Feasibility Study of West Estonia

Aquaculture potential and circular economy 2020-30

The Report is structured according to guidelines stated in the public procurement reference number 232693

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Aquaponic analyses linked to the fish farming setup are provided from Prof. Jonne Kotta and Prof. Georg Martin, Estonian Marine Institute, University of Tartu, Estonia

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1. FEASIBILITY STUDY REPORT STRUCTURE

Chapter 1

1. Purpose of the analysis – introduction

This Report illustrates strategic decisions the West Estonia Municipalities WEM should consider to be evaluate to establish a motivated platform that can be used among stakeholders where various aquaculture production initiatives aimed for the West Estonian coastal zone for the period 2020–30 can be materialized. Such strategies include the following:

- Illustrations of the production potential of large rainbow trout biomass/harvested volumes, farmed by various technical platforms.

- The potential of integrating aquaponic setup with fish production for cultivation of both mussel and macroalgae illustrated with yearly aquaponic harvest biomass.

- New farming techniques and the link to aquaponic integration may reduce the normal waste fluxes to the environment from fish farming.

    - Different quantities of waste fluxes are shown for alternative platforms, open nets, fish tanks on land and for semi-enclosed floating fish bags in the sea.

- These updated flux performances are illustrated by use of the latest Baltic fish feed 2021 and the fluxes are benchmark against the current Water Act thresholds for nutrient fluxes from fish farming set by West Estonia.
- Illustrations of potential circular economy, how it can be arranged where new initiatives can exploit the marine resources.
- Suggestions how West Estonia region best could organize the way forward.
- Highlight the risk elements related to such circular economy introduction.

These main tasks listed above is illustrated and summarized as:

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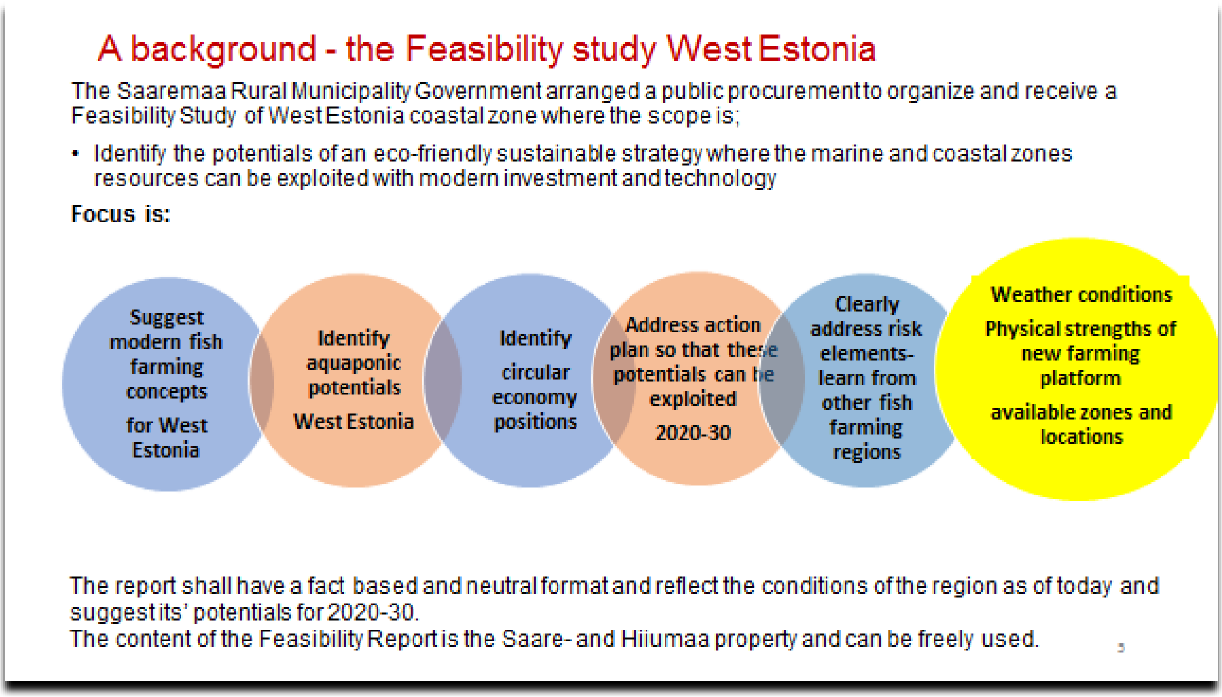

Figure 1. Scope of the analysis.

The recommendations in this study should be careful evaluated, and WEM should form its final decisions also based upon other documents and inputs. *Aquaconsulting Senstad* is not responsible for any outcome, positions if WEM should follow up this these observations. The same position is also for the aquaponic contributions provided by Jonne Kotta and Georg Martin, University Tartu. WEM nor any partner/business relationship WEM creates can sue/claim the authors for direct nor indirect losses, we are also not responsible for any customer's nor its customers clients direct nor indirect loss, loss of earnings related to our contributions and suggestions.

Other levels of fish farming planning, its biomass density, its feed demand, and the fish feed in use will show other fluxes of waste, so will also other mechanical water filtration setup. Our observations are based upon a standard well used water filtration, moderate fish biomass density and one of the commercial fish feed available in the Baltic region today. Density and cultivation techniques for the mussel and macroalgae will also influence the final performances. The flux reduction per kg fish produced should however be relevant and be within reach based upon our knowledge as of to date.

WEM with its local knowledge and expertise specially related to environmental conditions, mapping its coastal zone for various exploiting positions should allow dedicated zones/ locations to be allocated for aquaculture activities.

Chapter 2

2. Concluding remarks and recommendations

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West Estonia region has updated some terms for aquaculture activity with the Water Act setting maximum waste/nutrients flux quantity to sea per kg fish produced.

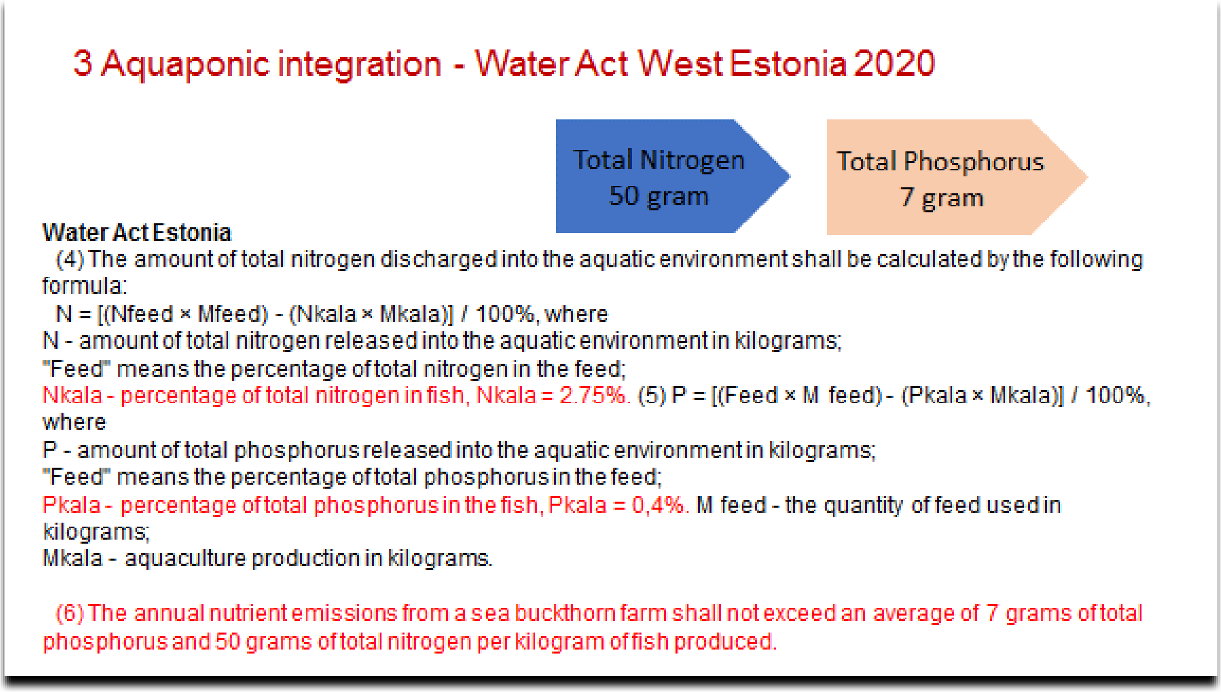

Figure 2 Water Act threshold per kg fish produced.

The Act has specified the maximum total flux of Nitrogen as 50 grams per 1 kg fish produced and a 7 grams Phosphorus per kg fish produced. The Act is not splitting between dissolved nutrient to the free water column, nor the proportion bound to materials. Norway and Denmark have very much the same assimilation factors for Nitrogen-N (2.75%) and Phosphorus-P (0.4%) as West Estonia with respect of the quantity being built into the growing fish from its digestion of these nutrients.

West Estonia has not specified nor quantified zones, sites, and total yearly flux quotas to the dedicated zones where aquaculture activity could be established. It would be very useful if public stakeholders do consider the best locations for aquaculture purposes which also have a minimum of environmental disturbances.

These undefined factors do result in an uncertainty for the coastal zone`s members and special for private stakeholders who have an interest in establishing circular activity in West Estonia:

a) West Estonia lacks motivation terms for aquaculture investors to take decision – biomass volume, nor flux quotas per sites, per region, per year are defined.
b) This represents uncertainties and risk factors.
c) Today, the aquaculture sector in West Estonia is fragile, lack major partners that could lead the way forward.
d) Commercial fish farming activity exists in Finland, Sweden, and Denmark; however, each individual permit is very small – they lack permits that could survive for a longer

period with a good foundation of economy of scale, such elements are important to consider for West Estonia.

a. Farming activity in West Estonia is very small and does not represent any robust economy of scale.

e) There are a few applications for offshore open net farming - the final outcomes are not yet made.
f) Many previous public grants have failed to motivate and initiate active farming and marine cultivations.

An illustration of the circular economy as of today.

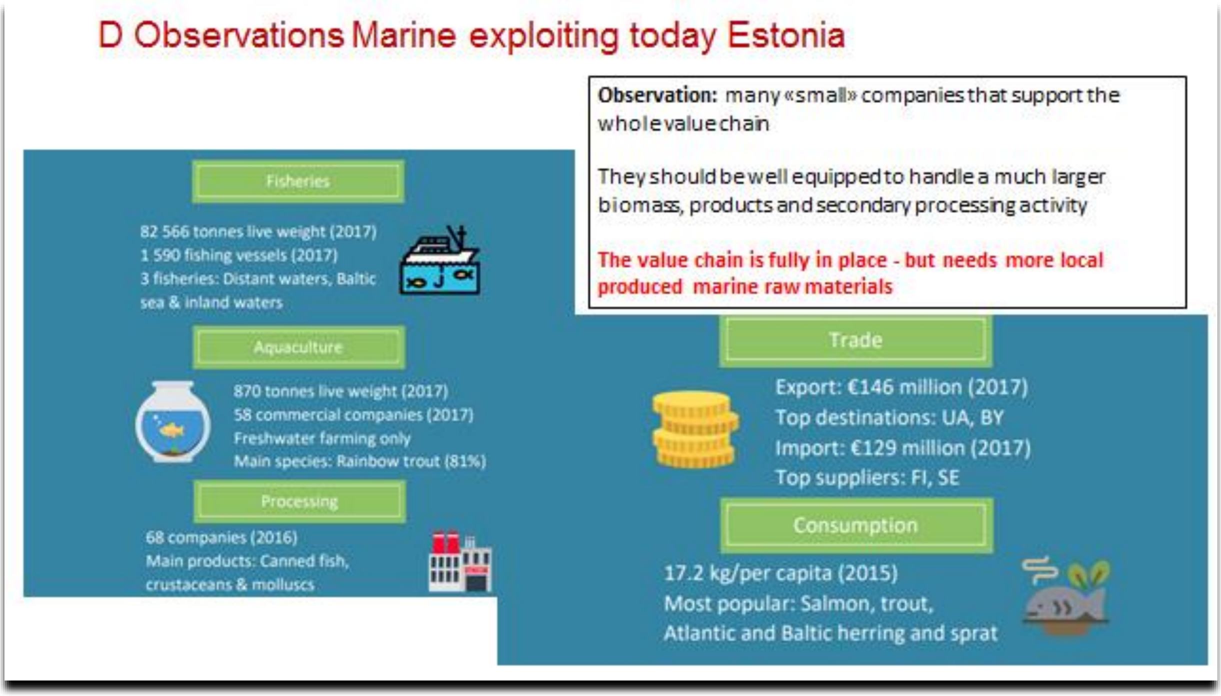

Figure 3. Circular economy of coastal zone.

The zone seems to have all elements of a required value-supply chain; however, their sizes are small and there are too little marine raw materials available. It seems also that the processing industry involving with both catches, processing the pelagic fish quotas is representing a volume scale which could be integrated toward a future fish production in the form of large rainbow trout.

<u>Below is our 3x suggested fish farming platforms suites for West Estonia and their production potential 2020-30.</u>

a) Authorities must update flux information for the latest **Baltic fish feed 2021** as this represent a major reduction of nutrient flux to sea.

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b) **No 1 is traditional Open net farming** with modern techniques could result in a production of approx. 20 000 tons rainbow trout per year – this is a conservative estimate. This is illustrated below where 20 sites are operated. Half of them each year with small fish and the last 10 sites with largest harvest fish. An annual harvest can then take place for 10 sites each conservative harvesting 2 000 tons live weight, totaling 20 000 tons per year.

- Each site could in theory be 5 km apart and harvested biomass per average km^2 is only 20 tons, see illustration – this should be environmentally friendly and trigger a good foundation for optimum fish health, low interference between sites and year-classes.
- This alone could represent a **circular economy of approx. 270 jobs and value of > 175 MEUR/year, for details see below.**

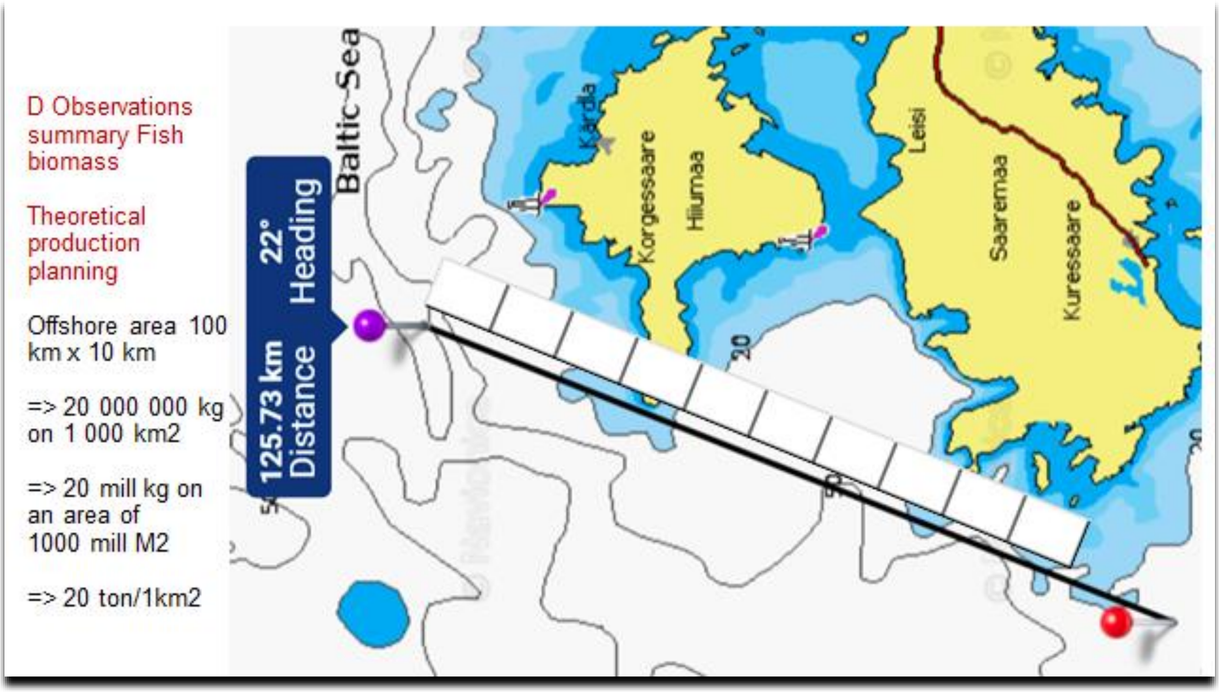

Figure 4. Illustration of theoretical Open net farming zone with potential distance apart each location.

<u>Other potential modern fish farming platforms for West Estonia are as follows:</u>

c) **No 2 is a modern land-based fish farming with mechanical water filtration where** the organic waste i.e., can be withdrawal from the water flux back to Baltic Sea is illustrated where 55% of the organic fluxes are collected, treated, and is not entering the marine environment. The reduction of Nitrogen and Phosphorus by this mechanical filtration is shown in figure below. A potential of setting up 10 large on-land sites could result in **10 000 tons rainbow trout biomass per year – 125x jobs and a circular contribution as 90 MEUR/year.**

d) **No 3 is new large floating bags concept** for sea-based fish farming which do represent major new innovative solutions, special suited for the Baltic Sea. The advantages which this concept shows above the standard Open net platform is:

- better fish health;
- higher growth, increased survival;
- better fish quality;
- the enclosed fish bag/structure act as a protection against algae bloom and contaminations, allow for a fully oxygenated water column year-round and partly also act as a temperature control;
- further this enclosed protected water unit enables the fish farmer to have full control of the waste fluxes which we consider to be a game changer for Baltic aquaculture and represent a key foundation for our report.

Details of production planning is shown in Appendix 2.

Detail information from the international fish farming industry is shown in Appendix 10.

<u>Further we have integrated the on-land and the floating bag concept with an aquaponic setup:</u>

This is arrangement as illustrated in figure 5 below.

- Exploiting the natural ambient macroalga green grass *(Ulva intestinalis*) and the shellfish blue mussel (*Mytilus edulis*) will **represent large quantity of cultured biomasses.**

- **Harvesting these will result in nutrient out-fluxes from the coastal zone where:**

- dissolved nutrients, because of the fish digestion of the fish feed, are in the steady water column out of the fish farming units and is kept inside fluxes pipes that can be directed toward similar enclosed floating aquaponic units. Here, cultivation of macroalgae can assimilate a high proportion of such nutrient and shellfish cultures will capture a large proportion of suspended particles.
- However, an introduction of this farming platform must be carefully verified according to local weather conditions (currents and wave height and suitable locations with annual waste quota).
- The shellfish will physical active filter out suspended organic particles from the same fish holding units, these particles are directed in a closed pipe loop toward similar mussel bags.
- The mussel capturing organic materials result in reduced waste fluxes year-round, the photosynthesis by the macroalgae will assimilate the dissolved nutrient only part of the year when there is enough sunlight that trigger such a photosynthesis.

All details related to Aquaponic setup, principles and calculations is found in Appendix 1, 4 and 5.

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The potential of annual produced rainbow trout from fish tanks on-land 10 000 tons and similar biomass form floating bag concept shows the total potential of 40 000 tons rainbow trout in the region per year. Circular economy for the on-land and bag concept is approx. 250 jobs.

Circular economy by the aquaponic integration may, roughly estimated to be additional 175 jobs. Appendix 7 gives more information of Circular economy.

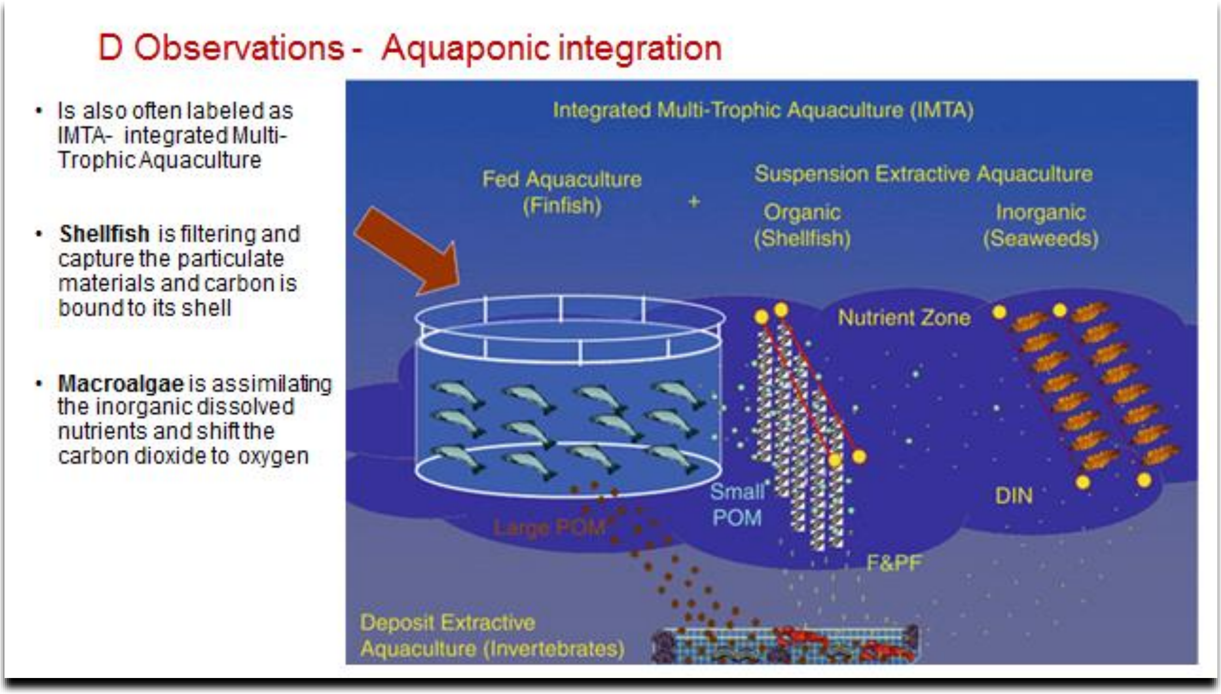

Figure 5. Illustrations of aquaponic setup.

<u>The growth potential of macroalgae *Ulva intestinalis* in the region.</u>

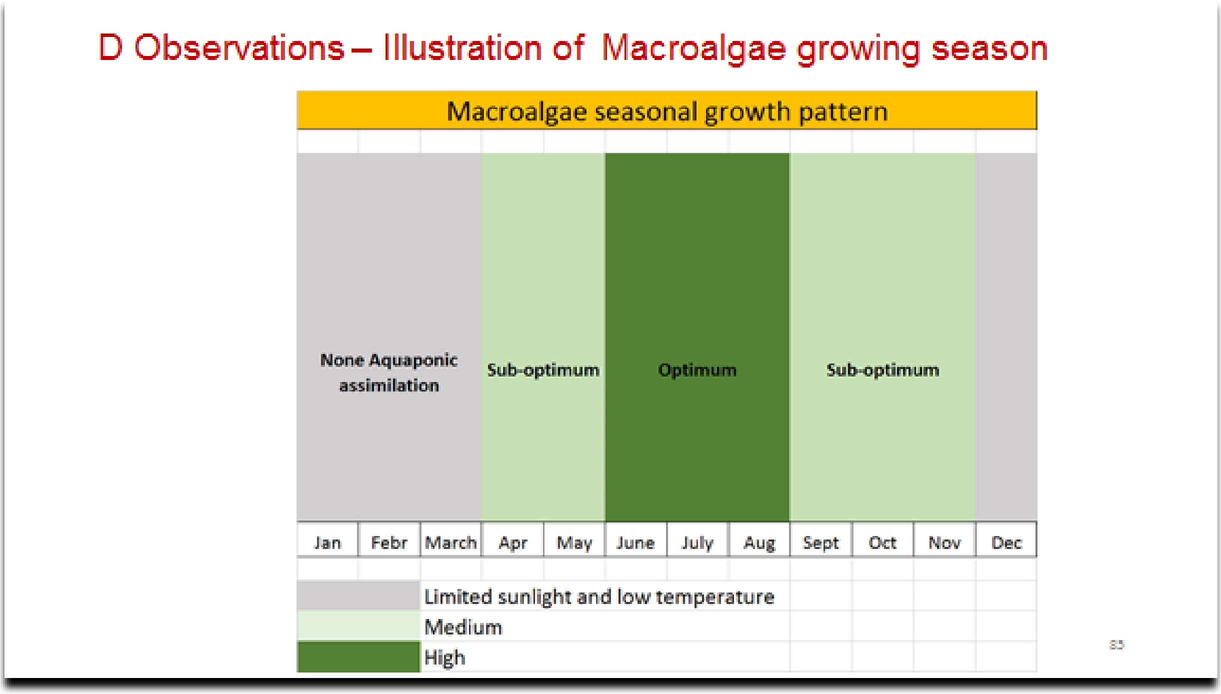

Figure 6. Macroalgae growth potential.

<u>The filtration potential of blue mussel in the region.</u>

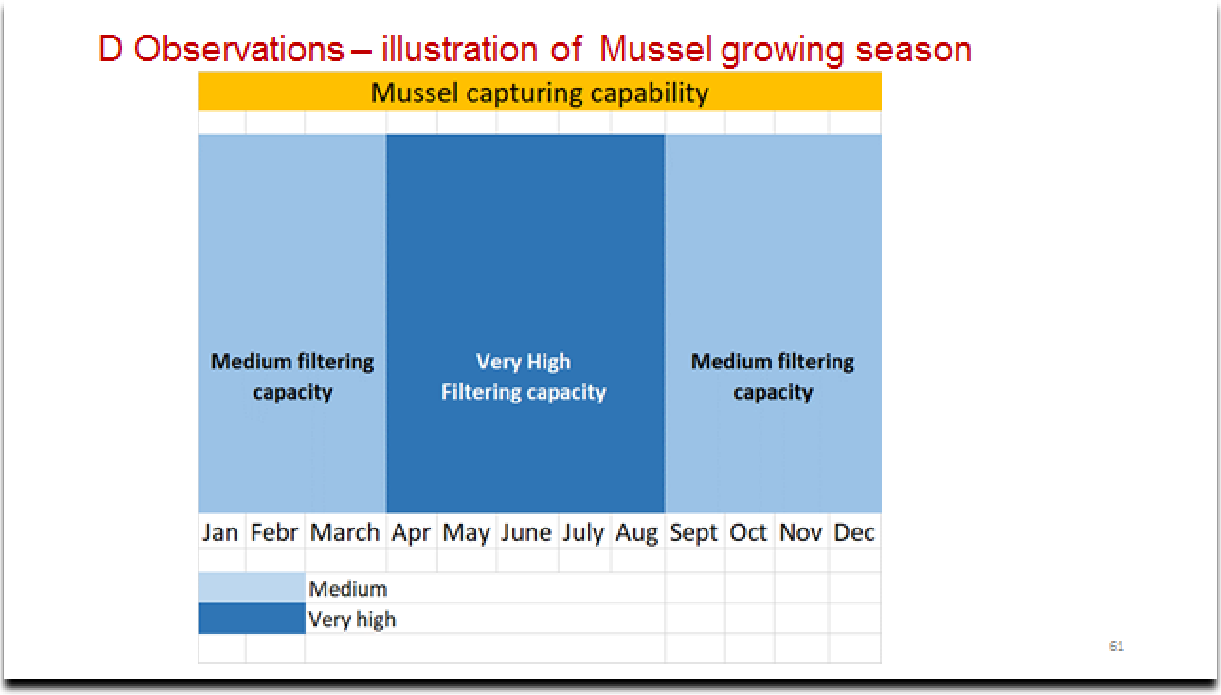

Figure 7. Blue mussel filtration performance.

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For the best integration toward an **aquaponic mussel cultivation** we predict that it is best if a high proportion of the organic suspended particles from the fish units (land based or the listed floating fish bags) are captured first by mechanical water filtration units – in this report suggested as 100 micro screens. This may result that approx. 55% of the organic waste is physical taken out from the fluxes – the remaining smaller particulate fraction is then dedicated to filtering shellfish populations.

a) The organic fish waste fraction entering mussel units can be fully captured by the filtering mussel population. This represents a zero net organic flux to sea. Fluxes of nitrogen (N) and phosphorus (P) which are bound to these particles are reduced, see Figure 8 below.

b) Further, similar arrangement can also be done with aquaponic macroalgae production reducing the dissolved nutrient fluxes (N and P) further to the next level, see Figure 8.

c) The combined water mechanical filtration, mussel and macroalgae aquaponic setup shows a potential that total N quantity per kg fish produced can be reduced by 60% compared to the threshold level of the Water Act and total P is reduced by 90% benchmark against the Water Act, Figure 8.

d) These reduction levels of nitrogen and phosphorus is the average yearly levels where the macroalgae reduction in the best growing months is high and it is absent in the dark winter months (Figure 6) whereas mussels show almost steady activity (Figure 7).

e) These reductions requires that the water floating out of fish bags and tanks on-land are first directed to mechanical filtration as stated above. Other advanced filtration setups may reduce the fluxes more.

C Executive Summary - West Estonian environmental impact

	Nitrogen gram/kg fish	Phosphorus gram/kg fish
Current Water Act per 1kg fish produced	50,0	7,0
Latest Baltic fish feed Open nets	44,4	5,1
Tanks/ bags excluding mechanical water filtration	37,6	4,0
Tanks/bags with water filtration 100 micro	35,5	2,7
Tanks/bags with water filtration + mussel	33,7	1,6
Tanks/bags with water filtration + mussel + algae	20,2 (-60%)	0,8 (-89%)

Physical integrated aquaponic algae and mussel to Open net farming is impossible

Organic waste can be fully captured by the filtering mussel for tanks on land and floating fish bags
Open sea cultivation of macroalgae «green grass» is difficult to setup, fragile, weather conditions - problematic economy platform?
Open sea cultivation of blue mussel is capable of capture waste volume of ambient natural suspended organic materials, that can counterbalance the fluxes from fish farming activity - however the cultivation dimensions are very very large

Figure 8. Gross and net fluxes with and without aquaponic setup.

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Comments;

The Open nets strategy illustrated in Figure 8 is having fluxes as 44 grams N and 5.1 grams P. As such water fluxes is impossible to be linked to mechanical water filtrations nor the mussel-macroalgae integration can be applied.

The net waste fluxes fully integrated with aquaponic setup in close water loops may result in

1. Zero organic waste to sea.
2. Nitrogen and phosphorus levels is reduced by 60% and 89% benchmark with the maximum threshold level listed in the Water Act.

Such an integration with both algae and mussel will also reduce the carbon dioxide from the fish farming units and will end up as oxygen (algae activity) and carbonate bound to the shell (the mussel activity).

- The photosynthesis will also have the result that large quantity of oxygen is produced by the algae – dissolved to the water column during daytime.
- The final products from mussel and algae cultivation should be directed toward animal feed, human food, energy resource and fish feed.
- The aquaponic integration if successful will also improve the circular economy - a best guess is that this may introduce in the range of 175 jobs to the zone.

Appendix 1 gives more information of waste and nutrient allocations.

The figure below summarizes the potential of circular economy.

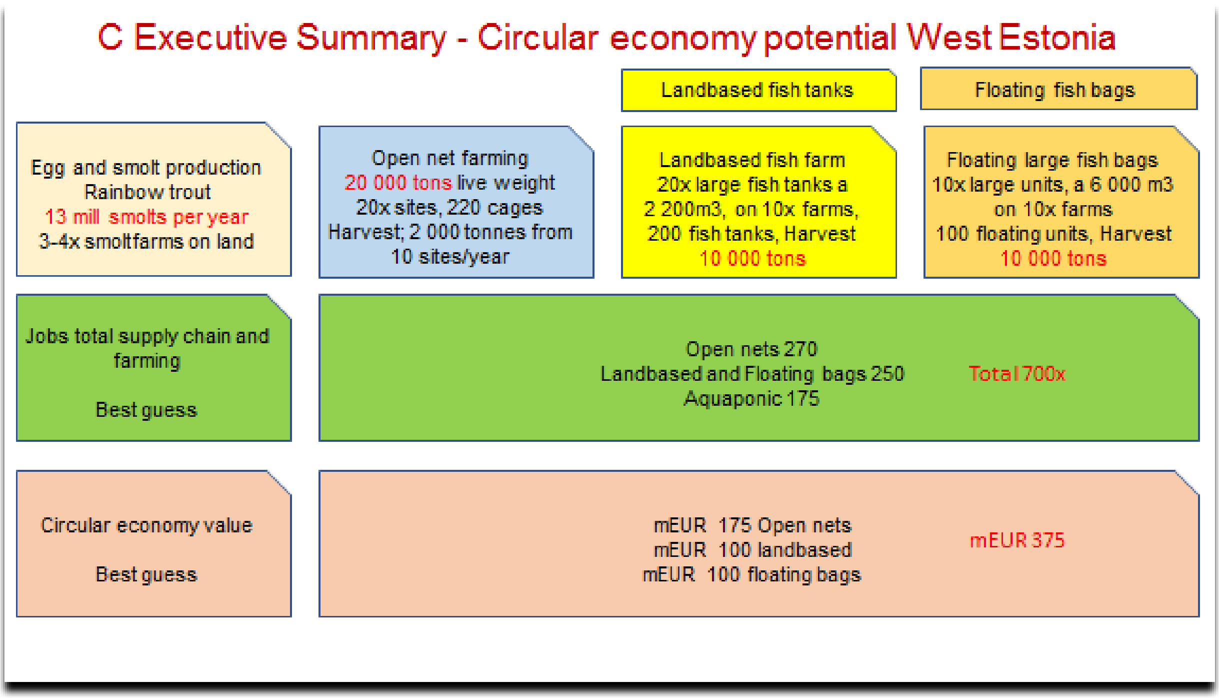

Figure 9. Potential circular economy.

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If Open nets and the two illustrated enclosed farming concepts can be arranged a total of approx. **700 jobs, 40 000 tons /year live weight and 350 MEUR in circular economy** can be found - a high proportion of the jobs are related to logistic and services/ maintenance.

Potential good location should be found at the Western part of Hiiumaa and Saaremaa Island.

We consider this coastal zone to have the best conditions both for fish farming but also for aquaponic integration. This zone has

- The best water quality in terms of ambient nutrient concentrations
- Good current
- Not too high summer temperature
- Not too low winter temperature
- The best environmental conditions for blue mussel
- Is among the less populated areas that receives almost no industry waste.

On the other hand, these good conditions are very often associated with a more rougher climatic conditions where one will experience stronger wind, larger waves and a periodic presence of winter ice.

Such conditions are not complicated for land-based fish farms; however, for Open net and special for floating bag concept one must be careful.

Open Nets can easily withstand 2–3 m wave height, whereas the more "Offshore" version can withstand 3–5 m waves and the large heavy duty Offshore steel constructions can withstand any wave and wind conditions in the North Sea, this is also probably true for the Baltic Sea region.

A criteria list for farming sites.

