BONUS OPTIMUS
D.3.1 Optimized Production of Mitigation Mussels

Background and Aim

BONUS OPTIMUS and WP3

One of the aims of BONUS OPTIMUS is to document methods to adapt and optimize modes of mussel (*Mytilus edulis*) production to reduce cost : production volume ratios, and adapt cultivation to the challenging environmental conditions in many areas of the Baltic Sea. Work Package 3 was designed to test mussel cultivation practices and technologies to maximize nutrient extraction, evaluate mussel growth in low salinity waters, reduce risks of cultivation (i.e. ice cover and predatory waterfowl), and explore integration into other aquaculture production. Under task 3.1, different configurations of mussel cultivation substrate were evaluated to optimize the mitigation of nutrient enrichment in Baltic waters.

Mussel cultivation for nutrient extraction

Conventional mussel cultivation is designed to produce high quality mussels with even growth for human consumption, where conditions are optimized for individual growth. Mitigation mussel cultivation intends to maximize total nutrient content in a given area (often equated to total biomass) at the lowest cost; a fundamentally different cultivation mode[1]. Adaptation of conventional cultivation practices and technologies is expected to increase areal yield and increase efficacy of mitigation culture as a mitigation measure in eutrophic waters.

Optimizing yields

Yield potential and optimization of production for mitigation were characterized in different study areas. In order to increase biomass on long-line farms, different configurations of settling material were tested; e.g. density, total length of droppers, to maximize areal yield. Alternative settling material and buoyancy technologies were tested alongside the conventional setup to evaluate further enhancements in areal yield. Production volume and labor effort was monitored continuously as a function of treatments.

Production Capacities

Production Capacities in low-saline waters

In order to characterize production potentials in low-saline Baltic waters, a test farm (50x50m) was established in Greifswald Bay (GWB), Germany; where salinities range from 6.1-7.8 PSU. A longline configuration was adopted from Danish cultivation techniques, utilizing 5cm polypropylene collector bands and seasonal buoyancy strategies to accommodate ice coverage. Individual growth and bulk biomass was tracked through the growing seasons. These data were then used to update a Dynamic Energy Budget (DEB) model.

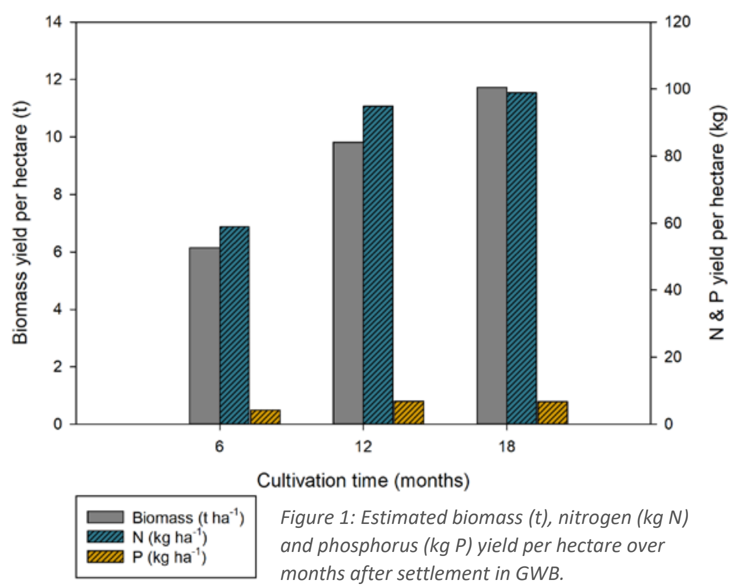

Figure 1: Estimated biomass (t), nitrogen (kg N) and phosphorus (kg P) yield per hectare over months after settlement in GWB.

Strong settlement was observed at the test farm in the spring of 2017; however, reportedly due to high temperatures (>20°C) in the summer of 2018, most standing biomass was lost. Yield potential was therefore modeled after 12 months following individual biometrics according to the updated DEB model, and continued environmental monitoring. Biomass and nutrient extraction potential stabilizes after 18 months (Figure 1).

Production Capacities in Western Sweden

Swedish mariculture along the west coast has been established for decades. Current practices of spat collection and cultivation (on-growth) resemble methods proposed for adaptation of conventional practices for human consumption; i.e. self-thinning and minimal intervention after spat fall. A survey of 73 farms was conducted to assess average yields per farm over several years. A typical Swedish farm consists of 10 longlines of 200 m length, utilizing 5 cm polypropylene woven spat collectors up to 6 m depth, with a total length of 36 km and an areal coverage of 2 ha.

