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Best practice for restoration of stone reefs in Denmark (codes of conduct)

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Contents

1. Introduction

This memorandum on best practice for restoration of stone reefs in Denmark was prepared as part of the BlueReef project, which was carried out by the Danish Nature Agency from 1 August 2006 to 1 April 2013 in collaboration with Aarhus University and the Danish National Institute of Aquatic Resources. The project was funded under EU LIFE III.

The memorandum first introduces its scope and definitions (section 2). This is followed by a description of best practice and experience from previous nature restoration projects involving reefs (section 3) and information on how to use and further development the memorandum (section 4). Section 5 provides suggestions for further reading.

Since there are substantial statutory differences between onshore and offshore areas, section 6 outlines the statutory conditions and permits relating to marine nature restoration in Denmark.

1.1 Purpose

The purpose of this memorandum is

- to describe best practice and experience from stone reef restoration projects in Denmark;
- to create a platform for knowledge exchange and knowledge-building as more experience is gained from restoring stone reefs;
- to communicate this experience at international level;
- to provide a list of relevant Danish authorities, including a list of required permits.

To some extent, the recommendations for best practice may also be applied to the establishment of other types of natural as well as artificial reefs, as many of the considerations related to planning and construction will be the same.

1.2 Background

Many areas with stone reefs, in particular shallow waters (<10m) and coastal areas, have previously been destroyed due to the removal of stones and boulders for use in the construction of piers and breakwaters, as well as for other construction work. Removal of stones and boulders from the seabed was ultimately banned through an amendment to the Danish Raw Materials Act 1 January 2010.

So far, there has been no systematic monitoring of stone reefs in Denmark, so the extent and occurrence of natural reefs are not known. A conservative estimate from the Danish Nature Agency says that, over the past 50 years, a total of 40km^2 of exposed stone surface have been removed from stone reefs in coastal Danish waters (Dahl et al., 2003).

Some stone reefs have had almost all of their boulders removed, while others have primarily had boulders removed from the most shallow depths. The removal of boulders from stone reefs causes the remaining reef to become unstable due to erosion that further scatters the remaining stones and boulders.

Since stone reefs are important for marine biodiversity, nature restoration projects can be an important tool to conserve marine plants and animals.

2. Scope and definitions

This memorandum is limited to addressing the restoration of natural stone reefs, by which is meant re-establishment or restoration of naturally occurring, or previously naturally occurring, stone reefs.

Below is a definition and a brief description of natural reefs, including stone reefs, as well as artificial reefs. Furthermore, the text specifies what is meant by nature restoration in this memorandum.

2.1 Natural reefs

Natural reefs in Denmark were formed during the last glacial period, the Weichselian glaciation. The glacial movements and melting were responsible for depositing the materials that form the seabed in Danish waters today. Following the glacial period, erosion due to changes in water levels has shaped the seabed as we know it today, with its reefs, shoals, banks, fjords and channels.

Natural reefs can be divided into soft-bottom and solid-bottom reefs, of which the latter can be further divided into stone reefs, bedrock reefs and biogenic reefs.

Stone reefs vary considerably in shape and structure, from tightly packed collections of stones that arise abruptly from the surrounding seabed, to mosaic rocky bars, or they can have a more scattered structure with dispersed stones on a sand or gravel bed.

2.2 Artificial reefs

Artificial reefs are man-made reefs.

The purpose of creating artificial reefs is, for example, to enhance biodiversity or to increase the production of living marine resources in an area in order to promote recreational values, e.g. in the form of diving and sports fishing; commercial values, e.g. in the form of commercial fishing; or socio-economic values, e.g. in the form of tourism or the commercial development of a given area.

Some artificial reefs are created for non-biological purposes in connection with various installations such as coastal protection, harbour piers, offshore wind turbines, oil rigs, and similar.

Artificial reefs can consist of various materials, for example boulders, concrete or iron. Ship wrecks, which are favoured destinations for divers, can also function as reefs.

2.3 The concept of nature restoration

For the purposes of this memorandum, nature restoration of stone reef refers to both re-establishing (rebuilding) and restoring naturally occurring stone reefs.

Where virtually all of the stones and boulders have been removed, nature restoration will involve rebuilding both the physical and the biological structure of the stone reef. This may refer to nature restoration in a narrow meaning of the concept, i.e. when a project recreates the original characteristics of the reef with regard to type and size of the stones, as well as depth conditions, etc.

This could also be nature restoration in a wider meaning of the concept, when a project primarily seeks to re-establish the biological structure and function of the stone reef. Here, re-establishment can be realised using other types of stone and depth conditions if knowledge is lacking about the original structure, or if access to original materials is lacking.

Where more of the original reef still exists, the project will be about restoring it to its original state. This involves adding additional stones in order to protect the reef against erosion and improve its biological structure and function.

3. Best practice for restoration of stone reefs in Denmark

This section includes recommendations for restoration of stone reefs on the basis of experience from the BlueReef project and other restoration projects.

The recommendations concern public involvement as well as the various phases of the restoration project, including planning, construction and management. Processing by the authorities and permits in Denmark are dealt with in section 6.

A time table for the project and the individual elements broken down by phase are described in the following sections.

3.1. Involving the public

'The public' refers to all relevant stakeholders, including authorities, stakeholder organisations, users and citizens.

General
Public involvement is important to secure local backing for a project, just as local players can contribute useful knowledge to the project, see section 3.2.2.

