

Mussel farming as a nutrient reduction measure – a case study in Limfjorden, Denmark.

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Denmark is one of the most intensively farmed regions in the world, with more than 60% of its land surface used for agriculture. It also has one of the most developed environmental regulation systems in the world (Dalgaard *et al*, 2014). However, despite the progress in lowering nutrients loss from agricultural systems, there is still a need to improve environmental performance of agricultural production systems.

It is acknowledged in the literature that effective regulation of agro-ecosystems needs to take a spatial approach, and that introducing spatially differentiated and targeted regulation of the agricultural production can potentially reduce the economic costs of achieving environmental targets in freshwater and marine environments. (Lescot *et al*. 2013; Konrad *et al*. 2014)

In recent years, studies have advocated including marine measures to the pool of land-based policy measures. In particular, it is theorized that mussel production, when optimized for mitigation purposes, can be carried out at a lower cost and work as an effective measure in reducing nutrient concentration in coastal waters. (Hart 2003; Gren *et al*. 2009; Petersen *et al*. 2014; Lindahl *et al*. 2017).

Economic analyses of nitrogen mitigation for water quality improvements including mussels have so far taken a static modelling approach. This assumes that the effectiveness of the mussel mitigation measure is independent of the water quality status and the required mitigation targets. In order to take this effect into account, a more dynamic understanding of the system is required. We hypothesize that the mitigation effectiveness of the mussels depends on the water quality status, as the mussel productivity depends on the N concentration of the water flowing through the farms. Therefore, we include the effect of decreasing N concentration, due to implementation of mitigation measures or other environmental factors, on mussel productivity.

Our study aims to understand the economic and physical conditions under which mussel farming is a cost-effective abatement measure for improving water quality in Limfjorden, the largest fjord in Denmark. To that end, we set-up a mixed integer optimization problem including every farm in the catchment and 25 possible abatement measures, including mussel farming, to find the cost minimizing combination of measures capable of achieving the desired reduction in N disposal to the fjord. By analyzing the results, especially under what circumstances mussels are included in the optimum mix, we aim to identify the conditions under which mussel farming is a desirable measure for the catchment when competing with land measures.

Bibliography:

- Dalgaard T, Hansen B, Hasler B, Hertel O, Hutchings NJ, Jacobsen BH, Jensen LS, Kronvang B, Olesen JE, Schjørring JK, Kristensen IS, Graversgaard M, Termansen M, Vejre H (2014) Policies for agricultural nitrogen management-trends, challenges and prospects for improved efficiency in Denmark. *Environ Res Lett* 9:115002–16 . doi: 10.1088/1748-9326/9/11/115002
- Gren IM, Lindahl O, Lindqvist M (2009) Values of mussel farming for combating eutrophication: An application to the Baltic Sea. *Ecol Eng* 35:935–945 . doi: 10.1016/j.ecoleng.2008.12.033
- Hart R (2003) Dynamic pollution control - Time lags and optimal restoration of marine ecosystems. *Ecol Econ* 47:79–93 . doi: 10.1016/j.ecolecon.2002.09.002
- Konrad MT, Andersen HE, Thodsen H, Termansen M, Hasler B (2014) Cost-efficient reductions in nutrient loads; identifying optimal spatially specific policy measures. *Water Resour Econ* 7:39–54 . doi: 10.1016/j.wre.2014.09.001
- Lescot JM, Bordenave P, Petit K, Leccia O (2013) A spatially-distributed cost-effectiveness analysis framework for controlling water pollution. *Environ Model Softw* 41:107–122 . doi: 10.1016/j.envsoft.2012.10.008
- Lindahl O, Hart R, Hernroth B, Kollberg S, Loo L, Svensson J, Svensson S, Syversen U (2017) Royal Swedish Academy of Sciences Improving Marine Water Quality by Mussel Farming : A Profitable Solution for Swedish Society Linked references are available on JSTOR for this article : Improving Marine Water Quality by Mussel Farming : A Profitable Solu. 130–138
- Petersen JK, Hasler B, Timmermann K, Nielsen P, Tørring DB, Larsen MM, Holmer M (2014) Mussels as a tool for mitigation of nutrients in the marine environment. *Mar Pollut Bull* 82:137–143 . doi: 10.1016/j.marpolbul.2014.03.006