As there are various activities for tourists, navy, commercial fishing along the coast and the fact that defined zones are yet to be allocated for aquaculture, below we list criteria that could act as one of several selection/ identification of suitable farming sites.

Open net farming conventional dimensions (steel or plastic cages ø 90m, 120m or 160 m circumference, special criteria for **Floating bags** is marked in red.

a. max temp 18,0 °C, min 2,0 °C
b. no ice
c. > 20 m to seabed, bags minimum >15 m
d. max wave height 1–2 m for floating bags
e. max wave height for Open nets near shore approx. 3 m
f. max wave height for Offshore Open net farming medium duty version 3–5 m

g. max wave height for Offshore heavy-duty cages >10 m
h. distances between farming locations near shore > 2–3 km, best is 3–5 km; this is very dependent on topography and landscape
i. current > 15 cm/sec < 100 cm/sec, good current is very positive as the depth to seabed is normally somewhat restricted, this current will ensure that wastes are spread over a large area thereby causing less eutrophication
j. floating feed barge with kwh or access to grid system from land or by generator, wave height 3 m
k. defined waste flux quota per year per location
l. access to pier is very positive, but pier/harbor could easy be located 1–2 km from the fish farm (net farm)
m. service boat 15 m long

Land based in seawater

n. near shore, try to avoid a construction building height > 5 m above the sea level, otherwise pumping cost is costly
o. very close to shore < 30 m, reduce water pipe dimensions
p. filtering station should be a criterion, define filtering screen
q. oxygen generator
r. electric generator
s. warehouse – personnel, workshop, service, feed, equipment
t. fish tanks can be open, no need inhouse structures
u. sea temperature 2–18 °C, optimum is 14 °C
v. permit for a seawater-based land-based farm should be allowed to use and pumps as much seawater that is wanted, there should not be any limitations (example Kesknõmme)
w. defined waste flux quota per year
x. 2 km from nearby farms (open nets and other land-based farms
y. Large backup system for oxygen and kWh
z. There are natural ambient virus and bacteria in the marine ecosystem, and these will find their routes to the fish; careful evaluate the need for UV, ozone and disinfection of the incoming water.

Land based in freshwater

aa. The freshwater reservoir would probably be small along the coastline
bb. The best would be that a water reservoir is as large as possible
cc. I strongly avoid you to exploit the freshwater lakes you have, as they are very valuable
dd. If location had gravity freshwater even far from the coastline – for hatchery/ smolt production – that would be perfect
ee. A modern RAS hatchery/smolt construction should then be looked upon
ff. High tech version is fully functional but very costly
gg. Re-use of water, normally full control of the temperature, oxygen, and water chemistry parameters
hh. Heat recovers for the water year round

ii. Large backup system for oxygen and kwh
jj. Too high freshwater temperature mid-summer–September could cause problems
kk. Sterile groundwater is the absolutely best location, if not a UV and disinfection system should be installed.

Harvest station/processing for farmed fish

ll. The best selection is a seabed plat with pier
mm. Access to sweater and live fish hauling by use of well boat
nn. Ensure good harvest quality
oo. Could consider being located to an already existing pelagic processing plant
pp. Does not need to be located close to the fish farms, one could easy have a sailing route of 2–8 hours without this being negative for the live fish

The proper growth of green grass *U. intestinalis* is normally found:

- the salinity is 0.5 psu to max. 15 psu
- sea temperature is 5-15 °C
- elevated nutrient concentrations (especially nitrogen compounds)

The proper growth of blue mussel (*M. edulis*) is expected under the following conditions:

- the salinity is above 5.5 psu;
- sea temperature is not limiting its growth but longer periods (> 2 weeks) above 28 °C should be avoided;
- suitable growth areas are situated in marine waters west to Saaremaa (Baltic Proper) providing a minimum depth of 5 m;
- suitable growth areas are situated in marine waters west and north to Hiiumaa (Baltic Proper) providing a minimum depth of 5 m.

Aquaculture companies in cooperation with the region must verify this Reports finding and lead the way forward to

a. Identify sea and on-land locations/zones, each with defined flux quota, we highly recommend focusing of the exploiting of the Western part of Hiiumaa and Saaremaa Islands.
b. **Update terms for aquaculture** that motives economy of scale plants to be constructed.
c. **Identify smolt farm locations** - i.e., 2–3 mill capacity each, for every 10 000 tons large fish one need 3.5 mill smolts, without smolt plant no growing activity will take place, motivation terms for these are crucial.
d. Take initiatives for a Governmental **marine lab and field station** that act as knowhow and service delivery and **importantly** link this to cross Nordic co-operation and make West Estonia be a leading playing partner in aquaponic integration in the region.
e. **Invite international leading industrial company to seminar**; wind energy, fish farmer, investors, secondary processing industry, local pelagic fishing companies, shipyard,

Norwegian/Scottish manufacturer of modern farming platforms. The seminar should strategically motivate partners to

- Get in touch.
- Be aware of the possibilities.
- Look towards Estonia instead of Iceland, North Sea, Newfoundland, or RAS investments on land.
- All partners are 45 minutes flight from Tallinn, are under a Nordic culture and business understanding. Estonia being a major IT and IoT provider could take very good positions in such aquaponic integration.
- **Forward fact-based information about the possibilities, region, conditions, companies, motive for JV.**
- **Wind energy companies** may play a major role - as Baltic Sea do need innovative solutions for maritime aquaculture constructions.
  - Set up a shared pool of service, maintenance and logistic.
  - JV
  - Construction components
  - Terms for applied wind energy licenses could certainly be linked to various requirements, one could be to establish a wind-aqua fond, where the sizes of wind park could have a price/ contribution value.
  - Such contributions could be services, kwh, cash so that the Pilot stations / marine lab could be setup.
  - The wind energy companies need service from such a station too.

f) **Secondary salmon processing industry** in France, Germany, Poland is desperate to have control of their own farming biomass, cost wise, risk mitigation, harvest, and biomass planning in house.

g) Avoid the position which fish farmers in Finland, Sweden and Denmark currently experience.

h) **There are none farming licenses cost entry barrier today** but be smart and find an economical/ contribution friendly mechanisms for this.

i) **Risks,** weather conditions, aquaponic net result (filtering and photosynthesis capabilities inside floating units), smolt farms, political willingness, protest from neighbors, tourist, and agriculture.

j) **Remark: production cost** of gutted large rainbow trout without aquaponic integration is previous been found identical as Norway.

<u>The main risk elements are illustrated below.</u>

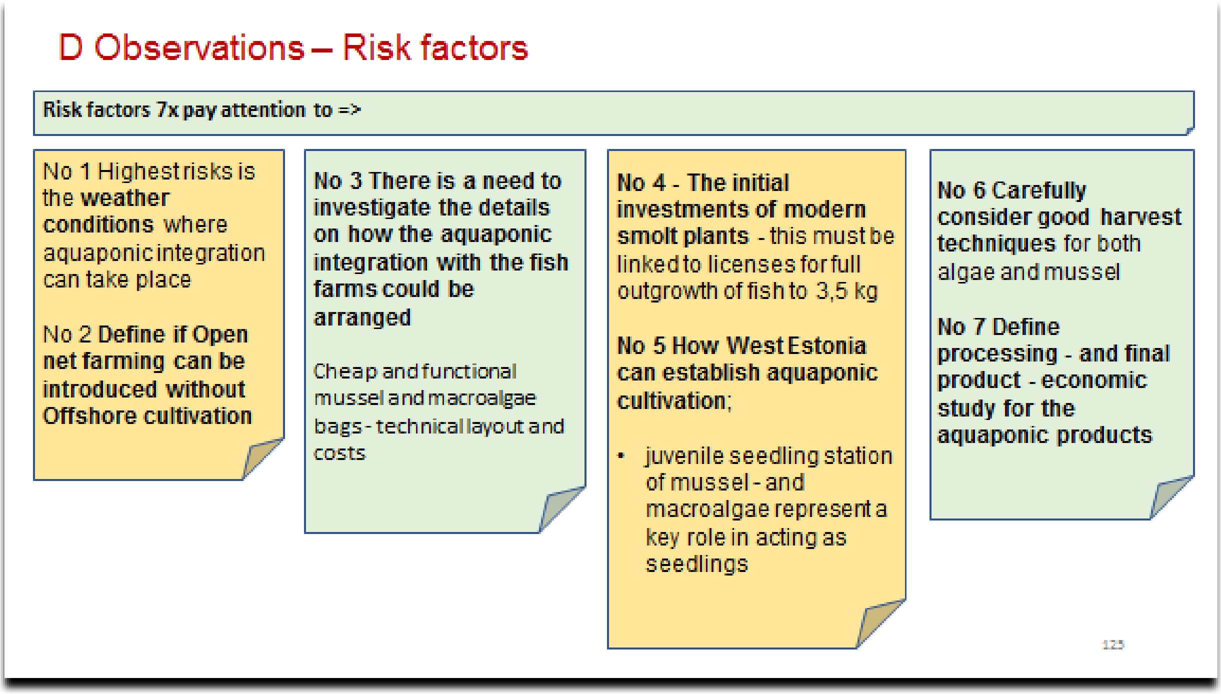

Figure 10. Risk elements.

These risk elements must be considered.

<u>Conclusion flux waste reduction identified in this report.</u>

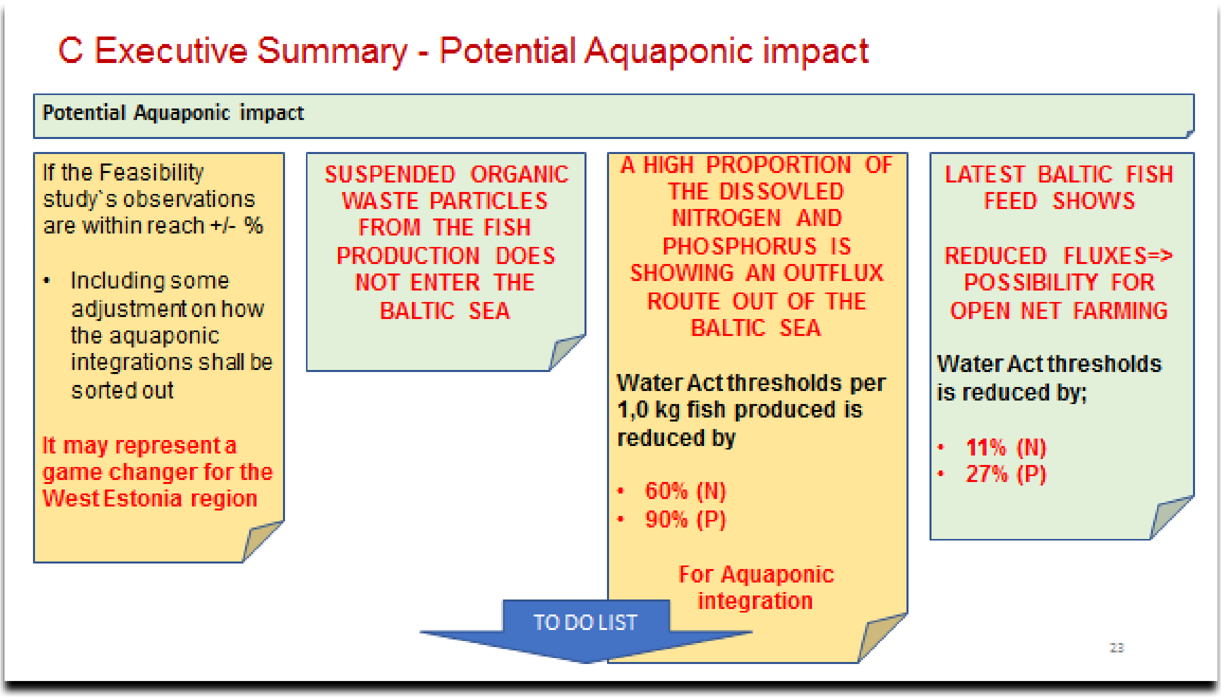

Figure 11. Aquaponic flux reductions.

<u>Comments:</u>

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a) It is important that the suggested aquaponic solution is carefully integrated in a manner where nutrients and organic wastes are conserved.
b) That the mussels and macroalgae are given good growth conditions.
c) That little macroalgae and mussel are lost to the environment.
d) That waste from the mussel filtering activity should also physically be pumped a shore.

<u>Our recommended TO DO list for WEM.</u>

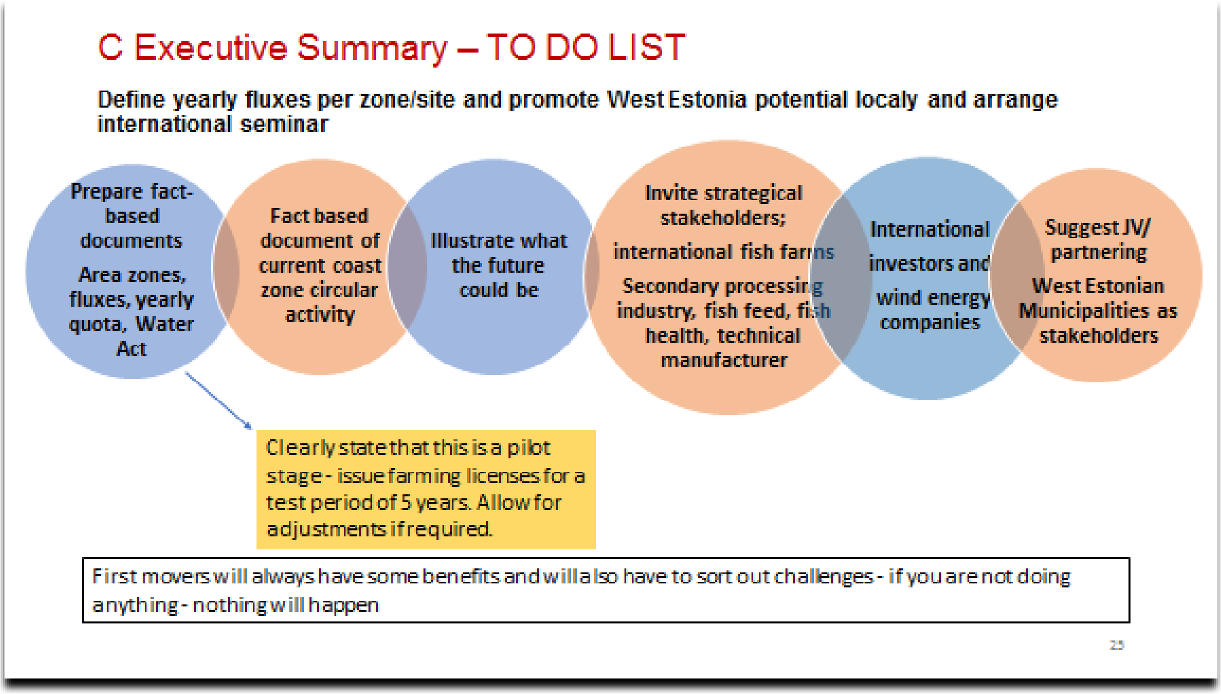

Figure 12. TO DO list.

Some details to circular economy.

Open net platform - Potential fish farming production and other sector services for West Estonia

	number of farms	no of companies	management and admin for each company	sum admin employees	no of farming staff	Biomass live harvested per year MT	fish health	no of nets and cages	net service staff	cages and moorings adn logistic to sea sites incl fishfeed	mechanicl services	Processing gutted in box	wellboat jobs	styro box and transport	n truck trips per year to Tallinn	transport gutted fish to Tallinn, 18 MT/truck- n manyear per year on eperson 1x trip 250 days a year	no of primary processing plants	foodsafety monitoring, weekly inspection of processing plants	total manyear per year
smolt plants	1	1	3	3	7		1				2								
	2	2	3	6	14		2				2								
	3	3	3	9	21		2				4								
	4	4	3	12	28		3				4								
	5	5	3	15	35		3				5								
Open net farms	2	1	4	4	20	4 000	0,3	44	4	4	2	8	5	2	222	1	1	0,5	
	4	2	4	8	40	6 000	0,5	67	6	8	4	12	5	2	333	1	1	0,5	
	8	4	4	16	80	16 000	1	178	12	16	5	32	10	4	889	4	1	1	
	10	5	4	20	100	20 000	1,5	222	15	20	8	40	10	4	1 111	4	1	1	
Open net platform - no of man-year per year excl aquaponic smolt to market																			
production volume at sea																			
4 000				7	27		1,3		4	4	4	8	5	2		1		0,5	64
6 000				14	54		2,5		6	8	6	12	5	2		1		0,5	111
16 000				25	101		3		12	16	9	32	10	4		4		1	217
20 000				32	128		4,5		15	20	12	40	10	4		4		1	271

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Floating bags and land based fish tanks - Potential fish farming production, aquaponic integration and other sector services for West Estonia																			
	number of farms	no of companies	management and admin for each company	sum admin employees	no of farming staff	Biomass live harvested per year MT	fish health	no of tanks bags	net service staff	logistics and fish feed	mechanicl services	Processing gutted in box	wellboat jobs	styro box and transport	n truck trips per year to Tallinn	transport gutted fish to Tallinn, 18 MT/truck- n manyear per year on eperson 1x trip 250 days a year	no of primary processing plants	foodsafety monitoring, weekly inspection of processing plants	total manyear per year
Landbased	1	1	3	3	10	2 000	1	20		1	2	4		1	111	0	1	0,5	
	2	2	3	6	20	4 000	2	40		1	4	8		1	222	1	1	0,5	
	3	3	3	9	30	6 000	2	60		2	6	12		2	333	1	1	1	
	4	4	3	12	40	8 000	3	80		2	8	16		2	444	2	1	1	
	5	5	3	15	50	10 000	3	100		3	10	20		3	556	2	1	1	
															-				
Floating bags	2	2	3	6	20	2 000	1	20		2	4	4	5	2	111	0	1	0,5	
	4	4	3	12	40	4 000	2	40		3	8	8	5	2	222	1	1	0,5	
	8	8	3	24	60	8 000	3	80		3	16	16	10	4	444	2	1	1	
	10	10	3	30	100	10 000	4	100		4	20	20	10	4	556	2	1	1	
Sum landbased and floating bags - no of man-year per year - smolt to market, excl aquaponic activity																			
production volume at sea																			
6 000				9	30		2			3	6	8	5	3		1		1	68
10 000				18	60		4			4	12	16	5	3		2		1	125
16 000				33	90		5			5	22	28	10	6		3		2	204
20 000				42	140		7			6	28	36	10	6		4		2	281
Aquaponic integration to landbased and floating bags; cultivation, harvest and processing																			
production volume at sea	No landbsed and floating sitesopen pen sites				no of aquaponic production staff	no of staff processing mussel	secondary processing no staff	producing and mussel seedling	staff number processing macroalgae	sedconadry processing no staff	producing and mussel seedling	black solider, waste cycle		fish health smolt and ongrowing					number must be verified
4 000	4		Aquaponic		8	4	4	2	4	4	2	3							31
6 000	6		Aquaponic		12	8	8	4	8	8	4	6							58
16 000	16		Aquaponic		32	16	16	8	16	16	8	12							124
20 000	20		Aquaponic		40	20	20	20	20	20	20	15							175

Figure 13. Detail circular economy observations.

Chapter 3

3. Potential within trout production.

This Study report covers the need for Brood stock, eggs, smolt and on growing.

3.1. Potential for brood stock, egg, smolt and ongoing production and locations

The modern egg breeding program for selection of brood stock and disease resistance are well established in the Nordic region. It is highly recommended that West Estonia select egg materials based upon low saline environment but also on the experience seawater farmed large rainbow trout have with respect to disease, virus as Flavobacteria and bacteria as Furunculoses must be paid attention to.

Source eggs abroad, at a later stage one could introduce a local breeding program; however, that takes many years.

Imported eggs should be kept in quarantine locations prior to being distributed.

3.2. Land based farming techniques for West Estonia.

Land based farm is normally setup by 2 techniques.

a. Conventional large tanks on land, often in metal, concrete or fiberglass, water is pumped onshore, used once by the growing fish biomass, filtered off organic particles and is entering back the sea. Most smolt farms and brood stock station are constructed in this manner. They represent a very robust and reliable platform and are dependent upon pumping saltwater, oxygen, and kWh supply.

b. Modern RAS Recirculation Aquaculture System is a more advanced and technical land-based platform. Here, one could use solely freshwater – or brackish or saltwater.

> Recirculation aquaculture systems (RAS) represent a new and unique way to farm fish. Instead of the traditional method of growing fish outdoors in open tanks and raceways, this system rears fish at high densities in indoor tanks with a "controlled" environment. Recirculating systems filter and clean the water for recycling back through fish culture tanks. New water is added to the tanks only to make up for splash out and evaporation and for that used to flush out waste materials. In contrast, many raceway systems used to grow trout are termed "open" or "flow through" systems because all the water makes only one pass through the tank and then discarded. Fish grown in RAS must be supplied with all the conditions necessary to remain healthy and grow. They need a continuous supply of clean water at a temperature and dissolved oxygen content that are optimum for growth. A filtering (biofilter) system is necessary to purify the water and remove or detoxify harmful waste products and uneaten feed.

In this Study report we assume that conventional land-based tanks system with single use of water could be the first choice. We consider the RAS system to be very modern but also very expensive.

We have modelled fish production for conventional land tanks where cohorts of smolts are stocked every 2nd week year-round. As smolt is approx. 100 gram and fed to approx. 3.5 kg- this requires 60–70 weeks farming period. The individual land tanks are stocked, fed and harvested year-round; there will also every 2nd week be similar quantity fish harvested out of the farm. In this manner one reaches a steady status of biomass, feed volume and water flow during the 2nd and 3rd year. At this stage, the digestion of feed nutrient and the outflux of wastes from the platform is having a steady state 24/7; however, with some seasonal adjustment according to temperature in the water as this trigger the growth of the trout.

Land based fish farming

We have included large fish tanks on-land to estimate the production, feed volume and waste fluxes for location being approved with such a farming concept.

The fish will digest and produce waste regardless of which tank farm they are kept in; however, our study is large tanks 4.5 m water height and diameter of 22 meter, 2 200 m^3 each. With a density of approx. 35 kg trout/m^3, the productivity per fish tank is in the range of 90 tons live weight per year. This biomass produced require then a fish feed volume and will produce its wastes entering the outflux water to the mechanical filter station prior entering the sea. In an enclosed aquaponic integration this flux is entering mussel and/or macroalgae units.

There is a vast number of fish tanks configurations – below are some illustrations.

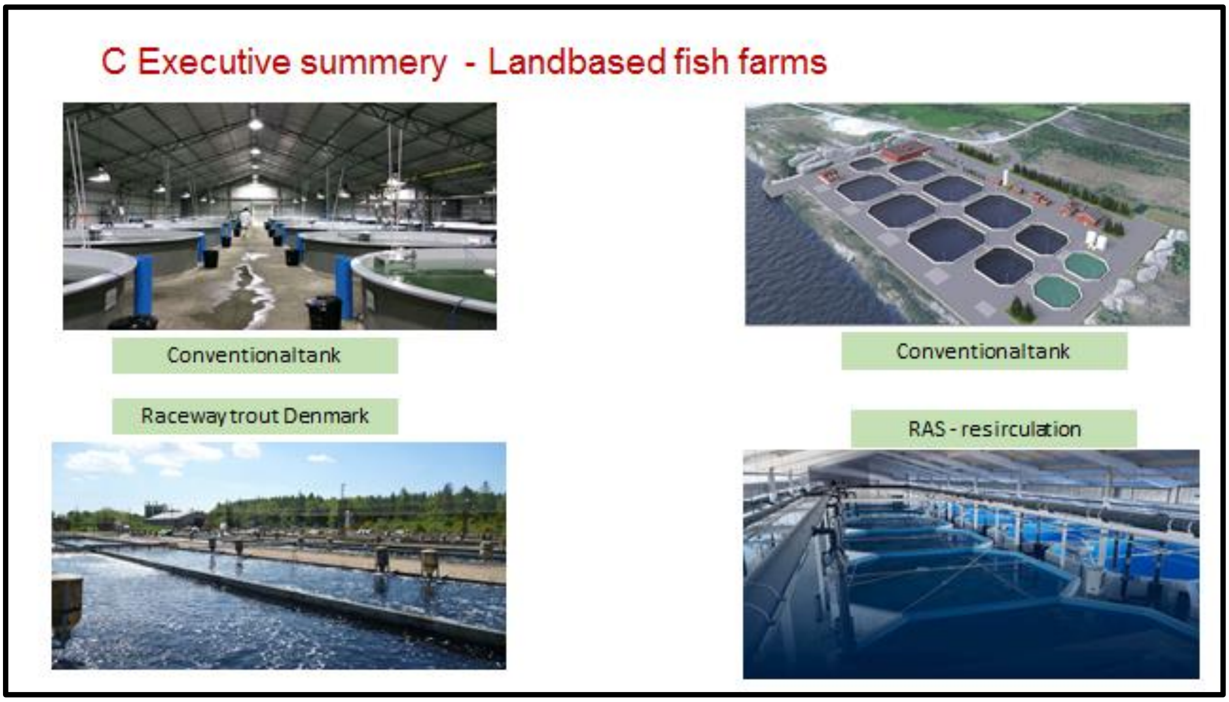

Figure 14. Various fish tanks on land.

3.3. Offshore farming techniques for West Estonia.

In this study we label Open net farming platform similar as “Offshore farming”. However, there are various types of Open net platform.

a. Conventional Open net framed over smaller steel cages or plastic round cages formed by two large PEH pipes, where the fish nets are installed to. The nets hang vertical down to approx. 10 m or deeper depending upon the depth to seabed.
b. Offshore plastic cages, often found in Norway, Scotland, and the Faroe Island. Some manufacturer even allows the nets to be periodic submersible under the ocean surface which is best suited for severe winter conditions and or if drifting ice should show up.
c. Large rougher Offshore steel platform has been constructed and are in use in the North Sea, Yellow Sea (China), Australia. These constructions are suitable for salmonid production and are very large, each unit has a volume up to 500 000 m^3 seawater inside the net and could produce approx. 10–20 000 tons per year.

In this Study report we have not discriminated among these Open net platforms; however we predict that Open net cages versions a) and b) listed above would be the first choice.

Open net farm general information

All nutrients and waste from the Open net farming setup do enter the water column.

a) However, with modern fish feed these fluxes are reduced.
b) The Open net platform is the dominant strategy worldwide for salmonid production.

c) It is very effective.
d) Represent a low capex entry cost.
e) The faming technique and protocols is highly improved over many years.
f) Requires hardly any land-based setup except for harvest and processing.
g) Is a very low area demanding platform with a fantastic high productivity.

Figure 15. Open net farm illustration.

- The overall salmon production dominated by Norway, Scotland, Chile and North America is by use of Open net technology which is characterized by
    - A low-cost setup.
    - Very functional and easy to operate, but it is also a very low utilization of the aquaponic potential. All wastes and nutrients are entering the open sea where they are heavily diluted.
    - It is difficult to collect the large, suspended particle fraction from the open nets. The excess waste from the fish production will settle to the seabed and will increase the eutrophication and drive the oxygen combusting in a negative direction.
    - However, any increased amount of land animal meat production will also result in extra fluxes both from the agriculture sector by producing the animal feed itself (fertilizer, transport), and by the animal digestion of the feed.

Floating fish bag technique

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Figure 16 depicts one four different enclosed systems commercially available in Norway; manufacturer www.Ecomerden.no

The drawings illustrate the arrangement of the floating surface collar ring where the bag is attached. Inlet pipes, generator and pumping facilities are integrated into the collar. This unit is of large size, 30 000 m^3 with a diameter of 40 m and a depth of 20 m.

Smaller arrangements with smaller volume sizes special adapter for the shallow exposed West Estonia coastline must be considered. In our report we have scale the dimensions down to cover a bag unit of 6 200 m^3, being 10 m deep and a diameter of 24 meter. We will lead the outcoming wastewater with the organic materials and dissolved nutrient by an enclosed pipe loop to a mechanical filtration station. Here a high proportion of the suspended particles is withdrawn from the outlet water; however, the dissolved nutrients remain in the water passing through this mechanical filter.

The remaining suspended micro-particles will also be remained in the outflux water from the fish bags and can act as mussel food. The dissolved nutrient will act as macroalgae food for its photosynthesis.

The water volume is not pumped but is pushed into the aquaponic units, resulting in approx. ⅙ of the energy requirement compared to land-based fish farming.

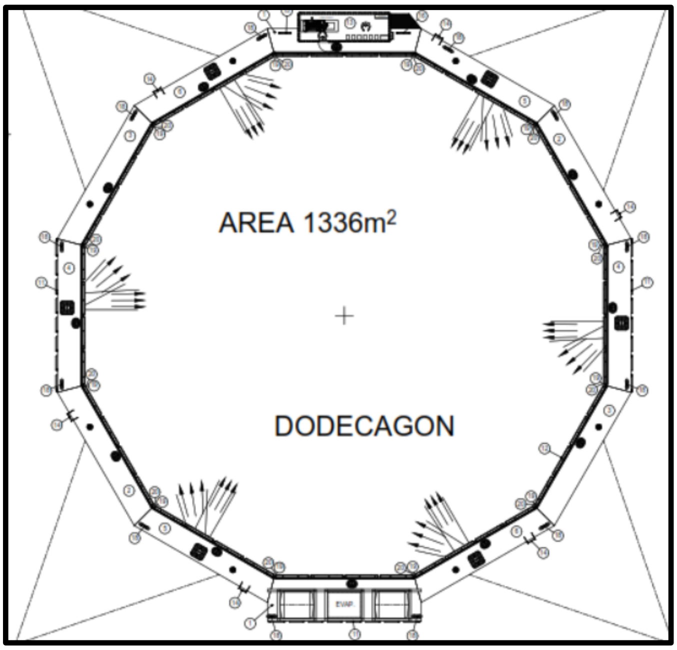

Figure 16. Illustration of the bag concept.

Illustration of the combination of one floating fish bag with traditional Open net platform Norway;

Figure 17. Floating fish bag in combination with traditional Open nets.

<u>Comments:</u>

- One large semi-enclosed floating bag with salmon production in Norway is integrated with 5 traditional open net cages.
- These units may hold approx. 100 000 – 200 000 Atlantic salmon each, at harvest their biomass is 500 MT up to 1 000 MT per unit.
- There are in total approx. 45 such enclosed floating bags in operation (24/7) in Norway today.
- Some of them are smaller, see Figure 18 below, units are operated at R&D stations providing trials for the industry, fish vaccine and for fish feed manufacturers.
- In our feasibility study for West Estonia, we have drastically reduced the number of fish per unit, but have a density of approx. 35 kg/m^3 enclosed volume at maximum resulting in approx. a total biomass prior harvest of 200–230 tons per unit, bag depth of 10 m.

Figure 18. Various dimensions of semi-enclosed floating units.

2 Production planning fish farming

The potential of fishfarming production in West Estonia is very promissing, however as with other regions one must consider the pro and con for such activity and also pay attention to potential risk factors:

As for any Open net strategy

- we predict a farming time of approx. 62 weeks for each fish group released
- where the live swimming weight is 3,5 kg
- with 10% accumulated loss
- the winter temperature will restrict the entry of smolts year round
- Natural smolt entry to sea is 1 April- 1 Oct- this will expand the whole generation period by 7 months- total generation period is close to 21 months
- A 3 months fallow period could result that re-stocking takes place every 75 weeks per site

Figure 19. Generation time, accumulated loss, harvest weight.

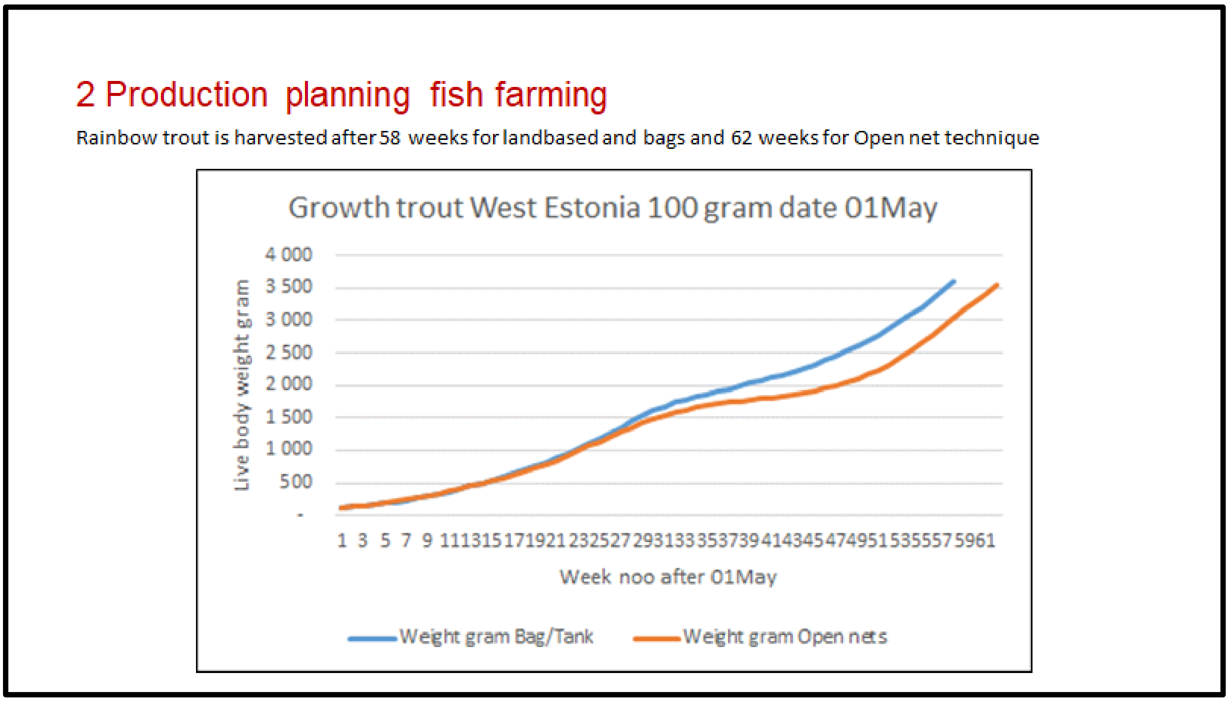

Figure 20. Growth performance Open nets versus Floating bags/tanks on land.

<u>Current fish farming activity in the Baltic Sea</u>

The situation among fish farmers, especially the one operated in Denmark, Sweden, and Finland, with Open net technique, is that their permits are under pressure and the total farmed volume of approx. 35 000 MT trout is consolidated among a few players. It is also a fact that some does practice Ocean cultivation of blue mussel (Sweden, Denmark, Finland), but to our knowledge basically none have yet strategically changed their Open net technology. Alternative farming platforms are illustrated in this report to secure a long-term predictable farming activity where public officials easy can monitor and take active part of new farming techniques which are special designed and adapted to the eutrophication conditions of the Baltic Sea.

