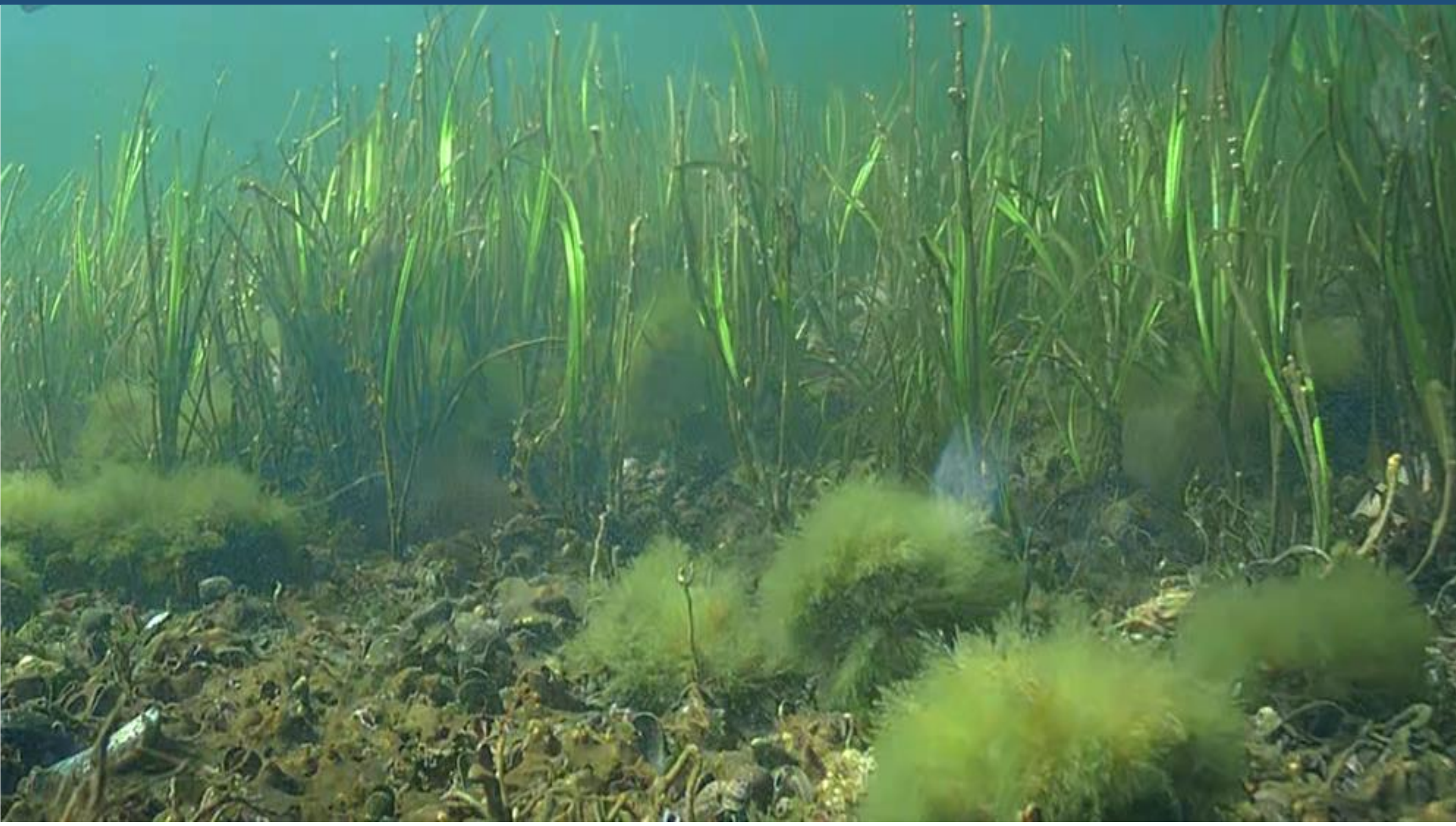
Concepts in relation to marine nature restoration



Center for
Marine Restoration

Colophon

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Summary: The report describes key concepts and definitions related to marine nature improvement activities. With this review, the Centre will ensure that there is clarity about the concepts within the area and what this entail but will not decide whether the various activities described below can be considered appropriate from a nature or environmental perspective, either locally or in general.

Contents

1. Introduction

Despite decades of efforts to improve the water quality of our marine environment, the ecological condition of Danish coastal waters is generally unsatisfactory, protected nature types have an unfavourable conservation status and biodiversity is under pressure. Danish marine ecosystems are thus generally not in a good state as only a few water bodies meet or are expected to soon meet the requirements of the EU Water Framework Directive. Moreover, also only a few Natura 2000 areas are in favourable conservation status (1).

