

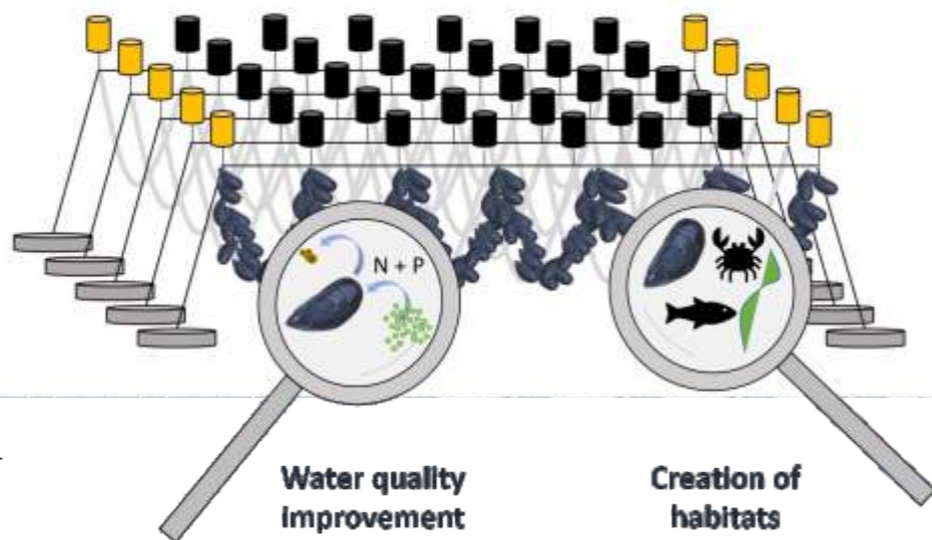
REGULATING AND MAINTAINING ECOSYSTEM SERVICES

Cultivation of blue mussels addresses a variety of regulating and maintaining services, which play an important role in the current discussion about water quality improvement in eutrophic coastal waters. Key services are cycling and removal of nutrients, providing and maintaining habitats, as well as coastal protection.

The blue mussel (*Mytilus spp.*) belongs to the filter feeding organisms and is therefore able to locally effect water quality around the mussel farm. Improvement of water quality is achieved by reducing nutrients as well as removing phytoplankton from the water column and thus improving water transparency.

By feeding on phytoplankton, blue mussels take up nitrogen and phosphorous, which is utilized during tissue and shell growth. At harvest, nutrients are removed from the marine system. Phytoplankton and other detritus which is filtered from the water column and cannot be utilized by mussels is discarded as pseudofaeces. Pseudofaeces are conglomerates from unused phytoplankton or detritus, which due to their increased size tend to sink faster to the ground than other particles. The resulting accelerated sedimentation also favors the improvement of water transparency.

Restoring higher water transparencies could lead to the recovery of submersed macrophytes which are characterized as valuable habitats and important for sediment stabilization.



Regulating and maintaining ecosystem services provided by blue mussel cultivation. Exemplary illustration of water quality improvement by water filtration of cultivated blue mussel and creation of habitats by using long line cultivation systems.



Mytilus spp. filter water.

Besides the reestablishment of submersed macrophytes, artificial structures like longlines or nets used in blue mussel aquaculture provide a habitat for several other organisms. These artificial habitats provide both food and shelter leading to richer ecological communities. Furthermore, mussels which become detached and drop to the ground can be the basis for mussel reefs creating new habitats by providing shelter and food for benthic organisms.

CULTURAL SERVICES

Mussel cultivation also bears opportunities for cultural ecosystem services. These include environmental education and research aspects as well as recreational and touristic activities. Mussels play a key role within the aquatic environment not only as a food source for other organisms, but also as ecosystem engineers creating new habitats and as an indicator of water quality. Therefore, they are of importance for coastal education and research.

Mussel aquaculture can also have a beneficial impact on tourism since sea food has become a recognized tourist attraction. Blue mussels, sold as authentic local seafood that is regionally cultivated, can positively contribute to the visitor's experience of maritime sites.

OVERVIEW - ECOSYSTEM SERVICES

Ecosystem services are the benefits provided to humans by functioning ecosystems. They are most commonly classified in three main categories: provisioning, regulating and maintenance as well as cultural ecosystem services.

Provisioning services consist of goods that can be harvested directly from ecosystems, for example: wild animals and plants or aquaculture products. Also nonliving goods are assigned to that service (e.g. drinking water).

Regulating and maintenance ecosystem services describe ecosystem processes that support ecosystem functioning and integrity. These services do not provide any goods that can be consumed or utilized directly, instead they are responsible for regulating ecosystems providing indirect benefits to humans (e.g. coastal protection or nutrient regulation). Services like primary production or habitat formation make it possible for ecosystems to be able to continuously provide provisioning, regulating as well as cultural services. Thus, sometimes they are also referred to as supporting services for ecosystem functioning.