The foundation for such a circular utilization of marine resources is looked upon where an alternative modern setup of salmonid production in the region is the baseline. This report is not specifically focusing on modern RAS facilities, Recirculation Aquaculture System, as they are very costly, technical and we consider that an entry of other modern fish farming alternatives is better suited. However, the high-tech RAS I and RAS II setup may also reduce the waste fluxes at a higher level than the straightforward mechanical water filtration set up in this report.

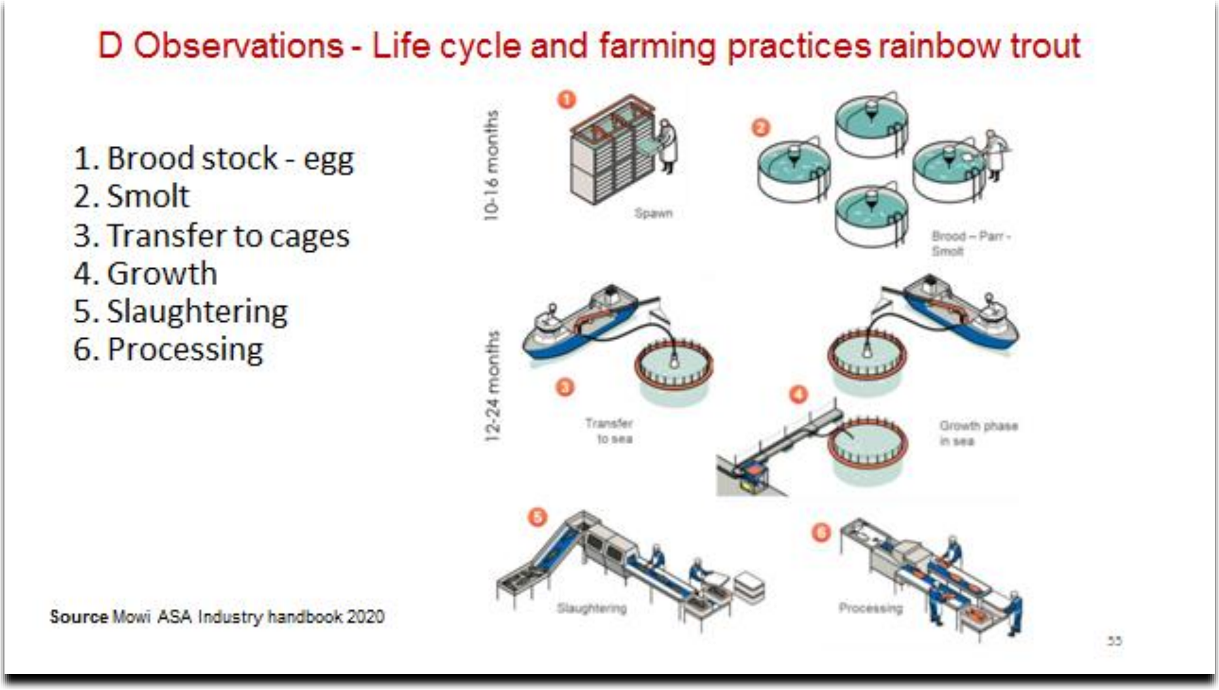

Figure 21. Life cycle rainbow trout.

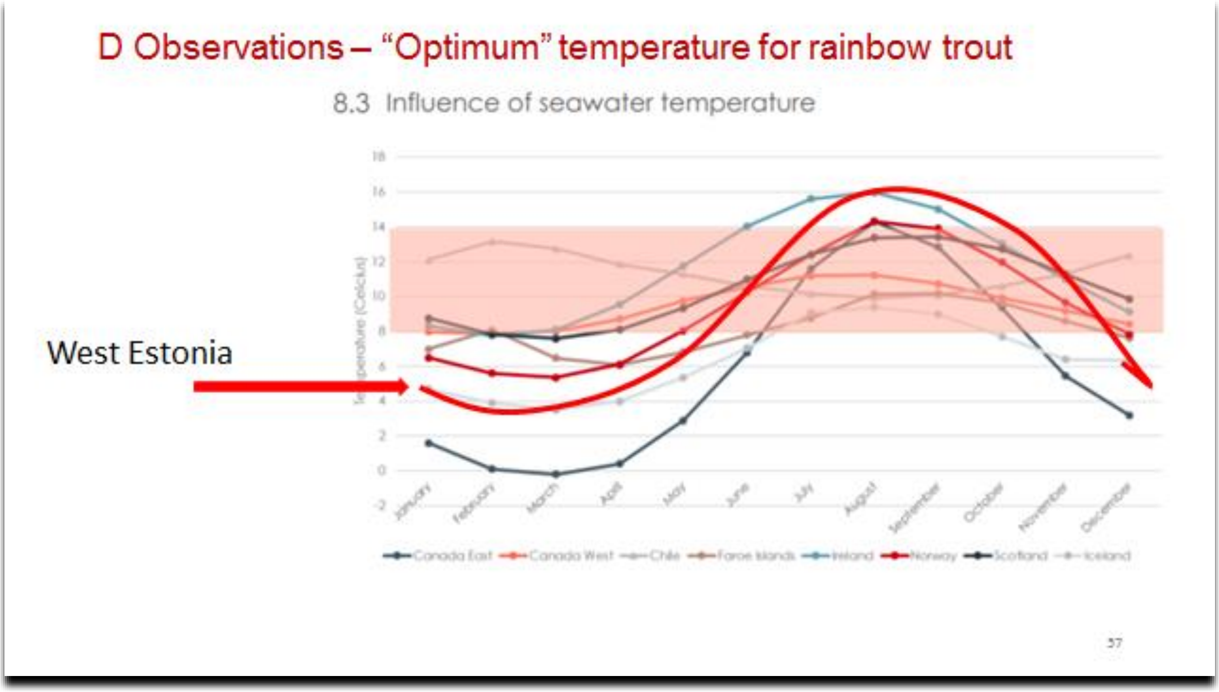

Figure 22. Temperature profile West Estonia.

Comments: the temperature profile in wintertime may be lower than 3.5 degrees, and in summertime under very good weather conditions the surface layer may reach higher profile than the illustrated 16 degrees. Swedish/Finnish trout farmer in the Northern Baltic regions have farmed trout for approx. 40 years, also in freshwater lakes. In Southern Norway trout is

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also farmed for a long period. There exist farming protocols that is well adapted to the conditions of West Estonia. Drifting ice in the springtime and severe bad weather at exposed sites will cause precaution.

3.4. Summary potential farming volume, number of sites, employees.

The overall production capacity for West Estonia of farmed volume is illustrated below.

<u>The figure below summarizes the potential of circular economy.</u>

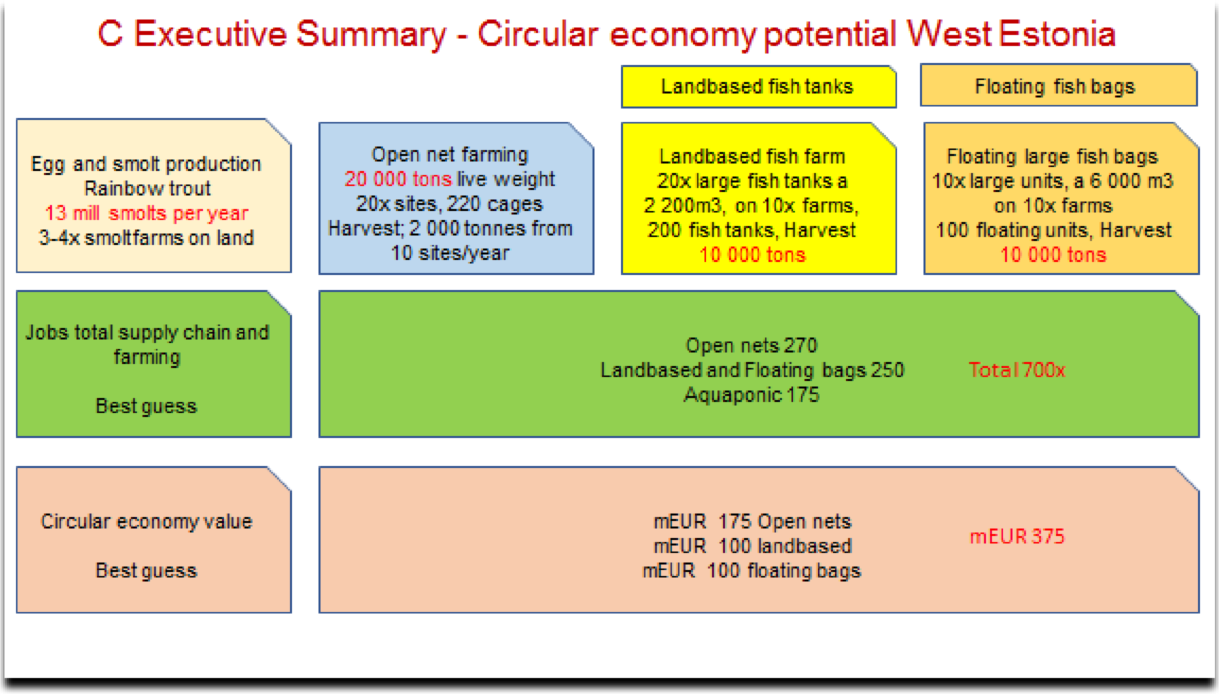

Figure 23. Potential circular economy.

If Open nets and the two illustrated enclosed farming concepts can be arranged a total of approx. **700 jobs, 40 000 tons /year live weight and 350 MEUR in circular economy** can be found – a high proportion of the jobs are related to logistic and services/maintenance.

3.5. Summary of historic and current market prices for salmonids in Estonia.

The market price for farmed rainbow trout sold from Norway are illustrated below.

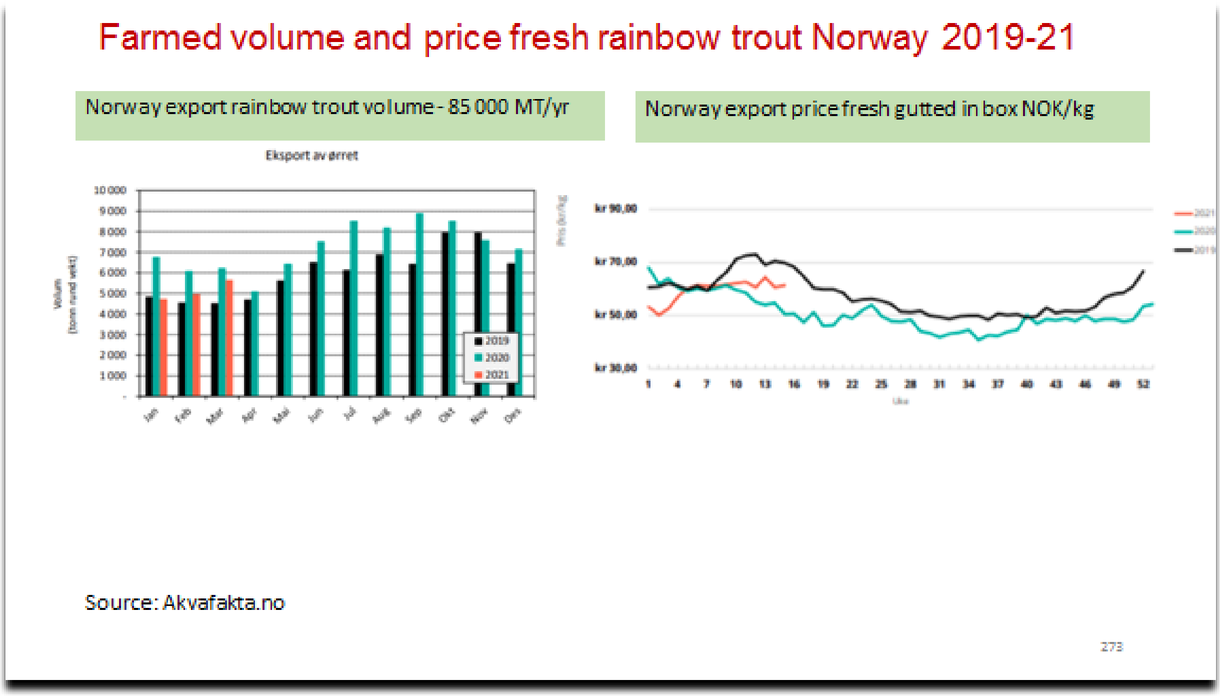

Figure 24. Farmed large seawater farmed rainbow trout from Norway is showing sold volume of approx. 100 000 tons and with a market price of NOK 45–70 per kg head on gutted.

The market price fluctuates very much also within each year with supply and demand determining such pattern. However, there is a large quantity of farmed rainbow trout in Finland, Denmark, and Sweden. Some of this is for domestic needs, rest is exported as frozen, fresh, or various added value products. Chile produces the largest volume of sea-based trout; however, a large quantity is exported to Brazil, Asia, China, and Japan.

Historic Norwegian trout farmers have received approx. NOK 60 or close to EUR 6,00 per kg gutted head on fresh trout in the last 3–4 years.

3.6. Risks, opportunities for chapter 4, (technical, volumes, discharge regulations).

Risks and opportunities are shown on page 16 above.

Chapter 4

4.1. Potential seaweed and shellfish

When setting up seaweed and shellfish cultivation one needs to consider the following aspects.

<u>The growth potential of macroalgae *Ulva intestinalis* in the region.</u>

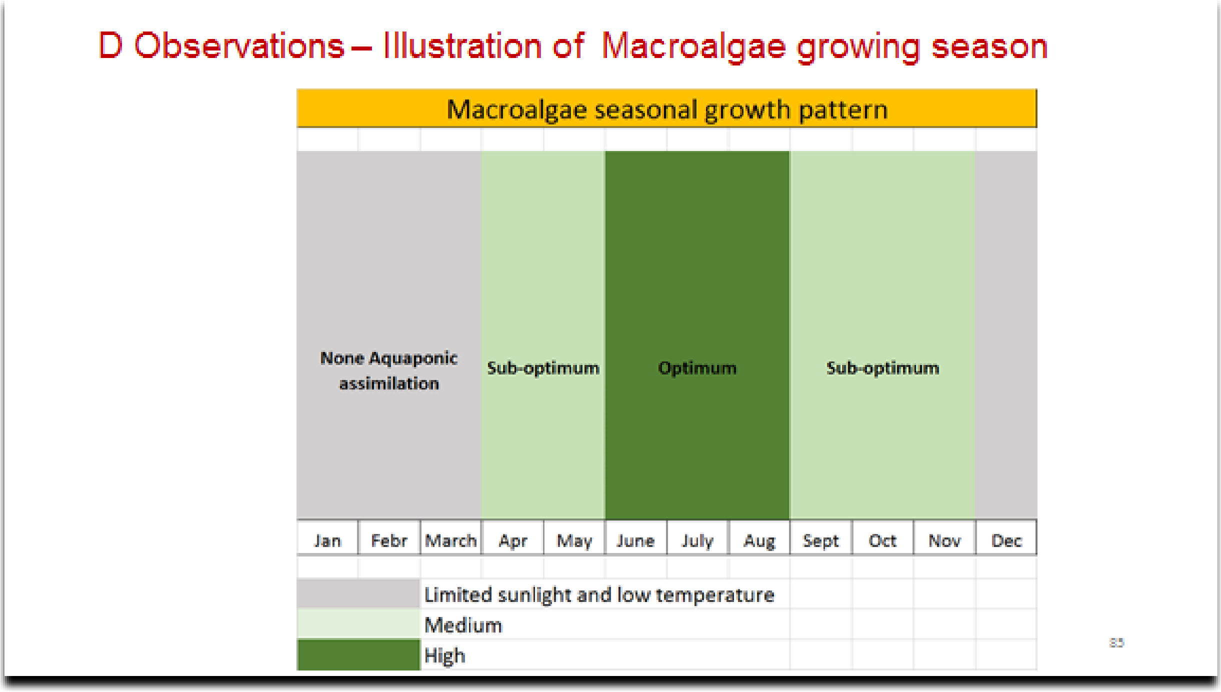

Figure 25. Macroalgae growth potential.

<u>The filtration potential of blue mussel in the region.</u>

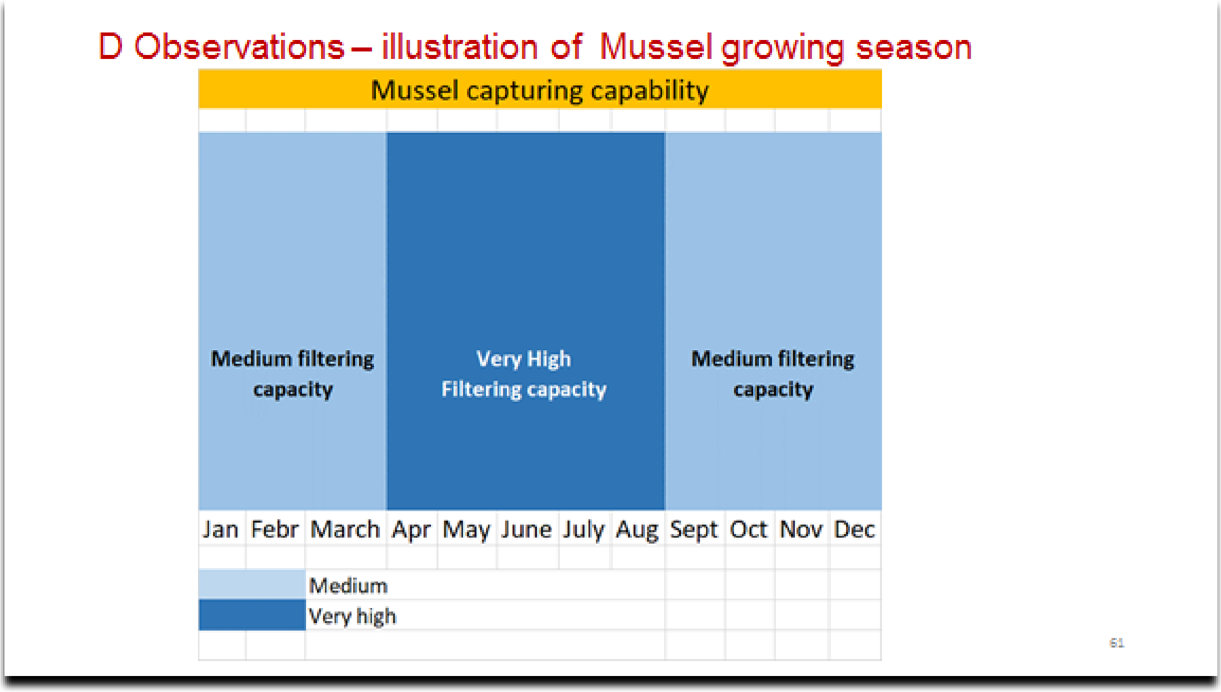

Figure 26. Blue mussel filtration performance.

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4.2. Locations

The location for aquaponic cultivation of mussel and macroalgae will be dependent upon final fish farm sites, their conditions and annual flux quota.

See also web link to various marine maps, link found on page 68.

4.3. Farming techniques

For the cultivation of macroalgae and shellfish we consider 2 options for West Estonia.

- An aquaponic integration with the fish farm
- In sea cultivation of natural populations of algae and shellfish

The Aquaponic setup

The Report is structured around **aquaponic platforms** where modern finfish production results in marine protein, rainbow trout, as human food and this activity is further linked to both macroalgae and shellfish cultivation. By combining the finfish production with algae/shellfish the nutrients and wastes from the fish production are actively assimilated and/or captured by cultured stocks of algae and shellfish. All aquaculture species are held in structures where their growth is monitored and controlled prior to harvest.

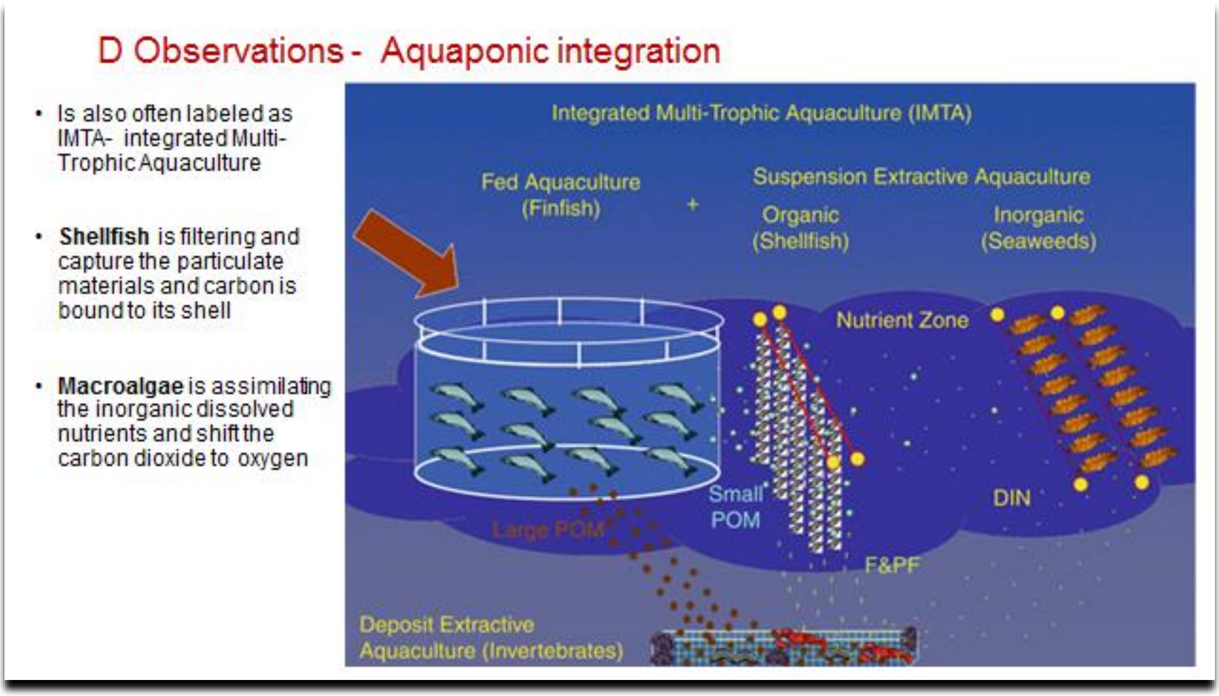

Figure 27. Illustration of aquaponic integration.

The resulting algae and shellfish products are suited as animal feed, human food, sludge, and organic wastes from the fish farms can be dewatered and act as fertilizer for the agriculture sector, other cosmetic products and may also act as an energy resource or nutrient source for black soldier flies. Blending waste from both the pelagic fishing sector, fish farming, land animal meat production and other carbohydrate sources could be directed to bio-gas production.

A mechanical water filtration from the enclosed fish biomass may result in approx. 50 grams dry weight (DW) per kg fish produced, annual volume may reach 1 000 tons DW or 10 000 tons if water content is 90%.

<u>Aquaponic principles</u>

In aquaponic system macroalga, mussel and fish units are integrated in a way that organic waste and nutrients, which are normally released to the environment, will be circulated. These wastes are the result that the fish do digest fish feed, and this result in an assimilation of lipid, protein to the growing fish, whereas feces and dissolved compounds excreted by the fish do enter the surrounding water column.

By having a planned production scheme, the harvesting of algae and shellfish results in outflux of these captured wastes from the sea.

This may drastically reduce the environmental impact of traditional fish farming activity, where we have selected farming technical platforms that allow for maximum outflux of these waste fluxes. By selecting the best algae and shellfish candidate present in the West Estonia region we will illustrate new observations of aquaponic net fluxes that may lead to a new decision platform for the West Estonia. Here, private stakeholders with public assistance can create a new positive eco-friendly utilization of the potential resources “hidden” in the West Estonia coastline.

Such an integrated circular setup is illustrated for the West Estonia region and our observations are further listed as element for an Action plan for West Estonia Government.

4.4. Summary potential farming volume, number of sites, employees, revenue

A summary of the overall farmed volume, employees, and revenue of the aquaponic cultivation of mussel and macroalgae is shown in Figure 28,

A total of approx. 175x employees could be involved in this cultivation.

Aquaponic integration to landbased and floating bags; cultivation, harvest and processing																			
production volume at sea	No landbsed and floating sitesopen pen sites				no of aquaponic production staff	no of staff processing mussel	secondary processing no staff	producing and mussel seedling	staff number processing macroalgae	sedconadry processing no staff	producing and mussel seedling	black solider, waste cycle		fish health smolt and ongrowing					number must be verified
4 000	4		Aquaponic		8	4	4	2	4	4	2	3							31
6 000	6		Aquaponic		12	8	8	4	8	8	4	6							58
16 000	16		Aquaponic		32	16	16	8	16	16	8	12							124
20 000	20		Aquaponic		40	20	20	20	20	20	20	15							175

Figure 28. Aquaponic employee summary.

There is a need for aquaponic production staff, personnel handling the final mussel volume, production of the seedling for mussel and macroalgae and last the black soldier waste recovery requires management (blending wastes from fish farm & agriculture sector).

4.5. Marketing domestic and export

Marketing the macroalgae and mussel products.

The macroalgae may be produced in very large quantities, it is rich both in nitrogen and in lipid. It should be a candidate for:

- Animal feed
- Agricultural fertilizer
- Energy source for burning (production of biofuel)
- It could also enter fish feed diets.

We consider the end products to be of domestic routes.

The blue mussel can be produced at smaller quantities compared to macroalgae. Mussels are protein rich and like macroalgae can be used for multiple purposes.

- The Norwegian salmon feed industry have recently had a success with mixing the dry protein compound made of mussels with fishmeal and other sources and this blend demonstrated a very good growth and nutrient utilization for Atlantic salmon.
- Mussels can be feed for domestic animals (poultry, pigs). Shellfish grown in the Baltic Sea have a big advantage over shellfish grown in other regions as their shells are thinner and do not cause injury to chickens.
- The ongoing innovation project "Creating innovative solutions for mussel farming and product valuation" is currently testing some novel application to use the Baltic mussels for human consumption.

We consider that these end products will be actively used locally in Estonia.

4.6. Risks, opportunities for chapter 4-5

The main risk for the aquaponic cultivation is as follows:

- The physical conditions on sites where floating aquaponic units can be installed.
- How well the macroalgae can be suspended in the water column without settling, fragmented or that it creates shadow for optimum photosynthesis.
- How well the blue mussel can capture the suspended organic particles from the water column.
- How one can avoid settling, epizoon and predation of both the mussel and macroalgae populations.

- How well can the macroalgae seedling be cultivated prior to the peak spring period every season.

Chapter 5

5.1. Restrictions and potential- coastline, seabed area and freshwater locations.

A characterization of environmental conditions best suited for both fish farming activity and integration with aquaponic setup is listed on page 13.

5.2. Highlight, if current aquaculture legislation has limitations or restriction to the proposed report findings (finfish, seaweed, and shellfish).

The current Water Act manages the max. flux of nitrogen and phosphorus and calculates the assimilation of nutrient into the flesh correctly. However, stakeholders should be updated with the latest modern fish feed to fully understand the future possibilities.

Onshore pumping of seawater to a land based farm should not have restrictions of the total flow of m^3 volume per year.

It is strongly recommended that potential permits are given where predictable conditions is as clear as possible and that for given permits the economy of scale is within reach. We strongly recommend not to issue too many smaller permits. It is better to reduce the volume and rather allow for a larger flux quota per year.

5.3. Any pollution loads in the marine area can cause production kickback, risk of food safety (i.e., dioxin content in fishmeal, the fish oil used for feed production), contamination today within the shellfish sector. Areas banned for future aquaculture.

As with all coastal activity that have interference with agriculture, industry on land and or is close to densely populated areas must pay attention to foreign load and current EU food safety acts.

In the Baltic Sea there are some heavy metals, cadmium, and lead, which when present tends to accumulate upward in the marine food chain. This can cause special lipid rich marine organisms to have a higher metal concentration in their body. Carnivore animal feeding on such food chain can be found to have threshold levels.

For lipid rich pelagic fish in the Baltic Sea this can cause restriction; however, if rainbow trout is fed with fish feed with no such origin, this should not cause any contaminations.

5.4. Suggestions to alternative onshore and offshore aquaculture regulations.

One strategy could be to issue new permits on various locations. Second, dedicate i.e., 3 sites to one company and let this company produce trout on one of the sites at a time. Next generation could be moved to site No 2 and, in this manner, circulate and spread the wastes over as large seabed area as possible.

This is a much more economy and ecofriendly strategy compared to farm smaller quantity on all sites simultaneously. Care must be paid toward the fact that the fish farmer should be given access to a site with smolt every year so that his productivity does not stop.

Another interesting approach is to produce i.e., larger post smolt on tanks on land, treating the wastewater. For a 500 gram or 750-gram post smolt this contribute to approx. 14% and 21% of the overall waste fluxes for the generation. By splitting the waste fraction (14 and 21%) to a fully functional waste filtering system on land, this improves the Open net flux situation if a standard 100-gram smolt was released directly into Open nets. This could be one alternative mechanisms – either linked to more difficult farming zones with less diluting capacity to re-capture to normal conditions after each generation.

5.5. Description of the potential for import/export eggs and vaccines.

We strongly advice WEM to import proven fish egg quality and fish vaccines. The farming volume potential in West Estonia is probably too small to initiate inhouse development and production of vaccines. For egg quality large commercial producers and exporter suites all EU requirements.

Good and proper fish health screening should be performed prior shipment, Quarantine station is strongly advice to setup prior eggs are distribution prior hatching.

Scotland, Norway, and Faroe Island have done this for years.

Chapter 6

6.1. Strength and weakness of the AAS report findings.
The strength of our AAS report is as follows.

Large rainbow trout is very well suited for growing in seawater of the coastline of West Estonia. There is NOTHING wrong with the quality of the seawater – temperature profile is good, salinity is low, sea lice cause no problem, and the fish should reach market size of 3.5 kg after 60–70 weeks. The absence of sea lice, extremely low density of fish farms should represent a solid platform to be built on. No other similar large sea region has such an opportunity.

Smolt released as 100-gram early in the year should perform well, and various small-scale setup in conventional open net cages in Estonia do demonstrate so. Certainly for 40 years this have also been the case for Swedish and Finnish fish farmers who operate Open net platforms for approx. +/- 30 000 tons rainbow trout per year.

Our aquaponic integration shows very promising assimilation of dissolved nutrient in the free water column and certainly our prediction of the filtering capacity the blue mussel unit shows very promising performances.

A reduction of 60% and 90% of N and P benchmark with the threshold level stated in the Water Act is very promising. We are not aware of similar high trophic circulation of these wastes driven by the enclosed floating bag concept.

We are impressed by the high nutrient assimilation of the macroalgae *Ulva intestinalis* linked to predictions that these algae may well be grown in large density in these large floating units. Preliminary small-scale trials in West Estonia 2020 and 2021 do confirm our findings from real field trials.

The weakness in our prediction is that such large floating bags are not yet been integrated with aquaponic and we have not identified final locations, however we are fairly certain of which coastal zones that is of attractive value.

Challenges which must be sorted out over time are as follows:

- How dense macroalgae populations can be kept floating inside the bag units
- How suspended organic particles can be suspended for the filtering mussel population.

6.2. Suggested prioritizations and why.

Prioritizations are listed as our top 10 points.

1. Define new flux rates from latest modern fish feed, illustrate this in the Water Act as example.
2. Define yearly waste fluxes on dedicated zones/sites.
3. Seriously look for good freshwater sites for future smolt production, also consider if the existing permits could be expanded.
4. Compile all relevant coastal zone facts to stakeholder's information folder and invite for a seminar, regional and international.
5. Seriously consider wind energy companies as supporting entrepreneur candidates that should have interest in mutual activity linking wind energy with eco-friendly marine protein production.
6. Consider elements for setting up a Pilot Marine Station acting as a practical R&D facility for education, farming practices, integrating aquaponic setup and to monitor food safety elements for farmed fish, final aquaponic products.
7. Setting up a smaller fish vet lab should also be considered.
8. Circular economy: consider various sources and routes of by products from forest industry, agriculture and fish farming and the pelagic fishing sector. Seek possibility to blend volume and setting up Black Soldiers fly production.

9. Issue 3–5 farming permits with aquaponic integration and motivate expansion of the current smolt production capacity in the region. This should allow for a first production stage – 2 mill smolt could contribute with approx. 6 000 MT live biomass over the next 5 years.
10. Try this and adjust/correct accordingly prior to next stage is launched.

6.3. Strength of this AAS report findings.

This Study shows:

- West Estonia suites very well the conditions for commercial rainbow trout production

- Modern fish feed represents a lower flux of nutrients compare to just a few years ago

- Setting up conventional water filtering system from land based and floating fish units do show reduction of Nitrogen and Phosphorous to the sea
- Introducing semi-enclosed floating bags for fish production represent a fundament for integrating aquaponic circular economy. It also represents a lower Capex cost entry for enclosed fish farming- the alternative is costly RAS farms on land

- Expertise knowledge of marine ecosystem and growth potential by both shellfish and macroalgae specific taken West Estonia conditions and field trial experiments into account represent a strength

- Nitrogen and Phosphorous can be reduced by 60& and 90% compared to the current Water Act (April2020) if enclosed system and aquaponic is integrated

- Aquaponic production specially related to green grass is modelled and show very large potentials- waste volume can be produced from modern fish farm wastewater

- Conservative predictions are an annual farmed biomass of 40 000 tons, a total of 700 jobs and circular economy in the range of 350 MEUR/year, see page 13

- The current industry sector operating in the shipyard, pelagic fishing, transportation, waste management and seafood products in general show a diverse mix of small and medium sizes operations. An extra supply of fresh harvested rainbow trout biomass with a stable monthly harvested volume should represent large opportunities. Many of these existing setups could easy combine their current operations where farmed fish could be added on.

- Hardly any land- nor sea- based zones are dedicated for aquaculture as of today- this represent a strength where WEM could map and structure a very modern ecofriendly marine industry where the latest findings and recommendations of fish health and marine ecosystem are the foundation.

6.4. Risk elements to the AAS report.

The main risk elements to this Study report are listed on page 17:

- Offshore farming platforms must be installed with strengths adapted to winter conditions
- Floating bags for fish and aquaponic integration must be placed on location with great care
- Modern smolt production must first be establish, otherwise none farmed biomass will show up
- We consider the Marine Pilot station to be one of the largest risk factors- this new industry needs expertise and support, which should be placed here. If such support is not established there will always be challenges and troubleshooting - but this to be borne by each individual stakeholder. The opposite is a well-founded service and competence staff who could provide updated protocols, learn from previous episodes and thereby avoid multiple events of the "similar casus."
- The second risk factor is if the WEM and other public department is not creating a round map for aquaculture activities with defined terms and conditions. Such initial terms must be flexible, and care must be addressed so that initial permits very clearly specifies that conditions could over time be adjusted- this reduces the risk for the WEM
- WEM nor any other public office should determinate what type and techniques to be used as farming platform- this should be totally up to the private stakeholders to evaluate.
- Important but last; our aquaponic predictions of integrating green grass and blue mussel for waste flux reduction should be tested out in semi large scale as soon as possible. It is vital importance that updated field trials in larger scales will be established as these results may represent a game changer for the Baltic Sea as such. If such trials are not established, then private stakeholders may attend a wait and see positions as risks can be considered as high. Or opposite the first movers will identify his own results ahead of all the others. The best structure is to have a transparent open sharing managed by our suggested Marine Pilot station

6.5. Startup and scaling experiences of the Scandinavian aquaculture sector, what should Estonia learn and adapt.

1. Proper zones for dedicated aquaculture activity are No 1 where distances between locations should be maintained. This should allow for a less interference and disruptive contact with various large fish populations and generations.
2. All farming sites should have monthly fish vet inspection.
3. All fish health data should be register online without any protected information.
4. Establish guidelines for maximum number of fish per unit and a maximum density kg fish/m^3 water during its production.
5. Screen all imported eggs.