Basically, nature and environmental protection is about reducing human pressures, either by intervening against them and/or by designating protected areas. The focus in Danish marine environmental policy has for many years been on reducing or removing the human pressures, most clearly exemplified in the river basin management plans where a reduction of the input of nutrients is the main objective. However, other important human pressures exist that may affect the Danish marine environment and for these too, a significant part of the environmental effort is to contain and reduce the extent.

Conservation and other types of protection have also been used in Danish marine environmental policy, for instance in relation to the protection of seals, birds, and habitats. In terms of area, most of the marine protected areas are designated either based on the EC Bird Protection Directive or the EU Species and Habitats Directive. The protected areas designated based on the two directives are referred to as “Natura 2000 areas”. In the upcoming EU biodiversity strategy, it is planned that 30% of the area on land and water be protected and that 10% be designated as strictly protected areas. There is no official Danish definition of” strict protection”, but if you lean on the IUCN definitions in category 1a and 1b (https://www.iucn.org/theme/protected-areas/about/protected-area-categories), such protection will stop virtually all activity in the designated areas and limit human access significantly but, expectedly, allow nature restoration activities. In a Danish context, the guidelines for “strict protection” must be different as there are virtually no untouched marine habitats in Danish waters, and the prerequisites for protecting an un-spoilt nature, cf. the UICN definition, are therefore unlikely present. There is no guarantee that marine protected or strictly protected areas will achieve all the desired objectives in the long term. Protection does not bring, for instance, stones removed by extraction back to the protected area, and protecting a coastal area does not necessarily bring back eelgrass beds, particularly not in the short term. In addition, the protection of marine areas does not in itself protect against all types of pressures as some cannot be kept out of the protected areas. This applies not only in relation to nutrients and harmful substances but also to, for example, invasive species.

However, the promotion of robust and species-rich marine ecosystems does not need to be based solely on restrictions on human activities. Changes have occurred in marine ecosystems, such as, for instance, physical changes through stone extraction, that do not return to their original state without active human intervention. Active nature restoration with a view to promoting permanent changes in the environmental and natural state of Danish marine areas is thus an alternative or rather a supplement to limiting pressures and conservation. Where marine nature protection can improve nature quality by reducing several pressures, active nature restoration can be a necessary supplement to achieve the objectives of an improved environmental and natural state. Furthermore, marine nature protection can be a prerequisite for successful restoration of a habitat or a key species within the protected area. It will therefore often make good sense to combine marine nature protection and nature improvement measures.

The main objective of the Centre for Marine Nature Restoration is to promote knowledge-based implementation of marine nature restoration in Danish waters with a view to strengthening the resilience of marine ecosystems, the ecological balance, and the ecosystem services that healthy habitats and nature types provide. Central to this work, the centre will through documentation, experience and collected data develop tools that can be used to identify the most suitable areas for nature restoration as well as plan the activities and the associated monitoring of the state of environmental and natural conditions. Furthermore, the centre will provide documentation on the effects of different types of marine nature restoration activities by compiling experiences from such activities.

Nature enhancing measures include several different human activities with the aim of improving the natural and environmental conditions in the sea. But not all these activities can be characterized as nature restoration. When choosing measures, it is important to keep in mind what the precise purpose of the activity is. Activities to promote local populations of fish can, for instance, include artificial reefs that have been documented locally to increase the occurrence of some fish species. However, creating reefs where they did not previously exist or dumping decommissioned ferries or the like to use them as reefs cannot be characterized as restoration of lost nature. Likewise, marine eutrophication mitigation measures such as extractive cultures may have positive environmental effects on water clarity and locally increase biodiversity, but the grow-out structures are not natural habitats, and the activity cannot therefore be described as nature restoration. So, not all activities with positive environmental and/or nature enhancement characteristics are in themselves marine nature restoration.

This document reviews key concepts and definitions related to marine nature-enhancing activities. With this review, the Centre will ensure that there is clarity about the concepts in the area and what these entail, but it will not determine whether the various activities described below can be considered appropriate from a nature or environmental perspective, either locally or in general.

