content depending on size, and calculating net waste / dissolved waste with this constant, the NCG-model did not estimate waste according to the mass balance principle, therefore causing variation in percentage discharged waste between the productions.
It was evident in the results that there is a lack of knowledge and estimations when it comes to technical and system factors affecting the feces stability and, ultimately, total waste production. It was also evident that the OCG-model was outdated and that the NCG-model was simple and user friendly, but the results showed that a thorough production plan calculated by farmers was needed to estimate and assess waste production from facilities correctly, along with proper and updated mass balance estimates.

6. Final conclusion

The current license policy control/regulate the emissions from land-based fish farms by deciding a percentage purification of the discharge from a farm, or by restricting the total biomass, total feed usage or a maximum number of fish. This licensing system gives no rewards, and in some cases restricting possibilities, to improve within the current regulations. A licensing system like this do in few cases, urge or stimulate to reduce emissions from land-based salmon farms, neither FTS or RAS. The thesis provides information and shows evident differences between fry, fingerling, and smolt, in FTS and RAS, and from these variations, it can no longer be assumed that land-based emissions are equal to sea-based emissions from salmon production.

It is fully possible to develop an improved model that better calculate the emissions from land-based salmon farms, by incorporating a weekly production model, production system factors, and mass balance estimates. However, to do this accurately, further research is necessary, specifically focusing on land-based salmon production. Research needs to be provided for nutrient retainment with different feed types for fry, fingerling, and smolt, with updated mass balance studies on land-based salmon. There is also a need to understand how the feed affects salmon waste, how the feed and waste are handled with different production equipment, and in the different FTS and RAS solutions. In addition to research on how fouling in the tanks influences the waste production from salmon farms.

7. Future perspective

A suggestion for future licensing of land-based aquaculture facilities in Norway can be by not limiting the production with the number of fish, biomass, and feed usage like today (Myksvoll.S, 2002), but instead, issue licenses on particle waste produced throughout a year with a limitation on maximal particle waste produced per week. For larger productions where the recipient may be more exposed, or for productions in areas with lesser sustainable recipients, a limitation on dissolved waste emissions may also be incorporated. With a licensing method like this, it can also take into account the more concentrated emissions from RAS, that occur at shorter intervals than the traditional FTS waste. However, as long as a recipient can handle the dissolved waste emissions, it can be justifiable only to restrict the particle waste emissions.

This type of licensing system may also stimulate feed producers and equipment suppliers for FTS and RAS in working together to document waste created, broken down, and possibly gathered in FTS and RAS with different designs. The VØF-model is now only to some degree accurate in estimating theoretical waste production in the salmon tanks, and further research is necessary to understand how the structure of different facilities and systems affect the waste released from a farm. It is also important that the calculation method is designed for each specific fish type that is to be produced. The C, P, and N levels in the feed are different for different species (Chatvijitkul.S, Boyd.C.E and Davis.D,A, 2018), and it may be fair to assume that the mass balance between, e.g., salmon and trout are different.

The point is that the licensing system must not only be beneficial for salmon farmers, it needs to be beneficial for the industry as a whole to stimulate innovation and technological development. E.g., say that a license only regulates with maximum feed usage. This may stimulate farmers to search for feed with certain capabilities, and it will also stimulate feed manufacturers to produce a feed with those capabilities. The salmon farmer is pleased, but the feed manufacturer is not as pleased. The feed manufacturer, of course, get a profit by increasing the price of the new feed, but the salmon farmer does not buy more feed. Therefore the amount of feed purchased remain the same. If the outcome of the arrangement is not equally beneficial for both parts, one may risk that the innovative process is not at a 100%, which indirectly causes the licensing system to lose, because it could have performed better.

The type of licensing system suggested, may provide good control of waste production but, at the same time, cause challenges in long term estimations of environmental impact. However, by rewarding salmon farmers for keeping their waste production down, the negative environmental impact can assumably be kept to a minimum. E.g., If FCR is kept as low as possible and more particle waste is taken out of the wastewater, by minimizing particle breakage and optimizing filtration, the local impact zone may be less affected since there are smaller amounts of waste that will accumulate and form H_2S. This assumption is made by the fact that dissolved waste is easier for water currents to transport further away than particle waste, that has a tendency to accumulate in the local impact zone close to the facilities waste pipeline (Carroll.M.L, Cochrane.S, Fieler.R, Velvin.R and White.P, 2003).

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Appendix 1

ALPHEUS 50 B5

A complete feed for Atlantic salmon (Salmo salar).

Product code: [redacted]

Formula code: [redacted] Formula version: [redacted]

Manufacturing (M3) order number: [redacted]
Bag number:
Date of Manufacture: [redacted]
Best Before Date: [redacted]

Net weight: 500 kg.

ANALYTICAL CONSTITUENTS:

Crude protein	48.0 %	Calcium	15.1 g/kg
Crude fats & oils	24.2 %	Phosphorous	14.6 g/kg
Crude fibre	1.3 %	Sodium	5.2 g/kg
Crude ash	7.3 %		

COMPOSITION:
Fish meal, Soya (bean) protein concentrate, Fish oil, Vital wheat gluten, Peas dehulled, Rapeseed oil, Maize gluten, Wheat, Minerals, Vitamins, L-Histidine monohydrochloride, Yeasts & parts thereof, Guar meal roasted, Carotenoids, Amino acids

ADDITIVES:
2.a.(ii): Sensory additives
2a161j Astaxanthin 69.2 mg/kg
3.a: Vitamins
3a671 Vitamin D3 3150.0 IU/kg
3a672a Vitamin A 3937.5 IU/kg
3.b: Trace Elements
3b103 Iron, (Iron (II) sulphate monohydrate) 67.6 mg/kg
3b202 Iodine, (Calcium iodate anhydrous) 2.0 mg/kg
3b405 Copper, (Copper sulphate pentahydrate) 3.4 mg/kg
3b503 Manganese, (Manganous sulphate monohydrate) 20.3 mg/kg
3b605 Zinc, (Zinc sulphate monohydrate)135.2 mg/kg
3b8.10 Selenium, (Selenised yeast, inactivated) 0.0 mg/kg

USER INFORMATION:

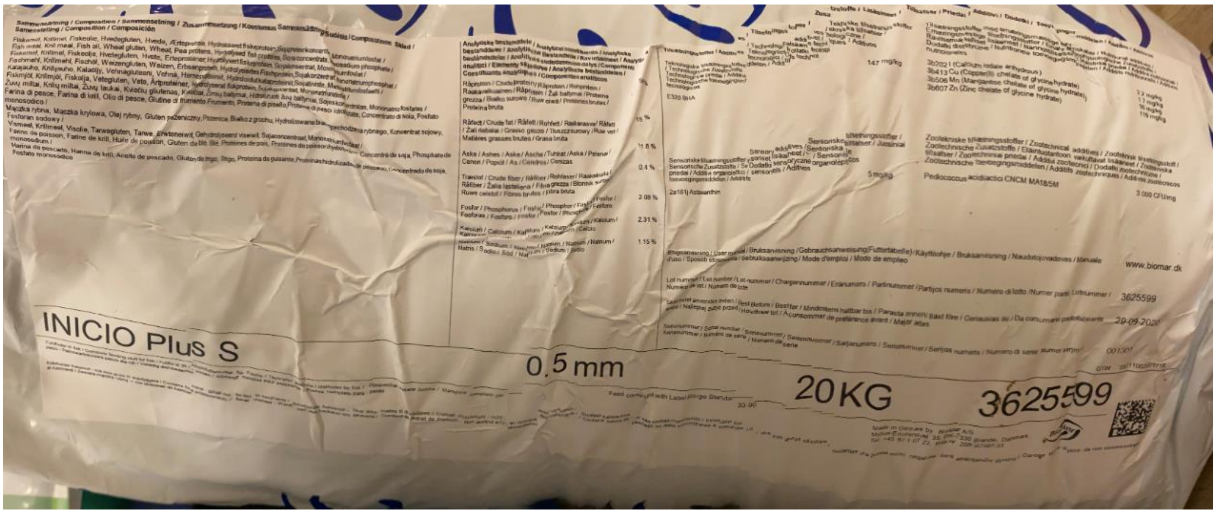
INSTRUCTIONS FOR USE:
Feed in accordance with MOWI guidelines.
This product contains fishmeal (category 3 animal by-product). Not for human consumption.
Do not feed to ruminants.

STORE IN A COOL DRY PLACE

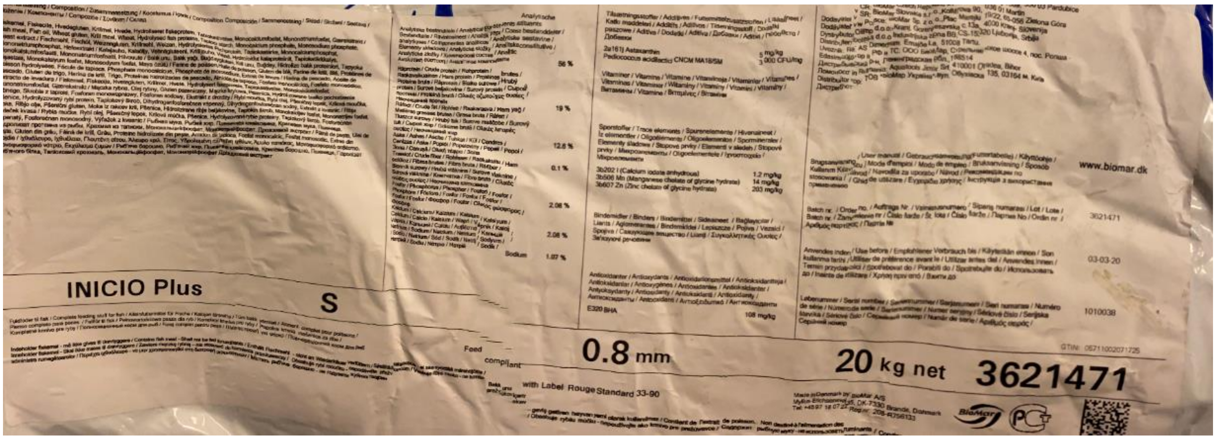
Manufactured by: Mowi Scotland Ltd, Kyleakin Fish Feed Mill, Isle of Skye, Inverness-shire, UK. IV41 8PQ
Tel: [redacted] Email: [redacted]
Registration No. alpha GB 777 120528

Registered office: Mowi Scotland Ltd, 1st Floor, Admiralty Park, Admiralty Road, Rosyth, Fife, UK. KY11 2YW

