# Circulating nutrients in the Åland Islands aquaculture

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# Description

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**Abstract**

Aquaculture on the Åland Islands, and in the Baltic Sea, has declined during the last decades, partly because of strong regulation and a negative public opinion. Aquaculture is increasing on a global scale due to a growing demand for fish. Currently aquaculture in the Baltic Sea is at risk of falling behind global developments. Innovative means of increasing production with lessened environmental impact on the Baltic Sea are needed. In order to find sustainable ways of increasing aquaculture production in the Åland Islands, this paper discusses the idea of a fish feed with nutrients recirculated from the Baltic Sea. The Baltic Sea fish feed would contain fish meal produced from fish caught in the Baltic Sea and potentially also meal from mussels farmed in the Baltic Sea. By using regional ingredients the phosphorus and nitrogen in the feed can be recirculated within the Baltic Sea instead of importing nutrients to the region. The potential gain in production, which considers a political 20% reduction target for nutrient load from Åland Island aquaculture, is calculated in order to see how much fish farmers in the Åland Islands could potentially increase production if utilizing a Baltic Sea fish feed. In order to implement such a feed, which potentially would cost more than regular fish feed, incentives need to be offered in the legislation regarding fish farming on the Åland Islands so as to make a switch to these feeds commercially feasible. The formula helps licensing authorities to calculate lessened emissions due to recirculation of nutrients from Baltic Sea fish feed and enables it to be included in the license. A fish feed with a fish meal content of 20% originating solely from the Baltic Sea could potentially allow an increase in aquaculture production on the Åland Islands without causing a decreased status of the environment. This should be seen as a first step towards a more thriving industry. A recirculation based feed is currently amongst the few viable alternatives for a sustainable increase in Baltic Sea aquaculture production.

**Keywords**
Baltic Sea, aquaculture, recirculation based feed

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# 1. Introduction

As the global consumption of fish has increased to a world total of 154 million tons of captured and farmed fish (FAO 2012), decision makers are increasingly recognizing fish as an important resource. Aquaculture is the fastest growing animal protein-producing sector in the world; the production of farmed fish for human consumption increased globally by 7.5% between 2009 and 2010, to a total of 59.9 million tons. In 2010, Europe produced just 4.2% of the world total aquaculture production and only 50% of the European aquaculture production occurred inside member countries of the EU (FAO, 2012). The European Commission, as part of the Blue Growth Strategy and as a contribution to the Europe 2020 Strategy, has recently pushed for increased aquaculture within the EU in order to keep up with global competition (European Commission, 2013). Sixty-five percent of the EU seafood market is made up of imports and only 10% of the consumed seafood comes from EU aquaculture. As fisheries cannot provide for the growing demand of fish, alternative methods like aquaculture need to be encouraged.

The Åland Islands currently produces 63% of the rainbow trout and 39% of the whitefish farmed in marine waters in Finland (RKTL 2012a, ÅMHM 2013). The Åland Islands are an archipelago in the Baltic Sea in which marine waters comprise almost 90% of the total administrative area (Lantmäteriverket, 2011), meaning that open cage farming in marine waters is the most practical form of aquaculture. Commercial-scale freshwater and land based recirculating aquaculture systems (RAS) are currently non-existent. The practice of open cage fish farming has received a lot of criticism due to a perception of its nutrient load negative effects to the local environment. Compared to other industries and nutrient sources, fish farms in the Åland Islands were calculated to be responsible for 62% of the total load of phosphorus (P) and 28% of the total load of nitrogen (N) released from the region into the water in 2011 (ÅSUB, 2012). The total figures for nutrient (N and P) emissions into the Baltic Sea from the Åland Islands do not include atmospheric deposition and shipping. The Åland Islands had no more than 28355 inhabitants and no major industries in 2011 (ÅSUB, 2012). On a larger scale, fish farms on the Åland Islands contribute only a very small part of the total emission of nutrients to the Baltic Sea. Aquaculture on the Åland Islands is responsible for 0.9% of the 3490 tons P and 0.3% of the 79000 tons N that Finland releases into the Baltic Sea yearly (HELCOM, 2012a). Aquaculture is also an important local employer in the sparsely populated archipelago communities and a supplier of raw material to the fish processing industry. These environmental and social concerns were the basis for the participation of the Government of the Åland Islands in the Aquabest-project.

This working paper discusses the Åland Islands as a case study for achieving a more sustainable aquaculture by using a nutrient recirculation, or rather, a nutrient compensation feed. First the Åland Islands and their aquaculture is introduced along with current regulations and action plans affecting fish farming. This is followed by, firstly, an introduction of current use fish feeds and, secondly, by a discussion of a Baltic Sea fish feed (BSFF) as an environmentally sustainable way forward. In the final chapters, different ingredients in BSFF are reviewed along with what possible effects they can have on recirculation of nutrients in the Baltic Sea if used for aquaculture on the Åland Islands. In conclusion the results are weighed against each other and some general guidelines are drawn for future action. The concepts presented in this working paper should be seen as a basis for discussion and not a proposal for legislation by the Government of Åland.

# 2. Aquaculture on the Åland Islands

Commercial fish farming in the Åland Islands started in 1978 and has always been dominated by rainbow trout (*Oncorhynchus mykiss*) cage farming (Wennström *et al.* 2011). Farming of European whitefish (*Coregonus lavaretus*) was introduced in 2002. The commercial production of whitefish is currently performed on a small scale with 360 tons farmed in 2012 (Broström pers. comm. 2013, ÅMHM 2013). Aquaculture is conducted in seven municipalities on the Åland Islands, but 75% of the production is performed in the archipelagic municipalities of Brändö, Kumlinge and Föglö (The Government of Åland, 2009). These municipalities are largely dependent on aquaculture as a provider of job opportunities and tax income. Setälä *et al.* (2007) present scenarios describing the direct impact on municipalities of reductions in aquaculture production and associated loss of employment. The close link between aquaculture and rural sustainability makes it crucial to find environmentally sustainable solutions where aquaculture can remain viable.

Stricter environmental regulations have led to lowered emissions from fish farms but also stagnation in production. In 2012, production amounted to 5519 tons which can be compared to the highest documented year of 1989 when production was estimated to be around 7000 tons. Total P loads from aquaculture fell from 84 tons in 1993 to 31 tons in 2012, the N emissions have also been reduced significantly from 560 tons in 1989 to 253 tons in 2012.

The specific load, i.e. the emission per produced unit of fish, was on average 5.5 g P/kg fish and 45.9 g N/kg fish in 2012 (ÅMHM 2013), which can be compared to the significantly higher specific load of 36 g P/kg fish and 170 g N/kg fish when fish farming started in 1980 (Broström pers. comm. 2013) or 7.9 g P/kg fish and 58.3 g //kg fish in 1997 (Figure 1) (ÅMHM 2013). The reduction since 1997 is close to 20% for P and more than 17% for N.