2. Concepts

Nature Restoration

Nature restoration is the re-establishment of lost habitats where they had known occurrence or of lost species in their natural historical distribution area and densities. Nature restoration is defined as an action that re-establishes/restores natural habitats, hydrological processes, biological mechanisms and/or populations. For the habitats, this means that there must preferably be solid indications or actual records as documentation that they have historically been present at the location in question. Habitats in this context are, for instance, stone reefs, gravel beds, sandbanks, eelgrass beds or beds of mussel species (blue mussel, flat oyster, horse mussel). When restoring lost stone reefs, it is also relevant to assess whether restoration with stones and boulders is possible and to aim for the correct formation; for instance, were the stone reefs cavernous or did they have a more diffuse distribution?

Some practical circumstances can make it difficult to fulfil the conditions for whether a project on the establishment of habitats can be defined as nature restoration. This applies to the requirement for locating known previous occurrences if there is no documentation of previous occurrences based on, for example, historical charts. Despite the circumstance that it is probable that more than 8.3 m^3 million boulders have disappeared from Danish coastal areas and that the homeports of the extraction boats are known, there are very few precise records of from where the boulders were removed or whether they formed cavernous reefs. Similarly, a significant correlation between water transparency and eelgrass distribution does not mean that if sufficient water transparency at a given water depth in a specific area is obtained, eelgrass has historically been present in the area. It is even more difficult to find precise documentation of historical presence of habitat types such as mussel beds. The general lack of documentation for the precise location of lost habitats may make it relevant to discuss whether the described definition of nature restoration/recovery is appropriate or whether it can also be accepted as nature restoration if it is likely that the habitat has been present in the area in question. It may also be appropriate to include a probable previous presence of a given habitat in a specific area as a sufficient condition for nature restoration. Alternatively establishing a habitat without prior documentation of historical presence may fall under the category of nature-based solutions (see below). Especially for stone reefs, the choice of material can make it difficult to meet the conditions for the criteria for restoration. Unless you are re-laying previously collected boulders, which, for instance, are used for piers, the re-establishment of stone reefs will involve the use of other material. Today, it is generally accepted to use blasting stone for nature restoration. In contrast, artificial hard bottom substrates such as concrete are not accepted as nature restoration today. For biogenic reefs, a similar limitation may arise in relation to the genetic origin of the re-established species. For some species – such as the European flat oyster – it cannot be guaranteed that there are remaining individuals of the original strain. Here it may be necessary to use individuals from as close geographically distant intact populations as possible.

A special part of the marine nature restoration is linked to the restoration of the natural hydrology in each area, for example through the removal of dams, sluices and physical coastal protection. This restores a more original balance between coast and sea. This type of nature restoration is currently challenged by rising sea water levels due to the climate change, which will change an area’s natural hydrology compared to the situation when the physical changes were implemented. At the very least, this could cause changes to the terrestrial part of the thus restored natural area.

Nature restoration also includes attempts to re-establish populations of species in their former densities. There are several challenges regarding the re-establishment/re-stocking of species. Many species are dependent on a suitable habitat for foraging or reproduction and will re-immigrate “automatically” when habitats are re-established. For other species, active re-stocking programmes are needed. It can be difficult to obtain accurate information about historical but now disappeared or reduced occurrences; however, generally the more mobile the species is in one or more life stages, the less the documentation requirement for precise localisation will be. For bird species, there are often historical data on distribution.

Nature Inclusive Design

Nature inclusive design (NID) is a concept that aims to integrate nature into the design of human-made structures and environments, which can support the natural environment and ensure sustainable and beneficial development for both people and nature (2, 3). NID can be integrated into or added to the design of structures and environments with the aim of promoting the rehabilitation of a degraded habitat, improving ecological function and increasing biological production and diversity in an area. For example, NID in offshore wind farms can be used to minimize the impact of wind turbines on marine ecosystems by designing wind farms in a way that minimizes the impact on marine life and promotes coexistence between wind farms and marine ecosystems. NID is a new form of environmental action and is often used in conjunction with nature-based solutions (see below).

It is important to note that the two concepts have different meanings. NID is a way of designing spaces that integrate nature, while nature-based solutions are actions that use nature to address societal challenges.

In relation to the assessment of the overall environmental impacts of projects, it is important to be aware that the extent of potentially positive effects of NID on individual habitat types, species survival, pressure factors or the like is not necessarily able to match the overall negative impacts of a project on the marine environment.

Nature-based Solutions

Nature-based solutions (NbS) arise from a fundamental idea that a number of current societal challenges related to, for example, food production and security, climate adaptation, social development, etc. in many places could be fully or partially addressed using solutions that imitate natural processes and ecosystems in such a way that local, regional or global natural values can also be preserved or restored at the same time.