- The public should be involved from start to finish in all phases of the project (planning, construction and future management).

- The decision-making process must be transparent and all stakeholders must be given opportunity to contribute with their knowledge and experience before any decisions are taken.

- It is important to ensure broad backing for the objective and name of the project. Not calling the project a 'restoration project' may be considered if there is any uncertainty or lack of documentation as to whether the re-established stone reef will deviate from the original, for example in terms of the types of stone used.

- A plan should be prepared for how to involve the public as early in the process as possible. This plan should address the issue of 1) stakeholders, 2) activities and 3) information.

Stakeholders
Stakeholders include 1) the people that will benefit from or will be affected by the activity; 2) the people involved in implemented the project (project participants), and 3) the people that manage the project.

- Stakeholders should be identified. Stakeholders typically include: local authorities, commercial navigation, the fishing industry, anglers, divers, yachters, local nature and recreation associations, as well as local tourist associations.

- An advisory group can be set up for the groups of stakeholders with the largest interest in monitoring and contributing to the project. Contributions include local knowledge and experience that could come into play in connection with identifying suitable locations and determining design, objective and future management aspects.

Activities
Activities include meetings and events for the general public to communicate information about the project and facilitate dialogue with and between stakeholders.

- Public meetings may be held at which there will be opportunity to gather relevant knowledge and discuss the implementation of the project, as well as different management scenarios for the re-established stone reef.

- Various other activities may be organised, for example, 'open-boat' events.

Information
It is important to provide information about the project so as to ensure awareness about the background and objective of the project, as well as how far the project has progressed. Restoration of stone reefs poses a special challenge because the project takes place at sea and below the sea surface, which means it is not readily visible to the public.

The following type of information could be considered in this context:
- Website with general information about the project, pictures, news service, publication of minutes, etc.
- Adds and articles in local newspapers and weeklies.
- Newsletters, fliers, posters, etc.
- Information via local radio and TV.
- Information via social media, e.g. Facebook.

3.2. The planning phase

This phase involves development and planning, from the idea phase to final project proposal, including defining the objective, collecting data, assessing risks, and e.g. preparing a monitoring programme.

3.2.1. Defining the objective

It is important to define and describe an objective, as the objective is significant for the choice of design, the location of the new stone reef, future management of the reef, as well as the preparation of a possible monitoring programme.

- Often, the primary objective will be to recreate the physical structure as well as the biological structure and function of a stone reef. This will help recreate a favourable conservation status for reef habitats that have been designated as particularly important habitats (1170 Reef) under the EU Natura 2000 sites.

- Other examples of objectives for rebuilding stone reefs include:
    - to protect or recreate certain habitat types, e.g. seaweed forests;
    - to conserve or enhance biodiversity;
    - to restore the stability or physical complexity of a reef;
    - to conserve blue corridors;
    - to improve water quality;
    - to nurture fish stocks.
    - to promote socio-economic objectives, e.g. diving or sports fishing, or commercial fishing, by nurturing local fish stocks; or
    - to promote the breakdown of nitrogen or improve oxygen conditions.

- It may be relevant to make adjustments to the objective during the planning phase due to the information and data collected about the locations and the original stone reefs.

3.2.2 Gathering local knowledge

It is important to gather local knowledge about the stone reef that is to be restored. Local knowledge can contribute valuable information about the original stone reef, any previous removal of stones, local currents, etc.

- Local fishermen, divers and others should be contacted as these people may be able to contribute information about the original stone reef, see section 4.1. Older fishermen often have knowledge about previously existing reefs and they may even have been active parties in the removal of stones from the reef.

- Information to be gathered includes information about
    - the current use of the area to help identify local interests;
    - the location, depth and extent of the original stone reef to help determine the geographical location of the re-established reef;
    - the scope of any previous removal of stones to gain more knowledge about stone size and the structure of the original stone reef;
    - previous and current fish stocks to gain more knowledge about local and regional developments in stocks;
    - local water level, currents and waves, etc. to acquire more information about exposure, risks of sediment transport, and similar.

3.2.3 Using historical sources to identify location

In addition to consulting the local population (see section 3.2.2.), knowledge about the historical occurrence of stone reefs or their vertical extent can be obtained from the following sources:

- *Old nautical charts*. The Danish Geodata Agency's archives contain nautical charts of Danish coastal waters from the years 1869, 1904, 1940 and 2001, which may be relevant. Furthermore, nautical charts exist for a number of local areas from a number of historical periods, and these should also be consulted.

- *Written descriptions for nautical charts* These contain a number of descriptions of local areas that pose a danger to navigation and maritime traffic. Stone reefs at shallow water will therefore often have been described here. Changes to depth isolines around bars and the indication of 'rocks' or 'stone reef' on the chart should be analysed together with "*Beretninger til søkortet over...*" (Written description for nautical chart of ...), which is intended for use together with the separate nautical chart.

- *Pilot books*. Older pilot books exist for certain areas, which e.g. contain detailed descriptions of local navigation conditions, stone reefs and individual rocks. The Danish Maritime Museum holds a collection of these pilot books published by the Royal Danish Nautical Charts Archive from 1843 and onwards.

3.2.4 Acquire relevant data about the location

Depth and bottom contour (prior hydrographic surveys)

Depth and bottom profile will typically vary within short distances, and it may therefore be relevant to obtain verification and more detailed descriptions of data from nautical charts.