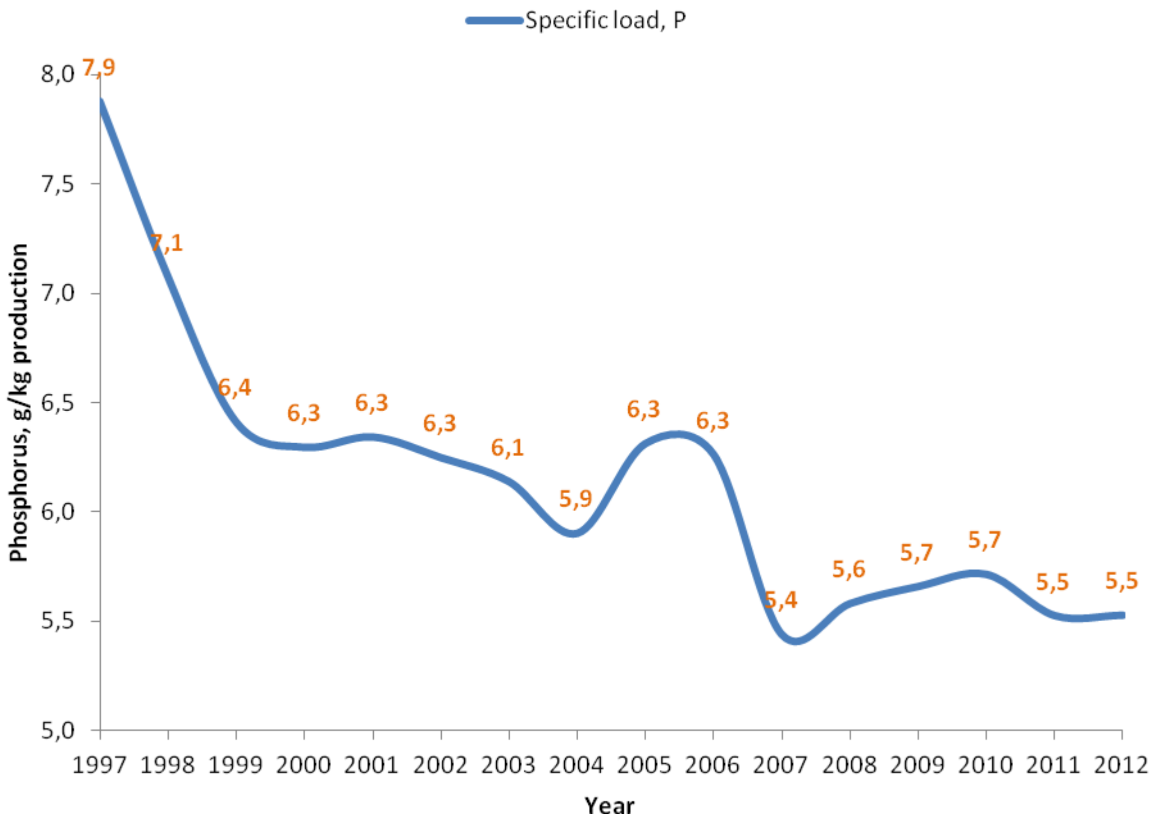


**Figure 1.** The specific load from 1997 to 2012 expressed as g/kg

Fish farmers on the Åland Islands are dependent on international prices for salmon and trout. As imports of Norwegian and other foreign fish have increased in Finland, fish farmers on the Åland Islands are struggling to keep their prices competitive, as almost all fish they produce is exported to Finland and only very small portions staying on the local markets. The price of fish varies a lot during and in-between years. They usually hit their annual minimum during the winter and annual maximum during the summer. Gutted rainbow trout sold for an annual average of 3.20 €/kg in 2012 in Finland, but prices tend to vary in relation to the international market. Gutted whitefish was sold at an annual average of 6.73 €/kg. The prices for trout and whitefish dropped by 0.80 €/kg and 1.74 €/kg respectively between 2011 and 2012 (RKTL 2012b, RKTL 2013). Fish farmers estimate that the break-even point for rainbow trout on the Åland Islands is ~3 €/kg, a sales price lower than this makes production unprofitable.

Smolt and fry are bought at different sizes that determine how long the fish has to be farmed in the open cages. The smolt and fry are either bought in spring or in autumn, and are subsequently farmed for one to two years. Fish are slaughtered at different sizes depending on demand and market price.

The first cases of Viral Hemorrhagic Septicemia (VHS) were reported in 2000 in Finland, with cases on the Åland Islands as well as in Pyhtää in the Kymenlaakso region of Eastern Finland (Evira, 2012). Since the outbreak, the Åland Islands is a restricted area where regular inspections and samplings are performed as measures to control the disease. Veterinary costs have increased slightly because of legislated regular samplings, but the highest costs are caused by actual outbreaks. Due to occasional VHS-outbreaks on the Åland Islands, live fish may not be exported and trucks that come from the Åland Islands need to be disinfected. Fear of VHS is one of the reasons to why there is no production of fry or smolt on the Åland Islands as such production would be limited to local markets.

## 2.1. Water legislation on the Åland Islands

The Åland Islands are governed according to The Act on the Autonomy of Åland, which stipulates that The Åland Islands are guaranteed autonomy by international law, while sovereignty is retained by Finland. Legislative responsibilities are split between Åland and Finland. For example, laws regarding taxation are legislated and governed by The Government of Finland, while laws regarding water are legislated and governed by The Government of Åland. The water act issued by The Government of Åland in 1996 (1996:61) states that commercial water use or dangerous activities in water may not be carried out in any water body if it causes a hindrance to fulfill water quality standards or other water quality requirements (chapter 5, section 9). This clause has stopped all expansion of aquaculture on the Åland Islands, as it is not possible to increase production without proving that it would not cause a negative effect on nutrient levels in the water. However, according to the water act, if the party behind the activity utilizes an improvement surplus, their activities are allowed to be carried out. As a complement to the water act the water regulation for surface, ground- and marine waters (2010:93) regulates in detail how to protect the water quality of the Åland Islands.

Fish farming is furthermore regulated by the Åland Islands fish farming decree (2007:57) that imposes requirements on the site where the fish farm is placed. The decree has led to the merging of several fish farms and their subsequent re-location to more exposed waters, in order to reduce their immediate effects on the local aquatic environment. The regulation also specifies the limits to phosphorus (6 g P/kg of produced trout or salmon) and nitrogen (50 g N/kg) specific loads. Furthermore, the regulation specifies the handling of dead fish and demands that those handling fish feed have undergone adequate training.

## 2.2. Plans of action and marine improvement strategies

Fish farming is additionally governed by political strategies and regional plans of action that stem from the EU Water Framework (WFD) and Marine Strategy Framework (MSFD) Directives and aim for the environmental improvements of water bodies. On the Åland Islands this has been particularly clear as environmental legislation has had considerable implications for aquaculture. When applying for permits, fish farmers have to consider the regional legislation which in Finland is modified by EU regulations. The different legislation and plans of action create a patchwork of rules that together cause an administrative burden which is difficult to navigate. There are a few specific documents that have shaped aquaculture on the Åland Islands and these will be discussed in the following paragraphs.

