Pilot Mussel

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NutriTrade - A Flagship project of the EU Baltic Sea region strategy

EUROPEAN UNION
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INTRODUCTION

Harvest of blue mussels (*Mytilus edulis*) is a relatively new method for reducing phosphorous (P) and nitrogen (N) loads in the Baltic Sea Proper. Previous experiments in the Baltic Sea have indicated that cultivation of blue mussels has potential to be a cost effective measure to reduce nutrient loads. There is currently no commercial market for blue mussels from the Baltic Sea. However, mussel meal can be used as feed for poultry and fish, a high value fertilizer on arable land, or for production of biogas. The project NutriTrade set out to arrange a tender for mussel harvest contracts, where the mussels were to be harvested in 2017 and 2018. The economic support provided through this tender for mussel harvesting will potentially stimulate the establishment of mussel farms in the Baltic Sea. A larger harvest would in turn promote the establishment of a market for mussels. The experiences from the pilot are of interest for public bodies responsible for the environmental state of the Baltic Sea and willing to investigate the possibilities to introduce an environmental support system for mussel farming.

STATE OF THE ART MUSSEL FARMING IN THE BALTIC SEA BEFORE PROJECT START

The NutriTrade project team at The Swedish University of Agricultural Sciences (SLU) started the work by making a thorough inventory of mussel farming capacity and competence. A first step was an inventory of current and potential future production and markets for mussels produced in the Baltic Sea. This inventory showed that berfore the start of the project, there were four mussel farmers along the Swedish east coast. Two were joint partnerships between municipalities (Västervik, Oskarshamn) and Baltic Blue Growth (BBG), which is a 3-year transnational EU-project aiming to investigate the feasibility of large scale mussel farming as a means for reducing nutrient loads to the Baltic Sea. One is a partnership between a private company and BBG, and one is run by an economic association. Three out of four farms plan to sell the mussels to an animal feed factory, which was planned to be built within the framework of the BBG. An earlier pilot feed factory in Ellös on the Swedish west coast funded by, e.g., the Board of Agriculture and the Environmental Protection Agency, is in principle not operating anymore, as the technology used did not work well. This showed a need to consider alternative uses of harvested mussels, in case the planned factory will not be in place in time for the mussel harvest within the NutriTrade project.

Simultaneously, an inventory of scientific and local competence was made. We discussed the outline of the NutriTrade mussel project with Swedish scientific expertise at SLU and the University of Gothenburg. This ensured a good understanding of the fundamentals of the production process, and gave access to local expertise in form of SMEs at both the east and west coast, municipalities and county administrations. We attended a workshop on mussels to be used as animal feed in Kalmar on 22-23 October 2015, organized by Baltic Mussel Feed. This gave us the opportunity to present the plans for the Mussel Pilot in NutriTrade, and to get feedback on the planned tender. There were more than 30 participants in the workshop, representing mussel expertise and stakeholders from universities, municipal and county administration, mussel farmers, consultants and livestock holders.

Having had an extensive dialogue with the above mentioned stakeholders, we were able to proceed with development of the design of nutrient trade within the Pilot Mussel.

DESIGNING A MUSSEL TENDER

A number of issues of critical importance for the design of a mussel tender were identified, and solutions found in dialogue with other partners and with good help from SLUs tender experts. Those issues are briefly discussed in the following.

Choice of geographical conditions for the tender.

To avoid trade and market distortions, only mussel farms located along the Baltic Proper coastline were included in the tender. This was motivated by the fact that on the west coast, mussels were cultivated for food purposes, whereas this was not possible on the east coast. Moreover, mussel farms could have a local beneficial or detrimental impact on water quality, in addition to the overall beneficial effect on nutrient removal. The tender does not place any restrictions on the localization of mussel farms on the micro scale, as the county administration has the duty to decide on permits for mussel farming, which take into account their environmental consequences.

