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Tools to assess the conservation status of marine Annex 1 habitats in Special Areas of Conservation

Phase 1: Identification of potential indicators and available data

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Karsten Dahl
Martin M. Larsen
Jesper H. Andersen
Michael Bo Rasmussen
Jens Kjerulf Petersen
Alf B. Josefson
Steffen Lundsteen
Ingela Dahllöf
Trine Christiansen
Dorte Krause-Jensen
Jørgen L.S. Hansen
Gunni Ærtebjerg
Peter Henriksen
National Environmental Research Institute

Stig Asger Helmig
Johnny Reker
Danish Forest and Nature Agency

Data sheet

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Authors: Karsten Dahl[1)], Martin M. Larsen[1)], Jesper H. Andersen[1)], Michael Bo Rasmussen[1)], Jens Kjerulf Petersen[1)], Alf B. Josefson[1)], Steffen Lundsteen[1)], Ingela Dahllöf[1)], Trine Christiansen[1)], Dorte Krause-Jensen[1)], Jørgen L.S. Hansen[1)], Gunni Ærtebjerg[1)], Peter Henriksen[1)], Stig Asger Helmig[2)], Johnny Reker[2)]

Departments: [1)] National Environmental Research Institute, Department of Marine Ecology
[2)] Danish Forest and Nature Agency, Division of Sea and Habitats

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Abstract: The report is the first part of a project whose overall aim is to develop an assessment tool to evaluate conservation status for Danish marine habitats included in the Habitats Directive. The report includes several main issues: a proposal for a concept for development of a quality assessment system including a discussion of problems related to the definitions of the marine habitats, an evaluation of available national data from marine habitats in Natura 2000 areas, identification of possible indicators to be used in the assessment and a suggestion of documentation guidelines for chosen indicators.

Keywords: Marine habitats, Habitats Directive, assessment tools, assessment data, indicators, conservation status, Nature 2000 areas

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For sale at: Ministry of the Environment
Frontlinien
Rentemestervej 8
DK-2400 Copenhagen NV
Denmark
Tel.: +45 7012 0211
frontlinien@frontlinien.dk

Contents

Summary

This project is the first phase of a larger project with the overall aim to define specific conservation objectives for the marine Annex 1 habitats of the Habitats Directive.

Eight of the marine Annex 1 habitats occur in Danish waters. Marine Natura 2000 sites where Annex 1 habitats are the reason or part of the reason for the designation cover 10,584 km^2 or 74,7% of the total area covered by the Danish Natura 2000 network.

The report discusses the weaknesses of the definitions of the marine Annex 1 habitats. These habitats are defined primarily on the basis of geomorphology and not biology. Most (perhaps all) of the marine Annex 1 habitats encompass different biological communities. These should be defined or at least treated as separate habitats, each with their own set of indicators and thresholds. As a solution to this problem, it is proposed to divide the Annex 1 habitats into smaller often biologically founded units, called sub-features.

The biological content of a habitat is governed by a large number of natural factors such as depth, illumination, salinity, distance to nutrient sources, bottom type, and exposure to wind and currents. Therefore, it can be difficult, if not impossible, to identify meaningful universally applicable biological indicators for assessing the conservation status of the Annex 1 habitats. The choice of indicators and their thresholds may, therefore, be applicable in certain water types only or even be site-specific.

All marine habitats are negatively influenced by human activities, and assessments of Danish marine areas state that the quality of the ecosystems in general is not acceptable. A reduction of pressure from many of the anthropogenic pressure factors will have a positive effect on the structure and functioning of the Annex 1 habitats. Other pressure factors exist, like introduction of invasive non-indigenous species, which may result in irreversible negative impacts.

The development of a quality assessment system for marine Annex 1 habitats should, ideally, be based on knowledge of the habitats distribution, extent, structure, and functioning and of the occurrence of characteristic species in the absence of known anthropogenic pressure factors. However we face the problem that description of impact of pressure factors in scientific and other types of literature is a rather recent thing for Danish marine waters. The task – and the challenge – is to choose the levels of human impacts that can be accepted, if a favourable state of conservation is to be attained.

The development of a system for assessing conservation status for the marine Annex 1 habitats must take the following central aspects into account:

- Annex 1 habitats should be subdivided into biologically meaningful units (sub-features) in accordance with JNCC's proposal for Great Britain.

- Knowledge of the distribution of the Annex 1 habitats and of their contents of biological based well-defined habitats is for Danish waters generally very poor. Considerable effort is needed to gather such knowledge. Until this has been done, the first step is to develop an assessment system for habitats or habitat sub-features based on indicators and thresholds, that reflects the general quality of the site rather than specific communities of fauna and flora.

- Most marine habitats have a depth dimension, which is central to the vegetation due to light extinction. The system of conservation objectives must take this important factor into account, perhaps by typological segregation.

- Marked structuralising natural physical and chemical gradients through the inner Danish waters strongly influence biology. Typological segregation or site-specific indicators and/or thresholds are, therefore, relevant.

- Marine ecosystems are generally very dynamic. Knowledge of natural variations in controlling factors is essential for development of an assessment system for conservation status.

- A baseline describing favourable condition of the Annex 1 habitats or habitat sub-features can not solely be based on existing environmental conditions.

The important first step in developing a biological based system for assessing Annex 1 habitat conservation status is to achieve knowledge about the interaction between important pressure factors and the chosen indicators response to these pressure factors.

The chosen indicators must together be able to report on the condition of structure, function and characteristic species of the annex 1 habitat or sub-feature in question and they shall function as tool to evaluate management of Natura 2000 sites in the future.

Knowledge about the relationships between indicators and pressure factors will be established using historic as well as recent data combined with empirical or dynamical modelling where possible.

A satisfactory description of the relationships between pressure factors and attributes will be a powerful management tool. The tool will enable environmental managers to set thresholds for interest features and, thereby assess the condition of the feature.

If there is no sufficient data for scientific based thresholds, temporarily thresholds can be set based on expert judgement until proper data is available.

The ecological objectives of the EU Water Framework Directive are based on a different concept. This directive state that the objectives have to be defined based on knowledge of reference conditions. The reference condition is defined as pristine conditions with no or very minor human impacts. Despite of this difference between the two directives, it is very important to ensure the highest level of harmonisation between them.

The most important anthropogenic pressure factors have been identified for 7 of the 8 Annex 1 habitats present in Danish waters. Potential indicators have been identified and suggestions for methods to define their thresholds have been formulated.

The data evaluation indicates that a great amount of valuable data exists from Danish marine areas. However, dealing with specific habitat sites, this assessment also show that at present none or only sporadic data exists from many sites, making a judging of conservation status impossible in those cases.

The Danish regional and national environmental monitoring and mapping data have largely been collected according to standardised procedures since the 1980s. A large portion of the data is stored electronically. In spite of this, the process of attaining an overview of these data in connection with this project has been very time consuming, since the data were found in many different types of databases. Comprehensive analyses of data from the various Annex 1 habitats will entail some work gathering the data prior to analysing them.

The report also gives a proposal for guidelines for documenting the conservation objectives, to be described at a later stage of the process of developing a quality assessment tool for marine habitats.

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1 Introduction and aim

This project is the first phase of a larger project initiated by the Danish Forest and Nature Agency. The overall aim is to develop a tool (a system) to assess the conservation status of marine habitats, listed in Annex 1 of Council Directive 92/43 EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (the Habitats Directive). This work is likely to support the revision of existing technical guidelines, for a suite of national and regional monitoring programmes. The results of the project will also be reported to the European Commission

The first phase of the project has the following 3 aims:

- To identify potential indicators for a quality assessment system for marine Annex 1 habitats. The identification is done with focus on the anthropogenic pressure factors, which have an impact on the quality of nature. Major natural physical factors in Danish waters such as salinity, depth, water exchange, act to structure very different biological communities and their influence should be taken into consideration as well. The indicators must as a minimum be able to describe the condition of the structure and function and characteristic species and species communities characterising the specific habitat.

- To verify whether data exists from a range of national and regional monitoring programmes and/or other relevant investigations, which can be used to identify relevant indicators and thresholds. These include regional monitoring and surveillance programs performed by the Danish counties as well as the national monitoring programme under the ”Action Plan for the Aquatic Environment” and from the follow-up programme NOVA.

- To describe documentation requirements for the formulated indicators.

The Danish Forest and Nature Agency has stressed that the problems in the definitions of the marine Annex 1 habitats should be thoroughly described along with the difficulties that the present definitions create for the development of a system for assessing the conservation status. Consequently, the report includes a description of the present knowledge concerning Danish marine habitats, anthropogenic pressure factors and a concept on which the development of a system for assessing the conservation status for the marine Annex 1 habitats can be based.

The report also includes a general description of the national status of marine data on which an evaluation of the conservation status of the habitats can be based. The data are stored in the national database MADS located at the National Environmental Research Institute and regionally in the counties databases ore in some cases in printed reports published by the counties.

Further, a proposal is given for potential indicators that can be used when assessing the conservation status of a habitat for 7 of the 8 marine Annex 1 habitats present in the Danish waters. The indicators have been chosen on the basis of known or potential pressure factors acting on each habitat.

The last section of the report deals with documentation requirements for the formulated indicators.

The report has been prepared with assistance from a group consisting of senior biologist Stig Helmig of the Danish Forest and Nature Agency (project leader), Henning Karup of the Danish Environmental Protection Agency and two county representatives, senior biologist Nanna Rask of the county of Fyn and senior biologist Jens Sund Laursen of the county of Sønderjylland, both appointed by the Danish County Association.

Figure 1.1 Bognæs at Roskilde Fjord. *Photo Karsten Dahl*

2 Background

2.1 The Habitats Directive and the Natura 2000 Network

According to Council directive 92/43/EEC of 21 May 1992 on the conservation of habitats and wild animals and plants, popularly called the Habitats Directive, each Member State shall maintain or restore a favourable conservation status, natural habitats and species of wild fauna and flora listed in the annexes to the directive. This is to be done by designating Special Areas of Conservation (SACs). Together with the Danish Special Protection Areas (SPAs) of the Wild Birds Directive, the SACs are to form part of a European ecological network of conservation areas called the Natura 2000 network.

Both directives cover the marine area of Member States' inshore as well as offshore waters. Inshore waters include the territorial waters extending to 12 nautical miles from baselines and off-shore waters are in Denmark defined as the Exclusive Economical Zone (EEZ) extending from 12 to 200 nautical miles from baselines. In Denmark, the directives are implemented via national legislation whereas legislation has been or is being altered in other Member States, to permit implementation of the directives offshore as well. Consequently, most of the Natura 2000 designations in EU Member States so far include inshore areas only.

The proposals for SACs from each Member State are analysed and assessed by the European Topic Centre on Nature Protection and Biodiversity (ETC) in Paris and are approved by the European Commission at bio-geographic seminars. At these seminars, each national proposal is assessed habitat by habitat and species by species. The outcome is "sufficient" or "insufficient"; the latter implies that the Member State has to designate more areas.

The Habitats Directive operates in different biogeographical regions. Denmark is part of both the Atlantic Region and the Continental Region. These two regions meet along a line, which runs north - south through the middle of Jutland, more or less following the line where the glaciers halted during the last ice age.

At the Atlantic biogeographic seminar in June 2002 a general reservation was made on the designation of SACs based on the marine Annex 1 habitats, which occur in both inshore and offshore waters. The reason for this reservation was the scientific uncertainty regarding the distribution of the Annex 1 habitats and species offshore.

Since then, the Commission decided to set up a marine experts group under the Habitats Committee to solve the problems with habitats 1110, 1170, 1180, and 8330. In this way, the Commission follows the recommendation made by a meeting of the forestry and nature directors in Thy, Denmark during the Danish EU-presidency (for further definition of the habitats, see *Table 2.1*).

The task of the expert group is to focus on the implementation of the Habitats Directive and the Wild Birds Directive offshore, and to ensure natural coherence between the habitats in question in and outside territorial waters.

The experts group is to focus especially on I-IV in the list below:

I Propose habitats and species of Annex I and II of the Habitats Directive and Annex I and migratory bird species of the Wild Birds Directive for which marine NATURA 2000 sites should be considered.

II Propose the best means of locating and assessing these habitat types and species.

III Propose definitions of marine habitats, and propose amendment to the Interpretation Manual as necessary.

IV Propose site selection rationale(s).

V Consider management measures necessary for adequate site protection.

VI Consider alternative/complementary conservation measures for 'wide ranging' species (for which sites cannot be meaningfully identified or for which sites might only represent a minor contribution to their overall protection).

VII Based on the above to draw together some initial impressions on adaptation of the Annexes for marine habitat types and species.

During the first meeting of experts in Mach 2003, three sub-groups were set up to deal with subjects I and III, II and IV, and V and VI respectively. The expert groups do not deal with subject VII at the moment.

According to article 17 of the Habitats Directive, the conservation status of the habitats is to be reported to the Commission every 6 years. The first report covered the period 1994 – 2000. The next 6-year period will be 2001 – 2006 and has to be reported in 2007.

Many Natura 2000 sites include several of the Annex 1 habitats. All sites of a given habitat type are not considered equally important by the EU. Each of the proposed sites has been assessed and classified on a scale from A to D according to how well they represent the habitat in question. SAC's classified "A" represents the habitat "excellent". SAC's classified "B" or "C" represents the habitats "good" or "significantly". Finally, SAC's classified "D" is regarded as "unrepresentative".

The conservation status of habitats in Natura 2000 sites classified as "A", "B", or "C" must be assessed and the results reported to the commission. Sites classified as "D" do not have to be assessed. How representative the Danish sites are, is still under consideration.

2.2 The marine Annex 1 habitats in the Danish Natura 2000 sites

Annex 1 includes 9 marine habitats, of which 8 occur in Danish waters (*Table 2.1*).

A description of the marine Annex 1 habitats is found in the Interpretation Manual of European Union Habitats (*Anon. 1999a*).

The *coastal lagoons* habitat is classified as a priority habitat, as the only marine habitat, because it is considered particularly threatened. The Member States have a special responsibility to preserve priority habitats.

In 2002, the EU-commission arranged two bio-geographic seminars, which dealt with the national designation proposals. The Danish proposals were classed as "sufficient" with respect to the purely coastal marine habitats, 1130, 1140, 1150, and 1160, ref. *Table 2.1*. When the marine expert group has finalised its work, further assessment will take place of the habitats 1110, 1170 and 1180, which occur both offshore and inshore. For each of the 8 marine habitats the number of Danish Natura 2000 sites, which were designated due solely or in part to the presence of the habitat, is listed in *Table 2.1*. An overview of the number of marine Annex 1 habitats involved in the designation of each of the Natura 2000 sites is shown in *Figure 2.1*.

Danish marine Natura 2000 sites, which have been designated solely or in part on the basis of habitats of the Habitats Directive, cover 10,584 km^2 equal to 10% of the Danish marine area. The marine Natura 2000 areas designated today cover 74.5% of the total national Natura 2000 areas in Denmark.

Table 2.1 Numbers of Danish Natura 2000 sites, for which each of the 8 marine Annex 1 habitats solely or partly constitute the basis for designation. The number in ( ) indicate Natura 2000 sites where the representativity of the habitat is assessed to "D" – no significant presence. All other sites are classified "A", "B" or "C".

Habitat	Habitat code	Number
Sandbanks which are slightly covered by seawater all the time	1110	40 (+3)
Estuaries	1130	4
Mudflats and sandflats not covered by seawater at low tide	1140	25
Coastal lagoons	1150	42
Large shallow inlets and bays	1160	38
Reefs	1170	52 (+2)
Submarine structures made by leaking gases	1180	6
Submerged or partially submerged sea caves	8330	1

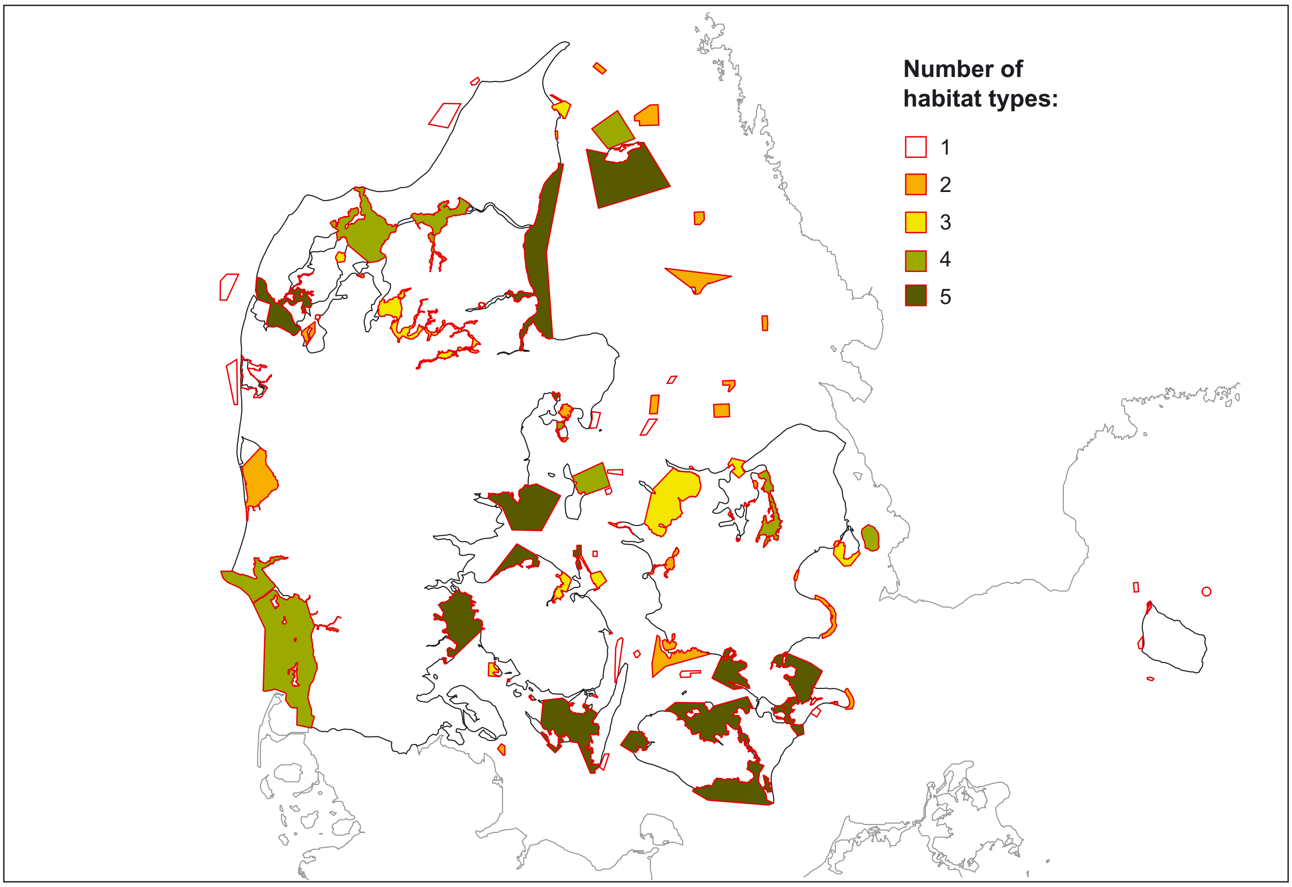


Figure 2.1 The Danish Natura 2000 sites where one or more of the marine Annex 1 habitats classified as "A, "B" or "C" sites, are the reason for the designation. The number of marine Annex 1 habitats (interest features of the SAC) involved in each designation is indicated.