The environmental action program for 2005-2008, issued by The Government of Åland, put particular emphasis on the aquatic environment (The Government of Åland, 2005). The program was based on the polluter pays-principle and demanded that the aquaculture sector should reduce its P and N emissions by 80% in 2015. This decision stemmed from the fact that aquaculture was responsible for such a large amount of the nutrient (N and P) loads in the region's waters. In comparison to the target reductions of 20% of N and P by 2010 which was placed on agriculture and 10-20% reductions in N and P losses from forestry, the pressure was mainly put upon fish farming to reduce eutrophication in the waters of the Åland Islands. As the load reduction targets formulated in the original action program were deemed as too strict, the Government of Åland adopted new load reduction objectives in the Water Action Plan 2009-2015. A group, consisting of the most important stakeholders, was assembled to put forward a new action plan for fish farming. As this group consisted of more diverse interest groups than the previous one, the new conclusions drawn were widely divergent from previous ones. In 2011, new targets were specified by the Government of Åland in an Implementation Plan. In this plan, a 20% reduction target of phosphorus by the year of 2015 was agreed upon. An indicative target to reach a more than 20% reduction in net load in 2021 was decided upon (The Government of Åland, 2011). The 20% reduction in P loads from fish farming was agreed upon as being a realistic goal if use of phytase feed is mandatory and fish farming does not expand from a 2011 baseline. This action plan was one of the main reasons why the Government of Åland decided to join the Aquabest project. The fish farming decree, caused a significant decrease from 45 to the current 25 in the number of aquaculture farms (Figure 2), all owned by five companies. The decrease was due to the consolidation of smaller farms into bigger ones. Even though the number of farms has decreased, production has stayed the same, disregarding inter-annual variation.

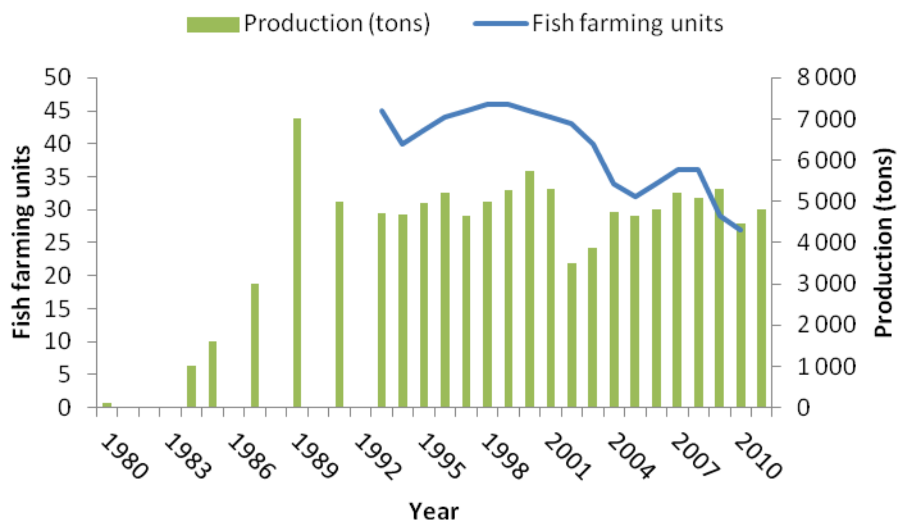


**Figure 1**. Fish production and the amount of fish farming units over time (Broström pers. comm. 2013).

In addition to changed targets for aquaculture, the action plan focuses on basic improvements in order to achieve EU WFD and MSFD standards. Besides reduction in emissions from aquaculture, the action plan also mentions mussel farming for potential inclusion in some sort of nutrient trading system. HELCOM and other intergovernmental organizations, as well as collaboration projects are also mentioned as important actors to achieve better water quality on the Åland Islands.

In the marine strategy of the Åland Islands the general and operational objectives for achieving a good status for marine waters according to the EU Article 8, 9 and 10 of the EU Directive 2008/56/EC are set (The Government of Åland, 2012). The directive obligates the EU member states to reach good environmental status in their marine waters by the year 2020. In addition to environmental sustainability the marine strategy also considers the economic importance of fish farming on the Åland Islands and points out that aquaculture is about ten times more important on the Åland Islands than in mainland Finland, as well as having a significant importance for the economy of certain municipalities.

Future fish farms are likely to be localized in the outer archipelago, such as in the Åland territorial sea, where the water exchange is better and the water is deeper. A new localization plan will also strive to ensure that there are no conflicts between the fish farms and other interests and concerns; especially environmental concerns regarding water quality, but also areas worthy of protection because of their biological, archeological or recreational status. A generalized first localization plan for the Åland Islands will be finalized during the spring of 2014.

# 3. Current fish feeds

Fish feed used in Åland Islands fish farming make up at least 50% of the total production cost of the final product (Broström pers. comm. 2013) and the price of fish feed is expected to keep on rising (FAO 2009). Due to an increasingly globalized market and declining stocks of wild fish, fish feeds used in the Åland Islands have gone through considerable changes since the beginning of fish farming. Since the 1980s fish meal and fish oil content of the fish feed has decreased steadily, from as high as 60% to current levels of just under 20% fish meal and 15% fish oil in feed used in the cage phase of farming (Biomar, 2013). It is therefore important to discuss the current feeds and look at potential future alternatives in order to be able to choose alternatives that are more financially and environmentally sustainable.

Fish feed used in farms on the Åland Islands is mainly purchased from two different producers. The fish feed manufacturers buy their ingredients, including fish meal and oil on global commodity markets depending on several criteria including price, quality and availability. Global fish meal production peaked in 1994 at 30.2 million tons of fish and has dropped to 15.0 million tons in 2010 (FAO, 2012). The price of ingredients is influenced by a number of different factors like speculation, harvest, currency exchange rates and so on, and they fluctuate with global trends. As feed producers stock ingredients by planning 6-8 months ahead, they also have to predict possible future demand for fish feeds, this further complicates the economics to fish feed production.

## 3.1. Historical perspective on fish feed

When fish farming started in the 1970s, fish were fed raw fish which had been caught in the Baltic Sea, minced and then either fed as such or mixed with binder, vitamins and minerals to form moist feed. The feed conversion ratio (FCR) that is the ratio between the amount of feed used and the weight gained by the farmed fish was extremely high, approximately 4-5. This practice led to many local environmental problems, despite technically being a closed nutrient loop on the larger scale. The high feed conversion ratio is mostly explained by the high water content of fodder fish, but also in part due to the fact that the fish feed was in a semiliquid state meaning that much of the nutrients would dissolve directly in the water, and additionally the balance of nutrients was poor as the feed had an especially a low lipid content. During the 1980s, semi-moist feed was introduced. The feed conversion ratio was improved, but still very high, approximately 2 on a dry matter-basis (Lerche pers. com. 2013). Persistent Organic Pollutants (POPs) like the ones mentioned in the section below temporarily stopped the use of Baltic Sea fish in feed for fish farms, until dioxin removal processes for fish meal were developed. Today, fish feed is used in the form of dry pellets with a water content of barely 10%. Feeds are designed carefully for the needs of different species and age groups of fish. According to the official data of ÅMHM, the phosphorus and nitrogen content in the feed used in the Åland Islands has decreased from 1.0 and 6.9% to 0.8 and 6.2% respectively from 1997 to 2012 (ÅMHM 2013). The average feed conversion ratio in fish farms is currently slightly below 1.2 and this has stayed more or less constant for the last 15 years. The optimization of feed composition and use reduces the need for feed and also minimizes the amount of nutrients released to the water. Plant ingredients have been increasingly present in fish feeds (BioMar 2013). Because of the global market, manufacturers are constantly revising and modifying their recipes in order to provide a stable quality and price of the fish feed.

