Biogenic reefs – site selection guideline for blue mussel bed establishment

Photo: Daniel Taylor

Center for Marin Naturgenopretning

Colophon

Title:	**Biogenic reefs – site selection guideline for blue mussel bed establishment**
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Summary: The report provides a concise overview and outlines important criteria of practical, physical, and biological nature, which are of importance for selecting suitable sites for the establishment of blue mussel beds. These criteria are selected based on general conditions in Danish fjords and coastal areas, and this guidance is intended to assist in planning the work.

Content

Introduction to biogenic reefs

Biogenic reefs are marine habitats that consist of hard, complex structures created by animals, which rise from the seabed. They often occur in subtidal areas but can extend into the intertidal zone, where air exposure is experienced at low tide. Only a few invertebrate species can form biogenic reefs, where coral reefs found in tropical waters are the most familiar. In shallow temperate waters, biogenic structures typically consist of bivalves like horse mussels (*Modiolus modiolus*), European flat oysters (*Ostrea edulis*), blue mussels (*Mytilus edulis*), maerl (*Phymatolithon calcareum*), or tube-building polychaetes (*Sabellaria spinulosa*); where the term “reef” is often used for oyster and polychaete species, whereas “beds” often are used for mussel species. Biogenic habitat-building organisms create a complex three-dimensional structure, which provides solid foundation for other marine organisms to settle upon (e.g., tubeworms, barnacles, ascidians and seaweeds), shelter for mobile organisms (e.g. crustaceans, worms, molluscs, small fish or juvenile fish species). Biogenic reefs often provide other ecosystem services, such as improved water quality, stabilisation of sediments, and enhanced nutrient cycling.

Many human activities have contributed to a profound loss of biogenic reefs, to the extent that they are considered a threatened habitat in most marine waters. Important adverse human activities include fishing with mobile bottom contacting gear, introduction of non-native shellfish, disease and parasite outbreaks, dredging, extraction, nutrient and waste runoffs from agriculture and urban effluents. The decline of biogenic habitats not only leads to loss of critical habitat, but also important ecosystem services provided by biogenic reefs in temperate marine and estuarine waters. In ecosystems that have experienced anthropogenic degradation and loss of biogenic habitats, active establishment of biogenic reefs can potentially enhance basin scale habitat complexity and increase biological diversity, ecosystem resilience and associated ecosystem services (Flindt et al. 2023).

Blue mussel beds

In Denmark, blue mussels (*M. edulis*) typically exist in relative dense populations at water depths from 2 to 10 m but can also be found in tidal areas in the Wadden Sea, where the mussel beds are exposed to air at low tide. Blue mussels are found widely distributed across inner Danish coastal waters, implying establishment of new mussel beds can rely on naturally-recruited local seed (newly recruited mussels) compared to other biogenic reef-forming bivalves like European flat oysters and horse mussels, which will mainly rely on hatchery produced seed or transplants.

Blue mussels are often found in large aggregations forming beds. The beds are formed by settling of mussel seed that attach with byssus threads to each other and other hard substrata incl. older/larger mussels or mussel shells. Mussel beds tend to increase in size due to gregarious settlement and sequential population growth until a limit where patches break due e.g. to food limitation. Beds are heterogeneous and complex habitats, where the spaces between mussels can provide refuges for a diverse community of organisms, including various age classes of mussels. The hard bottom structures generated by the mussel beds also provides both settling ground for sessile organisms (e.g. anemones, barnacles, hydroids, ascidians, sponges, and macroalgae species) and shelter for mobile organisms (e.g. various fish and shrimp species). Contributing to further trophic development, starfish and crabs can be locally abundant as they feed on mussels, and predatory fish species can be attracted by the elevated abundance of prey associated to (incl. also the mussels) or near the mussel bed (Figure 1).

Apart from improving complexity and diversity of coastal habitats with hard, complex substrate, mussels are filter feeders and remove suspended particles (e.g. phytoplankton and detritus) from the

water column. This facilitates a reduction in suspended particle concentrations and generally improves water transparency, leading to better conditions for benthic vegetation (e.g. eelgrass and macroalgae). Increased habitat complexity and biodiversity, reduction in particle concentrations and other ecosystem services provided by mussel beds are diverse and are influenced by local environmental conditions; likewise, desired ecosystem services can be different between locations and stakeholders.

