Impact of environmental conditions on biomass yield, quality, and bio-mitigation capacity of *Saccharina latissima*

Seaweeds are attractive as a sustainable aquaculture crop for food, feed, bioenergy and biomolecules. Further, the non-value ecosystem services of seaweed cultivation (i.e. nutrient recapture) are gaining interest as an instrument towards sustainable aquaculture and for fulfilling the aims of the EU Marine Strategy Framework Directive. Environmental factors determine the yield and quality of the cultivated seaweed biomass and, in return, the seaweed aquaculture affects the marine environment by nutrient assimilation. Consequently, site selection is critical for obtaining optimal biomass yield and quality and for successful bio-mitigation. In this study, 5 sites for cultivation of *Saccharina latissima* were selected within a eutrophic water body to guide site selection for future kelp cultivation activities. Results were coupled to marine monitoring data to explore the relationship between environmental conditions and cultivation success. The biomass yields fluctuated 10-fold between sites due to local variations in light and nutrient availability. Yields were generally low, i.e. up to 510 g fresh weight (FW) per meter seeded line; however, the dry matter contents of protein and high-value pigments were high (up to 17% protein and 0.1% fucoxanthin). Growth performance, biomass quality and bio-mitigation potential was restricted by low availability of light and bioavailable phosphorus, and biofouling through juvenile suspension feeders was a critical factor at all cultivation sites. At specific sites, the tissue metal contents (Pb and Hg) exceeded the limit values for feed or food. Our results emphasize the importance of careful site selection before establishing large-scale cultivation, and stress the challenges and benefits of kelp cultivation in eutrophic waters.
Bioaccumulation of metals (Cd, Cu, Ni, Pb and Zn) in suspended cultures of blue mussels exposed to different environmental conditions

Farming of suspended mussels is important for generating high protein food and animal feed or for removing nutrients in eutrophic systems. However, the harvested mussels must not be severely contaminated by pollutants posing a potential health risk for the consumers. The present study estimated the bioaccumulation of cadmium, copper, nickel, lead and zinc in suspended blue mussels (Mytilus edulis L.) in the Limfjorden, Denmark, based on observations and modelling. Modelling was used to assess the suitability of suspended blue mussels as animal feed and food products at sea water metal concentrations corresponding to Good Ecological Status (GES) in the European Union Water Framework Directive (WFD) and in future climate change scenarios (higher metal concentrations and higher temperatures). For this purpose, GES is interpreted as good chemical status for the metals using the Environmental Quality Standards (EQS) defined in the WFD priority substance daughter directives. Observations showed that suspended mussels were healthy with respect to metal pollution and generally less polluted than benthic mussels due to the smaller contact with the contaminated sediment. The model results showed that the WFD targets for Cd, Ni and Pb are not protective with respect to marine mussel production and probably should be reduced for marine waters. Climate changes may increase the metal contamination of mussels, but not to any critical level at the relatively unpolluted study sites. In conclusion, WFD targets should be revised to assure that the corresponding body burdens of metals in mussels are below the safety limits according to the EU Directives and the Norwegian classification for animal feed and food production.
Mussels cultured on lines for nine months and harvested in March were boiled to remove shells and processed into a dry meal or a silage acidified by formic acid. Starfish meal was prepared from starfish caught in May, and a starfish juice fraction was obtained by pressing fresh starfish. Commercial fish silage from farmed salmon was also included in the experiment. The standardized ileal digestibility (SID) of crude protein (CP) and amino acids (AA) was evaluated in a Latin square design with pigs (initial weight 39.3 kg) fitted with a simple T-cannula in the terminal ileum. Diets contained 131–162 g CP/kg and 5 g chromic oxide/kg. Endogenous losses of protein and AA were estimated by feeding an N-free diet. On a dry matter (DM) basis, mussel meal contained 605 g, mussel silage 575 g, starfish meal 700 g, starfish juice 393 g.
g, and fish silage 776 g CP/kg. The ratio of AA to CP ranged from 0.83 to 0.87. The content of crude fat was high in the mussel products (157–161 g/kg DM), and the starfish meal and juice were high in ash (203 and 474 g/kg DM) with one-fourth being calcium. The AID of CP was 0.74, 0.81, 0.70, and 0.61 for mussel meal, mussel silage, starfish meal, and fish silage. The SID of CP was 0.83, 0.87, 0.80, and 0.68 for mussel meal, mussel silage, starfish meal, and fish silage. For both CP and AA digestibility, the lowest (P<0.05) was found in fish silage and the highest (P<0.05) in mussel silage. In conclusion, both mussel and starfish products showed chemical characteristics arguing for their use as feedstuffs in pig diets. Processing into silage rather than meal increased the SID of CP and AA, and both mussel products and starfish meal had greater SID compared to commercial fish silage.