## 3.2. Persistent organic pollutants (POPs)

Dioxins and dioxin-like compounds including polychlorinated dibenzo-p-dioxins (PCDD), polychlorinated dibenzofurans (PCDF) and polychlorinated biphenyls (PCB), are all persistent organic pollutants (POPs) that can cause long-term impacts on both ecosystems and humans (HELCOM, 2004a). PCDDs and PCDFs are by-products or impurities of industrial processes as well as fossil energy production and burning. PCBs were previously used as coolant and dielectric fluids in capacitors and transistors. From 1939 to 1993, a total of 180 000 tons of PCB was produced in the Soviet Union (HELCOM, 2001).

In addition to being highly toxic, POPs have a very slow rate of degradation and can therefore be transported long distances via waterways or stay buried in the sediment for a long time without degrading. Because of their persistent and lipophilic properties, they accumulate in animals and tend to increase in concentration with trophic level, meaning that predators will have a higher bodily concentration of POPs than the grazers they feed upon. The threat POPs pose to human health has led to the adoption of EU Regulations setting a maximum for levels of dioxins and other contaminants in fish for human consumption and animal feed. Fish from the Baltic Sea is generally twice as contaminated with dioxin as fish from the North Sea (HELCOM, 2004a) and this has led to the sale of Baltic Sea herring (*Clupea harengus membras*) over 17 cm being banned in the EU except in Sweden and Finland and sale of all wild caught salmon (*Salmo salar*) from the Baltic Sea being banned in the EU except in Sweden, Finland and Latvia (European commission 2011a). It is estimated that 60% of the dioxins found in the Baltic Sea originate from outside its catchment area and that the aerial deposition of dioxins in the Baltic Sea has been reduced by 60% between 1990 and 2007 (HELCOM, 2012b). The threat of ingesting high amounts of POPs was among the reasons to why the practice of using freshly caught fish as feed in the fish farms stopped in the Baltic Sea (Setälä et al. 2007). For this reason, Baltic Sea sourced fish meal and -oil needs to be purified before being used. The fish meal and oil produced in two Danish factories from Baltic Sea fish is cleaned of POPs.

## 3.3. Plant ingredients in fish feed

The increased prices and inadequate supply of both fish meal and fish oil have turned feed producers towards an increased use of plant sources for cheaper protein and oil. Soy currently constitutes a considerable amount of the protein in many feeds and rapeseed oil has replaced a part of the fish oil. The quality of the finished product, and especially its fatty acid content is strongly influenced by the fatty acid content of fish feed (NRC 2012). Therefore, changes in feed formulations are not only evaluated from the point of view of the fish but also from that of the consumer.

Possible future vegetable ingredients include locally produced plants such as field beans and rapeseed. As monogastric animals like fish cannot utilize all plant phosphorus because of the presence of phytate, an addition of phytase might be necessary as the fraction of plant ingredients in fish feed increase (Kumar 2011).

# 4. Baltic Sea fish feed

Ingredients for fish feed are bought by the feed producers from the global commodity market. Several criteria, especially price and availability are important factors. A vast majority of the ingredients are imported from outside the Baltic Sea and this practice results in a net flow of N and P into the Baltic Sea. Eutrophication in the Baltic Sea is affected by levels of both N and P in the water but there is discussion about which element is most important (Elmgren 2001, Savchuk & Wulff 1999). The microbial fixation of atmospheric N by cyanobacteria is believed responsible for a large part of the input of N (Savchuk & Wulff 1999). As the air we breathe consists of 78% N there is never a shortage of nitrogen for cyanobacteria that can utilize atmospheric nitrogen. Phosphorus on the other hand is not freely available in the atmosphere and enters the Baltic Sea almost exclusively via waterways. It is desirable to reduce both N and P but the main focus for the formulated feed is P, in part because of the reason mentioned above. To reduce the import of N and P to the Baltic Sea, a Baltic Sea fish feed (BSFF), that to a high degree or exclusively contains nutrients sourced from the Baltic Sea, has been proposed as a nutrient abatement measure. Using raw materials from the Baltic Sea will reduce the import of nutrients through external ingredients which could result in a decrease of dissolved nutrients in the Baltic Sea (Ruohonen & Mäkinen 1991; Asmala & Saikku 2010). During the roundtable discussions arranged in the Aquabest-project, a definition for BSFF has been developed. The BSFF formulation is based on a mass balance of nutrients sourced from Baltic Sea marine ingredients. Further, in order to avoid difficulties with price fluctuations and availability the mass balance needs to be calculated as an average over several years. An average mass balance is proposed so as to minimize the risk that inadequate supply means producers are not able to include the promised amount of fish meal from the Baltic Sea. The mass balance concept is similar to the concept of green electricity, is not concerned with returning the exact same N or P atom to the Baltic Sea, but is rather based inputs to fish feed from harvest and fishing, and intake through aquaculture feeds.

## 4.1. BSFF formulation

To illustrate potential gains from using BSFF, comparisons of nutrient emissions at the local and Baltic Sea scale were carried out using different feed formulations. A simplified current feed formulation was assumed to consist of 20% fish meal with all remaining protein originating from soybean protein concentrate. The P content in current fish feed was assumed to be 0.8%. Total P and N loads were calculated. Natural removal processes which occur after the nutrient release from fish farms including sedimentation and denitrification were not simulated. The basic idea is that the formula should provide results that are comparable to current mass-based emission figures for agriculture, sewage treatment plants and diffuse effluents, which also ignore nutrient concentrations.

To calculate nutrient emissions, the feed conversion ratio (1.18), P content of farmed rainbow trout (0.4%) and P content of the feed (0,8%), are the same as the licensing authority of the Åland Islands use when evaluating licenses for fish farms (ÅMHM 2013). It is assumed that the fish meal has a protein content of 700 g/kg and a fat content of 100 g/kg. The P content of fish meal is 20 g per kg (Vielma 2013). The feed which is currently used is assumed to contain no ingredients from the Baltic Sea.

## 4.2. Baltic Sea fish meal in the BSFF

Sustainable fishing of herring and sprat in the Baltic Sea can provide fish for both direct human consumption and animal feed including fish meal production. As fish meal is one of the most N and P rich ingredients in the fish feed, using Baltic Sea fish for the fish meal could reduce the inflow of nutrients to the region (Table 1).

**Table 1.** Content of Baltic Sea fish meal in the fish feed, with a feed conversion ratio (FCR) of 1.18

| | **g Baltic Sea fish meal / kg feed** | **% Baltic Sea fish meal of total dietary fish meal** | **% of dietary total nutrients** | **Specific load (total, g/kg growth)** | **Released from Baltic Sea fish meal into the water (g/kg growth)** |
|---|---|---|---|---|---|
| Phosphorus | 0 | 0% | 0% | 5.44 | 0.0 |
| | 25 | 13% | 6% | 5.44 | 0.3 |
| | 50 | 25% | 13% | 5.44 | 0.7 |
| | 75 | 38% | 19% | 5.44 | 1.0 |
| | 100 | 50% | 25% | 5.44 | 1.4 |
| | 125 | 63% | 31% | 5.44 | 1.7 |
| | 150 | 75% | 38% | 5.44 | 2.0 |
| | 175 | 88% | 44% | 5.44 | 2.4 |
| | 200 | 100% | 50% | 5.44 | 2.7 |

The specific load is slightly lower (-0.06 g/kg) in the calculations than in the data supplied by ÅMHM (2013). By formulating a fish feed in which all fish meal is manufactured from Baltic Sea fish, fish farmers on the Åland Islands who choose to implement it can increase their feeding by a maximum of 60% while still achieving a target of 20% lessened P emissions. The incentive will however be dependent on political discussions. At the most 50% of the P and can be reduced by using Baltic Sea fish meal in a feed in with 20% fish meal content if the total P content is 8 g/kg and the P content of the fish meal is 4% (Vielma 2013).