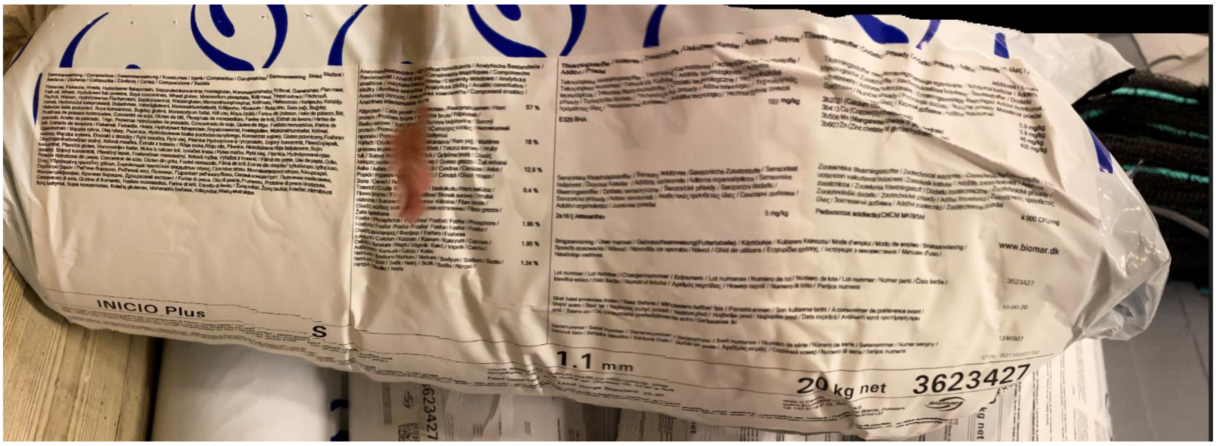
Appendix 2



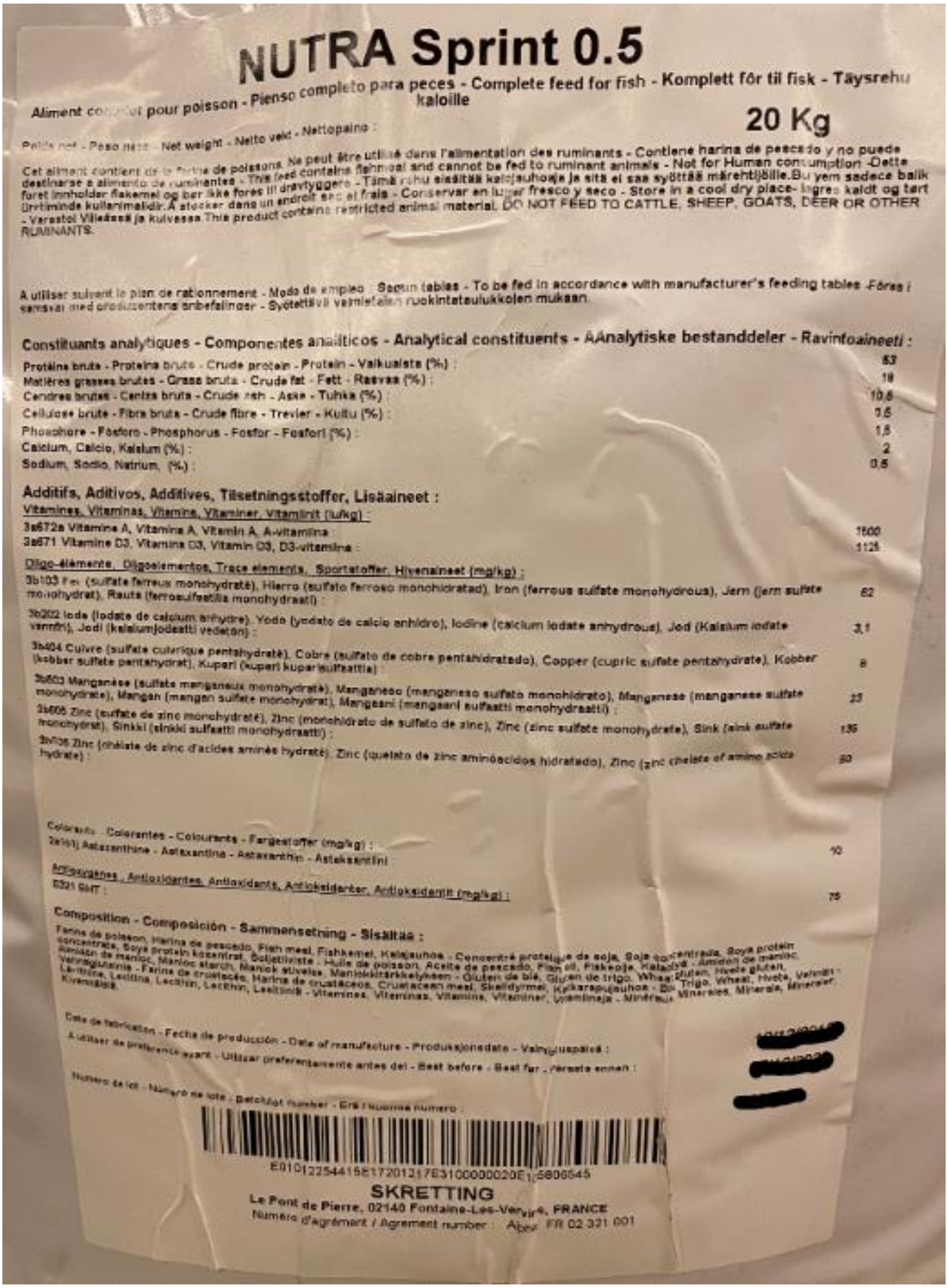
Appendix 3



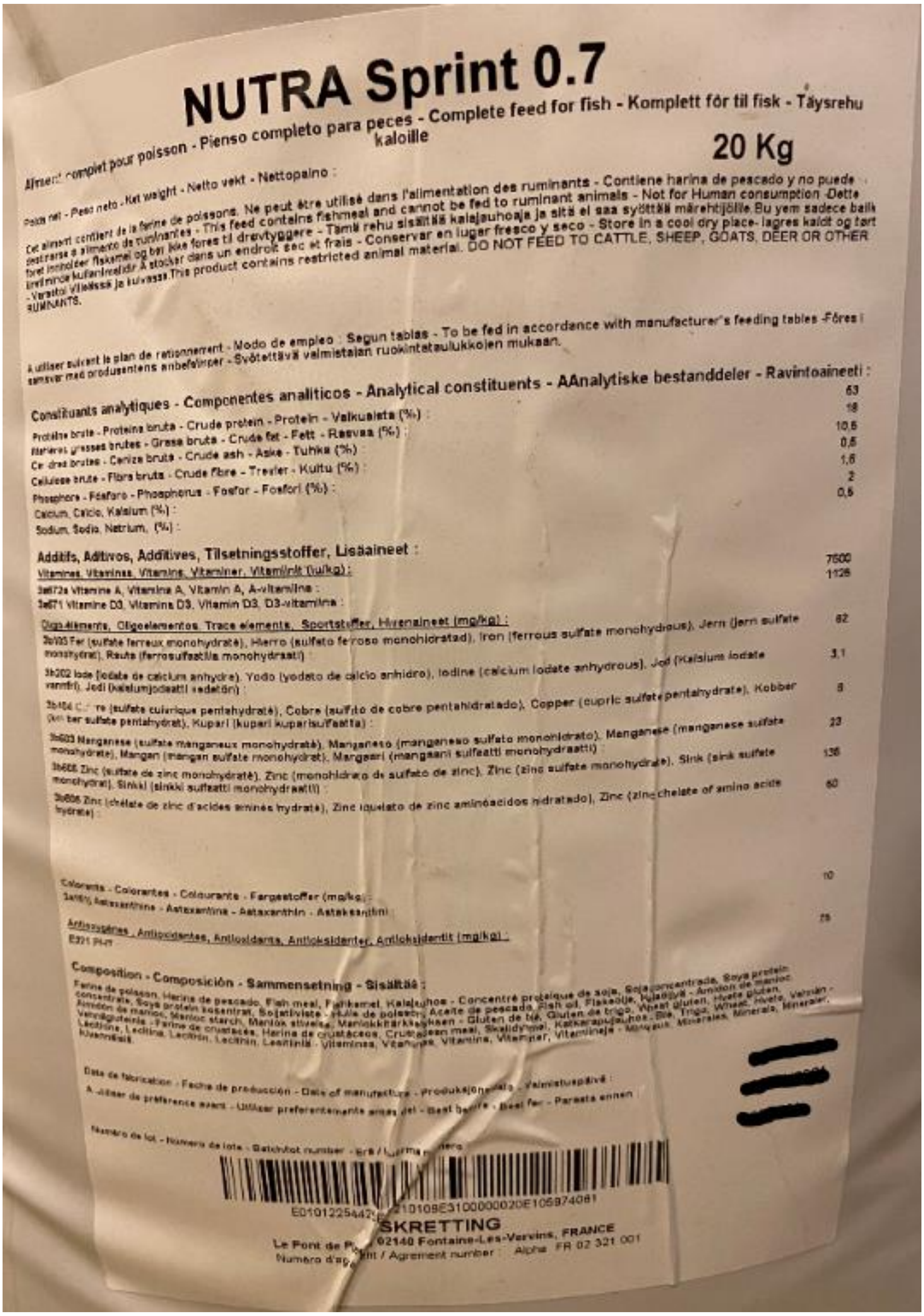
Appendix 4



Appendix 5


NUTRA Sprint 0.5
Aliment complet pour poisson - Pienso completo para peces - Complete feed for fish - Komplett fôr til fisk - Täysrehu kaloille
20 Kg
Poids net - Peso neto - Net weight - Netto vekt - Nettopaino :
Cet aliment contient de la farine de poissons. Ne peut être utilisé dans l'alimentation des ruminants - Contiene harina de pescado y no puede destinarse a alimento de rumiantes - This feed contains fishmeal and cannot be fed to ruminant animals - Not for Human consumption - Dette fôret inneholder fiskemel og bør ikke fôres til drøvtyggere - Tämä rehu sisältää kalajauhoja ja sitä ei saa syöttää märehtijöille. À stocker dans un endroit sec et frais - Conservar en lugar fresco y seco - Store in a cool dry place - Varastoi viileässä ja kuivassa. This product contains restricted animal material. DO NOT FEED TO CATTLE, SHEEP, GOATS, DEER OR OTHER RUMINANTS.
A utiliser suivant le plan de rationnement - Modo de empleo : Según tablas - To be fed in accordance with manufacturer's feeding tables - Fôres i samsvar med produsentens anbefalinger - Syötettävä valmistajan ruokintataulukkojen mukaan.
Constituants analytiques - Componentes analíticos - Analytical constituents - Analytiske bestanddeler - Ravintoaineeti :
Protéine brute - Proteína bruta - Crude protein - Protein - Valkuaista (%) : 53
Matières grasses brutes - Grasa bruta - Crude fat - Fett - Rasvaa (%) : 18
Cendres brutes - Ceniza bruta - Crude ash - Aske - Tuhka (%) : 10,6
Cellulose brute - Fibra bruta - Crude fibre - Trevler - Kuitu (%) : 0,6
Phosphore - Fósforo - Phosphorus - Fosfor - Fosfori (%) : 1,5
Calcium, Calcio, Kalsium (%) : 2
Sodium, Sodio, Natrium, (%) : 0,6
Additifs, Aditivos, Additives, Tilsetningsstoffer, Lisäaineet :
Vitamines, Vitaminas, Vitamins, Vitaminer, Vitamiinit (IU/kg) :
3a672a Vitamine A, Vitamina A, Vitamin A, A-vitamiina : 1500
3a671 Vitamine D3, Vitamina D3, Vitamin D3, D3-vitamiina : 1125
Oligo-éléments, Oligoelementos, Trace elements, Sporstoffer, Hivenaineet (mg/kg) :
3b103 Fer (sulfate ferreux monohydraté), Hierro (sulfato ferroso monohidratado), Iron (ferrous sulfate monohydrous), Jern (jern sulfate monohydrat), Rauta (ferrosulfaatti monohydraatti) : 62
3b202 Iode (iodate de calcium anhydre), Yodo (yodato de calcio anhidro), Iodine (calcium iodate anhydrous), Jod (Kalsium iodate vannfri), Jodi (kalsiumjodaatti vedeton) : 3,1
3b404 Cuivre (sulfate cuivrique pentahydraté), Cobre (sulfato de cobre pentahidratado), Copper (cupric sulfate pentahydrate), Kobber (kobber sulfate pentahydrat), Kupari (kupari kuparisulfaattia) : 8
3b503 Manganèse (sulfate manganeux monohydraté), Manganeso (manganeso sulfato monohidrato), Manganese (manganese sulfate monohydrate), Mangan (mangan sulfate monohydrat), Mangaani (mangaani sulfaatti monohydraatti) : 23
3b606 Zinc (sulfate de zinc monohydraté), Zinc (monohidrato de sulfato de zinc), Zinc (zinc sulfate monohydrate), Sink (sink sulfate monohydrat), Sinkki (sinkki sulfaatti monohydraatti) : 135
3b606 Zinc (chélate de zinc d'acides aminés hydraté), Zinc (quelato de zinc aminoácidos hidratado), Zinc (zinc chelate of amino acids hydrate) : 60
Colorants - Colorantes - Colourants - Fargestoffer (mg/kg) :
2a161j Astaxanthine - Astaxantina - Astaxanthin - Astaksantiini : 10
Antioxygènes, Antioxidantes, Antioxidants, Antioksidanter, Antioksidantit (mg/kg) :
E321 BHT : 75
Composition - Composición - Sammensetning - Sisältää :
Farine de poisson, Harina de pescado, Fish meal, Fiskemel, Kalajauhoa - Concentré protéique de soja, Soja concentrada, Soya protein concentrate, Soya protein konsentrat, Soijatiiviste - Huile de poisson, Aceite de pescado, Fish oil, Fiskeolje, Kalaöljy - Amidon de manioc, Almidón de manioc, Manioc starch, Maniok stivelse, Maniokkitärkkelys - Gluten de blé, Gluten de trigo, Wheat gluten, Hvete gluten, Vehnägluteeni - Farine de crustacés, Harina de crustáceos, Crustacean meal, Skalldyrmel, Äyriäisjauho - Lécithine, Lecitina, Lecithin, Lecithin, Lesitiini - Vitamines, Vitaminas, Vitamins, Vitaminer, Vitamiineja - Minéraux, Minerales, Minerals, Mineraler, Kivennäisiä
Date de fabrication - Fecha de producción - Date of manufacture - Produksjonsdato - Valmistuspäivä : [redacted]
A utiliser de préférence avant - Utilizar preferentemente antes del - Best before - Best før - Parasta ennen : [redacted]
Numéro de lot - Número de lote - Batch/lot number - Erä / numero numero : [redacted]
SKRETTING
Le Pont de Pierre, 02140 Fontaine-Les-Vervins, FRANCE
Numéro d'agrément / Agrement number : FR 02 321 001

Appendix 6


NUTRA Sprint 0.7
Aliment complet pour poisson - Pienso completo para peces - Complete feed for fish - Komplett fôr til fisk - Täysrehu kaloille
20 Kg
Poids net - Peso neto - Net weight - Netto vekt - Nettopaino :
DO NOT FEED TO CATTLE, SHEEP, GOATS, DEER OR OTHER RUMINANTS.
To be fed in accordance with manufacturer's feeding tables
Constituants analytiques - Componentes analíticos - Analytical constituents - AAnalytiske bestanddeler - Ravintoaineet :
Protéine brute - Proteína bruta - Crude protein - Protein - Valkuaista (%) :
Matières grasses brutes - Grasa bruta - Crude fat - Fett - Rasvaa (%) :
Cendres brutes - Ceniza bruta - Crude ash - Aske - Tuhka (%) :
Cellulose brute - Fibra bruta - Crude fibre - Trevler - Kuitu (%) :
Phosphore - Fósforo - Phosphorus - Fosfor - Fosfori (%) :
Calcium, Calcio, Kalsium (%) :
Sodium, Sodio, Natrium, (%) :
63
18
10,5
0,5
1,6
2
0,5
Additifs, Aditivos, Additives, Tilsetningsstoffer, Lisäaineet :
Vitamines, Vitaminas, Vitamins, Vitaminer, Vitamiinit (IU/kg) :
3a672a Vitamine A, Vitamina A, Vitamin A, A-vitamiini :
3a671 Vitamine D3, Vitamina D3, Vitamin D3, D3-vitamiini :
7500
1125
Oligo-éléments, Oligoelementos, Trace elements, Sporstoffer, Hivenaineet (mg/kg) :
62
3,1
8
23
135
60
Colorants - Colorantes - Colourants - Fargestoffer (mg/kg) :
Astaxanthine - Astaxantina - Astaxanthin - Astaksantiini
10
Antioxygènes, Antioxidantes, Antioxidants, Antioksidanter, Antioksidantit (mg/kg) :
75
Composition - Composición - Sammensetning - Sisältää :
Date de fabrication - Fecha de producción - Date of manufacture - Produksjonsdato - Valmistuspäivä :
Numéro de lot - Numero de lote - Batch/lot number
SKRETTING
02140 Fontaine-Les-Vervins, FRANCE
Alpha FR 02 321 001

Appendix 7

Inicio plus

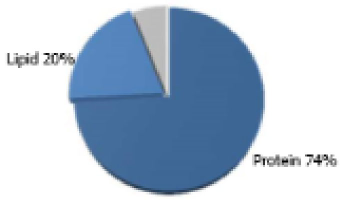
6-4-2018

BioMar

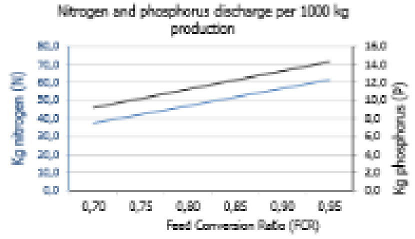
INICIO Plus G SALMON

Declaration		0,4 mm	0,6 mm	1 mm
Crude protein	%	60	60	60
Crude lipid	%	10	10	10
Carbohydrates (NFE)	%	11	11	11
Crude Fiber	%	0,3	0,3	0,3
Ash	%	12,2	12,2	12,2
Total phosphorus (P)	%	2,0	2,0	2,0
Gross energy	MJ/kg	20,4	20,4	20,4
Digestible energy	MJ/kg	17,8	17,8	17,8

Energy distribution



Ecological value



Values stated on the datasheet can vary depending on producing factory and natural variations in raw materials. More information and actual values and ingredients, can be found on the label*. Product contains probiotics.

The information on energy distribution and ecological values applies to 0.6 mm

Feeding guides (kg feed per 100 kg fish per day)

Lowest possible feed conversion rate – to be used when optimal feed utilisation is required

Fish size gram	cm	Pellet size mm	2°C	4°C	6°C	8°C	10°C	12°C	14°C	16°C	18°C
0,1 - 0,2	2 - 3	0,4	Ad lib	Ad lib	Ad lib	Ad lib	Ad lib	Ad lib	Ad lib	Ad lib	Ad lib
0,2 - 0,5	3 - 4	0,6	1,27	1,50	1,88	2,16	2,76	3,41	3,67	3,79	3,65
0,4 - 1,4	4 - 5	1	1,10	1,30	1,62	1,87	2,39	2,95	3,18	3,29	3,16

Optimal feeding – to be used when an optimal relation between large production and good feed utilisation is required

Fish size gram	cm	Pellet size mm	2°C	4°C	6°C	8°C	10°C	12°C	14°C	16°C	18°C
0,1 - 0,2	2 - 3	0,4	Ad lib	Ad lib	Ad lib	Ad lib	Ad lib	Ad lib	Ad lib	Ad lib	Ad lib
0,2 - 0,5	3 - 4	0,6	1,55	1,81	2,24	2,97	4,32	6,02	7,21	7,99	7,58
0,4 - 1,4	4 - 5	1	1,31	1,53	1,89	2,51	3,68	5,15	6,19	6,88	6,52

Feeding should be adapted to the chosen production strategy and current farming conditions.
Recommended storage of feed is in dry and cool place, protected from direct sunlight and pests.
BioMar A/S - Mylius-Erichsensvej 35 - DK-7330 Brande - Phone +45 97 18 07 22 - info@biomar.dk - www.biomar.dk (0,84 - 1,3)

*The label can be found on the product itself as mandated by EU Regulation.

Appendix 8

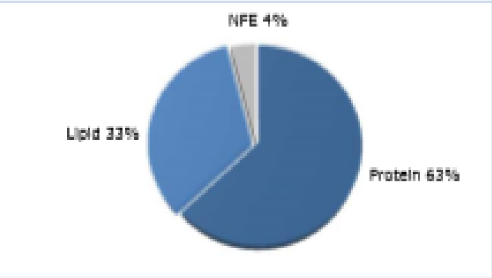
Inicio *plus*

7-8-2018

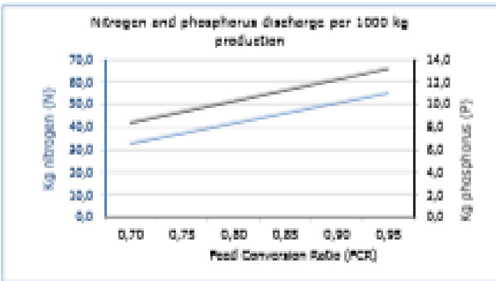
INICIO Plus S | SALMON

Declaration		**0,5 mm**	**0,8 mm**	**1,1 mm**
Crude protein	%	58	56	56
Crude lipid	%	15	18	18
Carbohydrates (NFE)	%	6,2	7,9	8,4
Crude Fiber	%	0,2	0,2	0,3
Ash	%	12,4	11,9	12,0
Total phosphorus (P)	%	2,0	1,9	1,9
Gross energy	MJ/kg	21,2	22,0	21,9
Digestible energy	MJ/kg	18,5	19,3	19,1

Energy distribution



Ecological value



Values stated on the datasheet can vary depending on producing factory and natural variations in raw materials. More information and actual values and ingredients, can be found on the label*. Product contains probiotics.

The information on energy distribution and ecological values applies to 0,8 mm

Feeding guides (kg feed per 100 kg fish per day)

Lowest possible feed conversion rate – to be used when optimal feed utilisation is required

Fish size		Pellet size										
gram	cm	mm	2°C	4°C	6°C	8°C	10°C	12°C	14°C	16°C	18°C	20°C
0,2 - 0,4	3 - 4	0,5	1,26	1,49	1,86	2,14	2,73	3,37	3,63	3,75	3,61	3,03
0,4 - 1,5	4 - 5	0,8	1,07	1,27	1,59	1,83	2,34	2,89	3,12	3,22	3,10	2,60
1,5 - 5	5 - 8	1,1	0,95	1,12	1,40	1,62	2,07	2,56	2,77	2,86	2,75	2,30

Optimal feeding – to be used when an optimal relation between large production and good feed utilisation is required

Fish size		Pellet size										
gram	cm	mm	2°C	4°C	6°C	8°C	10°C	12°C	14°C	16°C	18°C	20°C
0,2 - 0,4	3 - 4	0,5	1,54	1,79	2,21	2,93	4,27	5,96	7,13	7,90	7,50	4,13
0,4 - 1,5	4 - 5	0,8	1,28	1,49	1,85	2,46	3,61	5,05	6,07	6,74	6,39	3,48
1,5 - 5	5 - 8	1,1	1,11	1,29	1,60	2,14	3,14	4,41	5,31	5,92	5,61	3,02

Feeding should be adapted to the chosen production strategy and current farming conditions.
Recommended storage of feed is in dry and cool place, protected from direct sunlight and pests.
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*The label can be found on the product itself as mandated by EU Regulation.

Appendix 9

Inicio plus

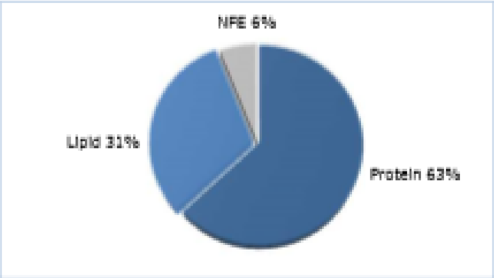
BioMar

7-8-2018

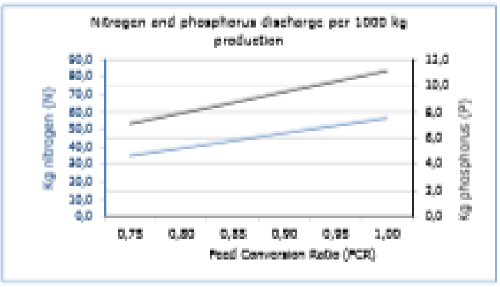
INICIO Plus 18% | SALMON

Declaration		1,5 mm
Crude protein	%	54
Crude lipid	%	18
Carbohydrates (NFE)	%	11
Crude Fiber	%	1,1
Ash	%	11,0
Total phosphorus (P)	%	1,6
Gross energy	MJ/kg	21,9
Digestible energy	MJ/kg	18,8

Energy distribution



Ecological value



Values stated on the datasheet can vary depending on producing factory and natural variations in raw materials. More information and actual values and ingredients, can be found on the label*. Product contains probiotics.

The information on energy distribution and ecological values applies to 1,5 mm

Feeding guides (kg feed per 100 kg fish per day)

Lowest possible feed conversion rate – to be used when optimal feed utilisation is required

Fish size		Pellet size										
gram	cm	mm	2°C	4°C	6°C	8°C	10°C	12°C	14°C	16°C	18°C	20°C
5 - 15	8 - 11	1,5	0,81	0,96	1,20	1,39	1,78	2,20	2,37	2,45	2,36	1,97

Optimal feeding – to be used when an optimal relation between large production and good feed utilisation is required

Fish size		Pellet size										
gram	cm	mm	2°C	4°C	6°C	8°C	10°C	12°C	14°C	16°C	18°C	20°C
5 - 15	8 - 11	1,5	0,93	1,08	1,34	1,79	2,64	3,72	4,49	5,01	4,74	2,54

Feeding should be adapted to the chosen production strategy and current farming conditions.
Recommended storage of feed is in dry and cool place, protected from direct sunlight and pests.
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*The label can be found on the product itself as mandated by EU Regulation.