General information
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Scopus rating (2005): SJR 0.747 SNIP 1.395
Scopus rating (2004): SJR 0.768 SNIP 1.485
Scopus rating (2003): SJR 0.718 SNIP 1.118
Reducing the impact of blue mussel (Mytilus edulis) dredging on the ecosystem in shallow water soft bottom areas

Dredging blue mussels (Mytilus edulis) and thus removing structural elements, inducing resuspension of sediment as well as reducing filtration capacity, will inevitably affect the ecosystem. The study demonstrates that the impacts of fishing can be reduced through gear developments. A new light dredge was tested on commercial vessels using two different experimental setups. First, a twin haul experiment tested the standard gear (i.e., a Dutch dredge) against the light dredge by fishing the two gears side by side onboard the same vessel. Second, a single dredge experiment tested the absolute performance of the two gears by fishing in areas with a known blue mussel density. Results from the twin haul experiment demonstrate that the weight of sediment retained in the gear per square metre fished is 49% less in the light dredge compared with the Dutch dredge which will reduce resuspension of sediment at the surface. Also, the drag resistance of the light dredge was significantly less (177.1 vs. 202.7 kg m⁻¹). In the twin haul experiment no significant difference was found in the catch per unit effort (CPUE) of the two gears. The single dredge experiment, on the other hand, demonstrated a significant increase in CPUE exceeding 200% when using the light dredge. Seafloor tracks made by the two dredges could not be distinguished by use of side-scan sonar and the tracks were still detectable 2 months after fishing. It was concluded that replacement of the Dutch dredge with the light dredge would reduce the impact of the fishery on the ecosystem by (i) reducing resuspension of sediment, (ii) reducing fuel consumption, and (iii) potentially reducing energy transfer to the sediment through a reduced gear drag resistance. A potential increase in catch efficiency may reduce the area affected. Fishing with the light dredge is discussed in relation to management of Natura 2000 sites.

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Organisations: National Institute of Aquatic Resources, Section for Ecosystem based Marine Management, Danish Shellfish Centre, Section for Marine Living Resources, Section for Maritime Service, NIRAS A/S, Orbicon
Authors: Frandsen, R. (Intern), Eigaard, O. R. (Intern), Poulsen, L. K. (Ekstern), Tørring, D. B. (Intern), Stage, B. (Intern), Lisbjerg, D. (Intern), Dolmer, P. (Ekstern)
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BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.116 SNIP 1.009 CiteScore 1.95
Mussels as a tool for mitigation of nutrients in the marine environment

Long-line mussel farming has been proposed as a mitigation tool for removal of excess nutrients in eutrophic coastal waters. A full-scale mussel farm optimized for cost efficient nutrient removal was established in the eutrophic Skive Fjord, Denmark where biological and economic parameters related to nutrient removal was monitored throughout a full production cycle (1yr). The results showed that it was possible to obtain a high area specific biomass of 60tWWha−1 equivalent to a nitrogen and phosphorus removal of 0.6–0.9 and 0.03–0.04tha−1yr, respectively. The analysis of the costs related to establishment, maintenance and harvest revealed that mussel production optimized for mitigation can be carried out at a lower cost compared to mussel production for (human) consumption. The costs for nutrient removal was 14.8€kg−1N making mitigation mussel production a cost-efficient measure compared to the most expensive land-based measures.