Production and market uncertainty

Mussel farming is subject to production uncertainty, as the harvest is determined by weather and local-specific conditions for the farms. Hence, the mussel farmers would prefer compensation which is based on their investment and operation costs, rather than the output. However, the aim of our pilot to provide ecosystem services, which suggest that compensation should rather be paid for harvests. The risk for moral hazard (see below) further supports that compensation should be based on harvests, rather than on investments. The tender will therefore provide compensation for harvested mussels only. We also want strong incentives for good farm management. It was therefore stipulated that harvests above the contracted volume could be compensated as well, but that the compensation would equal that for the lowest bid. Further, there is some market uncertainty, as it is not certain what the demand for the mussels will be at the time of the harvest. The feed factory might not be in place. As an alternative, mussels could be used as a high-quality fertilizer. This is a feasible option from an environmental perspective, albeit it might require a permit from the municipality at the time the fertilization is going to take place.

Grower competence

There are few experienced mussel famers on the east coast. Data for the Swedish west coast, obtained from the Board of Agriculture, as well as an interview with the single large mussel company on the west coast, clearly show that production uncertainty is considerably diminished if the mussel farmer is experienced. It was therefore decided that mussel farmers with experience were to be ranked before those without experience, as this increased the likelihood of planned harvests being realized, and reduced the risk that contracted mussel farmers run with a large financial loss after completion of the contracted mussel farming.

Verification

To ensure proper verification of harvests, the mussel farmers were to be allocated an inspector, defined by SLU, or in other suitable manner verify their harvest at the time of harvesting. This inspection could be carried out by municipal or county expertise (public employees), preliminary contacts were taken to ensure the feasibility. As an alternative, harvests could be verified through receipts from buyers.

Moral hazard

There is a certain risk of moral hazard when carrying out a tender, as mussel farmers could involve in opportunistic behaviour. First, it is not possible for either SLU, inspectors or buyers to know when the mussel farming has started. It was therefore decided that it would not matter when the mussel farm started, or whether this was before or after the announcement of the tender. This was further motivated by the fact that the sheer harvesting cost could be an obstacle stopping mussels from being harvested. The aim of the pilot was to provide an ecosystem service, which is obtained at the moment of harvesting, hence it is the action of harvesting which is beneficial to society. Second, there could be other types of opportunistic actions, i.e. claiming an extremely high price in the hope that the number of bidders will be few. This is counteracted by setting a reserve price, i.e. a maximum compensation which is unknown to the bidders, to ensure that the compensation is reasonable in relation to the environmental benefits achieved. A considerable number of other types of opportunistic behaviour, including e.g. different type of business arrangements were also considered in the tender.

Bids could then be sent in through the online tool TendSign. Before the tenders were advertised in the public procurement database, it was announced in Land and Yrkesfiskaren ("The Fisherman"). The former had a very high outreach among farmers and people who live and work in rural areas and was delivered to more than 160.000 people. The latter, which was issued by The Swedish Fishermen's Federation and The Union of Swedish Fishermen, had a high outreach among fishermen. Both were considered to be categories where potential new mussel farmers, with relevant competence for the task, could be found. Moreover, press releases was sent out, and the tender was published on the SLU newspage. After the tenders were announced, an information meeting was arranged at SLU in Uppsala, where anyone interested in the tender could participate in person or via a video link to get further information on the project, the tender, and the technicalities for providing bids. After the deadline of the tenders, one bid was obtained in the first round and six in the second. This resulted in one contract in the first round and five in the latter.

RESULTS OF THE MUSSEL FARMING TENDER

In the first round, mussel farms were contracted aiming at a start of the farm in the spring 2016, and harvests in the autumn 2017. The second round of tender implied farming and harvesting one year later. Table 1 shows planned and actual outcomes of the contracts.

Table 1. Planned and actual harvest, contracted price, total payment for contracted and excess harvest, nitrogen and phosphorus removal for all mussel farms contracted by NutriTrade, as known 6 September 2018.