2.3 Assessment of the conservation status of Annex 1 habitats

For each of the Annex 1 habitats favourable conservation status must be defined based on the biological characteristics by which the habitats were chosen for inclusion under the Directive. This favourable conservation status must be maintained or restored through management performed by the Member State.

The conservation status of a habitat will be taken as favourable when:

- Its natural range and areas it covers within that range are stable or increasing, and
- The specific structures and functions which are necessary for its long-term maintenance exist and are likely to continue to exist in the foreseeable future, and
- The conservation status of its typical species is favourable as defined in *litra* (*i*) (*of article 1 in the directive*).

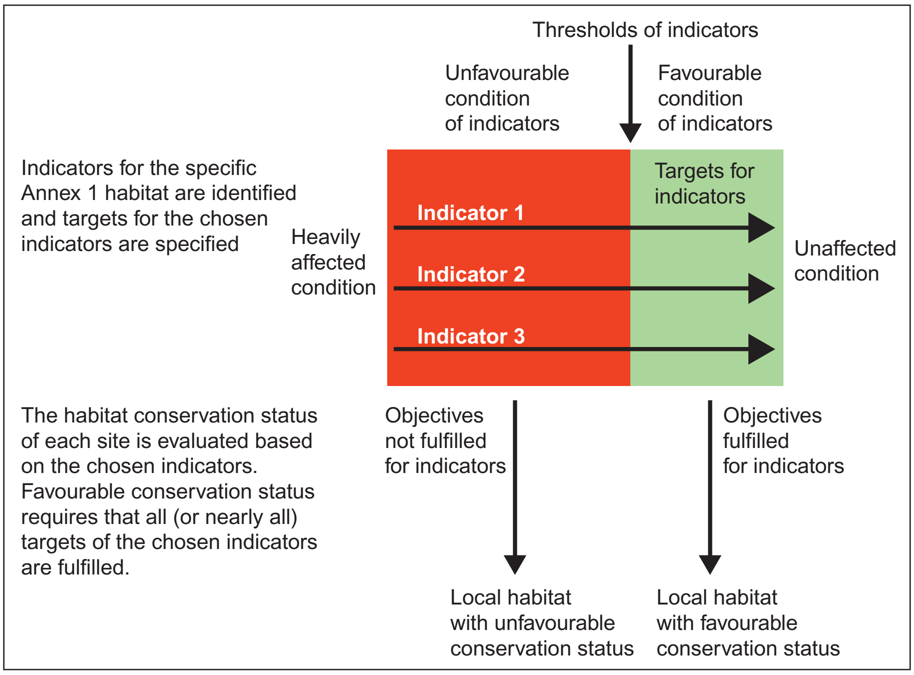
The criteria describing the circumstances at which the conservation status of an Annex 1 habitat will be taken as favourable are kept in general terms, which cover all habitats and species listed in the directive. Consequently, there is a need to develop more detailed and precise criteria for favourable conservation status for each habitat. Important terms used in this report and their definition is given in *Box 1*.

Box 1 Definition of terms used in the report. There are minor differences compared with the UK terminology defined in Davies et al. 2001 due to a different approach to management and existing monitoring programmes.

Term	Definition
Annex 1 habitat (interest feature)	Defined in the Habitats Directive, article 1c.
Sub-features	Sub-features are distinctive biological communities, or particular structural or geographical elements of the Annex 1 habitat. Indicators and threshold values are identified for each sub-feature.
Indicator (attribute)	Indicator is used for the specific variable, which best describes the condition of an Annex 1 habitat or its sub-features, and thus reports on the Annex 1 habitat's conservation status. The term indicator is used instead of attribute (Davies et al. 2001) in order to harmonise the Danish quality classification used in the Habitats Directive and Water Framework Directive as much as possible. An indicator is characterised by being a measurable unit.
Threshold	A threshold is the scientific determined indicator values, which set the range of values for favourable condition for the individual indicator. A threshold is characterised by being a measurable scientific determined value.
Favourable condition	Favourable condition is the minimum required condition (set by the threshold value) that the chosen indicators must reach before a specific Annex 1 habitat on a site is considered in Favourable Conservation Status.
Favourable Conservation Status	Defined in the Habitats Directive article 1. In this report it is also used for the conservation status of a specific Annex 1 habitat within a SAC, for which the indicators are in favourable condition.
Conservation objective	A conservation objective is a statement of the nature conservation aspirations for a specific Annex 1 habitat on a SAC. It consists of site-specific thresholds set by the local authorities for an Annex 1 habitat. Each SAC must contribute to the overall goal of favourable conservation status, and the conservation objectives have to be set accordingly to this purpose. This includes the identification of sub-features, indicators and threshold values for favourable condition.

These more detailed criteria must include relevant quantifiable indicators describing the quality of the habitat. For each indicator a threshold value must be set which, as a minimum, has to be maintained or achieved if the conservation status of the habitat is to be taken as favourable (see *Box 2*).

Box 2 Model of the national evaluation of the conservation status of marine habitats.



The chosen indicators should be:

- Biologically relevant, so that the achievement of thresholds ensure that the overall conservation objectives of the habitats have been met, and

- Immediately understandable and based on scientifically sound simplifications.

It is a prerequisite that monitoring of the chosen indicators is carried out in accordance with international guidelines, with regard to method as well as quality assurance.

In October 2000 the British Joint Nature Conservation Committee (JNCC) held a scientific meeting in Edinburgh followed by a workshop, where results from the comprehensive LIFE project "UK MARINE SACs Project" were presented. The project included the development of a system of conservation objectives for the marine Annex 1 habitats and Annex 2 species, and gave examples of relevant monitoring and mapping programmes for selected SACs in Great Britain (*Davies et al. 2001*).

An associated scientific workshop demonstrated that the national and international experiences on how to make a quality classification system operational were limited regarding the marine habitats. Discussions showed that further clarification of effects of natural biological variations over time and distance, as well as of anthropogenic impacts is needed. Decisions about a "reference condition" for impacted areas like Danish waters is also needed in order to define favourable conservation status.

Tools for classifying the state of nature in marine areas are under development in other national and international forums. The Swedish Environmental Protection Agency has developed a concept for the assessment of the quality of nature and the environment in terrestrial, limnetic and marine areas. The concept is a two-string classification system consisting of 1) the present state of nature and the environment segregated into 5 classes and 2) a classification of the quality in relation to reference values also segregated into 5 classes. The Swedish model for the marine area is based on selected variables, which describe the general state of the environment in relation to three defined pressure factors (eutrophication, physical disturbance, and environmentally harmful substances (*Anon. 2000a*). The Swedish concept partly accounts for salinity effects on the biological communities by dividing the Swedish marine waters into 4 – 5 typologically different areas. Furthermore the influence of plant nutrients on the ecosystem is taken into account by operating with 3 classes of retention time for water.

The Water Framework Directive (WFD) from 2000 (*Anon. 2000b*) is a directive, which, like the Habitats Directive, requires that future management of coastal marine areas is based on a biologically derived quality classification system.

The WFD Directive states that all water bodies shall fulfil an environmental quality objective of "high" or "good" ecological status before 2015. The "high" ecological status, which also include reference conditions for classification of the waters bodies is defines as “no or only very minor anthropogenic alterations” while “good” status only deviate slightly from those values normally associated with the water body type under undisturbed conditions. Where the WFD and the SACs/SPAs overlap, the most strict conservation objectives or standards are valid.

During the implementation of the WFD, the EU has started the preparation of a ”Marine Strategy” under the 6th Environmental Action Programme. This strategy aims at integrating the protection of the marine areas of the EU, with the overall purpose of 50% reduction in annual biodiversity losses before 2010.

The formulation and documentation of conservation objectives, indicators and thresholds for marine habitats should take the implementation of the WFD into account. Principles regarding documentation should be identical. In addition, the criteria defining the boarder between favourable and unfavourable conservation station <u>and</u> good and moderate ecological status should to the extent possible be the same.

Such an identity is evident in relation to the ongoing work to manage and reduce eutrophication in Danish marine waters, cf. the sketch in *Figure 2.2*. An informed strategic environmental management system without the suggested identity is likely the complicate matters beyond reason.

Input of nutrients is not the only pressure affecting the ecological status of marine habitats. Other pressures influencing structure, function and species in marine habitats are fishing of mussels, extraction of material, trawling or offshore constructions. These pressures could be of an order calling for additional protection measures or even alternative conservation objectives corresponding to “high” ecological status, cf. the sketch in *Figure 2.3*. The same may apply for nutrient inputs to shallow coastal waters with limited exchange with adjacent and more open coastal waters. However, this discussion is outside the scope of this report.

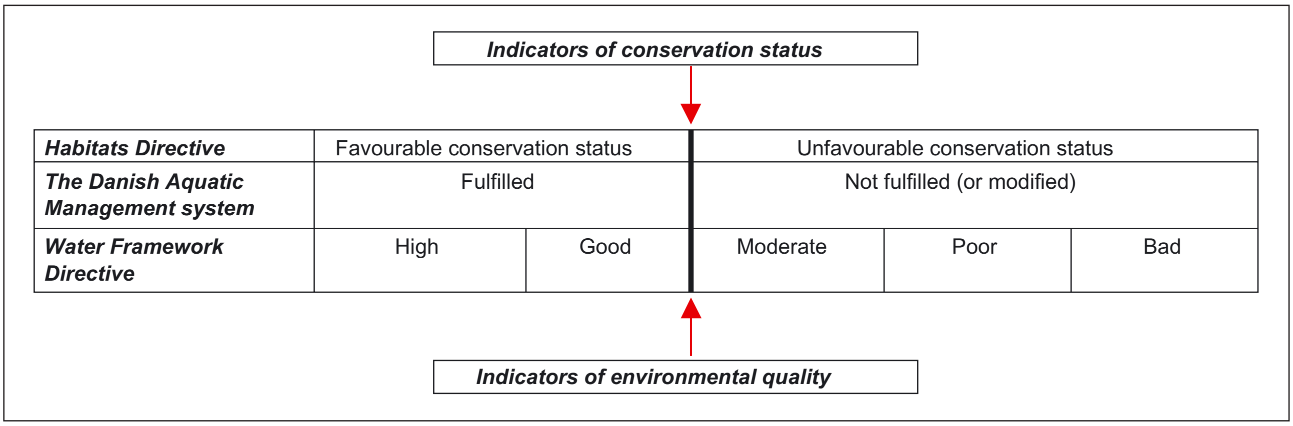


Figure 2.2 Illustration of the proposed parallelism between indicators which are included in the assessment of both the conservation objectives ((*sensu* the Habitats Directive) and the ecological quality objectives (*sensu* the Water Framework Directive) as well as the existing Danish Aquatic Management System (among others based on *Henriksen et al. 2001* and *OSPAR 2001*).

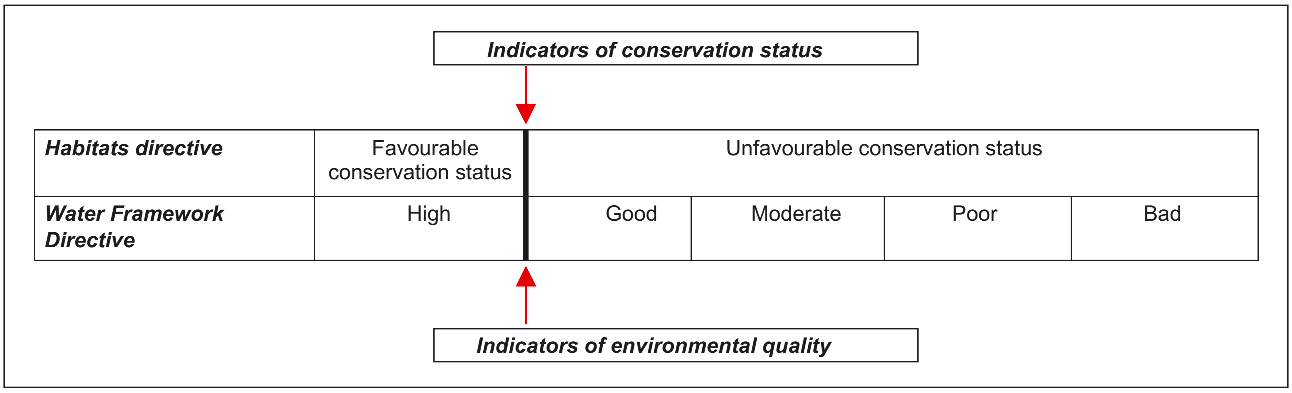


Figure 2.3 Alternative illustration of parallelism between indicators which are included in both the conservation objectives (*sensu* the Habitats Directive) and the ecological quality objectives (*sensu* the Water Framework Directive).

3 Important issues for development of a habitat quality classification system for marine areas

3.1 Problems concerning the definitions of the marine Annex 1 habitats

The marine Annex 1 habitats have been defined in the Interpretation Manual of European Union Habitats (*Anon. 1999a*) primarily on the basis of geomorphology and not biology, as opposed to most of the terrestrial Annex 1 habitats. Several (perhaps all) of the marine Annex 1 habitats contain very different biological communities, each of which should be defined or at least treated as separate habitats (sub-features), each with their own set of conservation objectives, indicators and thresholds.

The very weak definitions of the marine Annex 1 habitats can be exemplified by the habitat *reefs,* which is described as:

> "Submarine, or exposed at low tide, rocky substrates and biogenic concretions, which arise from the sea floor in the sub-littoral zone but may extend into the littoral zone where there is an uninterrupted zonation of plant and animal communities. These *reefs* generally support a zonation of benthic communities of algae and animal species including concretions, encrustations and corallogenic concretions.
>
> In northern Baltic areas, the upper shallow-water filamentous algal zone with great annual succession is normally well developed on gently sloping shores. *Fucus vesiculosus* is submerged at depths of 0.5-6 m in the sub-littoral zone. A red algae zone occurs below the *Fucus* zone at depths of about 5 to 10 m."

The biological content is described as:

> "Plants: Brown algae (species of the *Fucus*, *Laminaria* and *Cystoseira* genuses, and *Pilayella littoralis*), red algae (*e.g.* species of the families Corallinaceae, Ceramiceae and Rhodomelaceae), and green algae. Other plant species: *Dictyota dichotoma*, *Padina pavonica*, *Halopteris scoparia*, *Laurencia obtusa*, *Hypnea musciformis*, *Dasycladus claveformis*, and *Acetabularia mediterranea*.
>
> Animals: Mussel beds (on rocky substrates), invertebrate specialists of hard marine substrates (*e.g.* sponges, Bryozoa and cirripedian Crustacea)."

Several of the species of plants listed do not occur in Danish waters, but in entirely different ecological regions.

Not only geological formations – rocky or biogenic made up of shell structures - constitute the habitat *reefs.* The vegetation is an important describing and structuralising parameter of *reefs* in the photic zone, where there is enough light to permit plant growth. As light intensity decreases with increasing depth, the vegetation is reduced from being complex, multi-layered and species rich to consist of a single crusty layer on stones or shells at 20-25m's depth. The biological community changes from being dominated by algae to being dominated by or to consist solely of animals. Although animal species among the coelenterates, bivalves, bryozoans, polychaetes and even crustaceans can create niches for other animals, it is reasonable to state that the complexity of *reefs* decreases with increasing depth. The overall conclusion is that the structure and functioning of *reefs* change very significantly with depth. Those changes are illustrated in *Figure 3.1A-D*.