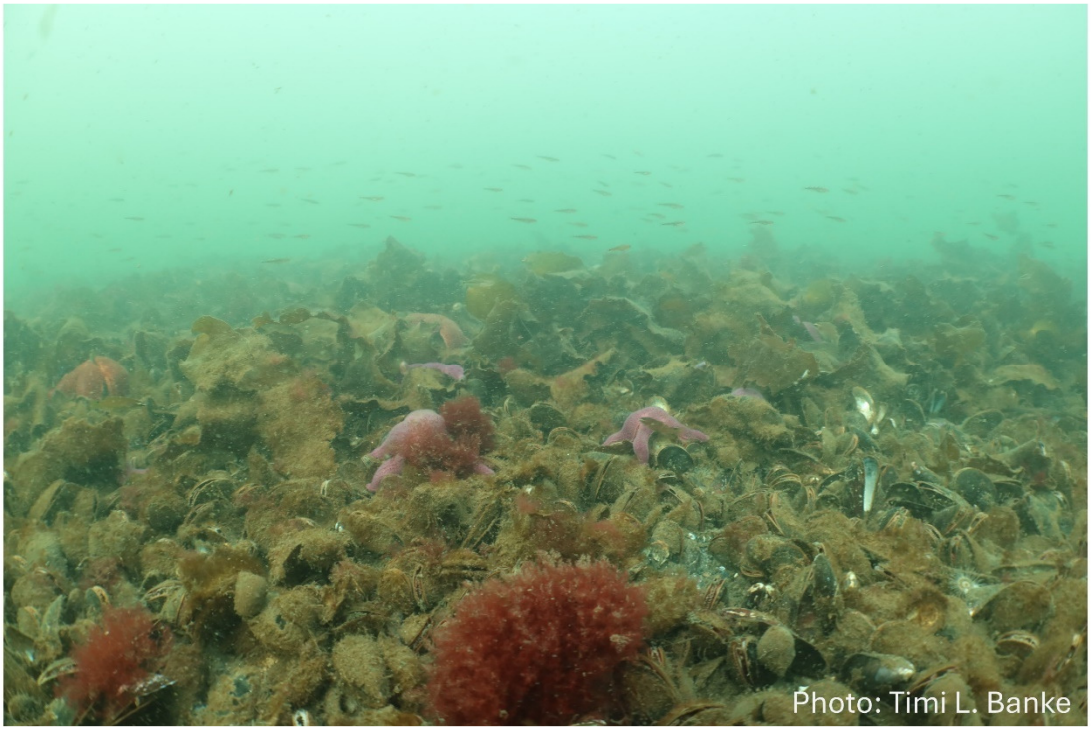

Figure 1. *Established blue mussel bed with associated flora and fauna. Photo: Timi. L. Banke, SundVejleFjord*

Site selection guideline

Selecting a proper site for blue mussel bed establishment by emphasizing survival, growth and reproduction is a solid foundation for ensuring long-term success for the restoration project. The site selection guideline aims at providing an overview of important factors of both practical and biological importance and is intended to assist structuring the work and help in selecting proper sites for blue mussel bed establishment. The guideline is organized as a catalogue of criteria where all should be considered but not all are essential. Any inability to meet the requirements should therefore not automatically preclude initiation of mussel bed establishments but should be evaluated to assess the potential for a successful restoration effort adapted to each project.

A short introduction is provided for each criteria including the level of importance. The criteria are grouped in three categories: Environmental conditions, project logistic and marine spatial planning to provide a better overview; neither the listing of subgroups nor the listing of the criteria within each subgroup reflects a prioritised order of the criteria. All the criteria are listed in Table 1, which gives a quick overview of criteria and their importance. Remember that the site selection guideline is designed to be universally and should therefore always be adapted to fit the individual project.