Appendix 10

ORBIT

BioMar

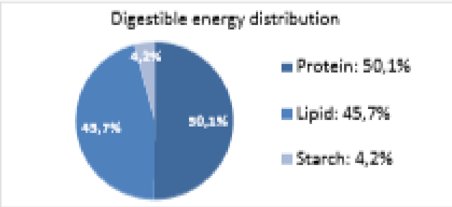
02-10-19

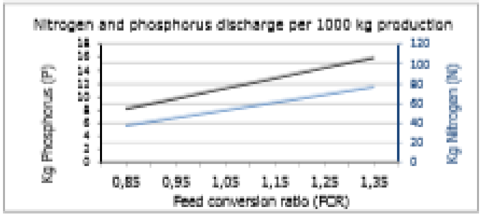
ORBIT Intro+	SALMON		
Declaration		**2 mm**	**3 mm**
Crude protein	%	47-50	46-49
Crude lipid	%	24-27	24-27
Carbohydrates (NFE)	%	9,1-15,1	10,1-16,1
Crude cellulose	%	0,5-1,4	0,6-1,7
Ash	%	7-9	6,8-8,8
Total phosphorus (P)	%	1,6	1,5
Gross Energy	MJ/kg	22,6-24,6	22,6-24,6
BioMar's digestible energy*	MJ/kg	20,3	20,1
Classical digestible energy**	MJ/kg	21,5	21,5
Typical content of nitrogen (N)	%	7,8	7,6
Number of pellets per kg - indicative***		138000	35700

*BioMar digestible energy calculated on proteins, lipids and starch only
**Classical digestible energy calculated on proteins, lipids and NFE
***Figures are ± 10% depending on batches and based on available figures

Digestible energy distribution & Ecological values

The information on energy distribution and ecological values applies to 2 mm





Values stated on the datasheet can vary depending on producing factory and natural variations in raw materials. More information and actual values and ingredients, can be found on the label. The label can be found on the product itself as mandated by EU Regulation. Product contains probiotics.

Feed formulation is based on BioMar's Performance Concept. Please visit our website for more information on the Performance Concept. For further information on the product, please visit our website or ask your sales representative.

Indicative feeding guide (kg feed per 100 kg fish per day)

Fish size grams	Pellet size mm	4 ºC	6 ºC	8 ºC	10 ºC	12 ºC	14 ºC	16 ºC	18 ºC	20 ºC
		Temperature (°C)								
15 - 30	2,0	0,76	0,95	1,10	1,40	1,74	1,88	1,94	1,86	1,56
30 - 50	2,0	0,69	0,87	1,01	1,29	1,59	1,72	1,78	1,71	1,43
50 - 100	3,0	0,61	0,77	0,89	1,14	1,41	1,52	1,58	1,51	1,26

Feeding should be adapted to the chosen production strategy and current farming conditions. Data are set to reach the minimum FCR in optimum conditions (oxygen, health, etc.) and do not take into account possible losses of feed due to farm configuration. To obtain maximum growth, more feed can be distributed. For further details, please contact your BioMar technical advisor (BioFarm).

Recommended storage of feed is in dry and cool place, protected from rain, direct sunlight and pests.
Best-before date: refer to label.

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Appendix 11

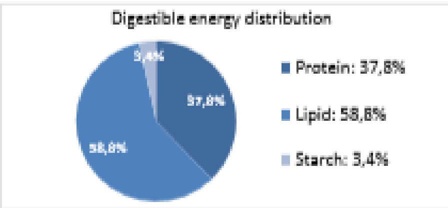
07-10-19

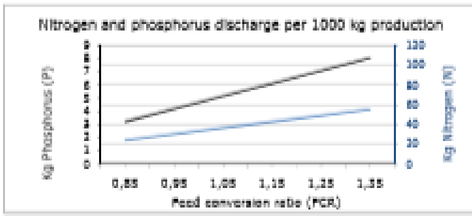
EFICO Enviro 940	SALMON				
Declaration		**3 mm**	**4,5 mm**	**6 mm**	**8 mm**
Crude protein	%	44-47	44-47	38-41	36-39
Crude lipid	%	23-26	24-27	33-36	32-35
Carbohydrates (NFE)	%	12,2-18,2	11,4-17,4	10,7-16,7	12,1-18,1
Crude cellulose	%	1,2-3,2	1,8-3,8	1-3	1,7-3,7
Ash	%	6,8-8,8	6,4-8,4	5,3-7,3	4,5-6,5
Total phosphorus (P)	%	1,2	1,1	1,0	0,8
Gross Energy	MJ/kg	22,2-24,2	22,9-24,9	24,2-26,2	24,6-26,6
BioMar's digestible energy*	MJ/kg	19,2	19,8	21,0	21,3
Classical digestible energy**	MJ/kg	20,6	21,2	22,7	22,9
Typical content of nitrogen (N)	%	7,3	7,3	6,3	6,0
Number of pellets per kg - indicative***		48700	14800	6050	2600

*BioMar digestible energy calculated on proteins, lipids and starch only
**Classical digestible energy calculated on proteins, lipids and NFE
***Figures are ± 10% depending on batches and based on available figures

Digestible energy distribution & Ecological values

The information on energy distribution and ecological values applies to 6 mm





Values stated on the datasheet can vary depending on producing factory and natural variations in raw materials. More information and actual values and ingredients, can be found on the label. The label can be found on the product itself as mandated by EU Regulation.

Feed formulation is based on BioMar's Performance Concept. Please visit our website for more information on the Performance Concept. For further information on the product, please visit our website or ask your sales representative.

Indicative feeding guide (kg feed per 100 kg fish per day)

Fish size grams	Pellet size mm	Temperature (°C) 4 °C	6 °C	8 °C	10 °C	12 °C	14 °C	16 °C	18 °C	20 °C
50 - 100	3,0	0,64	0,81	0,93	1,19	1,48	1,60	1,65	1,59	1,33
100 - 200	4,5	0,57	0,71	0,83	1,06	1,31	1,42	1,47	1,41	1,18
200 - 300	4,5	0,52	0,65	0,75	0,97	1,20	1,29	1,34	1,28	1,07
300 - 450	4,5	0,47	0,59	0,69	0,88	1,09	1,18	1,22	1,17	0,98
450 - 600	6,0	0,45	0,56	0,65	0,83	1,03	1,11	1,15	1,10	0,92
600 - 800	6,0	0,43	0,53	0,62	0,79	0,98	1,06	1,10	1,06	0,88
800 - 1000	6,0	0,40	0,50	0,57	0,74	0,91	0,99	1,02	0,98	0,82
1000 - 1400	8,0	0,36	0,45	0,53	0,67	0,83	0,90	0,93	0,90	0,75
1400 - 2000	8,0	0,32	0,40	0,46	0,59	0,73	0,79	0,82	0,79	0,66
2000 - 3000	8,0	0,26	0,33	0,38	0,49	0,61	0,66	0,68	0,65	0,54

Feeding should be adapted to the chosen production strategy and current farming conditions. Data are set to reach the minimum FCR in optimum conditions (oxygen, health, etc.) and do not take into account possible losses of feed due to farm configuration. To obtain maximum growth, more feed can be distributed. For further details, please contact your BioMar technical advisor (BioFarm).

Recommended storage of feed is in dry and cool place, protected from rain, direct sunlight and pests.
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Appendix 12

ORBIT

BioMar

02-10-19

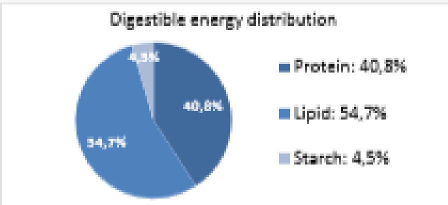
ORBIT 6040	SALMON

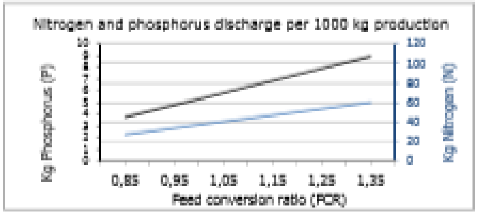
Declaration		4,5 mm	6 mm	8 mm	10 mm
Crude protein	%	45-48	40-43	37-40	35-38
Crude lipid	%	26-29	30-33	32-35	34-37
Carbohydrates (NFE)	%	9-15	11,7-17,7	12,8-18,8	13,5-19,5
Crude cellulose	%	0,7-2,1	0,9-2,6	1,2-3,2	1,1-3,1
Ash	%	6,4-8,4	4,7-6,7	4,5-6,5	4-6
Total phosphorus (P)	%	1,4	1,0	0,9	0,8
Gross Energy	MJ/kg	23,1-25,1	24,1-26,1	24,2-26,2	24,6-26,6
BioMar's digestible energy*	MJ/kg	20,7	21,3	21,1	21,5
Classical digestible energy**	MJ/kg	22,0	22,9	23,0	23,3
Typical content of nitrogen (N)	%	7,4	6,6	6,2	5,8
Number of pellets per kg - indicative***		14800	6050	2600	700

*BioMar digestible energy calculated on proteins, lipids and starch only
**Classical digestible energy calculated on proteins, lipids and NFE
***Figures are ± 10% depending on batches and based on available figures

Digestible energy distribution & Ecological values

The information on energy distribution and ecological values applies to 6 mm





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Feed formulation is based on BioMar's Performance Concept. Please visit our website for more information on the Performance Concept. For further information on the product, please visit our website or ask your sales representative.

Indicative feeding guide (kg feed per 100 kg fish per day)

Fish size grams	Pellet size mm	4 °C	6 °C	8 °C	10 °C	12 °C	14 °C	16 °C	18 °C	20 °C
100 - 200	4,5	0,55	0,68	0,79	1,01	1,26	1,36	1,40	1,35	1,13
200 - 300	4,5	0,50	0,62	0,72	0,93	1,15	1,24	1,28	1,23	1,03
300 - 450	4,5	0,45	0,57	0,66	0,84	1,04	1,13	1,17	1,12	0,93
450 - 600	6,0	0,44	0,55	0,64	0,82	1,01	1,09	1,13	1,09	0,91
600 - 800	6,0	0,42	0,53	0,61	0,78	0,97	1,05	1,08	1,04	0,87
800 - 1000	6,0	0,39	0,49	0,57	0,73	0,90	0,97	1,00	0,96	0,80
1000 - 1400	8,0	0,37	0,46	0,53	0,68	0,84	0,91	0,94	0,91	0,76
1400 - 2000	8,0	0,32	0,40	0,47	0,60	0,74	0,80	0,83	0,80	0,66
2000 - 3000	8,0	0,27	0,33	0,39	0,50	0,61	0,66	0,69	0,66	0,55
3000 - 4000	10,0	0,22	0,27	0,32	0,41	0,50	0,54	0,56	0,54	0,45

Feeding should be adapted to the chosen production strategy and current farming conditions. Data are set to reach the minimum FCR in optimum conditions (oxygen, health, etc.) and do not take into account possible losses of feed due to farm configuration. To obtain maximum growth, more feed can be distributed. For further details, please contact your BioMar technical advisor (BioFarm).

Recommended storage of feed is in dry and cool place, protected from rain, direct sunlight and pests.
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Appendix 13

13A	–	Production plan for 100g salmon in FTS
13B	–	Production plan for 100g salmon in RAS
13C	–	Production plan for 300g salmon in FTS
13D	–	Production plan for 300g salmon in RAS
13E	–	Production plan for 500g salmon in FTS
13F	–	Production plan for 500g salmon in RAS
13G	–	Waste estimation model (VØF)
13H	–	Waste estimation County governor (OCG)
13I	–	Waste estimation County governor (NCG)

13A - 100g Salmon production in FTS

Month	Week	Activity	cor. SGR	Temp	Light (h)	Number of fish	Number of fish destroyed	Weight (grams)	d°	BFCR	Biomass (kg)	Feed demand (kg)	SGR	Oxygen (FW) (mg/kg)	Specific water usage (l/kg/min)	Specific water demand (m3/min)	C (%)	P (%)	N (%)
Jan	1		1	8,0		140 664		0,2	220		28		4,88	7,23	1,68	0,05			
	2		1	8,0		136979		0,2	276		27		4,88	7,23	1,68	0,05			
	3		1	8,0		133390		0,2	332		27		4,88	7,23	1,68	0,04			
	4		1	8,0		129895		0,2	388		26		4,88	7,23	1,68	0,04			
Feb	5		1	8,0		126492		0,2	444		25		4,88	7,23	1,68	0,04			
	6	Hatching	1	8,0		123178		0,2	500		25		4,88	7,23	1,68	0,04			
	7		1	8,0		119951		0,2	556		24		4,88	7,23	1,68	0,04			
	8		1	8,0		116808		0,2	612		23		4,88	7,23	1,68	0,04			
Mar	9		1	8,0		113747		0,2	668		23		4,88	7,23	1,68	0,04			
	10		1	9,7		110767		0,2	724		22		5,90	9,18	2,48	0,05			
	11	Start feed	1	13,8	24	107865		0,299	792	0,77	32	7,75	7,93	12,15	4,19	0,13	45,21	1,86	8,52
	12		1	14,2	24	107811		0,510	889	0,77	55	17,49	6,32	12,15	4,19	0,23	45,21	1,86	8,52
	13		1	14,2	24	107757		0,783	988	0,77	84	22,63	6,32	12,15	4,19	0,35	45,21	1,86	8,52
Apr	14		1	14,2	24	107703		1,202	1087	0,77	129	34,74	5,33	8,90	3,07	0,40	45,21	1,86	8,52
	15		1	14,2	24	107650		1,73	1187	0,77	186	43,58	5,33	8,90	3,07	0,57	45,21	1,86	8,52
	16		1	14,2	24	107596		2,48	1286	0,77	267	62,63	4,49	8,90	3,07	0,82	45,21	1,86	8,52
	17		1	14,2	24	107542		3,38	1386	0,77	363	73,92	4,06	8,90	3,07	1,12	45,21	1,86	8,52
May	18		1	10,2	24	107488		4,46	1485	0,77	480	89,74	2,78	6,72	1,82	0,87	45,21	1,86	8,52
	19	Grading	0,5	10,2	24	104894	-2540	5,41	1556	0,77	568	67,47	2,63	4,91	1,33	0,75	47,6	1,54	7,71
	20		1	10,2	24	104842		5,93	1628	0,77	622	41,65	2,63	4,91	1,33	0,83	47,6	1,54	7,71
	21		1	10,2	24	104790		7,11	1699	0,77	745	95,20	2,63	4,91	1,33	0,99	47,6	1,54	7,71
	22		1	10,2	24	104737		8,53	1771	0,77	893	114,13	2,63	4,91	1,33	1,19	47,6	1,54	7,71
Jun	23		1	10,4	24	104685		10,23	1842	0,77	1071	136,83	2,22	4,29	1,16	1,24	47,6	1,54	7,71
	24		1	11,3	24	104633		11,93	1915	0,77	1248	136,45	2,42	4,29	1,16	1,45	47,6	1,54	7,71
	25		1	12,9	24	104580		14,11	1994	0,77	1475	174,62	2,82	4,95	1,50	2,21	47,6	1,54	7,71
	26		1	14,4	24	104528		17,14	2084	0,77	1792	243,83	2,75	5,69	1,96	3,51	47,6	1,54	7,71
Jul	27		1	15,9	24	104476		20,72	2185	0,77	2165	287,14	2,49	5,69	2,59	5,61	47,6	1,54	7,71
	28		1	15,1	24	104423		24,62	2296	0,77	2570	312,37	2,74	5,69	1,96	5,04	47,6	1,54	7,71
	29		1	14,5	24	104371		29,73	2401	0,77	3103	410,37	2,60	5,69	1,96	6,08	47,6	1,54	7,71
	30		1	14,1	24	104319		35,58	2503	0,77	3711	468,15	2,25	5,69	1,96	7,27	47,6	1,54	7,71
Aug	31		1	13,7	12	104267		41,57	2602	0,77	4335	480,08	2,18	5,69	1,96	8,50	47,27	1,31	7,27
	32		0,3	12,8	12	104215		48,36	2697	0,77	5040	542,84	1,98	4,95	1,50	7,56	47,27	1,31	7,27
	33	Vaccination	0,5	11,9	12	102893	-1270	50,41	2787	0,82	5187	120,52	1,80	3,63	1,10	5,71	47,27	1,31	7,27
	34		0,9	11,9	12	101571	-1270	53,67	2870	0,82	5451	216,55	1,80	3,63	1,10	6,00	47,27	1,31	7,27
	35		0,9	10,7	12	100250	-1270	60,04	2954	0,82	6019	465,97	1,59	3,14	0,85	5,12	46,32	1,6	7,52
Sep	36		1	10,7	12	100200		66,32	3029	0,82	6646	513,64	1,59	3,14	0,85	5,65	46,32	1,6	7,52
	37		1	10,7	24	100150		74,07	3103	0,82	7418	633,45	1,54	3,14	0,85	6,31	46,32	1,6	7,52
	38		1	10,7	24	100100		82,43	3178	0,82	8251	682,93	1,50	3,14	0,85	7,01	46,32	1,6	7,52
	39		1	10,7	24	100050		91,46	3253	0,82	9150	737,65	1,46	3,14	0,85	7,78	46,32	1,6	7,52
Oct	40		1	10,7	24	100000		101,23	3328	0,82	10123	797,71	1,43	2,75	0,74	7,49	46,32	1,6	7,52