Figure 3.1A A boulder reef with dense multilayered red and brown macroalgae vegetation.
Location: Briseis Flak, water depth 7 m.
Photo Kim Lundshøj

Figure 3.1B A boulder reef dominated by more open erect red macroalgae vegetation. Crustforming algae species are visible on the surface of the boulders.
Location: Tønneberg Banke, water depth 12 m.
Photo Karsten Dahl

Figure 3.1C A reef with mixed substrate of boulders and silt. The biomass is dominated by epifauna. Algae vegetation is sparse.
Location: Schultz's Grund 18 m water depth.
Photo Karsten Dahl

Figure 3.1D Biogene reef on silted sediment bottom with sparse gravel. The reef-forming bivalve Modiolus modiolus functions as the substrate for epifauna and the macroalgae Phycodrys rubens.
Location: Schultz's Grund 19 m water depth.
Photo Karsten Dahl

A reasonable analogy to the changes in biological communities on *reefs* as a function of differences in depth and thereby in light intensity at the bottom as well as salinity can be found in the differences between terrestrial habitats such as forests, thickets, meadows and stony beaches expressing a decrease in vegetation biomass. These terrestrial habitats can be divided further into more specific habitats such as coniferous forests, deciduous forests, etc.

Similar problems can be experienced with other marine Annex 1 habitats. The habitat *sandbanks, which are slightly covered by seawater all the time (1110),* can be with or without submerged vegetation, depending on exposure to waves and currents and on depth.

The habitat *large shallow inlets and bays (1160),* create even greater problems. According to the Interpretation Manual, this Annex 1 habitat should be more protected from waves than more exposed areas. The shape of the coastline and shallow water depths almost solely defines this habitat. However other habitats, such as those already mentioned (1110 and 1170) as well as *mudflats and sandflats not covered by seawater at low tide (1140),* can very well be present inside this *large shallow inlets and bays habitat.*

The problems with the definitions of the marine habitats become even more apparent, when a system of conservation objectives based on biological content is proposed for these habitats. In Great Britain the marine Annex habitats or *interest features* of the SACs have been divided into *sub-features.* A *sub-feature* is a biological or particular structural or geographical element of the feature. The system for assessing conservation status based on indicators and thresholds will for the most part be focused on the *sub-features* and not on the more superficial *features* (*Davies et al. 2001*). The same approach is suggested in this report.

3.2 Annex 1 habitats and habitat classification systems

The weak or rather the lack of differentiation into biologically based marine habitats of the Interpretation Manual (Anon. 1999a) reflects the generally low level of knowledge concerning marine habitats. In recent years initiatives have been taken to change this state of affairs in a European context. Under the auspices of OSPAR, ICES, and the EEA work has been ongoing to define and classify a great number of marine, limnetic, and terrestrial habitats (European Nature Information System, EUNIS). The starting point for the marine habitat classification was an earlier British project BIOMAR, which has been developed further to include a larger portion of the Atlantic area at a certain level of detail concerning biology. The habitat types of the EUNIS system are now connected to those of the Habitats Directive via links on the respective home pages

http://mrw.wallonie.be/dgrne/sibw/eunis and
http://mrw.wallonie.be/dgrne/sibw/N2000/

Initiatives have been taken to formulate an international project to further develop the *EUNIS* system, so it will also cover the Baltic marine area, including the Danish/Swedish transitional area to the Baltic Sea.

Recently, the *JNCC* also published a marine habitat classification for Great Britain and Ireland (*Conner et al. 2003*).

In 1998, *HELCOM* published a red list of coastal and marine biotopes in the Baltic region (including the Kattegat), that builds on a biotope classification system (*HELCOM 1998*). The first classification level of the benthic marine part of this system is based on the sedimentological (physical and chemical) characteristics of the sea bottom, including biogenic substrates (mussel banks). Next level is depth/light conditions and finally vegetation cover. The Baltic system does not go into greater detail concerning biology, and for this reason it can not be used as a fundament for a biologically based system of conservation objectives.

So, at present the status is that there is no adequate international interpretation of the habitats of the Baltic marine area, including the Danish/Swedish transitional area to the Baltic Sea. Thus, there is no habitat classification system, which can be used as a guideline to divide the Annex 1 habitats into biological based sub-features to which conservation objectives can be developed.

3.3 Natural factors, which have a fundamental impact on the biological components characterising the marine Annex 1 habitats

Light, and thereby depth, is an important parameter for the natural conditions of the Annex 1 habitats controlling the benthic primary production of sea grasses, macrophytes and diatoms.

The inner Danish waters are transitional waters between the very brackish Baltic Sea and the almost oceanic highly saline North Sea. Other transition zones exist in estuaries, in inlets and between coastal and offshore waters. Salinity also varies between surface and deeper waters and the gradient differs during the year (*Figure 3.2*).

Salinity gradients occur within a habitat area like an estuary or a fjord, and changes in salinity can be profound between sites in Danish waters. Salinity strongly influences the biological communities. In *Dahl et al. (2001), e.g.* it is shown that *reefs* in Kattegat and the Belt Sea do not have to be far apart before the macroalgae communities at a given depth are significantly different. *Nielsen et al. (1995)* document the loss of algae species diversity in the Baltic with decreasing salinity.

The nature of available substrate is one of the most important factors, which influence biodiversity and biological composition in the Danish waters and the Baltic Sea. This can be illustrated by the huge difference in the biological composition between the rocky shores of Sweden hosting a variety of epibenthic algae and fauna species compared to the relatively species poor sandy shores of Poland with almost no epibenthic species. Similarly, large differences in species composition exists on a local scale between areas dominated by mud with diverse infauna communities and areas dominated by gravel or small boulders. Thus the available substrate has a huge impact on the distribution of biomass and species composition. The interaction between the salinity gradient and available substrate are a key determent in the species distribution in Danish waters and the Baltic Sea.

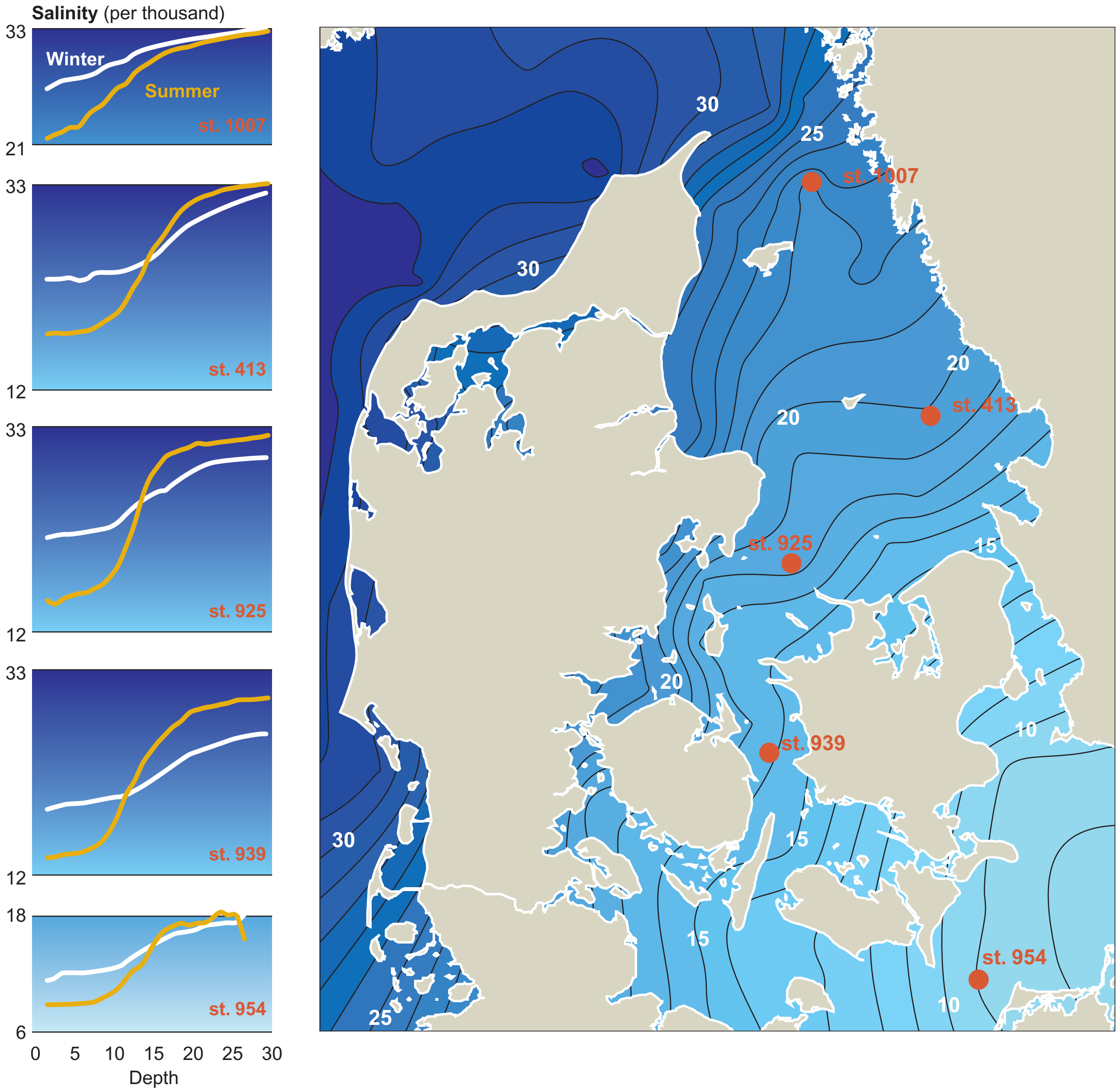


Figure 3.2 The map shows the mean salinity in the upper 5 meter of the water column in Danish waters with focus on open waters. The graphs show the mean salinity in vertical profiles on 5 sampling stations in summer and winter.

Natural physical stress factors are also of major importance for the biological content of several of the Annex 1 habitats. Sandbanks along the east coast of Jutland can have well-developed eelgrass beds. On the sand banks along the exposed west coast of Jutland there are no eelgrass beds, but instead there are dense populations of bivalves – at least off the Wadden Sea. Only in the sheltered waters of the Wadden Sea behind the islands of Rømø and Fanø and the Skallingen peninsula is the eelgrass able to get a foothold. Another example of the importance of physical stress concerns the stability of the substrate on *reefs*, which has a significant effect on the biological content. The stability of the substrate depends on the dimensions of the stones in combination with the degree of exposure to waves and current and the water depth at the specific location. In *Dahl et al. (2001)*, stable and unstable substrates were categorised as separate types of solid bottom, each with their own distinct algal communities, in spite of similar physical and chemical conditions.

As the case with salinity, the input of plant nutrients varies in different parts of the Danish waters. The availability of plant nutrients sets the balance between pelagic and benthic primary producers. Hereby it also influences the depth distribution of the structuralising macro-vegetation on both sandy and stony bottom. The benthic fauna biomass generally increases with the increase in phytoplankton production, but only to the point where oxygen deficiency occurs and mass mortality follow. Annex 1 habitats in sheltered areas with limited water exchange and a large direct input of fresh water from land. For example, lagoons like Nissum Fjord, will naturally, irrespective of eutrophication, have another biological structure caused by a higher availability of plant nutrients, than an area like Stavns Fjord, which receives only a small input of fresh water from land and has a high water exchange with the Belt Sea area. It has also been shown that the benthic faunal communities in fjords not far from each other can be very different with respect to species diversity. The decisive factor here is the difference in water retention time (*Josefson & Hansen in press.*).

The consequence of these important natural structuring factors is, that it can be difficult to identify meaningful universally applicable biological indicators for evaluating the conservation status of the same Annex 1 habitat located in areas with different salinities, availability of nutrients and degrees of physical stress. The chosen indicators and their threshold level can end up being applicable in areas with the same type of water masses or even be site specific.

3.4 Anthropogenic pressure factors impacting on the marine Annex 1 habitats

The choice of indicators describing the conservation status of a marine Annex 1 habitat must reflect the major known anthropogenic pressure factors, which impact on the habitat in question. The most suitable indicators will be universal to such a degree that they can be used also in connection with future pressure factors, or with existing ones that we at present are unaware of.

The eutrophication of the Danish waters has gradually increased, linked to the growth of the population in Denmark. The sewerage of the cities commencing at the beginning of the last century and the development of agriculture accompanied by a great increase in the use of fertilisers through the 1950s and 1960s made sewage and eutrophication effects in the aquatic environment very apparent. An NPO action plan in 1984 and later an Action Plan for the Aquatic Environment in 1987 set political targets for a reduction of the input of phosphorous and nitrogen to the aquatic environment of 80% and 50% respectively. At present only the target concerning phosphorous has almost been reached. Increased eutrophication leads to increased turbidity in the water column caused by phytoplankton, which decreases light penetration to the benthic vegetation. The increase in phytoplankton production, on the other hand, increases food availability for the benthic fauna. But it also increases the consumption of oxygen, which can lead to oxygen deficiency and "bottom death" (*Figure 3.3*).

Figure 3.3 Eutrophication effect: Sheets of white sulphur bacteria on a mussel bed.
Photo Nanna Rask/Fyn County

The offshore fisheries for fish and Norway lobster (*Nephrops norvegicus*) and inshore for Common mussels (*Mytilus edulis*) using towed bottom gear have developed greatly, especially since the 1960s with an increase in capacity and the introduction of new types of gear.

But it is not only the impacts of the gear on the bottom structures and benthic communities that affect the ecosystem. The systematic removal of large-size fish and of great quantities of fish, as well as the hunting and accidental by-catches of marine mammals is also argued to have a tremendous effects on the whole ecosystem (*Jackson at al. 2001*).

Fishery then influences both the structure and functioning of many marine Annex 1 habitats.

Stone fisheries in the 1950s and -60s removed substantial amounts of boulders from *reefs* in Danish waters. The exact amounts are not known, but the extraction techniques show that the removal of stones has primarily taken place where the stones were piled up at 4-9 meters' depth. Seen in the perspective of habitats, the cave forming *reefs*, which have been located close to or even partly above water, have been most severely affected. The cave forming *reefs* are now of particularly rare occurrence. There are some indication that reef can become unstable as a result of extraction of large boulders leaving the reef with smaller stone open for erosion. Stone fishery is now forbidden in all Natura 2000 areas but the damage of former times extraction is irreversible unless restoration is carried out.

The extraction of sand and gravel also impacts on the marine Annex 1 habitats. Deep pits or shallower furrows change the bottom topography. Hard reef forming substrates are removed when gravel is extracted from the surface of the seabed. Furthermore spillage by overflow can cause large amounts of finer material to settle around the excavation site or be dispersed over great distances changing the surface sediments and by this the habitats for plants and animals.

Environmentally hazardous substances, including heavy metals, are dispersed from diffuse sources and from point sources, ships, fish farms, and dumping of dredged materials. The loading to Natura 2000 areas depends on nearness to sources, precipitation and water exchange, which has been demonstrated through the nation wide

NOVA 2003 monitoring programme. The concentrations of certain environmentally harmful substances like PCB and DDT are dropping in the environment, while those of new ones such as synthetic estrogens and bromated flame inhibitors are rising.

Even if the loading of all substances could be measured, which is impossible, it would not be possible to predict the effects on the environment. These can depend on the mixture of substances, the pattern of dispersal, and on the species present and their state of health. Abiotic factors such as availability of nutrients, organic materials, etc. can also influence the effects of environmentally hazardous substances on animals and plants. Therefore, the effects must be measured directly on the organisms.

Changes in metabolism, sex distribution, biodiversity, and immune response are some of the expected effects. In order to assess the effects of environmentally hazardous substances on habitats, it would be relevant to look at general responses in different parts of the food web and, where suitable, effects of single substances, such as imposex or intersex development in some snails species caused by TBT.

Former land reclamation in shallow coastal areas, such as fjords and lagoons and coastal areas such as the Wadden Sea, has lead to the loss of habitats included in the Habitats Directive. At other sites locks have changed the pattern of water exchange to lagoons and fjords.

Lately, preliminary considerations on and modelling of climate change (global warming) have shown that a reduction in the species diversity and depth distribution of the benthic vegetation in the inner Danish waters can be expected due to increased precipitation runoff from land lowering the salinity and increasing eutrophication (*Gustavsen 2001*).

The discharge of plant nutrients, medicine residues and oxygen consuming substances from fish farms, the spreading of environmentally hazardous substances and plant nutrients caused by the dredging and dumping of benthic materials from shipping lanes and harbours, and recreational activities are additional anthropogenic pressure factors, which can have an effect on the natural state of Annex 1 habitats.

3.5 How to assess the conservation status of marine habitats

The concept for assessing the conservation status of Annex 1 habitats, which has been chosen by the Danish Forest and Nature Agency, is based on a system developed in Great Britain (*Anon. 1999b*).

The assessment concept shall function as:

- reference points for environmental impact assessments,
- standard in relation to monitoring in the area, and
- guidance for management.

The condition of selected indicators is to be used when assessing whether the conservation status of a Annex 1 habitat is favourable or not.

The chosen set of indicator attributes must be able to describe:

- area and distribution,
- structure and functioning, and
- species composition of characteristic species.

Most inshore marine Annex 1 habitats not defined by coastlines have yet to be mapped. Coastal habitats like *lagoons*, *estuaries*, and *large shallow inlets and bays* are defined solely by coastlines and/or by lines between two coasts.

Sandbanks and to some degree also *coastal lagoons* are dynamic structures of the sea bottom, and attempting to fix their borders to keep the area constant would be in direct opposition to the concept of natural coastal dynamics. Knowledge of changing area distribution of dynamic structures within SAC's are on the other hand important if the national or biogeographic area are to be kept constant or increasing, meaning that new SAC's might need to be designated in the future. Most of the *reefs*, on the other hand, will hardly change position in the foreseeable future. For this reason monitoring *reef* geomorphology is considered superfluous. Unstable *reefs*, which are now degrading due to the extraction of stones in former times as well as biogene reefs, are exceptions. Reefs can also be more ore less buried by dynamic sandbanks and in this way lost or reduced in area for a period. Such changes of the sea floor can both occur as natural processes, as a result of construction works and because of spill from extraction of sand and gravel from the seabed.