- It is recommended to perform hydrographic surveys of the stone reef and the adjacent area in order to calculate the amount of stones needed for the particular restoration project.

- The hydrographic surveys should be performed following the Danish Geodata Agency's guidelines (see the relevant guidance document), in particular if the data is to be included in nautical charts.

Hydrodynamic conditions

The plant and animal communities that develop in the re-established stone reef will be dependent on the local hydrodynamic conditions surrounding the reef. The hydrodynamic conditions will also be of significance for the stability of the reef.

- It may be relevant to collect data concerning e.g. wind-driven circulation, coastal front systems, local wind-driven wave patterns and wave patterns that are not driven by local wind patterns, sediment transport, and the characteristic and dynamics of the bottom sediment.

- In connection with large restoration projects which involve a change in the structure of the stone reef, it may be relevant to evaluate both extreme and normal wave conditions at the location. A dynamic wave model could be used here, which describes wave size and wave frequency in relation to different scenarios for water level and wind conditions.

- Information from local fishermen, divers or other people who frequent the relevant offshore area (see section 3.2.2.) may contribute to creating a picture of previous and current conditions at the location, and highlight what should be prioritised in connection with the restoration project.

- Knowledge about physical and biological conditions for a large number of fjords, open inshore waters and offshore waters is available from marine databases. The Department of Bioscience at Aarhus University manages the Danish environmental marine data database. From here you can acquire data on light conditions expressed as visibility depth and depth profiles that describe oxygen conditions and salinity analysed by time of year, as well as biological data on benthic fauna, eelgrass and seaweeds on hard-bottom surfaces. A description of the Danish database is available at MADS.dmu.dk, from where data can be retrieved.

3.2.5 Risks to consider

Seabed conditions

It is vital that the seabed can carry the weight of the restored stone reef, so that the stone reef does not collapse or become buried in the sediment. Geological preliminary surveys of the seabed may therefore have to be performed through seabed drilling and/or seismic surveys.

- At locations where stone reefs have previously existed but have since been damaged or entirely removed, the seabed will most likely be able to carry the weight of the new stones.

- If there is evidence of strong erosion in the area, or if there is documentation that sand and gravel dredging is taking place in the area, geological surveys should be performed before any decision about a restoration project is made.

- If stone reefs are established in areas which previously held no reefs, the associated risks are greater and geological surveys are therefore called for.

Sediment transport

The restored stone reef can affect currents and sedimentation in the area surrounding the stone reef. Performing model calculations of future sedimentation should therefore be considered.

- It may be relevant to assess sediment transport after the restoration, e.g. in relation to preventing channels or other natural habitats such as bubbling reefs from sanding up.

Establishing inappropriate habitat corridors

- The establishment of stone reefs in areas where previously there were no stone reefs could lead to unwanted invasion of non-native species. This risk can be examined by the use of distribution models for organisms that have pelagic distribution stages.

Risk of "oxygen-deprived locations"

- Establishing or re-establishing stone reefs in brackish environments or at water depths with reduced light penetration will benefit common mussel or other benthic fauna. If the reef is established with the objective of producing oxygen in bottom water, a predominance of fauna organisms will result in the opposite, namely a location that has net consumption of oxygen. A thorough examination of salinity and light at the bottom should be performed in order to clarify the risks under present conditions.

The effect of time of year

- Massive settlements of acorn barnacle or common mussel may affect and delay the migration of other species than desired on the newly established stone reef. To minimise the settlement of acorn barnacle and common mussel directly on newly placed stones, the stones should be placed during the winter season, although this is more costly due to less calm wind conditions.

3.2.6 Design and materials for construction

Stone type

Natural rock should be used when restoring stone reefs. This ensures a surface structure towards which benthic animals and algae have optimised their attachment structure through millennia of evolution. Furthermore, typically concrete only has a durability of around 30 years.

There are several possible sources of natural stone:

- The best solution is to reuse "sea boulders" from piers in connection with harbour expansion. Sea boulders originate from stone reefs and are typically very rounded in shape and have the greatest degree of originality.
- Another possible source is "fieldstones", which can be procured from construction works or from farmers. This type of stone also typically has rounded shapes.
- The third alternative is to use "quarry stones" from quarries in Sweden or Norway, for example. Compared with sea boulders and fieldstones, quarry stones have irregular shape and sharp edges.

Stone size

The size of the stones used should reflect the physical environment as well as the objective and budget of the project.

- It is important to ensure the stability of the stones laid out. At extremely exposed locations, it may be necessary to use large boulders.
- At very protected locations, a stone reef made from cobbles (very small stones down to 4-5cm in diameter) may be stable and function as an excellent habitat for hard-bottom communities.
- Cavernous boulder reefs have an extra quality in their high physical complexity and thus greater biological diversity. Using similar-sized boulders and placing them tightly packed or in several layers, will ensure the formation of more interstitial spaces.

Stone reef design

The design of the stone reef is vital for its biological function. It is therefore important to balance the design with the objectives of the restoration project. Below are some examples of how to do this (see also section 3.2.1).

Objective: To protect or recreate certain habitat types, e.g. seaweed forests

Stone reefs situated at a depth where sunlight can penetrate (the photic zone), and which have a large surface area, are generally well suited habitats for forests of seaweed (macro algae). The size of stones used in the top layer must be balanced against the expected size of the individual macro algae, otherwise, stones that are too small risk being "carried away" by the current. For example, leaf-bearing brown algae can move stones up to 7-10cm in very exposed areas.