6. Establish waste quota per site per year instead of fish feed quota.
7. Allow fish farmers to select the types of farming platforms they want, or they find of interest.
8. Permits should be valid for a long period, but the conditions, environmental impact may alter the permits guidelines over time. The initial waste flux quota is not fixed- they can be adjustable.
9. Establish a permit regime where advanced waste treatments are met by motivation factors as higher flux quotas, or opposite best waste flux setup could be allowed to be established in zones where i.e., Open nets platform is outbalanced.

6.6. Volume; employees, value chain, across other industrial sectors from 5-10-15 large finfish farms? Offshore or land based.

See information listed in:

Figure 9 page 12
Figure 13 page 19
Figure 23 page 28
Figure 28 page 32

Chapter 7 Education, expertise

7.1. Suggestions related to aquaculture education national, and exchange program in the Nordic region.

We strongly suggest establishing education in the aquaculture sector within the Nordic region. This should allow WEM quickly and cost efficiently to create a solid initial platform for farming techniques, fish health, monitoring and food safety aspect. It is very important that a new industry sector motivate younger people to take education in the aquaculture sector.

College, University should plan for this, both where lectures are held in West Estonia by invited speakers, but also where students are staying shorter or longer periods abroad. Very good candidates are found in Norway; Bergen, Trondheim and Tromsø city.

Norwegian environmental departments have a lot to learn from the conditions of the Baltic Sea, especially towards potential aquaponic integration with the fish farming industry in Norway.

7.2. Required skills, high tech services (private and public) – food safety, fishnet labs for the proposed report findings.

The public sector should be able to provide with the follow services:

- Food safety program
- Fish health survey

- Farming technical inspection to ensure that assets are of proper conditions and have various breaching strength thresholds
- Education
- Register and monitor relevant waste fluxes
- Adjust Water Act and permits over time
- Be part owner of a Marine Pilot station in the region

The private sector should deliver the follow services;

- Produce and maintain fish nets
- Service and maintenance to all farming equipment on sea and on land
- Deliver oxygen and kwh
- Provide with wellboat and packaging services
- Transport of smolt
- Production of smolt
- Wellboat transport to harvest station
- Styrobox
- Harvest services
- Fish feed delivery and transport
- Processing lines and cooling freezing facilities
- Private processors should look into whole fish, filet and VAP products combined with salt and smoking
- Waste collection setup
- Waste collection and transportation
- Waste station for biogas, agriculture fertilizers and or Black Soldiers fly
- If the industry is given reliable and good farming permits, ranging from 1 000 MT up to i.e., 5 000 MT for the largest Offshore locations- this industry should manage the economy itself.

7.3. Potential employee effects/demand.

Overall estimates for total employee effects are stated in Figure 9 page 12.

Chapter 8 Cross-industry synergies

8.1. Estonia re-invents shipyard and mechanical industry to a modern aquaculture industry.

Estonia has a well-known mechanical industry covering metal work and shipyards. Most of the feed barges used in the international salmon industry in the 1980–90es were actual produced in Tallinn. Today, a large proportion of all salmon fish nets are produced and maintained in Lithuania.

Estonia does manage very well its commercial trawlers and pelagic fishing fleet. This industry is well equipped also to handle service boat related to fish farming, cages, nets and moorings.

8.2. Feed barges.

See section above.

8.3. Mechanical and service-related industrial support add-on

All fish farms need service and inspection of electrical wires, internet, power stations, generators, back-up for kwh and oxygen. Harvest stations need service, cleaning duties every day. Cooling and freezing tunnels are vital components of any processing line. Waste collection of cutoffs from the processing lines need inspections.

For a maturing fish farming industry in Norway today there is approx. 3 land based full time employees per single fish farming staff. There is also approx. a productivity of close to 300 tons live fish biomass per single man-year in the farming sector.

8.4. Cages offshore

Eastern Europe have for many years and still represent an important place for manufacturing of cages and barges.

Offshore cages is today basically of 3 dimensions;

Plastic pipes melted together as a circumference of 90m up to 200m holding 100 to 1 000 tons live fish per unit. These pipes are transported to the destination as regular pipes on truck, at arrival they are melted together.

For medium and heavy-duty steel constructions- these are made at modern shipyards- as of today Chinese and Norwegian yards are involved in this. A well-known specification criterion for dimensions and strength of such marine constructions is founded under the NS 9415 standard (Norwegian document). This standard is use and could easy be implemented by Estonian industry.

Other solutions are to join forces with large Wind Energy companies to seek benefits.

8.5. Land based operational assets- discharge collection of waste/feces from land-based operations.

Land based operations requires:

Fish framing activity: proper waste treatment, se below, where seawater and wastes are separate.

Harvest station processing and secondary lines.

All heads, guts and cutoffs represent vital marine protein and oil. These wastes are often mixed and formic acid is added for preservation. The product is shipped to separation plants where further added value processes takes place. Protein could enter animal feed, human food; oil fraction could also be used similar.

8.6. Biogas, hydrogen, and agriculture treatments.

The waste from mechanical waste filtration from land-based fish farms and from the floating fish bags can be collected, dewatered before entering circular economy loops. The most used method is to blend this material with other carbon hydrate waste products and to produce biogas, methane. Such production will generate gas for turbine driven electricity either at high populated regions or at remote sites where on-site kwh can be used. This is very relevant on the land-based fish farm themselves where waste is generating local electricity, some of the largest land-based fish farms in Norway is currently doing so.

Other circular routes are to dewater the fish waste and use it as agriculture nutrient (nitrogen and phosphorus). Processing lines for harvest and packaging large rainbow trout can also use some of the cutoffs as supplement for bio-gas production too.

8.7. Fishnet production, repair, antifouling.

We estimate that for every large Open Net farm there will be approx. 10x smolt nets and 10x large mesh fish nets totaling 20x nets. These nets may be able to produce approx. 2 000 MT live biomass for each generation. One need approx. 20 such sites and 400 nets to annual harvest 20 000 tons large rainbow trout.

These fish nest need service, storage, and antifouling/coating to prevent algae growth on the net. It could be a good idea to integrate this activity with the already existing pelagic fishing sector, so that already existing commercial fishing gear companies could capitalize on their current assets.

A net service station needs large storage rooms and large service net building for inspection and drying of nets.

At a later stage specialized fish net service station could be established. In Europe there are large fish net manufacturer and service companies, one of these is in Lithuania.

8.8. Onshore tanks, waste techniques, processing lines

Onshore and floating fish bags should be equipped with mechanical filtering station. These can be installed with various screens and mesh pores. Today, 60 micro and 100 micrometer pores are used normally.

The wet weight sludge is pressed over filters and screw pumps and further entering dewater systems often by use of excess heat. The medium product is a sludge cake with i.e., > 20% dry matter content. This fraction can be transported to agriculture use, energy, biogas and or as Black Soldiers fly. Very often the land-based farms are in the remote districts, so the cost of transportation and handling of these large waste quantities is economically unfeasible. Therefore, the industry is looking into setup where the water content can be even reduced.

Other options are to setup small biogas turbines on site and to recirculate energy in the district.

Well known manufacturer of modern processing line installed at the harvest stations are found within Europe. All these have a cutting-edge technique and are very impressive.

A very practical web link is found on page 68- a marine lookup map function for of various topics.

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Appendices

App. 1 Aquaponic waste calculation and fish feed data

The main tasks behind this Report

Below are illustrations of the main tasks contributed by the authors followed by list of 11 focus area that do structure a frame of this report.

One of the main scopes of this Report is to introduce fish farming concepts (sea based and land-based units) that allows stakeholders to create eco-friend biomass production in West Estonia. New permits with new techniques may result that companies may have a good steady biomass permit which is important for the economical performances.

We predict that without such an understanding there will be impossible for West Estonia and other regions to meet future Water Directive requirements.

<u>To establish a fact-based neutral report the authors, have individual key insight into</u>

- fish farming in general, fish feed and nutrition
- marine ecology – the growth potential of algal and mussel
- In-depth knowledge on the Baltic Sea where Jonne Kotta and Georg Martin have performed various aquaponic studies in the region and have further analyzed this evidence in the report as well as applied the scenario fish farming biomass and its waste where aquaponic integrations are analyzed.

We aim to present fact-based performances and we predict that our conclusions are reflecting the potential of fish biomass, net flux of waste to the West Estonia zone. However as with all biological modelling we have considered the following conditions.

<u>Fish farming- background:</u>

- The farming platforms (floating bags and on-land fish tanks) are avoiding that any excess fish feed from their enclosed water column do enter the environment as opposed to the traditional open net platforms where this is physical impossible.

- As the platforms represent a controlled physical barrier, the risk of having fish feed in the water column without being captured by the fish population is also reduced to minimum.

- The basic mortality of fish farmed in Open net cages is somewhat higher than what is observed from floating bags / tanks on land.

<u>Mussel aquaponic:</u>

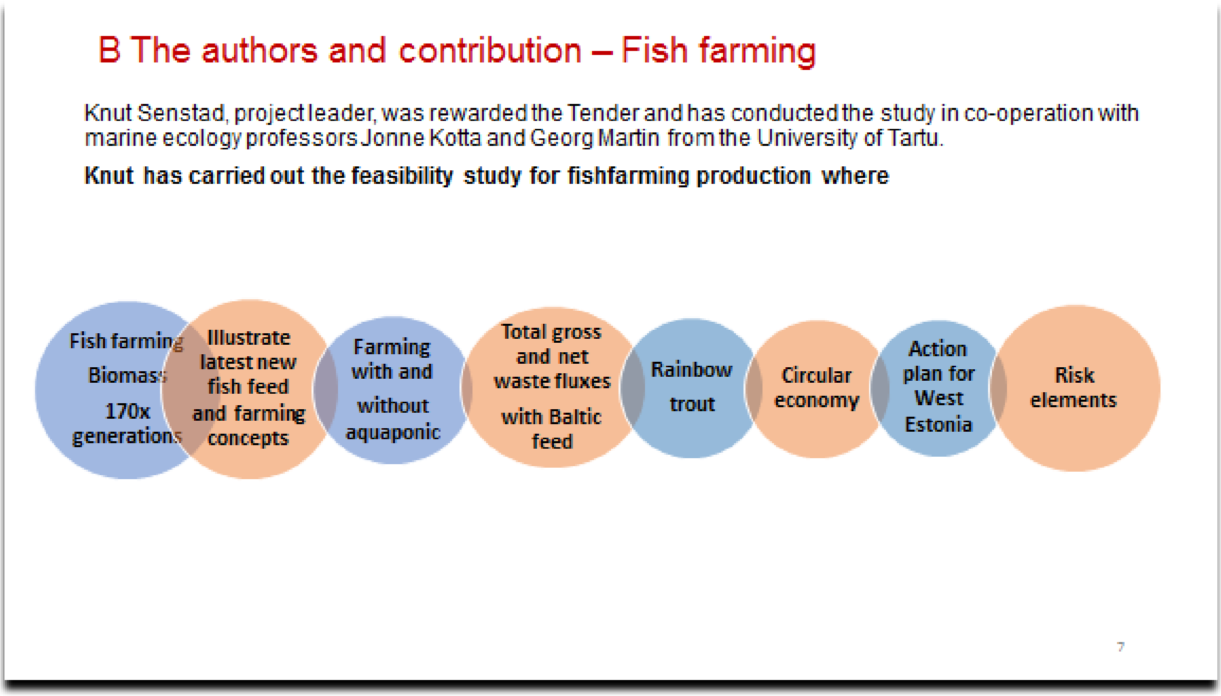
- In-depth understanding of the West Estonia conditions for natural growth, filtering potential or cultivation of mussel
- Locally tested growth model is used in this report to show the potential impact of mussel integration where the mussel received a much higher supply 24/7 of organic

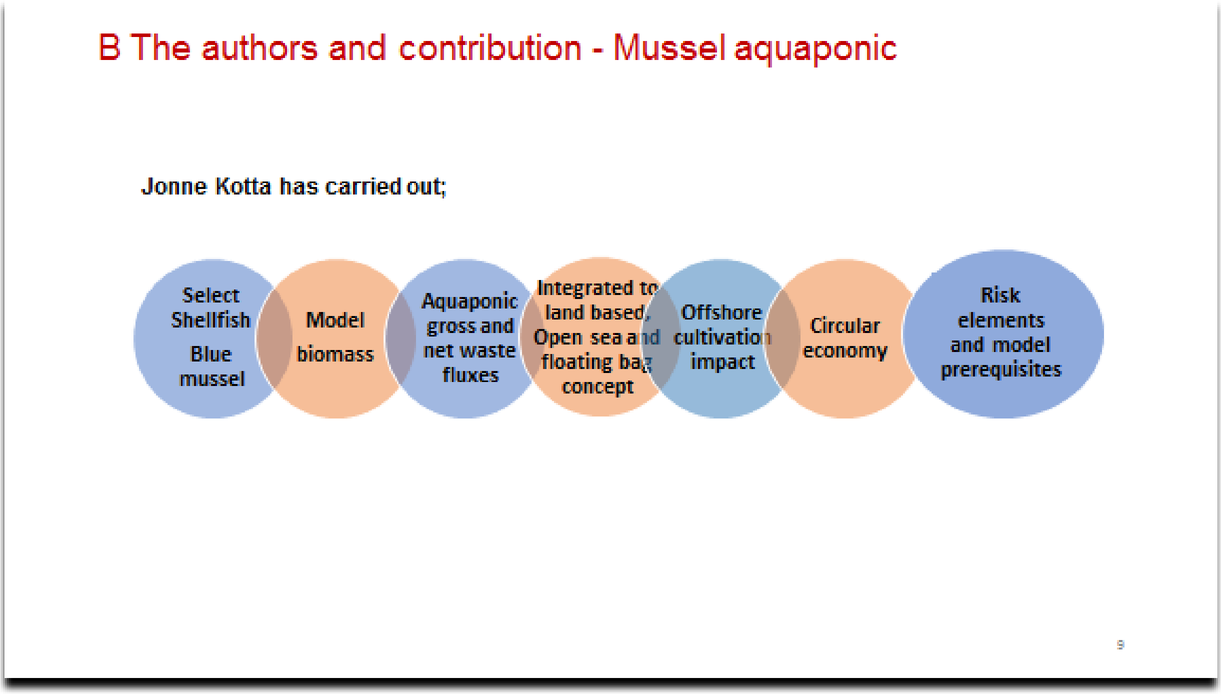
suspended particles from the fish holding units compared to the availability of natural suspended particles.

Macroalgae aquaponic:

- In-depth understanding and field experimental data from West Estonia are used where local macroalgae is held in enclosed large floating algae bags with a much high concentrations of dissolved nutrient benchmark than the macroalgae *Ulva intestinalis* was growing natural in the zone.

Below is our task contributions:





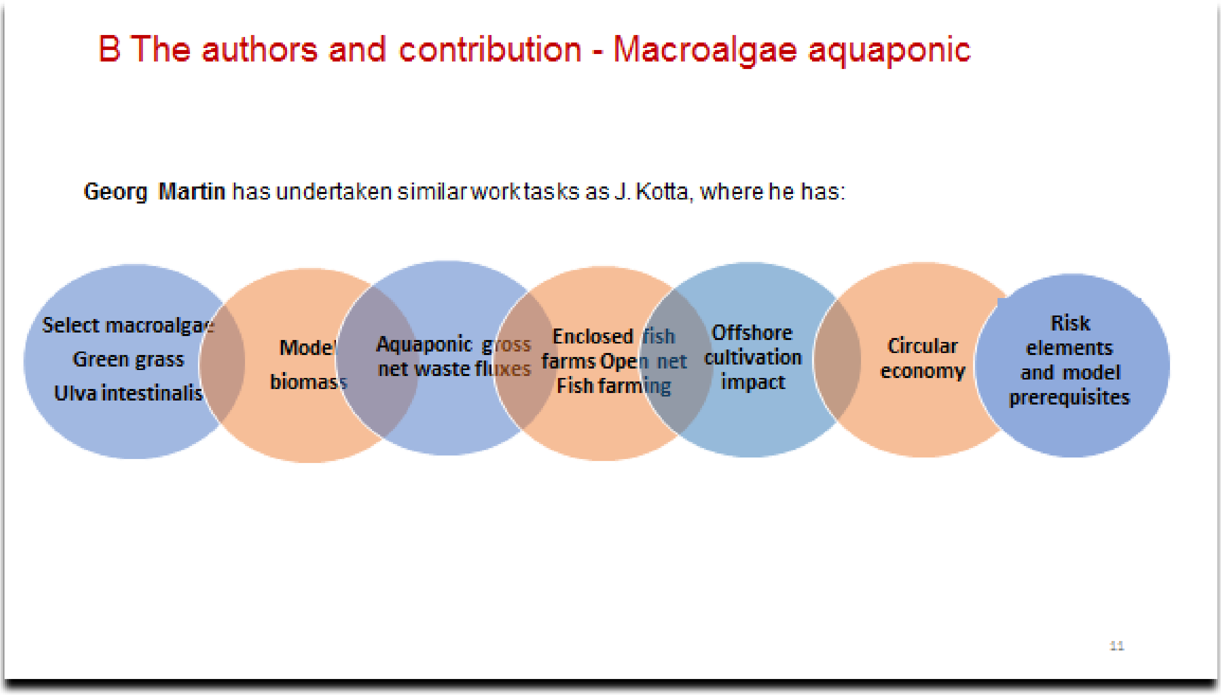


Figure 29. Analyses tasks.

Based upon the Scope and the Report content we have focused upon 11 main areas.

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D Observations Feasibility study targets

11x STEPS APPROCH

These environmental- and political- constrains => exploiting the coastal zone of West Estonia may look very difficult or impossible;

- Fish farming do increase the nutrient flux to Baltic Sea - yes
- How can we reduce these fluxes?
  - NO 1 - Use the latest modern Baltic fish feed- define new flux quantities
  - NO 2 Establish RAS on land- very expensive (75 M€ for 5 000 tons farm) but can be done
  - NO 3 Look for other land-based fish platforms that is less Capex demanding
    How are these?, Who operate them? How functional are they? Can they reduce the waste fluxes?
  - NO 4 Look for traditional Open nets and new Offshore-based Fish farming platforms. Floating enclosed bags - Which one? Where-to? What farming results? What advantages? What flux impact?

D Observations Feasibility study target

Cont. - 11x STEPS APPROACH

These environmental and political constrains => exploiting the coastal zone of West Estonia may look very difficult or impossible;

- NO 5 How can West Estonia aquaponic integrations further reduce fluxes?
  If yes- what must be organized?
- NO 6 What are the net new fluxes?
- NO 7 Action point; Way forward- public stakeholders

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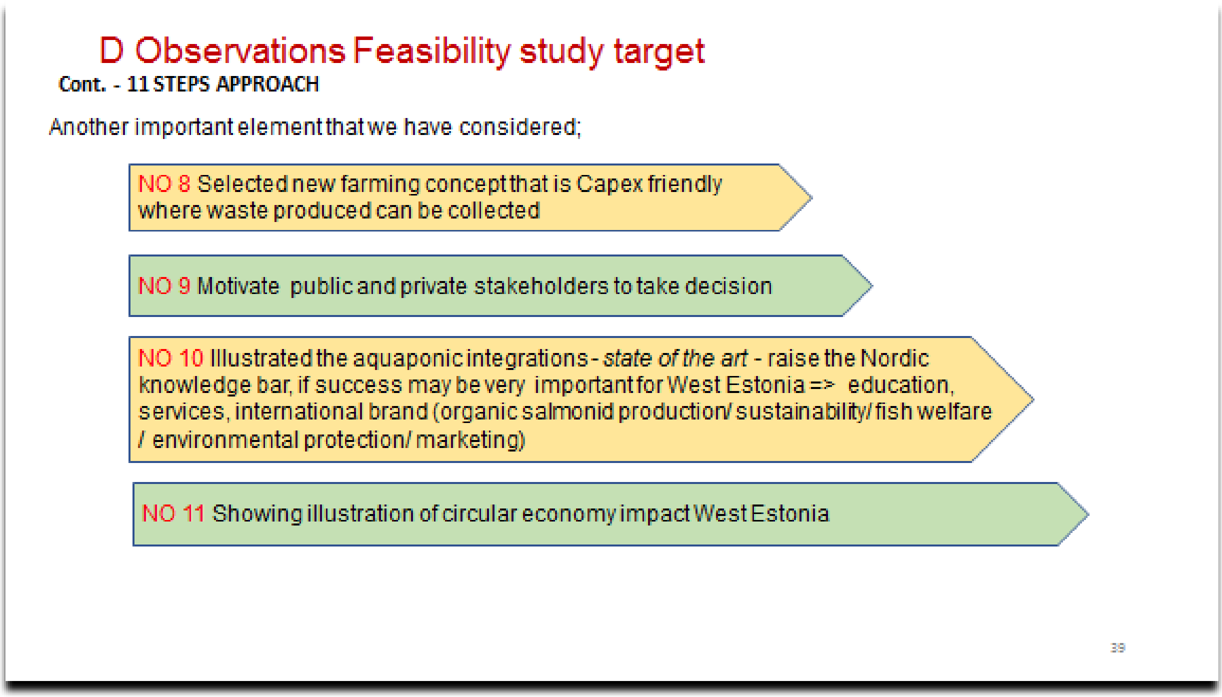

Figure 30. The 11 main task elements.

Below is a short illustration of the trends related to Western aquaculture sector activity.

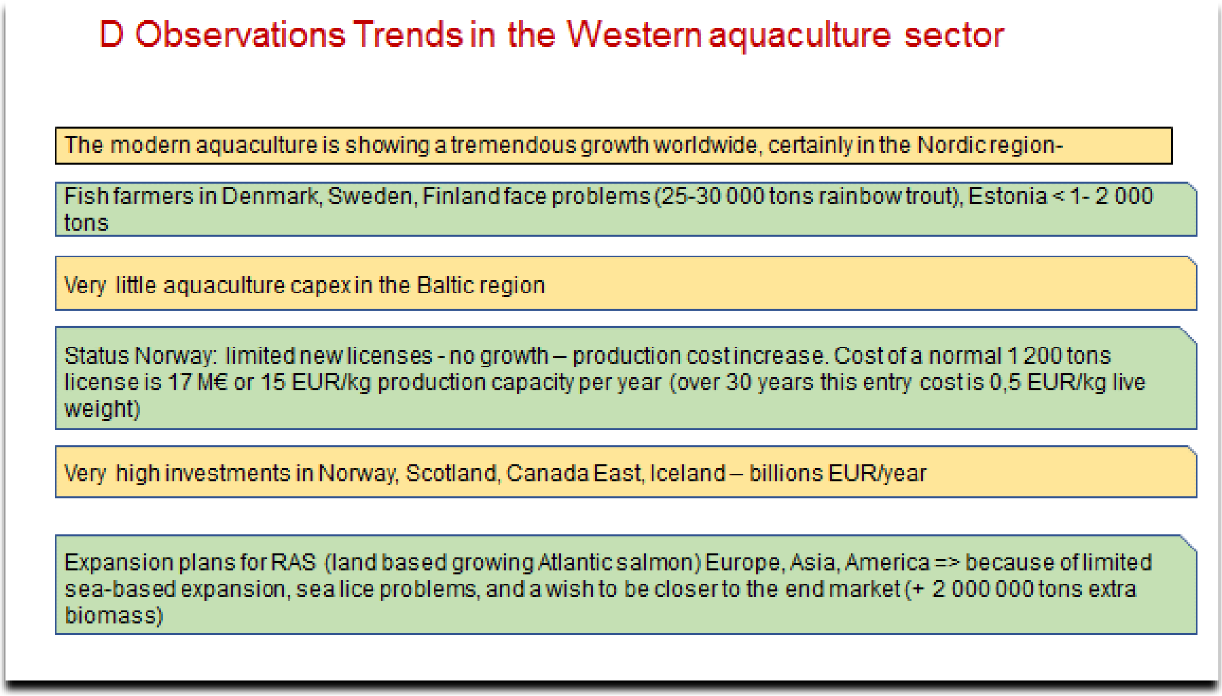

Figure 31. Western aquaculture sector.

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The illustrated opportunity for West Estonia with a modern fish farming production.

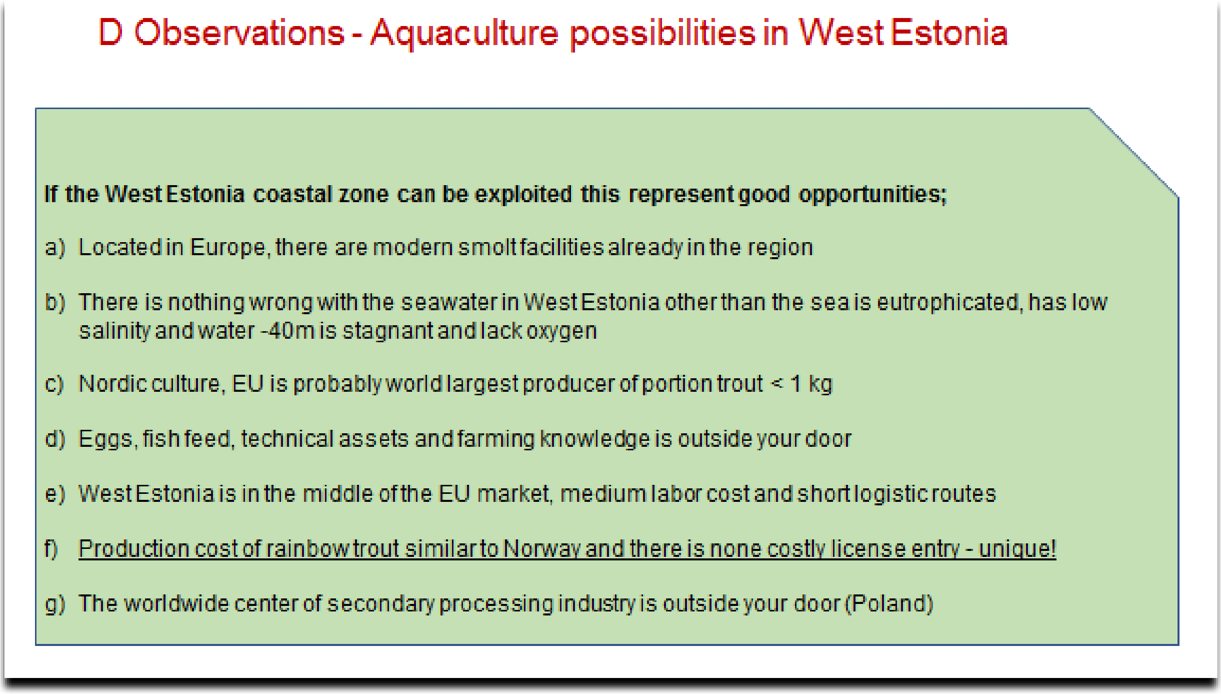

Figure 32. Aquaculture possibility in West Estonia.

Summary of net fluxes with and without Aquaponic integration.

Waste fluxes with and without aquaponic integration

Illustrated land based and floating platform.

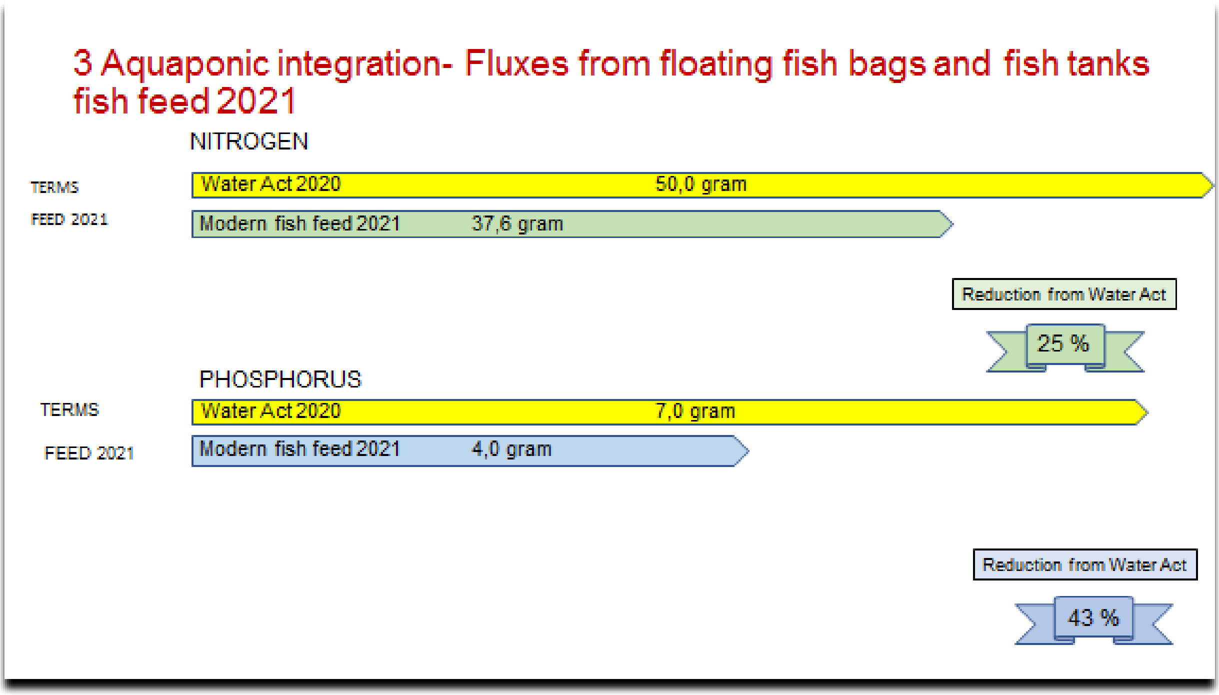

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Figure 33. Land based and floating bags concept fluxes.

With the said reduced / avoided overfeeding and slightly higher survival the two - 2 - technical enclosed platforms (tanks on-land and floating bags) already represent an improved position related to fluxes- 25% lower for N and 43% reduction of Phosphorous, see Figure 33. Our baseline is here illustrated as if 1.10 kg fish feed is required to produce 1.00 kg fish. These % reduced fluxes could allow farmers to produce similar increased % of biomass compared to traditional Open net concept. However, as of today these platforms are not in use in the Baltic Sea for larger rainbow trout.

<u>For Open net platform we have</u>

Feed status 2021 is showing Nitrogen fluxes of 11% and for Phosphorous flux reduction of 27% benchmark with the Water Act guideline. Here we are considering that 1.21 kg fish feed is required to produce 1 kg fish live weight.

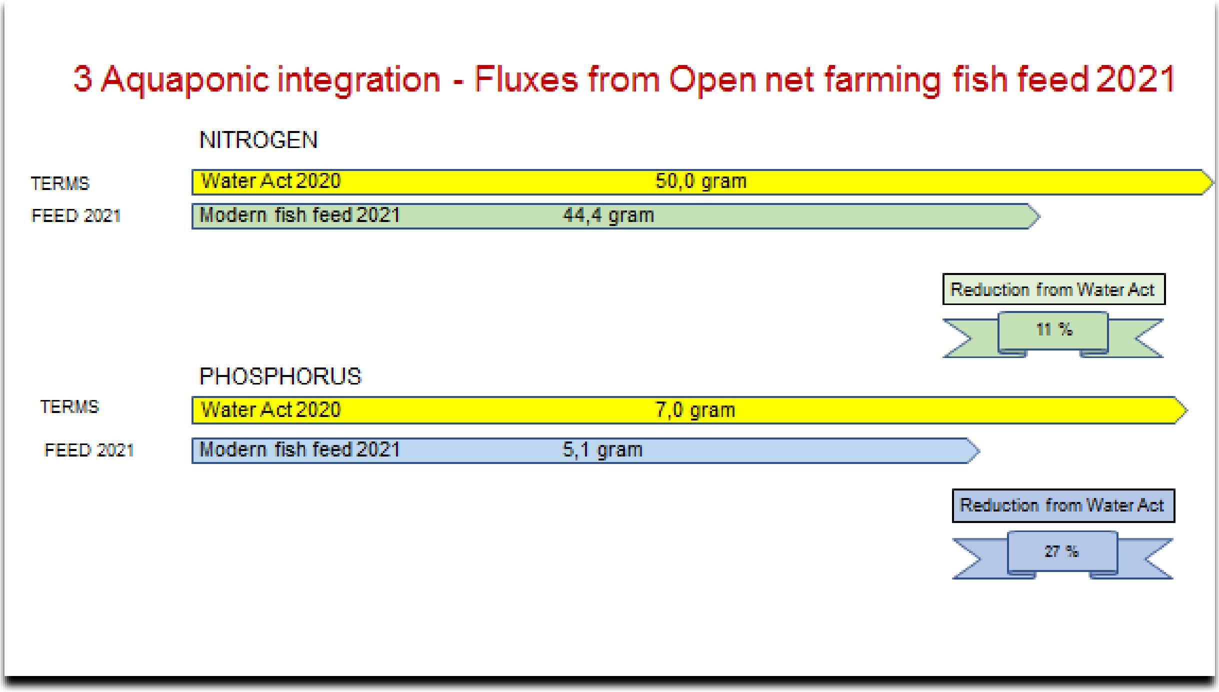

Figure 34. Illustrations of waste fluxes for Open net concept.

Details of the waste and dissolved nutrient mass balance for land-based fish tanks and floating bag concept.

The figure below shows the split of waste as dissolved and bounded fraction for both Nitrogen and Phosphorus.

D Observations - Total aquaponic integration with floating fish bag and fish tanks on land

Floating bag or tanks on land farming total flux gram per kg fish produced							
	Nitrogen			Phosphorous			Organic waste
Strategy impact	Total flux gram per kg fish produced	dissolved	bound to slugde	Total	dissolved	bound to slugde	Total flux gram DW per kg fish produced
water Act West West Estonia	50,00			7,00			
Fish feed 2021							
Bags/ tanks on land before filteringer	37,60	33,70	3,90	4,00	1,60	2,40	96,00
After mechanical filtration	35,50	33,70	1,76	2,68	1,60	1,08	43,20
After Aquaponic mussel integration	33,70	33,70	zero	1,60	1,60	zero	zero
After Aquaponic macroalgae integration	20,22	20,22	zero	0,80	0,80	zero	zero
After total Aquaponic integration	20,22	20,22	zero	0,80	0,80	zero	zero

Total Nitrogen can probably be reduced to 20 gram per kg fish produced- is a 60% reduction of the Water Act
Total Phosphorus can probably be reduced to 0,8 gram per kg fish produced- is 89% reduction of the Water Act
«All» organic suspended particles can be captured by the shellfish

Figure 35. Detail fluxes for enclosed farming platforms.