***Table 1**. Essential or desired criteria for selecting suitable areas for the establishment of blue mussel beds. The criteria are divided into four categories: Environmental conditions, project logistics, marine spatial planning, and practical establishment considerations.*

ENVIRONMENTAL CONDITIONS		YES	NO	NO INFORMATION
ESSENTIAL	*Water depth* : Minimum water depth of 3 m.			
	Suitable substratum : Site specific but generally sites with low content of organic matter indicated by a LOI-value <10%.			
	Salinity : Salinity of the area is between 10-35 PSU.			
	Oxygen depletion : The site is not affected by oxygen depletion (>4 mg O_2/L).			
DESIRABLE	*Resuspension frequency* : Areas with low resupension frequency			
	Resident blue mussel beds : Blue mussel beds are observed in the adjacent areas.			
	Phytoplankton concentration : Is chlorophyll-a concentrations >0.5 µg/L during the growth season (Mar-Oct).			
	Predators : Avoid areas with observations or knowledge of predators e.g. mussel eating birds and starfish.			
PROJECT LOGISTIC				
ESSENTIAL	*Agreement of use of the area* : Is collaboration and agreement with stakeholders in the area needed?			
	Licencing : Is licence(s) needed for e.g. seed collection and bed establishment? Are relevant authorities identified?			
DESIRABLE	*Protection status after establishment* : Is the site protected from physical disturbance?			
	Outreach and stakeholder engagement : Is stakeholder engagement and outreach activities required or relevant?			
	Supporting infrastructure: Is sufficient supporting infrastructure available?			
	Historical distribution : Maps or anecdotal knowledge of mussel beds in the area			
MARINE SPATIAL PLANNING				
ESSENTIAL	*Marine protected areas (MAP)* : Site located within a MPA?			
	Areas for resource utilisation or repositories : Is the site outside areas appointed to resource utilisation or repositories?			
	Infrastructure facilities : Selected site is located >100 m away from infrastructure facilities			
	Existing habitats: Site is at a sufficient distance to existing habitats e.g. eelgrass beds, stone reefs or ares with gravel			
DESIRABLE	*Outlet from rivers and streams* : Need for extra sampling of sediment and/or salinity?			
	Shipping and sailing routs : Sufficient distance to shipping or sailing routs (e.g. contact authorities).			
	Recreational activities : Use of the site by recreational activities?			
PRACTICAL ESTABLISHEMNT CONSIDERATION				
ESSENTIAL	*Seed collection:* what type of seeds (from the seabed or from the water colum), should be used?			
	Transfer of mussel seeds between areas : Are the seeds collected within the same area (or alternativley from nearby areas), as the area of establishment?			
	Areas required for seed collection and establishment of beds: Has an assessment been made of the areas needed for seed collection and establishment of bed(s)?			
	Method of deployment: What type of vessel should be used, and what method, for example, manual or mechanical?			
DESIRABLE	*Design of the mussel beds:* Have considerations been made regarding: i) density of the mussels ii) distance between beds iii) one or multiple deployments iv) time of year for establishment of beds			

Environmental conditions

Essential

Water depth

At water depths <2 m strong currents, wave exposure at storm events and ice cover potentially may cause dislodgement of mussels or even destruction of the bed, particularly newly established mussel beds might be unstable. A general recommendation is thus to establish mussel beds at water depths >3 m but will also depend on the logistic requirements (e.g. need for vessels and boats). At water depths >12-15 m, mussel beds are rarer due to shortage of food supply and water depths >12-15 m are not recommended for restoration purposes.

Suitable substratum

Blue mussels have the capability to attach byssus threads to substratum and they can settle on a wide variety of substrates consisting of hard surfaces (e.g. stones, gravel, shells, living conspecifics or artificial structures) or soft bottom types (e.g. sand and mud). Despite the huge variety of suitable settling substrate, selecting a site with the right sediment conditions may become important to ensure a successful establishment and survival of the established mussel beds. Sites with soft mud or in areas with high seedbed mobility are generally but not always unsuitable, as the mussels either sink into the mud or get smothered by mobile sediment, which is a function of waves, tidal flow/current velocity and the underlying sediment type. The reason for the sediment structure may often be a coinciding factor. Thus, a greater water depth, mud content is often high, but wave action is less, and the risk of smothering is thus lower. The general recommendation is to establish mussel beds in areas with soft bottom with low organic matter, indicated by a LOI (Loss of Ignition) value <10%, which characterise sand, sand-mud and some mud sediment types but this cannot be seen as an ultimate tolerance level.