Objective: To conserve or enhance biodiversity

A stone reef with large biodiversity must have many micro habitats where the individual species can settle. Varying bottom conditions and high physical complexity ensure this.

Objective: To restore the stability or physical complexity of a reef.
The stable stone reef is characterised by having a solid bottom layer, including layers of boulders on top of the exposed parts of the reef. Cavernous boulder reefs have the greatest possible physical complexity.

Objective: To conserve blue corridors
Several stone reefs which are to form part of a distribution corridor for organisms must be established in the down-stream direction of dominant ocean currents so as to take account of organisms with pelagic distribution, or so that the distance between the stone reefs allows the organisms to "migrate" between the areas. The distance between stone reefs influences both migration time and the duration of the operational phase and, consequently, may also influence whether the desired biological distribution of organisms is achieved.

Objective: To improve the water quality
Stone reefs can affect physical conditions such as currents, sediment transport and turbulence. Furthermore, they can be situated so that local upwelling is achieved (that is, when bottom water, which is usually nutrient-rich, is forced to the surface). If the reef is located at depths that border on oxygen-poor bottom layers, the location of the reef can influence the transportation of oxygen to bottom water.
Stone reefs with seaweed forests located in bottom water in areas with high water column stratification and problems with hypoxia can probably add oxygen to bottom water at critical points during late summer and thus reduce the risk of the release of nutrient salts from the bottom. During the establishment of stone reefs, nitrogen is bound up in the biomass of macroalgae and benthic animals that develop at the location.

Objective: To nurture fish stocks
Fish generally prefer complex habitats where plants or the bottom structure provide cover from predators and from currents. The many niches in a stone reef therefore provide a home for many species of fish, and the fish biodiversity is generally high.
Small fish are important food for many fish species, including the species that are important from a commercial and recreational perspective. Small fish such as goby are naturally drawn to the shadow provided by projections of the reef structure and areas of macroalgae and eelgrass. Species of pipefish also tend to stay in the area of macroalgae and eelgrass.
In addition to typical stone-reef fish species which stay in and around stone reefs, also codfish are drawn to topographical variations on the seabed. During autumn, in particular, codfish gather around stone reefs before they migrate to their spawning grounds. Stone reefs offer plentiful refuge, and it has been documented that in areas with stone reefs, codfish have higher survival and growth rates than codfish on sandy bottoms.

3.2.7 Monitoring

With the implementation of a monitoring programme, it will be possible to document what the restoration project has meant for fauna, benthic animals, fish, etc. and whether the project has realised its objective. For smaller projects, simple photo monitoring can serve to document the outcome.

- Monitoring should include preliminary surveys before the project is commenced as well as one or several surveys after its completion.

- So far, the existing knowledge base does not merit a recommendation as to how long monitoring should take place. The development of biomasses of benthic animals and plants on boulders that were restored to the Læsø Trindel reef was assessed to be far from complete after four years. According to a conservative estimate, the process of migration to the area, succession and development of biomasses corresponding to a climax community will take at least eight to ten years.

- The monitoring programme should be designed so that the results can be used to evaluate whether the success criteria have been met and whether the reef has had the intended favourable impact.

- On the basis of the expected colonisation by algae, benthic fauna or fish, the monitoring programme should be designed with a view to collecting information about the occurrence of these organisms. The methods may vary according to species, the physical structure and depth of the reef, etc.

- Monitoring of the occurrence and development of macroalgae can be used to evaluate whether the stability of the reef has been restored.

- It is recommended to survey a control area before and after the project. These surveys should be carried out simultaneously with surveys of the restoration area. This will make it possible to calibrate the results of the restoration projects and take general trends into account which are not linked exclusively to the restoration efforts.

3.3 Construction phase

3.3.1. Acquiring and placing stones

Acquiring and placing stones will typically be the largest item of expenditure in the project, and the organisation of this is of great importance to the project's financial framework and to the quality of the restored stone reef.

- Costs for transporting and placing the stones are lower in periods with quiet weather. In open and exposed areas, the weather may affect total costs significantly.

- The stones are to be placed with pinpoint accuracy with regard to position as well as the establishment of complex cavernous boulder reefs, and must follow a reef design. Such an assignment requires a specialised vessel.

- Choosing when to deploy the stones should take into account weather conditions as well as the possibilities for subsequent biological development.

The biological development is closely related to the project's objective (see section 3.2.6), and with the wish to promote specific species.

- It may be relevant to use excess material from other projects, such as offshore wind turbine installations, bridge installations etc.

3.3.2 Working area - buoying and bans

During the project, it may be appropriate to buoy the working area and to introduce a ban on navigation and fisheries. This must be in accordance with the regulations from the relevant authority, see section 6.

- Buoying a working area is recommended for safety reasons (and this may be a requirement as part of the permit), partly with regard to placement of stones, and partly with regard to changes in depths which are not included in nautical charts.

- If an actual monitoring programme is implemented, it is recommended the project obtains authority to issue a ban on any physical disturbances (navigation, the use of disturbing tools, noise) which can influence the developing community and monitoring.

- When communicating with stakeholders, the issue of buoying and introducing bans should be discussed with all groups, and these matters should be publicly known when discussing the location of the stone reef.