**Table 2.** Potential increments in fish farming. Note the 0% increase/decrease at an inclusion of 80g of Baltic Sea fish meal per kg of fish feed.

| Phosphorus | g Baltic Sea fish meal / kg feed | % of fish meal that originates from the Baltic Sea | Increase/decrease in production in percent if a 20% reduction target is to be reached |
|---|---|---|---|
| | 0.0 | 0.0% | - 20% |
| | 25.0 | 12.5% | - 15% |
| | 50.0 | 25.0% | - 9% |
| | 75.0 | 37.5% | - 2% |
| | 80.0 | 40.0% | 0% |
| | 100.0 | 50.0% | 7% |
| | 125.0 | 62.5% | 16% |
| | 150.0 | 75.0% | 28% |
| | 175.0 | 87.5% | 42% |
| | 200.0 | 100.0% | 60% |

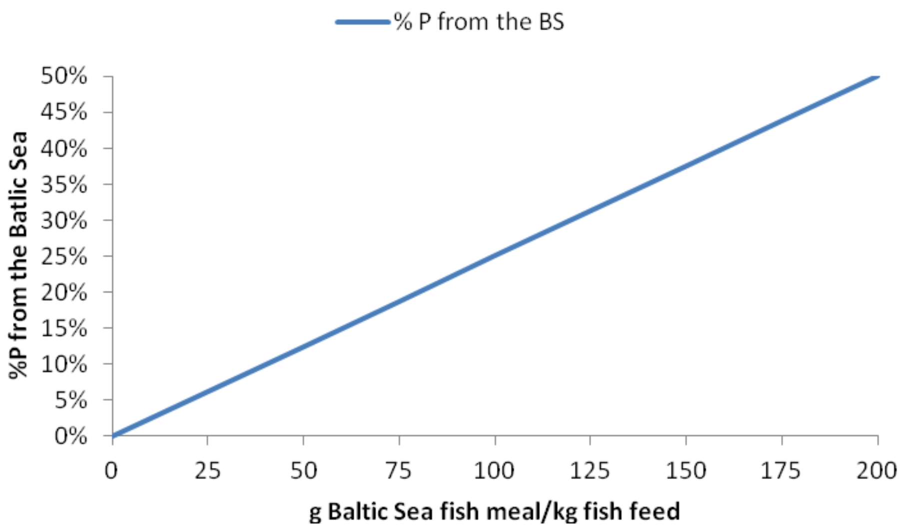


**Figure 3.** Increase in P sourced from the Baltic Sea with increased content of Baltic Sea fish meal in fish feed.

The amount of nutrients from the Baltic Sea increases with increasing content of Baltic Sea sourced fish meal (Figure 3). Based on current commercial formulations, content of more than 20% fish meal, i.e. 200 g of fish meal per kg of fish feed, is not economically feasible. The future content of fish meal in the fish feed might be even lower, potentially going near 10% within the next few years. Furthermore, in order to keep the fish in-fish out ratio as low as possible, meaning not using more fish in the feed than is produced from aquaculture, it is not reasonable to use higher proportions of fish meal in the fish feed. Slightly more fish is currently used for fish meal and oil than is produced from rainbow trout farming. If a reduction of 20% from current P emissions is to be attained, at least 80.0 g of the

200 g of fish meal in each kg of fish feed (e.g. 40% of the fish meal) should come from Baltic Sea fish (Figure 4). A content of Baltic Sea fish below this means that the reduction target cannot be achieved with current production. If a feed in which 100% of the fish meal comes from the Baltic Sea is used in the fish farms on the Åland Islands, their import of P to the Baltic Sea drops with 50%.

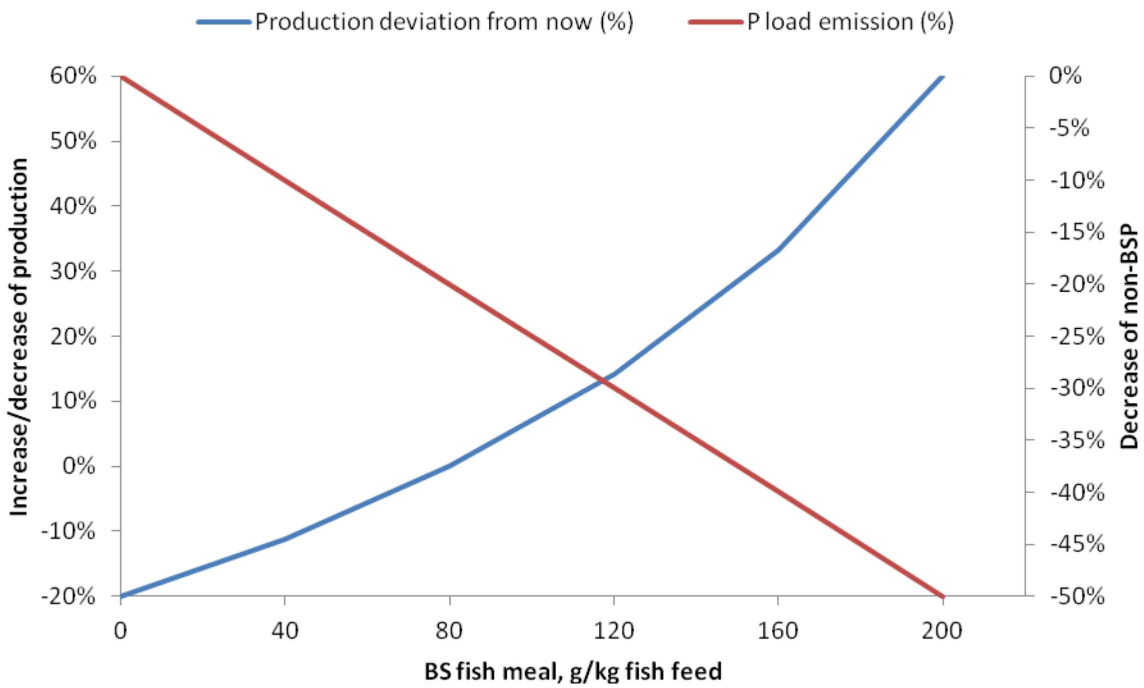


**Figure 4.** Potential decrease and increase in production with a 20% reduction in P (blue line, left-hand axis) and theoretical decrease in import of P due to fish meal from Baltic Sea fish (red line, right-hand axis).

**Table 3.** Required amount of Baltic Sea sourced fish meal needed to fulfill the need of aquaculture on the Åland Islands according to different fish meal contents per kg.

| | **Baltic Sea fish meal (g/kg)** | **Total Baltic Sea fish meal needed (ton)** |
|---|---|---|
| **2012** 5715 ton production, FCR. 1.18 (RKTL 2013b, ÅMHM 2013) | 10 | 67 |
| | 50 | 337 |
| | 80 | 518 |
| | 100 | 647 |
| | 150 | 1012 |
| | 200 | 1349 |

According to Table 3 using only Baltic Sea fish meal in the fish feed would require a production of around 1100 tons of Baltic Sea fish meal to support current aquaculture production on the Åland Islands. This would in turn mean 5500 tons of fresh Baltic Sea fish needs to be sent to fish meal production and purification. The fishing quotas in the Baltic Sea for Finland were set to 12,908 tons of sprat and 106,897 tons of herring for 2013. The mean quota for Finland during 2011 – 2013 was 13,150 and 106,918 tons for sprat and herring respectively (European Commission, 2010, 2011b, 2012).