Week	Total C Production (ton)	C Retained in salmon (ton)	C Waste Particulate (ton)	C Waste Dissolved (ton)	Total P Production (ton)	P Retained in salmon (ton)	P Waste Particulate (ton)	P Waste Dissolved (ton)	Total N Production (ton)	N Retained in salmon (ton)	N Waste Particulate (ton)	N Waste Dissolved (ton)	Sludge amount (kg) Solid quanteties	%C pr kg DW	%P pr kg DW	%N pr kg DW
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
11	3,50	1,32	0,64	0,11	0,14	0,04	0,07	0,03	0,66	0,27	0,10	0,29	2,15	29,89 %	3,49 %	4,73 %
12	7,91	2,98	1,45	0,24	0,33	0,10	0,17	0,06	1,49	0,60	0,23	0,66	4,93	29,43 %	3,44 %	4,66 %
13	10,23	3,85	1,88	0,31	0,42	0,13	0,22	0,08	1,93	0,77	0,30	0,86	6,39	29,35 %	3,43 %	4,65 %
14	15,71	5,92	2,88	0,47	0,65	0,19	0,34	0,12	2,96	1,19	0,46	1,31	9,84	29,25 %	3,41 %	4,63 %
15	19,70	7,42	3,61	0,59	0,81	0,24	0,42	0,15	3,71	1,49	0,57	1,65	12,36	29,22 %	3,41 %	4,63 %
16	28,31	10,67	5,19	0,85	1,16	0,35	0,61	0,21	5,34	2,14	0,82	2,37	17,79	29,18 %	3,41 %	4,62 %
17	33,42	12,59	6,13	1,00	1,38	0,41	0,72	0,25	6,30	2,53	0,97	2,80	21,01	29,16 %	3,40 %	4,62 %
18	40,57	15,28	7,44	1,22	1,67	0,50	0,87	0,30	7,65	3,07	1,18	3,39	25,52	29,15 %	3,40 %	4,61 %
19	32,12	12,10	5,89	0,96	1,04	0,31	0,54	0,19	5,20	2,09	0,80	2,31	19,17	30,71 %	2,82 %	4,18 %
20	19,83	7,47	3,63	0,59	0,64	0,19	0,33	0,12	3,21	1,29	0,49	1,43	11,81	30,77 %	2,82 %	4,19 %
21	45,31	17,07	8,31	1,36	1,47	0,44	0,76	0,26	7,34	2,95	1,13	3,26	27,07	30,68 %	2,82 %	4,18 %
22	54,33	20,47	9,96	1,63	1,76	0,53	0,91	0,32	8,80	3,54	1,36	3,91	32,47	30,67 %	2,82 %	4,17 %
23	65,13	24,54	11,94	1,95	2,11	0,63	1,10	0,38	10,55	4,24	1,62	4,68	38,94	30,66 %	2,81 %	4,17 %
24	64,95	24,47	11,91	1,95	2,10	0,63	1,09	0,38	10,52	4,23	1,62	4,67	38,83	30,66 %	2,81 %	4,17 %
25	83,12	31,31	15,24	2,49	2,69	0,81	1,40	0,48	13,46	5,41	2,07	5,98	49,71	30,65 %	2,81 %	4,17 %
26	116,07	43,72	21,27	3,48	3,76	1,13	1,95	0,68	18,80	7,55	2,90	8,35	69,43	30,64 %	2,81 %	4,17 %
27	136,68	51,49	25,05	4,10	4,42	1,33	2,30	0,80	22,14	8,90	3,41	9,83	81,77	30,64 %	2,81 %	4,17 %
28	148,69	56,01	27,25	4,46	4,81	1,44	2,50	0,87	24,08	9,68	3,71	10,69	88,96	30,63 %	2,81 %	4,17 %
29	195,34	73,58	35,81	5,86	6,32	1,90	3,29	1,14	31,64	12,71	4,87	14,05	116,90	30,63 %	2,81 %	4,17 %
30	222,84	83,94	40,85	6,69	7,21	2,16	3,75	1,30	36,09	14,50	5,56	16,03	133,36	30,63 %	2,81 %	4,17 %
31	226,93	85,49	41,60	6,81	6,29	1,89	3,27	1,13	34,90	14,02	5,37	15,50	136,76	30,42 %	2,39 %	3,93 %
32	256,60	96,66	47,04	7,70	7,11	2,13	3,70	1,28	39,46	15,86	6,08	17,52	154,65	30,41 %	2,39 %	3,93 %
33	56,97	21,46	10,44	1,71	1,58	0,47	0,82	0,28	8,76	3,52	1,35	3,89	34,29	30,46 %	2,39 %	3,94 %
34	102,36	38,56	18,76	3,07	2,84	0,85	1,48	0,51	15,74	6,33	2,42	6,99	61,66	30,43 %	2,39 %	3,93 %
35	215,84	81,31	39,56	6,48	7,46	2,24	3,88	1,34	35,04	14,08	5,40	15,56	132,74	29,80 %	2,92 %	4,07 %
36	237,92	89,62	43,61	7,14	8,22	2,47	4,27	1,48	38,63	15,52	5,95	17,15	146,33	29,80 %	2,92 %	4,07 %
37	293,41	110,53	53,78	8,80	10,14	3,04	5,27	1,82	47,64	19,14	7,34	21,15	180,47	29,80 %	2,92 %	4,06 %
38	316,33	119,16	57,98	9,49	10,93	3,28	5,68	1,97	51,36	20,64	7,91	22,80	194,58	29,80 %	2,92 %	4,06 %
39	341,68	128,71	62,63	10,25	11,80	3,54	6,14	2,12	55,47	22,29	8,54	24,63	210,17	29,80 %	2,92 %	4,06 %
40	369,50	139,19	67,73	11,09	12,76	3,83	6,64	2,30	59,99	24,10	9,24	26,63	227,29	29,80 %	2,92 %	4,06 %

13B – 100g Salmon production in RAS

Month	Week	Activity	cor. SGR	Temp	Light (h)	Number of fish	Number of fish destroyed	Weight (grams)	d°	BFCR	Biomass (kg)	Feed demand (kg)	SGR	Oxygen (FW) (mg/kg)	Specific water usage (l/kg/min)	Specific water demand (m3/min)	C (%)	P (%)	N (%)	Total C Production (ton)	C Retained in salmon (ton)	C Waste Particulate (ton)	C Waste Dissolved (ton)	Total P Production (ton)	P Retained in salmon (ton)	P Waste Particulate (ton)	P Waste Dissolved (ton)	Total N Production (ton)	N Retained in salmon (ton)	N Waste Particulate (ton)	N Waste Dissolved (ton)	Sludge amount (kg) Solid quanteties	%C pr kg DW	%P pr kg DW	%N pr kg DW
Jan	1		1	8		140 522		0,20	220		28,1043781		4,88	7,23	1,68	0,05																			
	2		1	8		136840		0,20	276		27		4,88	7,23	1,68	0,05																			
	3		1	8		133255		0,20	332		27		4,88	7,23	1,68	0,04																			
	4		1	8		129764		0,20	388		26		4,88	7,23	1,68	0,04																			
Feb	5		1	8		126364		0,20	444		25		4,88	7,23	1,68	0,04																			
	6	Hatching	1	8		123053		0,20	500		25		4,88	7,23	1,68	0,04																			
	7		1	8		119829		0,20	556		24		4,88	7,23	1,68	0,04																			
	8		1	8		116690		0,20	612		23		4,88	7,23	1,68	0,04																			
Mar	9		1	8		113632		0,20	668		23		4,88	7,23	1,68	0,04																			
	10		1	8		110655		0,20	724		22		4,88	7,23	1,68	0,04																			
	11	Start feed	1	8	24	107756		0,279	780	0,77	30	6,12	4,88	7,23	1,68	0,05	45,45	1,77	8,35	2,78	1,05	0,51	0,08	0,11	0,03	0,06	0,02	0,51	0,21	0,08	0,23	1,75	29,23 %	3,23 %	4,51 %
	12		1	10	24	107702		0,390	836	0,77	42	9,16	5,90	9,18	2,48	0,10	45,45	1,77	8,35	4,16	1,57	0,76	0,12	0,16	0,05	0,08	0,03	0,76	0,31	0,12	0,34	2,61	29,23 %	3,23 %	4,51 %
	13		1	14	24	107648		0,582	906	0,77	63	15,93	6,32	12,15	4,19	0,26	45,45	1,77	8,35	7,24	2,73	1,33	0,22	0,28	0,08	0,15	0,05	1,33	0,53	0,20	0,59	4,54	29,23 %	3,23 %	4,51 %
Apr	14		1	14	24	107595		0,894	1004	0,77	96	25,81	6,32	12,15	4,19	0,40	45,45	1,77	8,35	11,73	4,42	2,15	0,35	0,46	0,14	0,24	0,08	2,16	0,87	0,33	0,96	7,36	29,23 %	3,23 %	4,51 %
	15		1	14	24	107541		1,37	1102	0,77	148	39,62	5,33	8,90	3,07	0,45	45,45	1,77	8,35	18,01	6,78	3,30	0,54	0,70	0,21	0,36	0,13	3,31	1,33	0,51	1,47	11,29	29,23 %	3,23 %	4,51 %
	16		1	14	24	107487		1,97	1200	0,77	212	49,70	5,33	8,90	3,07	0,65	45,45	1,77	8,35	22,59	8,51	4,14	0,68	0,88	0,26	0,46	0,16	4,15	1,67	0,64	1,84	14,16	29,23 %	3,23 %	4,51 %
	17		1	14	24	107433		2,84	1298	0,77	305	71,43	4,49	8,90	3,07	0,94	45,45	1,77	8,35	32,46	12,23	5,95	0,97	1,26	0,38	0,66	0,23	5,96	2,40	0,92	2,65	20,36	29,23 %	3,23 %	4,51 %
May	18		1	14	24	107379		3,86	1396	0,77	414	84,31	4,06	8,90	3,07	1,27	45,45	1,77	8,35	38,32	14,44	7,02	1,15	1,49	0,45	0,78	0,27	7,04	2,83	1,08	3,13	24,03	29,23 %	3,23 %	4,51 %
	19	Grading	0,5	14	24	104786	-2540	5,10	1494	0,77	534	92,37	3,58	6,51	2,24	1,20	46,38	1,56	6,98	42,84	16,14	7,85	1,29	1,44	0,43	0,75	0,26	6,45	2,59	0,99	2,86	26,33	29,83 %	2,85 %	3,77 %
	20		1	14	24	104733		5,77	1592	0,77	605	54,23	3,58	6,51	2,24	1,35	46,38	1,56	6,98	25,15	9,47	4,61	0,75	0,85	0,25	0,44	0,15	3,79	1,52	0,58	1,68	15,45	29,83 %	2,85 %	3,77 %
	21		1	14	24	104681		7,39	1690	0,77	773	129,84	3,58	6,51	2,24	1,73	46,38	1,56	6,98	60,22	22,68	11,04	1,81	2,03	0,61	1,05	0,36	9,06	3,64	1,40	4,02	37,00	29,83 %	2,85 %	3,77 %
	22		1	14	24	104629		9,45	1788	0,77	989	166,04	3,58	6,51	2,24	2,22	46,38	1,56	6,98	77,01	29,01	14,12	2,31	2,59	0,78	1,35	0,47	11,59	4,66	1,78	5,15	47,32	29,83 %	2,85 %	3,77 %
Jun	23		1	14	24	104576		12,09	1886	0,77	1265	212,33	3,03	5,69	1,96	2,48	46,38	1,56	6,98	98,48	37,10	18,05	2,95	3,31	0,99	1,72	0,60	14,82	5,95	2,28	6,58	60,51	29,83 %	2,85 %	3,77 %
	24		1	14	24	104524		14,90	1984	0,77	1558	225,43	3,03	5,69	1,96	3,05	46,38	1,56	6,98	104,55	39,39	19,16	3,14	3,52	1,06	1,83	0,63	15,73	6,32	2,42	6,99	64,25	29,83 %	2,85 %	3,77 %
	25		1	14	24	104472		18,36	2082	0,77	1918	277,61	2,75	5,69	1,96	3,76	46,38	1,56	6,98	128,75	48,50	23,60	3,86	4,33	1,30	2,25	0,78	19,38	7,79	2,98	8,60	79,12	29,83 %	2,85 %	3,77 %
	26		1	14	24	104420		22,19	2180	0,77	2317	307,38	2,56	5,69	1,96	4,54	46,38	1,56	6,98	142,56	53,70	26,13	4,28	4,80	1,44	2,49	0,86	21,45	8,62	3,30	9,53	87,60	29,83 %	2,85 %	3,77 %
Jul	27		1	14	24	104367		26,49	2278	0,77	2765	344,82	2,43	5,69	1,96	5,42	46,38	1,56	6,98	159,93	60,24	29,31	4,80	5,38	1,61	2,80	0,97	24,07	9,67	3,71	10,69	98,27	29,83 %	2,85 %	3,77 %
	28		0,3	14	24	104315		31,35	2376	0,77	3270	388,83	2,33	5,69	1,96	6,41	46,38	1,56	6,98	180,34	67,93	33,06	5,41	6,07	1,82	3,15	1,09	27,14	10,90	4,18	12,05	110,82	29,83 %	2,85 %	3,77 %
	29	Vaccination	0,5	14	24	102993	-1270	32,92	2474	0,77	3390	92,39	2,33	5,69	1,96	6,64	46,38	1,56	6,98	42,85	16,14	7,85	1,29	1,44	0,43	0,75	0,26	6,45	2,59	0,99	2,86	26,33	29,83 %	2,85 %	3,77 %
	30		0,9	14	24	101672	-1270	35,70	2572	0,77	3629	184,29	2,25	5,69	1,96	7,11	46,38	1,56	6,98	85,47	32,20	15,67	2,56	2,88	0,86	1,50	0,52	12,86	5,17	1,98	5,71	52,52	29,83 %	2,85 %	3,77 %
Aug	31		0,9	14	24	100351	-1270	41,08	2670	0,77	4122	379,36	2,18	5,69	1,96	8,08	46,97	1,5	6,98	178,18	67,12	32,66	5,35	5,69	1,71	2,96	1,02	26,48	10,64	4,08	11,76	108,12	30,21 %	2,74 %	3,77 %
	32		1	14	24	100301		47,07	2768	0,77	4721	461,36	2,13	5,69	1,96	9,25	46,97	1,5	6,98	216,70	81,63	39,72	6,50	6,92	2,08	3,60	1,25	32,20	12,94	4,96	14,30	131,49	30,21 %	2,74 %	3,77 %
	33		1	14	24	100250		54,54	2866	0,82	5468	612,11	2,08	4,16	1,43	7,82	46,97	1,5	6,98	287,51	108,30	52,70	8,63	9,18	2,75	4,77	1,65	42,73	17,17	6,58	18,97	174,45	30,21 %	2,74 %	3,77 %
	34		1	14	24	100200		62,98	2964	0,82	6311	691,46	2,00	4,16	1,43	9,02	45,46	1,6	6,72	314,34	118,41	57,62	9,43	11,06	3,32	5,75	1,99	46,47	18,67	7,16	20,63	197,07	29,24 %	2,92 %	3,63 %
	35		1	14	24	100150		72,33	3062	0,82	7244	765,08	1,93	4,16	1,43	10,36	45,46	1,6	6,72	347,80	131,02	63,75	10,43	12,24	3,67	6,37	2,20	51,41	20,66	7,92	22,83	218,05	29,24 %	2,92 %	3,63 %
Sep	36		1	12	24	100100		82,70	3160	0,82	8278	848,17	1,62	3,63	1,10	9,11	45,46	1,6	6,72	385,58	145,25	70,68	11,57	13,57	4,07	7,06	2,44	57,00	22,90	8,78	25,31	241,73	29,24 %	2,92 %	3,63 %
	37		1	10	24	100050		92,57	3244	0,82	9262	806,65	1,34	3,14	0,85	7,87	45,46	1,6	6,72	366,70	138,14	67,22	11,00	12,91	3,87	6,71	2,32	54,21	21,78	8,35	24,07	229,89	29,24 %	2,92 %	3,63 %
	38		1	10	24	100000		101,59	3314	0,82	10159	735,37	1,31	2,75	0,74	7,52	45,46	1,6	6,72	334,30	125,93	61,28	10,03	11,77	3,53	6,12	2,12	49,42	19,86	7,61	21,94	209,58	29,24 %	2,92 %	3,63 %