3.3.3 Final hydrographic surveys and safety of navigation

A final hydrographic survey will usually be required in connection with the reef restoration permit. Data from the hydrographic survey must be submitted to the Danish Geodata Agency to update nautical charts. The establishment of stone reefs may influence safety of navigation.

- Method and accuracy of the hydrographic survey will be agreed with the Danish Geodata Agency before restoration begins.

- Stones laid out in shallow waters may create a risk of grounding, if the water depth is reduced considerably. The risk is greatest near fairways and other navigated areas, and any traditional routes for yachting should be taken into account.

- As grounding can lead to loss of human life and assets with subsequent claims for compensation, the establishment of new stone reefs must be notified through an official media; i.e. the Danish equivalent to Notices to Mariners.

- It is further recommended to minimise the risk of grounding through detailed information to yacht clubs, diving associations etc., and preferably over a number of years, as well as to buoy the reef.

3.4. Management

When the stone reef has been restored and any monitoring programme has been completed, the future management of the stone reef and its surroundings should be decided.

It is recommended to prepare a management plan to ensure the best possible holistic management of the restored stone reef area. If the management plan includes regulations for activities or if it covers Natura 2000 sites, it must be approved by the relevant authorities, who may also be responsible for preparing the plan, see section 6.

The management plan and various scenarios for the future management of the stone reef should be discussed with relevant stakeholders, see section 3.1.

The management plan should address possible threats to the stone reef. The management plan may include the following measures:

- protecting the stone reef against damage (for example by establishing an anchor buoy for divers and other activities)
- maintaining the stability of the restored reef (for example by preventing bottom-towed gear in the area)
- maintaining the possibility of further establishment/maintenance of stable plant and animal communities on the stone reef (water quality, habitat quality)

The management plan should address possible activities in the stone reef area. For activities that could have a negative effect on natural assets, the effect should, as far as possible, be surveyed and documented before these activities are allowed in the area. Typical activities include:

- Commercial fishing in, on and around the stone reef
- Navigation in general in the stone reef area
- Recreational fishing/angling in and around the stone reef
- Diving trails/diving in the area.

It is recommended that the management plan includes a monitoring programme to follow the continued development (colonisation) of the restored reef. Continued monitoring will also form the best basis for addressing the activities in the area.

The management plan should address safety of navigation in order to ensure safety, by using permanent buoying or buoying over a number of years.

Information about the management plan should be developed.

4. Use of and further development of this memorandum

This memorandum is the first collection of experiences and recommendations written on the basis of the BlueReef project and a few other stone reef projects.

Therefore, everyone working with nature restoration of stone reefs is encouraged to provide comments and input to the memorandum. Contributions should be submitted to the Danish Nature Agency, Haraldsgade 53, 2100 Copenhagen, Denmark. Email: nst@nst.

It should be noted that even though this memorandum is about nature restoration of original stone reefs, to some extent, the recommendations for best practice may also be applied to the establishment of other types of natural as well as artificial reefs, as many of the considerations related to planning and construction will be the same.

The Danish Nature Agency will therefore also be interested in relevant experience from other types of projects, including projects with other types of natural reef and establishment of artificial reefs.

5. Useful literature and links

The BlueReef project See www.Bluereef.dk

Dahl, K.; Lundsteen, S.; Helmig, S. 2003 *Stenrev, Havbundens oaser*, Gads Forlag

OSPAR Guidelines on Artificial Reefs in relation to Living Marine Resources. Agreement 2013-03.

Natura 2000. See www.naturstyrelsen.dk/Naturbeskyttelse/Natura2000 (only available in Danish)

6. Processing by the authorities and permits in Denmark

As a general rule, territorial waters do not belong to anyone, however the state exercises a sovereignty over territorial waters.

In a number of areas, this sovereignty has been converted into sectoral acts, including the Coastal Protection Act, which states that land reclamation and embankment, construction or placement of fixed or anchored devices or objects, placement of vessels intended for other purposes than navigation, or dredging or excavation activities in Danish territorial waters require authorisation from the Minister for Transport.

Territorial waters cover the sea from the coastline or a base line (a straight line between points on the coast or islands) to a line 12 nautical miles (about 22km) off the coast.

Moreover, sectoral acts have been implemented for the overall marine area with special authority for a number of government authorities, including oil and gas exploitation in the subsurface, offshore renewable energy exploitation, extraction of raw materials, fisheries and defence activities, regulation of navigation such as the establishment of prohibition zones as well as protection of the environment, nature and historical interests.

6.1 Nature restoration permits

A nature restoration project with restoration or rebuilding of stone reefs in territorial waters requires a permit from the Danish Coastal Authority. The permit is awarded pursuant to section 16a of the Coastal Protection Act:

> *In territorial waters and only after authorisation from the Minister for Transport, it may be allowed to:*
> *1) carry out land reclamation or embankment,*
> *2) construct or place fixed or anchored devices or objects,*
> *3) place vessels intended for other purposes than navigation, or*
> *4) carry out dredging or excavation.*

The Danish Coastal Authority assesses the application for nature restoration in relation to a number of conditions, such as the project's impact on the coastline and on environmental and natural conditions, including the impact on international nature conservation sites (Natura 2000 sites). The Authority also decides whether the type or scope of the project requires an environmental impact assessment (EIA).

Before the Danish Coastal Authority makes a decision, the application is subject to consultation by a number of authorities. Thus the project's consequences with regard to shipping, fisheries, environment, cultural heritage, protection of nature, planning and any nearby existing installations etc. are assessed.