In order to assess the conservation status of a marine Annex 1 habitat it is more relevant to monitor the biological content and the distribution of identified important *sub-features* of the habitat. The majority of the terrestrial Annex 1 habitats has been named and to a great extent defined on the basis of their vegetation. Choice of indicators and thresholds to assess the structure and functioning of these habitats will naturally be based mainly on the vegetation. Many of the marine Annex 1 habitats, however, lack vegetation entirely due to physical circumstances such as lack of sufficient light, unsuitable sediment, or great physical stress. For this reason both the benthic fauna and the vegetation, will be part of a quality assessment system for the conservation status of marine Annex 1 habitats.

An important point regarding the Danish concept of assessing habitat conservation status is that it has been developed to evaluate the individual Annex 1 habitats within a site. It corresponds to the term favourable condition adopted by the UK conservation agencies to represent the Favourable Conservation Status for the interest features of an individual SAC. The data from the monitoring of the Annex 1 habitats is also used in general assessments of the conservation status of larger areas such as the SAC's as well as on ecological status of water districts defined under the Water Frame Work Directive.

The quality assessment system is based on indicators and thresholds set for marine Annex 1 habitats at the local level (in single SACs) as well as nationally. The assessment must cover the structure and functioning of the specific site and the condition of characteristic species. In principle, the area covered by the habitat is also included as an assessment parameter.

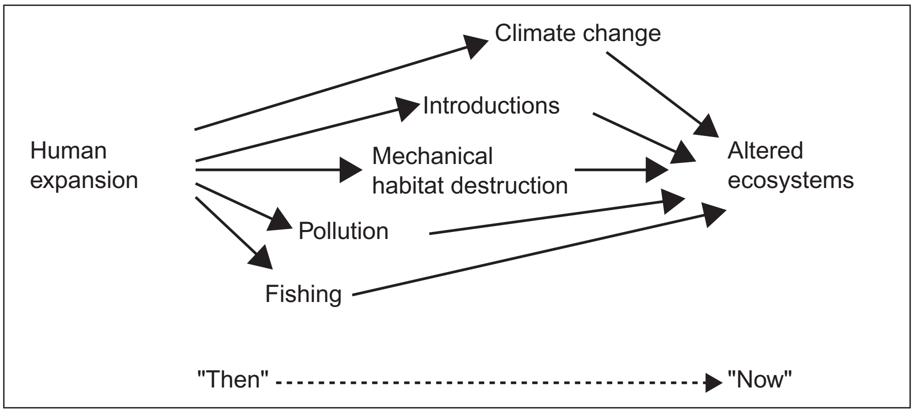
How to integrate the individual indicators in a common local or national assessment of the conservation status for the specific habitats, is still under consideration nationally as well as in EU. It is expected that all thresholds set for indicators must be fulfilled, if the conservation status of a site is to be assessed as favourable. Many designated Natura 2000 sites in Danish marine waters include several Annex 1 habitats. Different Annex 1 habitats in the same Natura 2000 site typically share the same anthropogenic environmental pressure factors such as eutrophication and hazardous substances. The concept of conservation objectives for different Annex 1 habitats should be correlated to the greatest degree possible. This is important in order to avoid as far as possible that the conservation status differs between habitats subjected to the same anthropogenic pressures in a given Natura 2000 site.

3.6 Frame of reference for conservation objectives regarding marine Annex 1 habitats

None of the marine Annex 1 habitats is based on the presence of human influence. The situation is rather the opposite, since many of our activities more or less have a negative influence on the marine environment. Less anthropogenic pressure will often have a positive effect on the structure and functioning of the marine Annex 1 habitats. But some pressure factors, such as the introduction of invasive non-indigenous species, may result in irreversible negative impacts on species or Annex 1 habitats.

Jackson et al. (2001) have set up an historical sequence of events for the human disturbances of the coastal ecosystem (*Figure 3.4*). The exploitation of fish resources started early, in Denmark soon after the last ice age some 11,000 years ago. Eutrophication and pollution with hazardous substances set in much later followed by physical destruction of habitats and the introduction of non-indigenous species. Finally, humanly induced climate change (global warming) has been recognised as a potential factor to be taken seriously. The various factors undoubtedly also have synergetic effects on the ecosystem.

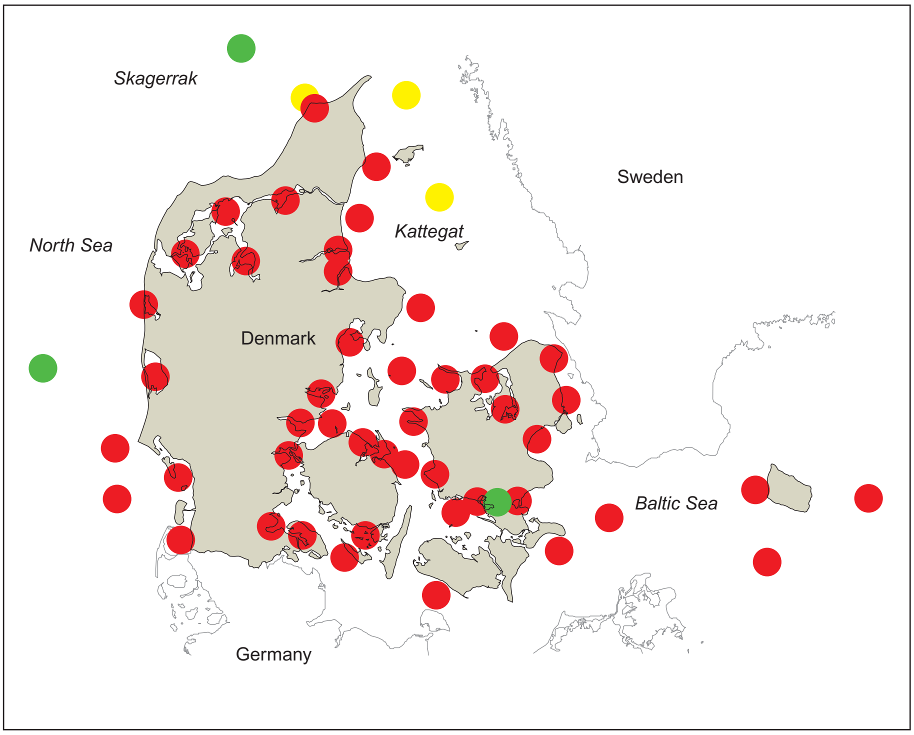
Figure 3.4 Historical sequence of events for human disturbances of the coastal marine ecosystem (from *Jackson et al. 2001*).



The development of a quality assessment system for marine habitats conservation status should, ideally, be based on knowledge of the habitats distribution, structure and functioning and of the biological composition under circumstances without the anthropogenic pressure factors. However we face the problem that description of impact on marine nature in scientific ore other literature is a rather new thing.

The latest quality assessment of the Danish marine areas, in accordance with the objectives set by the regional authorities (counties) and the national Environmental Protection Law, state that the targets are not fulfilled for the majority of water districts (*Rasmussen et al. 2003*), *Figure 3.5*.

Figure 3.5 Status for assessment of the quality of Danish marine waters in accordance to the Environmental Protection Law. Red circle: not fulfilled. Green circle: fulfilled. Yellow circle: close to fulfilment (from *Rasmussen et al. 2003*).



The task – and the challenge – is to choose the levels of human impacts, which can be accepted if a favourable state of conservation is to be attained, being well aware of the fact that one can only, to a certain degree, look back on the historic development of human impacts on nature.

As mentioned in chapter 2.3 the Water Framework Directive, stipulates that all water bodies covered by the directive must be of either "high" or "good" ecological status in 2015. The quality "high", which also serves as reference point regarding the classification of the ecological status of the waters, is described as having "no, or only very minor, anthropogenic alterations compared to the values of the physical/chemical and hydromorphologic quality elements for the surface water body type from those normally associated with undisturbed conditions", and "the values of the biological quality elements reflect those normally associated with that type of surface water body under undisturbed conditions, and show no, or only very minor, evidence of distortion." For the quality "good", "the values of the biological quality elements for the surface water body type show low levels of distortion resulting from human activity, but deviate only slightly from those normally associated with that type of surface water body under undisturbed conditions." The Water Framework Directive states that in those areas shared with the Habitats Directive ore Birds Directive the most restrictive conservation objective for all Directives is in force.

3.7 A concept for the development of assessment tools for the marine Annex 1 habitats

The proposed concept for assessment of the conservation status for the Danish marine Annex 1 habitats follow the basic ideas proposed by the *JNCC* in Great Britain for the British marine areas. This implies that the marine habitats listed in the Habitats Directive's Annex 1 probably in all cases should be subdivided into small units (*sub-features*) for which indicators and thresholds are formulated.

The conservation status of the habitats and their sub-features is assessed in relation to the objectives set for the favourable state of conservation locally as well as nationally.

The most optimal assessment system is based on sub-features, which correspond to biological based well-defined habitats. Lacking an adequate habitat classification system for the Baltic marine habitats and lacking substantial knowledge of the biological composition of the marine habitats in Danish waters as a whole, the required degree of detail needed for this optimal solution exists only in a few cases.

The proposed indicators for habitat sub-features, which are not directly associated with biological founded well defined habitats, should be more general. An example of such a general indicator is the total cover of erect macroalgae vegetation on deeper parts of stone reefs. This indicator does not describe a specific habitat like a community of *Laminaria* with associated red algae species, but the general growth condition (water quality) on the site.

Danish marine Natura 2000 sites are characterised by very different water masses. A starting point for defining conservation objectives and thresholds for the chosen indicators for each habitat or habitat sub-feature are Natura 2000 sites grouped by a typology *sensu* the water Framework Directive. Each type is characterised by a range of abiotic factors such as geomorphology, salinity, nutrient availability, physical stress and water exchange. If operating with a typology doesn't make sense, site-specific objectives and thresholds can be used instead.

For each type or individual site, specific thresholds are defined on the basis of biological content.

The development of a system for assessing conservation status for the marine Annex 1 habitats must take the following central aspects into account:

- Annex 1 habitats should be subdivided into biologically meaningful units (sub-features) in accordance to *JNCC*'s proposal for Great Britain.

- Knowledge of the distribution of the Annex 1 habitats and of their contents of biological based well-defined habitats is in general very poor and considerable effort is needed to gather such knowledge. Until this has been done, a first step is to develop an assessment system for habitats or habitat sub-features based on indicators and thresholds that reflect the general quality of the site rather than specific communities of fauna and flora.

- Most marine habitats have a depth dimension, which is central to the vegetation due to light extinction. The system of conservation objectives must take this important factor into account, perhaps by typological segregation.

- Marked structuralising natural physical and chemical gradients through the inner Danish waters strongly influence biology. Typological segregation or site-specific indicators and/or thresholds are, therefore, relevant.

- The biological systems in marine waters are generally very dynamic. Knowledge of natural variations in controlling factors is essential for development of an assessment system for conservation status.

- Reference points describing a favourable state of conservation for habitats or habitat sub-features can not be based on existing environmental conditions. This makes the task of developing a biologically founded conservation classification system very resource demanding.

Furthermore, the greatest degree of harmonisation between indicators used under the Habitats Directive and indicators used under the Water Framework Directive should be ensured.

The chosen indicators must all together be able to reflect the condition of structure, function and characteristic species of the habitat or sub-feature in question.

The important first step in developing a biological based system for assessing habitat conservation status is to achieve knowledge about the chosen indicators response to changes in important pressure factors. This knowledge can be achieved using different methods which reliability is reflected in the following list:

1. Knowledge of the present state of an indicator with today's pressure and its state in former times under reduced pressure. Empirical modelling of the relationship between indicator and pressure factor could be used. (*Figure 3.6A*) Depth distribution of eelgrass in the 1950'ies and at the beginning of the last century is an example of such a data set.

2. Data from areas within the same type of water, but where pressure factors such as inputs of nutrients vary considerably between sites. Empirical modelling could be used (*Figure 3.6B*).

3. Based on the empiric modelling of the relationships between indicators and pressure factors using data collected in resent years and extrapolated to a lower pressure level known from former time. (*Figure 3.6C*). This method needs a close link between pressure and indicator response and a fluctuating pressure level to give good model estimates.

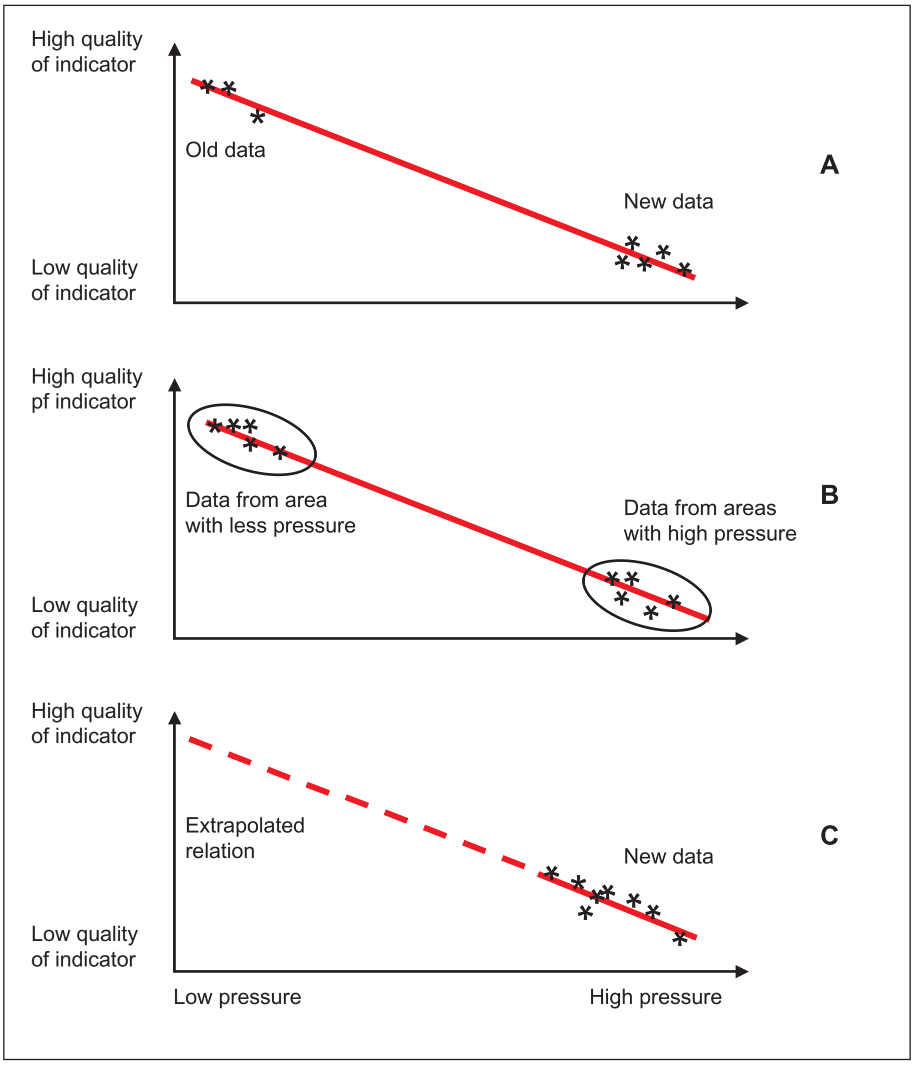
When the relationships between pressure factors and indicators is satisfactory described a tools exists for the relevant authorities to set thresholds to be fulfilled if the habitat or its sub-features are to be assessed as having a favourable conservation status.

Figure 3.6 Simplified empirical modelling of relationships between pressure factors and indicators.

A) Current and old data for pressure factors and indicators exist from the same sites or from sites were the natural structuring factors are equal.

B) Current data exist from different sites where the natural structuring factors are equal but where the pressure factors are different.

C) Only current data exist from a site or from sites where the natural structuring factors are equal. The variation in pressure factors and the resulting response on the indicator are so profound, that relations can be established and extrapolated to other levels of pressure.



If there is no sufficient data, for scientific based thresholds, temporarily thresholds can be set based on judgement by experts, until proper data is available.

Several examples exist of how thresholds for indicators can be set. *Rask et al.* (*2000*) and *Krause-Jensen et al.* (*submitted*) used data on the occurrence of eelgrass at the beginning of the last century. Similarly, *Sand Jensen et al. (2001)* used data on the occurrence of macro-algae in the Isefjord and Roskilde Fjord during the 1940s.

Glob (2002) have compared benthic fauna sampled in reason years with data sampled for 100 years ago.

Finally, Dahl et al. (in Henriksen et al. (2001)) describe a model linking the cover of total erect algae vegetation on deeper stone reefs in Kattegat to eutrophication parameters. This model has been used as a starting point in a proposal for a classification system for total vegetation coverage based on some assumptions concerning eutrophication in a reference situation.

4 Monitoring of the Danish marine waters

Monitoring of the Danish marine environment on a large scale has been undertaken for about 25 years. Monitoring of parts of the open marine waters and certain coastal waters began in the mid 70s. During the 1980s, the geographic range was extended with respect to both the open marine waters and the coastal waters. Upon establishment of the Nation-wide Monitoring Programme in 1988, systematic monitoring of the coastal waters was implemented in all counties and monitoring of the open marine waters was intensified (*Danish EPA 1989*).

Monitoring of the Danish marine environment was based on a number of environmental problems such as oxygen deficit (hypoxia), the occurrence of algae blooms, a decline in depth distribution of the benthic vegetation, a decline in coastal fish stocks and changes to the biological structure of estuarine fjords. These problems attracted attention in the mid 1970s and a number of research projects and monitoring activities through the 1980s demonstrated that these problems to a greater or lesser extent are associated with general eutrophication of the Danish marine waters.

The national marine monitoring programmes for the periods 1988-1992 and 1993-1997 (*Danish EPA 1993*) have focused on ecosystem health in relation to eutrophication. The marine monitoring hitherto undertaken has therefore focused on nutrients, -plankton, benthic vegetation and benthic fauna. Experience from the programmes showed that the selected indicators generally provide a good description of the state and temporal trends in the marine environment in relation to nutrient loading (*Danish EPA 2000*).