	Planned harvest (ton)	Actual harvest (ton)	Contracted price (SEK/kg harvested mussels)	Total payment for contracted harvest (SEK)	Total payment for excess harvest (SEK)	Phosphorus removal (kg)[a]	Nitrogen removal (kg)[a]
Bids 1st tender							
VCO, Östergötland	30	30	12	360,000		15	249
Bids 2nd tender							
VCO, Östergötland	20	23.472	12	240,000[b]		11,7	194,22
Kalmar municipality	15	13.416	20	201,240		6.7	111.22
Bohus havsbruk	50	0	11.75	0		0	0
Ålands landskapsregering	15		21,50				
Ålands fiskodlarförening	4	1.2875	25	32,187.5		0.6	9.96
Sum		68,175		833,427.5		34	564,4

[a] P and N content calculated as the average of the intervals provided in P-content 0.4-0.6 kg/ton, N-content 6.4-10.2 kg/ton, here calculated for the averages of the intervals (Persson, 2004).

[b] Harvests above contracted levels will be compensated in the end of the project provided there is budget available.

ANALYSIS OF THE COSTS FOR MUSSEL FARMING AND NUTRIENT REMOVAL

The bids from the different mussel farmers do not necessarily provide information about the marginal or average cost of mussel farming, which is the information that would be of interest for policy makers that want to know the level of an environmental support, necessary to provide potential mussel farmers with an economic incentive for engaging in production. Reasons bids could be higher than the actual average or marginal cost of production include: (1) the short time span of the NutriTrade project, which does not permit that gear is used for its full life time, and (3) farmers expecting few other bidders because of the current small mussel farming activity. Also bids could be below actual costs because many of the contracted mussel farmers had simultaneous support from public sources of various kind, albeit not for harvesting, We have therefore made a comprehensive evaluation of the available evidence on the costs of mussel farming in the Baltic Sea and the North Sea.

We used a combination on public and private information regarding data on planned production (harvesting) of blue mussels, investment and operational costs, projected lifespan of investments, and production timeline. The companies[1] contracted through NutriTrade contributed by sending the corresponding information by mail. The data collected are from the Baltic Sea and North Sea regions.

In the following, planned production refers to the estimated amount of harvested mussels that each source aims to harvest. The planned production could depend on for example climate conditions. In reality, production may be higher or lower for a number of reasons. Higher production may be due to underestimation of mussel settling and growth. Lower production may be due to bio-fouling and bio-toxins (Watson *et al.*, 2009; JV, 2012), predators, such as birds, mammals and starfish (Sanford, 1999; Harley et al., 2006; Harley, 2011), physio-chemical factors, i.e. high concentrations of organic matter may lead to further effects of hypoxia or even anoxia[2] (Carlsson *et al.*, 2009; Carstensen *et al.*, 2014; SMHI, 2016), or geological and environmental factors such as ice drifts, storm events and flooding (Hastie, 2003). Climate change potentially risks mussel production through changes in chemical composition of the water and an increased predator population (Schiedek *et al.*, 2007).

Investment costs are defined as the procurement and installation of new equipment or replacement equipment. These can include boats and vessels for harvesting, machinery, longline installation, navigational markings, anchors and buoys as well as transport and delivery of the equipment. Operational costs, on the other hand, refer to the maintenance, administration and harvesting costs that are incurred. These can be, for example, maintenance of boats and machinery, salaries, purchasing of expendable supplies, fuel, research and office costs.

Investment and operation costs are standardized in this study in Swedish Krona (SEK). For sources presenting values in Euro, Danish Krona (DKK) or U.S. Dollars, these are converted using average exchange rates in 2016 given by the Swedish Riksbank[3]. Due to the fact that many costs are collected from various time periods, and in order to get a consistent value of costs and adjust for inflation, investment and operational costs are adjusting to 2016 values using the producer price index (PPI) for fisheries within the various countries that are presented[4].