Content of Baltic Sea fish meal in the BSFF would, depending on the exact definition, probably increase the feed costs. The reason for the increased price is that feed factories which are not currently using Baltic Sea fish meal in their feed would have to alter their production in order to produce such a feed. The price for Baltic Sea fish also fluctuates as the availability and demand for fish changes; therefore it is difficult to estimate the actual price increase.

## 4.3. Non-commercial fish from the Baltic Sea in fish feeds

Non-commercial fish are here defined as fish species that hold a low or non-existent commercial value and are therefore not widely fished. The idea of using species like these from the Baltic Sea is that it would extract nutrients and thus reduce eutrophication. In addition, lowering the density of bottom feeding fish like bream and silver bream could have positive effects on the water quality. The fishing of such species has been proposed in Finland as a method to partially compensate for the nutrient emission from aquaculture (Ministry of Agriculture and Forestry, 2009). Currently there are a few species of fish that could be seen as non-commercial; different cyprinids like roach (*Rutilus rutilus*) and common bream (*Abramis brama*) and the European smelt (*Osmerus eperlanus*). Fishermen report that bycatch in coastal fisheries usually consists of half cyprinids, a third roach and a tenth smelt (Setälä *et al.* 2011).

Many of these species mainly reside in the coastal zone, which makes them harder to fish. Mäkinen et al. (2008) calculated that reduction fishing of 860 kg of these species of fish would offset the phosphorus load caused by farming one ton of fish in aquaculture. Non-commercial fish could theoretically be used as a raw material for fish meal that subsequently could be used in a BSFF. Catches of the magnitude of few thousand tons would however be dispersed spatially and temporarily, and fish meal manufacturing would require dispersed preservation before transport to fish meal factories. On the Åland Islands the populations of non-commercial fish species are estimated to be too small in order to be utilized more extensively for offsetting the nutrient load from local aquaculture or agriculture. Concerns have also been expressed that the bycatch might include valuable species like pike, perch and pike-perch. The local populations of fishes such as silver bream and bream might also collapse quickly if incitement is given for their removal, as information about their numbers in the waters of the Åland Islands is close to non-existent (Fisheries section, Åland government, pers. comm. 2013). Further information must be gathered about the non-commercial stocks of fish.

## 4.4. Mussel meal in Baltic Sea fish feeds

Mussel meal is being discussed as a replacement for fish meal in animal feed. Mussels can reduce the negative effects of eutrophication by filtering phytoplankton; a process that can be expected to improve water transparency. Investment in research has led to considerable improvements in the production techniques for mussel farming (Bonardelli 2013, van Deurs 2013) and mussel meal production (Lindahl 2013) Mussel farming has also been met with positive public interest, which has helped keeping mussel production on the agenda. However, the low salinity in the Åland archipelago has a negative impact on the growth rate and final size of the blue mussels (*Mytilus trossulus*/*Mytilus Edulis*).

A trial was conducted between 2010-2012 in order to determine conditions in the Åland archipelago for blue mussel farming (Engman, 2013) and there has been different reports discussing the possibility of large scale mussel farming in the Baltic Sea (Bonardelli 2013, van Deurs 2013). Four 120m long SmartFarm nets were placed next to the island of Synderstö. The trial farming, which ran for 2.5 years, determined that the optimal harvest is made after 2 years, since the mussels do not gain considerable biomass after this time. The size of the mussels was smaller than at other mussel farms in southern Sweden and Denmark. A chemical analysis showed that the toxic-contents of the mussels were well below regulatory limits, and the mussels were suited for mussel meal production and use in fish feed.

20 kg of mussels yield 1 kg of mussel meal, despite having slightly lower protein and fat content, could replace fish meal in fish feed (Lindahl & Kollberg, 2008). Mussels contain about 1% nitrogen and 0.1% phosphorus, which means that one ton of mussels removes about 10 kg nitrogen and 1 kg phosphorus (Lindahl *et al.* 2005). This means that 6200 tons of mussels would have to be farmed to take up 6.2 tons of P, i.e. 20% of the P released yearly from fish farms. Considering that Engman (2013) produced 14.4 tons of mussels, this production would have to be roughly 430 times larger.

Substituting the fish meal in the fish feed with mussel meal would require around 22000 tons of farmed mussels to account for the fish feed which is used on Åland Islands. Compared to the production achieved in the test cultivation on the Åland Islands (Engman 2013), the production would need to be around 76 times larger to achieve 1% content of regionally produced mussel meal in the fish feed used on the Åland Islands yearly. It should be noted that the low mussel harvest was in part due to unsuitable harvesting equipment and sub-optimal timing of the harvest, but even if it was estimated that optimized production technique could increase the harvest upwards to 20-25 tons, a vast increase in production volume and area would be needed to provide even a fraction of Baltic Sea mussel meal from the Åland archipelago for the BSFF. Areas of the Baltic Sea with higher salinity are likely to have more favorable conditions for mussel farming.

**Table 3**. The amount of farmed mussels needed to fulfill the need of Åland Island aquaculture according to different amounts of mussel meal in fish feed.

| | **g/kg** | **Tons of farmed mussels** |
|---|---|---|
| **2012**<br>5715 ton production,<br>FCR 1.18<br>(RKTL, 2013b) | 10 | 1348 |
| | 50 | 6742 |
| | 100 | 13486 |
| | 150 | 20228 |
| | 200 | 26972 |

Despite improvements, mussel farming is still a relatively expensive practice and performed only on a small scale. To achieve considerable nutrient uptake and commercial viability, mussel farming needs to be scaled up to a much larger level. Mussel meal might prove to be an option in the future and can achieve nutrient reductions when done on a larger scale.

## 4.5. Ingredients in the BSFF sourced from the Baltic Sea catchment area

The underlying idea with BSFF is to gradually increase the amount of regionally sourced nutrients in fish feed to decrease the import of nutrients from outside the Baltic Sea catchment area (BSCA). Besides fish meal, other potential BSCA sourced ingredients include wheat, field beans, and rapeseed products. Furthermore, yeast protein has been discussed as a potential future BSCA ingredient which could be included in the BSFF.

Including BSCA plant feedstuffs in fish feeds does not 'recycle' marine nutrients into aquaculture production and the nutrients from the plants would not end up in the Baltic Sea unless the plants had been put in the fish feed in the first place. Thus, no net gain in the nutrient status of the Baltic Sea as a result of using plants farmed in the BSCA in fish feed can be achieved. The use of ingredients from the BSCA does, however, have other environmental benefits. Use of BSCA ingredients in fish feed would increase the self-sufficiency of the region, reduce the externalizing of negative environmental effects of the cultivation and could decrease the fossil fuel consumption associated with food transport.