Short explanation

- The total Nitrogen flux is for bags and fish tanks that there is approx. 90% dissolved into the water column and 10% bound to particles. This indicates that mechanical filtration and or mussel capture filtration can act as the major source for reduction of N fluxes.
- For P there is approx. 40%/60% split - filtration (mechanical or by mussel) may here have a lower impact compared to N "filtration" results.
- There is approx. 100 grams DW sludge formed for every 1.0 kg rainbow trout from these enclosed farming setup – NB! this sludge is higher for Open net farming.
- After mussel integration there is zero organic waste to sea.
- After mussel integration N fluxes is reduced to approx. 34 grams and P to 1.6 grams.
- After macroalgae integration N can reach level of 20 grams and P 0.8 grams per kg fish produced.

Illustration for the open net's platform.

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D Observations - Macroalgae + mussel Offshore cultivation total waste flux from Open net farming

Open net farming total flux gram per kg fish produced							
	Nitrogen			Phosphorous			Organic waste
Strategy impact	Total flux gram per kg fish produced	dissolved	bound to slugde	Total	dissolved	bound to slugde	Total flux gram DW per kg fish produced
water Act West West Estonia	50,00			7,00			
Fish feed 2021							
Open nets none filteringer	44,40	40,10	4,30	5,10	2,70	2,40	96,00
After mechanical filtration	44,40	40,10	4,30	5,10	2,70	2,40	96,00
Ocean cultivation mussel	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Ocean cultivation macroalgae	TBD	TBD	TBD	TBD	TBD	TBD	TBD
After total Ocean cultivation	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Total Nitrogen will reach less than **44 gram per kg fish** produced (11% reduction of Water Act), is depended upon which Offshore cultivation zones to be selected.
Total Phosphorus will reach less than **5,1 gram** (27% of Water Act) per kg fish produced- is depended upon which Offshore cultivation zones to be selected. Organic suspended particles can be captured by Offshore cultivation arrangements of shellfish-TBD.

Figure 36. Fluxes for Open net farming.

<u>Short explanation</u>

- Therefore, the net fluxes of N and P is approx. 44 grams and 5.1 grams.
- Therefore, the total organic particles flux is 96 grams DW per 1.00 kg fish produced.

Modern fish feed data:

A Water Act - regulating the flux of N (Nitrogen) and P (Phosphorus) is highly relevant if one is considering the potential of modern fish farming in the region. This has resulted to the development of Baltic feed diets that do scope with such Water Act terms. The fish feed industry in Sweden, Denmark, Finland, and Poland is constant looking for new improvements and the latest commercial diet for rainbow trout production is incorporated into this report. The aim is that trout farmers in the region should meet the nutrient requirement from a health growing fish population and at the same time meet the nutrient flux terms.

The illustrated Water Act for West Estonia 2020.

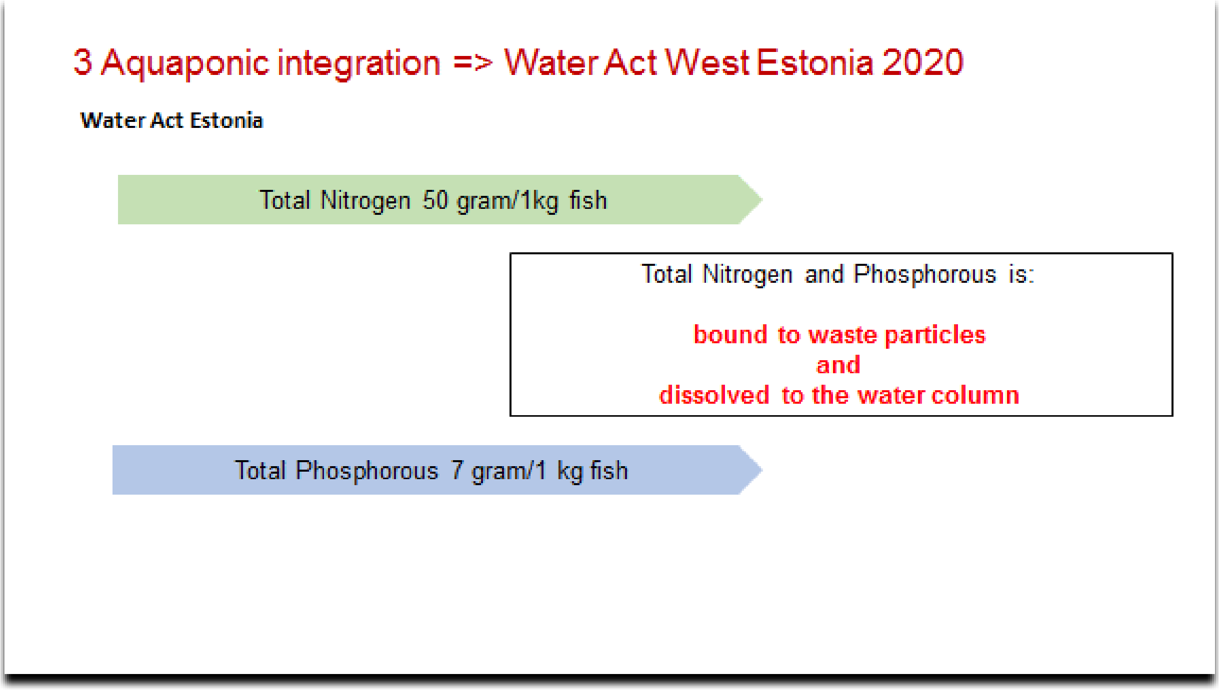

Figure 37. Water Act West Estonia.

8 Modern Baltic fish feed- waste position

However, the latest modern Baltic trout diet, status 2021, allows for a lower Nitrogen and Phosphorous than what is the maximum threshold values per kg fish produced shown above.

Illustration of the Nitrogen and Phosphorus assimilation to rainbow trout, figures are % nutrient bound to the fish flesh as a weight proportion of the live weight of the fish.

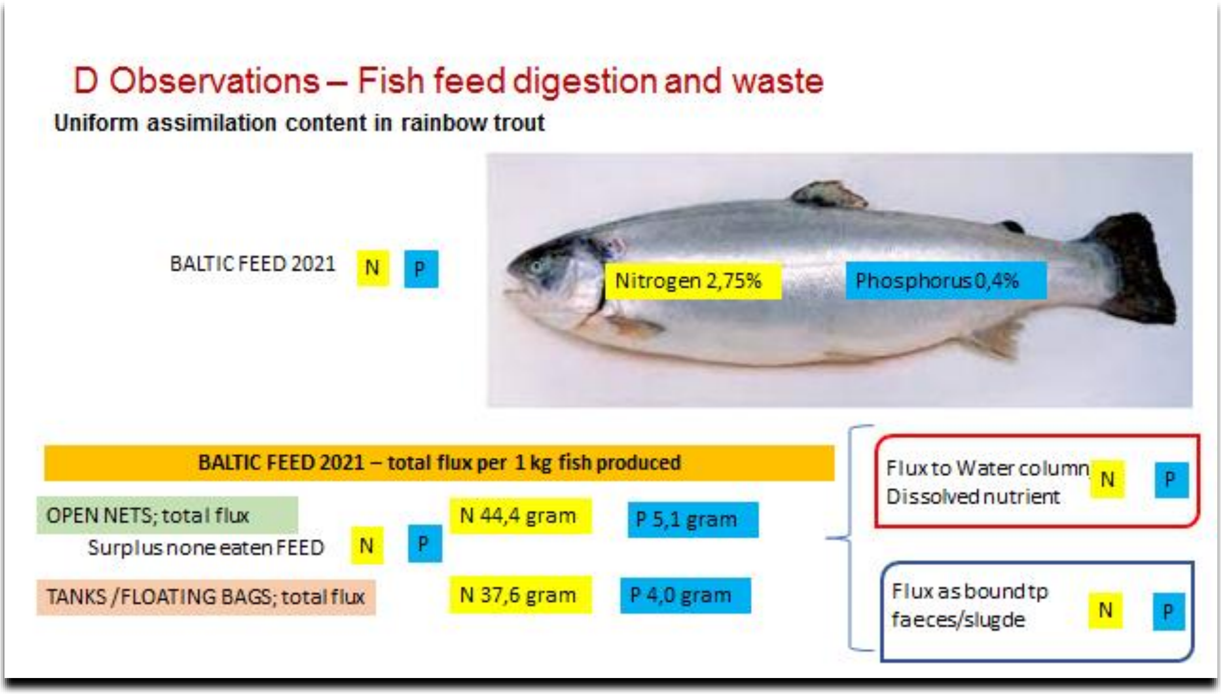

Figure 38. Assimilation of nutrient to the fish wet weight.

Fish feed Baltic 2021

A modern Baltic fish feed may have the following nutrition building composition:

3 Aquaponic integrations; N, P fluxes and sludge quantity per kg fish produced- Baltic fish diet- Split of waste bound to organic particles and as nutrients dissolved in the water column

UPDATE

Data sheet calculation for:		
mm	8	
Declaration		
Water %:	6,00	N %
Crude protein (%)	37,00	5,92
Crude fat (%)	33,00	
NfE (%)	13,60	
Fibre (%)	1,40	
Phosphor (%)	0,73	
Ash (%)	9,00	
Control	100	

Data from fish feed producer

TANKS AND BAGS

Feed conversion	1,10	
Feed consumption KG:	110,00	
Feed consumption in KG DM:	103,40	
Produced sludge in KG DM:	9,60	
KG N via feed:	6,51	
KG N in fish:	2,75	
N in faeces (kg)	0,39	10,4 %
N in water (kg)	3,37	89,6 %
Total (faeces + water) N KG	3,76	
KG P via feed:	0,80	
KG P in fish:	0,40	
P in faeces (kg)	0,24	59,8 %
P in water (kg)	0,16	40,2 %

OPEN NETS

Feed conversion	1,215	
Feed consumption KG:	121,50	
Feed consumption in KG DM:	114,21	
Produced sludge in KG DM:	10,60	
KG N via feed:	7,19	
KG N in fish:	2,75	
N in faeces (kg)	0,43	9,7 %
N in water (kg)	4,01	90,3 %
Total (faeces + water) N KG	4,44	
KG P via feed:	0,89	
KG P in fish:	0,38	
P in faeces (kg)	0,27	52,5 %
P in water (kg)	0,24	47,5 %

Figure 39. An illustration of one of the latest Baltic fish feeds.

Explanations:

- There is different volume of sludge to the environment considering Open nets and two other enclosed platforms. There is also different quantity and the % split of nutrient bound to particles and dissolved to the water column.
- The only difference we have setup is that feed conversion ratio (FCR) for Open nets is set at 1.215 and for enclosed platforms FCR is set at 1.100.
- Other fish feed compositions have different performances.

App.2 Detail fish farming production

Our base line production parameters are listed below.

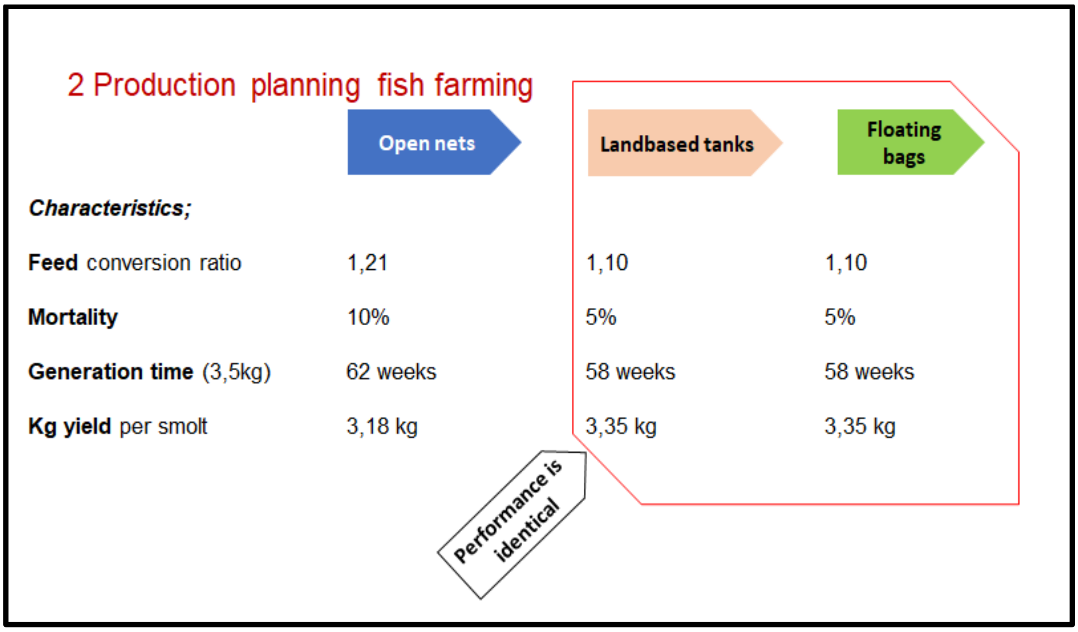

Figure 40. Feed usage, survival, generation time.

Comments

- These feed conversion ratios showing how much fish feed is required to produce 1 kg live fish weight shows that approx. +10% higher feed volume is spent on Open net farming compared to more controlled enclosed setup as fish tanks on-land or floating fish bags.
- This results in an extra nutrient flux to the environment.
- The other elements are that in this Report we have estimated that Open nets will have twice as high mortality compared to the other more controlled platforms (10% vs 5%) - this also represents an additional nutrient fluxes as this lost biomass also have digested and combusted an extra feed volume by this additional dead biomass with a result of some quantity of N and P as feces/sludge and also as dissolved nutrients to the water column.
- All these factors are incorporated into the Report.

These elements are also illustrated below:

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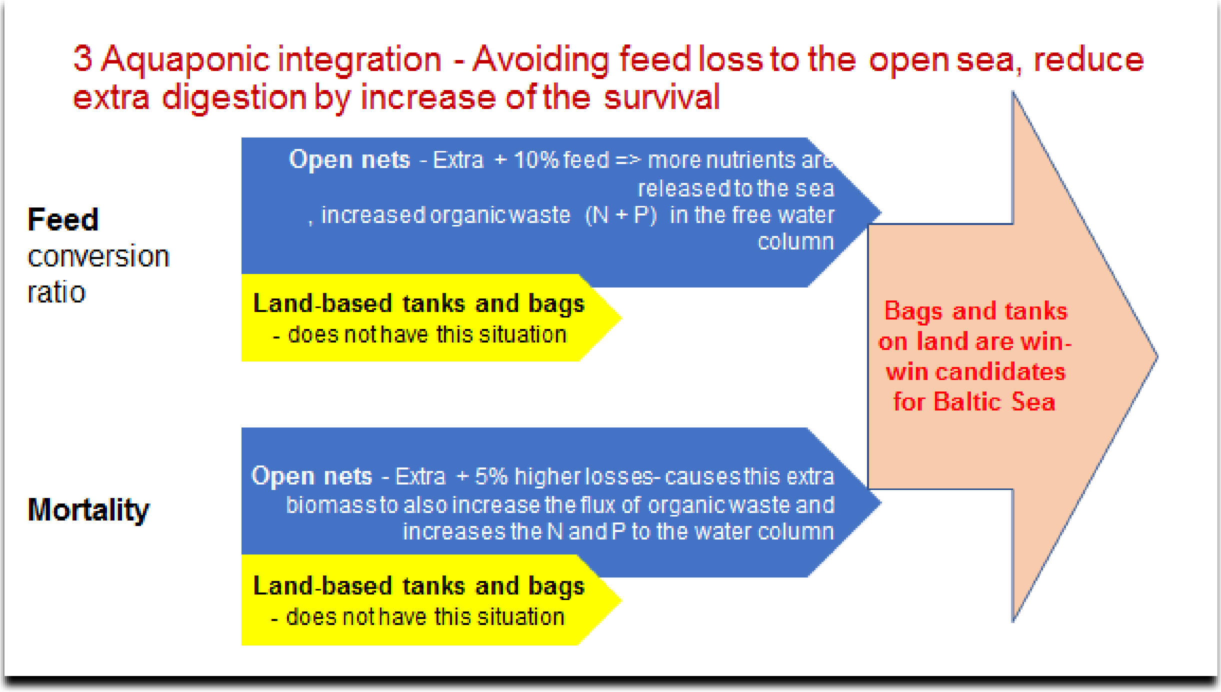

Figure 41. Surplus waste fluxed by Open net farming.

2 Production planning fish farming

The potential of fishfarming production in West Estonia is very promissing, however as with other regions one must consider the pro and con for such activity and also pay attention to potential risk factors:

As for any Open net strategy

- we predict a farming time of approx. 62 weeks for each fish group released
- where the live swimming weight is 3,5 kg
- with 10% accumulated loss
- the winter temperature will restrict the entry of smolts year round
- Natural smolt entry to sea is 1 April- 1 Oct- this will expand the whole generation period by 7 months- total generation period is close to 21 months
- A 3 months fallow period could result that re-stocking takes place every 75 weeks per site

Figure 42. Generation time, accumulated loss, harvest weight.

<u>Current fish farming activity in Baltic Sea</u>

The situation among fish farmers, especially the one operated in Denmark, Sweden, and Finland, with Open net technique, is that their permits are under pressure and the total farmed volume of approx. 35 000 MT trout is consolidated among a few players. It is also a fact that some do practice Ocean cultivation of blue mussel (Sweden, Denmark, Finland), but to our knowledge basically none have yet strategically changed their Open net technology. Alternative farming platforms are illustrated in this report to secure a long-term predictable farming activity where public officials easy can monitor and take active part of new farming techniques which are special designed and adapted to the listed eutrophication conditions of the Baltic Sea.

The foundation for such a circular utilization of marine resources is looked upon where an alternative modern setup of salmonid production in the region is the baseline. This report is not specific focusing on modern RAS facilities, Recirculation Aquaculture System, as they are very costly, technical and we consider that an entry of other modern fish farming alternatives is better suited. However, there is a fact that the high-tech RAS I and RAS II setup may also reduce the waste fluxes at a higher level than the straightforward mechanical water filtration set up in this report.

The sea temperature is low in winter approx. 3 degrees and reach a peak of approx. 16 Celsius in August/September. The growth curve of various fish groups entering the Open net cages during the spring/ summer period.

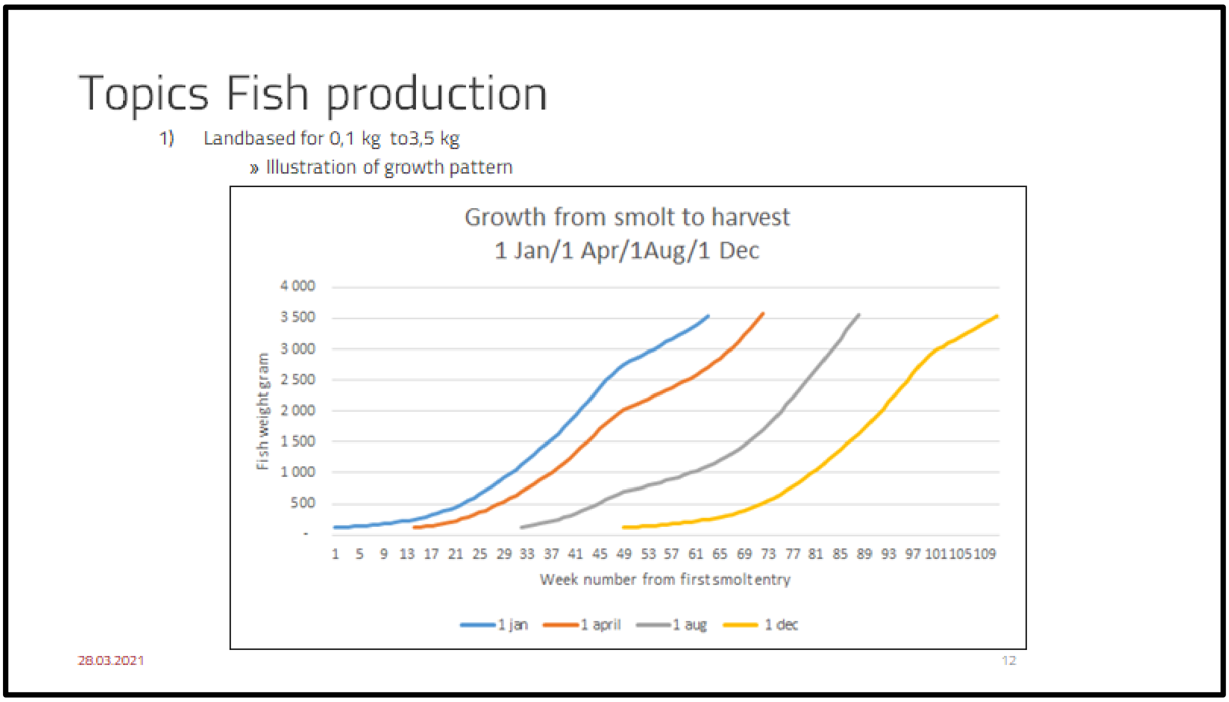

Figure 43. Growth pattern for land based and floating bag platform- different fish groups released at different time.

The growing period lasts from approx. 53 weeks up to approx. 57 weeks depended upon the temperature profile. Shorted generation time is for fish groups who experience the best temperature profile for its whole generation.

<u>Production planning</u>

It is important to have a steady state of biomass at the fish farm year-round so that the production can reach biomass volume where the economy of scale is utilizing the investment and thereby allows the fish farmer to reach a good economy. Without such a production planning the fish farm will have difficult cashflow positions and may also have a limited season window for its harvest and sales.

This is normally arranged where trout smolts are entered the fish farm at dedicated times of the year. In our production planning we have chosen all smolt of 100 gram and have estimated the number of smolt for the open net cages, the enclosed floating bags, and the modern fish tank configuration onshore, so that they all can produce and harvest biomasses of economical dimension.

The floating bag concept and the fish tanks on land is having identical growth, survival, and biomass year-round. The Open net cages in our internal demo for predicting fish feed volume week by week and its wastes to the sea is having a less frequent smolt entry and a different biomass development.

The figure below shows how each smolt group develop tis individual biomass over time until the harvested live weight of 3.5 kg is reached. After harvest, the fish tanks or the floating bags can be restocked with a new fish groups that is released at another time of the year and therefor has its separate growth pattern for its lifecycle. We have done this for approx. 170x different smolt entries to predict the steady state in the 3 where the biomass and fish feed volume is showing smooth and stable performances. From this status we have estimated the nutrient fluxes as bound to particle and being dissolved in the free water column.

From these fluxes we have then integrated the aquaponic elements to tanks on land and to the floating bag units.

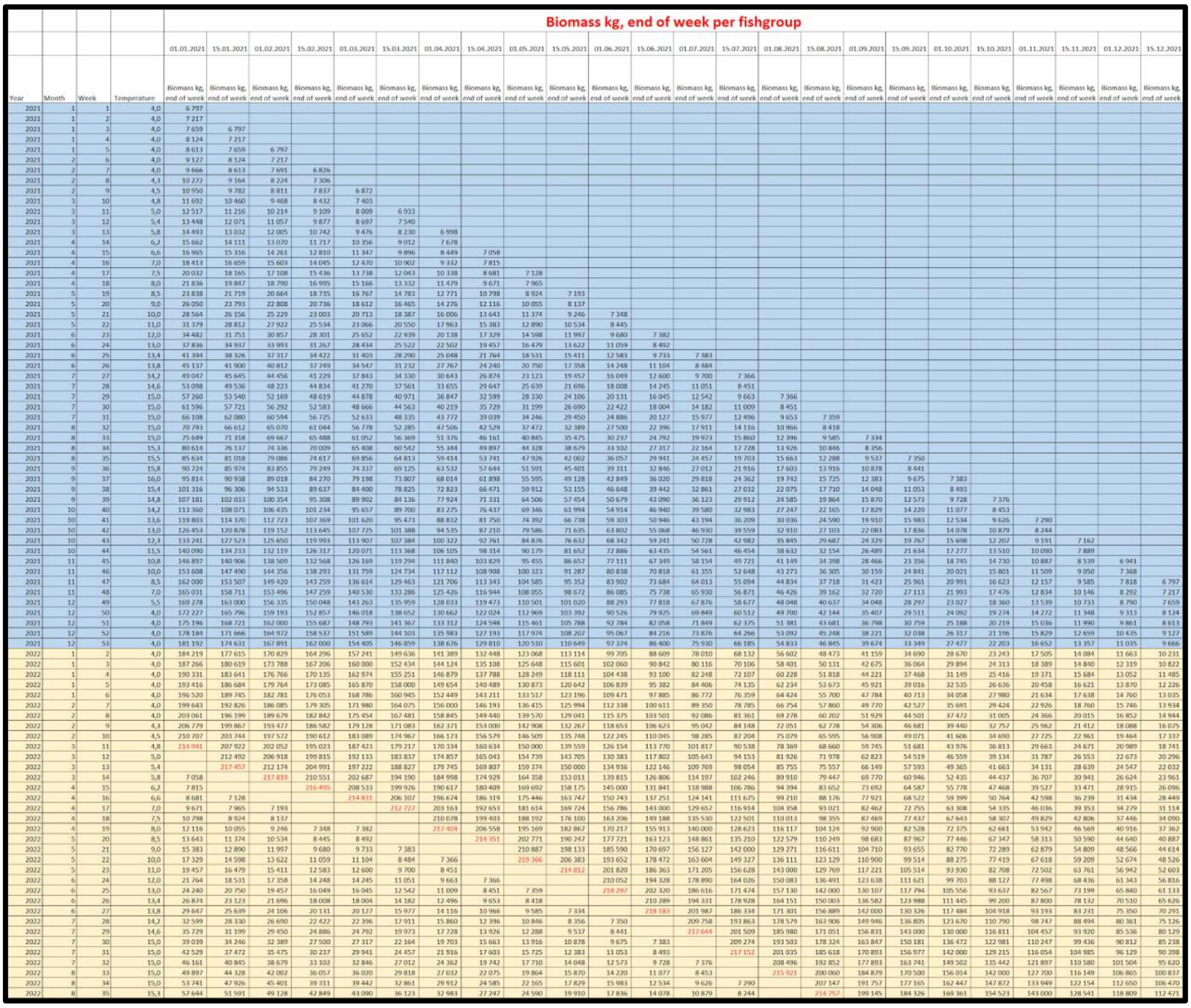

Figure 44. Illustration of different fish groups growth and biomass until harvest weight 3.5 kg is reached.

Here smolt groups are entering the tank farm every 14 days, in a year this is 24 fish groups. The number in the cells are the biomass live at weekly intervals. The first smolt groups is harvested as 214.9 MT after 53 + 10 weeks- sum 63 weeks. The next groups show very similar biomasses ranging from 214 MT up to 219 MT. Red number are the live biomass at harvest when 3,50 kg live weight is reached. Each tank is then cleaned, and new groups are entered after 2 weeks fallow period. This is an ongoing process leading to no fish harvested the first year, good biomass the 2[nd], and a steady stage level in the 3[rd] and 4[th] year. The biomass profile could be any volume, here it is fish group each illustrated as 64 000 smolt every 14 days.

Below is an illustration where the different smolt number must be released to farming units for all 3 platforms to reach the same biomass at harvest- all with average weight of 3,5 kg per rainbow trout.

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2 Productioni planning fish farming

Summery biomass potential large rainbow trout

- The illustrated pages above may result in;

	Open nets	Landbased tanks	Floating bags
500 MT biomass;			
Stocking no smolts	165 000	150 000	150 000
Smolt entry period	1 Apr-1 Nov	year round	year round
Fallow period per site	yes 3 months	none	yes 3 months
1 500 MT biomass			
Stocking no smolts	495 000	450 000	450 000
2 500 MT biomass			
Stocking no smolts	825 000	750 000	750 000
5 000 MT biomass			
Stocking no smolts	1 650 000	1 500 000	1 500 000

Figure 45 Elements for fish farming planning.

The advantage by introduction rainbow trout to the West region is the fact that salinity of the seawater is only a fraction of what is found in the Kattegat/North Sea region- levels are often within 5-10 psu (per mill), which act as a barrier for the sea lice. Experts in the West region confirm that this is the case, in addition the rainbow trout is more resistant against sea lice infection.

The rainbow trout is also best suited under these low saline conditions.

Local and international fish farming initiatives should exploit the potentials in the West Estonia region where the nutrient flux challenges must be considered. All modern land-based fish farms do operate where mechanical filtering of the waste is a foundation of their licenses. There should be no differences for the West region.

This means that traditional Open net farming also with proper fish feed and a good fish health is well adapted, however the fluxes are here larger per kg fish produced.

West Estonia should grant farming licenses approx. i.e., 5x for an initial modern phase for i.e., 10 years period where agencies from Estonia (environmental, fish health, food safety) are involved, controlling, and monitoring the progress over time and support with corrective action. Such permits should be granted with flexibility- if periods show performances in conflict of the Water Act and more precise to yearly flux quota issued per location, this should be observed, and corrective actions should be implemented. Should the case be that some of the illustrated fish farming platform listed in this report do show advantages- then supports should be given to further expand such biomasses if onsite threshold targets are remained.

An important principle should be that any yearly waste fluxes should act equal regardless of the platform chosen by the private stakeholders, as long as one considers individual locations.

Setup with flux reduction per kg fish produced should then be allowed to produce a larger biomass compared to a situation where they rather chose a platform with a higher flux ratio per kg fish produced. The importance is that the total flux is to be specified per sites & zone are maintain regardless of platform in use. The authorities must be careful so that they are not directing the technology development or is putting them in a responsible position.

The same situation is for fish farmers on land- the quantity use of seawater per kg fish per year should be the outcome of the technical system chosen by the stakeholders- it is wrong to address permits where the total yearly sea water volume is specified- it is not the sea water volume that caused fluxes to the sea- it is the dissolved and bounded nutrient that is the main factor, example is the permit given for the on land fish tanks at Kesknõmme with a 99 million m^2 sea water volume per year.

It is the private stakeholders who should select the system in use, its complexity, capex, and open level- the authorities should motivate and monitor.

Important is also that the West Estonian authorities motivate initiative setup on a larger volume scale so that all related parties can establish an economy of scale activity. We strongly recommend not to issue many too small licenses, group them together and issue less quantity of licenses. Some licenses should be small, medium, and large. According to the location`s capability to recover after a farming period- this is positive as then various stakeholders can select among a variation among dimensions, capex availability and willingness.

In line with this a private/ public marine service/ process laboratories/ education center and supporting lab, value added activity on land is crucial for both the finfish, fish health, macroalgae and shellfish initiatives being part of this report.

Our suggested aquaponic arrangements should attract wind driven energy companies in joining forces with production/farming stakeholders (energy is required for waterflow, production of oxygen, fish processing line, cultivation of macro algae and shellfish). Energy companies should also investigate the possibility where their floating offshore wind platforms could be adapted to also facilitate farming units- fundament here i.e., integration of oxygen production and storage, fish feed transport and storage, facility for farming crew and shared service/ maintenance staff and facilities and crew/ships.

There is valuable supporting industry already in the Estonia coastal zone that certainly can support and participate in the illustrated aquaponic and fish producing arrangements.

- combination of wild fish processing/ gear production and maintenance- linked to fish farming mooring and net production and net services
- food safety, packaging, freezer, and cooling facility and logistic
- in the Baltic/Nordic region there are multiple suppliers of various egg breeding program for trout, smolt, fish feed manufacturer
- Norway which is currently leading the technical development of new farming platform could certainly be an important supplier.

App.3 Status Baltic Sea

Any initiatives of modern fish farming activity, also for West Estonia, will result in waste products that normally will represent flux of organic waste and dissolved nutrients to the free water column (Nitrogen and Phosphorus). This is highly relevant for the Baltic Sea as such caused by

- being a very large marine sea area
- having limited seawater exchange in the Kattegat area where new more saline water can enter the Baltic Sea where at the same time pushes older sea out to the North Sea
- such water exchanges take place very seldom
- the whole Baltic Sea does receive waste and nutrient fluxes mainly form forest and agriculture activities for many years, wastes from modern land based industry activity and from human population causes all an increase in nutrient fluxes
- this have been the situation for many year=>
- this has resulted in an increased eutrophication; resulting in excess algae growth, excess oxygen demand, limited marine life in the deeper sea
- this situation results also in a pressure on the marine resources in general
- for a modern aquaculture perspective this has resulted in that the whole Baltic Sea is laid behind compared to the enormous growth which has and is taken place in the salmonid fish production in i.e., Norway and Scotland the last 40 years
- apart from this description the Baltic Sea water masses from surface and down to -30-40 m is well suited for marine exploiting
- on land structures for farming activity with high quality waste treatment techniques is hardly present in the region
- as in most coastal and offshore regions - weather conditions as wave and current and sporadic drifting ice in the northern part of Baltic Sea do represents physical risk to marine constructions.

<u>Illustrations of the main Directives and agreement for the Baltic Sea:</u>

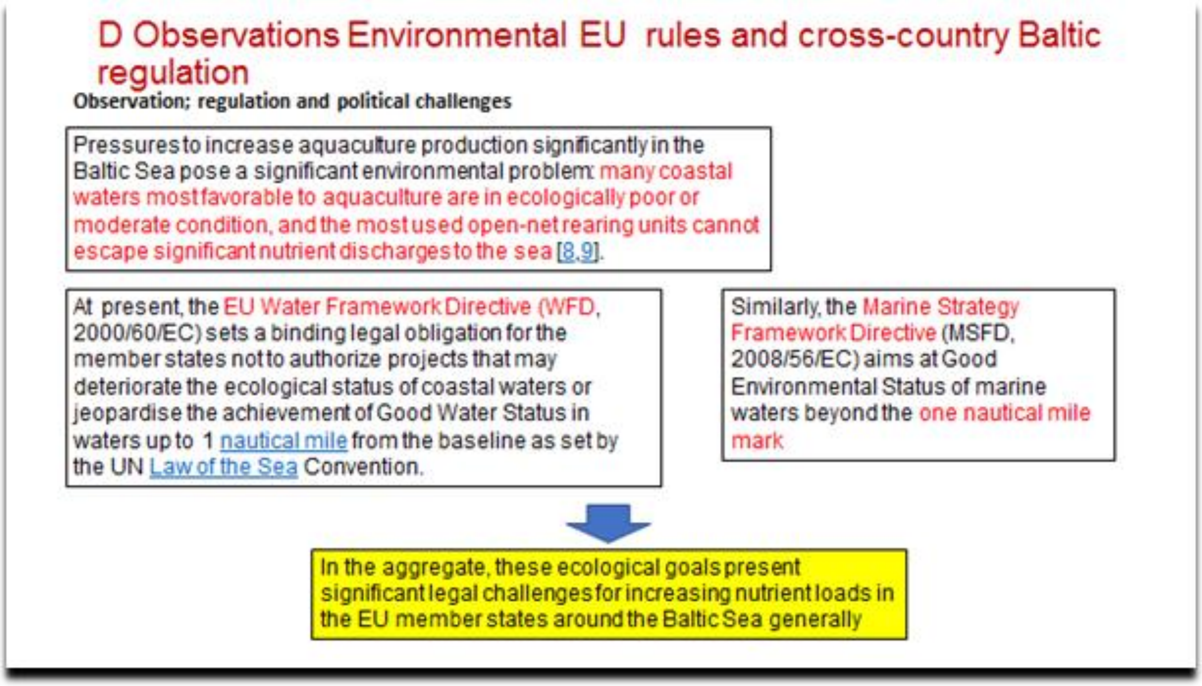

Figure 46. Regulation and Water Directives Baltic Sea.