Globally, nature-based solutions were defined by the UN Environment Assembly in May 2022 as "*actions that protect, conserve, restore, sustainably use and manage natural and modified terrestrial, freshwater and marine ecosystems that address social, economic and environmental challenges effectively and adaptively, while delivering well-being for people, ecosystem services, resilience and benefits for biodiversity*". The definition constitutes the first global politically consolidated definition (4). The need for a common global definition arose from a growing concern that the rising level of investment in so-called nature-based solutions could end in either conscious or unconscious greenwashing. The operationalization of this definition at project level, however, still contains several unresolved questions in a marine and coastal context regarding, among other things, how to prioritize between different potentially conflicting social, economic and environmental goals, relevant impact scale, need for life cycle assessments, stakeholder involvement, etc. The definition of when projects should be characterized as NbS is therefore expected to develop rapidly in the coming years as ongoing EU projects develop, among other things, minimum criteria for implementation processes. In terms of interpretation, it is pointed out that "nature-inclusive design" is generally perceived to move infrastructure projects such as coastal protection, wind turbine foundations, etc. closer to the category of projects that could potentially be perceived as NbS. It should also be noted that nature restoration, on the other hand, can be understood as a nature-based solution, although there will often be a clear expectation that the solution is implemented in a way that also contributes to solving other societal challenges. There is a considerable body of literature on NbS (see e.g. 3, 5 and 6).

Ecosystem Engineering

Ecosystem engineering or ecological engineering is a technique that combines ecological processes and organisms with technological solutions to predict, design, construct or restore and manage ecosystems, with the aim of integrating human society with its natural environment for the benefit of both (7). The term should not be confused with ecosystem engineers, who are organisms that affect their surrounding environment by creating structures or habitats such as eelgrass, large brown algae or blue mussels. Ecosystem engineering covers a number of diverse efforts (7) such as: i) Using ecosystems to reduce a pollution problem, e.g. creating wetlands to absorb nutrients; ii) Restoring or re-establishing lost ecosystem functions in relation to resource exploitation or pollution, e.g. afforestation or lake restoration; iii) Modifying ecosystems in an ecologically responsible way, e.g. selective logging, biomanipulation and introduction of predatory fish to reduce plankton-eating fish or introduction of plankton-eating organisms; iv) So-called sustainable exploitation of ecosystems used for benefit without destroying the balance, e.g. IMTA (Integrated Multi Trophic Aquaculture). The term thus covers a wide range of activities including elements of nature restoration with variable degrees of documentation and has to some extent been replaced by NbS or "marine mitigation measures" (see below) depending on the activity.

Biomanipulation

Biomanipulation in the form of regulation of species is known from terrestrial nature conservation and freshwater systems but is not used to the same extent in marine areas. Overall, biomanipulation or species management can be divided into two groups: i) increase of desired species through stocking programmes. An increase of desired species can also be achieved by providing more key habitats and is thus covered by the habitat creation tools, ii) reducing the density of "pests" with a view to reducing undesired effects on eco-systems, habitats or key species.

In Danish marine areas, the stocking of species is known primarily from marine fish stock management, which has as its primary purpose to increase the yield of fish caught in recreational fishing. There are stocking programmes for species such as trout, eel, flounder, and turbot. There is very little documentation of the effectiveness of stocking programmes as a tool to increase catches and even less in relation to local populations of the stocked fish (8). Even so, every year funds are spent on stocking different species in selected areas.

Limiting species with a recognised impact on key habitats or key species may, for instance, include controlling shore crabs in relation to the planting of eelgrass, starfish in relation to blue mussel beds, sea urchins in hard substrate areas or cormorants and seals in relation to fish populations. There are also examples of the control of Pacific oysters and Sargasso seaweed as part of limiting the effects of invasive species. Limiting species abundance will normally require documentation of their harmful effects and that the regulated populations can withstand a reduction in density or total biomass. Alternatively, efforts can be limited to selected areas such as, for instance, newly created habitats. There is limited experience with limiting marine species. The attempts to limit cormorant populations are best known and have been instrumental in stopping the increase in the population at national level. In the mussel industry, there is also experiences with on-bottom culture bed fishing for starfish, but the experiences are not fully documented or ambiguous and probably not directly applicable as a nature management tool.