A permit is contingent on compliance with a number of terms, of which several require authorisation from other authorities. For projects with restoration and re-establishment of stone reefs, these terms will typically include:

- Hydrographic survey and submission of drawings to the Danish Geodata Agency for updates of nautical charts and nautical publications (notification of completion)
- Establishment of working area with navigation restrictions
- Information to the Danish equivalent to Notices to Mariners
- Requirements for choice of material, design and establishment.

6.2 Other permits

Hydrographic survey

Hydrographic survey includes collection of matching data of depth, position and time. Hydrographic survey is carried out with single beam echo sounders or multibeam echo sounders which can provide more detailed information of the height profile of the seabed.

Hydrographic survey requires authorisation from the Danish Geodata Agency who can use the data to issue nautical charts and nautical publications free of charge. Among other things, the application for a permit must include information about the purpose, position and date of the survey, vessel and survey equipment. Furthermore signed declarations on use of data etc. are required.

The Danish Geodata Agency issues the publication *Søkortrettelser* (nautical chart corrections) and this publication ensures that yachters and other navigators can keep their nautical charts and nautical publications up-to-date at all times.

For further information, go to the Danish Geodata Agency website: www.gst.dk

Buoying of working area

Areas can be established for construction assignments at sea with prohibition against unauthorised navigation, anchoring, fisheries or diving, if this is for the sake of safety of navigation or prevention of danger otherwise.

The Danish Maritime Authority authorises the establishment of areas where navigation is restricted. The application for a permit must contain nautical chart sketches, information about position, when the restrictions shall apply to the area, the reason for establishment and the restrictions wanted. The applicant can collect statements from relevant parties to advance the administrative procedures.

Application template and further information can be obtained on the Danish Maritime Authority website: www.sofartsstyrelsen.dk

Ban against fisheries

The Danish AgriFish Agency under the Ministry of Food, Agriculture and Fisheries of Denmark is the authority responsible for fisheries regulation.
Authorisation to ban fisheries can be applied for from the Danish AgriFish Agency, if the project has a scientific, environmental or fish management-related aim, or if monitoring programmes are to be conducted.

More information is available from the Danish AgriFish Agency website:www.naturerhverv.dk

Safety of navigation

The Danish Maritime Authority is responsible for buoying a number of more specific areas, including the main waters the North Sea, the Skagerrak, the Kattegat and the Baltic Sea as well as major passages.

All other areas adjacent to these areas, or areas in which local interests, e.g. ports., create a need for buoying, the relevant stakeholders must pay the costs and are responsible for maintenance of buoying. All buoying activities must be carried out in accordance with Danish Maritime Authority guidelines and authorisation.

Planned changes in navigation conditions must be submitted to the Danish equivalent to Notices to Mariners in due time - typically four weeks in advance.

You can read more about buoying on the Danish Maritime Authority website: www.sofartsstyrelsen.dk

Annex A. Structure and function of stone reefs

This section describes the most important physical factors of significance for the biological content of a stone reef, and describes specific types of reef.

Physical factors must be assessed on the basis of the objective of the restoration project, and the possibilities and limitations associated with this.

Factors affecting the biological content

The design and location of the reef can be optimised to meet the desired biological outcome from the project.

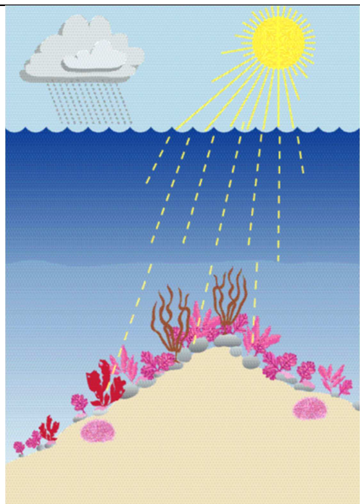
Light and exposure conditions are play a key role with regard to the biological communities found on a stone reef. For example, significant wave forces may limit the diversity in species to only include large resilient species of alga which can withstand the forces caused by waves and which are capable of staying firmly affixed to a stone surface throughout their lifetime.

The presence of light is essential for the algae on the stone reef. Light becomes weaker through the water column. How far light can penetrate, depends on several factors:

- the amount of suspended sediment and dissolved organic material in the water column
- the plant plankton production which, again, is dependent on the supply of nutrient salts
- the water's absorption of light.

Each algae species has adapted to an optimal level of light. Where there is plenty of light, a multi-layered seaweed forest often develops on the reef (figure 1). Species that require a lot of light are found at the top. In their shadow, there may be several layers of other species which thrive.

Figure 1 Multi-layered seaweed vegetation with major or minor elements of large brown algae which are found at depths with significant to moderate light and not too high exposure. The vegetation decreases and becomes dominated by red algae as light levels decrease, and eventually all vegetation disappears.



In addition, the salinity also plays a significant role. A reef in a area of an inlet system influences by freshwater, will typically contain less species than a similar reef at the mouth of the inlet where the salinity is higher.