# 5. Discussion

The Åland Islands has a relatively small aquaculture industry that despite its size is responsible for two thirds of the total annual P emissions from the region. This has led to harsh local criticism which has resulted in lowered emissions but also a stagnation of production. Discharges of N and P have been reduced and fish farming is now more efficient than ever before. The European Commission proposes to spur development of aquaculture in the EU by reduced administrative procedures, improved spatial planning, enhanced competitiveness of EU aquaculture and a leveled playing field for EU operators by the exploitation of competitive advantages (European Commission, 2013). EU wants to expand aquaculture within the union whereas current law on the Åland Islands makes it practically impossible to do so locally. In addition, HELCOM is also drafting its own recommendations for fish farming. Despite the signals from EU to increase fish farming, there is much pressure on the industry to become cleaner. How can production increase and emissions decrease?

The first step should be to get the fish feed manufacturers to manufacture a fish feed using Baltic Sea fish meal. The basic idea of such a feed is that it should be based as much as possible on ingredients from the Baltic Sea. Such a practice will allow for N and P imports to the Baltic Sea to be minimized and in a best case scenario, even removed. If such a feed is manufactured, its implementation at fish farms in the Åland Islands can hopefully be met with incentives. The most probable form of incentive is increased production allowances to the fish farmers who choose to it. There is also speculation that incentives could be used to encourage the use of raw materials grown in the Baltic Sea catchment area to replace plant raw materials from other parts of the world. The benefits of using field bean or rapeseed protein from the catchment area of the Baltic Sea lies in a reduced emission of greenhouse gases, rather than in decreased import of N and P to the Baltic Sea. This means that it will be hard to allow increased production due to the use of Baltic Sea region land ingredients in the feed.

A BSFF that consists of 20% of a fish meal which 100% from the Baltic Sea, would give the fish farmers an increase with 60% of their present production and still reduce the import of P to the Baltic Sea with 20%. This figure will however be dependent on how the incentives are calculated and what the feed contains. This will be a political issue and the calculations should be revised if a law is adopted. It is also not likely that it will be economically feasible to produce fish feed with so much Baltic Sea fish in it.

As for the discrepancies between the specific load of the calculations and the actual specific loads: this is because the specific load was calculated with the feed conversion ratio and P content of the feed. The actual figure was calculated with used feed and produced fish. As the discrepancy is very small (0.06 g P/kg farmed fish) it is unlikely to cause any major differences between the results of the examples presented here and reality.

There is also some speculation as to what the reaction from the politicians will be to the fact that feed manufacturers will use fish that would be fished anyway. The main argument in favor of this practice is that it would allow for a clear view of what the fish farms actually import to the Baltic Sea. It would also improve the transparency of the industry as a whole and could prove to be the basis for even more environmentally friendly practices. As it creates a demand for Baltic Sea sprat and herring from the feed industry, it might also lead to more such fish going to human consumption instead of going to fur animal farms.

It is currently hard to tell what this feed would mean from an economical point of view. For example: will the supposed increase in feed price be offset by increased production allowances? Another aspect is that local emissions will increase if fish farms expand; the localization of the fish farms will therefore be very important and structural planning will hopefully play a vital role in future licensing. Ideally, fish farms shall be placed away from human activity in areas where the water is deep and its exchange rate is rapid.

If countries in the Baltic Sea region accept recirculation based feed as an environmental measure that can improve the status of the Baltic Sea or at least lessen the impact from fish farming. Replacing 'imported' fish meal with Baltic Sea fish meal is only the first step towards a more sustainable aquaculture in the Baltic Sea. The formula shows how important it is to continue research to find alternative raw ingredients for fish feed. Continued feed development will allow open cage aquaculture to increase the efficiency of feed utilization and reduce environmental impacts. Aquaculture is still an important livelihood for several regions in the Baltic Sea and efforts should thus be made to provide solutions for the industry and rural communities to survive, without further compromising the environment.

# References

Asmala, E., Saikku, L. 2010: Closing a loop: a substance analysis of nitrogen and phosphorus in the rainbow trout production and domestic consumption system in Finland, AMBIO: 39: 126 – 135

Biomar, phone interview with Mikkel Detz Jensen and Henrik Aarestrup on the 10th of April 2013 and correspondance.

Bonardelli, J. 2013. Technical and practical requirements for Baltic mussel culture, Reports of Aquabest project 4/2013, 61 p

Broström, R. 2013. Personal correspondance and reported data 19.06.2013. Åland Islands fish farmers association.

van Deurs, M. 2013. Best practice for mussel farming in the Baltic Sea, Reports of Aquabest project 5/2013, 28 p

Engman, T. 2013. Möjligheter och förutsättningar för storskalig musselodling på Åland, Del 2 inom FAS II – odling och skörd [Opportunities and prospects for large-scale mussel farming in the Åland Islands, Part 2 in PHASE II - growing and harvesting]. The Government of Åland, Mariehamn, Finland.

European Commission 2011a: Commission regulation (EU) No 1259/2011 of 2 December 2011 amending regulation (EC) no 1881/2006 as regards maximum levels for dioxins, dioxin-like PCBs and non-dioxin like PCBs in foodstuffs

European Commission, 2013. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions -Strategic Guidelines for the sustainable development of EU aquaculture. COM(2013) 229 p. Brussels, 29.4.2013

European Commission 2010: Council Regulation (EU) No 1124/2010 of 29 November 2010 fixing for 2011 the fishing opportunities for certain fish stocks and groups of fish stocks applicable in the Baltic Sea

European Commission 2011b: Council Regulation (EU) No 1256/2011 of 30 November 2011 fixing for 2012 the fishing opportunities for certain fish stocks and groups of fish stocks applicable in the Baltic Sea and amending Regulation (EU) No 1124/2010

European Commission 2012: Council Regulation (EU) No 1088/2012 of 20 November 2012 fixing for 2013 the fishing opportunities for certain fish stocks and groups of fish stocks applicable in the Baltic Sea

Evira (Finnish Food Safety Authority Evira), 2012. Viral Haemorrhagic Septicaemia (VHS), occurrence in Finland.
http://www.evira.fi/portal/fi/elaimet/elainten_terveys_ja_elaintaudit/elaintaudit/kalat_ja_ravut/vhs
Retrieved 26.03.2013

FAO 2009: Impact of rising feed ingredient prices on aquafeeds and aquaculture productions, 63 p FAO, Viale delle Terme di Caracalla, 00153, Rome, Italy

FAO, 2012.The state of world fisheries and aquaculture. Fisheries and Aquaculture department, Rome.

HELCOM, 2004a. Dioxins in the Baltic Sea. Helsinki, Finland.

HELCOM. 2004b. HELCOM recommendations 25/4: Measures aimed at the reduction of discharges from fresh water and marine fish farming

HELCOM, 2001: Polychlorinated Biphenyls (PCBs): A compilation of information, derived from HELCOM Recommendations.

HELCOM, 2012a.The Fifth Baltic Sea Pollution Load Compilation (PLC-5) – An Executive Summary.Balt. Sea Environ. Proc. No. 128A.

HELCOM, 2012b. Hazardous Substances in The Baltic Sea – An Integrated Thematic Assessment of the Hazardous Substances in The Baltic Sea

Kiessling, A, Lindholm, T, Vielma J, Broström, R, Granholm P & Abrahamsson, D 2013. Closing the aquaculture nutrient loop: Roundtable discussion summary, Reports of Aquabest 7/2013 18 p

Kumar, V, Sinha, AK,Makkar, HPS, De Boeck, G, Becker, K, 2011. Phytate and phytase in fish nutrition. J Anim Physiol Anim Nutr (Berl). 96(3):335-64.