Artificial reefs

Artificial reefs have for many years (see e.g. 9) been a known tool to increase local populations of fish and crustaceans, and it can also increase the local biodiversity of epibenthic organisms and associated mobile epibenthic fauna. By placing often large and spatially complex fixed structures on soft bottom types, new habitats will be created that function both as a habitat and a shelter against currents. In recent years, several studies documenting such effects have been carried out, especially in connection with wind turbine foundations. For fish populations, there is an ongoing discussion about whether the artificial reefs work through attraction or whether they also lead to increased production and thereby increasing fish populations on a regional scale. Increased attraction of fish, which does not signify enhanced production, can potentially make the populations in question more vulnerable, for example in relation to fishery pressure. Artificial reefs include different types of construction: i) wind turbine platforms, bridge pylons and similar constructions, which are often made of concrete or similar materials. Many of these structures are also associated with scour protection on the sea floor, which can be made of stones, and where optimised design can increase the local biodiversity through higher spatial heterogeneity of the structures; ii) decommissioned material such as oil rigs, ferries and tanks, iii) artificial reefs designed for specific purposes, e.g. in relation to fisheries management of commercial species and in relation to the activities of private associations to promote local fishing grounds for anglers (9).

Artificial reefs can potentially cause undesired side effects linked to the choice of material, location of the reefs and purpose of the reefs. Establishing new dispersal routes (stepping stones) for non-native species is one of them. For artificial reefs made of decommissioned material, there is a particular focus on problems with leaching of harmful substances and lack of recycling. Establishment of artificial reefs can also be done at the expense of the existing original nature in areas that did not naturally exhibit hard substrates. Whether this will have a significant effect depends on local conditions.

Biodiversity offsetting

Biodiversity offsetting is a term used for activities where natural areas and habitats for species are lost typically because of construction work, such as harbours and other infrastructure, and where the lost nature is attempted to be compensated by creating replacement nature in the form of establishing new natural areas or habitats for species (10). Biodiversity offsetting is primarily known from land and freshwater areas (11) but is also gaining ground in large-scale construction work near the coast. Biodiversity offsetting is the “last resort” and is intended to compensate for environmental loss to ensure that new natural areas are created when human activity damages nature. According to the “mitigation hierarchy”, biodiversity offsetting should only be implemented when all measures have been taken to avoid and minimize impacts and to restore biodiversity on site. It is important to ensure that the replacement nature can develop a quality that is at least equivalent to the destroyed nature within a reasonable number of years and that methods are used that are not destructive to established nature in relation to, for example, eelgrass transplantations (see guidelines on this on the centre's website). A solid empirical basis is necessary for such a development indicator, as it must relate to habitat quality, the rarity of the habitat, the likelihood that a replacement nature area will develop into the planned nature type, the speed of development and the degree of protection of the area. Not all nature can be replaced. Several nature types are so unique that they are in principle irreplaceable.

Marine mitigation measures

Marine mitigation measures cover a wide range of different activities with specific purposes in relation to specific natural or environmental goals. As a concept, marine mitigation measures in Denmark are largely developed to achieve the goals in the water area plans, but marine mitigation measures can be understood in a broader context. Marine mitigation measures are thus not exclusively defined in relation to the reduction/binding of nutrients but may also be used for, for example, habitat improvement.

Mitigation of eutrophication effects

Nitrogen/phosphorus measures primarily aim to reduce the effects of eutrophication through immobilisation and subsequent removal or storage of nutrients in the sea floor. The individual measures may provide other ecosystem services related to the environmental indicators in the Water Framework Directive, but their effectiveness for immobilising/removing nutrients is the main parameter assessed. In the latest catalogue of potential marine mitigation measures in Danish waters (12), these include i) extraction cultures such as the cultivation of seaweed and mussels and ii) initiatives that bind nutrients in the sea sediment and in standing biomass or promote degassing of nitrogen such as the establishment of eelgrass beds.

Figure 1. *Mussel farming using long-lines. Photo: Daniel Taylor, DTU Aqua.*

Extraction cultures are based on the cultivation of either mussels (blue mussels) or seaweed (sugar kelp) in specially designed structures. The cultivated species immobilize nutrients, and when harvested they bring the nutrients to land and thus remove them from the local coastal area. Because it is a new production without the addition of fertilisers/excipients, the harvesting implies net removal of nutrients from the system. Extraction cultures provide several other ecosystem services, but each of these services also has several cascading effects that are not natural in the sense that the extraction cultures concentrate organisms in high densities in small areas. You can read more about extraction cultures in (12).

Immobilisation of nutrients can also occur by establishing conditions that immobilize the nutrients in the sediment or increase denitrification in the sediment. Planting eelgrass will thus immobilize nutrients in the root stems and lead to a gradual build-up and partial burial of nutrients in the sediment until a steady state is reached. There has also been speculation as to whether, for instance, stone reefs, sand capping and oxygenation of the bottom water can be used as N/P measures, but the few experiments undertaken in Danish waters have not been able to document an effect on nutrients. Establishment of eelgrass beds (including sand capping) and stone reefs will have several cascading natural effects (see below). Regarding the effectiveness of immobilisation of nutrients by these measures see (12).