Cultural ecosystem services include non-material and non-consumptive outputs of ecosystems that benefit the physical and mental state of humans through active or observational recreation.

CONCLUSION

In the past, the main purpose of blue mussel cultivation was to produce seafood for human consumption. After the reevaluation as a potential mitigation measure, the additional ecosystem services and benefits of mussel cultivation get more attention. By recognizing the benefits of these services, mussel cultivation can reach more social acceptance. An evaluation of ecosystem services and their benefits in monetary terms could support the establishment of future mussel aquaculture.



Lukas Ritzenhofen
 lukas.ritzenhofen@io-warnemuende.de
 Anna-Lucia Buer
 anna-lucia.buer@io-warnemuende.de

ABOUT BONUS OPTIMUS: OPTIMIZATION OF MUSSEL MITIGATION CULTURES FOR FISH FEED IN THE BALTIC SEA

The BONUS OPTIMUS project aims to provide robust evidence-based documentation (ecological, social, and economic) on optimized use of farmed mussel. The mussels are used as a mitigation tool for eutrophication that in turn can be a sustainable protein-rich feedstuff for fish. The project has partners from Denmark, Germany, Poland and Sweden and is supported financially by the BONUS programme and national funds. The project runs from 2017 to 2020.

Contact:
 Project coordinator Jens Kjerulf Petersen
 jekjp@aqua.dtu.dk

www.bonus-optimus.eu



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ECOSYSTEM SERVICES OF BLUE MUSSEL CULTIVATION

Traditionally, the main purpose of blue mussel cultivation has been the provision of edible mussels for human consumption. Rich in protein and healthy unsaturated fatty acids, they are commonly considered to be healthy food. But, with the uprising discussion about coastal eutrophication, mussel cultivation suddenly moved into the focus of science as a potential eutrophication mitigation measure.

What was otherwise only used for food production is now being evaluated as a measure to improve water quality in coastal systems. This has led to countries, that have previously no tradition of mussel cultivation, also testing the potential and feasibility of mussel farms in their regional waters.

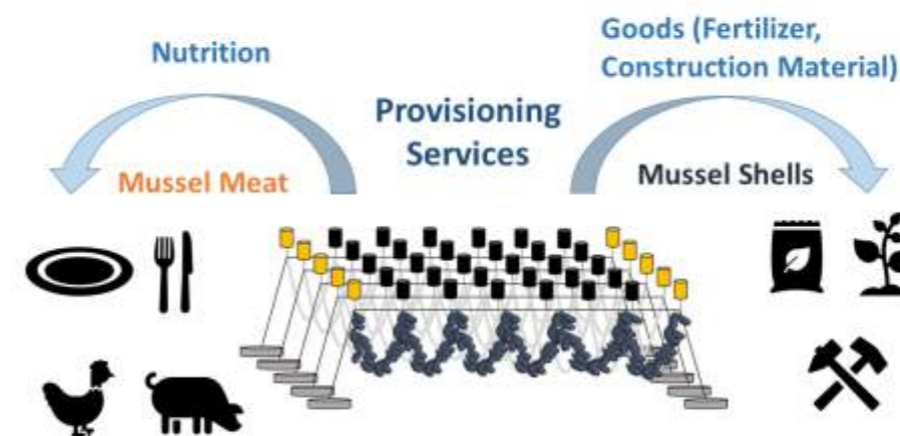
Recognizing the additional ecosystem services provided by mussel cultivation could not only help to increase acceptance among society but also provide financial income. The following gives an overview of the different ecosystem services that can be provided by mussel cultivation.

PROVISIONING ECOSYSTEM SERVICES

In general, the provisioning ecosystem services of blue mussel cultivation can be divided into two groups: supply of mussels for human or animal nutrition, and the provision of material for further processing of goods such as fertilizer, construction material or even ornamental use of mussel shells. The latter goods that are mainly based on the shells, make no use of the mussels' nutritional value.

Currently, the value of blue mussel aquaculture is calculated mostly on the basis of the market value of the meat that is produced for human consumption. According to the FAO, the total aquaculture production of bivalves for human consumption in 2017 was 17.39 million tons which corresponds to a market values of \$30.19 billion.

As of today, left over shells from blue mussels are discarded as waste. Instead of disposing them, they could be used as fertilizer, construction material or ornamental use (jewelry or art), converting them from waste into a valuable product.



Provisioning ecosystem services provided by blue mussel cultivation.

Division into two groups:
 1) human and animal nutrition, 2) provisioning of goods such as fertilizer or construction material.