One of the key challenges in this study is that producers have varying lengths and production timelines. One may present costs for a four year harvesting period whilst another may give costs over a two year period. In order to maintain consistency, values are presented in yearly terms. For investment costs, these are typically incurred before harvesting commences. However, for some producers, investment can be mostly in the first year with additional equipment purchased in the following year. Different investments may have varying lifespans[5]. For example, Baltic EcoMussel (2003) states that the lifespan for a 'boat for checking' is 12 years where Buck *et al.* (2010) states that the lifespan of such an

[1] Bohus Havsbruk, Vattenbrukscentrum Ost, Kalmar municipality and Västerviks kommun
[2] Hypoxia refers to oxygen depletion whilst anoxia refers to near total absence of oxygen.
[3] Assuming 1 Euro = 9.3731 SEK, 1 DKK = 1.2586 SEK and 1 USD = 8.3985 SEK.
[4] Producer price indices are used for Sweden from Statistics Sweden (SCB), for Denmark from Statistics Denmark, for Finland from Statistics Finland (Tilastokeskus) and for Germany from Destatis.
[5] This being how long the investment is usable for before needing to be replaced.

investment would be 20 years. Furthermore, it is unclear as to whether it is the same kind of boat used. This poses a challenge where not all investments are of a uniform type, quality or purpose. To control for this, we calculated the present value of investment costs. From the present value of costs, the annuity cost is calculated in order to obtain yearly values that can be compared across projects.

For operational costs, a similar procedure is used to get yearly values. Finally, total cost is calculated by summing up the annuity costs for both investment and operational costs. All data so obtained can be found in Appendix A. For each table in the Appendix, data is separated into the East Baltic Sea region and the West Baltic Sea/North Sea region.

Results

Using the data described above, we estimate a quadratic cost function using OLS regression. The function was estimated with and without robust standard errors. The functional form allows for diminishing or increasing returns to scale (Gould, 1968). From the results we can see that the coefficient for planned production is significant at the 1% significance level with positive sign. This shows us that as total costs rise, so does production of mussels. The squared value for planned production also is significant at the 1% significance level with negative sign, which shows the presence of diseconomies of scale in production. The coefficients for the location dummy variables and the time trend reverse sign for the two estimations but are not statistically significant in either estimation. Both models satisfy the F-ratio tests for whether the overall regression model is a good fit for the data at the 1% significance level. The explanatory power of the model, reflected in the R2 value which shows the proportion of variance which can be explained by the independence variables, is 0.97, i.e. the model explains 97% of the variation. There is evidence of some heteroscedasticity, but it is judged not to be problematic (Williams, 2015).

With respect to the estimated costs, the results show that the cost of mussel farming is 4.8 SEK/kg (≈0.5 EUR/kg). There are some economies of scale that can lower the costs per kilo for large farms. There is no evidence of a cost difference between the Baltic Sea and the North Sea, and no evidence of a time trend in costs. The estimated cost corresponds to 1,000 EUR/kg P or 60 EUR/kg N.

CONCLUSIONS

Several policy relevant conclusions can be drawn from the Pilot Mussel. First, the pilot has shown that successful blue mussel farming is a realistic option in the Baltic Sea region. This contrast with conclusions drawn from the Baltic2020 project (Lindahl, 2012), where mussel farming was highly unsuccessful. This shows mussel farming is a potentially viable option both for improving sea water quality and for strengthening rural livelihood. However, our pilot, together with earlier mussel farming experiments, also shows that mussel production is highly stochastic: actual harvests can differ quite strongly from planned harvests. If the mussel production is to be increased, this is likely to be facilitated by if the production by individual farmers, and in the aggregate, is sufficiently large to benefit from scale economies. If the individual farmer has a large farm, successful farming in one location could compensate for unsuccessful farming in another location. Also, considerable investment needed for harvesting equipment suggests that farms need to relatively large to utilize this equipment to its full capacity. Alternatively, schemes for capacity sharing need to be developed.