Harvesting of wild populations of species occurring in high densities, such as sea lettuce, starfish, or shore crabs, is often wholly or partly conditioned by anthropogenic pressures and leads to the removal of nutrients from the sea but harvesting/fishing of such species cannot constitute a marine mitigation measure in relation to nutrients. Regulation of imbalanced populations may increase the environmental load but may also improve the environment and should, in the latter case, primarily be regarded as a nature management tool. For further information on the effects of harvesting sea lettuce see (13).

Nature management tools

Nature management tools work primarily by establishing nature, for instance by creating new habitats or by regulating existing nature through, for example, stocking of fish or shellfish or regulation of top predators. Nature management tools will have cascading effects in addition to creating new habitats or increasing/decreasing the densities of specific species. Establishment of eelgrass beds, stone reefs and beds of mussel species is the most preferred marine habitat-creating nature management tool in Denmark. Nature restoration can be considered a nature management tool, but nature management tools can also be used where the habitat has not occurred naturally, based solely on a desire for more of the nature type in question at the expense of the existing nature types/habitats.

Habitat-creating nature management tools have changes in biodiversity as an important ecosystem service. In addition, there are services such as sediment stabilisation, prevention of coastal erosion and immobilisation of nutrients as well as general promotion of resilient ecosystems. Several of the projects that have been carried out in Denmark fall under the category of “habitat-creating nature management tools” without being nature restoration projects. There can be several challenges when using habitat-creating nature management tools and their location. If, for example, stone reefs are established on a sandy bottom, there will certainly be an increase in the local biodiversity, but this will be at the expense of the species composition characteristic of sandy bottoms, and some specific habitats and ecosystem functions will therefore disappear. The issues with this kind of nature or habitat management will depend on the extent of the established stone reefs and the habitat in which they are placed. When establishing stone reefs, there is also the risk of introducing distribution pathways for non-native species (stepping stones), and there is also an ethical issue linked to the extent to which we want to rearrange our marine landscape. Establishment of biogenic reefs can locally lead to organic enrichment of the sediment in the form of bio deposition, which would otherwise not have occurred, with resulting changes in the conditions for the benthic animals in the sediment.

3. Habitats

Regardless of which of the above measures are adopted, it is important to understand how they will interact with existing natural habitats. Some habitats are defined in accordance with the EU Habitats Directive, while others are designated as key habitats in Danish waters.

Below, the characteristics of some habitats relevant within the context of restoration are reviewed based on the definitions in the EU Habitats Directive. With the upcoming expected implementation of the EU Nature Restoration Law, the nature types in the EU Habitats Directive will be expanded with a more detailed description according to EUNIS (https://eunis.eea.europa.eu/about) and the associated annex (14). For some of the habitat types below, this may lead to further considerations regarding the interactions between naturally occurring habitats and the desired new habitats to be established.

Stone reefs

A stone reef is, biologically speaking, an area that rises from the surrounding sea floor and consists of a hard substrate such as stone or rock, covering minimum 5% of the sea floor surface, and the area must have a size of minimum 10 m².

Figure 2. *Sketch of a stone reef with associated vegetation and wildlife. Drawn by Tinna Christensen.*

If the reef has a bank structure, i.e. a reef divided into smaller collections of stones, the reef is demarcated by a line around all banks, each of which meets the requirements for size and coverage (15). In relation to the Habitats Directive, the stone reef nature type is defined, according to the Ministry of the Environment, as a bottom where the coverage of stones is minimum 25% and, if such a core area exists, with a boundary to bottom types such as, for example, sand and gravel, down to 10-25% stone coverage.

According to the EU Habitats Directive (16), stone reefs are defined as areas in the sea with hard compact substrates on firm or soft bottom, which protrude from the sea floor in deep or shallow waters, so that the reef is topographically distinct by being separate and protruding from the surrounding sea floor. Geogenic reefs (stone reefs) can be in the form of hydrothermal habitats, vertical rock walls, rock piles, horizontal rock shelves, overhanging rocks, pillars, ridges, pinnacles, sloping or flat bed rock, boulder reefs and stony reefs. The reef may possibly be exposed at low tide. The separation of a reef from the surrounding sea floor goes where it can no longer be recognised that it is part of the rising sea floor, or where there is no longer any sign of hard bottom substrate. Where in the designation basis for the EU Habitats Directive stone reefs are exclusively described as a substrate for macroalgae, on the in the annex to the EU Nature Restoration Law, there are eight different types of macroalgae vegetation for the Atlantic area and five for the Baltic Sea area. Some of these are most relevant for gravel bottom and not for actual stone reefs. The appendix for macroalgal forests refers EUNIS numbers for different habitat types, including a number of subnumbers with specific species and substrate types.