Salinity range

The blue mussel is a marine bivalve, which does not tolerate freshwater but can tolerate a wide range of salinities. Consequently, blue mussels can be found in the fully marine environment (>35 PSU) but also in brackish waters of <10 PSU. However, the growth and survival of both adult and larvae are affected by lower salinity, and in particular by fluctuation in salinity that can have a negative impact on growth and survival. It is therefore recommended to select a site with relatively stable salinities (e.g. consider freshwater input from streams) and with a salinity from 10 to 35 PSU to support good growth conditions and survival rates. Furthermore, transfer of mussels should be avoided between areas with wide differences in salinities e.g. 10-15 PSU.

Oxygen depletion

The oxygen concentration in the water changes over the year often caused by changes in the temperature of the water as an increase in temperature reduces the oxygen solubility. However, the oxygen concentration can also be affected by thermal stratification of the water leading to reduced oxygen concentrations or oxygen depletion in the bottom water. In coastal waters, nutrient input from farmland runoff and wastewater treatment effluents can influence oxygen concentrations because

nutrients often lead to increased primary production, which is decomposed by microbes and thereby enhance depletion of dissolved oxygen. Low oxygen concentrations can lead to stress and mortality in benthic animals. In Denmark, the criteria for oxygen depletion are defined as hypoxic, when dissolved oxygen concentrations are 2-4 mg O_2 L^{-1}, which will cause increased mortality of semi-sensitive benthic species and mobile organisms will flee. Severe acute oxygen depletion, anoxia, occurs at 0-2 mg O_2 L^{-1}, which can cause severe mortality for semi-sensitive benthic species. Generally, blue mussels can survive long time periods (days) with oxygen depletion (2-4 mg O_2 L^{-1}), whereas short time exposure (hours) to severe acute oxygen depletion (0-2 mg O_2 l^{-1}) can cause increased mortality especially as concentrations below 2 mg O_2 L^{-1}, often will be accompanied by release of toxic H2S during night-time. However, the specific effects of any exposure to low oxygen concentrations will be site specific as both the condition and age of the mussels as well as other environmental factors will affect their ability to survive. It is therefore recommended to establish blue mussel beds in areas known not to be affected by oxygen depletion (>4 mg O_2 L^{-1}).

Desirable

Resuspension frequency

Resuspension refers to the erosion of deposited organic (e.g. phytoplankton) and inorganic (e.g. sand, clay) material from the sediment to the water column as a result of high current velocities, wind-induced wave turbulence and the organic content of the sediment (LOI-value). Resuspension can affect benthic fauna by either increasing the abundance of phytoplankton, which is an important food source, or smother the blue mussel beds at high (daily) resuspension frequency. It is recommended to establish mussel beds in areas with a low resuspension frequency.

Resident blue mussel beds in the area

Presence of resident blue mussel beds in the area is desirable to ensure recruitment by naturally occurring larvae and thereby improve the longevity of the established mussel bed. Observations of multiple resident blue mussel beds in areas nearby e.g. >500 m but also further away (>5 km) would increase the likelihood of successful recruitment, as both the hydrodynamic conditions and the duration of the pelagic larvae will affect the recruitment potential.

Phytoplankton concentration (food)

Blue mussels are filter feeders, and a single mussel can filter several liters of water per hour. For instance, a mussel of 5 cm in shell length has a filtration rate of 7-8 L h-1. However, filtration is affected by multiple factors: mussel size, temperature, food concentration, food quality, or water flow. Food limitation can occur in areas with either low phytoplankton concentrations or low current velocities. Chlorophyll-a measurements are often used as a proxy for phytoplankton concentrations and blue mussels generally start filtering at chlorophyll-a concentrations >0.5 µg L^{-1}. The chlorophyll-a concentration in Danish coastal waters is typically well above 0.5 µg L^{-1} and therefore generally not a limitation when selecting a site for establishing mussel beds.