The programme for the period 1998-2003 (The National Aquatic Monitoring and Assessment Programme 1998-2003 (NOVA-2003), which together with regional monitoring activities (called ROVA), is the main data source for this technical report, is based on the experiences from the programmes running since 1988 and focuses on:

- eutrophication, including transports and retention of nutrients,
- hazardous substances, including biological effects monitoring, and
- biodiversity and protected habitats.

The difference between NOVA and ROVA activities is in principle limited to the funding. NOVA is directly funded via the Finance Act and the Ministry of the Environment is co-ordinating the programme, which is running for a period of 6 years. ROVA is indirectly funded by the Finance Act via so-called DUT-principles. ROVA activities, which are carried out by the 14 Danish counties and the Municipality of Copenhagen, are relying on the same methods as the NOVA-programme. However, the individual counties have are large degree of freedom to change strategies and priorities.

Priority has so far been given to eutrophication and hazardous substances. Monitoring of protected species and habitats has so far been focused on the so-called stone reefs. However, large parts of the eutrophication monitoring activities take place in Natura 2000 areas and provide an important source of information on the status of these areas. In addition, the data on species numbers and composition of phytoplankton, submerged aquatic vegetation and benthic macrofauna is used to assess the ecological status, including biodiversity.

4.1 Mandates, objectives and funding

The monitoring of marine biodiversity and the ecological status of the Danish marine waters is stipulated in a so-called List-of-Mandates compiled by the Danish Environmental Protection Agency and the National Forest and Nature Agency.

Denmark has negotiated and agreed a number of international commitments in HELCOM, OSPAR and the Convention on Biological Diversity together with many EU directives (The Urban Wastewater Directive, the Nitrates Directive, the Habitats Directive, the Birds Protection Directive and recently the Water Framework Directive). Together, all the international conventions and directives constitute a network of carefully negotiated commitments focusing on more or less the same problems and activities. As a consequence, it is not always clear which commitment is the most restrictive and thus the minimum commitment for Denmark to comply with.

In a national perspective a number of action plans have been adopted by the Parliament (Action Plan on the Aquatic Environment I and II), focusing on protection and monitoring of the ecological status of the marine waters in Denmark. Action Plan I included guiding principles for the nation-wide monitoring programmes including funding arrangements. The guiding principles are very general compared to the HELCOM and OSPAR commitments and the requirements of the EU directives.

The objectives of the national NOVA-programme 1998-2003 were:

- to follow the development in the physical conditions, including hydrographic conditions and oxygen deficit,
- to follow the development in occurrence and concentration of nutrients in the water phase and sediment,
- to follow the development in the biological conditions,
- to determine water and nutrient transport to Danish marine waters,
- to determine the occurrence and concentration in the water phase, sediment and biota of hazardous substances and heavy metals, and
- to assess the biological effects of selected hazardous substances and heavy metals.

The national NOVA-programme and the successor, the NOVANA programme (2004-2009) are supplemented by regional monitoring programmes funded by the Danish counties (called ROVA). The Ministry for the Environment funds the marine activities within the national monitoring programme (approx. 53.9m DKK per year in the NOVA-programme period). ROVA activities are estimated at approx. 26.9m DKK per year.

4.2 Scientific background

Since the first national marine monitoring programme was started in 1988, considerable new knowledge on the functioning of marine ecosystems has been obtained through the programmes themselves, the Belt Project, the Danish Marine Research Programme (Hav90), and the Danish Environmental Research Programme. The results of these research programmes and the knowledge and experience gained from the monitoring activities comprise the scientific background for the NOVA programme and its successor, the NOVANA programme.

As nutrient enrichment and eutrophication are dominating stress factors on marine biodiversity and habitats in Danish coastal waters the following text will focus on plankton, submerged aquatic vegetation, benthic macrofauna and nutrients. Detailed information on other marine monitoring activities as inputs, nutrients, primary production, oxygen concentrations, filter feeders, hazardous substances, biological effects monitoring, sediment processes (internal loading) and modelling can be found in a report written by the *Danish EPA (2000)*.

4.2.1 Phytoplankton and zooplankton

Phytoplankton comprises an important element in aquatic ecosystems. Variations in the amount and composition of phytoplankton decisively influence biological structure in marine waters. The biomass of phytoplankton determines how great a percentage of the light is absorbed in the water column and hence is available for production of organic matter. The phytoplankton biomass thus helps determine the potential primary production. In addition the phytoplankton biomass is a measure of the amount of food that is available for zooplankton and zoobenthos.

The phytoplankton biomass is the result of the balance between growth, i.e. primary production, and loss due to grazing and sedimentation. Phytoplankton is either grazed by zooplankton and in shallow waters also by mussels and other benthic filter feeders or sedimented to the seafloor. A study of Danish estuarine fjords shows that nitrogen availability and the amount of benthic grazers mainly regulate plankton biomass, and that the chlorophyll concentration can be reduced by 25% each time the nitrogen concentration is halved (*Kaas et al. 1996*).

The marine monitoring has traditionally always encompassed primary production measurements, and long time series are available for a large number of stations in open marine waters, coastal waters and estuarine fjords. Primary production expressed per unit water volume is closely correlated to the chlorophyll concentration (*Kaas et al. 1996*). The production per alga or per chlorophyll unit is particularly dependent on phytoplankton growth conditions and hence on nutrient input. The production per chlorophyll unit can thus be exploited in the monitoring as a measure of the degree of nutrient limitation.

Phytoplankton species composition is a major determinant of biological state in that both the composition and nutrient turnover in the food chains are affected when the structure of the phytoplankton community changes. Foreign investigations have shown that changes in nutrient levels in the North Sea have altered the species composition and structure of the phytoplankton community (*Radach et al. 1986* and *Radach & Berg 1986*). Dominance by large species indicates an adequate input of nutrients and a high loss to the seafloor (*Harris 1986*). At the same time, large algae are a good food resource for copepods and hence for fish. The best example of such a situation is the diatom spring bloom. High diatom density will generally increase sedimentation and hence the food availability for benthic invertebrates, but also the risk of oxygen deficit. In contrast, small flagellates are indicative of rapid turnover under stable nutrient conditions, where regeneration of nutrients in the water column plays a great role (*Harris 1986*). This situation is typical for the summer situation in open marine waters and some estuarine fjords. Dominance by flagellates can also reflect lack of competition from diatoms due to low silicate concentrations. An increased abundance of flagellates increases the risk of toxic algal blooms as the majority of toxic algae belong to this group.

In coastal and open marine waters as well as in some estuarine fjords, zooplankton grazing is a major cause of phytoplankton loss. The structure and biomass of the zooplankton community thus provide information on phytoplankton regulation and nutrient and carbon turnover, and hence are important for the understanding of causal relationships. The role of mesozooplankton in marine ecosystems has been known for a long time, but the significance of microzooplankton has only become fully accepted over the past decades. In contrast to the mesozooplankton, the growth rates of microzooplankton correspond to that of phytoplankton. In principle, therefore, changes in phytoplankton -biomass and species composition should be immediately reflected in microzooplankton biomass. No time series exist that demonstrate any correlation between the development of eutrophication and changes in the microzooplankton community, however.

4.2.2 Submerged macrophytes

Submerged vegetation is a robust indicator of ecological quality and of change in the surrounding environment because the vegetation has a relatively long lifetime and therefore reflects an integrated response to physical and chemical conditions in the environment.

The success of the vegetation in a given location depends on the balance between growth- and loss processes. Light and nutrients are main regulators of the growth of submerged macrophytes, while the loss of plant -biomass is mainly due to annual life cycles, physical disturbances (*e.g.* storms, ice scouring, fishing with scraping equipment), grazing and disease. Nutrients affect the vegetation through its stimulating effect on phytoplankton growth that leads to increased light attenuation in the water column (*Nielsen et al. 2002a*) and thereby limits the depth range of the vegetation (*Nielsen et al. 2002b*). A reduction in the vegetation cover may lead to an increased resuspension of sediments that further reduces the light levels and thereby generates a vicious cycle of vegetation decline (*Duarte 1995*). Increased nutrient loading also stimulates the growth of opportunistic macroalgae and epiphytes thereby changing the dominance patterns of the vegetation and further shading the perennial seagrasses and macroalgae (*Pedersen 1993*, *Duarte 1995*, *Middelboe & Sand-Jensen 2004*). The total number of macroalgae in the estuarine fjords is also related to nutrient loading as well as to the size of the fjords, the salinity and the availability of substrate (*Middelboe et al. 1998*). Moreover, nutrient loading can also indirectly affect the vegetation by enhancing the risk of oxygen deficit, which can be fatal for *e.g.* eelgrass (*Greve et al. 2003*). The effects of the Action Plan on the Aquatic Environment are therefore expected to be detectable as changes in the submerged macrophyte composition and distribution.

Eelgrass (Zostera marina)
Eelgrass is the most widespread rooted macrophyte in Danish estuarine fjords and coastal waters of low to moderate wave exposure, where it typically occurs on sandy seabed from the coast and as far out as light conditions permit.

Eelgrass meadows are highly productive (*Duarte & Chiscano 1999*) and their three-dimensional (3-D) meadow structure makes eelgrass an important habitat for benthic invertebrates and fish fry (*e.g. Boström & Bonsdorff 2000*). Eelgrass stands also limit coastal erosion because their rhizomes and roots form a dense net that stabilise the sediment and dense eelgrass stands attenuate the current and wave movement over the sediment surface (*Ward et al. 1984*). Eelgrass can therefore be characterised a key organism in Danish coastal waters.

Surveys from the beginning of the 20th century show that eelgrass used to be far more widespread than today. Many estuarine fjords were completely covered by eelgrass and the eelgrass grew down to great depths in the coastal waters (*Ostenfeld 1908*, *Boström et al. 2003*).

Macroalgae
While eelgrass occurs on soft and sandy substrate, macroalgae require a hard substrate such as boulders, stones or shells on which to anchor. The majority of Danish estuarine fjords and coastal waters have a sandy bottom with scattered stones and macroalgal distribution is thus often limited due to lack of suitable substrate. The rocky coasts around Bornholm and stone reefs are exceptions.

Macroalgal communities on *e.g.* stone reefs are often highly diverse and also constitute a habitat for diverse faunal communities (*Dahl et al. 2003*).

4.2.3 Benthic macrofauna

Many benthic fauna species play a key role in the marine ecosystem as filter feeders, s which degrades organic material produced plankton and macrophytes. They also comprise an important food resource for higher trophic levels such as fish.

In shallow waters the benthic fauna metabolises a large part of the pelagic production. This is particularly the case for the filter feeders, which are potentially able to control the pelagic phytoplankton in many areas (*Cloern 1996* and *Kaas et al. 1996*). The benthic fauna in shallow waters is very easily affected by stochastic events such as oxygen deficit and ice winters, with considerable resultant variations in biomass. The fluctuations in benthic biomass are of great significance for the ecosystem's biological structure and hence for the impact of eutrophication in these waters.

4.3 Strategy for the national marine monitoring programme

Through the analysis of samples from a large number of stations distributed throughout all Danish marine waters the Nationwide Monitoring Programme for the period 1988–2003 has documented the environmental state of the inner Danish marine waters well. Experience has shown, however, that concentrating and focussing the activities could improve the yield of the monitoring programme, and that a nationwide picture of the state and developmental trend may be obtained with fewer but more representative monitoring areas.

Knowledge of how and how quickly the ecosystems come out of balance after being affected by changes is limited. This means that as with the previous programme, the marine monitoring has to concentrate on some key elements. It is important to establish a detailed picture of the developmental trend by including a number of parameters that provide a broad account of ecosystem function.

The Danish marine waters range from small and enclosed shallow coves to open marine waters. When planning the monitoring programme account therefore has to be taken of the great variations in both physical and chemical/biological conditions that exist, and it is necessary to adapt the monitoring strategy to the local conditions. This means not only that a distinction has to be made between estuarine fjords and open marine waters, but also that distinction between fjords has to be taken into account.

4.3.1 Strategy for selection of marine waters and station types

The monitoring strategy for the estuarine fjords, coastal waters and open marine waters surveyed within the national marine monitoring programme is based on the experiences from and evaluations of the previous programmes. The activities are a combination of a nationwide extensive monitoring at selected stations and intensive surveys in selected waters (*Table 4.1*).

The background for introducing intensive surveys in the NOVA-programme is the complex causal relationships in the marine environment. In order to be able to assess these, it is necessary to include all significant variables. In some cases this necessitates the application of special sampling strategies (*e.g.* high sampling frequency). A limited number of estuarine fjords (modelling areas) and stations in open marine waters (intensive stations) have therefore been selected at which intensive surveys are carried out. The intensive investigation programme concentrates on the highly dynamical physical and chemical conditions, while sediment and biological conditions in the modelling areas are included in the ordinary monitoring programme. In addition, the intensive monitoring activities encompass additional sampling in order to model water and nutrient transport in the open marine waters and in the modelling areas. In the estuarine fjords, coastal waters and open marine waters, sampling will continue at a number of stations that have been investigated for a long period so as to enable statistical analysis of the long-term developmental trends.

Table 4.1 Elements of the marine monitoring programme under NOVA-2003. For each monitoring area an assessment has been made of the relevance of the programme elements and the associated parameters for monitoring of the area in question. MA: modelling area; RA: representative area; HAZ: hazardous substances; IS: intensive stations; ES: extensive stations; SR: stone reefs.

	Area and station type					
	Estuarine fjords and bays (areas)			Open marine waters (stations)		
Biological conditions	**MA**	**RA**	**HAZ**	**IS**	**ES**	**SR**
Phytoplankton	×	×	-	×	×	-
Zooplankton	×	-	-	×	×	-
Benthic vegetation	×	×	-	-	×	×
Benthic fauna	×	×	-	-	×	-

In order to ensure that the monitoring contributes to a nation-wide description of marine environmental state and developmental trends a number of more extensive activities was established in the NOVA-programme (1998-2003). These stations are geographical dispersed, located in the inner Danish marine waters, the North Sea and the Skagerrak. At these stations samples are to be collected at a relatively low frequency for analysis of water chemistry conditions, benthic fauna and submerged macrovegetation. In addition, samples have been collected for determination of the sediment content of hazardous substances and heavy metals. *Table 4.1* summarises the overall monitoring strategy.

4.4 Sampling, variables and frequencies

This section describes the measurement and analysis programme, the selection of variables, sampling frequency, etc. Focus is given to the NOVA-programme. In addition the detection limits are given and information is provided on which variables are included in which area type and station types. In those cases where the analysis results are method-dependent, the analysis method is stated. In the tables the frequencies are given as 1/6 (once during the 6-year programme period, 2/6 (twice during the programme period) and 3/6 (3 times during the programme period).

Selection of the monitoring variables (indicators) was based on a combination of knowledge as to what structures best characterise marine ecosystems, their resilience and measurability, and the costs of carrying out the measurements.

Sampling and analysis methods are described in the technical instructions for marine monitoring 1998-2003 (see *Kaas & Markager 1998*). The technical instructions follow the guidelines stipulated for monitoring under the international marine conventions: HELCOM's "Manual for Marine Monitoring in the Combine Programme of HELCOM", and OSPAR's "Joint Assessment and Monitoring Programme, Eutrophication Monitoring Guidelines". These guidelines are obligatory for the Danish stations included in NOVA-programme, just as older versions of the guidelines were for the programmes preceding the NOVA-programme.

4.4.1 Pelagic biological variables

The biological monitoring programme encompasses phytoplankton and zooplankton in the water column (the pelagic zone).

Phytoplankton

The monitoring encompasses determination of primary production, species composition as well as quantitative calculations of abundance (cell density), biovolume and carbon biomass for the individual species. In addition, algal blooms and unusual occurrences of blooms are to be followed.

Species composition: Species composition is used when assessing turnover in the pelagic system and to explain the results of the chlorophyll, oxygen and primary production measurements. The measurements are the basis for analyses of the long-term development in phytoplankton community structure and the occurrence of characteristic species, in particular potentially toxic species. In the case of algae blooms and blooms of toxic species, species composition data are used in the analysis of the background and causes of the blooms, in the assessment of any action taken and in prognoses for the development and consequences.

The monitoring of phytoplankton species continues the existing time series and is carried out using the methods hitherto used. Determination of species composition and the quantitative calculation is carried out using an inverted microscope, as described by *Utermöhl (1958)*. In some areas these enumerations and measurements are supplemented by epifluorescence microscopy as previously.

The surveys of species and quantitative composition encompass autotrophic and heterotrophic organisms that are traditionally counted together with phytoplankton. For example, the heterotrophic choanoflagellates are counted with the phytoplankton. In the representative areas and at intensive and extensive stations, where determination of microzooplankton is not included, species of autotrophic ciliates such as *Myrionectra rubra* (previously *Mesodinium rubrum*) are counted as phytoplankton. In contrast, heterotrophic ciliates are not encompassed by the phytoplankton surveys. In the modelling areas, these organisms are counted in either the phytoplankton sample or in the micro-zooplankton sample depending on which sample gives the most accurate cell count (*Table 4.2*).

Calculation of species abundance, biovolume and carbon biomass: In order to be able to follow the development in phytoplankton it is necessary to make exact calculations of the relative significance of the species/species groups. Quantitative analyses are therefore made of the abundance, biovolume and carbon biomass. The quantitative calculations help determine the causal relationships and possible future development in phytoplankton composition.

The quantitative calculation is omitted for samples from the fluorescence maximum; however, the samples are only being analysed qualitatively for dominant species.

Sample collection depth: The plankton samples are collected at various depths depending on the bottom depth at the individual station.