Eelgrass

An eelgrass bed is dominated by the species eelgrass (*Zostera marina*) and may be supplemented with dwarf eelgrass (*Zostera noltii*) and other rooted macrophytes such as, for instance, sea grasses (*Ruppia sp.*), pondweed (*Potamogeton sp.*) or horned pondweed (*Zannichellia sp.*). Eelgrass beds are found on sandy bottoms in shallow coastal areas and in saline-influenced estuaries in temperate areas. Denmark is a hotspot for eelgrass dispersal in the Nordic region and the Baltic Sea region (17, 18). The plant typically occurs in shallow water (<4-6 m) along most Danish beaches where the shoots can grow 30-140 cm high and form dense beds with a large biomass (17). Dense extended eelgrass beds are called eelgrass meadows.

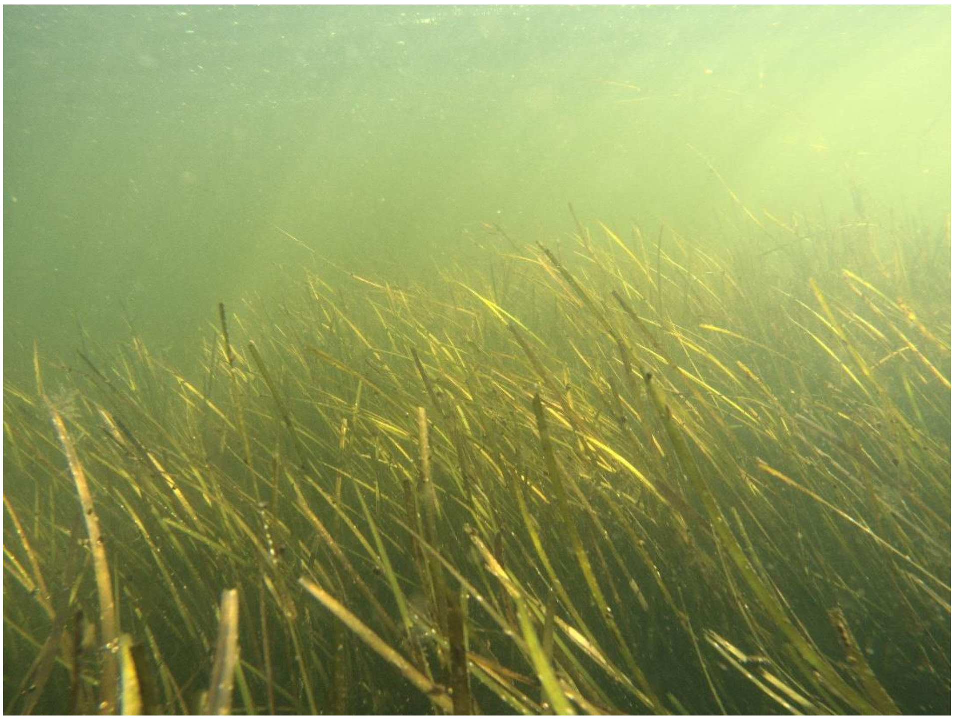

Figure 3. *Eelgrass bed in Roskilde Fjord. Photo: Peter A.U. Stæhr.*

In the Danish Environmental Protection Agency's monitoring of eelgrass, coverage levels of eelgrass <10% are no longer categorised as eelgrass beds. At the beginning of the 20th century, eelgrass dominated the sea floor along sandy coastal areas and most Danish fjords and grew considerably deeper than today. However, the eelgrass disease together with 50 years of human impact on the sea have pushed the populations into shallow water, where the eelgrass has difficulty reestablishing itself naturally. There is no eelgrass nature type defined in the Habitats Directive, but there are 3 different general seagrass types for the Atlantic area and 8 for the Baltic Sea area in the EUNIS list annex to the EU Nature Restoration Law (14) under "Seagrass beds". The referenced seagrass types refer to EUNIS habitat types including several sub-numbers with specific species and seabed conditions.