13C - 300g Salmon production in FTS

Month	Week	Activity	cor. SGR	Temp	Light (h)	Number of fish (5%)	Number of fish destroyed	Weight (grams)	d°	BFCR	Biomass (kg)	Feed demand (kg)	SGR	Oxygen (FW) (mg/kg)	Specific water usage (l/kg/min)	Specific water demand (m3/min)	C (%)	P (%)	N (%)	Total C Production (ton)	C Retained in salmon (ton)	C Waste Particulate (ton)	C Waste Dissolved (ton)	Total P Production (ton)	P Retained in salmon (ton)	P Waste Particulate (ton)	P Waste Dissolved (ton)	Total N Production (ton)	N Retained in salmon (ton)	N Waste Particulate (ton)	N Waste Dissolved (ton)	Sludge amount (kg) Solid quanteties	%C pr kg DW	%P pr kg DW	%N pr kg DW
Jan	1		1	8,0		142 396		0,2	220		28		4,88	7,23	1,68	0,05																			
	2		1	8,0		138665		0,2	276		28		4,88	7,23	1,68	0,05																			
	3		1	8,0		135032		0,2	332		27		4,88	7,23	1,68	0,05																			
	4		1	8,0		131494		0,2	388		26		4,88	7,23	1,68	0,04																			
Feb	5		1	8,0		128049		0,2	444		26		4,88	7,23	1,68	0,04																			
	6		1	8,0		124694		0,2	500		25		4,88	7,23	1,68	0,04																			
	7		1	8,0		121427		0,2	556		24		4,88	7,23	1,68	0,04																			
	8		1	8,0		118246		0,2	612		24		4,88	7,23	1,68	0,04																			
Mar	9		1	8,0		115148		0,2	668		23		4,88	7,23	1,68	0,04																			
	10		1	9,7		112131		0,2	724		22		5,90	9,18	2,48	0,06																			
	11	Start feed	1	13,8	24	109193		0,299	792	0,77	33	7,85	7,93	12,15	4,19	0,14	45,21	1,86	8,52	3,55	1,34	0,65	0,11	0,15	0,04	0,08	0,03	0,67	0,27	0,10	0,30	2,18	29,88 %	3,49 %	4,73 %
	12		1	14,2	24	109139		0,510	889	0,77	56	17,71	6,32	12,15	4,19	0,23	45,21	1,86	8,52	8,01	3,02	1,47	0,24	0,33	0,10	0,17	0,06	1,51	0,61	0,23	0,67	4,99	29,43 %	3,44 %	4,66 %
	13		1	14,2	24	109084		0,783	988	0,77	85	22,91	6,32	12,15	4,19	0,36	45,21	1,86	8,52	10,36	3,90	1,90	0,31	0,43	0,13	0,22	0,08	1,95	0,78	0,30	0,87	6,47	29,35 %	3,43 %	4,65 %
Apr	14		1	14,2	24	109029		1,202	1087	0,77	131	35,17	5,33	8,90	3,07	0,40	45,21	1,86	8,52	15,90	5,99	2,91	0,48	0,65	0,20	0,34	0,12	3,00	1,20	0,46	1,33	9,96	29,25 %	3,41 %	4,63 %
	15		1	14,2	24	108975		1,73	1187	0,77	188	44,11	5,33	8,90	3,07	0,58	45,21	1,86	8,52	19,94	7,51	3,66	0,60	0,82	0,25	0,43	0,15	3,76	1,51	0,58	1,67	12,51	29,22 %	3,41 %	4,63 %
	16		1	14,2	24	108920		2,48	1286	0,77	271	63,40	4,49	8,90	3,07	0,83	45,21	1,86	8,52	28,66	10,80	5,25	0,86	1,18	0,35	0,61	0,21	5,40	2,17	0,83	2,40	18,01	29,17 %	3,41 %	4,62 %
	17		1	14,2	24	108866		3,38	1386	0,77	368	74,83	4,06	8,90	3,07	1,13	45,21	1,86	8,52	33,83	12,74	6,20	1,01	1,39	0,42	0,72	0,25	6,38	2,56	0,98	2,83	21,27	29,16 %	3,40 %	4,62 %
May	18		1	10,2	24	108812		4,46	1485	0,77	486	90,84	2,78	6,72	1,82	0,88	45,21	1,86	8,52	41,07	15,47	7,53	1,23	1,69	0,51	0,88	0,30	7,74	3,11	1,19	3,44	25,83	29,14 %	3,40 %	4,61 %
	19	Grading	0,5	10,2	24	106217	-2540	5,41	1556	0,77	575	68,43	2,63	4,91	1,33	0,76	47,6	1,54	7,71	32,57	12,27	5,97	0,98	1,05	0,32	0,55	0,19	5,28	2,12	0,81	2,34	19,44	30,71 %	2,82 %	4,18 %
	20		1	10,2	24	106164		5,93	1628	0,77	629	42,18	2,63	4,91	1,33	0,84	47,6	1,54	7,71	20,08	7,56	3,68	0,60	0,65	0,19	0,34	0,12	3,25	1,31	0,50	1,44	11,96	30,77 %	2,82 %	4,19 %
	21		1	10,2	24	106111		7,11	1699	0,77	755	96,40	2,63	4,91	1,33	1,00	47,6	1,54	7,71	45,89	17,29	8,41	1,38	1,48	0,45	0,77	0,27	7,43	2,99	1,14	3,30	27,41	30,68 %	2,82 %	4,18 %
	22		1	10,2	24	106058		8,53	1771	0,77	905	115,57	2,63	4,91	1,33	1,20	47,6	1,54	7,71	55,01	20,72	10,08	1,65	1,78	0,53	0,93	0,32	8,91	3,58	1,37	3,96	32,88	30,67 %	2,82 %	4,17 %
Jun	23		1	10,4	24	106005		10,23	1842	0,77	1085	138,56	2,22	4,29	1,16	1,26	47,6	1,54	7,71	65,95	24,84	12,09	1,98	2,13	0,64	1,11	0,38	10,68	4,29	1,65	4,74	39,43	30,66 %	2,81 %	4,17 %
	24		1	11,3	24	105952		11,93	1915	0,77	1264	138,17	2,42	4,29	1,16	1,47	47,6	1,54	7,71	65,77	24,78	12,06	1,97	2,13	0,64	1,11	0,38	10,65	4,28	1,64	4,73	39,32	30,66 %	2,81 %	4,17 %
	25		1	12,9	24	105899		14,11	1994	0,77	1494	176,82	2,82	4,95	1,50	2,24	47,6	1,54	7,71	84,17	31,70	15,43	2,52	2,72	0,82	1,42	0,49	13,63	5,48	2,10	6,05	50,33	30,65 %	2,81 %	4,17 %
	26		1	14,4	24	105846		17,14	2084	0,77	1814	246,91	2,75	5,69	1,96	3,56	47,6	1,54	7,71	117,53	44,27	21,54	3,53	3,80	1,14	1,98	0,68	19,04	7,65	2,93	8,45	70,31	30,64 %	2,81 %	4,17 %
Jul	27		1	15,9	24	105793		20,72	2185	0,77	2192	290,76	2,49	5,69	2,59	5,68	47,6	1,54	7,71	138,40	52,14	25,37	4,15	4,48	1,34	2,33	0,81	22,42	9,01	3,45	9,95	82,81	30,64 %	2,81 %	4,17 %
	28		1	15,1	24	105740		24,62	2296	0,77	2603	316,30	2,74	5,69	1,96	5,10	47,6	1,54	7,71	150,56	56,72	27,60	4,52	4,87	1,46	2,53	0,88	24,39	9,80	3,76	10,83	90,09	30,63 %	2,81 %	4,17 %
	29		1	14,5	24	105687		29,73	2401	0,77	3143	415,55	2,60	5,69	1,96	6,16	47,6	1,54	7,71	197,80	74,51	36,26	5,93	6,40	1,92	3,33	1,15	32,04	12,87	4,93	14,23	118,37	30,63 %	2,81 %	4,17 %
	30		1	14,1	24	105634		35,58	2503	0,77	3758	474,05	2,25	5,69	1,96	7,37	47,6	1,54	7,71	225,65	85,00	41,36	6,77	7,30	2,19	3,80	1,31	36,55	14,69	5,63	16,23	135,04	30,63 %	2,81 %	4,17 %
Aug	31		1	13,7	24	105582		41,57	2602	0,77	4390	486,13	2,18	5,69	1,96	8,60	47,27	1,31	7,27	229,80	86,56	42,12	6,89	6,37	1,91	3,31	1,15	35,34	14,20	5,44	15,69	138,49	30,42 %	2,39 %	3,93 %
	32		0,3	12,8	24	105529		48,36	2697	0,77	5103	549,69	1,98	4,95	1,50	7,66	47,27	1,31	7,27	259,84	97,88	47,63	7,80	7,20	2,16	3,74	1,30	39,96	16,06	6,15	17,74	156,60	30,41 %	2,39 %	3,93 %
	33	Vaccination	0,5	11,9	24	104206	-1270	50,41	2787	0,82	5253	122,70	1,80	3,63	1,10	5,78	47,27	1,31	7,27	58,00	21,85	10,63	1,74	1,61	0,48	0,84	0,29	8,92	3,58	1,37	3,96	34,91	30,45 %	2,39 %	3,94 %
	34		0,9	11,9	24	102884	-1270	53,67	2870	0,82	5521	220,03	1,80	3,63	1,10	6,07	47,27	1,31	7,27	104,01	39,18	19,06	3,12	2,88	0,86	1,50	0,52	16,00	6,43	2,46	7,10	62,65	30,43 %	2,39 %	3,93 %
	35		0,9	10,7	24	101562	-1270	60,04	2954	0,82	6098	472,80	1,59	3,14	0,85	5,18	47,27	1,31	7,27	223,49	84,19	40,97	6,70	6,19	1,86	3,22	1,11	34,37	13,81	5,29	15,26	134,69	30,42 %	2,39 %	3,93 %
Sep	36		1	10,7	24	101512		66,32	3029	0,82	6733	520,36	1,59	3,14	0,85	5,72	47,27	1,31	7,27	245,98	92,66	45,09	7,38	6,82	2,05	3,54	1,23	37,83	15,20	5,83	16,80	148,24	30,41 %	2,39 %	3,93 %
	37		1	10,7	24	101461		74,07	3103	0,82	7515	641,74	1,54	3,14	0,85	6,39	47,27	1,31	7,27	303,35	114,27	55,60	9,10	8,41	2,52	4,37	1,51	46,65	18,75	7,18	20,71	182,84	30,41 %	2,39 %	3,93 %
	38		1	10,7	24	101410		82,43	3178	0,82	8359	691,87	1,50	3,14	0,85	7,11	47,27	1,31	7,27	327,05	123,20	59,95	9,81	9,06	2,72	4,71	1,63	50,30	20,21	7,75	22,33	197,12	30,41 %	2,39 %	3,93 %
	39		1	10,7	24	101359		91,46	3253	0,82	9270	747,31	1,46	3,14	0,85	7,88	47,27	1,31	7,27	353,25	133,07	64,75	10,60	9,79	2,94	5,09	1,76	54,33	21,83	8,37	24,12	212,92	30,41 %	2,39 %	3,93 %
Oct	40		1	10,7	24	101309		101,23	3328	0,82	10256	808,16	1,43	2,75	0,74	7,59	47,27	1,31	7,27	382,01	143,91	70,02	11,46	10,59	3,18	5,51	1,91	58,75	23,61	9,05	26,09	230,26	30,41 %	2,39 %	3,93 %
	41		1	9,0	24	101258		111,82	3403	0,82	11322	874,65	1,19	2,16	0,50	5,66	47,27	1,31	7,27	413,45	155,75	75,78	12,40	11,46	3,44	5,96	2,06	63,59	25,55	9,79	28,23	249,22	30,41 %	2,39 %	3,93 %

	42		1	8,4	24	101208		121,44	3466	0,82	12290	793,80	1,06	2,16	0,50	6,15	47,27	1,31	7,27	375,23	141,35	68,78	11,26	10,40	3,12	5,41	1,87	57,71	23,19	8,89	25,62	226,17	30,41 %	2,39 %	3,93 %
	43		1	8,3	24	101157		130,78	3525	0,82	13229	769,43	1,02	2,16	0,50	6,61	47,27	1,31	7,27	363,71	137,01	66,67	10,91	10,08	3,02	5,24	1,81	55,94	22,48	8,61	24,84	219,23	30,41 %	2,39 %	3,93 %
	44		1	8,1	24	101106		140,39	3583	0,82	14194	791,86	1,02	2,16	0,50	7,10	47,27	1,31	7,27	374,31	141,00	68,61	11,23	10,37	3,11	5,39	1,87	57,57	23,13	8,87	25,56	225,62	30,41 %	2,39 %	3,93 %
Nov	45		1	7,3	24	101056		150,72	3640	0,82	15231	849,66	0,87	1,67	0,34	5,18	47,27	1,31	7,27	401,64	151,30	73,62	12,05	11,13	3,34	5,79	2,00	61,77	24,82	9,51	27,43	242,09	30,41 %	2,39 %	3,93 %
	46		1	6,0	24	101005		160,16	3691	0,82	16177	775,73	0,76	1,67	0,34	5,50	47,27	1,31	7,27	366,69	138,13	67,21	11,00	10,16	3,05	5,28	1,83	56,40	22,66	8,68	25,04	221,02	30,41 %	2,39 %	3,93 %
	47		1	5,3	24	100955		168,85	3733	0,82	17046	712,89	0,64	1,26	0,23	3,92	47,27	1,31	7,27	336,98	126,94	61,77	10,11	9,34	2,80	4,86	1,68	51,83	20,82	7,98	23,01	203,11	30,41 %	2,39 %	3,93 %
	48		1	4,8	24	100904		176,61	3770	0,82	17820	634,99	0,63	1,26	0,23	4,10	47,27	1,31	7,27	300,16	113,07	55,02	9,00	8,32	2,50	4,33	1,50	46,16	18,55	7,11	20,50	180,91	30,41 %	2,39 %	3,93 %
Des	49		1	4,4	24	100854		184,50	3803	0,82	18608	645,55	0,52	1,26	0,23	4,28	47,27	1,31	7,27	305,15	114,95	55,93	9,15	8,46	2,54	4,40	1,52	46,93	18,86	7,23	20,84	183,92	30,41 %	2,39 %	3,93 %
	50		1	3,8	24	100803		191,26	3834	0,82	19280	551,20	0,52	1,26	0,23	4,43	47,27	1,31	7,27	260,55	98,15	47,76	7,82	7,22	2,17	3,75	1,30	40,07	16,10	6,17	17,79	157,03	30,41 %	2,39 %	3,93 %
	51		1	3,5	24	100753		198,27	3861	0,82	19976	571,11	0,52	1,26	0,23	4,59	47,27	1,31	7,27	269,96	101,69	49,48	8,10	7,48	2,24	3,89	1,35	41,52	16,68	6,39	18,43	162,71	30,41 %	2,39 %	3,93 %
	52		1	3,1	24	100703		205,54	3885	0,87	20698	627,82	0,39	0,93	0,15	3,10	47,27	1,31	7,27	296,77	111,79	54,40	8,90	8,22	2,47	4,28	1,48	45,64	18,34	7,03	20,27	178,87	30,41 %	2,39 %	3,93 %
Jan	1		1	3,2	24	100652		211,28	3907	0,87	21266	494,41	0,39	0,93	0,15	3,19	47,27	1,31	7,27	233,71	88,04	42,84	7,01	6,48	1,94	3,37	1,17	35,94	14,44	5,54	15,96	140,85	30,42 %	2,39 %	3,93 %
	2		1	3,0	24	100602		217,19	3929	0,87	21850	507,99	0,39	0,93	0,15	3,28	47,27	1,31	7,27	240,13	90,46	44,02	7,20	6,65	2,00	3,46	1,20	36,93	14,84	5,69	16,40	144,72	30,41 %	2,39 %	3,93 %
	3		1	2,6	24	100552		223,27	3950	0,87	22450	521,94	0,39	0,93	0,15	3,37	47,27	1,31	7,27	246,72	92,94	45,22	7,40	6,84	2,05	3,56	1,23	37,94	15,25	5,84	16,85	148,69	30,41 %	2,39 %	3,93 %
	4		1	2,4	24	100501		229,51	3969	0,87	23067	536,27	0,28	0,93	0,15	3,46	47,27	1,31	7,27	253,49	95,49	46,47	7,60	7,03	2,11	3,65	1,26	38,99	15,66	6,00	17,31	152,78	30,41 %	2,39 %	3,93 %
Feb	5		1	2,5	12	100451		234,05	3985	0,87	23511	386,33	0,39	0,93	0,15	3,53	47,27	1,31	7,27	182,62	68,79	33,47	5,48	5,06	1,52	2,63	0,91	28,09	11,29	4,33	12,47	110,05	30,42 %	2,39 %	3,93 %
	6		1	2,5	12	100401		240,47	4003	0,87	24143	550,58	0,39	0,93	0,15	3,62	47,27	1,31	7,27	260,26	98,04	47,71	7,81	7,21	2,16	3,75	1,30	40,03	16,08	6,16	17,77	156,86	30,41 %	2,39 %	3,93 %
	7		1	2,5	12	100351		247,07	4020	0,87	24793	565,40	0,39	0,93	0,15	3,72	47,27	1,31	7,27	267,26	100,68	48,99	8,02	7,41	2,22	3,85	1,33	41,10	16,52	6,33	18,25	161,08	30,41 %	2,39 %	3,93 %
	8		1	2,6	12	100301		253,84	4038	0,87	25461	580,62	0,38	0,93	0,15	3,82	47,27	1,31	7,27	274,46	103,39	50,31	8,23	7,61	2,28	3,96	1,37	42,21	16,96	6,50	18,74	165,42	30,41 %	2,39 %	3,93 %
Mar	9		1	2,8	12	100250		260,70	4056	0,87	26135	586,48	0,38	0,93	0,15	3,92	46,32	1,6	7,52	271,66	102,33	49,80	8,15	9,38	2,82	4,88	1,69	44,10	17,72	6,79	19,58	167,09	29,80 %	2,92 %	4,06 %
	10		1	2,8	12	100200		267,73	4076	0,87	26827	602,01	0,38	0,93	0,15	4,02	46,32	1,6	7,52	278,85	105,04	51,11	8,37	9,63	2,89	5,01	1,73	45,27	18,19	6,97	20,10	171,51	29,80 %	2,92 %	4,06 %
	11		1	2,7	24	100150		274,96	4095	0,87	27537	617,95	0,38	0,93	0,15	4,13	46,32	1,6	7,52	286,24	107,82	52,47	8,59	9,89	2,97	5,14	1,78	46,47	18,67	7,16	20,63	176,06	29,80 %	2,92 %	4,06 %
	12		1	3,0	24	100100		282,38	4114	0,87	28266	634,31	0,38	0,93	0,15	4,24	46,32	1,6	7,52	293,81	110,68	53,86	8,81	10,15	3,04	5,28	1,83	47,70	19,17	7,35	21,18	180,72	29,80 %	2,92 %	4,06 %
	13		1	3,5	24	100050		290,00	4135	0,87	29015	651,11	0,49	1,26	0,23	6,67	46,32	1,6	7,52	301,59	113,61	55,28	9,05	10,42	3,13	5,42	1,88	48,96	19,67	7,54	21,74	185,51	29,80 %	2,92 %	4,06 %
Apr	14		1	3,6	24	100000		300,04	4160	0,87	30004	860,54	0,48	1,26	0,23	6,90	46,32	1,6	7,52	398,60	150,15	73,06	11,96	13,77	4,13	7,16	2,48	64,71	26,00	9,97	28,73	245,19	29,80 %	2,92 %	4,06 %