Table 4.2 Sampling frequency per year for the biological measurements of phytoplankton, zooplankton, benthic vegetation and benthic fauna in modelling areas and representative areas and at intensive and extensive stations under the NOVA-programme.

	Frequency/year			
	Areas		Stations	
Biological variables	**Modelling**	**Representative**	**Intensive**	**Extensive**
Phytoplankton				
Species composition	26	17–28	3–26	4
Biomass	26	17–28	3–26	4
Microzooplankton				
Species composition	26	-	-	-
Biomass	26	-	-	-
Mesozooplankton				
Species composition	26	-	3–26	4–26
Biomass	26	-	3–26	4–26
Benthic vegetation				
Intensive	1	3/6	-	2[1)]
Extensive	-	3/6	-	-
Distribution (aerial photography)	2/6	2/6	-	-
Benthic fauna				
Species composition	1	1	-	1
Individual density	1	1	-	1
Biomass of soft bottom fauna	1	1	-	1

[1)] Surveys on stone reefs

At all stations at which a subsurface chlorophyll maximum occurs a sample is collected in the chlorophyll maximum for determination of dominant species and the chlorophyll a content. The presence of a deep chlorophyll maximum is assessed from the fluorescence profile and is defined as a fluorescence value greater than 2 times the normal level in the profile for the depth interval 0.1–1 m at shallow stations and 0.1–5 m at deep stations.

In modelling areas and representative areas, an integral sample is collected covering the photic zone, i.e. the depth interval from the surface down to 1% light depth or, if this exceeds the water depth, down to 0.5 m above the seafloor.

At intensive stations an integrated sample is collected covering the depth interval 0–10 m.

Sampling frequency: The annual sample collection frequency in modelling areas and representative areas and at the intensive and extensive stations is shown in *Table 4.2*. In the modelling areas sampling must cover the whole year. In the winter period sampling is to be conducted no more than once per month. The remaining samples are to be collected during the growth season. In the representative areas and at the intensive stations, sampling during the growth season has highest priority. At high sampling frequency (≥ 24 per year) the winter period has to be included with a maximum of 1 sample per month.

Algal blooms and unusual occurrences: During events such as algae blooms, fish kills, death of benthic invertebrates, toxic mussels, etc. it may be necessary to take samples at other times and locations than those stipulated. In these cases, sampling has to be adapted to the situation in question (see *Kaas & Markager 1998*).

Zooplankton
The zooplankton monitoring aims to clarify its significance for the development in phytoplankton and to clarify the long-term development in zooplankton species composition (*Table 4.2*). The programme encompasses determination of dominant species and a quantitative calculation of the abundance and biomass of the most important species/species groups.

Microzooplankton: The most important groups of protozooplankton are flagellates and ciliates. Microzooplankton monitoring is carried out in selected modelling areas. Samples are collected from the same integrated sample as the phytoplankton sample.

Mesozooplankton: Mesozooplankton consist of multicellular organisms that spend all (holoplankton) or part (meroplankton) of their life in the pelagic. Typical representatives of the holoplanktonic zooplankton are copepods and rotifers, while the meroplankton encompasses larval stages of mussels, molluscs, bristle worms, malacostracans, echinoderms, etc. The significance of the meroplankton generally increases with decreasing water depth.

Monitoring of the mesoplankton is carried out in the modelling areas and at the intensive and extensive stations. The sample collection frequencies are given in *Table 4.2*.

Sample collection methodology and sample processing, etc. are described in the technical instruction for marine monitoring (*Kaas & Markager 1998*).

4.4.2 Submerged aquatic vegetation

The benthic vegetation is monitored in the modelling areas and in representative areas. The monitoring is carried out as diver surveys in points along transect lines. Transects are located away from point sources and represent the vegetation in both the inner and outer sections of the estuarine fjords. About 10 transect lines are investigated in each estuary. The inner and outer sections of the estuaries are also represented by a centrally situated water chemistry site, making it possible to couple vegetation surveys to water quality.

Types of monitoring: The benthic vegetation monitoring consists of 3 types of surveys:

- algal surveys
- eelgrass surveys
- area surveys

While the coastal algal and eelgrass surveys provide detailed information on the composition of the vegetation along selected transects on hard and sandy/soft substrates, respectively, the area surveys are used to chart the spatial distribution of a mainly eelgrass beds.

Sampling methods for different survey types are summarised below. More details are available in the technical instructions for marine monitoring (*Kaas & Markager 1998*).

Algal surveys: In coastal areas algal surveys are carried out along transects with considerable occurrence of hard substrata. The algae are investigated in 3 points ($25m^2$) within each 2-m depth interval along the transect line. The points are selected randomly in areas having at least 10-20% hard substrata. The diver visually assesses the cover of individual macroalgal species, the cover of the total macroalgal community and the composition of substrate (see *Table 4.2*).

The surveys take place every second year during the period June-August in both modelling areas and representative areas.

The monitoring of stone reefs encompasses the same variables as the algal surveys in coastal waters, but includes a more detailed analysis of species composition in the laboratory. The stations (points) are distributed from the top to the bottom of the reefs at 2-3 meter depth intervals as long as suitable hard substrate is available. No replicates are taken. Algal surveys on stone reefs was carried out twice annually.

Eelgrass surveys: Eelgrass surveys encompass primarily eelgrass but also other rooted macrophytes, charophytes and loose-lying ephemeral/opportunistic macroalgae. The surveys are carried out in all modelling and representative areas except the few areas with rocky or stony substrates.

The surveys are carried out in points along transect lines where the diver assesses coverage of the individual species of macrophytes, the total macrophyte cover and the fraction of soft/sandy substrate. Moreover, the maximum depth limit of eelgrass shoots is assessed in a number of points located across the deep end of the main transect line (see *Table 4.2*).

The surveys are carried out once a year during the period June-August in both modelling areas and representative areas.

Area surveys: While eelgrass surveys provide detailed information on coverage and depth distribution of eelgrass etc. within selected eelgrass areas, area surveys assess the average cover and the total distribution area of eelgrass in the estuarine fjords - i.e. area surveys also take the bare areas into account. In addition the area surveys describe the distribution area of common mussel (see *Table 4.2*).

The surveys are carried out along a dense net of transect lines covering the estuarine fjords. The surveys along each transect closely resembles the eelgrass surveys. In some areas the survey is supplemented with analysis of aerial photographs.

The surveys take place in selected modelling areas every third year in the period June-August.

4.4.3 Benthic macrofauna

The monitoring of benthic fauna encompasses species composition, abundance and biomass of soft bottom fauna in coastal and open marine waters, and calculation of the biomass of filter feeders in estuarine fjords. The occurrence of imposex in molluscs is also included in the monitoring.

The sedentary nature of the benthic fauna also renders it relatively easy to quantify, thereby enabling the temporal development to be followed reasonably easily.

Species composition, abundance and biomass
Three to four groups of animals normally dominate in benthic fauna samples: Polychaetes, molluscs, crustaceans and echinoderms. It is generally recommended that they are identified to species level, although this can be time-consuming in the case of some families and genera (*e.g.* Cirratulidae, Polydora and Capitella).

The biomass is determined either as wet weight or dry weight or preferably as both biomass measures. Alternatively, conversion factors from other surveys (*Rumohr et al. 1987*) or other documented relationships for determination of dry weight from wet weight or size measurements can be used. In certain cases, ash-free dry weight or carbon biomass can be determined (*Kaas & Markager 1998*).

Samples of benthic fauna are to be collected once a year in modelling areas and representative areas. In addition, soft-bottom fauna was sampled at extensive stations with uniform substrate (*Table 4.2*).

5 Biological and physical-chemical data from Danish waters

A GIS-based meta-database has been established as part of the present project. This database contains information on data stored in the database MADS at the National Environmental Research Institute, and in regional databases or on paper in the counties. The meta-database is a further development of a previous database made for the Danish Forest and Nature Agency (*Sand 2001*).

The meta-database contains information on investigations of benthic flora and fauna, which includes species mentioned in the Interpretation Manual of the Habitats Directive. It also contains information on investigations of biological and physical/chemical parameters, which are not mentioned in the manual, but which are essential in connection with the typological segregation of habitats and as explanatory parameters for the benthic communities.

The meta-database contains tables for data on:

- *Coastal macrovegetation*
- *Benthic fauna*
- *Reef vegetation*
- *Reef fauna*
- *Phytoplankton*
- *Zooplankton*
- *Water quality*
- *Conductivity, density and temperature (CTD)*

The meta-database gives a superficial description of the available data from Danish marine waters of relevance to the project. The uppermost registration level is the sampling station, which for vegetation can include several depths on one transect, and for physical/chemical data the entire water column.

The database does not include data from newly started monitoring of the effects of TBT on snails.

The total numbers of sampling stations in Danish marine waters for each of the main parameter groups are shown in *Table 5.1.*

The National Environmental Research Institute and the counties have put great efforts into ensuring that all relevant information on data, electronically stored as well as stored on paper, are included in the meta-database. Duplicate information from different sources has been identified and the duplicates erased. The result is a meta-database with the most comprehensive description of biological and physical/chemical investigations in Danish marine waters to date.

Sampling stations inside the Natura 2000 sites have been identified with the use of GIS in the few cases where this information was not given by the counties.

Table 5.1 Numbers of sampling stations in Danish marine waters for each of the main parameter groups, and numbers among each of these from which time series of different number of years exist, from which data are stored electronically, from which electronically stored data are found only in the databases of the counties, and from which data have been gathered according to VMP/NOVA guidelines. * 23 datasets are not indicated as time series.

	No. of sampling stations	1 year of sampling	2-5 years of sampling	6-10 years of sampling	> 10 years of sampling	Data stored electronically	Data in county databases	VMP/NOVA guidelines followed
Coastal vegetation	1320	618	317	173	212	1185	759	1131
Benthic fauna	3307	750	2012	252	293	No information	No information	No information
Reef vegetation	119	55	15	36	13	113	40	96
Reef fauna	32	19	6	7	0	32	0	0
Phytoplankton	252 *	93	56	80	45	218	61	58
Zooplankton	31	6	9	1	15	14	7	7
Water quality	946	296	286	127	237	937	167	933
CTD	1124	266	423	144	291	1119	226	1101

Data from the National Environmental Research Institute's database MADS is, by definition, available in electronic form. During recent years MADS has been through a process of verification and quality control, so these data can now be said to be of high quality. The counties have many data stored electronically, but some are found on paper in reports or otherwise only. Other regional data are in the process of being moved from one database to another.

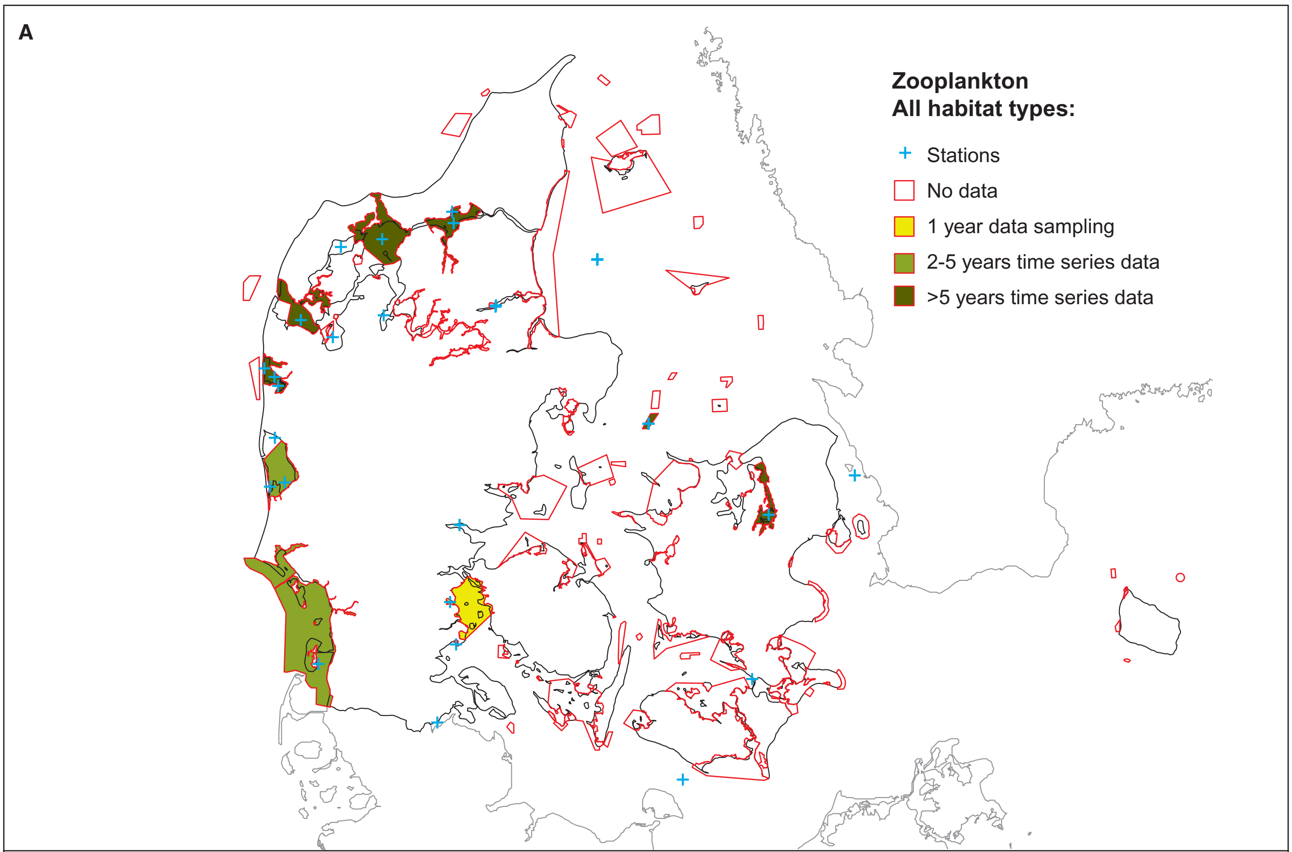
The meta-database makes it possible, relatively quickly, to discover whether data are lacking from a certain SAC and whether certain data are available in electronic form in MADS or in a county database or it must be retrieved in some other form and perhaps digitalised.

The meta-database is to be used for deciding whether data are sufficient to perform an actual analysis with the aim of setting up a classification system, which makes it possible to define a favourable state of conservation for the Annex 1 habitats.

Data for the pelagic physical/chemical and biological parameters follow the moving water masses and are not bound to fixed locations or habitat sites, as are the data for the benthic parameters. The distributions of pelagic data are, therefore, described for all marine waters in this section. The data on the benthic biological parameters (fauna and vegetation) and their distribution among the Natura 2000 sites are dealt with in each of the habitat sections.

The distribution of the sampling stations for *phytoplankton*, *zooplankton*, and *water quality* are shown in *Figure 5.1A-C*. The *CTD* stations are not shown since their distribution is almost identical to that of the *water quality* stations.

The available data from Natura 2000 sites, which is specific for the Annex 1 habitats, are dealt with in the next chapters.



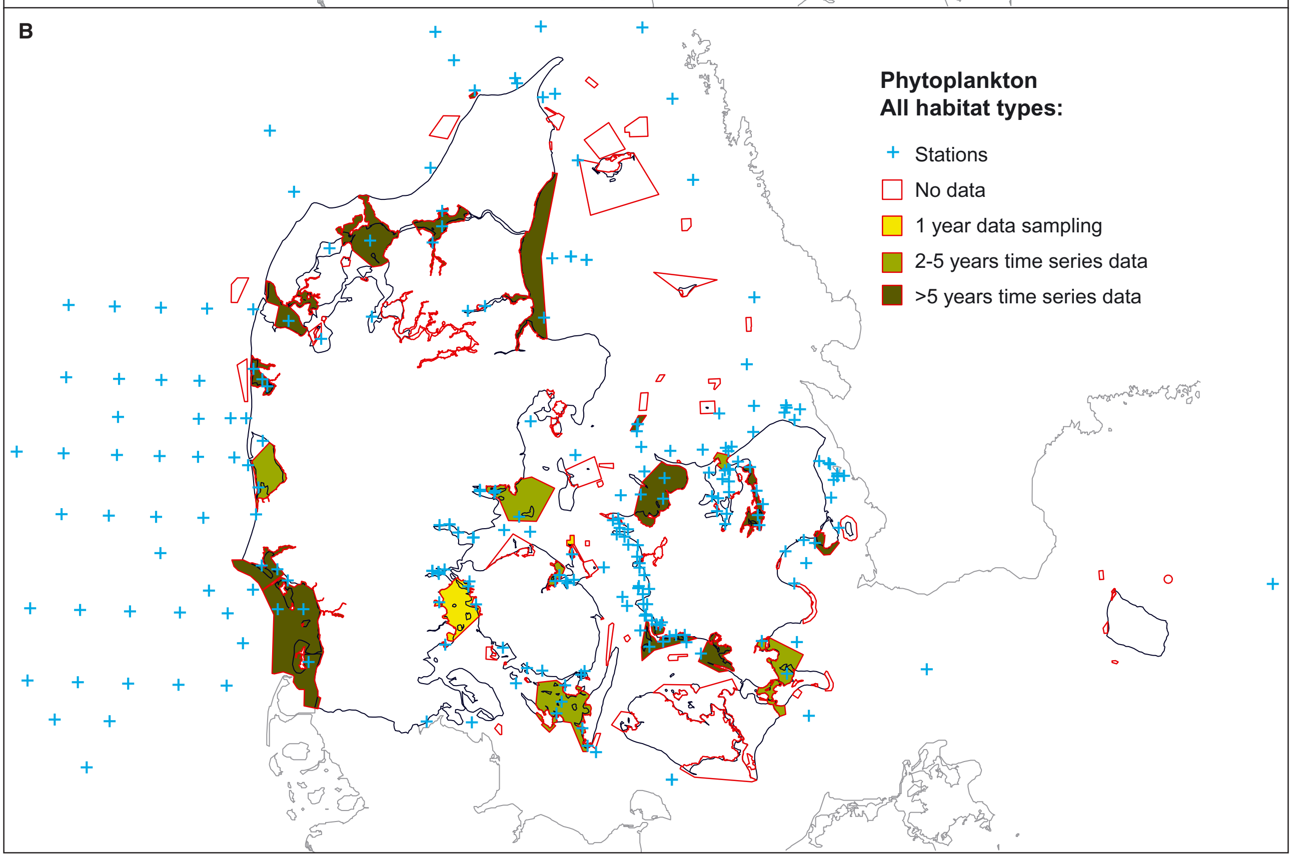


Figure 5.1 Natura 2000 sites with at least 1 of the 8 marine Annex 1 habitats (areas bordered with red) of the Habitats Directive occurring in Denmark. Locations of regional and national sampling stations on *zooplankton* (A), *phytoplankton* (B) and *water quality* (C) is indicated by blue crosses. The colour of each Natura 2000 site indicates the length of the longest time series for a sampling station inside the site for the parameter in question (continues).