Predators

Predation by either shore crabs, starfish or mussel eating birds cause mortalities and can cause eradication of blue mussel beds (Figure 2). Predation pressures can be mitigated by selecting areas with low densities of mussel eating birds or starfish if sufficient information is available for the area.

Figure 2. *Mussel beds with occurrences of relatively dense populations of starfish. Photo: Timi. L. Banke, SundVejleFjord*

Project logistics

Essential

Agreement of use of the area and licences

Most marine areas are often used for other activities and therefore an agreement that the area can be used for establishing blue mussel beds is necessary. The licencing is an essential prerequisite for establishing blue mussel beds and can include different types of licences (e.g. licence for seed collection and licence for establishing the blue mussel beds) (Figure 3), it is therefore recommended to involve the relevant authorities early in the process.

Furthermore, general environmental and protection regulations need to be considered. In marine protected areas like Natura2000 sites, multiple habitats and species are protected and any negative impact caused by the restoration activities is critical, and therefore restoration activities in Natura2000 sites will require an assessment by the authorities. The licencing process can take long time, sometime even years, and might include a hearing process causing adjustments of sites, which can then lead to a new hearing process. It is therefore often beneficial to initiate the licencing process early in the project to avoid delays.

Desirable

Protection status after establishment

Physical damage of the established blue mussel beds can be detrimental. Fisheries with mobile bottom-contacting gear (e.g. dredges or trawls) will often have substantial effects, so the established blue mussel beds should be located in areas closed for fishery with mobile bottom-contacting gear. Anchoring (e.g. sailing boats) in the areas with established blue mussel beds can also damage stablished beds, as well as private hand collection by snorkelling. Protection of non-commercial activities is often difficult through legislation but can to some extent be prevented by collecting input from stakeholders and informing the public about the restoration project.

Outreach and stakeholder engagement

Support from the local community of stakeholders can help secure long-term success of established blue mussel beds and may even be a requirement from funders. Collaborative engagement of stakeholders can facilitate practical work, publicity and funding but also increase the local awareness and understanding of the marine environment, which can be further improved by involvement of, for instance, local schools through education and outreach activities.

Supporting infrastructure at establishment/ monitoring

Availability and distances of supporting infrastructure facilities, resources and operators (e.g. harbours, mussel farms and boats) in the area is important both in terms of logistics but can also reduce the costs. Furthermore, involvement of companies (e.g. commercial mussel farmers or mussel fishers) for seed collection and relaying practices can help optimise the procedure and save time, which contribute to the overall success of the establishment of blue mussel beds.

Historical distribution

Knowledge or evidence of historical distribution of blue mussels at the site can be useful in the site selection process. However, it is important to evaluate the information carefully both in terms of the reliability of the source but also in terms of applicability (the Danish Center for Marine Restoration 2024). Sites with presence of blue mussel beds long time ago might no longer be suitable for establishment of blue mussel beds due to change in physical and environmental conditions in the area (e.g. area is use for resource utilisation or change of sediment type) or infrastructure facilities, which need to be taken into consideration during the site selection process.