These elements have resulted in a situation where the Baltic region has established cross country agreements and understandings to conserve and to protect the Baltic Sea. There is agreement among the countries according to the EU Framework Directive and other rules that have guidelines to be followed prior any approval of any new activity that may disturb the environmental conditions in negative directions.

Some countries do practice this in slightly different manners, and for aquaculture farming terms there are also diverting terms and conditions. There is also conflict of interest if i.e., an aquaculture activity can be further exploited, or new techniques can be introduced, and how waste flux quotas can be organized.

In some region there is a conflict of interest among the agriculture and aquaculture sectors i.e., Denmark.

A situation in Denmark as of today must be avoided.

- the open net trout farmers in Denmark have also shown a consolidation
- today there is approx. 4x farming companies
- in Denmark also fronting the Baltic Sea there have been discussions related to farming permits, possibility to use new better locations
- permits in Denmark is in principle based upon 2 elements
    - a discharge volume of x kg N and x kg P per site
    - some location has also an annual feed quota as part of the permits
    - not all farming locations has all l3 listed permits types
    - most production of large rainbow trout in Denmark is very different from other regions; they release large smolt to sea early spring, i.e., 800 gram, and harvest then as 3-3,5 kg in November, then leave the sites without any production at

  - all, a large proportion of the biomass is actually farmed in the end as maturing fish where the target is to produce eggs for caviar sales
  - in this way a waste related to 0-800 gram takes place on land- resulting in that the annual waste fluxes per individual sea sites is “undisturbed” in this period which allows the farmers to a similar additional sea-based waste volume
  - a seabed area permit
  - when these 2 permits are approved then a Danish fish farmer can start production
  - during the last 7 years these permits have been under different public institutional responsibility, and have been managed in a way where new applications have not yet been verified, farmers are waiting for final conclusions, nonnew sites have been granted
  - second and more severe- all previous granted permits are today in a “limbo” situation, they are all to be verified under to-days situation
  - their outcome for final result is unknown and makes the life as a fish farmer very unpredictable and unstable
- this is NOT saying that open net farming in Denmark is stopped nor banned- it is just a re-settling and a consolidation from the authorities on how to judge waste fluxes/ permits for the coming period
- some argue that fish farmers should move on land- but

WEM should create up to-day contact with aquaculture authorities in Norway, Denmark, Finland, and Sweden to make observations, learn of success and failure so that a new growing industry in West Estonia is framed under reliable conditions and terms, creating clear objective terms and conditions and with minimum of surprises for private farming companies.

App.4 Detail shellfish aquaponic

Aquaponic system for shellfish for this report

<u>Modelling the clearance rate of *M. edulis/trossulus*</u>

To define an effective aquaponic system, which cleans the wastewater of fish farms, the knowledge on the filtration potential of mussels needs to be known. The effectiveness of filtration of mussels depends on several factors, such as shell size, water temperature, salinity, water movement and concentration of suspended solids. Importantly, relationships between these environmental variables and the filtration rate are highly location-specific (Petersen & Loo, 2004; Lauringson et al., 2007, 2009, 2014; Kotta et al., 2009).

In this project, we combined all the experimental measurements collected in previous regional projects covering the West Estonian area into a single aggregated database to model the clearance rate of *M. edulis/trossulus*. Data on the clearance rates of the Estonian *M. edulis/trossulus* were obtained from the following scientific papers and associated databases:

Kotta & Møhlenberg (2002), Kotta et al. (2005), Lauringson et al. (2009), Lauringson et al. (2014).

Modelling algorithms. The contribution of different environmental variables on the filtration rate of *M. edulis/trossulus* was explored using the Boosted Regression Trees technique (BRT). BRT models are capable of handling different types of predictor variables and their predictive performance is superior to most traditional modelling methods (see e.g., comparisons with GLM, GAM and multivariate adaptive regression splines, (Elith et al., 2006; Leathwick et al., 2006). Overfitting is often regarded as a problem in statistical modelling but can be overcome by using independent data sets. The BRT modelling iteratively develops a large ensemble of small regression trees constructed from random subsets of the data. Each successive tree predicts the residuals from the previous tree to gradually boost the predictive performance of the overall model (Elith et al., 2008). Important parameters in building BRT models are the learning rate and tree complexity. The learning rate determines the contribution of each tree to the growing model and tree complexity defines the depth of interactions allowed in a model. A tree complexity of 1 assesses only main effects; A tree complexity >1 includes interactions. Different combinations of these parameters may yield variable predictive performance but generally a lower learning rate and inclusion of interactions gives better results (Elith et al., 2008). In the current study, the model learning rate was kept at 0.001 and tree complexity at 5. Model performance was evaluated using the cross-validation statistics calculated during model fitting (Hastie et al., 2009). The BRT modelling was done in R using the gbm package (Elith et al., 2008). Standard errors for the predictions and pointwise standard errors for the partial dependence curves, produced by R package "pdp" (Greenwell, 2017), were estimated using bootstrap (100 replications). Multicollinearity can be an issue with BRT modelling when assessing when environmental variables are of ecological interest. Thus, prior to modelling, the Pearson correlation analysis between all environmental variables were calculated to avoid including highly correlated variables into the model. The correlation analysis showed that most variables were only weakly intercorrelated ($r < 0.5$).

Key results. BRT models on the clearance rate of *M. edulis/trossulus* accounted for a significant proportion of the variability with r^2 values estimated at 0.93. Salinity was the best overall predictor in the model of clearance rate. Other important variables were water temperature and the concentration of organic particles in the seawater.

Increasing salinity increased the clearance rate of *M. edulis/trossulus* individuals up to a certain threshold value (i.e., 5 psu). The temperature response was more gradual with increasing temperatures resulting in increasing clearance between 0 and 25 °C. The clearance rate was inversely related to the content of organic particles. Importantly, in order to maintain an effective filtration by mussels, the concentration of organic particles should be kept below 2.5 g m^{-3} (Figure 47). In order to extrapolate the clearance rate of mussel individuals to the population scale, we established allometric relationship between mussel length and weight using mussels collected from the western parts of the Estonian maritime areas (Figure 48).

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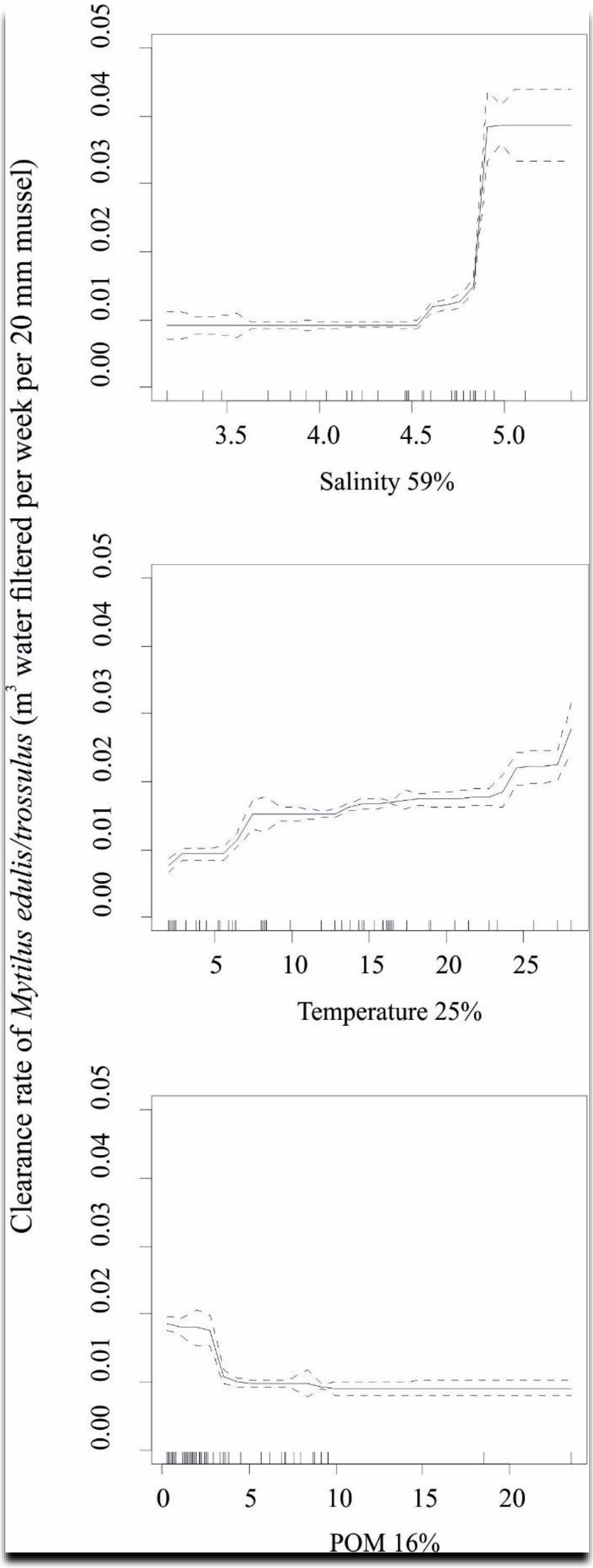

Figure 47. Standardized functional-form relationships (± Standard Error) showing the effect of key environmental variables on the clearance rate of individual mussels of *M. edulis/trossulus*, whilst all other variables are held at their means. The variables are ordered by their relative

contribution in the BRT model (shown in %). Upward tick marks on x-axis show the frequency distribution of data along this axis.

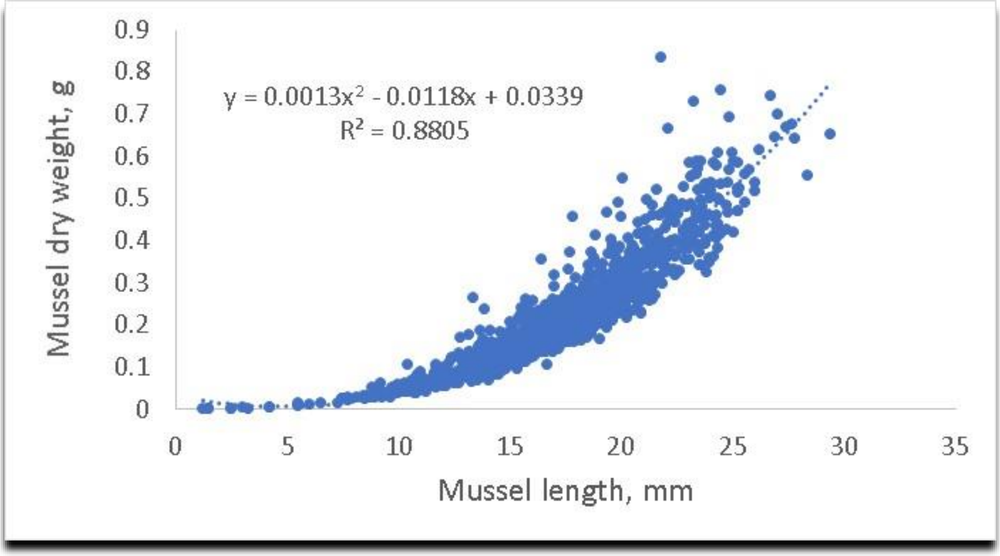

Figure 48. Relationship between mussel length and weight in Estonian marine areas (unpublished data).

Using mussel aquaponic units to clean the wastewater of land-based fish farms

It is important to notice that in our base calculation of fish production, biomass, feed and waste volumes we used one of many potential mix of smolt entry. The listed values of production capacity of mussel, macroalgae is not directly transferable to other production setup. Our numbers are only relevant for our dimensions of tanks and fish bags and also our average density of kg fish/m^3 enclosed water, time of year and their feed volume per day, per week.

The trawl nets dimensions and the macroalgae density in the water column of the algae bags are other important parameters that certainly influences the aquaponic effectiveness of capturing fluxes.

Our baseline setup: Aquaponic unit installed in sea (mussel bags)

The aquaponic system is installed at sea in the vicinity of the land-based fish farm. Effluent from the fish farm is channeled by pipeline to a mussel aquaponic unit. Importantly, nutrients do not leak out from such a system into the marine environment. Our mussel aquaponic unit has the following dimensions: diameter 28 m, depth 10 m, surface area 615 m^2 and volume 6154 m^3. Each of such mussel aquaponic unit includes trawl net as a substrate for mussel growth. Each trawl net element has 9 x 13 m in size, the trawl nets are arranged in series, the distance between trawl net elements is 25 cm and such an arrangement results a total of 6552 m^2 of growth substrate for mussels in the aquaponic system. There is a pump at the bottom of the mussel aquaponic station that daily removes mussel feces and dead shells settled at the bottom.

In order to develop sewage treatment schemes for fish farm effluents based on shellfish culture (i.e., a mussel aquaponic unit) and to assess the efficiency of such a system we applied the model of clearance rate on the estimated dynamics of effluents originating from a hypothetical fish farm (Figure 49). To clean up all the effluent originating the fish farm, seven (minimum 6 and maximum 9 units) such shellfish units need to be set up (Figure 50). Even though at some seasons a lower number of mussel units can purify all the effluents, it is not practically feasible to change the number of such treatment units seasonally.

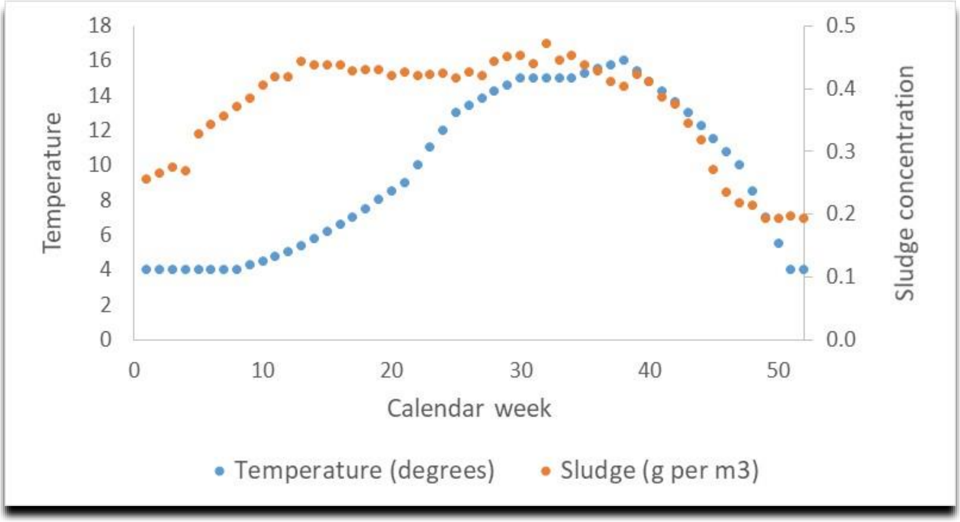

Figure 49. The dynamics of water temperature and sludge concentration in the sea based aquaponic mussel unit within one calendar year, for our baseline fish farm.

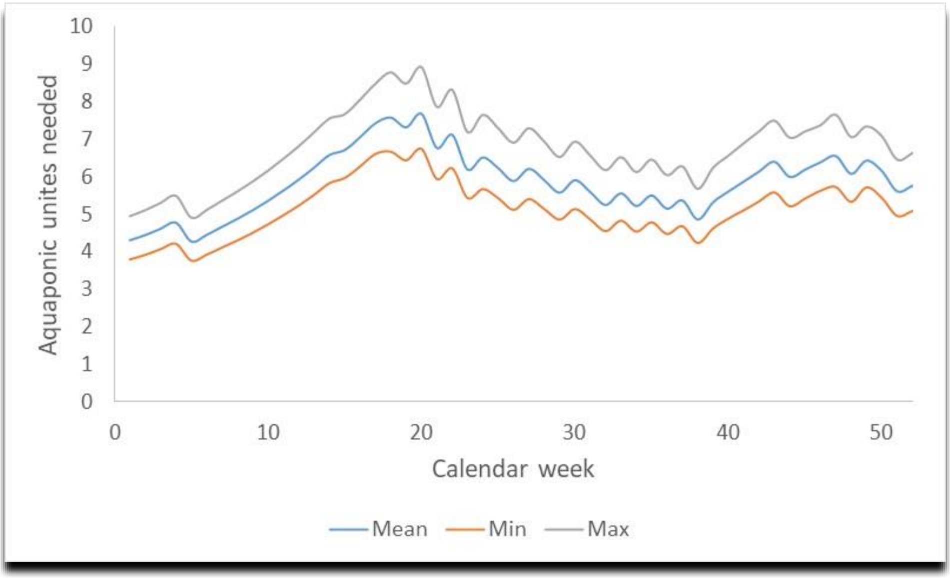

Figure 50. The number of seas based aquaponic units needed to filter out 100% sludge coming from the drum filter within one calendar year for our baseline fish farm.

To set up such purification stations, the trawl net must first be placed in the marine environment in May-June. These nets must then be inspected to see whether the juveniles of the shellfish have attached to the net. If successful, the nets can be moved to the aquaponic system. It takes about nine months for the shellfish to grow, at which point such a mussel treatment unit is ready to receive the fish farm effluent at full potential. Such a treatment plant can work for years without being harvested. However, if the aim is to harvest shellfish, it is most reasonable to do this when the shellfish are 2.5 years old. The expected mussel yield of each aquaponic unit is in minimum 47.9 tons wet weight of mussels (flesh and shell) per harvest (i.e., for a period of 2.5 years), or said 24 tons per year. Mussel harvesting should be preferably taken place in autumn when the biochemical composition of the mussels is at its best and when the amount of fish farm effluent is not the highest.

<u>Aquaponic unit installed on land (tanks on land)</u>

Alternatively, mussel aquaponic units can be installed on land. Here, the mussel unit has the following dimensions: diameter 25 m, depth 4.5 m, surface area 491 m^2 and volume 2208 m^3. Similar dimensions as for our baseline biomass for fish farmed on land.

As for sea-based system, each of such mussel aquaponic unit includes trawl net as a substrate for mussel growth. Each trawl net element has 4 x 11 m in size, the trawl nets are arranged in series, the distance between trawl net elements is 25 cm and such an arrangement results a total of 2112 m^2 of growth substrate for mussels in the aquaponic system. There is a pump at the bottom of the mussel aquaponic station that daily removes mussel feces and dead shells settled at the bottom. There is different average density of fish per enclosed m^3 for bags versus fish tanks.

To clean up all the effluent originating the fish farm, 24 (minimum 21 and maximum 28 units) such shellfish processing plants need to be set up (Figure 52). The expected mussel yield of each aquaponic unit is in minimum 15.4 tons wet weight of mussels (flesh and shell) per harvest (i.e. for a period of 2.5 years).

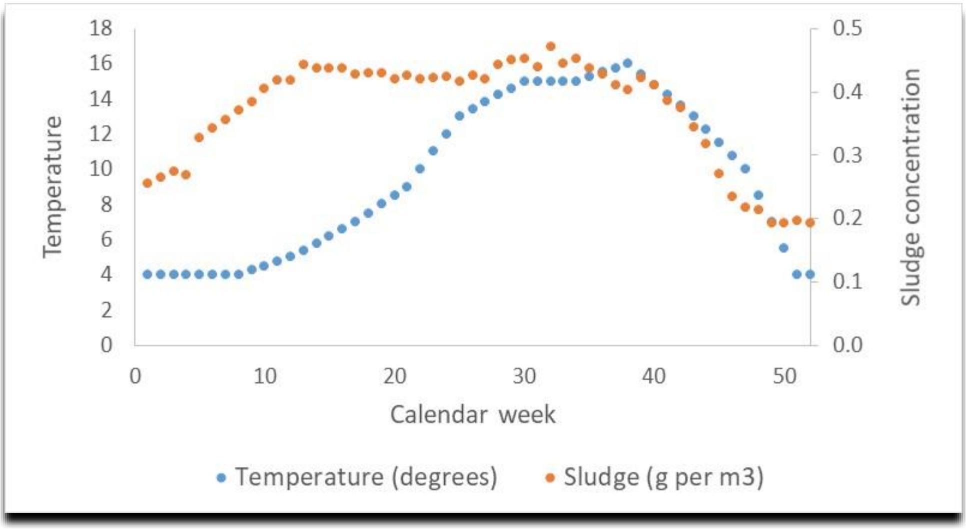

Figure 51. The dynamics of water temperature and sludge concentration in the land based aquaponic mussel unit within one calendar year.

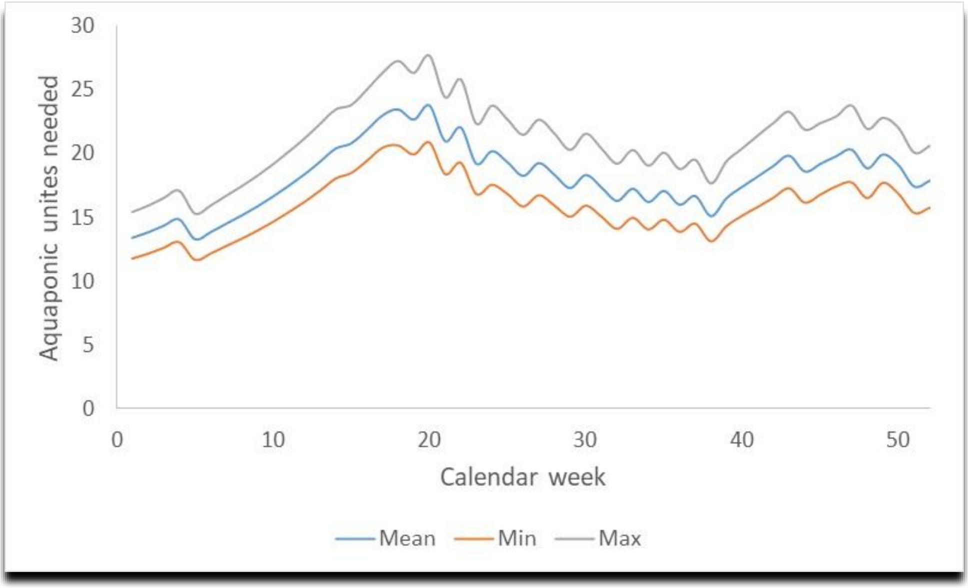

Figure 52. The number of land based aquaponic units needed to filter out 100% sludge coming from the drum filter within one calendar year.

Using mussel aquaponic units to clean the wastewater of Open net fish farm.
Similar aquaponic system (mussel bags) as described above for the land-based fish farms can be used in the Open net solution. Here, it is important to assure that nutrients do not leak out from such a system into the marine environment. Moreover, it is important to assure the maintenance of a pump at the bottom of the mussel aquaponic station that daily removes mussel faeces and dead shells settled at the bottom.

The actual number of such mussel aquaponic stations will depend on the temperature regime in a given sea area, but in general the Open net areas of west Estonia are characterized by a similar seasonality of temperatures as described above for the land-based system and therefore the expected number of mussel aquaponic units do not significantly deviate within the entire area of interest of west Estonia and is estimated at 7 ± 2 mussel units per fish farm.

Offshore shellfish cultivation
In addition to offsetting the impacts of fish farming, shellfish farms can be independently established over a very large area, and in essence, there is an unlimited natural resource (microalgae) for this activity. Besides nutrient removal, such a shellfish farm significantly increases water transparency and mitigate the risks of local algal blooms within a radius of about 1 km^2. Consequently, it makes sense to locate shellfish farms in areas experiencing land-based nutrient load, as such co-existence can compensate for the nutrient fluxes released into the sea and keep the water in the vicinity of wastewater outlet pipe transparent. Information on the suitability of different marine areas for shellfish farming can be found on the ODSS portal at http://www.sea.ee/bbg-odss/Map/MapMain. The same portal (see section plan your farm) shows the production yield of mussel farms in each sea area as well as the expected removal of nutrients following the mussel harvest.

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App.5 Detail macroalgae aquaponic

Introduction

Macroalgae have a long history of exploitation by peoples all around the globe (Periera, 2016). Primarily utilized as a food source, edible seaweed provides a good source of proteins, lipids and dietary fibers when consumed by humans (Dawczynski et al., 2007; Macartain et al., 2007).

Macroalgae's high photosynthetic productivity also implicates it as an important source of carbon storage globally. As macroalgal material is sequestered into sediments and exported into the deep marine environment, it locks away atmospheric CO2 and acts as a carbon sink (Gao & McKinley, 1994). Additionally, collecting or cultivating macroalgae for use in the production of fuels can act to offset anthropogenic atmospheric carbon production from fossil-based fuels by providing an alternative fuel source in the form of carbon neutral biofuels and bio-butanol (Enquist-Newman et al., 2014; Kraan et al., 2013; Potts et al., 2012; Wei et al., 2013). In addition to the capture of CO2, macroalgae uptake dissolved inorganic nutrients

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such as nitrogen and phosphorous. This process stimulates algal growth and is important in mediating the deleterious effects eutrophication has in coastal zones, which as it stands, represents a major issue for many coastal regions around the globe (Leandro, 2019).

Macroalgae cultivation is primarily dependent upon seawater containing sufficient nutrients to act as a growth medium. As a photosynthetic organism, macroalgae growth rates are determined upon environmental factors such as temperature, nutrient availability, pH, CO2, solar radiation and salinity (Dawes et al., 1998; Choi et al., 2010; Guo et al., 2015). However, such factors combine in a complex interplay to determine a given growth rate dependent on the macroalgae species under cultivation, of which each species is unique. Furthermore, as many algal species display complex and poorly understood life stage histories, the factors that control both germination and growth likely change through time adding to the complexities of cultivation and maximizing production (Cumming et al., 2019).

Suitable species for cultivation in NE Baltic Sea

As Baltic Sea is a brackish environment most of the macroalgal species cultivated in the other parts of the world ocean cannot survive in these conditions. Species suitable for cultivation should usually correspond to one or more of following criteria:

1. Opportunistic species with fast growth and high nutrient and CO_2 uptake
2. Generalists in substrate requirements
3. Effectively controlling epiphytism
4. Vegetative reproduction, simple life cycle
5. Tolerant to moderate mechanical disturbance

Total number of macroalgae native to Estonian coastline is up to 80 species with about 20 being most frequent. Out of them less than 10 can be selected based on listed criteria. Most promising candidate species for mass cultivation belong to group of green algae.

Chlorophyta (Green algae)

Chlorophyta or green algae so called due to the chlorophyll (a and b) pigments that give its appearance form a large group of photosynthetic organisms. Chlorophyta utilize these pigments along with carotenoids, not only for energy production but also to protect the damaging effects of ultra-violet light (Barsanti & Gualtieri, 2006) and as chemical defense (Kadam et al., 2013).

Chlorophyta have been shown to be a rich source of carbohydrates, particularly that of sulphated polysaccharide which are structured within the algal cell walls (Lahaye & Robic, 2007). One such polysaccharide, ulvan, derived from Ulvaceae is a water-soluble gelling polysaccharide with bioactive properties such as immunomodulating, antiviral, antioxidant and anti-cancer (Kidgell et al., 2019). Ulvans account for roughly 20-30% of the total carbohydrate component of chlorophyta but their bioactive concertation and function vary dependent upon factors that pertain its given chemical structure. Therefore, ulvan bioactivity is highly diverse and differs based on the species from which it is extracted from as well as the environmental factors effecting an individual plant (Kidgell et al., 2019). Ulvan is of interest to the biomedical industry, its potential use in applications related to tissue engineering, antibacterial biofilm prevention and as a drug delivery device have been noted by researchers once it was proven ulvan is recognised animal liver cells (Kidgell et al., 2019; Alves et al., 2013; Wijesekara et al., 2011; Venkatesan et al., 2015; Cunha & Grenha, 2016). The development of products related to such effects has the potential lead to significant economic opportunities.

In addition to ulvans unique gelling and bioactive properties, chlorophyta are reported to have novel uses outside of the food and pharmaceutical industries. Anionic polysaccharides found within Ulva sp. have the ability to accumulate heavy metals within the algal cell structure. As such, Ulva sp. can concentrate heavy metals found to pollute contaminated waters and when removed and destroyed can mediate pollution (Webster & Gadd, 1996; Bocanegra et al., 2009; Schijf & Ebling, 2010). This ability by *Ulva* sp., therefore, can be utilised in the mitigation of anthropogenic wastewaters as the species display high growth rates particularly under high nutrient regimes (Kraan, 2013; Castine et al., 2013, Lawton et al., 2013; Glasson et al., 2017). Ulva propagation is therefore positioned as a useful tool for environmental managers for heavy metal bioremediation.

Overall chemical compounds derived from chlorophyta have been demonstrated to be highly diverse in nature with applications in pharmaceuticals, nutraceuticals, foods, feed, agriculture, and bioremediation.

For Estonian coastal conditions species *Ulva intestinalis* is recognized to be one of the most perspective species for mass cultivation:

1. species is present in Estonian coastal sea most of the vegetative period (April November)
2. species can grow both in attached and free floating form
3. species is salinity tolerant (0,1-15 PSU)
4. species utilizes high concentrations of nutrients
5. gives several generations during the vegetative season
6. active control of epiphytes
7. simple structure
8. simple life cycle (Figure 1.)
9. multitude of commercial applications

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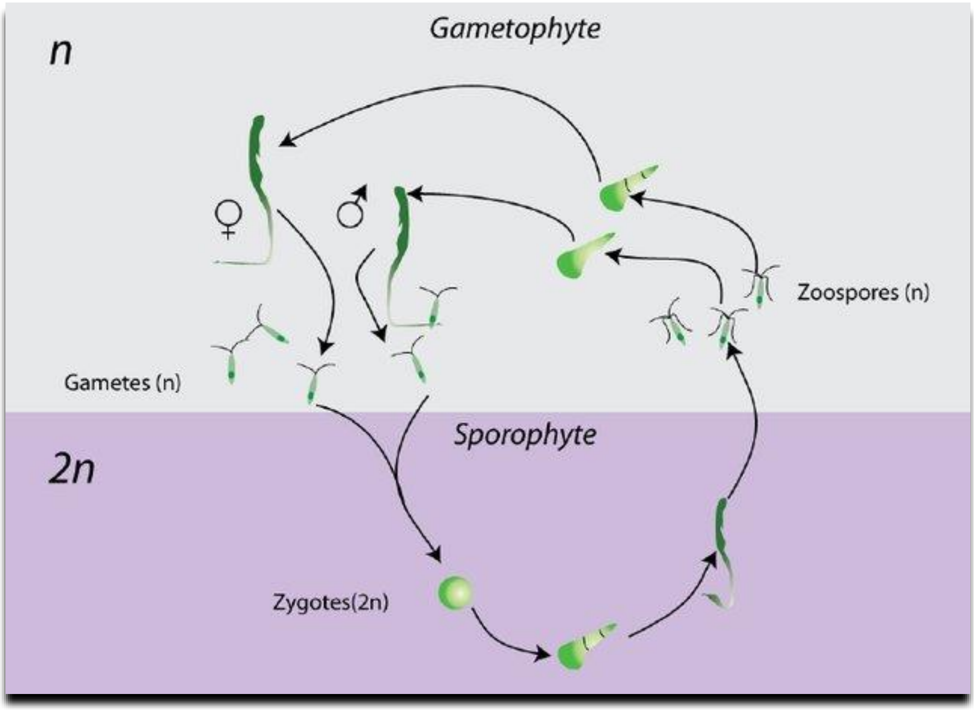

Figure 53. Life cycle of *Ulva intestinalis*. (from Bast 2014).

Methods of Cultivation

The cultivation of macroalgae is predetermined by the specific growth requirements of a given algal species. In general, the physical properties of seawater used as a cultivation medium are the main environmental factor regulating growth. Macroalgae growth is always regulated to varying degrees by the factors of temperature, pH, salinity, nutrient availability and solar radiation (PAR). Moreover, macroalgae often display complex lifecycles and as such certain environmental factors will affect algal growth disproportionality at varying life phases. Thus, a high degree of biological and technical knowledge is required for a cultivation venture to succeed.

Integrated Multitrophic Aquaculture

Traditional single species aquaculture whereby one species is cultivated in a manner that maximizes biomass production is increasingly viewed as overly simplistic and one that contributes to environmental degradation of the marine environment. To mediate some of the environmental impacts associated with animal aquaculture, such as eutrophication from excess nutrients, the spread of disease, as well as improving farm output from a given area, seaweeds are being integrated into traditional animal aquaculture operations. The practice of co-farming multiple aquaculture species in proximity is known as integrated multitrophic aquaculture (IMTA) and provides numerous benefits through the interconnection of species. The IMTA model prioritizes cultivating species whose products (inorganic and organic) of one species are up taken by another to serve as an energy source. As such, the need for the

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addition of costly fertilizers to promote seaweed growth is reduced and profit is increased sustainably through seaweed biomass growth.

Several studies have assessed the effect fish aquaculture effluent and waste products has on the growth of macroalgae. These investigations found that seaweed biomass increased when cultivated within existing fish farms. A study by Buschmann et al., (2008) demonstrated that seaweed grown near salmon aquaculture operations in combination with other filter feeders in an IMTA arrangement resulted in the uptake of, and absorbance of, organic and inorganic nutrients. Such an arrangement reduces the environmental impact of salmon farming operations (Buschmann et al., 2008).

Integrating macroalgae production into current animal cultivation methods may also benefit farm operations through bioremediation and other biological services. As macroalgae grow they uptake excess nutrients from the water column providing a filtering effect improving overall water quality and offsetting detrimental farm effects. Furthermore, macroalgae cultivation can offset environmental impacts on land. Through their use as a fertilizer to improve soil condition and substituting synthetic chemicals macroalgae can offset atmospheric emissions. The environmental benefits of macroalgae aquaculture are therefore felt both at a local and global scale with the mitigation of eutrophication and increased support of biodiversity acting locally, and carbon sequestration or 'blue carbon' acting globally. With this in consideration aquaculture operations can make use of environmental tax subsidies to improve their economic viability.