Moreover, the development of a commercial market for blue mussels from the Baltic Sea for feed purposes requires not only mussel production of a certain aggregate scale but also technologies for feed production to be created. Such technologies are not yet in place. Mussels are less suitable for biogas production due to the low carbon content. An alternative is to use mussels for fertilization, such as is done with most of the mussels produced within the framework of the pilot. At this point, it is not clear what is the economic value of blue mussels in this use.

Another lesson learned from the project relates to the design of environmental policy instruments for blue mussels with a purpose to increase nutrient removal from the sea. Experiences drawn from the mussel tenders are relevant for such design, and show the need to account for production uncertainty and moral hazard if the policy maker targets nutrient reductions that are both high and reliable. The experiences from the pilot show that to be cost-effective, policies should be long-term to make advantage of the full life time of capital equipment necessary for the production and the costs for mussel farmers to gain knowledge and experience. Furthermore, to encourage participation, it is an advantage to provide some certain compensation to the farmers. That could be combined with some share of the compensation being dependent on the achieved mussel harvests and nutrient removal in order to create incentives for careful management and harvesting of the farm. Verification of harvests in terms of receipt, or through inspections, can be necessary to ensure compliance with contracts.

Finally in terms of the cost-efficiency of blue mussel harvesting in relation to the overall nutrient policies for the Baltic Sea, our results from the wider cost analysis show that blue mussel farming achieves nutrient removal at a cost that is lower than that for several other measures currently applied in the agri-environmental policy (Elofsson, 2010) and for scattered dwellings. Hence, increased blue mussel production could save policy costs and help achieving environmental targets.

References

Adelman, M.A. and Watkins, G.C. (2003), "*Oil and Natural Gas Reserve Prices, 1982-2002: Implications for Depletion and Investment Cost*", Center for Energy and Environmental Policy Research, MIT-CEEPR 03-016 WP

Baltic EcoMussel (2003), "*The Baltic Ecomussel Project: Final Report*", Central Baltic INTERREG IV A Programme, Riga, Latvia

Box, G.E.P. and Cox, D.R. (1964), "An Analysis of Transformations", *Journal of the Royal Statistical Society*, Series B, 26(1), pp. 211-252

Buck, B.H., Ebeling, M.W. and Michler-Cieluch, T. (2010), "Mussel Cultivation as a Co-Use in Offshore Wind Farms: Potential and Economic Feasibility", *Aquaculture Economics & Management*, 14(4), pp. 255-281

Carlsson, M., Holmer, M., Petersen, J.K. (2009), "Seasonal and Spatial Variations of Benthic Impacts of Mussel Longline Farming in a Eutrophic Danish Fjord, Limfjorden", *Journal of Shellfish Research*, 28(4), pp. 791-801

Carstensen, J., Andersen, J.H., Gustafsson, B.G. and Conley, D.J. (2014), "Deoxygenation of the Baltic Sea during the Last Century", *Proceedings of the National Academy of Sciences*, 111(15), pp. 5628-5633

Cook, R.D. and Weisberg, S. (1982), "*Residuals and Influence in Regression*", New York: Chapman and Hall

Dansk Akvakultur (2015), "*Kombi-Opdræt Kombinationsopdræt af Havbrugsfisk, Tang og Muslinger til Foder og Konsum*", Dansk Akvakultur Report No. 2015-12, Silkeborg, Denmark

Elofsson, K. 2010. Baltic-wide and Swedish Nutrient Reduction Targets: An Evaluation of Cost-effective Strategies. Expertgruppen för Miljöstudier (Expert Group for Environmental Studies), Ministry of Finance, Stockholm.