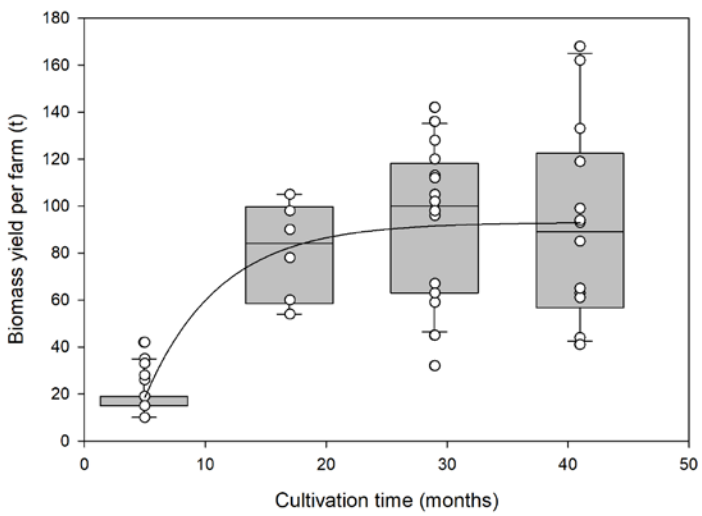

Figure 2: Average biomass yields per farm in Western Swedish waters over 41 months following settlement.

In western Swedish waters, a dramatic increase in yields is observed between a 5 month (9.2 t ha^{-1}) and 17 month (40.4 t ha^{-1}) cultivation period (Figure 2), where total yields only marginally increase beyond 20 months (45-47 t ha^{-1}). A large degree of variability is observed in this data set owing to interannual and spatial conditions. Longer cultivation periods will also increase operational costs and risk of predation [2].

Optimization of Mitigation Culture in Denmark

Over two production seasons (2017–2018), the optimization of nutrient extractive potential of mussels at full commercial-scale was evaluated by first testing multiple density configurations of conventional longline-spat collector setups (spacing of 30 or 60 cm between loops, and 2 or 3 m loop depths – Figure 3) and potential harvest times (early winter vs. spring) at three locations in the Limfjorden: Sallingsund (SALL), Dråby Vig (DV), and Skivefjord (SKIV). Alternative cultivation technologies were tested at multiple farms, including X-plora Ladder system, and tube-net systems with mesh sizes of 17.5 cm, 20 cm, and 25 cm at all previous sites plus a commercial compensation farm outside of Horsens Fjord (AV). Individual growth and bulk biomass was tracked through the growing seasons.

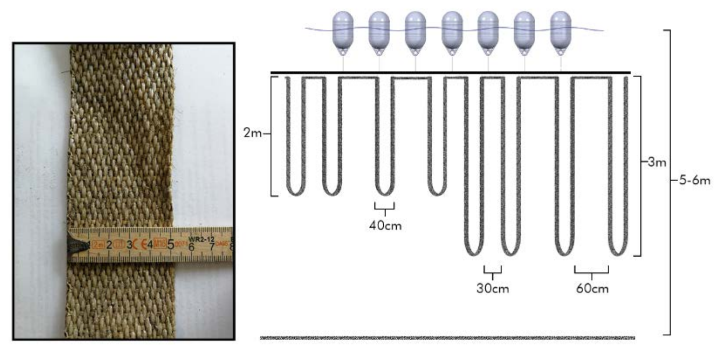

Figure 3: Experimental configuration of collector band spacing

Potential biomass volumes of 770–1700 t (41.1-90.7 t ha^{-1}) with longlines and 2100–2600 t (112-138.7 t ha^{-1}) on nets was demonstrated in full-scale production (18.8 ha), yielding 0.6–1.27 t N ha^{-1} and 0.04–0.1 t P ha^{-1}, and 1.63–2.0 t N ha^{-1} and 0.1–0.12 t P ha^{-1} respectively. Dense spat collector spacing on loglines increases yields up to 191% of previously published estimates. Winter harvests (~6-7 mo cultivation), where tested, exhibited higher yields (103–124%) than early spring harvests (10-12 mo) on optimized configurations, favoring an abbreviated production season (Fig 4).

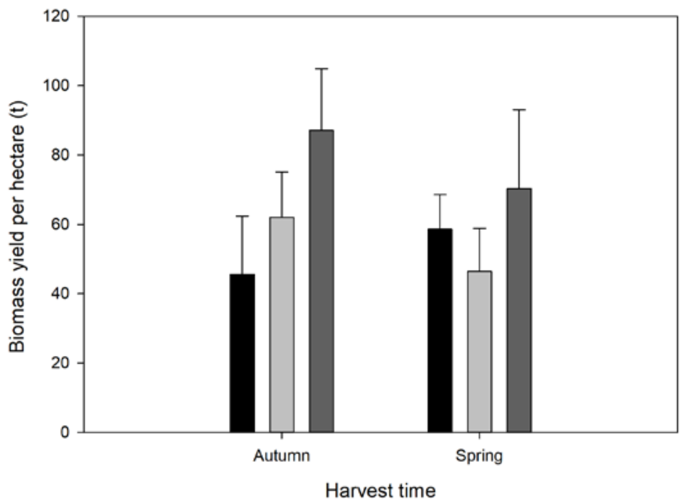

Figure 4. Biomass yields per hectare (t) from one farm, comparing current results ad prior experimentation. Autumn vs spring harvests compared.

Further enhancement in total biomass yields with alternative technologies was documented (Fig 5); at the extreme, 17.5 cm nets exceeded 300% of prior estimates [3].