One of the greatest challenges with implementing IMTA into traditional single species aquaculture operations is identifying suitable seaweed species for culture. Typically, species high in productivity/growth rates i.e. high nutrient uptake, high in economic value and that are relatively hardy in regard to environmental conditions are most suitable for IMTA. By optimizing farm design and utilizing data driven models combined with primary biological research seaweed species can be selected for IMTA to optimize economic gain and environmental mediation.

By adopting IMTA practices, aquaculture operations can not only reduce their environmental impacts, but also gain economic benefit by diversifying products that can be commercialized and brought to market. Figure 2 provides an example of an IMTA operation.

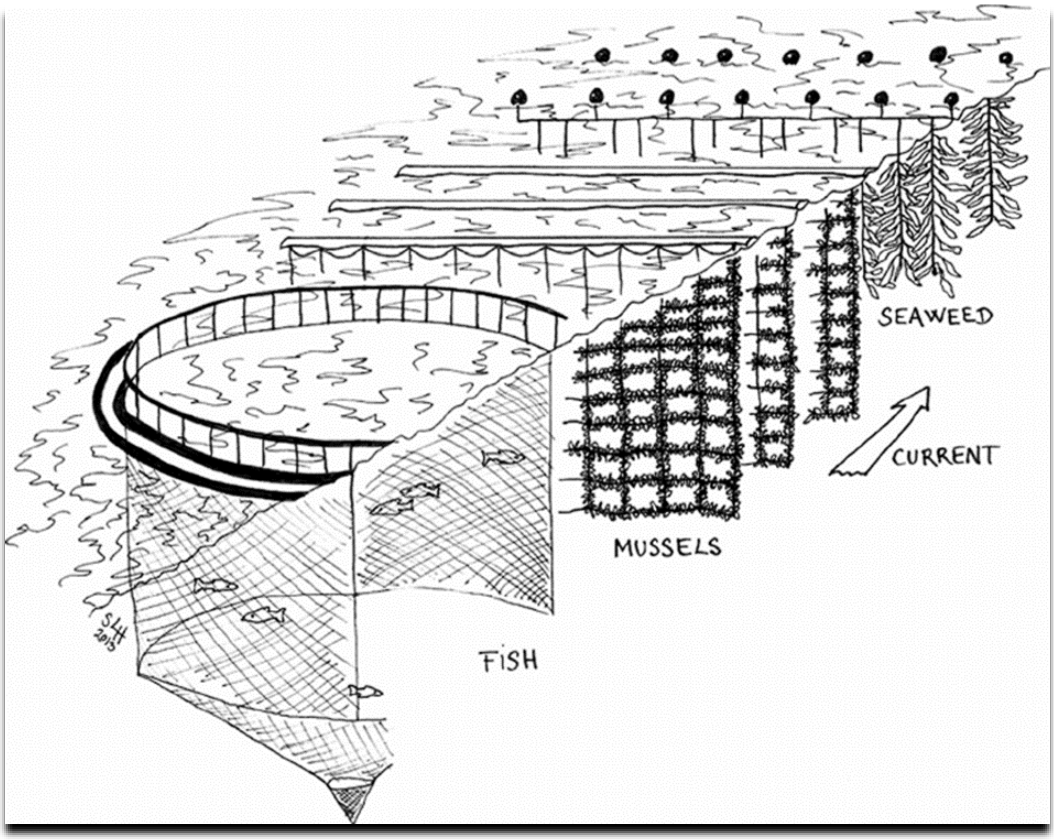

Figure 54. Schematic of an integrated multi-trophic aquaculture (IMTA) example of rainbow trout in a polar circle cage, mussels on a SmartFarm TM longline and seaweed suspended on droppers on longlines (Holdt & Edwards, 2014).

Cultivation of *Ulva intestinalis*

Ulva sp. is used for cultivation worldwide for a big number of different applications. This group of species is cultivated both free floating in tanks and on ropes in open water. Experiences with *Ulva* cultivation in Estonia are almost absent. Recently ended project was a first attempt for such cultivation and using of the *Ulva* biomass to remove nutrients from fish-farm effluents (TÜ EMI, 2021). During this project, the main aim was to study the possibility of removing nutrients from fish farm wastewater before entering back to the sea but as a side product the maximum of 4% of gain in biomass daily was achieved in successful experiment (figure 3.). According to literature the biomass gain of Ulva in such systems can reach up to 30 %/day.

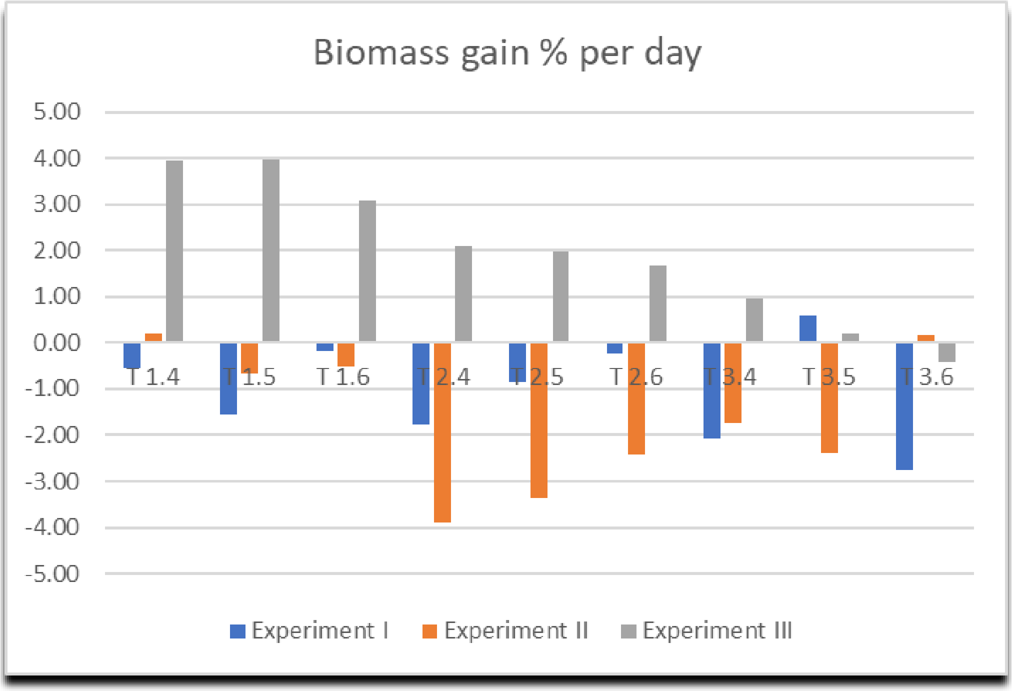

Figure 55. Biomass gain in incubation tanks (% per/24h) during the *Ulva* cultivation experiment carried out in Kesknõmme (NW Saaremaa Island) in 2020. Each experiment lasted 4-5 weeks. Experiments I and II failed because of overheating of the water in incubation tanks (TÜ EMI 2021).

The concentration of the nutrients tested was found to decrease throughout the mesocosm series. Both Nitrite and Nitrate were observed to be up taken by the mesocosms containing the macroalgae *Ulva intestinalis* when compared to the associated control. Under favorable growth conditions *U. intestinalis* demonstrated a significant increase in the uptake of both nitrate and nitrite resulting in a decrease of 18.4% and 25.2% of the nutrients respectively when compared to the control series (students t-test; $p < 0.05$) (figure 4.). The phosphorous nutrient data was found to have a large degree of variability among the samples and due to this high variability, no significant difference between the control series and macroalgal stocked series for these nutrients was observed. Overall, the system demonstrated a high degree of nutrient removal efficiency, with up to 60% of both nitrate and nitrite removed from the system and 60% of phosphate and 30% of phosphorous also removed relative to concentration of nutrients measured in the trout mesocosm (Hall and Martin 2021).

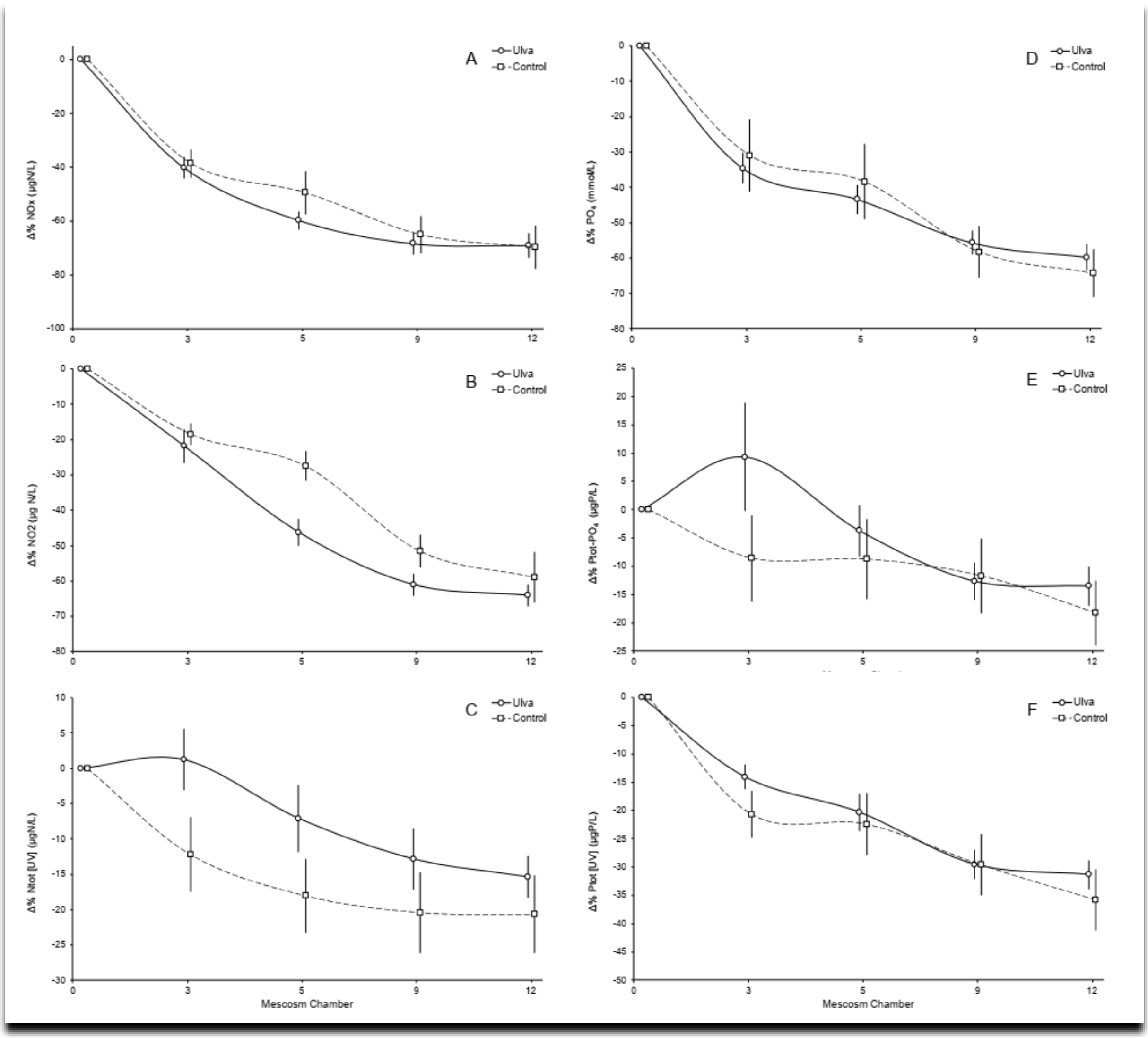

Figure 56. Change in the mean concentration of the nutrients (A= nitrite, B= nitrate, C= total nitrogen, D= phosphate E= phosphorus and F= total phosphorus) as a percentage relative to the initial trout stocked mesocosm across the mesocosm series. The mesocosms ranked four, five and six in the *Ulva* series were stocked with macroalgae. The control series contained no macroalgae. Error constructed as ±1 standard error (from Hall & Martin 2021).

Modelling Ulva growth potential for WE fish farm case

In our case we assume that we will be able to cultivate *Ulva* in the continuous flow of seawater coming from fish farm bags and mussel farm bags. Mussel incubation bags will remove most of the suspended solid and water entering *Ulva* bags will be saturated with CO_2 and having high concentration of nutrients. Water temperature will change with the season, but we assume that farm will be in the area with deeper water (not in the archipelago area where the water temperature can reach 20+ during the summer months). Temperature optimum for cultivation of Ulva should be in the range of 13–18 °C (observation from TÜ EMI 2021). Temperatures higher and lower are considered as not optimal.

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Modelling result is presented in Table 1. So, we consider cultivation unit to be of volume 6154 m^3. Optimum density of *Ulva* in such unit is 1.6 kg dw/m^3. This density will result in close to 10 t of dry weight of *Ulva* kept continuously in the unit. For aeration and enabling circulation of algal material it is needed to continuously aerate the tank/bag, so the vertical water circulation is created, and algal mass is equally exposed to the sunlight. It is assumed that nutrient and CO_2 are available in optimum amounts (no limitation) and the productivity of biomass is estimated to be at 10% per day for 3 months and half of that for 5 months per year.

Key modelling observations:

- Nutrient content of *Ulva* sp. 30–36 mg/g dw for nitrogen and 1.2-1.8 mg/g dw phosphorus was used (Villares et al 1999).

- Result shows approx. 160 t of dry weight production of *Ulva intestinalis* for the one season per one tank/bag.

- Amount of nutrients removed from the effluents by generating this biomass is close to 4.8 t of nitrogen and 0.230 t of phosphorus.

Table 1. Results of productivity estimates for *Ulva* cultivation in WE fish farm setup.

Calculation for 1 bag	
density kg dw/m^3	1.6
volume m^3	6154
standing stock kg dw	9846.4
growth 1 day (10%)	984.64
growth 30 days	29539.2
growth 90 days (optimum)	88617.6
growth 150 days (50% of optimum)	73848
growth per season kg dw	162465.6
growth per season kg ww	1624656

Figure 57 Productivity data *Ulva intestinalis*

Possible restrictions:

1. biomass should be constantly harvested/removed from the incubation tank (at least once per 3 days 1/3 of the biomass should be removed during optimum season)

2. Starting biomass or generation G0 is needed to operate the incubation facility. This cannot be harvested from the nature nor purchased – separate on land farming facility is needed.

3. This mass cultivation has not been done in practice – so the development and testing stage is needed before real-life application.

Figure 58. Cultivated *Ulva intestinalis* at Kesknõmme experimental farm in September of 2019.

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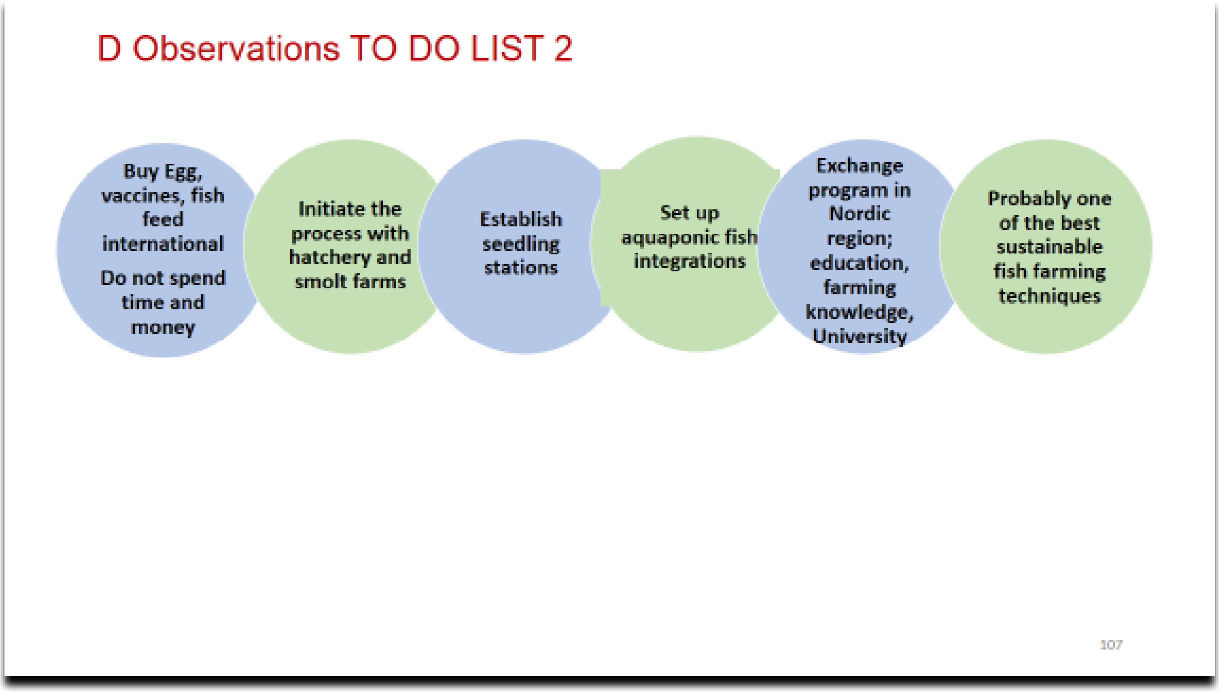
App.6 Details TO DO list

Below is listed various TO DO actions. It is important that WEM do spend time and allocate resources for its strategic direction in evaluation the way forward. Our circular economy estimates are conservative; in Norway there is approx. 3x land jobs per every fish farming production staff, and there is approx. 300 tons productivity for each such staff. For our West Estonia estimates we have rather kept it as job: job as 1:1 and a productivity as 100 tons per man-year.

Inspection and visiting i.e. Norwegian fish platforms, and key fish health, licenses staff within the public aquaculture department is considered to be very valuable. A suggestion could be to meet such public staff first, then to visit the fish farms.

A video meeting with the leader of the Danish Sea based Open net trout farmers will highlight valuable elements too.



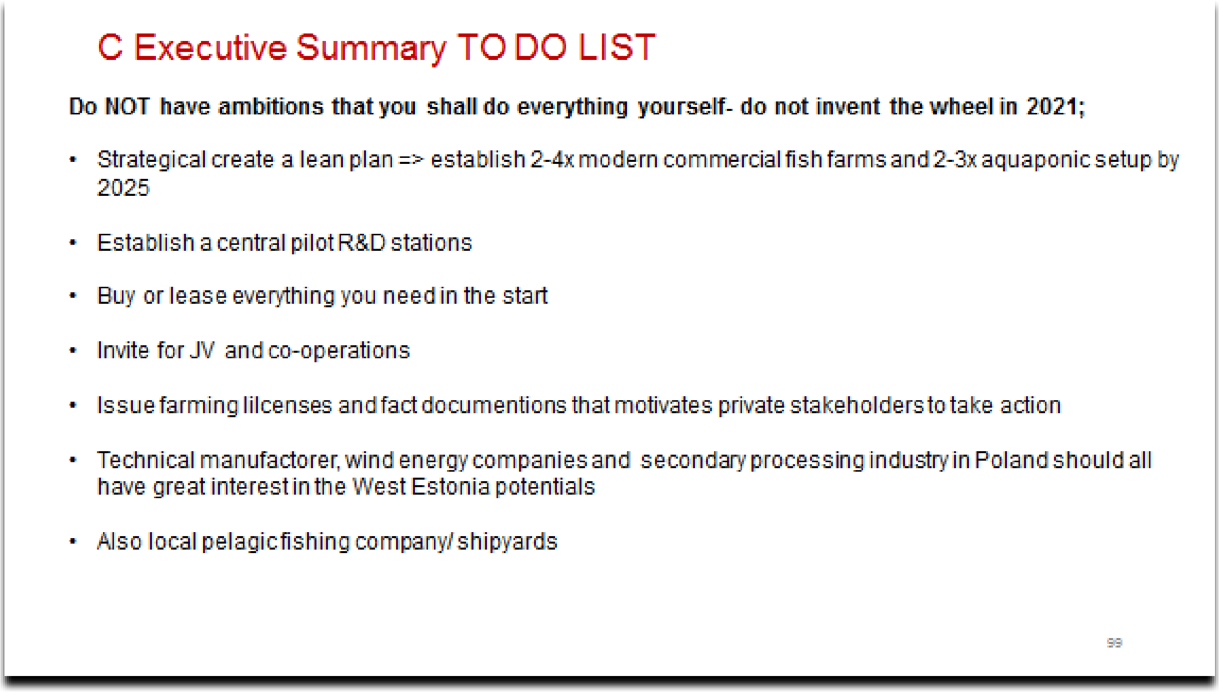


Figure 59 TO DO list.

<u>Comments:</u>

We consider that setting up a R&D station where science and practical farming and aquaponic activities can share resources and knowledge is very important. A separate document, meant for restricted distribution related how to set it up, its stakeholders, how to create contributions (opex, labor, capex) is part of this report.

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Figure 60 TO DO list Pilot station.

<u>Comments:</u>

These floating units is owned and operated by the largest private R&D company in Norway, LetSea AS, www.letsea.no. They are by far the largest owner and operator of floating fish bags.

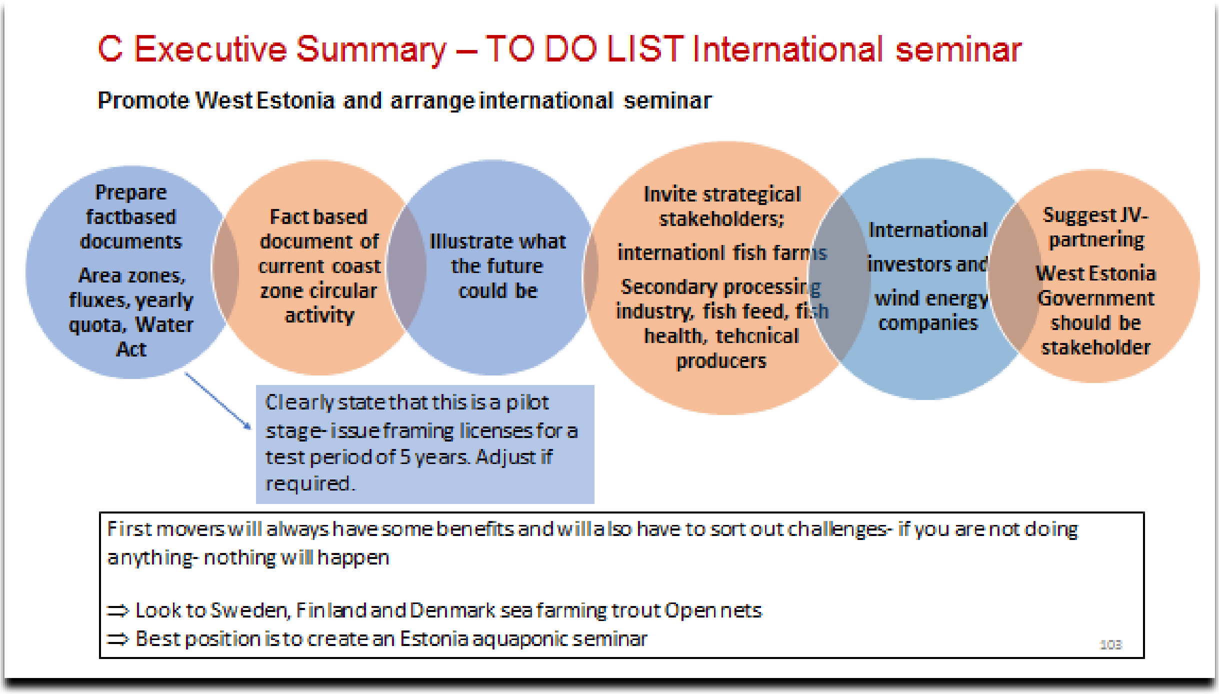


Figure 61 International seminar.

Comments:

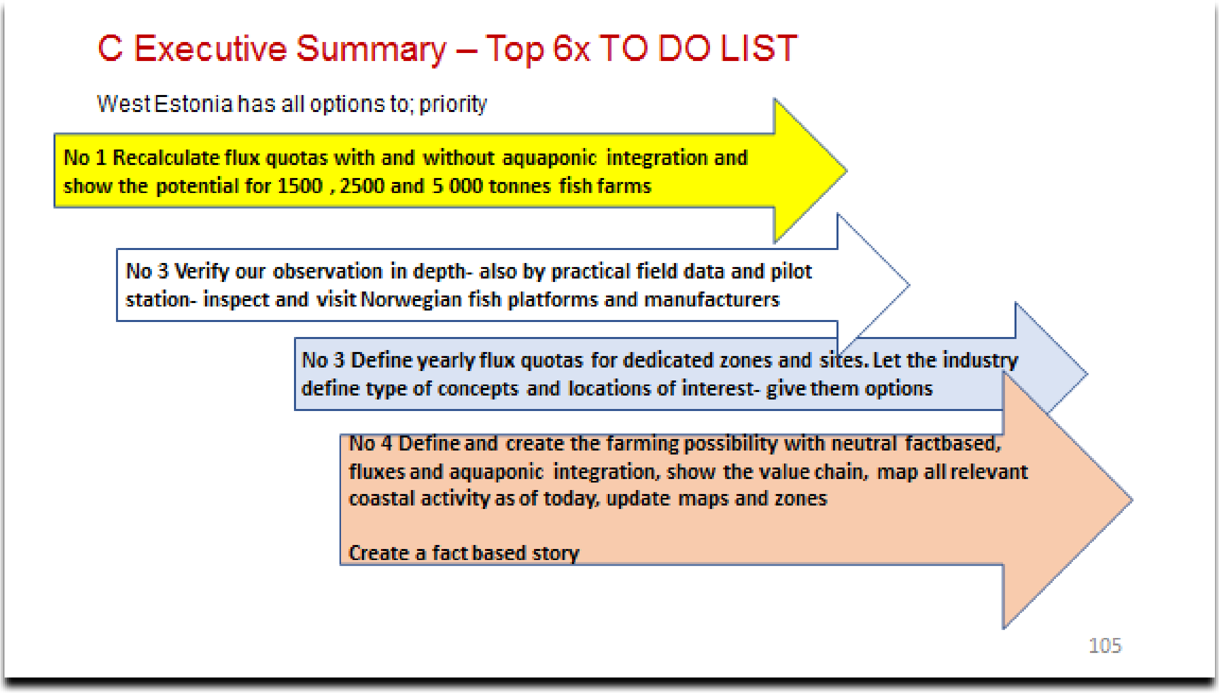
General fact based, English version, of the structure of the various elements to current circular coastal economy is very valuable- There potential stakeholders will see that there is a valuable structure today, that they do not have to invent everything from scratch. List of company, web pages, location and main activity will reduce the risk factors for an expansion phase. Private and public sector must be part of such overview.

Create drafted, illustrations of areas where the public sector do consider to be the best aquaculture zones. Licenses and biomass quota must not be 100% finalized, but ranges could be shown i.e. 500.1 00 tons, 1500-2000 tons or > 2 000 tons. All linked to flux quantity per kg fish produced.

<u>More precise Water Act definition:</u>

The definition of what is fish produced must also be shown, is it the live harvested swimming biomass or is it the harvested plus the round weight of the mortality? This will influence the total fluxes to sea.

<u>The most important 6x TO DO elements:</u>



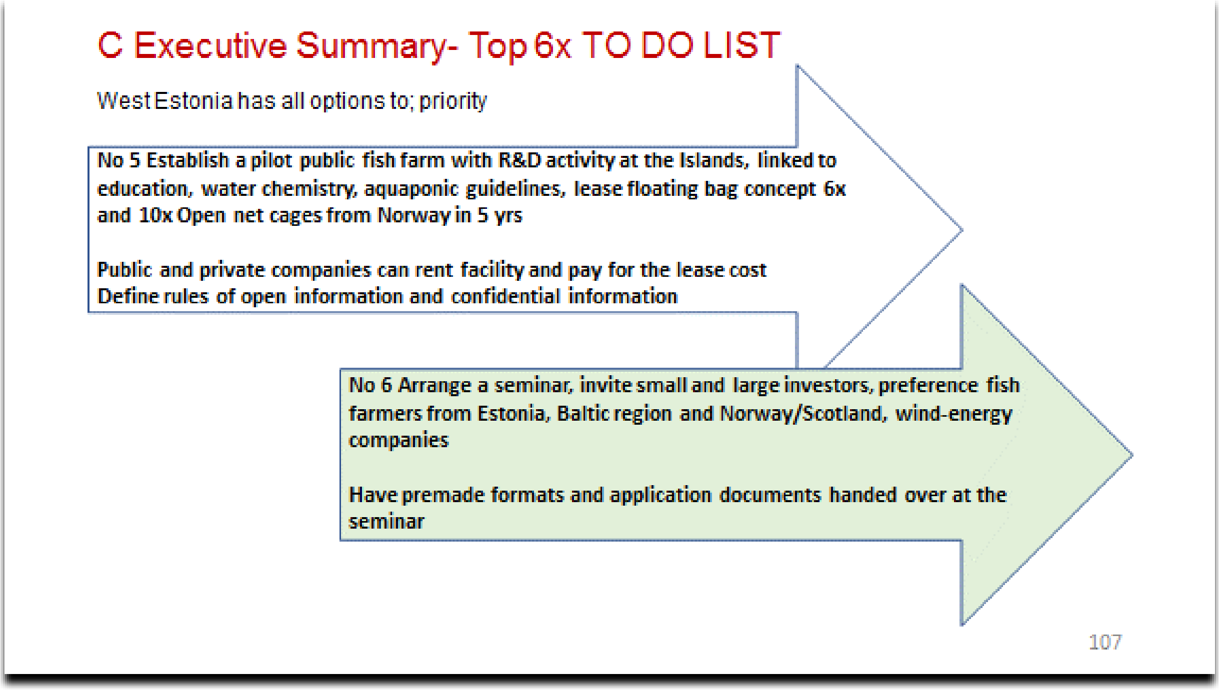


Figure 62 Various TO DO elements.

App.7 Circular economy observations

Summary of circular economy observations

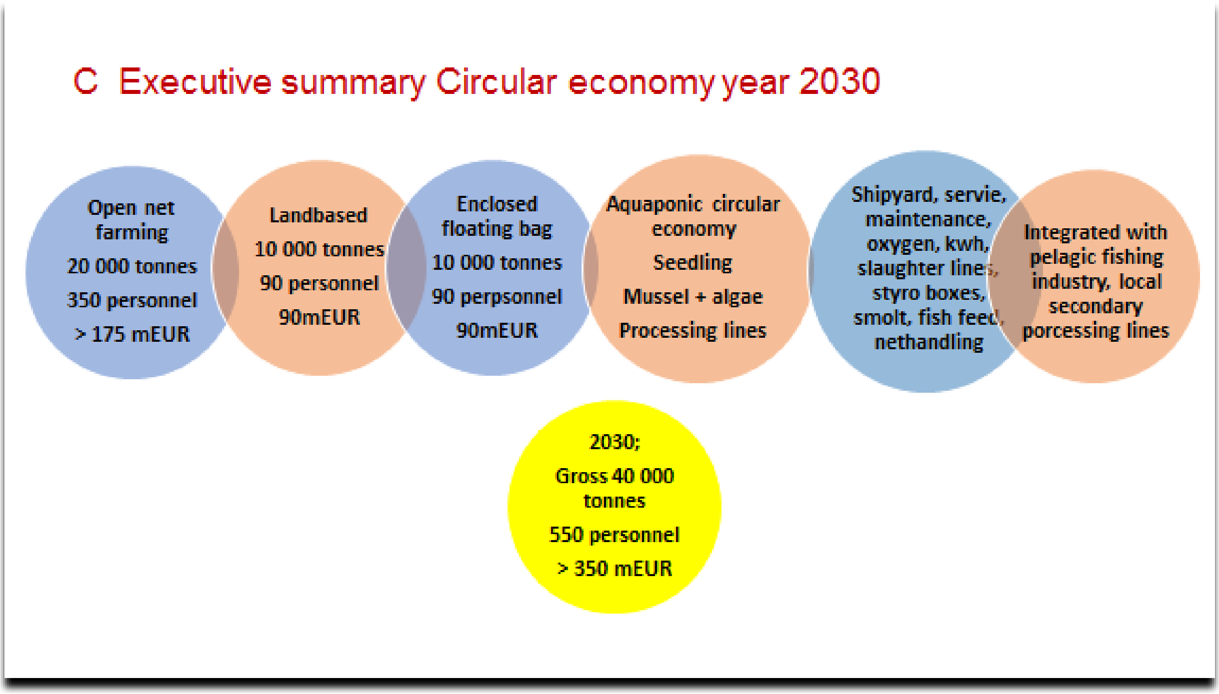


Figure 63 Gross circular observations.

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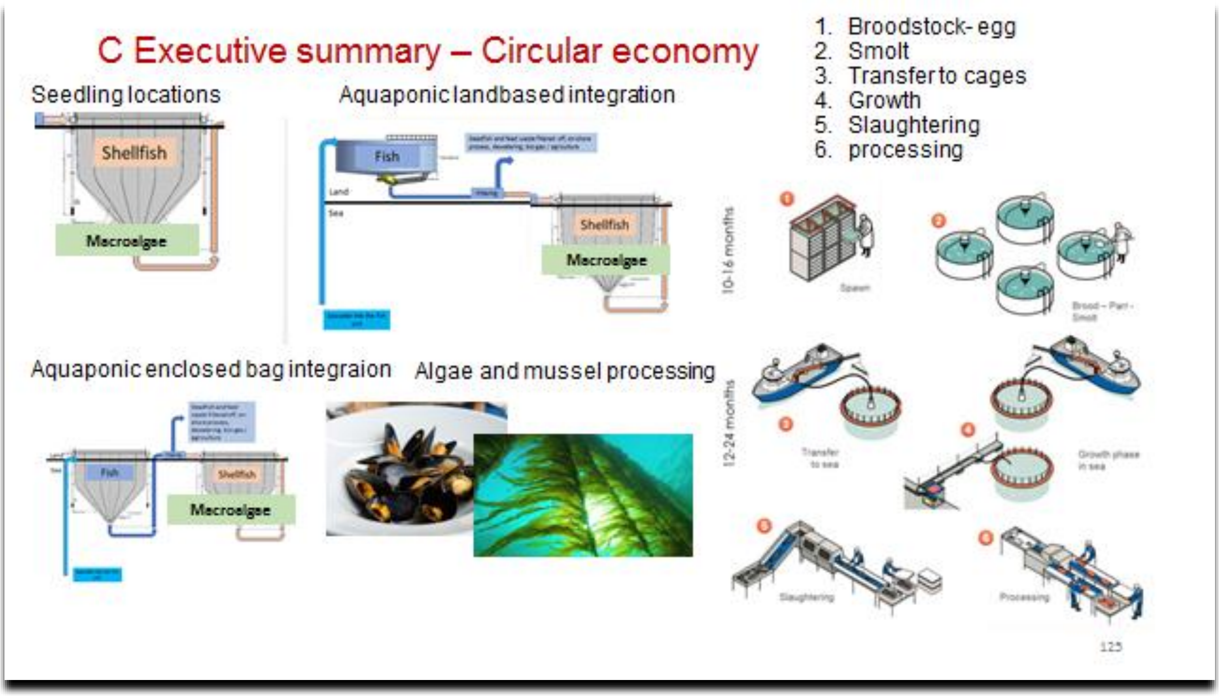

Figure 64 Illustration of the potential integration elements for an aquaponic setup West Estonia.