Gould, J.P. (1968), "Adjustment Costs in the Theory of Investment of the Firm", *The Review of Economic Studies*, 35(1), pp. 47-55

Gren, I.M., Lindahl, O. and Lindqvist, M. (2009), "Values of Mussel Farming for Combating Eutrophication: An Application to the Baltic Sea", *Ecological Engineering*, 35(1), pp. 935-945

Haamer, J. (1996), "Improving Water Quality in a Eutrophied Fjord System with Mussel Farming", *Ambio*, 25(5), pp. 356-362

Harley, C.D.G., Hughes, A.R., Hultgren, K.M., Miner, B.G., Sorte, C.J.B., Thornber, C.S., Rodriguez, L.F., Tomanek, L. and Williams, S.L. (2006), "The Impacts of Climate Change in Coastal Marine Systems", *Ecology Letters*, 9(2), pp. 228-241

Harley, C.D.G. (2011), "Climate Change, Keystone Predation, and Biodiversity Loss", *Science*, 334(6059), pp. 1124-1127

Hastie, L.C., Cosgrove, P.J., Ellis, N. and Gaywood, M.J. (2003), "The Threat of Climate Change to Freshwater Pearl Mussel Production", *Ambio*, 32(1), pp. 40-46

Hjortberg, A.S., (2003), "*Blåmusselodling på Västkusten*", Acquaculture Department Project, Swedish University of Agricultural Sciences, Uppsala

JV (2012), "*Swedish Aquaculture – A Green Industry in Blue Fields: Strategy 2012-2020*", Jordbruksverket, Available from: http://www.svensktvattenbruk.se/download/18.65ea4bd915019557221948d4/1443605006808/Swedishaquacultureagreenindustry_w.pdf

Lindahl, O. (2012). Mussel farming as an environmental measure in the Baltic. Final Report. BalticSea2020, Stockholm.

Krost, P., Rehm, S., Kock, M. and Piker, L. (2011), "*Leitfaden für Nachhaltige Aquakultur*", CRM-Coastal Research and Management GbR Report

Martínez-Budría, E., Jara-Díaz, S. and Ramos-Real, F.J. (2003), "Adapting Productivity Theory to the Quadratic Cost Function. An Application to the Spanish Electric Sector", *Journal of Productivity Analysis*, 20(1), pp. 213-229

Nguyen, T.T., Van Deurs, M.A., Ravn-Jonsen, L. and Roth, E. (2013), "*Assessement of Financial Feasibility of Farming Blue Mussel in the Great Belt by the 'Smart Farm System'*", IME Report 15/13, University of South Denmark, Odense, Denmark

Persson, M. 2004. Musslor för miljön – musselodlingens positiva och negativa miljöeffekter. En populärrapport utarbetad i samarbete mellan två Interregprojekt.

Petersen, J.K., Hasler, B., Timmermann, K., Nielsen, P., Tørring, D.B., Larsen, M.M. and Holmer, M. (2014), "Mussels as a Tool for Mitigation of Nutrients in the Marine Environment", *Marine Pollution Bulletin*, 82(1), pp. 137-143

Ray, S.C. (1982), "A Translog Cost Function Analysis of U.S. Agriculture, 1939-77", *American Journal of Agricultural Economics*, 64(3), pp. 490-498

Sanford, E. (1999), "Regulation of Keystone Predation by Small Changes in Ocean Temperature", *Science*, 283(5410), pp. 2095-2097

Schiedek, D., Sundelin, B., Readman, J.W. and Macdonald, R.W. (2007), "Interactions between Climate Change and Contaminants, *Marine Pollution Bulletin*, 54(1), pp. 1845-1856

SMHI (2016), "Oxygen Survey in the Baltic Sea 2016 – Extent of Anoxia and Hypoxia, 1960-2016", Report Oceanography No. 58, Swedish Meteorological and Hydrological Institute, Göteborg, Sweden, Available from: https://www.smhi.se/polopoly_fs/1.115313!/Oxygen_timeseries_1960_2016.pdf

Watson, D.I., Shumway, S.E. and Whitlatch, R.B. (2009), "Biofouling and the Shellfish Industry", *Shellfish Safety and Quality*, pp. 317-336