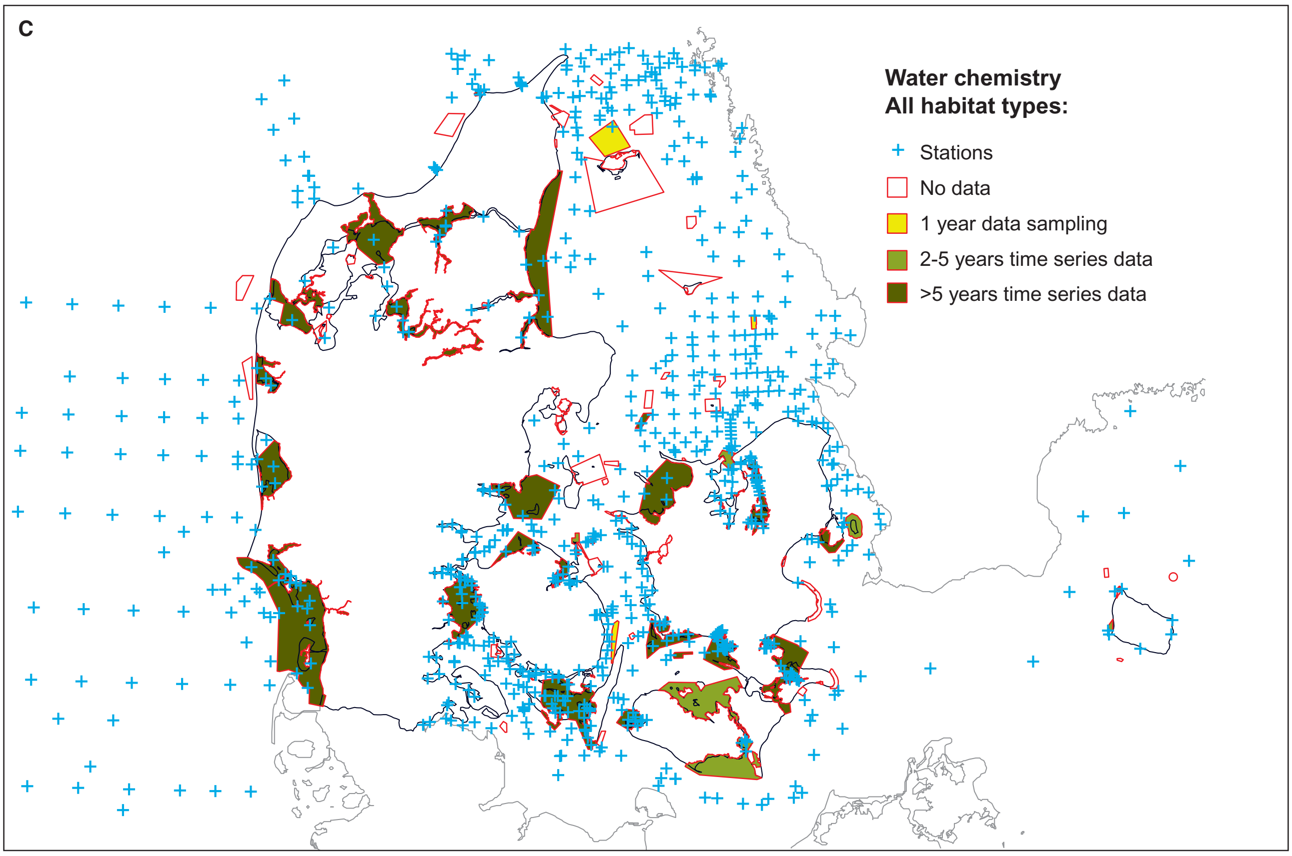


Figure 5.1 (Continued)

6 Identification of subfeatures, pressure factors, potential indicators and available data of Annex 1 habitats in Danish waters

6.1 *Sandbanks which are slightly covered by seawater all the time* (1110)

6.1.1 Identification of sub-features, pressure factors and potential indicators

This Annex 1 habitat occurs in designated Natura 2000 sites from the North Sea to the Baltic Sea. The biological elements of these *sandbanks* can, therefore, be exposed to salinities from ca. 34‰ to 8 - 10‰ depending on location. Unstable substrates are found at all locations due to currents and wave action. These *sandbanks* can be without or with vegetation, primarily consisting of sea grasses (*Zostera*). The sediments of the *sandbanks* are in general not well described, which makes it difficult to give an exact biological description of the habitat. The degree of exposure to currents and waves will also, to a great extent, influence the biological composition of the habitat.

Existing knowledge permits a division of the habitat, into at least the following 3 *sub-features*:

1. *Non-exposed sandbanks in shallow water (Figure 6.1.1A)*
2. *Exposed sandbanks in shallow water (Figure 6.1.1B)*
3. *Sandbanks in deep water*

Figure 6.1.1A Sandbank at sheltered shallow water. *Photo Dennis Lisberg*

Figure 6.1.1B Sandbank at exposed shallow water. *Photo Dennis Lisberg*

The most important anthropogenic pressure factors for the habitat are eutrophication, fisheries where gear is dragged along the bottom, extraction of sand, and hazardous substances like antifouling paints. Introduced invasive non-endemic species may also impact on the quality of nature. Human induced climate change (global warming) may, in the long term, turn out to be a pressure factor.

Anthropogenic pressure factors and possible indicators for the 3 types of *sandbanks* are shown in *Table 6.1.1*.

6.1.2 Available data

Of the 40 Natura 2000 sites, which have been proposed solely or partly on the basis of the occurrence of the habitat *sandbanks, which are slightly covered by seawater all the time* data have been gathered in 18. The location of these sites is shown in *Figure 6.1.2*. The figure also indicates the length of the longest data series on *coastal vegetation* and *benthic fauna* respectively, taken from a sampling station in each of the sites. The position of all the stations is shown.

Table 6.1.1 Proposals for potential indicators for assessing conservation status of the habitat *sandbanks, which are slightly covered by sea water all the time (1110)* listed according to possible anthropogenic pressure factors, the unit of measurement, the method suggested to develop the indicators and thresholds and remarks.

Pressure factors	Indicator	Unit of measurement	Method for developing indicators and threshold values	Comments
Sand extraction, fishing with towed bottom gears, and eutrophication	Area	km^2	Surveys or old data	Applicable for all sub-features
	Species composition and density of, and biomass per area for benthic fauna	Nos. and g per m^2	Empirical modelling	Applicable for all sub-features. Data on benthic fauna probably problematic due to sampling problems
	Species diversity, occurrence, coverage and depth distribution of coastal vegetation	%, m^2, m, number of species, various indexes, similarity	Old maps and empirical modelling	Applicable for sub-feature 1
Climate change (global warming)	Species composition	Similarity (indexes/numbers)		Applicable for all sub-features
Environmentally hazardous substances	Concentrations in biota and sediment	Concentrations		Applicable for all sub-features
	Reproductive disorders in Viviparous blenny (lysosomal stability) – general effect indicator	Activity/frequency	Activity/frequency levels compared to reference areas	Applicable for sub-feature 1
	Specific effect indicators for PAH-like substances (EROD)	Activity/frequency	Activity/frequency levels compared to reference areas	Applicable for all sub-features
	Imposex and intersex in snails (specific effect indicator for TBT)	Indexes for imposex and intersex		Applicable for all sub-features
	Species composition	Similarity (indexes/numbers)		Applicable for all sub-features

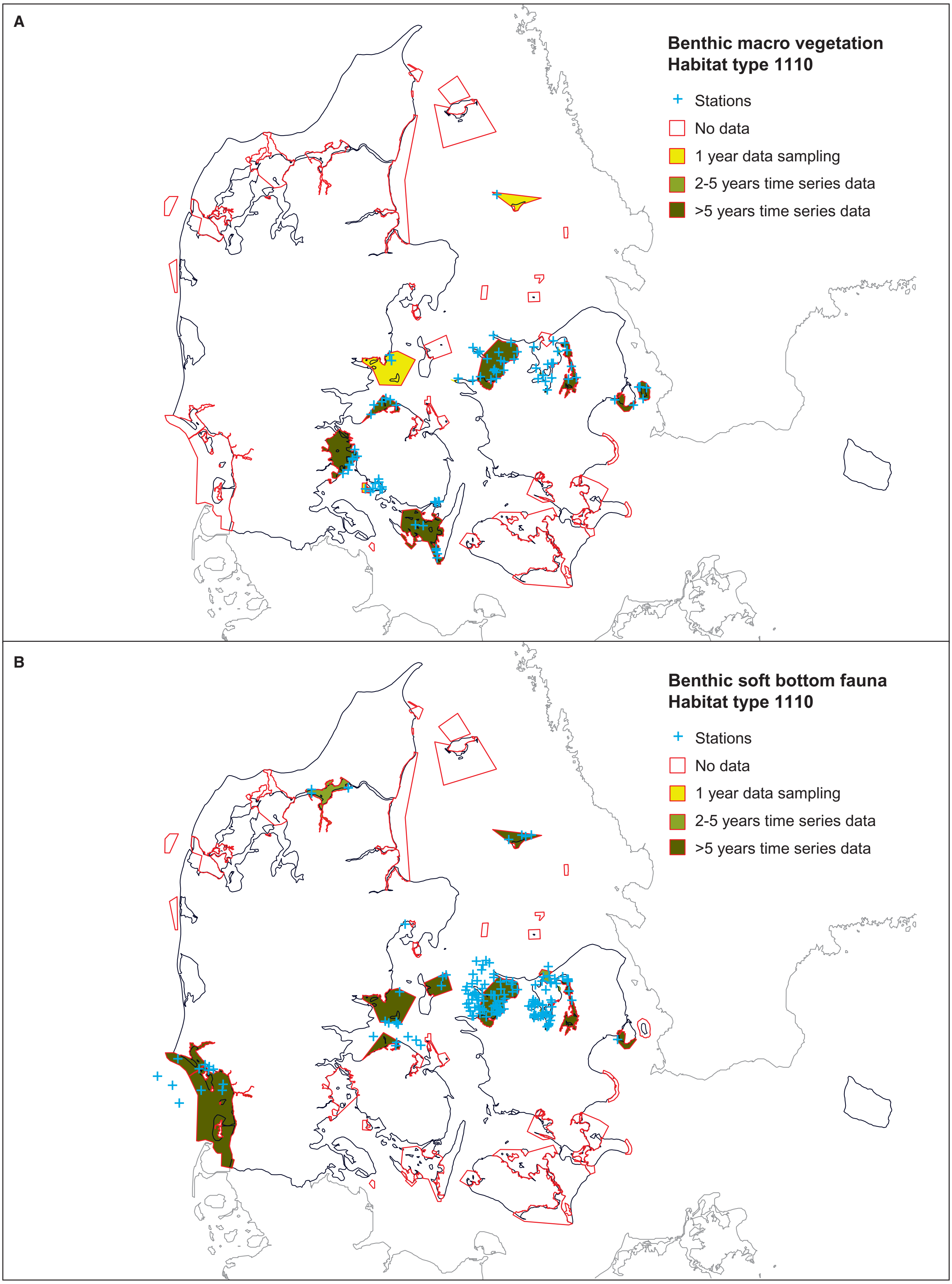


Figure 6.1.2 Natura 2000 sites designated solely or partly due to the presence of the habitat sandbanks, which are slightly covered by seawater all the time (1110) (areas bordered with red). The maps show where coastal vegetation and benthic fauna respectively have been sampled inside the habitat (as blue crosses). The colour of a site indicates the length of the longest time series from a sampling station at the site.

In site 136, the county has identified a *sandbank* habitat on which the designation of the site was not based.

As indicated in *Table 6.1.2*, great heterogeneity exists between the sites as to number of sampling stations and the necessary accompanying data on, *e.g. water quality* and *CTD*. There is only accompanying data to the data on *benthic fauna* from 5 sites, as is the case for *coastal vegetation*. The lengths of time series for all parameters differ both at and among stations and sites. This does not necessarily constitute a problem, since differences in time and space are of importance when using empirical modelling or when treating data in other ways. One long time series from an area where the pressure factors are constant does not necessarily provide more information than short time series from two areas that are different with respect to the intensity of pressure factors.

Less than 30% of the data on *coastal vegetation* and *benthic fauna* indicated in *Table 6.1.2* are stored at the National Environmental Research Institute, in MADS or otherwise. All remaining data is stored electronically and can be transferred to MADS.

6.1.3 Conclusions and recommendations

The habitat *sandbanks which are slightly covered by seawater all the time* have few sites with good data on benthic as well as water quality variables and some other sites with rather sporadic data. The best dataset on coastal vegetation and benthic fauna can probably be used for empirical modelling, especially if suitable accompanying data from areas outside Natura 2000 sites are available. Subdividing the habitat into 3 sub-features will, however, reduce the amount of usable data, especially for benthic fauna. There is also some concern regarding the method used to sample benthic fauna on sandy bottom that might affect the quality of data. Finally, the delimitation of the habitat within the Natura 2000 sites is not entirely known due to lack of marine habitat mapping,

It is recommended to analyse the existing data, especially data on *coastal vegetation* since all these data are presumed to be from areas of the same sub-feature "non exposed sandbanks in shallow water". Before new sampling programs for *benthic fauna* are launched, the applicability of existing data should be established. Also the proposed sub-features should be scrutinised.

Table 6.1.2 The Natura 2000 sites with the habitat *sandbanks, which are slightly covered by seawater all the time (1110)* with the Danish Natura 2000 number and the number of sampling stations for each parameter shown. Also the number of sites with sampling stations, and the number of stations sampled per parameter, according to information from the counties, are shown. ( ) indicates that the site was not designated on the basis of the *habitat*, but that the habitat was later registered by the regional authority.

Natura 2000 sites	Natura 2000 no.	Vegetation	Benthic fauna	Phytoplankton	Zooplankton	Water quality	CTD
Hirsholmene, the sea to the West and the mouth of Ellinge Å	4						
Coastal meadows on Læsø and the sea to the South	9						
Ålborg Bugt, Randers Fjord and Mariager Fjord	14						
Nibe Bredning, Halkær Ådal and Sønderup Ådal	15		4				
Løgstør, Bredning, Vejlerne and Bulbjerg	16						
Agger Tange	28						
Anholt and the sea to the North	42		5				
South Helgenæs	47						
Stavns Fjord, Samsø Østerflak and Nordby Hede	51		3				
Horsens Fjord, the sea to the West and Endelave	52	3	1				
The Wadden Sea	78		12	6	1	22	24
Fyns Hoved, Lillegrund and Lillestrand	91						
Æbelø, the sea to the South and Nærå	92	5	9			3	3
The sea between Romsø and Hindsholm plus Romsø	93						
Odense Fjord	94		2			1	1
Lillebælt	96	5		1		8	6
Maden on Helnæs and the sea to the West	108	2					
Sydfynske Øhav	111	6		2		6	6
Hesselø and surrounding reefs	112						
Roskilde Fjord	120	6	28	3		13	
Saltholm and surrounding sea	126	4					
Vestamager and the sea to the South	127	2	1	1		1	
The sea and the coasts between Hundested and Rørvig	134		2				
Sejrø Bugt	135	13	3	2		3	3
Udby Vig	(136)						
The sea and coasts between Præstø Fjord and Grønsund	147						
The sea and coasts between Karrebæk Fjord and Knudshoved Odde	148						
Smålandsfarvandet north of Lolland, Guldborg Sund, Bøtø Nor and Hyllekrog-Rødsand	152						
Nakskov Fjord	158						
Lysegrund	167						
St. Middelgrund	169					1	
Bredegrund	173						
The sea around Nordre Rønner	176					1	
Hadsten grund	204						
Stevns Klint	206						
Klinteskov Kalkgrund	207						
Risum Enge	221						
Kalø woods and Kalø Vig	230						
Thurø Rev	242						
Kyndby Kyst	245	1	1				
Sandbanks of Thyborøn	253						
Sandbanks of Thorsminde	254						
Number of sites sampled per parameter		10	12	6	1	11	7
Number of stations per parame		47	71	15	1	60	44

6.2 *Estuaries* (1130)

6.2.1 Identification of sub-features, pressure factors and potential indicators

In Denmark *estuaries* are mouths of large streams or small rivers. The water from these often transports sediments and organic material. Much of this is deposited in the *estuaries*, as the flow of water slows down and fresh water mixes with salt water causing flocculation of particles. The deposited material can form extensive mud and sand flats, which can become exposed at low tide. Depending on the rate of outflow of fresh water, more or less marked salinity gradients can extend from the innermost to the outermost parts of the *estuaries*. Estuaries can be with or without vegetation. The vegetation in the innermost parts usually consists of fresh or brackish water species while marine algae and phanerogams dominate in the outermost parts.