13D – 300g Salmon production in RAS

Month	Week	Activity	cor. SGR	Temp	Light (h)	Number of fish	Number of fish destroyed	Weight (grams)	d°	BFCR	Biomass (kg)	Feed demand (kg)	SGR	Oxygen (FW) (mg/kg)	Specific water usage (l/kg/min)	Specific water demand (m3/min)	C (%)	P (%)	N (%)	Total C Production (ton)	C Retained in salmon (ton)	C Waste Particulate (ton)	C Waste Dissolved (ton)	Total P Production (ton)	P Retained in salmon (ton)	P Waste Particulate (ton)	P Waste Dissolved (ton)	Total N Production (ton)	N Retained in salmon (ton)	N Waste Particulate (ton)	N Waste Dissolved (ton)	Sludge amount (kg) Solid quanteties	%C pr kg DW	%P pr kg DW	%N pr kg DW
Jan	1		1	8		141 128		0,2	220		28		4,88	7,23	1,68	0,05																			
	2		1	8		137431		0,2	276		27		4,88	7,23	1,68	0,05																			
	3		1	8		133830		0,2	332		27		4,88	7,23	1,68	0,04																			
	4		1	8		130324		0,2	388		26		4,88	7,23	1,68	0,04																			
Feb	5		1	8		126909		0,2	444		25		4,88	7,23	1,68	0,04																			
	6	Hatching	1	8		123584		0,2	500		25		4,88	7,23	1,68	0,04																			
	7		1	8		120346		0,2	556		24		4,88	7,23	1,68	0,04																			
	8		1	8		117193		0,2	612		23		4,88	7,23	1,68	0,04																			
Mar	9		1	8		114123		0,2	668		23		4,88	7,23	1,68	0,04																			
	10		1	8		111133		0,2	724		22		4,88	7,23	1,68	0,04																			
	11	Start feed	1	8	24	108221		0,279	780	0,77	30	6,15	4,88	7,23	1,68	0,05	45,45	1,77	8,35	2,80	1,05	0,51	0,08	0,11	0,03	0,06	0,02	0,51	0,21	0,08	0,23	1,75	29,23 %	3,23 %	4,51 %
	12		1	10	24	108167		0,390	836	0,77	42	9,20	5,90	9,18	2,48	0,10	45,45	1,77	8,35	4,18	1,57	0,77	0,13	0,16	0,05	0,08	0,03	0,77	0,31	0,12	0,34	2,62	29,23 %	3,23 %	4,51 %
	13		1	14	24	108113		0,582	906	0,77	63	15,99	6,32	12,15	4,19	0,26	45,45	1,77	8,35	7,27	2,74	1,33	0,22	0,28	0,08	0,15	0,05	1,34	0,54	0,21	0,59	4,56	29,23 %	3,23 %	4,51 %
Apr	14		1	14	24	108059		0,894	1004	0,77	97	25,92	6,32	12,15	4,19	0,40	45,45	1,77	8,35	11,78	4,44	2,16	0,35	0,46	0,14	0,24	0,08	2,16	0,87	0,33	0,96	7,39	29,23 %	3,23 %	4,51 %
	15		1	14	24	108005		1,37	1102	0,77	148	39,79	5,33	8,90	3,07	0,46	45,45	1,77	8,35	18,09	6,81	3,32	0,54	0,70	0,21	0,37	0,13	3,32	1,34	0,51	1,48	11,34	29,23 %	3,23 %	4,51 %
	16		1	14	24	107951		1,97	1200	0,77	213	49,91	5,33	8,90	3,07	0,65	45,45	1,77	8,35	22,69	8,55	4,16	0,68	0,88	0,27	0,46	0,16	4,17	1,67	0,64	1,85	14,23	29,23 %	3,23 %	4,51 %
	17		1	14	24	107897		2,84	1298	0,77	306	71,73	4,49	8,90	3,07	0,94	45,45	1,77	8,35	32,60	12,28	5,98	0,98	1,27	0,38	0,66	0,23	5,99	2,41	0,92	2,66	20,44	29,23 %	3,23 %	4,51 %
May	18		1	14	24	107843		3,86	1396	0,77	416	84,68	4,06	8,90	3,07	1,28	45,45	1,77	8,35	38,49	14,50	7,05	1,15	1,50	0,45	0,78	0,27	7,07	2,84	1,09	3,14	24,13	29,23 %	3,23 %	4,51 %
	19	Grading	0,5	14	24	105249	-2540	5,10	1494	0,77	537	92,82	3,58	6,51	2,24	1,20	46,38	1,56	6,98	43,05	16,22	7,89	1,29	1,45	0,43	0,75	0,26	6,48	2,60	1,00	2,88	26,45	29,83 %	2,85 %	3,77 %
	20		1	14	24	105196		5,77	1592	0,77	608	54,47	3,58	6,51	2,24	1,36	46,38	1,56	6,98	25,26	9,52	4,63	0,76	0,85	0,25	0,44	0,15	3,80	1,53	0,59	1,69	15,52	29,83 %	2,85 %	3,77 %
	21		1	14	24	105144		7,39	1690	0,77	777	130,41	3,58	6,51	2,24	1,74	46,38	1,56	6,98	60,49	22,78	11,09	1,81	2,03	0,61	1,06	0,37	9,10	3,66	1,40	4,04	37,17	29,83 %	2,85 %	3,77 %
	22		1	14	24	105091		9,45	1788	0,77	993	166,77	3,58	6,51	2,24	2,23	46,38	1,56	6,98	77,35	29,14	14,18	2,32	2,60	0,78	1,35	0,47	11,64	4,68	1,79	5,17	47,53	29,83 %	2,85 %	3,77 %
Jun	23		1	14	24	105039		12,09	1886	0,77	1270	213,26	3,03	5,69	1,96	2,49	46,38	1,56	6,98	98,91	37,26	18,13	2,97	3,33	1,00	1,73	0,60	14,89	5,98	2,29	6,61	60,78	29,83 %	2,85 %	3,77 %
	24		1	14	24	104986		14,90	1984	0,77	1564	226,42	3,03	5,69	1,96	3,07	46,38	1,56	6,98	105,02	39,56	19,25	3,15	3,53	1,06	1,84	0,64	15,80	6,35	2,43	7,02	64,53	29,83 %	2,85 %	3,77 %
	25		1	14	24	104934		18,36	2082	0,77	1927	278,83	2,75	5,69	1,96	3,78	46,38	1,56	6,98	129,32	48,72	23,70	3,88	4,35	1,30	2,26	0,78	19,46	7,82	3,00	8,64	79,47	29,83 %	2,85 %	3,77 %
	26		1	14	24	104881		22,19	2180	0,77	2328	308,73	2,56	5,69	1,96	4,56	46,38	1,56	6,98	143,19	53,94	26,25	4,30	4,82	1,44	2,50	0,87	21,55	8,66	3,32	9,57	87,99	29,83 %	2,85 %	3,77 %
Jul	27		1	14	24	104829		26,49	2278	0,77	2777	346,34	2,43	5,69	1,96	5,44	46,38	1,56	6,98	160,63	60,51	29,44	4,82	5,40	1,62	2,81	0,97	24,17	9,71	3,72	10,73	98,71	29,83 %	2,85 %	3,77 %
	28		1	14	24	104776		31,35	2376	0,77	3285	390,55	2,33	5,69	1,96	6,44	46,38	1,56	6,98	181,14	68,23	33,20	5,43	6,09	1,83	3,17	1,10	27,26	10,95	4,20	12,10	111,31	29,83 %	2,85 %	3,77 %
	29		1	14	24	104724		36,84	2474	0,77	3858	441,31	2,25	5,69	1,96	7,56	46,38	1,56	6,98	204,68	77,10	37,52	6,14	6,88	2,07	3,58	1,24	30,80	12,38	4,74	13,68	125,77	29,83 %	2,85 %	3,77 %
	30		1	14	24	104671		43,05	2572	0,77	4506	499,01	2,18	5,69	1,96	8,83	46,97	1,5	6,98	234,38	88,29	42,96	7,03	7,49	2,25	3,89	1,35	34,83	14,00	5,36	15,46	142,22	30,21 %	2,74 %	3,77 %
Aug	31		1	14	24	104619		50,07	2670	0,82	5239	600,88	2,08	4,16	1,43	7,49	46,97	1,5	6,98	282,23	106,32	51,73	8,47	9,01	2,70	4,69	1,62	41,94	16,85	6,46	18,62	171,25	30,21 %	2,74 %	3,77 %
	32		0,3	14	24	104567		57,82	2768	0,82	6046	662,47	2,08	4,16	1,43	8,65	46,97	1,5	6,98	311,16	117,21	57,04	9,33	9,94	2,98	5,17	1,79	46,24	18,58	7,12	20,53	188,80	30,21 %	2,74 %	3,77 %
	33	Vaccination	0,5	14	24	103245	-1270	60,39	2866	0,82	6235	154,90	2,00	4,16	1,43	8,92	46,97	1,5	6,98	72,75	27,41	13,34	2,18	2,32	0,70	1,21	0,42	10,81	4,34	1,67	4,80	44,15	30,21 %	2,74 %	3,77 %
	34		0,9	14	24	101923	-1270	64,74	2964	0,82	6599	298,01	2,00	4,16	1,43	9,44	46,97	1,5	6,98	139,98	52,73	25,66	4,20	4,47	1,34	2,32	0,80	20,80	8,36	3,20	9,24	84,93	30,21 %	2,74 %	3,77 %
	35		0,9	14	24	100602	-1270	73,34	3062	0,82	7378	638,98	1,93	4,16	1,43	10,55	46,97	1,5	6,98	300,13	113,06	55,01	9,00	9,58	2,88	4,98	1,73	44,60	17,92	6,87	19,80	182,11	30,21 %	2,74 %	3,77 %
Sep	36		1	14	24	100552		82,75	3160	0,82	8320	772,63	1,88	4,16	1,43	11,90	46,97	1,5	6,98	362,90	136,71	66,52	10,89	11,59	3,48	6,03	2,09	53,93	21,67	8,31	23,94	220,20	30,21 %	2,74 %	3,77 %
	37		1	14	24	100501		94,27	3258	0,82	9474	946,00	1,84	4,16	1,43	13,55	46,97	1,5	6,98	444,34	167,38	81,45	13,33	14,19	4,26	7,38	2,55	66,03	26,53	10,17	29,32	269,61	30,21 %	2,74 %	3,77 %
	38		1	14	24	100451		107,07	3356	0,82	10755	1050,36	1,80	3,65	1,26	13,55	46,97	1,5	6,98	493,36	185,85	90,43	14,80	15,76	4,73	8,19	2,84	73,32	29,46	11,29	32,55	299,35	30,21 %	2,74 %	3,77 %
	39		1	14	24	100401		121,29	3454	0,82	12177	1166,49	1,80	3,65	1,26	15,34	46,97	1,5	6,98	547,90	206,39	100,43	16,44	17,50	5,25	9,10	3,15	81,42	32,71	12,54	36,15	332,45	30,21 %	2,74 %	3,77 %
Oct	40		1	14	24	100351		137,40	3552	0,82	13788	1320,78	1,72	3,65	1,26	17,37	46,97	1,5	6,98	620,37	233,69	113,71	18,61	19,81	5,94	10,30	3,57	92,19	37,04	14,20	40,93	376,42	30,21 %	2,74 %	3,77 %
	41		1	14	24	100301		154,86	3650	0,82	15533	1430,53	1,67	3,65	1,26	19,57	46,97	1,5	6,98	671,92	253,11	123,16	20,16	21,46	6,44	11,16	3,86	99,85	40,12	15,38	44,33	407,70	30,21 %	2,74 %	3,77 %

	42		1	14	24	100250		173,89	3748	0,82	17433	1557,91	1,67	3,65	1,26	21,96	45,46	1,6	6,72	708,23	266,79	129,82	21,25	24,93	7,48	12,96	4,49	104,69	42,07	16,12	46,48	444,00	29,24 %	2,92 %	3,63 %
	43		1	14	24	100200		195,26	3846	0,82	19565	1748,47	1,63	3,65	1,26	24,65	45,46	1,6	6,72	794,85	299,42	145,70	23,85	27,98	8,39	14,55	5,04	117,50	47,21	18,09	52,17	498,31	29,24 %	2,92 %	3,63 %
Nov	44		1	14	24	100150		218,62	3944	0,87	21895	2027,29	1,60	3,65	1,26	27,59	45,46	1,6	6,72	921,60	347,17	168,93	27,65	32,44	9,73	16,87	5,84	136,23	54,74	20,98	60,49	577,78	29,24 %	2,92 %	3,63 %
	45		1	14	24	100100		244,23	4042	0,87	24448	2220,71	1,57	3,65	1,26	30,80	45,46	1,6	6,72	1009,53	380,29	185,05	30,29	35,53	10,66	18,48	6,40	149,23	59,96	22,98	66,26	632,90	29,24 %	2,92 %	3,63 %
	46		1	13	24	100050		272,35	4140	0,87	27248	2436,71	1,44	3,17	0,96	26,16	45,46	1,6	6,72	1107,73	417,28	203,05	33,23	38,99	11,70	20,27	7,02	163,75	65,79	25,22	72,70	694,46	29,24 %	2,92 %	3,63 %
	47		1	12	24	100000		301,05	4231	0,87	30105	2484,89	1,31	3,17	0,96	28,90	45,46	1,6	6,72	1129,63	425,53	207,06	33,89	39,76	11,93	20,67	7,16	166,98	67,09	25,72	74,14	708,19	29,24 %	2,92 %	3,63 %