Williams, R. (2015), "Heteroskedasticity", University of Notre Dame, Available from: https://www3.nd.edu/~rwilliam/stats2/l25.pdf

Appendix A

Table A1: Planned Production

Company/Source	Location	Total planned production volume (kg)	Lifespan of project
East Baltic			
Bohus Havsbruk	Kalmar, Sweden	50 000	2-year
Baltic EcoMussel (2003)	Hanko, Finland	200 000	1-year
	Åland, Finland	40 000	1-year
Buck *et al.* (2010)	German Bight	9 520 000	4-year
Petersen *et al.* (2014)	Skive Fjord, Denmark	1 100 000	1-year
Vattenbrukscentrum Ost	Sankt Anna, Sweden	30 000	2-year
Kalmar municipality	Hasselö, Sweden	15 000	2-year
	Hagby, Sween	15 000	2-year
Gren *et al.* (2009)	North Baltic Proper	90 000	2-year
	South Baltic Proper	100 000	2-year
Västerviks kommun, kommunsyrelsens förvalting	Gamlebyviken, Sweden	14 000	3-year
West Baltic			
Nguyen *et al.* (2013)	The Great Belt (Storebælt)	20 000 000	1-year
Baltic EcoMussel (2003)	Denmark	210 000	1-year
	Lysekil, Sweden	293 750	1-year
Hjortberg (2003)	Vrångö, Sweden	150 000	2-year
Dansk Akvakultur (2015)	Hjarnø, Denmark	4 000 000	2-year
Krost *et al.* (2011)	Kieler Förde, Germany	100 000	1-year
Gren *et al.* (2009)	Kattegat	400 000	2-year
	The Sound	180 000	2-year
Haamer (1996)	Orust-Tjörn fjord, Sweden	200 000	1-year

Table A2: Investment Costs

Company/Source	Total cost (SEK)	Annuity cost (SEK)	From planned production (SEK/kg)
East Baltic			
Bohus Havsbruk	1 451 890	758 773	15.16
Baltic EcoMussel (2003)	512 591	253 391	1.27
	906 005	129 066	3.23
Buck *et al.* (2010)	79 494 800	9 799 603	1.03
Petersen *et al.* (2014)	2 215 191	539 998	0.49
Vattenbrukscentrum Ost	1 604 080	838 310	27.94
Kalmar municipality	320 000	167 235	11.15
	150 000	78 392	5.23
Gren *et al.* (2009)	70 401	15 372	0.17
	70 401	15 372	0.15
Västerviks kommun, kommunsyrelsens förvalting	298 400	105 493	7.54
West Baltic/North Sea			
Nguyen *et al.* (2013)	189 470 231	21 823 103	1.09
Baltic EcoMussel (2003)	539 609	76 871	0.37
	6 127 180	1 194 727	4.07
Hjortberg (2003)	324 046	45 709	0.30
Dansk Akvakultur (2015)	6 916 888	6 916 888	1.73
Krost *et al.* (2011)	2 490 343	564 787	5.65
Gren *et al.* (2009)	97 105	21 203	0.05
	105 602	23 059	0.13
Haamer (1996)	221 119	115 559	0.58