Run-off from land transports large amounts of plant nutrients to the sea, making eutrophication the most important anthropogenic pressure factor. Other pressure factors can be salinity variations and sand and mud flats being left dry. If shipping lanes must be dredged and the extracted sediments dumped, then vegetation and faunal communities can be destroyed or their distribution changed. Human induced climate change (global warming) may turn out to have marked effects on the plant and animal communities, especially in very shallow *estuaries*.

Anthropogenic pressure factors and possible indicators for *estuaries* are shown in *Table 6.2.1*.

6.2.2 Available data

Of the 4 Natura 2000 sites, which have been designated solely or partly on the basis of the occurrence of the habitat *estuaries* data have been gathered in 2 only (*Table 6.2.2*). The locations of these two sites, Randers Fjord and Ringkøbing Fjord are shown in *Figure 6.2.1*. The figure also indicates the length of the longest data time series on *coastal vegetation* and *benthic fauna* respectively, taken from a sampling station in each of the sites. The position of all the stations is shown. No time series for *coastal vegetation* or *benthic fauna* from any station is more than 4 years long (*Figure 6.2.1*), and there are few data on *phyto-* and *zooplankton*. Many of the time series for *water quality*, on the other hand, are more than 5 or even more than 10 years long.

In Natura 2000 site 96, Lillebælt, the counties of Fyn and Sønderjylland have registered the habitat *estuaries,* on which the designation of the site was not based.

Table 6.2.1 Proposals for potential indicators for assessing conservation status of the habitat *estuaries (1110)* listed according to possible anthropogenic pressure factors, the unit of measurement, the method suggested to develop the indicators and thresholds and remarks.

Pressure factors	Indicator	Unit of measurement	Method for developing indicators and threshold values	Comments
Dredging and dumping of sediments	Area	km^2	Measurements on recent or old aerial photos	
Eutrophication	Vegetation coverage	Coverage %	Empirical modelling	Salinity dependent
	Species diversity of algae	Number of species, various indexes, similarity	Empirical modelling	Salinity dependent
	Species diversity of phanerogams	Number of species, various indexes, similarity	Empirical modelling	Salinity dependent
	Species diversity of fauna	Number of species, various indexes, similarity	Empirical modelling	Salinity dependent
Climate change (global warming)	Species composition	Similarity		Impact probably greatest in shallow water
Environmentally hazardous substances	Concentrations in biota and sediment	Concentration		
	Reproductive disorders in Viviparous blenny (lysosomal stability) – general effect indicator	Activity/frequency	Activity/frequency compared to reference area	No data at present
	Specific effect indicators for PAH-like substances (EROD)	Activity/frequency	Activity/frequency compared to reference area	
	Imposex and intersex in snails (specific effect indicator for TBT)	Indexes for imposex and intersex		
	Species composition	Similarity		Impact probably greatest in shallow water
Salinity variations	Species diversity for algae, phanerogams and fauna	Indexes for algae, phanerogams and fauna	Recent and old data	Depends on run-off from land
Being left dry	Area	km^2	Measurements on recent or old aerial photos	Only aerial photos taken at low ”tide” can be used

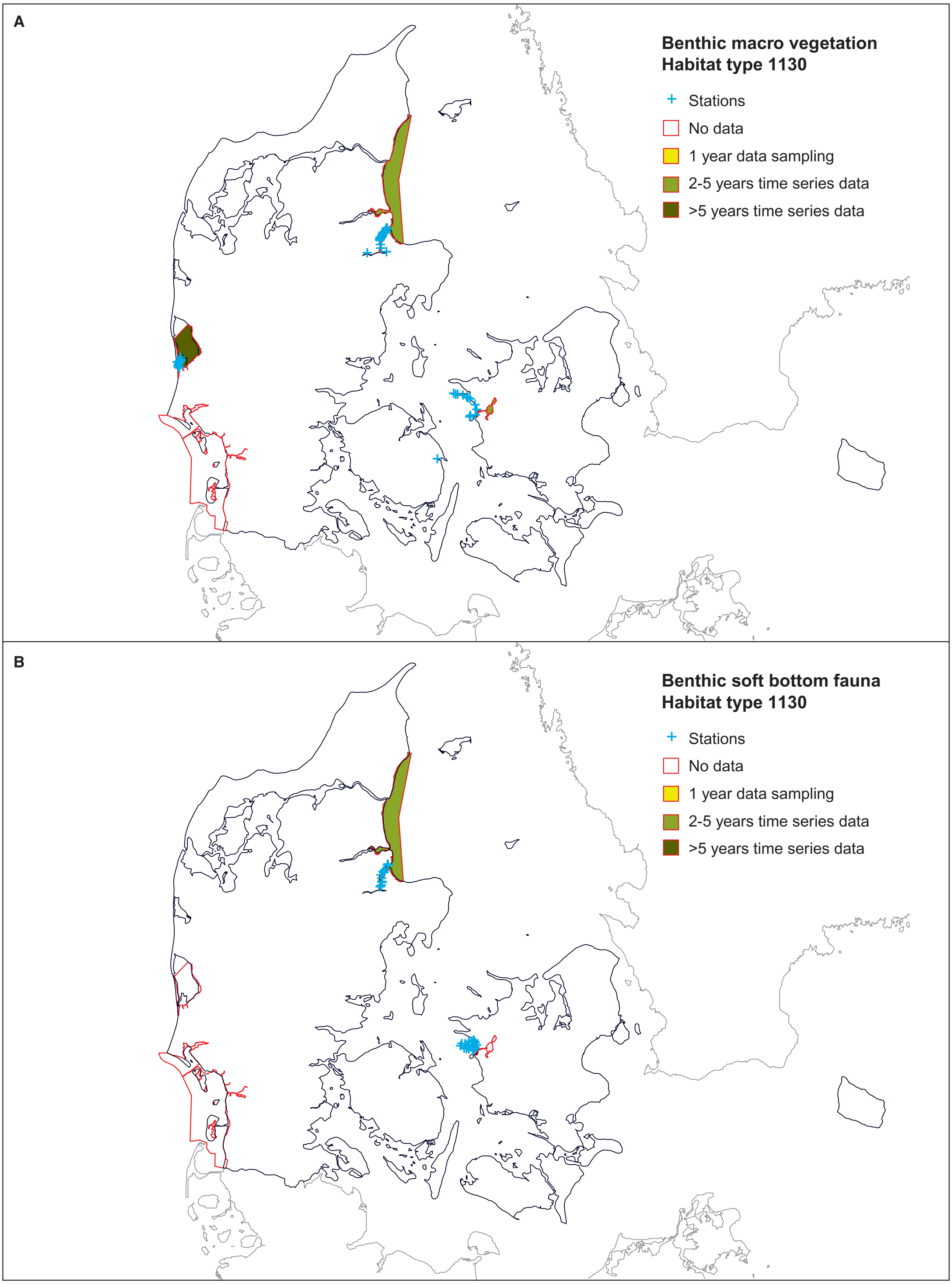


Figure 6.2.1 Natura 2000 sites designated solely or partly due to the presence of the habitat *estuaries (1130)* (areas bordered with red). The maps show where *coastal vegetation* and *benthic fauna* respectively have been sampled inside the habitat (as blue crosses). The colour of a site indicates the length of the longest time series from a sampling station at the site.

Table 6.2.2 The Natura 2000 sites with the habitat *estuaries (1130)* with the Danish SAC number and the number of sampling stations for each parameter shown. Also the number of sites with sampling stations, and the number of stations sampled per parameter, according to information from the counties, are shown. ( ) indicates that the site was not proposed on the basis of the habitat, but that the habitat was later registered by the regional authority.

Natura 2000 sites	Danish SAC no.	Vege-tation	Ben-thic fauna	Phyto-plank-ton	Zoo-plank-ton	Water quality	CTD
Ålborg Bugt, Randers Fjord and Mariager Fjord	14	21	15			2	4
Ringkøbing Fjord and Nymindestrømmen	62	1		1	1	1	1
The Wadden Sea	78						
Lillebælt	(96)						
Åmosen, Tissø, Halleby Å and Flasken	138						
Number of sites sampled per parameter		2	1	1	1	2	2
Number of stations per parameter		22	15	1	1	3	5

6.2.3 Conclusions and recommendations

Only data on and in relation to *coastal vegetation* is sufficient to detect effects of anthropogenic pressure factors using the proposed indicators. It is recommended to analyse existing data. Especially the data from Randers Fjord is sufficient to allow the setting up of a research programme, which will satisfy the need for data on indicators, especially in relation to *benthic fauna* and environmentally hazardous substances. Changes in area covered by the habitat can be evaluated by using existing aerial photos.

6.3 *Mudflats and sandflats not covered by seawater at low tide* (1140)

6.3.1 Identification of sub-features, pressure factors and potential indicators

Figure 6.3.1 The Wadden Sea.
Photo Michael Deacon

No terrestrial plants occur in this Annex 1 habitat, which is often covered by a layer of microscopic blue-green algae and diatoms. Eelgrass can occur in places. The habitat is of great importance as feeding place for web-footed waterfowl and wading birds (*Figure 6.3.1*).

Coastal protection by the use of dykes, fascines and coastal nourishment can change the area of this Annex 1 habitat. Oil and other hazardous substances can harm the habitat. Another major anthropogenic pressure factor is eutrophication, and human induced climate change (global warming) may also, in the long term, turn out to be so.

Anthropogenic pressure factors and possible indicators for *mudflats and sandflats not covered by seawater at low tide (1140)* are shown in *Table 6.3.1*.

6.3.2 Available data

Of the 25 Natura 2000 sites, which have been proposed solely or partly on the basis of the occurrence of the habitat *mudflats and sandflats not covered by seawater at low tide,* data have been gathered in 6 (*Table 6.3.2*). Data on coastal vegetation exists from 4 sites and on benthic fauna from 2. Most of the data time series on *coastal vegetation* are relatively short, and only a few are more than 10 years long. Several of the time series for *benthic fauna* are more than 5 and even more than 10 years long (*Figure 6.3.2*). Very different choices of "main parameters" for each site (*Table 6.3.2)* make comparisons among the type areas difficult.

6.3.3 Conclusions and recommendations

On the basis of an analysis of existing data, it is recommended to attempt a harmonisation of sampling parameters for each site. Among the indicators proposed in *Table 6.3.1*, data relating to benthic diatoms and alien substances are lacking. Only the data from the Wadden Sea seems sufficient to permit the setting of conservation objectives.

Table 6.3.1 Proposals for potential indicators for assessing conservation status of the habitat *mudflats and sandflats not covered by seawater at low tide (1140)* listed according to possible anthropogenic pressure factors, the unit of measurement, the method suggested to develop the indicators and thresholds and remarks.

Pressure factors	Indicator	Unit of measurement	Method for developing indicators and threshold values	Comments
Coastal protec-tion	Area	km^2	Measurements on recent or old aerial photos	Depends on tides
Eutrophication	Distribution of benthic dia-toms, coverage of phanerogams and possibly drifting algae	Coverage %	Empirical modelling	
	Species diversity of fauna	Number of species, various indexes, similarity		
Climate change (global warming)	Species composition	Similarity		
Environmentally hazardous substances	Concentrations in biota and sediment	Concentration		
	Reproductive disorders in Viviparous blenny (lyso-somal stability) – general effect indicator	Activity/frequency	Activity/frequency com-pared to reference area	
	Specific effect indicators for PAH-like substances (EROD)	Activity/frequency	Activity/frequency com-pared to reference area	
	Imposex and intersex in snails (specific effect indi-cator for TBT)	Indexes for imposex and intersex		
	Species composition	Similarity		

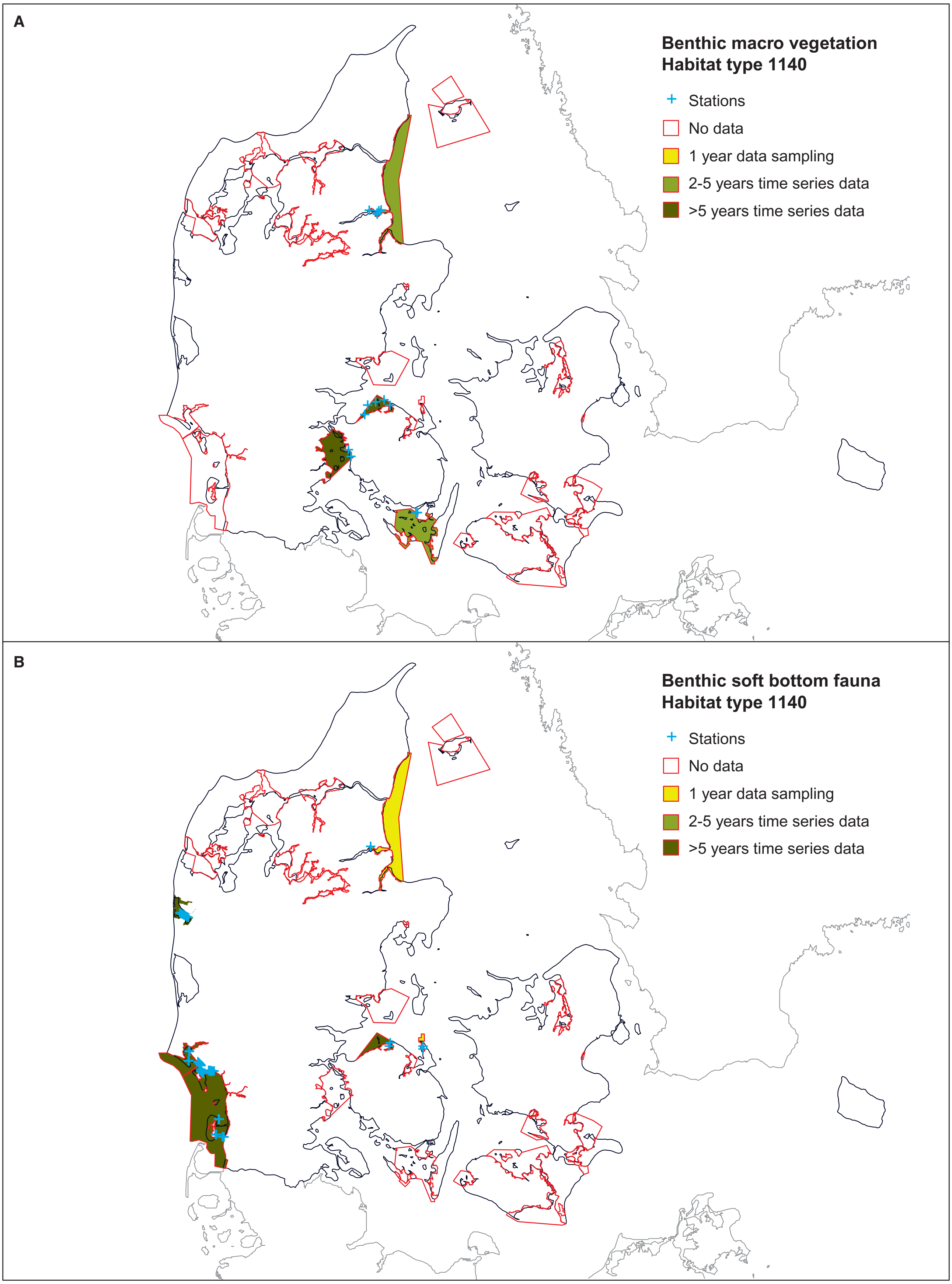


Figure 6.3.2 Natura 2000 sites designated solely or partly due to the presence of the habitat *mudflats and sandflats not covered by seawater at low tide (1140)* (areas bordered with red). The maps show where *coastal vegetation* and *benthic fauna* respectively have been sampled inside the habitat (as blue crosses). The colour of a site indicates the length of the longest time series from a sampling station at the site.

Table 6.3.2 The Natura 2000 sites with the habitat mudflats and sandflats not covered by seawater at low tide (1140) with the Danish SAC number and the number of sampling stations for each parameter shown. Also the number of sites with sampling stations, and the number of stations sampled per parameter, according to information from the counties, are shown.

Natura 2000 sites	Danish SAC no.	Vege-tation	Benthic fauna	Phyto-plankton	Water quality	CTD
Coastal meadows on Læsø and the sea to the South	9					
Ålborg Bugt, Randers Fjord and Mariager Fjord	14	5				
Nibe Bredning, Halkær Ådal and Sønderup Ådal	15					
Løgstør Bredning, Vejlerne and Bulbjerg	16					
Agger Tange	28					
Dråby Vig, Nissum Bredning, Skibsted Fjord and Agerø	29					
Lovns Bredning, Hjarbæk Fjord and Skals Ådal	30					
Horsens Fjord, the sea to the West and Endelave	52					
The Wadden Sea	78		76	1	20	22
Fyns Hoved, Lillegrund and Lillestrand	91					
Æbelø the sea to the South, and Nærå	92	4			3	3
Odense Fjord	94		2		1	1
Lillebælt	96	1			5	5
Sydfynske Øhav	111	2			2	2
Roskilde Fjord	120					
Ølsemagle Strand and Staunings Ø	130					
Jægerspris Skydeterræn	133					
The sea and coasts between Præstø Fjord and Grønsund	147					
The sea and coasts between Karrebæk Fjord and Knudshoved Odde	148					
Smålandsfarvandet north of Lolland, Guldborg Sund, Bøtø Nor and Hyllekrog-Rødsand	152					
Nakskov Fjord	158					
The sea around Nordre Rønner	176					
Risum Enge	221					
Kalø woods and Kalø Vig	230					
Kyndby Kyst	245					
Number of sites sampled per parameter	6	4	2	1	5	5
Number of stations per parameter	25	12	78	1	31	36