13E – 500g Salmon production in FTS

Month	Week	Activity	cor. SGR	Temp	Light (h)	Number of fish	Number of fish destroyed	Weight (grams)	d°	BFCR	Biomass (kg)	Feed demand (kg)	SGR	Oxygen (FW) (mg/kg)	Specific water usage (l/kg/min)	Specific water demand (m3/min)	C (%)	P (%)	N (%)	Total C Production (ton)	C Retained in salmon (ton)	C Waste Particulate (ton)	C Waste Dissolved (ton)	Total P Production (ton)	P Retained in salmon (ton)	P Waste Particulate (ton)	P Waste Dissolved (ton)	Total N Production (ton)	N Retained in salmon (ton)	N Waste Particulate (ton)	N Waste Dissolved (ton)	Sludge amount (kg) Solid quanteties	%C pr kg DW	%P pr kg DW	%N pr kg DW
Jan	1		1	8,0		143 135		0,2	220		29		4,88	7,23	1,68	0,05																			
	2		1	8,0		139385		0,2	276		28		4,88	7,23	1,68	0,05																			
	3		1	8,0		135733		0,2	332		27		4,88	7,23	1,68	0,05																			
	4		1	8,0		132177		0,2	388		26		4,88	7,23	1,68	0,04																			
Feb	5		1	8,0		128714		0,2	444		26		4,88	7,23	1,68	0,04																			
	6	Hatching	1	8,0		125342		0,2	500		25		4,88	7,23	1,68	0,04																			
	7		1	8,0		122058		0,2	556		24		4,88	7,23	1,68	0,04																			
	8		1	8,0		118860		0,2	612		24		4,88	7,23	1,68	0,04																			
Mar	9		1	8,0		115746		0,2	668		23		4,88	7,23	1,68	0,04																			
	10		1	9,7		112713		0,2	724		23		5,90	9,18	2,48	0,06																			
	11	Start feed	1	13,8	24	109760		0,299	792	0,77	33	7,89	7,93	12,15	4,19	0,14	45,21	1,86	8,52	3,57	1,34	0,65	0,11	0,15	0,04	0,08	0,03	0,67	0,27	0,10	0,30	2,19	29,88 %	3,49 %	4,73 %
	12		1	14,2	24	109705		0,510	889	0,77	56	17,80	6,32	12,15	4,19	0,23	45,21	1,86	8,52	8,05	3,03	1,48	0,24	0,33	0,10	0,17	0,06	1,52	0,61	0,23	0,67	5,01	29,43 %	3,44 %	4,66 %
	13		1	14,2	24	109650		0,783	988	0,77	86	23,03	6,32	12,15	4,19	0,36	45,21	1,86	8,52	10,41	3,92	1,91	0,31	0,43	0,13	0,22	0,08	1,96	0,79	0,30	0,87	6,50	29,35 %	3,43 %	4,65 %
Apr	14		1	14,2	24	109596		1,202	1087	0,77	132	35,35	5,33	8,90	3,07	0,40	45,21	1,86	8,52	15,98	6,02	2,93	0,48	0,66	0,20	0,34	0,12	3,01	1,21	0,46	1,34	10,01	29,25 %	3,41 %	4,63 %
	15		1	14,2	24	109541		1,73	1187	0,77	189	44,34	5,33	8,90	3,07	0,58	45,21	1,86	8,52	20,05	7,55	3,67	0,60	0,82	0,25	0,43	0,15	3,78	1,52	0,58	1,68	12,58	29,22 %	3,41 %	4,63 %
	16		1	14,2	24	109486		2,48	1286	0,77	272	63,73	4,49	8,90	3,07	0,84	45,21	1,86	8,52	28,81	10,85	5,28	0,86	1,19	0,36	0,62	0,21	5,43	2,18	0,84	2,41	18,10	29,17 %	3,41 %	4,62 %
	17		1	14,2	24	109431		3,38	1386	0,77	370	75,22	4,06	8,90	3,07	1,14	45,21	1,86	8,52	34,01	12,81	6,23	1,02	1,40	0,42	0,73	0,25	6,41	2,58	0,99	2,85	21,38	29,16 %	3,40 %	4,62 %
May	18		1	10,2	24	109377		4,46	1485	0,77	488	91,31	2,78	6,72	1,82	0,89	45,21	1,86	8,52	41,28	15,55	7,57	1,24	1,70	0,51	0,88	0,31	7,78	3,13	1,20	3,45	25,96	29,14 %	3,40 %	4,61 %
	19	Grading	0,5	10,2	24	106782	-2540	5,41	1556	0,77	578	68,84	2,63	4,91	1,33	0,77	47,6	1,54	7,71	32,77	12,34	6,01	0,98	1,06	0,32	0,55	0,19	5,31	2,13	0,82	2,36	19,56	30,71 %	2,82 %	4,18 %
	20		1	10,2	24	106729		5,93	1628	0,77	633	42,40	2,63	4,91	1,33	0,84	47,6	1,54	7,71	20,18	7,60	3,70	0,61	0,65	0,20	0,34	0,12	3,27	1,31	0,50	1,45	12,02	30,77 %	2,82 %	4,19 %
	21		1	10,2	24	106675		7,11	1699	0,77	759	96,91	2,63	4,91	1,33	1,01	47,6	1,54	7,71	46,13	17,38	8,46	1,38	1,49	0,45	0,78	0,27	7,47	3,00	1,15	3,32	27,56	30,68 %	2,82 %	4,18 %
	22		1	10,2	24	106622		8,53	1771	0,77	910	116,19	2,63	4,91	1,33	1,21	47,6	1,54	7,71	55,30	20,83	10,14	1,66	1,79	0,54	0,93	0,32	8,96	3,60	1,38	3,98	33,05	30,67 %	2,82 %	4,17 %
Jun	23		1	10,4	24	106568		10,23	1842	0,77	1090	139,29	2,22	4,29	1,16	1,26	47,6	1,54	7,71	66,30	24,98	12,15	1,99	2,15	0,64	1,12	0,39	10,74	4,32	1,65	4,77	39,64	30,66 %	2,81 %	4,17 %
	24		1	11,3	24	106515		11,93	1915	0,77	1271	138,91	2,42	4,29	1,16	1,47	47,6	1,54	7,71	66,12	24,91	12,12	1,98	2,14	0,64	1,11	0,39	10,71	4,30	1,65	4,76	39,53	30,66 %	2,81 %	4,17 %
	25		1	12,9	24	106462		14,11	1994	0,77	1502	177,76	2,82	4,95	1,50	2,25	47,6	1,54	7,71	84,61	31,87	15,51	2,54	2,74	0,82	1,42	0,49	13,71	5,51	2,11	6,09	50,60	30,65 %	2,81 %	4,17 %
	26		1	14,4	24	106409		17,14	2084	0,77	1824	248,22	2,75	5,69	1,96	3,58	47,6	1,54	7,71	118,15	44,51	21,66	3,54	3,82	1,15	1,99	0,69	19,14	7,69	2,95	8,50	70,68	30,64 %	2,81 %	4,17 %
Jul	27		1	15,9	24	106356		20,72	2185	0,77	2204	292,31	2,49	5,69	2,59	5,71	47,6	1,54	7,71	139,14	52,41	25,50	4,17	4,50	1,35	2,34	0,81	22,54	9,06	3,47	10,01	83,25	30,64 %	2,81 %	4,17 %
	28		1	15,1	24	106302		24,62	2296	0,77	2617	317,99	2,74	5,69	1,96	5,13	47,6	1,54	7,71	151,36	57,02	27,74	4,54	4,90	1,47	2,55	0,88	24,52	9,85	3,78	10,89	90,57	30,63 %	2,81 %	4,17 %
	29		1	14,5	24	106249		29,73	2401	0,77	3159	417,76	2,60	5,69	1,96	6,19	47,6	1,54	7,71	198,85	74,91	36,45	5,97	6,43	1,93	3,35	1,16	32,21	12,94	4,96	14,30	119,00	30,63 %	2,81 %	4,17 %
	30		1	14,1	24	106196		35,58	2503	0,77	3778	476,57	2,25	5,69	1,96	7,41	47,6	1,54	7,71	226,85	85,45	41,58	6,81	7,34	2,20	3,82	1,32	36,74	14,76	5,66	16,31	135,76	30,63 %	2,81 %	4,17 %
Aug	31		1	13,7	24	106143		41,57	2602	0,77	4413	488,72	2,18	5,69	1,96	8,65	47,27	1,31	7,27	231,02	87,02	42,35	6,93	6,40	1,92	3,33	1,15	35,53	14,28	5,47	15,78	139,23	30,42 %	2,39 %	3,93 %
	32		0,3	12,8	24	106090		48,36	2697	0,77	5131	552,61	1,98	4,95	1,50	7,70	47,27	1,31	7,27	261,22	98,40	47,88	7,84	7,24	2,17	3,76	1,30	40,17	16,14	6,19	17,84	157,43	30,41 %	2,39 %	3,93 %
	33	Vaccination	0,5	11,9	24	104767	-1270	50,41	2787	0,82	5281	123,63	1,80	3,63	1,10	5,81	47,27	1,31	7,27	58,44	22,01	10,71	1,75	1,62	0,49	0,84	0,29	8,99	3,61	1,38	3,99	35,17	30,45 %	2,39 %	3,94 %
	34		0,9	11,9	24	103444	-1270	53,67	2870	0,82	5551	221,51	1,80	3,63	1,10	6,11	47,27	1,31	7,27	104,71	39,44	19,19	3,14	2,90	0,87	1,51	0,52	16,10	6,47	2,48	7,15	63,07	30,43 %	2,39 %	3,93 %
	35		0,9	10,7	24	102123	-1270	60,04	2954	0,82	6132	475,72	1,59	3,14	0,85	5,21	47,27	1,31	7,27	224,87	84,71	41,22	6,75	6,23	1,87	3,24	1,12	34,59	13,90	5,33	15,36	135,52	30,42 %	2,39 %	3,93 %
Sep	36		1	10,7	24	102072		66,32	3029	0,82	6770	523,23	1,59	3,14	0,85	5,75	47,27	1,31	7,27	247,33	93,17	45,34	7,42	6,85	2,06	3,56	1,23	38,04	15,28	5,86	16,89	149,06	30,41 %	2,39 %	3,93 %
	37		1	10,7	24	102021		74,07	3103	0,82	7557	645,28	1,54	3,14	0,85	6,42	47,27	1,31	7,27	305,02	114,90	55,91	9,15	8,45	2,54	4,40	1,52	46,91	18,85	7,22	20,83	183,84	30,41 %	2,39 %	3,93 %
	38		1	10,7	24	101970		82,43	3178	0,82	8405	695,69	1,50	3,14	0,85	7,14	47,27	1,31	7,27	328,85	123,88	60,28	9,87	9,11	2,73	4,74	1,64	50,58	20,32	7,79	22,46	198,21	30,41 %	2,39 %	3,93 %
	39		1	10,7	24	101919		91,46	3253	0,82	9321	751,43	1,46	3,14	0,85	7,92	47,27	1,31	7,27	355,20	133,80	65,11	10,66	9,84	2,95	5,12	1,77	54,63	21,95	8,41	24,26	214,10	30,41 %	2,39 %	3,93 %
Oct	40		1	10,7	24	101868		101,23	3328	0,82	10312	812,61	1,43	2,75	0,74	7,63	47,27	1,31	7,27	384,12	144,70	70,41	11,52	10,65	3,19	5,54	1,92	59,08	23,74	9,10	26,23	231,53	30,41 %	2,39 %	3,93 %
	41		1	9,0	24	101817		111,82	3403	0,82	11385	879,48	1,19	2,16	0,50	5,69	47,27	1,31	7,27	415,73	156,60	76,20	12,47	11,52	3,46	5,99	2,07	63,94	25,69	9,85	28,39	250,59	30,41 %	2,39 %	3,93 %

	42		1	8,4	24	101766		121,44	3466	0,82	12358	798,18	1,06	2,16	0,50	6,18	47,27	1,31	7,27	377,30	142,13	69,16	11,32	10,46	3,14	5,44	1,88	58,03	23,32	8,94	25,76	227,42	30,41 %	2,39 %	3,93 %
	43		1	8,3	24	101715		130,78	3525	0,82	13302	773,67	1,02	2,16	0,50	6,65	47,27	1,31	7,27	365,71	137,76	67,04	10,97	10,14	3,04	5,27	1,82	56,25	22,60	8,66	24,97	220,44	30,41 %	2,39 %	3,93 %
Nov	44		1	8,1	24	101664		140,39	3583	0,82	14273	796,23	1,02	2,16	0,50	7,14	47,27	1,31	7,27	376,38	141,78	68,99	11,29	10,43	3,13	5,42	1,88	57,89	23,26	8,91	25,70	226,86	30,41 %	2,39 %	3,93 %
	45		1	7,3	24	101613		150,72	3640	0,82	15315	854,35	0,87	1,67	0,34	5,21	47,27	1,31	7,27	403,85	152,13	74,03	12,12	11,19	3,36	5,82	2,01	62,11	24,96	9,57	27,58	243,43	30,41 %	2,39 %	3,93 %
	46		1	6,0	24	101562		160,16	3691	0,82	16266	780,01	0,76	1,67	0,34	5,53	47,27	1,31	7,27	368,71	138,89	67,59	11,06	10,22	3,07	5,31	1,84	56,71	22,78	8,73	25,18	222,24	30,41 %	2,39 %	3,93 %
	47		1	5,3	24	101512		168,85	3733	0,82	17140	716,82	0,64	1,26	0,23	3,94	47,27	1,31	7,27	338,84	127,64	62,11	10,17	9,39	2,82	4,88	1,69	52,11	20,94	8,03	23,14	204,23	30,41 %	2,39 %	3,93 %
	48		1	4,8	24	101461		176,61	3770	0,82	17919	638,50	0,63	1,26	0,23	4,12	47,27	1,31	7,27	301,82	113,69	55,32	9,05	8,36	2,51	4,35	1,51	46,42	18,65	7,15	20,61	181,91	30,41 %	2,39 %	3,93 %
Des	49		1	4,4	24	101410		184,50	3803	0,82	18710	649,11	0,52	1,26	0,23	4,30	47,27	1,31	7,27	306,84	115,59	56,24	9,21	8,50	2,55	4,42	1,53	47,19	18,96	7,27	20,95	184,94	30,41 %	2,39 %	3,93 %
	50		1	3,8	24	101359		191,26	3834	0,82	19386	554,24	0,52	1,26	0,23	4,46	47,27	1,31	7,27	261,99	98,69	48,02	7,86	7,26	2,18	3,78	1,31	40,29	16,19	6,21	17,89	157,90	30,41 %	2,39 %	3,93 %
	51		1	3,5	24	101309		198,27	3861	0,82	20087	574,26	0,52	1,26	0,23	4,62	47,27	1,31	7,27	271,45	102,26	49,76	8,14	7,52	2,26	3,91	1,35	41,75	16,77	6,43	18,54	163,60	30,41 %	2,39 %	3,93 %
	52		1	3,1	24	101258		205,54	3885	0,87	20812	631,28	0,39	0,93	0,15	3,12	47,27	1,31	7,27	298,41	112,41	54,70	8,95	8,27	2,48	4,30	1,49	45,89	18,44	7,07	20,38	179,86	30,41 %	2,39 %	3,93 %
Jan	1		1	3,2	24	101208		211,28	3907	0,87	21384	497,14	0,39	0,93	0,15	3,21	47,27	1,31	7,27	235,00	88,52	43,08	7,05	6,51	1,95	3,39	1,17	36,14	14,52	5,57	16,05	141,63	30,41 %	2,39 %	3,93 %
	2		1	3,0	24	101157		217,19	3929	0,87	21971	510,79	0,39	0,93	0,15	3,30	47,27	1,31	7,27	241,45	90,95	44,26	7,24	6,69	2,01	3,48	1,20	37,13	14,92	5,72	16,49	145,52	30,41 %	2,39 %	3,93 %
	3		1	2,6	24	101106		223,27	3950	0,87	22574	524,82	0,39	0,93	0,15	3,39	47,27	1,31	7,27	248,08	93,45	45,47	7,44	6,88	2,06	3,58	1,24	38,15	15,33	5,88	16,94	149,51	30,41 %	2,39 %	3,93 %
	4		1	2,4	24	101056		229,51	3969	0,87	23194	539,23	0,28	0,93	0,15	3,48	47,27	1,31	7,27	254,89	96,02	46,72	7,65	7,06	2,12	3,67	1,27	39,20	15,75	6,04	17,41	153,62	30,41 %	2,39 %	3,93 %
Feb	5		1	2,5	24	101005		234,05	3985	0,87	23640	388,47	0,39	0,93	0,15	3,55	47,27	1,31	7,27	183,63	69,17	33,66	5,51	5,09	1,53	2,65	0,92	28,24	11,35	4,35	12,54	110,65	30,42 %	2,39 %	3,93 %
	6		1	2,5	24	100955		240,47	4003	0,87	24277	553,62	0,39	0,93	0,15	3,64	47,27	1,31	7,27	261,70	98,58	47,97	7,85	7,25	2,18	3,77	1,31	40,25	16,17	6,20	17,87	157,72	30,41 %	2,39 %	3,93 %
	7		1	2,5	24	100904		247,07	4020	0,87	24930	568,52	0,39	0,93	0,15	3,74	47,27	1,31	7,27	268,74	101,23	49,26	8,06	7,45	2,23	3,87	1,34	41,33	16,61	6,37	18,35	161,97	30,41 %	2,39 %	3,93 %
	8		1	2,6	24	100854		253,84	4038	0,87	25601	583,82	0,38	0,93	0,15	3,84	47,27	1,31	7,27	275,97	103,96	50,59	8,28	7,65	2,29	3,98	1,38	42,44	17,05	6,54	18,85	166,33	30,41 %	2,39 %	3,93 %
Mar	9		1	2,8	24	100803		260,70	4056	0,87	26279	589,72	0,38	0,93	0,15	3,94	47,27	1,31	7,27	278,76	105,01	51,10	8,36	7,73	2,32	4,02	1,39	42,87	17,23	6,60	19,04	168,01	30,41 %	2,39 %	3,93 %
	10		1	2,8	24	100753		267,73	4076	0,87	26975	605,33	0,38	0,93	0,15	4,05	47,27	1,31	7,27	286,14	107,79	52,45	8,58	7,93	2,38	4,12	1,43	44,01	17,68	6,78	19,54	172,46	30,41 %	2,39 %	3,93 %
	11		1	2,7	24	100703		274,96	4095	0,87	27689	621,36	0,38	0,93	0,15	4,15	47,27	1,31	7,27	293,72	110,64	53,84	8,81	8,14	2,44	4,23	1,47	45,17	18,15	6,96	20,06	177,03	30,41 %	2,39 %	3,93 %
	12		1	3,0	24	100652		282,38	4114	0,87	28422	637,81	0,38	0,93	0,15	4,26	47,27	1,31	7,27	301,49	113,57	55,26	9,04	8,36	2,51	4,34	1,50	46,37	18,63	7,14	20,59	181,72	30,41 %	2,39 %	3,93 %
	13		1	3,5	24	100602		290,00	4135	0,87	29175	654,70	0,49	1,26	0,23	6,71	47,27	1,31	7,27	309,48	116,58	56,73	9,28	8,58	2,57	4,46	1,54	47,60	19,12	7,33	21,13	186,53	30,41 %	2,39 %	3,93 %
Apr	14		1	3,6	24	100552		300,04	4160	0,87	30169	865,28	0,48	1,26	0,23	6,94	47,27	1,31	7,27	409,02	154,08	74,97	12,27	11,34	3,40	5,89	2,04	62,91	25,28	9,69	27,93	246,55	30,41 %	2,39 %	3,93 %
	15		1	3,8	24	100501		310,17	4185	0,87	31173	873,27	0,48	1,26	0,23	7,17	47,27	1,31	7,27	412,79	155,50	75,67	12,38	11,44	3,43	5,95	2,06	63,49	25,51	9,78	28,19	248,82	30,41 %	2,39 %	3,93 %
	16		1	4,1	12	100451		320,65	4212	0,87	32210	902,32	0,48	1,26	0,23	7,41	47,27	1,31	7,27	426,53	160,67	78,18	12,80	11,82	3,55	6,15	2,13	65,60	26,36	10,10	29,13	257,10	30,41 %	2,39 %	3,93 %
	17		1	5,0	12	100401		331,49	4240	0,87	33282	932,34	0,58	1,26	0,23	7,65	47,27	1,31	7,27	440,72	166,02	80,78	13,22	12,21	3,66	6,35	2,20	67,78	27,23	10,44	30,09	265,66	30,41 %	2,39 %	3,93 %
May	18		1	5,2	12	100351		345,18	4275	0,87	34639	1180,79	0,58	1,26	0,23	7,97	47,27	1,31	7,27	558,16	210,26	102,31	16,74	15,47	4,64	8,04	2,78	85,84	34,49	13,22	38,11	336,47	30,41 %	2,39 %	3,93 %
	19		1	5,8	12	100301		359,44	4312	0,87	36052	1228,94	0,68	1,67	0,34	12,26	47,27	1,31	7,27	580,92	218,83	106,48	17,43	16,10	4,83	8,37	2,90	89,34	35,90	13,76	39,67	350,19	30,41 %	2,39 %	3,93 %
	20		1	6,3	12	100250		377,00	4352	0,87	37794	1516,05	0,68	1,67	0,34	12,85	46,32	1,6	7,52	702,23	264,53	128,72	21,07	24,26	7,28	12,61	4,37	114,01	45,81	17,56	50,62	432,01	29,80 %	2,92 %	4,06 %
	21		1	6,9	12	100200		395,42	4396	0,87	39621	1589,33	0,79	1,67	0,34	13,47	46,32	1,6	7,52	736,18	277,32	134,94	22,09	25,43	7,63	13,22	4,58	119,52	48,02	18,41	53,07	452,90	29,80 %	2,92 %	4,06 %
Jun	22		1	7,2	24	100150		417,75	4445	0,87	41837	1928,22	0,79	1,67	0,34	14,22	46,32	1,6	7,52	893,15	336,45	163,71	26,79	30,85	9,26	16,04	5,55	145,00	58,26	22,33	64,38	549,48	29,79 %	2,92 %	4,06 %
	23		1	7,6	24	100100		441,33	4495	0,87	44178	2036,08	0,89	2,16	0,50	22,09	46,32	1,6	7,52	943,11	355,27	172,87	28,29	32,58	9,77	16,94	5,86	153,11	61,52	23,58	67,98	580,22	29,79 %	2,92 %	4,06 %
	24		1	8,0	24	100050		469,63	4548	0,87	46987	2444,00	0,89	2,16	0,50	23,49	46,32	1,6	7,52	1132,06	426,45	207,51	33,96	39,10	11,73	20,33	7,04	183,79	73,85	28,30	81,60	696,48	29,79 %	2,92 %	4,06 %
	25		1	8,4	24	100000		499,75	4604	0,87	49975	2599,41	0,89	2,16	0,50	24,99	46,32	1,6	7,52	1204,05	453,56	220,70	36,12	41,59	12,48	21,63	7,49	195,48	78,54	30,10	86,79	740,77	29,79 %	2,92 %	4,06 %