Table A3: Operational Costs

Company/Source	Location	Annuity cost (SEK)	From planned production (SEK/kg)
East Baltic			
Bohus Havsbruk	Kalmar, Sweden	576 873	11.54
Baltic EcoMussel (2003)	Hanko, Finland	428 724	2.14
	Åland, Finland	221 439	5.54
Buck *et al.* (2010)	German Bight	3 619 013	0.38
Petersen *et al.* (2014)	Skive Fjord, Denmark	1 033 727	0.94
Vattenbrukscentrum Ost	Sankt Anna, Sweden	263 918	8.80
Kalmar municipality	Hasselö, Sweden	366 742	24.45
	Hagby, Sween	168 614	11.24
Gren *et al.* (2009)	North Baltic Proper	124 016	1.38
	South Baltic Proper	53 032	0.53
Västerviks kommun, kommunsyrelsens förvalting	Gamlebyviken, Sweden	237 144	16.94
West Baltic/North Sea			
Nguyen *et al.* (2013)	The Great Belt (Storebælt)	9 531 836	0.48
Baltic EcoMussel (2003)	Denmark	239 261	1.14
	Lysekil, Sweden	2 160 514	7.35
Hjortberg (2003)	Vrångö, Sweden	439 250	2.93
Dansk Akvakultur (2015)	Hjarnø, Denmark	1 175 871	0.29
Krost *et al.* (2011)	Kieler Förde, Germany	1 294 245	12.94
Gren *et al.* (2009)	Kattegat	288 422	0.72
	The Sound	271 567	1.51
Haamer (1996)	Orust-Tjörn fjord, Sweden	297 152	1.49

Table A4: Total Costs

Company/Source	Location	Total cost (SEK)	From planned production (SEK/kg)
East Baltic			
Bohus Havsbruk	Kalmar, Sweden	1 335 646	26.71
Baltic EcoMussel (2003)	Hanko, Finland	682 115	3.41
	Åland, Finland	350 506	8.76
Buck *et al.* (2010)	German Bight	13 418 616	1.41
Petersen *et al.* (2014)	Skive Fjord, Denmark	1 573 725	1.43
Vattenbrukscentrum Ost	Sankt Anna, Sweden	1 102 228	36.74
Kalmar municipality	Hasselö, Sweden	533 978	35.60
	Hagby, Sween	247 005	16.47
Gren *et al.* (2009)	North Baltic Proper	139 389	1.55
	South Baltic Proper	68 404	0.68
Västerviks kommun, kommunsyrelsens förvalting	Gamlebyviken, Sweden	342 637	24.47
West Baltic/North Sea			
Nguyen *et al.* (2013)	The Great Belt (Storebælt)	31 354 939	1.57
Baltic EcoMussel (2003)	Denmark	316 132	1.51
	Lysekil, Sweden	3 355 241	11.42
Hjortberg (2003)	Vrångö, Sweden	484 958	3.23
Dansk Akvakultur (2015)	Hjarnø, Denmark	8 092 759	2.02
Krost *et al.* (2011)	Kieler Förde, Germany	1 859 032	18.59
Gren *et al.* (2009)	Kattegat	309 625	0.77
	The Sound	294 625	1.64
Haamer (1996)	Orust-Tjörn fjord, Sweden	412 711	2.06

Appendix B

Table B1: OLS Estimation (with constant term and constant term suppressed)

Variable	Model 1	Model 2
pprod	4.828788*** (0.5561113)	4.916417*** (0.5203925)
pprod2	-1.64e-07*** (2.52e-08)	-1.67e-07*** (2.63e-08)
loc	597771.4 (1693762)	-2472.205 (1255872)
Trend	-130545.4 (293602.2)	4178.799 (153953.4)
_cons	476847.5 (877101.6)	

***, **, *: Significant at the 1%, 5% and 10%, respectively

Table B2: Descriptive Statistics

Variable	Coefficient	Coefficient
F (4, 15)	121,05	154.36
Prob > F	0.0000	0.0000
R-squared	0.9700	0.9747
Adj. R-squared	0.9619	0.9684

Table B3: OLS Estimation with robust standard errors

Variable	Model 1	Model 2
pprod	4.828788*** (0.9529571)	4.916417*** (0.9585647)
pprod2	-1.64e-07*** (4.70e-08)	-1.67e-07*** (4.70e-08)
loc	597771.4 (1466516)	-2472.205 (995073.7)
Trend	-130545.4 (246446.4)	4178.799 (91193.03)
_cons	476847.5 (776908.5)	

***, **, *: Significant at the 1%, 5% and 10%, respectively