General information
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Organisations: National Institute of Aquatic Resources, Danish Shellfish Centre, University of Southern Denmark, Aarhus University
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Comparative study of predatory responses in blue mussels (Mytilus edulis L.) produced in suspended long line cultures or collected from natural bottom mussel beds

Blue mussels (Mytilus edulis L.) are a valuable resource for commercial shellfish production and may also have uses as a tool in habitat improvement, because mussel beds can increase habitat diversity and complexity. A prerequisite for both commercial mussel production and habitat improvement is the availability of seed mussels collected with minimum impact on the benthic ecosystem. To examine whether mussels collected in suspended cultures can be used for bottom culture production and as tool in habitat improvement, the differences in predatory defence responses between suspended and bottom mussels exposed to the predatory shore crab (Carcinus maenas L.) were tested in laboratory experiments and in the field. Predatory defence responses (byssal attachment and aggregation) and morphological traits were tested in
laboratory, while growth and mortality were examined in field experiments. Suspended mussels had an active response in relation to the predator by developing a significantly firmer attachment to the substrate and a closer aggregated structure. Bottom mussels had a passive strategy by having a thicker shell and larger relative size of the adductor muscle. In a field experiment mussels originated from suspended cultures had a higher length increment and lower mortality when compared to bottom mussels. It is concluded that suspended mussels potentially are an alternative resource to bottom culture and can be used in habitat improvement of mussel beds, but that the use of suspended mussels has to be tested further in large-scale field experiments.

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Authors: Christensen, H. T. (Intern), Dolmer, P. (Intern), Petersen, J. K. (Intern), Tørring, D. B. (Intern)
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Scopus rating (2013): SJR 0.632 SNIP 0.999 CiteScore 1.43
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Scopus rating (2004): SJR 0.67 SNIP 0.693
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Scopus rating (2002): SJR 0.566 SNIP 0.818
Web of Science (2002): Indexed yes
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Opbevaring og konditionering af ferske muslinger - med fokus på optimering af kvalitet og holdbarhed

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Udvikling af kulturbanker til produktion af blåmuslinger i Limfjorden

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Projects:

Development of sustainable mussel production (Idékataloget) (39250)
It is the overall objective of the project to develop sustainable methods of mussel production involving mussel fisheries, on-bottom culture and off-bottom long-line culture.
With regard to mussel fisheries, a GIS-based model of eelgrass habitats and their potential recovery was developed and has been reported. Further, macro algae were mapped in selected estuaries. In relation to on-bottom culture, focus has been on testing whether moving mussels from deeper to shallower areas during oxygen depletion was tested. Results showed that this can be a good strategy to move mussels that grew rapidly after relay in contrast to mussels not moved that died due to oxygen depletion. It is however important that careful monitoring of the relayed mussels are carried out by the fishermen as mussels otherwise risk to be eaten by starfish. Experiments with relay of mussel spat from water column spat collectors are currently being carried out.
In relation to long-line farming, DTU Aqua provided basic information and numbers to an economic analysis of the industry carried out by Copenhagen University, Department of Food and Resource Economy.

This project is coordinated by DTU Aqua.

The project was funded by the Ministry of Food, Agriculture and Fisheries through a special governmental funding for sustainable fisheries ("Bæredygtighedsfuldten").

National Institute of Aquatic Resources
The macroalgae biorefinery - Sustainable production of 3G energy carriers and fish feed from macroalgae (MAB3) (39165)

MAB3 is a four-year research project promoting biomass resources from the sea, namely algae. The overall goal is to contribute to solving the challenges with food and energy supply and find ways to exploit the sea instead of farm land.

The project aim is to develop new technologies in laboratory and pilot scale that will lead to sustainable growth and subsequent conversion of two brown algae (Saccharina latissima and Laminaria digitata) into three energy carriers - bioethanol, biobutanol and biogas - and a high-protein fish feed supplemented with essential amino acids. This project was coordinated by DTU Aqua.

The project was funded by the Danish Council for Strategic Research.