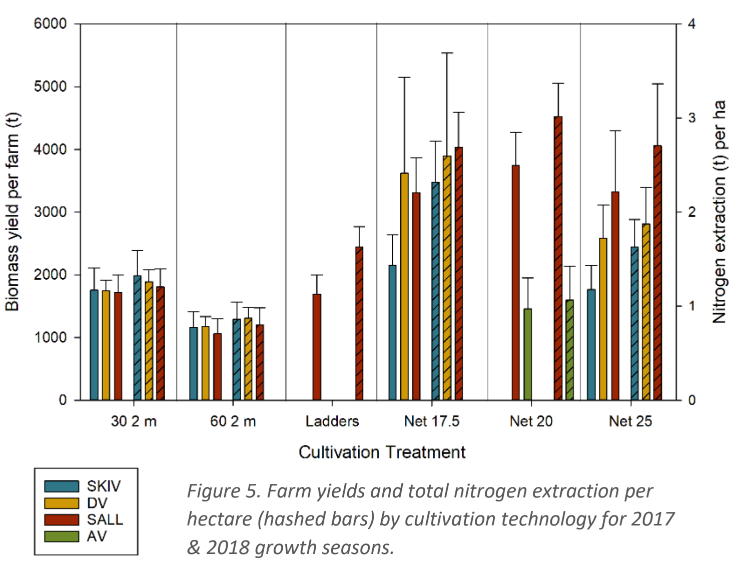

Figure 5. Farm yields and total nitrogen extraction per hectare (hashed bars) by cultivation technology for 2017 & 2018 growth seasons.

Extractive potential of sites within the Limfjorden (SALL, DV, SKIV) did not considerably differ, while yields in AV with nets (only Net 20) were comparably less; likely due to reduced food concentrations, increased exposure to high-energy hydrodynamics, and limited predation by eider ducks.

Comparing potential yields

Differences in cultivation practices and local environmental conditions will influence yield. Biomass volumes expressed in the case of German waters are preliminary and require further study along the salinity gradient. Farm design has been adopted from conventional Danish longline setups, and has not yet undergone optimization. In the Swedish case, farms are designed for the unique physical conditions of the Swedish west coast in conjunction with historical practices and regulation. These farms are also not optimized for mitigation production, while in the Danish case an optimization exercise demonstrated much higher potential yields by modifying conventional techniques or adopting alternative technologies. These distinctions indicate further optimization efforts may enhance potential yields (Fig 6).

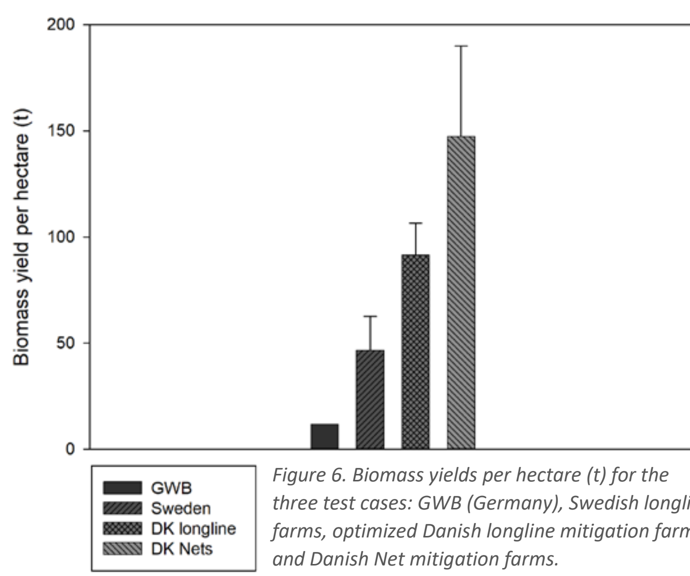

Figure 6. Biomass yields per hectare (t) for the three test cases: GWB (Germany), Swedish longline farms, optimized Danish longline mitigation farms, and Danish Net mitigation farms.

Key points

- Environmental conditions (i.e. salinity, phytoplankton loads) and farming techniques (optimized configurations, alternative technologies) are primary drivers for the extractive capacities of mitigation production.

- Increased substrate in the water column increases total areal yield; modifying conventional methods is a straightforward step. Alternative technologies may be more feasible for maximizing yields; nets in Danish waters potentially double extractive potential.

- Harvest timing is critical to minimizing operational costs. Annual harvests are optimal in Denmark, while biannual harvests maximize biomass in Swedish and German coastal waters.

- Further testing of substrate configuration in these different environmental conditions over a longer time period can expose variability in spat fall, growth rates, predation patterns, and hazard of ice coverage.

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2. Lindegarth, M. *et al. Slutrapport för projektet ”Utveckling av metoder och kunskap för att minska ejderpredation i blåmusselodlingar (in Swedish)*. (2019). doi:10.13140/RG.2.2.28536.60169.

3. Taylor, D., Saurel, C., Nielsen, P. & Petersen, J. K. Production Characteristics and Optimization of Mitigation Mussel Culture. *Frontiers in Marine Science* **6**, 698 (2019).