Biogenic reefs

Biogenic reefs are biogenic concretions in the form of hard, compact substrates on firm and soft bottom, which arise from the sea floor in the sublittoral and littoral zone. Biogenic concretions are defined as: concretions, crusts, coralligenous communities and bivalve mussel beds that originate from dead or living animals, i.e. biogenic hard bottom that acts as habitat for surface-living species. According to the EU Habitats Directive (16), biogenic reefs are a subdivision of the reef habitat type and differ solely by the nature of the hard bottom substrate. For biogenic reefs, for instance mussel beds, the structure often arises gradually and perhaps only 20-30 cm above the sea floor so that the criterion of protrusion is not as relevant as for stone reefs. In Denmark, biogenic reefs are only defined for the species blue mussel (*Mytilus edulis*) and horse mussel (*Modiolus modiolus*), while in other countries there are definitions for fan worms (sabellids), cold-water corals and encrusting coralline algae. For blue mussels, the Danish definition (19) is: Contiguous areas of minimum 2,500 m^2 with an average coverage of blue mussels of minimum 30% and the presence of minimum three cohorts of blue mussels. A horse mussel bed is defined as a horse mussel reef when the bank covers minimum 100 m^2 and where there is a central degree of coverage of 20% horse mussels and shells, of which 10% are live horse mussels and mainly consist of horse mussels more than 4 cm long (19). In the annex to the EU Nature Restoration Law (14) on "Shellfish beds" there are 5 different general types for the Atlantic area and 7 for the Baltic Sea area, not all of which are relevant in a Danish nature restoration context. In the relevant types of shellfish beds, reference is made to EUNIS habitat types including several sub-numbers with specific species and seabed conditions.

Coastal lagoons

Coastal lagoons are a prioritized habitat type, which, according to the Habitats Directive, implies that Member States are obliged to implement the measures necessary to maintain or restore habitats and populations of wild animals and plants in a favourable condition. According to the Habitats Directive (16), coastal lagoons are water areas on the coast with more or less shallow water of varying salinity, which are completely or almost completely separated from the sea by seawall formations, salt meadows, dunes, or in rare cases by rocks, so that there is still some water exchange with the sea - possibly only in the form of temporary flooding or by seepage through soil layers. The salinity typically varies quite a lot depending on the balance between precipitation, evaporation and the supply of seawater during storms, occasional winter floods or tidal changes. The water can therefore vary from largely fresh to very saline depending on the geographical location and water balance of the lagoon. Coastal lagoons can be vegetated or unvegetated, and their location and extent can change during floods. Coastal lagoons can include anything from larger water areas to beach lakes and water holes on salt marshes and behind beach dikes fall under the definition. Modified and dammed water areas can also be considered coastal lagoons in this context if the area was originally a lagoon or beach area, provided that the area is an area with limited impact from human use, so that the area is not very culturally influenced. Lagoons can occur in a mosaic with salt marshes and marshes, as most water bodies in such places will meet the conditions for being a coastal lagoon. Coastal marshes dominated by, for example, sea clubrush (*Bolboschoenus maritimus*) or common reed (*Phragmites australis*) will thus be coastal lagoons where the plants grow in water, while they will be salt marshes where the plants grow on land (16).

Sandbanks

According to the Habitats Directive, sandbanks are topographic features in the sea in the form of protruding or elevated parts of the sea floor, which are mainly surrounded by deeper water of up to 20 m depth, and which are permanently submerged at low tide. They mainly consist of sandy sediments, but other grain sizes in the form of mud, gravel or large stones can also occur on a sandbank. They often have a rounded or elongated shape but can also have irregular shapes, for example in the form of ripples. Their sides can extend down into water deeper than 20 m. Areas with mud, gravel or large stones on a bank belong to this habitat type if mainly animals and plants attached to sandy bottom are found in the area, even if it is only a thin layer of sand on a harder surface of, for instance, clay. Sandbanks can be found close to the coast in connection with, for instance, reef formations or as more permanent banks further from the coast (16).

Soft mud bottom

The soft mud bottom is a natural habitat in sedimentation areas. These are found in most fjords, many bays and deeper sea areas where the physical effect of waves and high current speeds is limited. In these areas, the bottom conditions are defined by a higher content of fine-grained (grain sizes <63 µm) organic material, which also results in a higher water content. The mud bottom varies in terms of organic content from 2 to 10% organic dry matter. The high organic content with low density means that no physical compaction of the bottom occurs. Mud bottoms with a low organic content (2-5%) characterise, for instance, open areas in the Kattegat.

In addition, several other marine habitats are defined in the Habitats Directive (11) and mentioned on the more extensive EUNIS list of habitat types.

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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.