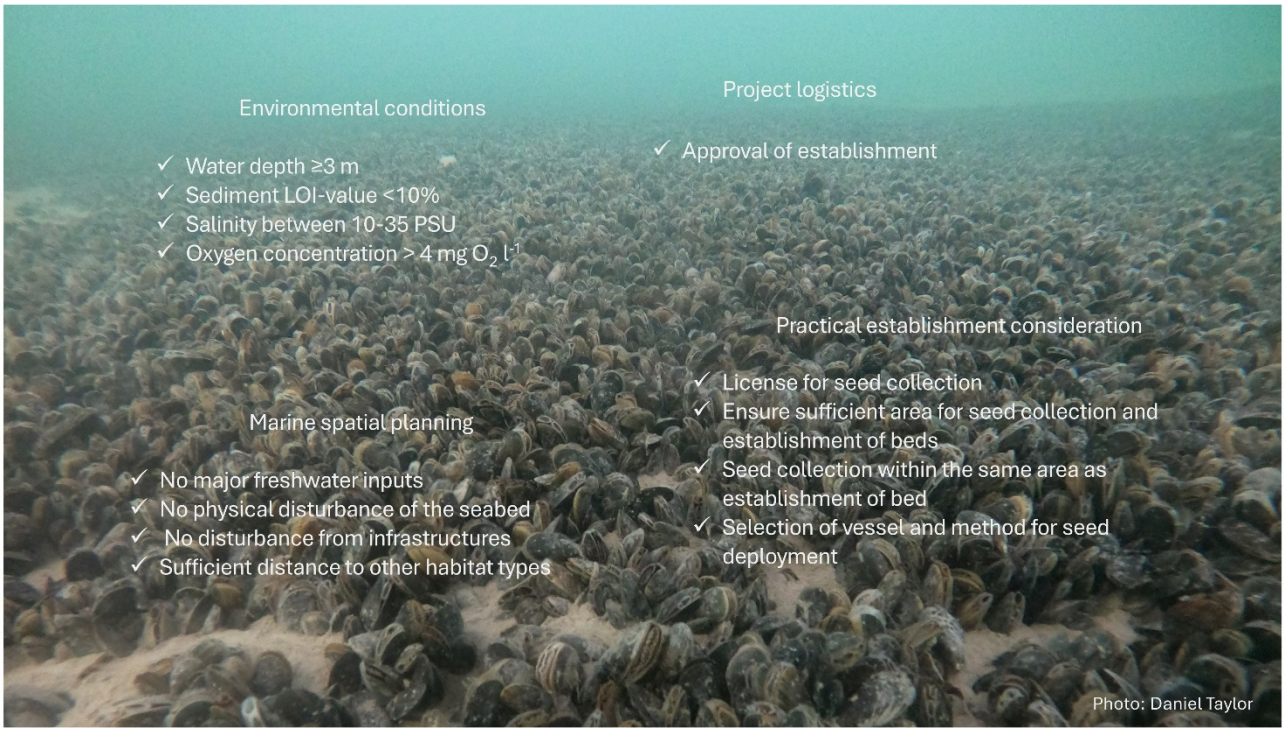

Figure 3. *Criteria assessed as essential for selecting areas for establishing blue mussel beds within environmental conditions, project logistics, marine spatial planning, and practical establishment considerations.*

Marine spatial planning

Essential

Marine protected areas

Establishing blue mussel beds in or nearby marine protected areas (MPAs) like Natura2000 sites may be attractive by potentially benefitting the protected area and securing the established beds from being fished or otherwise damaged by anthropogenic pressure. However, establishment of mussel beds in MPAs will require an assessment of the protected habitats and species impacted by establishing mussel beds. Furthermore, it may also increase the administrative requirements for the project (e.g. licencing process) and thereby increase the risk of delays. Location within an MPA also does not necessarily provide absolute protection, as some human activities may still be allowed.

Areas designated to resource utilisation of repositories

Some areas of the seabed are allocated for extractive practices (e.g. sand or gravel). Any physical removal of seabed material will have an impact if the established blue mussel beds are either physically removed by the extraction process or buried by resuspended material from the extractive activities in adjacent areas. Areas designated for resource utilisation should be avoided, whereas adjacent areas should be considered carefully in terms of the impact caused by resuspension by the extractive practices. Furthermore, areas allowed for fishery with mobile bottom-contacting gear should also be avoided.

Other areas are allocated for repositories for dredged sediments from harbours or shipping routes. Establishment of blue mussel beds in these or in adjacent areas can also be impacted by detrimental sediment burial or smothering caused by resuspension.

Infrastructure facilities in place or planned

Selection of a suitable site for establishment of mussel beds can also include existing and planned infrastructure facilities. Infrastructure facilities like bridges, tunnels and cables that have been in place for >5 years can be assumed to have already affected environmental factors like sediment type, resuspension and hydrodynamics in the areas. However, it should be considered if the infrastructure changes longshore sediment transport, which may lead to by-pass permits (sediment are manually transferred into the area where it would have settled in if the infrastructure was not in place). Potential by-pass areas should therefore be avoided, and it is recommended to contact the authorities to identify any existing by-pass permits.