Lerche, K-O. 2013 personal communication 10.06. Raisioagro.

Lindahl, O. & Kollberg, S. 2008. How mussels can improve coastal water quality. Mussel farming – a way to combat eutrophication. Bioscience-explained, vol 5, no 1.

Lindahl, O. 2013. Mussel meal production based on mussels from the Baltic Sea, Reports of Aquabest Project 6/2013, 11 p

Lindahl, O., Hart, R., Hernroth, B., Kollberg, S., Loo, L-O., Olrog, L. Rehnstam-Holm, A-S., Svensson, J., Svensson, S. & Syversen U. 2005. Improving Marine Water Quality by Mussel Farming: A Profitable Solution for Swedish Society. Ambio. 34: 131–138

Ministry of Agriculture and Forestry, 2009. Statsrådets principbeslut ”Det nationella vattenbruksprogrammet 2015” [Government Resolution "National Aquaculture Programme 2015"]. Wildlife- and fisheries department.

Mäkinen, T. (ed.) 2008. Fishery as a preventive action against the nutrient loading from fish farming: fish farming net loading system, a preliminary study. Riista- ja kalatalous – Selvityksiä 2/2008. 36 p. Game and fisheries research institute.

National Nutrition Council, 2005.Suomalaiset ravitsemussuositukset – ravinto ja liikunta tasapainoon [Finnish dietary recommendations – the balance between nutrition and exercise]. Edita Publishing, Helsinki. 56 p.

NIFES, National Institute of Nutrition and Seafood Research, http://www.nifes.no/forskning/akvakulturernering/tema/planteoljer%20i%20fiskef%F4r/?lang_id=2 Retrieved 10.6 2013

RKTL, 2012a. Food fish production – statistics. http://tilastot.rktl.fi/Dialog/view.asp?ma=3_Ruokakalatuotanto&ti=Ruokakalantuotanto+%281000+kg%2C+milj%2E+%80%29&path=../Quicktables/Tilasto/2_Vesiviljely/1_Vesiviljely/&lang=3&multilang=fi Retrieved 07.06 2013

RKTL, 2012b. Producer Prices for Fish 2011, Finnish Fish and Research Institute, 37 p. Helsinki

RKTL, 2012c. Aquaculture 2011, Finnish Fish and Research Institute, 28p. Helsinki

RKTL, 2013a. Producer Prices for Fish 2012, Finnish Fish and Research Institute, 37 p. Helsinki

RKTL 2013b. Aquaculture 2012. Finnish Fish and Research Institute, 28 p. Helsinki

Ruohonen, K. and Makinen, T., 1991. Potential ways to diminish environmental impact of mariculture on the Baltic Sea. Finnish Fisheries Research 12, 91–100.

Setälä, J., Tarkki, V., Mannerla, M. and Vielma, J. 2011. Vajaasti hyödynnetyn kalan kaupalliset käyttömahdollisuudet [Commercial use of under-utilized fish]. RKTL:n työraportteja 11 /2011. Game and fisheries research institute.

Setälä, J., Vielma, J., Koskela, J., Honkanen, A., Saarni, K., Jokelainen, T., Suvanto, M., Kankainen, M. & Virtanen, J. 2007. Utvecklingsalternativ för hållbar fiskodling på Åland [Development options for sustainable fish farming on the Åland Islands]. Game and fisheries research institute, Helsinki, Finland.

The Government of Åland, 2011. Genomförandeplan för det åländska vattenbruket [Actionplan for the Åland aquaculture]. Mariehamn, Finland.

The Government of Åland, 2005.Miljöhandlingsprogram för Åland 2005-2008 [Environmental acts program for the years 2005-2008]. Mariehamn, Åland.

The Government of Åland, 2007.Landskapsförordning om odling av regnbågslax och lax i havet [Provincial regulation for farming of rainbow trout and salmon in the sea]. 2007:57.

The Government of Åland, 2010.Vattenförordning för landskapet Åland [Water regulation for Åland]. 2010:93

The Government of Åland, 1996.Vattenlag för landskapet Åland [Water law for Åland].1996:61.

The Government of Åland, 2012. Ålands marina strategi - Sammanställningar och bedömningar enligt artikel 8, 9 och 10 i EU:s direktiv 2008/56/EG [Marine strategy of the Åland Islands - Compilation and assessment according to Article 8, 9 and 10 of the EU Directive 2008/56/EC]. Mariehamn, Åland.

The Government of Åland, 2009. Åtgärdsprogram för Ålands kust-, yt- och grundvatten 2009-2015 [Action program for the coastal-, surface- and groundwater on the Åland Islands 2009-2015]. Mariehamn, Åland.

Vielma, J. 2013: Fish feed formulation, received via personal communication 25.04.2013

Wennström, M., Vävare, S., Broström, R., Rosenqvist-Metsik, B., Karlsson, O., Sjöblom, S., Eriksson, M., Henriksson, K-J. & Dahlin, H. 2011. Fiskodling på Åland ur ett helhetsperspektiv [A holistic perspective on fish farming in the Aland]. The Government of Åland.

Ådjers, K. 2013, Personal correspondence, Government of Åland, Fisheries section,

ÅMHM, 2013. Permissions for fish farms, received via personal communication

ÅSUB, 2012. Strain on watercourse in Åland 2003-2012, Statistical Yearbook of Åland 2012, 252 p. Mariehamn.

# Appendix

**Calculations on incitements of Baltic Sea fish feed**

The calculations for the incitements:

Fish feed which is currently used has an average P content of 8 g/kg (ÅMHM 2013), of which 50% (4 g/kg) comes from fish meal. Fish meal has a P content of 20 g/kg (Vielma 2013).
It is therefore theoretically possible to reduce the phosphorus import from outside the BS with 50%.

The feed conversion ratio was 1.18 kg feed/kg farmed fish and the average P content of the feed was 8 g P/kg fish feed whereas the P content of fresh fish is estimated to be 4 g/kg (ÅMHM 2013):

1.18 * 8 – 4 = 5.44 (P released into the water per kg farmed fish)

5.44 * 0.8 = 4.35 (80% of current P released into the water per kg farmed fish)

The specific load is 5.44 and should be reduced to 4.35 if the goal is a reduction with 20% of the current emissions

(X * 20) / 1000 / 8 = Y (% of the total P of the fish feed that is from the Baltic Sea if X is the amount of the BSFM)

Y * 5.44 = Z (The amount of P from the Baltic Sea in g that is released per kg of farmed fish)

5.44 / (5.44 – Z) = (The theoretical increase of production in % if the import of P from outside the BS is allowed to stay at the current level)

4.35 / (5.44 – Z) = (The theoretical decrease or increase of production in % if the import of P from outside the BS is reduced with 20%)

The percentage of P in the fish feed that comes from fish meal is an estimation. The data available indicates that a higher amount of P will come from fish feed: approximately 67% or 4 g P/kg, of the P in a phytase-enriched fish feed with 7 g P/kg comes from fish meal (Vielma 2013). As the P content of this feed (7 g P/kg) is lower per kg than the feed which is actually used (8 g P/kg) (ÅMHM 2013), it was assumed that 4 g P/kg of fish feed will come from fish meal and the rest will come from other sources.