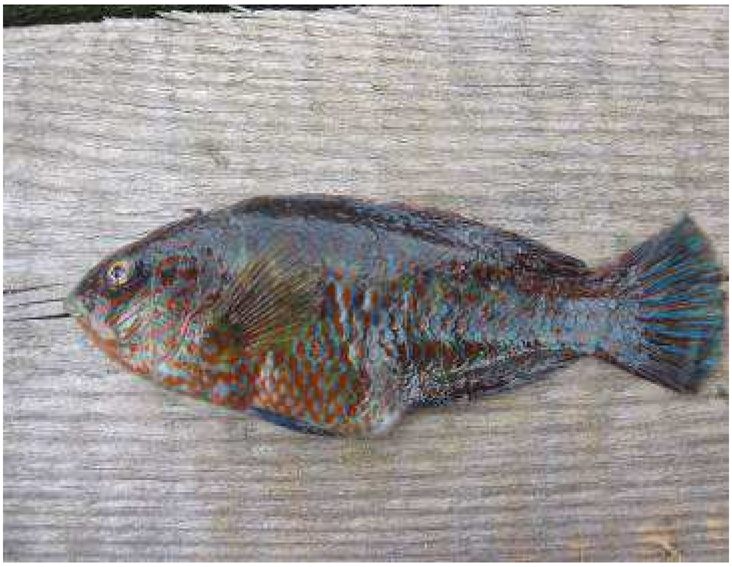
Higher values of nutrient salts in an aquatic area will also stimulate growth of a special type of alga. These algae are often filamentous or thin and more plate-like. Such algae have a relatively short life cycle, but are able to spread and grow very quickly and typically on other seaweed plants. Large, dense populations of this type of algae can have negative impacts on perennial algae communities.

Finally a reef with great variations in the topography will also be more attractive to a number of fish species than a reef with a flat structure. Cavernous boulder reefs, in particular, serve as a refuge for a number of fish species, which exploit the hiding and foraging possibilities provided by such a reef. This type of reef is also attractive to European lobsters, especially if it allows the lobster to dig holes under the stones. Stone reefs in shallow waters will typically have a richer fish fauna, and also more juvenile fish compared with a stone reef in more deep waters.

Examples of different stone reef communities

The following section mentions some of the main types of stone reef communities and describes some of the physical conditions required in order to achieve certain idealised types of reef habitat. The physical structure and boundary of the reefs can vary a great deal. In the real world, there is obviously a gradual transition between the different types of reef, which differ in terms of light and exposure. These two physical parameters that influence reef structure also play different roles in protected inlets as opposed to in open and exposed waters.

Stone reefs in shallow waters with high exposure and much light
Biological contents: Seaweed forest will dominate and relatively little diversity in species. Presence of large brown algae will often generate a relatively high biomass (figure 2a). Filamentous algae may dominate where there are high levels of nutrient salts and very high levels of stress. Depth area: can vary from 0.5-6m depending on the physical exposure. The fish fauna will be dominated by fish from the wrasse family such as the corkwing wrasse (figure 2b) and the goldsinny wrasse, moreover two-spotted gobies, butterfish, eel and species of short-spined sea scorpion as well as juvenile codfish, particularly coalfish and pollack are often seen.



Figures 2a-2b.
2a (left): Fucus community on 1½m depth at Hellebæk north of Sealand. Foto: Karsten Dahl.
2b (right): Corkwing wrase caught at Læsø Trindel. Foto: Claus Stenberg.

Stone reefs with moderate exposure and good to moderate light conditions

Biological contents: Seaweed forest will dominate and great diversity in species of macroalgae. The presence of multi-layered vegetation with both brown algae and red algae (figure 3b). The biomass is large or very large. Studies have documented the occurrence of average biomasses of up to 1.9 kg/ashless dry weight/m^2 on hard bottom (Dahl et al, 2005). There will also be a greater variety of fish species than on the exposed reef. Wrasse fish will typically dominate with several species e.g. ballan wrasse (figure 3a), small-mouthed wrasse and female cuckoo wrasse/cuckoo wrasse. Species from the goby family, such as the two-spotted goby, the black goby and the sand goby, will also be more frequent, and, at lower depths of the reef, also the glass goby. Codfish will include cod or coalfish, mostly juvenile, but also adults at deeper parts of the reef. Eel and species of short-spined sea scorpion also live on this type of reef, and sea trout will typically forage here.

Depth area: There is a lack of biomass data for seaweed forest in inlet areas which can support the knowledge base. At stone reefs in open waters, this type of reef is common in a depth interval of 4-15m.


Figure 3a-3b.
3a (left):Caught of ballan wrasse (photo: Claus Stenberg).
3b (right): Multi-layerede algae community at 6m dybde from Briseis Flak in the southern part of Kattegat (photo: Karsten Dah).

Stone reef with little exposure and poor light conditions

Biological contents: hard-bottom fauna typically dominates with some algae. Typical species are moss animals at very high salinity, the soft coral dead men's fingers (figure 4a) which also require relatively high salinity, a wide range of fungi and sea anemones, as well as common mussels in the western part of the Baltic Sea (figure 5). Fish fauna will be dominated by larger species from the wrasse family such as ballan wrasse, and adult codfish such as cod and coalfish. From the goby family, the sand goby and the glass goby will be common. Catfish is also one of the species which can be found on the deeper stone reefs together with lobster (figure 4b).