Infrastructure facilities that are on-going (e.g. aquaculture or sewer outlet) may continuously change the environmental conditions (e.g. sediment type and nutrient load) and it is therefore recommended to establish mussel beds at a distance of >100 m from these activities.

Existing habitats

When establishing blue mussel beds, it is important to consider the habitats that already exist at the selected site or adjacent areas, as the establishment can impact existing habitats. For instance, mussel beds in adjacent areas of eelgrass beds can potentially improve the light conditions for the eelgrass but can also cause limitation of the eelgrass distribution by competing for space or cause increased organic content in the sediment. Establishment of blue mussel beds should therefore take place with sufficient distance to existing habitats.

Desirable

Outlets from rivers and streams

Freshwater inputs closely link to both salinity and sediment loads and varies over the year due to seasonal changes. High freshwater inputs from larger streams or rivers can cause both fluctuations in the salinity and cause smothering by high sediment loads which may have detrimental effects on both the survival and growth of the established mussel beds. It is therefore recommended to carry out additional sediment and salinity sampling throughout the year if blue mussel beds are established in areas adjacent to outlets from larger rivers and streams.

Commercial shipping routes and common recreational sailing routes

Establishment of blue mussel beds does generally not alter the seabed in a way that affects marine traffic, and it will typically not need a permit from the maritime authorities. However, from a practical point it is recommended to keep a distance to both commercial shipping routes and common recreational sailing routes to avoid conflicts between operating boats used for deployment and monitoring activities. If a permit for suspended mussel seed collection is needed, distances to shipping and

recreational sailing routes need to be considered in the application process and contact to relevant authorities can be very useful.

Recreational activities

The marine environment is used for many recreational activities (e.g. sailing, bathing, angling, kayaking and scuba diving/snorkelling). Mapping of recreational activities could be considered in the site selection process to ensure a balanced and transparent process with preferably early involvement of stakeholders to mitigate potential conflicts.

Practical establishment considerations

The aim of initiating establishment of blue mussel beds can be to support different ecosystem services like enhance habitat complexity, increase biodiversity, improve water quality or enhance nutrient cycling. However, if the specific focus is to establish biogenic blue mussel reefs, the established reefs need to comply with the national definition of a biogenic blue mussel reef. Within the EU different national biogenic blue mussel reef definitions exist and some countries have definitions for different areas. It is therefore important to identify if a definition for biogenic blue mussel reefs exist for a given area before establishing the reefs if the specific aim is establishment of biogenic reefs.

The criteria listed below give a short introduction to the practical considerations that can be included in the site selection process. This criteria do not contain specific values e.g. mussel density (kg m-2) and bed size (m2) but include general information beneficial in the site selection process. Specific values and detailed information will be provided in a best practices manual for establishing blue mussel beds, which will be available at www.marinnatur.dk later in 2023.

Essential

Seed origin

Seed supply is needed for establishment of blue mussel beds. The easiest and cheapest way is to collect wild seed that can either come from natural mussel beds or from mussel farms, whereas hatchery produced seed are currently not recommended due to costs and lack of availability. It is therefore important, early in the process, to identify seed origin (bottom or suspended) as this will affect the licensing process and thereby the site selection process. Collecting mussel seed from natural occurring mussel beds will require hiring of a fishing vessel to collect the mussels with dredges and therefore a permit from the fishing authorities. Suspended mussel seed can either come from commercial mussel farms or by establishing suspended mussel collectors in an area (Figure 4). Setting up mussel collectors will require selection of an area and subsequently a permit for setting it up. Irrespective of the seed origin, it is recommended to evaluate the cost and environmental impact of seed collection e.g. environmental impact by collecting seed from natural mussel beds with dredges or establishment of suspended collectors in an area. It is therefore recommended to involve experienced mussel fishers or mussel farmers in the process when relevant, to increase the chances for successful collection of mussel seed.