C Executive summary Fish biomass potential sea area 100 km x 10 km => 1 000 km2 Open net platform;

With a distance of 125 km there should be room for; **20x sites each 5 km apart**

10x sites (small fish) and 10x sites (large fish) seperate generations

Generation harvest 10x a 2 000 MT => sum 20 000 MT/generation => 7 mill smolts
Identify, learn and adjust minimum 20 m depth- risk factor

On land fish tank platform;

First 1-2 large smolt plant locations, then 3x new

Then 4x ongrowing locations 4x a 2 500 MT/yearly => sum 10 000 MT/year
Identify, learn and adjust

Floating fish bag platform;

6x sites each 10x bags, each bag holding 200 MT at max generation harvest 6x10 bags => 1 200 MT x 10= 12 000 MT/ generation - Identify, learn and adjust

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Figure 65 Some criteria and fish farming biomasses.

Comments:

If Open nets have dimensions as -10 m deep nets and a wish to have additional 10 m to the seabed- we are talking about location that have a gross depth of -20 m Such location with good current could be suitable, however the less depth under the cages normally the less natural distribution of the wastes. This may be negative in a longer perspective as organic wastes can be accumulated over time.

Other locations with larger depth will be even better, one could however rank and priorities such current and dispersal capability to the biomass per site or more accurate to a yearly flux quantity quota. Should it turn out that these initial quotas were too large, well then one could adjust accordingly. Opposite the other way round.

Moving further out from the coast West Estonia should be well suited to with larger farming licenses, the sizes should be evaluated according to the waste and environmental impact. We stress here that our suggested aquaponic units for enclosed lop of wastes is currently not dimensions for the weather and ocean forces in the outer coastline. Significant wave heights to some of the manufacturer today is said to be in the range of 2.5 m. There is however enclosed setup where larger oil tankers and Suezmax ships can be modified with enclosed bag arrangements. We are aware that such ideas do exists, and one example is the current Chinese plans for exploiting Atlantic salmon in the Southern Ocean between China and Taiwan with a fleet of ships with protect fish holding units. In this region there are regular typhoons that otherwise is a major risk factor.

A second-hand maxi ship could be considered for the more exposed West Estonia zone, or some of the concrete enclosed fish farms also being developed in Norway and UK for time being could also be considered. This new concrete version is not being made yet. We strongly therefor suggest that West Estonia address such potentials also to candidate within the wind-energy sector, se figure xx below.

App.8 Aquaculture in Estonia- local report

F Public report Baltic Sea, activities, conditions, and environment

The characterization of the West Estonian region from an aquaculture perspective has been detailed described 2020:

” AQUACULTURE IN ESTONIAN MARINE WATERS, UNDERLYING DATA AND RESEARCH” JONNE KOTTA, GEORG MARTIN, REDIK ESCHBAUM, ROBERT APS, LIISI LEES, RISTO KALDA - ESTONIAN MARINE INSTITUTE OF THE UNIVERSITY OF TARTU

Below is copied some of the information from the listed Report above, however by goggle translate that may be of interest:

Political guidelines promoting the growth of aquaculture are outlined in the European Union's sustainable development of aquaculture strategy of 2002. This strategy improved the environmental impact, safety and quality of aquaculture products in the European Union (Communication from the Commission – Progress Report on the Sustainable Development Strategy, SEC(2002) 511). Estonia has good prerequisites (including fish, water, and land resources) to produce fishing and aquaculture products. Companies in the fishing sector have long-lasting traditions, expertise, and experience in addition to implementing modern technological solutions and technologies for production and environmentally friendly pisciculture. The Estonian aquaculture sector is currently comprised almost entirely of pisciculture; alternative trends that restore natural environments are lacking. New, environmentally friendly aquaculture fields such as farming mussels and seaweed are being introduced (Ministry of Rural Affairs 2020).

While piscicultures established in natural bodies of water increase nutrient strain on the environment, mussel and seaweed farming are seen as a flagship of environmentally friendly economics in the European Union as they remove nutrients from the sea environment (Kotta et al. 2020).

In 2018, Estonian aquaculture companies sold 944 tons of fish and crawfish worth 4.2 million euros. The volume of aquaculture produce sold in 2018 was the highest of the past 25 years (Statistics Estonia 2019). Estonia has good prerequisites for producing aquaculture products according to the 'Agriculture and Fisheries Development Plan to 2030' (Ministry of Rural Affairs 2020). The potential production capacity of Estonian aquaculture companies has been estimated to be more than 4000 tons per year. There has been a rise in demand for fishery products in the European Union, and aquaculture is seen as a potential solution to the rising demand for animal protein, considering that fishing and aquaculture are one of the most effective ways of producing it. Marine waters potentially suitable for aquaculture and the need to develop infrastructure are described in a study conducted by the Estonian University of Life Sciences (2015). However, the underlying conditions for aquaculture have changed a lot in the past five years (such as laws and the ongoing spatial planning of Estonian maritime areas) and new knowledge about cultivating aquaculture species has been gained. Creating a new overview is essential for interest groups to be able to orientate themselves in the aquaculture field.

The size of the Estonian marine area is approximately 36,500 km2 (i.e. almost 10% of the Baltic Sea), of which the Exclusive Economic Zone takes up one-third, with an area of 11,300 km 2. The length of the Estonian coastline (based on the base map, and including islands and islets) is *ca* 4015 km.

The marine area under Estonian jurisdiction lies in the north-east of the Baltic Sea and is comprised of several large Baltic Sea basins that differ from one another greatly due to natural conditions and human activity. These basins are the Gulf of Finland; the open part of the Western Isles; and the Gulf of Riga, which includes the Väinameri strait located in the western-Estonian archipelago. Coastal waters are divided into 16 coastal water bodies according to the Water Act. These bodies are divided into six types of coastal waters based on their natural

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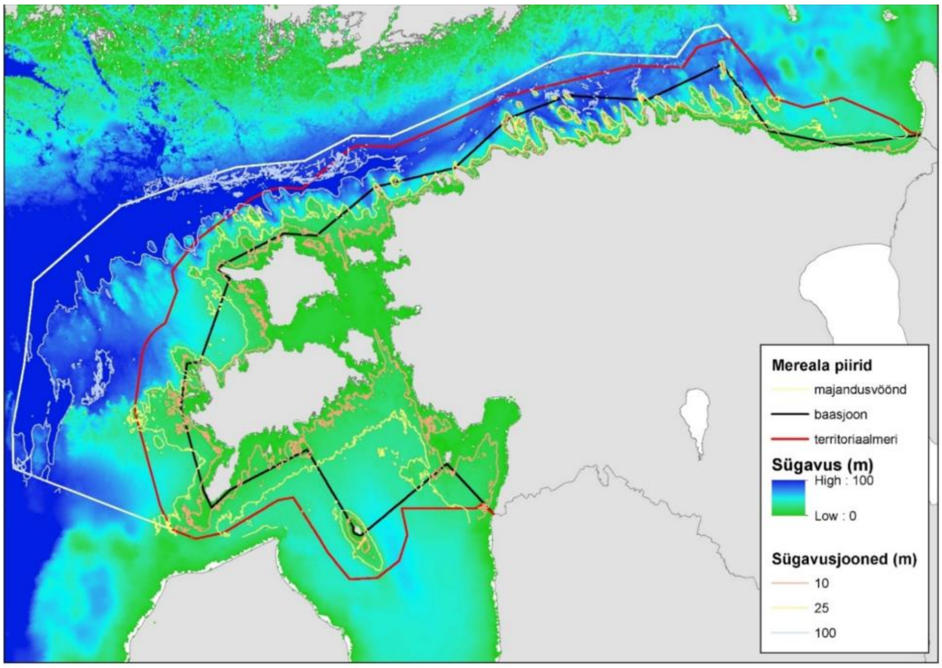
properties (Regulation no. 44 of the Minister of the Environment) (Ministry of Environment 2019).



Maritime borders

Figure 66. The maritime boarder of Estonia.

Water **temperature and salinity** are important factors in determining the borders of distribution for species characteristic − of the ecosystem, including the distribution potential for aquaculture species and the relative abundance of species in their habitats. The salinity of the Estonian marine area varies greatly between areas. In the open Baltic Sea, salinity can be as high as 10 g/kg, while smaller bays have relatively fresh water. The salinity of a certain area does not vary much temporally in general, with the variation being no more than a few salinity units. Water temperature is usually highest in Estonia’s coastal waters at the end of June and in August.

The Baltic Sea is characterized by a phenomenon that is extremely important for aquaculture. Namely, the Baltic Sea proper is stratified and is marked by both seasonal stratification (temperature-based) and constant stratification (based on the density of seawater, i.e. its salinity). Seasonal stratification occurs in summer when the uppermost layer of water warms up, creating a 10−20 m thick warm layer. This layer can warm up to 20−25 degrees Celsius. The water beneath this layer remains close to 4−5 degrees Celsius. This kind of stratification lasts for a few months until it is eradicated by autumn storms. Stratification caused by the salinity of water masses is constant. This is expressed through the change in the level of several physical-chemical parameters at a depth of around 50−60 m. At this depth, water salinity (and thus density) rises sharply. The drop in **oxygen concentration** caused by this change is of aquacultural and ecological importance. Oxygen concentration in the layer nearest to the seabed is the most decisive indicator of the ‘health’ of the Baltic Sea.

Eutrophication is one of the biggest environmental problems faced by the Baltic Sea. It is caused by the accumulation of nutrients (mostly compounds of nitrogen and phosphorus) in the marine environment. Both simple and complex phenomena can be caused by eutrophication, either within singular components of an ecosystem or ecosystem wide. Some can be positive for human society (such as large secondary production, i.e. plankton-eating fish like Baltic herring and sprats developing large biomass), but others can be negative (growth in primary production – algal blooms, lack of oxygen in the bottom layers of the sea and lessening of species variety).

2. Pisciculture and fishing

A large part of Estonian **pisciculture** produce comes from freshwater pisciculture. One company is currently farming fish in sea cages. Suitable water resources are necessary to develop freshwater pisciculture. An appropriate location is necessary for surface water pisciculture, as the freshwater body must be self-flowing, either through water pumps or damming. Thorough preparatory work is necessary to find the right location.

Estonia's only cage fishery is in Tagalaht near Veere. Cage fisheries were somewhat active near Veere in Tagalaht near Veere and in the Kolga Bay in Salmistu in the 2000s. They were closed in the second half of the 2000s. The reasons behind these closures vary. Many of the fisheries were established with the help of the European Maritime and Fisheries Fund but failed to meet the standards set by the project (planning faults in buildings, incorrect financial plans, etc.).

The fish best suited to Estonian pisciculture is the rainbow trout. When establishing a fishery, it is important to make sure that the marine area is deep enough and that the appropriate currents provide the fishery with fresh water. The fish can be farmed during ice-free periods, since ice and volatile weather can destroy the cages. Estonia lacks deep marine areas protected from the wind (such as Finland’s Åland Islands). This must also be considered when choosing a location for the cages.

Fishing takes place throughout Estonia’s marine area, except in areas where it is forbidden by law. Coastal and recreational fishing is intense in coastal areas and areas with a lower sea level. It is recommended to utilize industrial fish stock in a manner that allows for a yield of similar size the following year. Industrial trawl fishing (Baltic herring and sprat) takes place in marine areas deeper than 20 m. Trawling is forbidden in shallower waters, as it damages the seabed and therefore affects biodiversity.

4. Farming large seaweed

Large seaweed species are those with measurements larger than 2 cm. The Baltic Sea is home to over 550 species of large seaweed. The spread of such seaweed in the Baltic Sea is affected by salinity, the existence of a suitable substrate, openness, and water transparency. Each species requires a certain set of ecological factors to thrive. The seabed in Estonia's coastal sea is not diverse in plant species due to low salinity. Up to 80 species of seaweed and taller plants can be found in our waters. Around 20 of those species occur commonly. Some aquaculture technologies can help control and modify environmental factors (such as substrate, the impact of waves, the concentration of nutrients and the availability of light), but not all environmental parameters (e.g. salinity) can be controlled in this manner. As such, it makes sense, in the context of aquaculture, to farm species already native to the Baltic Sea.

Large seaweed is the most suitable for aquaculture as it grows very quickly, uses up the most nutrients and can compete with other species for resources. As part of the 'Compiling of regional aquaculture designs to control potential environmental pressure' project (University of Tartu 2019b), a list of the large seaweed species native to the Estonian coastal sea, their economic potential, and their ability to offset environmental risks was compiled. The species of large seaweed with aquaculture potential are *Fucus vesiculosus*, *Furcellaria lumbricalis*, *Cladophora glomerata* and *Ulva intestinalis*. The correlation between environmental factors and the production of large seaweed was modelled based on these species, and their potential growth rates in the Estonian marine area were estimated. In parts of the Baltic Sea with lower salinity, including Estonia, seaweed culture has not yet become an economic activity and the few experimental farms which have been constructed are still only in the development phase. It is necessary to establish a few pilots seaweed and mussel farms in the Estonian marine area to assess their economic effectiveness and their efficiency in removing nutrients from the marine environment (assessing the number of nutrients extracted from the sea and the scope of the effect). It is also necessary to assess any negative effects such farms could have on the environment. Smaller, more widely distributed farms a couple of hectares in size are preferable. Smaller farms produce higher yields per unit of area, they can remove a larger amount of nutrients from the marine environment at the same investment rates as large farms and their potential negative impact on the environment is smaller (University of Tartu 2019b).

The following is a description of the species of large seaweed best suited to aquaculture in the Baltic Sea. **Furcellaria** is native to the entire North-Atlantic area and is a very common species in Estonian waters. It appears in two forms: the most common is attached Furcellaria, which inhabits moderately or completely open coasts at depths of 5−10 m on hard substrate; while the second form is loose-lying Furcellaria, which can only be found on seabed that are hydrologically compatible (usually on soft bottoms in archipelagos). In Estonia it is found most commonly in the Väinameri Strait and it is industrially harvested in Kassari Bay. Furcellaria's natural spread is well documented and thus can be modelled. Furcellaria is a very sturdy species and can withstand lower salinity (up to 3−4 g/kg).

Its life cycle is complex and includes several stages (Figures 4.1 and 4.2). Both sexual and asexual reproduction have been noted in the Furcellaria found in the more saline southern part of the Baltic Sea. In the northern part of the Baltic Sea, only two methods of asexual reproduction have been described: reproduction via tetra spores and fragmentation. Fragments of the seaweed thallus can reattach themselves to substrates. However, these reproductive processes need further research. Several studies have been conducted in Estonia in which duplication of both the tetra spores and fragmentation reproduction methods have been attempted. These efforts have not yet borne fruit as the seaweed has not attached itself to an artificial substrate.

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Furcellaria is the only **industrially used large seaweed** species in Estonia. Gelling polysaccharides are manufactured from it. It is collected from beaches and trawled from the sea in the Väinameri Strait. The first instance of this kind of collection can be traced back to the late 1960s. According to statistics, 653.9 tons of seaweed was gathered from the Väinameri Strait in two years (2014−2015) (University of Tartu 2019a).

Fucus vesiculosus is one of the most widespread species in the Baltic Sea. It is found throughout the parts of the sea where salinity is higher than 3−4 g/kg and where suitable substrates can be found in the euphotic zone. Fucus vesiculosus can be found in deeper marine areas than Furcellaria. Fucus vesiculosus has been known to grow in areas of the Baltic Sea with varying hydrodynamic conditions or water properties.

Its reproduction cycle is well documented, but complex. Fucus vesiculosus mainly reproduces sexually (Figure 4.3). Artificial reproduction has only worked in very rare cases (Fordlund & Kautsky 2013). Vegetative reproduction in fucus vesiculosus has been described in rare cases, mostly occurring under experimental circumstances (Schagerström 2013). The seaweed also possesses very good regenerative ability (e.g. after ice damage).

Ulva intestinalis is an aquaculture species with among the greatest potential due to its rapid increase in growth. The species occupies a large part of the Baltic Sea and can also be found in fresh water. It has a simple reproduction cycle (Figure 4.4). Farms growing freshwater *Ulva are* being established in Germany, the Netherlands, and various Asian countries. This species is better cultivated in containers rather than open water, due to its delicate structure. Technological solutions in Estonia for cultivating *Ulva* in containers are still in the testing phase. When growing, the plant does not need to be attached to a substrate but can float freely in a water gauge. This property makes its cultivation a lot simpler.

The ‘Treatment of marine water-based pisciculture waters via the cultivation of macroalgae’ project is currently being conducted by the Estonian Marine Institute of the University of Tartu (end date: March 2021). Although this project is not aimed at the cultivation of *Ulva*, the weed is still used as a test species for removing nutrients from wastewater originating from fisheries. Experiments conducted as part of the project have achieved good results and *Ulva* will likely be the species to help effectively clean fisheries' wastewater. More information regarding the project can be found in Chapter 8.

Macroalgae production/ harvest in West Estonia region

Currently, the only species of large seaweed industrially farmed in Estonia is *Furcellaria lumbricalis*. It is either collected from the shore or trawled from the seabed. Est-Agar AS is the only user of *Furcellaria lumbricalis* seaweed in Estonia. The amount of seaweed collected and processed annually is around 1000 tons (wet weight). The yearly production of furcellaran has been on average 50-60 tons in the recent years (Fisheries Information Centre & SakiConsult OÜ, 2018). Experiments with collecting and processing other species have been undertaken (e.g. collecting *Fucus vesiculosus* to use it in cosmetics and as food).

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Based on the experience of neighboring countries, big vessels are not used when maintaining seaweed and mussel farms and collecting produce. Sweden uses vessels with draughts of no more than 1.5 m to collect produce. Mussels are collected in 2 m3 bags, and only a small crane is needed to unload them at the port. As such, seaweed and mussel farms do not require specialized solutions at ports and most smaller ports can be used to service the farms.

Summary and status of the Water Act for aquaculture business

The Water Act (VeeS) is the most important act for potential aquaculture businesses to follow. A new Water Act came into effect in October 2019. The previous Water Act dated from 1994. An important change to the act is that a permit is no longer needed for activities that pose no danger to the water environment. Activities with limited impact need to be registered with the Environmental Board, but this process is much simpler than applying for a permit for the special use of water. The definition of a body of water is also specified – sewage treatment plant lagoons, aquaculture lagoons and basins are no longer treated as bodies of water.

Based on §131 section 2 of VeeS, the regulation **'Water protection requirements for aquaculture and limit values for pollutant concentration of effluent water from aquaculture and requirements for discharge of such water into a recipient and monitoring thereof' was established in April 2020.**

The new Water Act treats water discharged from aquaculture as different from sewage. As such, a new empowering provision was established for the regulation. This regulation provides changes in determining the number of pollutants and assessing pollution costs in the event that the limit of pollutants allowed in the special use of water is exceeded. Previously, the number of pollutants in the water discharged by fish farms was determined through an analysis conducted using water samples. Pollution costs were calculated based on the difference between the indicators of incoming and outgoing water of the fish farm and the Environmental Fee Act. The explanatory statement to the new regulation outlines that a conceptual change has taken place: to determine the pollution levels spreading into nature from aquaculture companies, **a nutrient-based calculation method will be used.**

This approach will help to assess the number of pollutants making their way more effectively from the farm into the environment and thus assess the impact the farm has on the environment. This will improve the inspection of pollution sources and reduce the impact pollutants have on the environment. This in turn will have an economic impact on owners of fisheries, as the method for assessing the pollutant amounts necessary for calculating pollution costs will be changed. The goal of this change is to encourage owners to use effective feed whose effect on the environment (i.e. the amount of pollutants in the water exiting the fishery) is minimal effect on the environment (i.e. the amount of pollutants in the water exiting the fishery) is minimal. This will also be beneficial to the owners as they will be allowed to produce more while adhering to the same amount of pollutant load (Ministry of the Environment 2020).

Sea aquaculture and aquaculture in public bodies of water

The following chapter provides an overview of permits and establishments instrumental to launching marine aquaculture in public bodies of water, including cage fisheries in the coastal sea. Public bodies of water are listed in § 23 of VeeS. The chapter will also advise on the first steps towards procuring all necessary permits, but the overview does not contain every detail.

App.9 Wind energy sector

We consider that a strategic well considered plan to integrate wind energy licenses with fish farming activity are:

- Combining two natural resources that actually share many similar tasks and conditions
- Need very much of the same "type" of service, maintenance, inspections
- A careful planning of wind platform linked to fish and aquaponic platform is representing a huge potential- win-win
- Aquaculture setups need kwh, oxygen and backup system
- Feed storage, pumping and harvest services, also well boat for smolt and shipping market sized fish to processing plant
- A eco-friendly sustainable profile, marketing and goodwill creating is considered to represent huge potential of all stakeholders involved
- Criteria for issuing wind energy licenses should be considered where such partners also had to offer time, resources for such integration potentials.

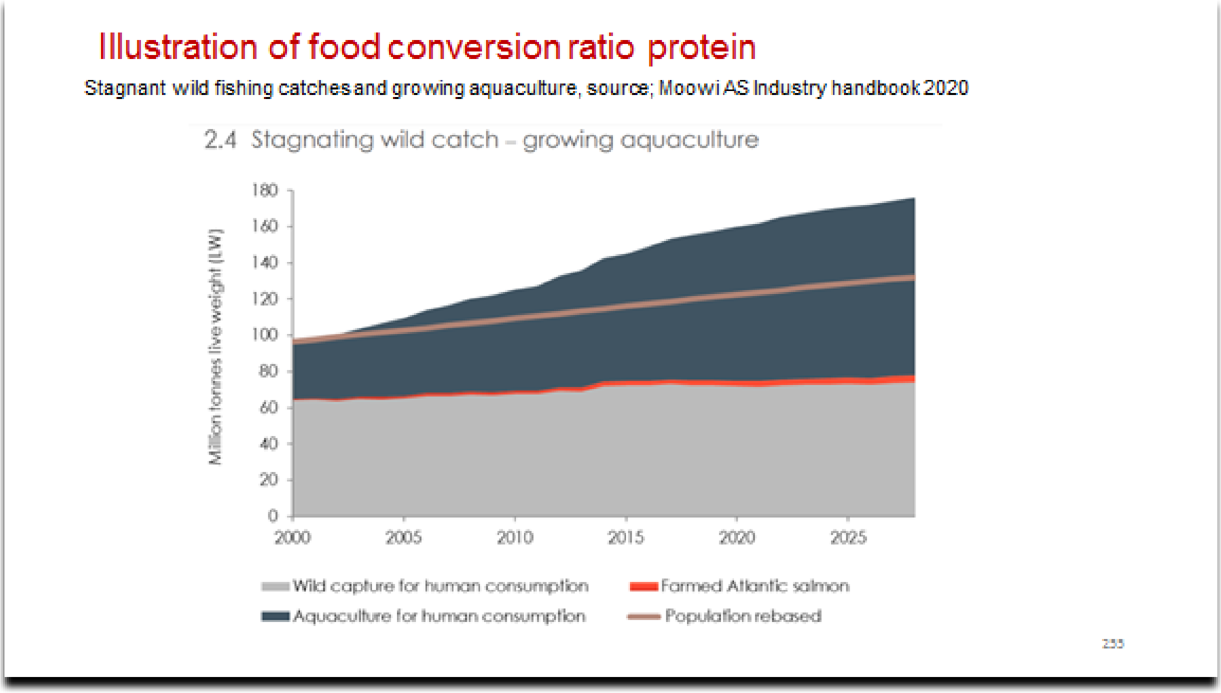
Figure 67 Some Wind-energy illustrations.

App. 10 International fish farming information

Below are various elements that have important information elements.

We strongly advice stakeholders to read the Industry Report a yearly public report made by the largest salmon farming company Mowi ASA (www.mowi.com). This is among the best objective summary of major elements linked to marine protein, farming conditions, biomasses, and future challenges.

https://mowi.com/blog/annual-report-2020/



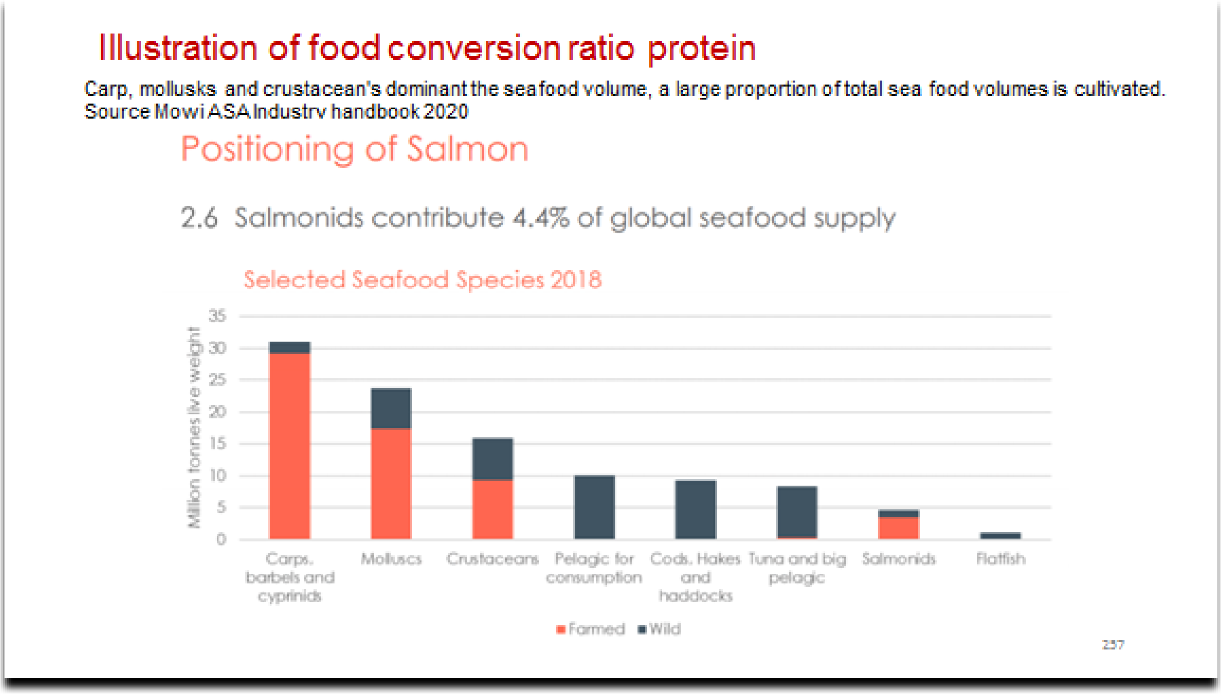


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Illustration of food conversion ratio protein

Farmed Atlantic salmon and large trout. Source Mowi ASA Industry handbook 2020

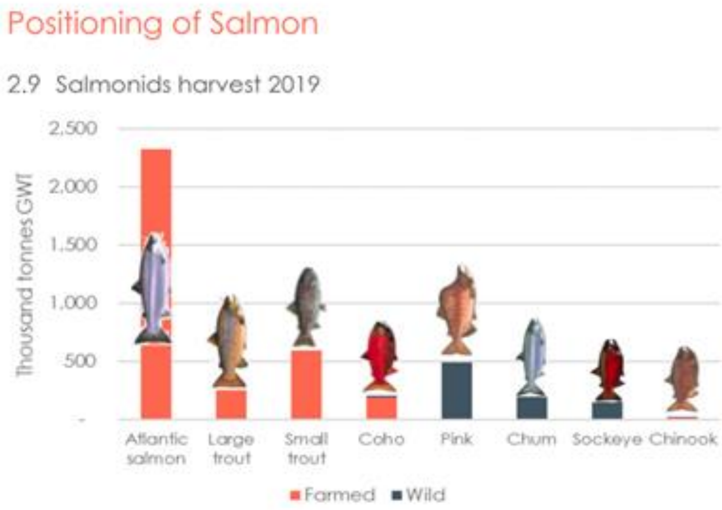

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Illustration of food conversion ratio protein

Coastlines for Atlantic salmon production; Source Mowi ASA Industry handbook 2020

4.3 Few coastlines suitable for salmon farming

The main coastal areas adopted for salmon farming are depicted on the above map. The coastlines are within certain latitude bands in the Northern and Southern Hemispheres.

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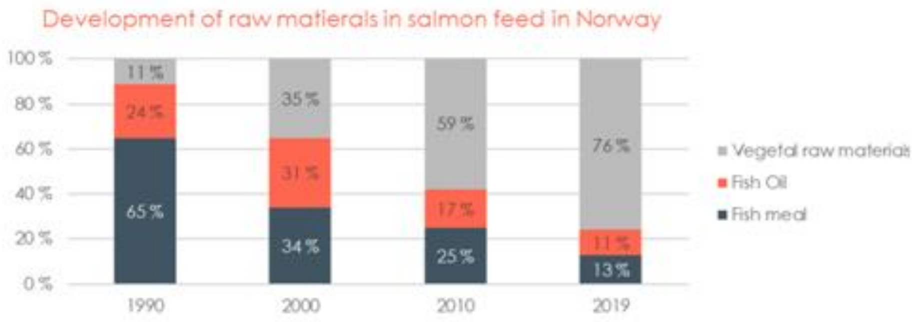
Illustration of food conversion ratio protein

Salmon fish feed; Source Mowi ASA Industry handbook 2020



* Life Cycle Assessment (LCA) determines the environmental impacts of products, processes or services, through production, usage, and disposal
Source: SINTEF (2020) Greenhouse gas emissions of Norwegian seafood products in 2017, Ytrestøyl T., Aas T.S., Åsgård T. (2014) Resource utilisation of Norwegian salmon farming in 2012 and 2013, NOFIMA, Mowi

Potential industrial partners West Estonia

7.1 Top 5-10 players of farmed Atlantic salmon 2019

	Top 10 - Norway Company	H.Q. HOG	Top 5 - United Kingdom Company	H.Q. HOG	Top 4 - North America Company	H.Q. HOG	Top 10 - Chile Company	H.Q. HOG
1	Mowi	236,900	Mowi	65,400	Cooke Aquaculture	56,500	"New Aquachile" (Agrosuper)	141,300
2	Salmar	153,100	Bakkafrost (SSC)	33,800	Mowi	54,400	Salmones Multiexport	77,600
3	Lerøy Seafood	128,700	Scottish Sea Farms	25,900	Mitsubishi / Cermaq	17,800	Mitsubishi / Cermaq	71,900
4	Mitsubishi / Cermaq	73,000	Cooke Aquaculture	23,400	Grieg Seafood	14,100	Mowi	65,700
5	Grieg Seafood	57,600	Grieg Seafood	11,300	*		Australis Seafood	53,500
6	Nova Sea	46,000	*				Camanchaca	48,300
7	Nordlaks	35,000					Salmones Antartica	27,100
8	Sinkaberg-Hansen	30,500					Salmones Blumar	25,700
9	Alsaker Fjordbruk	30,500					Salmones Austral	22,800
10	Norway Royal Salmon	30,500					Yadran	22,500
	Top 10	821,800	Top 5	159,800	Top 4	142,800	Top 10	556,400
	Others	378,300	Others	5,400	Others	5,100	Others	64,800
	Total	1,200,100	Total	165,200	Total	147,900	Total	621,200

All figures in tonnes GWT
* The industry in the UK and North America are best described by the top 5 and top 4 producers, respectively.

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Investment situation Norway vs West Estonia – Fish farming

A 4 200 MT gutted salmon production costs;

License MEUR 60
Capex MEUR 5

Inventory cost of biomass, 4,2 mill kg gutted x EUR 5,00/kg = 21 MEUR

Total invested first generation; MEUR 87

West Estonia total investment MEUR 26

Cost avoidance MEUR 60, over 20 yrs=> MEUR 3/yr

10.2 Capital return analysis

Investments and payback time (Norway) - assumptions

- Normal site consisting of 4 licenses

- Equipment investment: MEUR 3.5 - 4.5
- Number of licenses: 4
- License cost (second hand market) MEUR: 60 (~MEUR 15 per license)
- Output per generation: ~4,200 tonnes GWT
- Number of smolt released: 1,100,000

- Smolt cost per unit: EUR 1.7
- Feed price per kg: EUR 1.3 (LW)
- Economic feed conversion ratio (FCR): 1.2 (to Live Weight)
- Conversion rate from Live Weight to GWT: 0.84
- Harvest and processing incl. well boat cost per kg (GWT): EUR 0.4

- Average harvest weight (GWT): 4.5kg
- Mortality in sea: 15%

- Sales price: EUR 5.9/kg

Source: Mowi Industry handbook 2020

Farming license regime

Due to biological constraints, seawater temperature requirements and other natural constraints, farmed salmon is only produced in Norway, Chile, Scotland, the Faroe Islands, Ireland, Iceland, Canada, USA, Tasmania and New Zealand.

Atlantic salmon farming began on an experimental level in the 1960s and evolved into an industry in Norway in the 1980s and in Chile in the 1990s.

In all salmon-producing regions, the relevant authorities have a licensing regime in place. In order to operate a salmon farm, a licence is the key prerequisite. Such licences restrict the maximum production for each company and the industry as a whole. The licence regime varies across jurisdictions.

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Source: Mowi Industry handbook 2020

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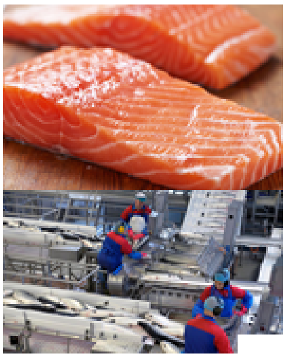
Secondary processing fish farming – Poland/Denmark 250 000 MT- 55 trucks or 55 000 boxes(18kg) per day

Source: Mowi Industry handbook 2020

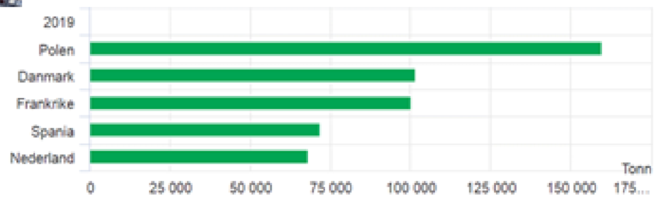


In processing we distinguish between primary and secondary processing.

Primary processing is slaughtering and gutting. This is the point in the value chain at which standard price indexes for farmed salmon are set.

Secondary processing is filleting, fillet trimming, portioning, producing different fresh cuts, smoking, marinating or breading. Depending on the setup of the processing plant, products are fresh packed with Modified Atmosphere (MAP), vacuum packed or frozen and stored for distribution.

Products that have been secondary processed are called value-added products (VAP), as they represent an additional value to the retailer and foodservice operator but most of all to the final consumer.



Kjelde: Statistisk sentralbyrå.

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