13F – 500g Salmon production in RAS

Month	Week	Activity	cor. SGR	Temp	Light (h)	Number of fish	Number of fish destroyed	Weight (grams)	d°	BFCR	Biomass (kg)	Feed demand (kg)	SGR	Oxygen (FW) (mg/kg)	Specific water usage (l/kg/min)	Specific water demand (m3/min)	C (%)	P (%)	N (%)	Total C Production (kg)	C Retained in salmon (kg)	C Waste Particulate (kg)	C Waste Dissolved (kg)	Total P Production (kg)	P Retained in salmon (kg)	P Waste Particulate (kg)	P Waste Dissolved (kg)	Total N Production (kg)	N Retained in salmon (kg)	N Waste Particulate (kg)	N Waste Dissolved (kg)	Sludge amount (kg) Solid quanteties	%C pr kg DW	%P pr kg DW	%N pr kg DW
Jan	1		1	8		141 461		0,2	220		28		4,88	7,23	1,68	0,05																			
	2		1	8		137754		0,2	276		28		4,88	7,23	1,68	0,05																			
	3		1	8		134145		0,2	332		27		4,88	7,23	1,68	0,05																			
	4		1	8		130631		0,2	388		26		4,88	7,23	1,68	0,04																			
Feb	5		1	8		127208		0,2	444		25		4,88	7,23	1,68	0,04																			
	6	Hatching	1	8		123875		0,2	500		25		4,88	7,23	1,68	0,04																			
	7		1	8		120630		0,2	556		24		4,88	7,23	1,68	0,04																			
	8		1	8		117469		0,2	612		23		4,88	7,23	1,68	0,04																			
Mar	9		1	8		114392		0,2	668		23		4,88	7,23	1,68	0,04																			
	10		1	8		111394		0,2	724		22		4,88	7,23	1,68	0,04																			
	11	Start feed	1	8	24	108476		0,279	780	0,77	30	6,17	4,88	7,23	1,68	0,05	45,45	1,77	8,35	2,80	1,06	0,51	0,08	0,11	0,03	0,06	0,02	0,51	0,21	0,08	0,23	1,76	29,23 %	3,23 %	4,51 %
	12		1	10	24	108422		0,390	836	0,77	42	9,22	5,90	9,18	2,48	0,10	45,45	1,77	8,35	4,19	1,58	0,77	0,13	0,16	0,05	0,08	0,03	0,77	0,31	0,12	0,34	2,63	29,23 %	3,23 %	4,51 %
	13		1	14	24	108367		0,582	906	0,77	63	16,03	6,32	12,15	4,19	0,26	45,45	1,77	8,35	7,29	2,74	1,34	0,22	0,28	0,09	0,15	0,05	1,34	0,54	0,21	0,59	4,57	29,23 %	3,23 %	4,51 %
Apr	14		1	14	24	108313		0,894	1004	0,77	97	25,99	6,32	12,15	4,19	0,41	45,45	1,77	8,35	11,81	4,45	2,16	0,35	0,46	0,14	0,24	0,08	2,17	0,87	0,33	0,96	7,41	29,23 %	3,23 %	4,51 %
	15		1	14	24	108259		1,37	1102	0,77	149	39,89	5,33	8,90	3,07	0,46	45,45	1,77	8,35	18,13	6,83	3,32	0,54	0,71	0,21	0,37	0,13	3,33	1,34	0,51	1,48	11,37	29,23 %	3,23 %	4,51 %
	16		1	14	24	108205		1,97	1200	0,77	214	50,03	5,33	8,90	3,07	0,66	45,45	1,77	8,35	22,74	8,57	4,17	0,68	0,89	0,27	0,46	0,16	4,18	1,68	0,64	1,85	14,26	29,23 %	3,23 %	4,51 %
	17		1	14	24	108151		2,84	1298	0,77	307	71,90	4,49	8,90	3,07	0,94	45,45	1,77	8,35	32,68	12,31	5,99	0,98	1,27	0,38	0,66	0,23	6,00	2,41	0,92	2,67	20,49	29,23 %	3,23 %	4,51 %
May	18		1	14	24	108097		3,86	1396	0,77	417	84,88	4,06	8,90	3,07	1,28	45,45	1,77	8,35	38,58	14,53	7,07	1,16	1,50	0,45	0,78	0,27	7,09	2,85	1,09	3,15	24,19	29,23 %	3,23 %	4,51 %
	19	Grading	0,5	14	24	105503	-2540	5,10	1494	0,77	538	93,06	3,58	6,51	2,24	1,21	46,38	1,56	6,98	43,16	16,26	7,91	1,29	1,45	0,44	0,75	0,26	6,50	2,61	1,00	2,88	26,52	29,83 %	2,85 %	3,77 %
	20		1	14	24	105450		5,77	1592	0,77	609	54,60	3,58	6,51	2,24	1,36	46,38	1,56	6,98	25,32	9,54	4,64	0,76	0,85	0,26	0,44	0,15	3,81	1,53	0,59	1,69	15,56	29,83 %	2,85 %	3,77 %
	21		1	14	24	105397		7,39	1690	0,77	779	130,73	3,58	6,51	2,24	1,74	46,38	1,56	6,98	60,63	22,84	11,11	1,82	2,04	0,61	1,06	0,37	9,12	3,67	1,41	4,05	37,26	29,83 %	2,85 %	3,77 %
	22		1	14	24	105345		9,45	1788	0,77	996	167,17	3,58	6,51	2,24	2,23	46,38	1,56	6,98	77,53	29,21	14,21	2,33	2,61	0,78	1,36	0,47	11,67	4,69	1,80	5,18	47,64	29,83 %	2,85 %	3,77 %
Jun	23		1	14	24	105292		12,09	1886	0,77	1273	213,78	3,03	5,69	1,96	2,50	46,38	1,56	6,98	99,15	37,35	18,17	2,97	3,34	1,00	1,73	0,60	14,92	6,00	2,30	6,63	60,93	29,83 %	2,85 %	3,77 %
	24		1	14	24	105239		14,90	1984	0,77	1568	226,97	3,03	5,69	1,96	3,07	46,38	1,56	6,98	105,27	39,65	19,30	3,16	3,54	1,06	1,84	0,64	15,84	6,37	2,44	7,03	64,69	29,83 %	2,85 %	3,77 %
	25		1	14	24	105187		18,36	2082	0,77	1931	279,51	2,75	5,69	1,96	3,79	46,38	1,56	6,98	129,64	48,83	23,76	3,89	4,36	1,31	2,27	0,78	19,51	7,84	3,00	8,66	79,66	29,83 %	2,85 %	3,77 %
	26		1	14	24	105134		22,19	2180	0,77	2333	309,48	2,56	5,69	1,96	4,57	46,38	1,56	6,98	143,54	54,07	26,31	4,31	4,83	1,45	2,51	0,87	21,60	8,68	3,33	9,59	88,20	29,83 %	2,85 %	3,77 %
Jul	27		1	14	24	105082		26,49	2278	0,77	2784	347,18	2,43	5,69	1,96	5,46	46,38	1,56	6,98	161,02	60,66	29,52	4,83	5,42	1,62	2,82	0,97	24,23	9,74	3,73	10,76	98,95	29,83 %	2,85 %	3,77 %
	28		1	14	24	105029		31,35	2376	0,77	3292	391,49	2,33	5,69	1,96	6,45	46,38	1,56	6,98	181,57	68,40	33,28	5,45	6,11	1,83	3,18	1,10	27,33	10,98	4,21	12,13	111,57	29,83 %	2,85 %	3,77 %
	29		1	14	24	104976		36,84	2474	0,77	3867	442,37	2,25	5,69	1,96	7,58	46,38	1,56	6,98	205,17	77,29	37,61	6,16	6,90	2,07	3,59	1,24	30,88	12,41	4,76	13,71	126,08	29,83 %	2,85 %	3,77 %
	30		1	14	24	104924		43,05	2572	0,77	4517	500,21	2,18	5,69	1,96	8,85	46,97	1,5	6,98	234,95	88,51	43,07	7,05	7,50	2,25	3,90	1,35	34,91	14,03	5,38	15,50	142,56	30,21 %	2,74 %	3,77 %
Aug	31		1	14	24	104872		50,07	2670	0,82	5251	602,33	2,08	4,16	1,43	7,51	46,97	1,5	6,98	282,92	106,57	51,86	8,49	9,04	2,71	4,70	1,63	42,04	16,89	6,47	18,67	171,66	30,21 %	2,74 %	3,77 %
	32		0,3	14	24	104819		57,82	2768	0,82	6061	664,07	2,08	4,16	1,43	8,67	46,97	1,5	6,98	311,91	117,50	57,17	9,36	9,96	2,99	5,18	1,79	46,35	18,62	7,14	20,58	189,26	30,21 %	2,74 %	3,77 %
	33	Vaccination	0,5	14	24	103497	-1270	60,39	2866	0,82	6251	155,42	2,00	4,16	1,43	8,94	46,97	1,5	6,98	73,00	27,50	13,38	2,19	2,33	0,70	1,21	0,42	10,85	4,36	1,67	4,82	44,30	30,21 %	2,74 %	3,77 %
	34		0,9	14	24	102175	-1270	64,74	2964	0,82	6615	298,90	2,00	4,16	1,43	9,46	46,97	1,5	6,98	140,39	52,89	25,73	4,21	4,48	1,35	2,33	0,81	20,86	8,38	3,21	9,26	85,19	30,21 %	2,74 %	3,77 %
	35		0,9	14	24	100854	-1270	73,34	3062	0,82	7396	640,75	1,93	4,16	1,43	10,58	46,97	1,5	6,98	300,96	113,37	55,17	9,03	9,61	2,88	5,00	1,73	44,72	17,97	6,89	19,86	182,61	30,21 %	2,74 %	3,77 %
Sep	36		1	14	24	100803		82,75	3160	0,82	8341	774,56	1,88	4,16	1,43	11,93	46,97	1,5	6,98	363,81	137,05	66,69	10,91	11,62	3,49	6,04	2,09	54,06	21,72	8,33	24,00	220,75	30,21 %	2,74 %	3,77 %
	37		1	14	24	100753		94,27	3258	0,82	9498	948,37	1,84	4,16	1,43	13,58	46,97	1,5	6,98	445,45	167,80	81,65	13,36	14,23	4,27	7,40	2,56	66,20	26,60	10,19	29,39	270,29	30,21 %	2,74 %	3,77 %
	38		1	14	24	100703		107,07	3356	0,82	10782	1052,99	1,80	3,65	1,26	13,58	46,97	1,5	6,98	494,59	186,31	90,66	14,84	15,79	4,74	8,21	2,84	73,50	29,53	11,32	32,63	300,10	30,21 %	2,74 %	3,77 %
	39		1	14	24	100652		121,29	3454	0,82	12208	1169,41	1,80	3,65	1,26	15,38	46,97	1,5	6,98	549,27	206,91	100,68	16,48	17,54	5,26	9,12	3,16	81,62	32,80	12,57	36,24	333,28	30,21 %	2,74 %	3,77 %

Oct	40		1	14	24	100602		137,40	3552	0,82	13823	1324,08	1,72	3,65	1,26	17,42	46,97	1,5	6,98	621,92	234,28	114,00	18,66	19,86	5,96	10,33	3,58	92,42	37,13	14,23	41,04	377,36	30,21 %	2,74 %	3,77 %
	41		1	14	24	100552		154,86	3650	0,82	15572	1434,12	1,67	3,65	1,26	19,62	46,97	1,5	6,98	673,60	253,75	123,47	20,21	21,51	6,45	11,19	3,87	100,10	40,22	15,42	44,45	408,72	30,21 %	2,74 %	3,77 %
	42		1	14	24	100501		173,89	3748	0,82	17476	1561,81	1,67	3,65	1,26	22,02	46,97	1,5	6,98	733,58	276,34	134,47	22,01	23,43	7,03	12,18	4,22	109,01	43,80	16,79	48,40	445,12	30,21 %	2,74 %	3,77 %
	43		1	14	24	100451		195,26	3846	0,82	19614	1752,85	1,63	3,65	1,26	24,71	46,97	1,5	6,98	823,31	310,14	150,91	24,70	26,29	7,89	13,67	4,73	122,35	49,16	18,84	54,32	499,56	30,21 %	2,74 %	3,77 %
Nov	44		1	14	24	100401		218,62	3944	0,87	21950	2032,36	1,60	3,65	1,26	27,66	46,97	1,5	6,98	954,60	359,60	174,98	28,64	30,49	9,15	15,85	5,49	141,86	57,00	21,85	62,99	579,22	30,21 %	2,74 %	3,77 %
	45		1	14	24	100351		244,23	4042	0,87	24509	2226,27	1,57	3,65	1,26	30,88	46,97	1,5	6,98	1045,68	393,91	191,67	31,37	33,39	10,02	17,36	6,01	155,39	62,44	23,93	68,99	634,49	30,21 %	2,74 %	3,77 %
	46		1	14	24	100301		272,35	4140	0,87	27317	2442,81	1,55	3,65	1,26	34,42	46,97	1,5	6,98	1147,39	432,22	210,32	34,42	36,64	10,99	19,05	6,60	170,51	68,51	26,26	75,71	696,20	30,21 %	2,74 %	3,77 %
	47		1	14	24	100250		303,26	4238	0,87	30401	2683,83	1,52	3,65	1,26	38,31	45,46	1,6	6,72	1220,07	459,60	223,64	36,60	42,94	12,88	22,33	7,73	180,35	72,47	27,77	80,08	764,89	29,24 %	2,92 %	3,63 %
	48		1	14	24	100200		336,93	4336	0,87	33761	2922,48	1,52	3,65	1,26	42,54	45,46	1,6	6,72	1328,56	500,47	243,52	39,86	46,76	14,03	24,32	8,42	196,39	78,91	30,24	87,20	832,91	29,24 %	2,92 %	3,63 %
Des	49		1	13	24	100150		374,35	4434	0,87	37491	3245,39	1,41	3,17	0,96	35,99	45,46	1,6	6,72	1475,35	555,77	270,43	44,26	51,93	15,58	27,00	9,35	218,09	87,63	33,59	96,83	924,94	29,24 %	2,92 %	3,63 %
	50		1	13	24	100100		412,95	4525	0,87	41336	3345,06	1,41	3,17	0,96	39,68	45,46	1,6	6,72	1520,66	572,83	278,74	45,62	53,52	16,06	27,83	9,63	224,79	90,32	34,62	99,81	953,34	29,24 %	2,92 %	3,63 %
	51		1	12	24	100050		455,52	4616	0,87	45575	3688,11	1,31	3,17	0,96	43,75	45,46	1,6	6,72	1676,62	631,58	307,32	50,30	59,01	17,70	30,69	10,62	247,84	99,58	38,17	110,04	1051,11	29,24 %	2,92 %	3,63 %
	52		1	10	24	100000		498,89	4700	0,87	49889	3753,52	1,10	2,75	0,74	36,92	45,46	1,6	6,72	1706,35	642,78	312,77	51,19	60,06	18,02	31,23	10,81	252,24	101,35	38,84	111,99	1069,75	29,24 %	2,92 %	3,63 %

13G - Waste estimation model (VØF)

Input variables					
Production model	Number of fish	Feed usage pr. production (pr.ton)	Carbon pr ton salmon feed	Phosphorus pr ton salmon feed	Nitrogen pr ton salmon feed
100g FTS	100 000	8,107	466,63	16,07	78,29
100g RAS	100 000	8,152	460,13	16,21	73,25
300g FTS	100 000	24,907	469,45	14,69	75,70
300g RAS	100 000	25,045	462,21	15,92	72,34
500g FTS	100 000	42,275	469,98	14,43	75,20
500g RAS	100 000	42,255	463,10	15,81	72,04

Massbalance			
	C	P	N
Total feed input	100 %	100 %	100 %
Total waste production	62,33 %	70,00 %	59,82 %
Retained in salmon	37,67 %	30,00 %	40,18 %
Respired (CO2)	41,00 %		
Waste Particle	18,33 %	52,00 %	15,40 %
Waste Dissolved	3,00 %	18,00 %	44,40 %

Amount of dry weight taken out per kg fishfeed		
DW/kg fish feed	0,285	

Production model	Total (kg)	Retained in salmon (kg)	Respired C02 (kg)	Particle (kg)	Dissolved (kg)	Total (kg)	Retained in salmon (kg)	Particle (kg)	Dissolved (kg)	Total (kg)	Retained in salmon (kg)	Particle (kg)	Dissolved (kg)	Sludge amount (kg)	%C pr kg DW	%P pr kg DW	%N pr kg DW	Sludge amount (kg)	Sludge amount (kg)
	C	C		C	C	P	P	P	P	N	N	N	N	DW	% C	%P	%N	10% DW	90% DW
100g FTS	3783,01	1425,06	1551,03	693,43	113,49	130,25	39,08	67,73	23,45	634,74	255,04	97,75	281,82	2310,48	30,01 %	2,93 %	4,23 %	2079,43	231,05
100g RAS	3751,12	1413,05	1537,96	687,58	112,53	132,13	39,64	68,71	23,78	597,15	239,94	91,96	265,14	2323,40	29,59 %	2,96 %	3,96 %	2091,06	232,34
300g FTS	11692,52	4404,57	4793,93	2143,24	350,78	365,87	109,76	190,25	65,86	1885,37	757,54	290,35	837,11	7098,45	30,19 %	2,68 %	4,09 %	6388,60	709,84
300g RAS	11576,27	4360,78	4746,27	2121,93	347,29	398,83	119,65	207,39	71,79	1811,80	727,98	279,02	804,44	7137,95	29,73 %	2,91 %	3,91 %	6424,15	713,79
500g FTS	19868,35	7484,41	8146,02	3641,87	596,05	609,96	182,99	317,18	109,79	3179,26	1277,43	489,61	1411,59	12048,27	30,23 %	2,63 %	4,06 %	10843,44	1204,83
500g RAS	19568,50	7371,45	8023,08	3586,91	587,05	668,24	200,47	347,48	120,28	3043,99	1223,07	468,77	1351,53	12042,74	29,78 %	2,89 %	3,89 %	10838,47	1204,27

13H – Waste estimation County governor (OCG)

Production model	TOC Waste	P Waste	N Waste
100g FTS	972,86	95,39	356,30
100g RAS	978,27	96,14	359,80
300g FTS	2988,85	295,95	1114,30
300g RAS	3005,45	298,26	1125,02
500g FTS	5072,98	505,99	1916,30
500g RAS	5070,63	505,66	1914,78

13I – Waste estimation County governor (NCG)

Production model	TOC NCG	P NCG	N NCG
100g FTS	849,24	95,39	356,30
100g RAS	859,53	96,14	359,80
300g FTS	2681,30	295,95	1114,30
300g RAS	2712,86	298,26	1125,02
500g FTS	4642,89	505,99	1916,30
500g RAS	4638,42	505,66	1914,78

Norges miljø- og biovitenskapelige universitet
Noregs miljø- og biovitskapelege universitet
Norwegian University of Life Sciences

Postboks 5003
NO-1432 Ås
Norway