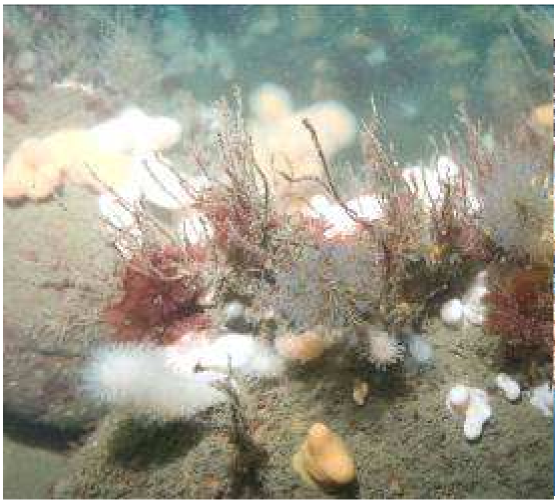



Figure4 a-4b.
4a (left): Community dominated by the soft coral ded mens finger and hydroider, which both are typical elements on the deeper stone reef. From the stone reef "Den Kinesiske Mur" at 18 m depth. Photo: Karsten Dahl.
4b (right): Lobster. Photo: Claus Stenberg.

Stone reefs with low salinity

This type of reef is distinct because common mussels can become a very dominant element at almost all water depths (figure 5). Low salinity restricts starfish in keeping down the common mussel population. Where the level of light is adequate for algae growth, some algae species and common mussels in particular can live closely entangled. This type of reef is e.g. completely dominant south and east of the shallow threshold at Gedser-Dars and Drogden.

The fish fauna will typically be relatively poor in species. The goldsinny wrasse will often be the only species from the wrasse family. The goby species will often be two-spotted gobies, black gobies and sand gobies and from the codfish family only cod will be present. Sea trout also tolerates low salinity, and they can be found on these stone reefs, particularly during winter when they migrate to areas with lower salinity. Perch is also one of the species which can be observed.

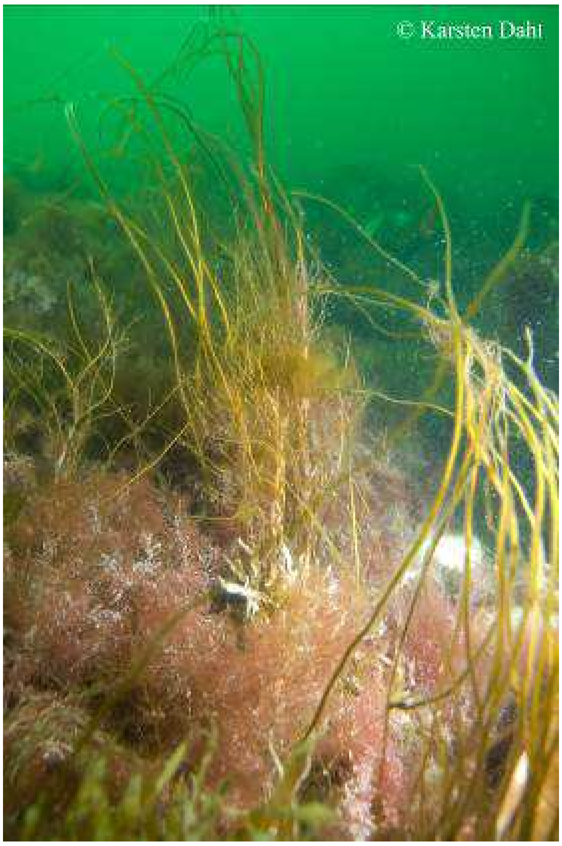
Figure 5. Stone reef at Møns Klint on 17m depth. Common mussels dominate the biomass but between the mussels can also be found the algae "gaffeltang" (Furcelaria lumbricalis) Photo: Karsten Dahl

Stone reef with smaller stones

This type of reef is characterised by low exposure and moderate light levels. A high level of light will typically result in the development of algae vegetation of opportunistic species (figure 6). Perennial species can also be present when they have grown so big that the stones their growing on, can be transported to deeper water due to currents at the bottom. These bio-induced erosion processes can only take place if there is adequate exposure.

The physical complexity of this type of stone reef is small, and this is reflected in the number of fish species, which typically will be relatively modest and dominated by the smaller species from the wrasse family. Depending on the vegetation density, there may also be codfish, gobies, butterfish and short-spined sea scorpions.

Figure 6. Algae community with typical opportunistic species. “Strengetang” (*Corda Filum)* is a characteristic species for unstable bottom. Photo from Læsø Trindel 6m depth in 2007 before the restoration project.
Photo: Karsten Dahl.



Stone reefs with dispersed stones

Such stone reefs are quite common (figure 7). Studies from Mejl Flak (Dahl et al, 2005) show that biomasses on dispersed stones that constitute less than 10% of the bottom clearly exceed the infauna in the surrounding gravel and sand bottom. The typical fish species found on the types of stone reef mentioned above, can also be found on this type of stone reef, but often only in the immediate vicinity of the individual stones, and will therefore in total be fewer in number than on the compact stone reef. The surrounding gravel and sand bottom will also contain many of the typical species for this type of sediment such as dab, plaice, sole, brill and turbot. Therefore many fish species will be represented in areas with stone reefs with dispersed stones.

Figure 7. Disperse d stones on sandy bottom close to Hornbæk plantage. Photo: Karsten Dahl.

Reference:

Dahl, K., Lundsteen, S. & Tendal, O. S. 2005: Mejlgrund og Lillegrund. En undersøgelse af biologisk diversitet på et lavvandet område med stenrev i Samsø Bælt. Danmarks Miljø-undersøgelser & Århus Amt, Natur & Miljø. 87 s. – Faglig rapport fra DMU nr. 529.
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