Figure 4. Seed collection on longlines *Photo: Daniel Taylor, DTU Aqua.*

Transfer of mussel seed between areas

The transfer of mussel seed from any origin between water bodies can be problematic for several reasons and can complicate the licencing process. Transfer of mussel seed from one estuary to another increases the risk of transfer of unwanted species like invasive species, parasites, or diseases, which may not necessarily be harmful to blue mussels, but to other species in the receiving area. Furthermore, transport of mussels seed into another water body may conflict with the EU Water Framework Directive, as import of mussel biomass can be seen as import of nutrients to an area. If it can be sustained that the new mussel bed will be stable or even grow over time, there will be no net import of nutrients. Furthermore, the import of nutrients may be low compared to reduction targets or not relevant if the area has achieved GES. It is however generally recommended that collection of mussel seed is carried out within the estuary, or if this is not possible from nearby areas.

Areal distribution of the bed(s)

The size(s) and number of mussel beds that will be established, determine how large of an area(s) that needs to be applied for in the deployment permit. However, it will also affect the number of seed needed i.e. how many tons need to be either fished or produced on the suspended collectors, which again will affect the licencing process for the seed collection. It is recommended early in the process to perform estimations of seed quantity needed for the sufficient permits for both ensuring sufficient seed and area(s) for the established mussel bed(s).

Relay method

After the collection of mussel seed by either fishery of bottom or harvest of suspended material, the seed need to be relayed in the selected area at a suitable density to support survival of the mussel beds. The mussel seed can be relayed from the vessel either manually or mechanically e.g. conveyer belts, whereas some vessels have the possibility to pump seeds out from each side of the vessel. It is recommended to use larger vessels for large-scale restoration projects, as tons of mussel seeds are relayed, to ensure stable relay practices, better working environment and due to safety issues.

Desirable

Design of the mussel bed

A proper design of the restoration initiative is recommended to include several factors like: i) relay density of the mussels, ii) distances between beds, ii) single or multiple relay times and iv) time of the year for establishment of the bed(s). The final design of the mussel bed will depend on number of seeds available, and the size of the restoration area. Availability of support facilities such as vessels, harbours and mussel farms in the area can also be included to estimate the need for manpower and costs.

References

Danish Center for Marine Restoration. 2024. Concepts in relation to marine nature Scientific report from the Danish Center for Marine Restoration. https://marinnatur.dk/media/72519/concepts-in-relation-to-marine-nature-restoration-uk.pdf

Flindt M, Jørgensen TB, Petersen JK, Stæhr PAU. 2023. Marine habitaters understøttelse af vigtige biologiske økosystemtjenester. Videnskabelig rapport fra Nationalt Center for Marin Naturgenopretning. https://marinnatur.dk/media/72366/marine-habitaters-oekosystemtjenester.pdf

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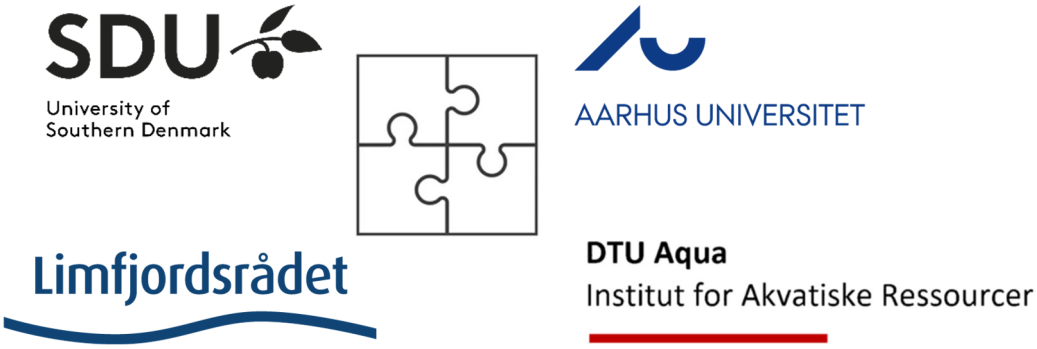

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The main goal of the Center is to promote knowledge-based implementation of marine restoration, to strengthen the health and resilience of marine ecosystems, and enhance associated marine ecosystem services.