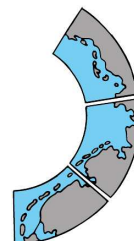




HARBASINS Report:

Monitoring of Seagrass in the Wadden Sea.

Prepared by: **TMAP Ad-hoc working group Seagrass**
Common Wadden Sea Secretariat, Wilhelmshaven
28 August 2006



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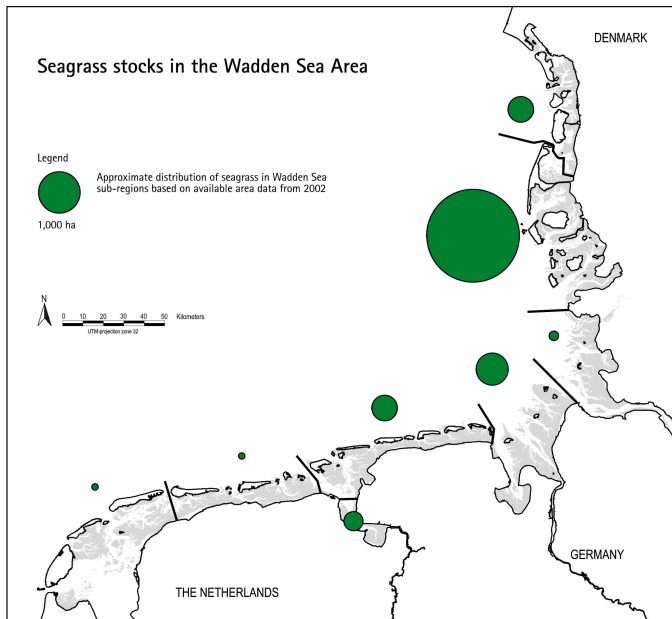


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1. INTRODUCTION

Seagrass beds indicate an high ecological quality status and have an important ecological function for coastal ecosystems. They provide habitats for several species such as fish, juvenile bivalves, crustaceans and a diverse range of other organisms. *Zostera* beds constitute a food for birds such as brent geese and wigeon. With their dense growth, they also protect the sediment against erosion and facilitate deposition.



In the southern and central Wadden Sea, a decline of seagrass was observed between the 1950s and 1990s which seems to have come to a halt, and some recovery is evident. In 2002/2003, intertidal seagrass beds were distributed rather unevenly. More than 80% of the beds occur in the northern Wadden Sea between Eiderstedt and Skallingen (Wadden Sea QSR 2004).

Figure 1: Distribution of seagrass beds in the Wadden Sea (in ha) in different subregions in 2002 (source: Wadden Sea QSR 2004)

In the Wadden Sea, monitoring of seagrass is still performed at diverging levels of accuracy in the different subregions, mainly due to widely differing sizes of vegetated areas and differing efforts. As a consequence, it is still unknown how much *Z. marina* and *Z. noltii* occurs in the entire Wadden Sea, and general trends in development can not easily be separated from more local phenomena and fluctuations.

The 11th International Scientific Wadden Sea Symposium in Esbjerg (April 2005) and the Wadden Sea QSR recommended to improve seagrass monitoring and research in the Wadden Sea and to establish a trilateral seagrass expert group.

As a result, a TMAP ad-hoc group on seagrass was established in February 2006. The main objectives of the ad hoc group were:

- to support the TMAP Revision process (Monitoring for Wadden Sea Plan and EU Directives) and
- to enhance the comparability and consistency of Wadden Sea monitoring (TMAP) based on the QSR 2004 experiences

The Terms of Reference and the members of the TMAP ad hoc group on seagrass are given in **Annex I**.

The group met on 20-21 February and 9-10 May 2006 and prepared a work scheme to implement the given tasks.

The report analyzes the existing monitoring programs (strategies, methods, assessment) and outlines how to make maximum use of these data in order to obtain comparable data sets for the whole Wadden Sea.

Based on this, a proposal for a monitoring guideline for seagrass was elaborated. Additionally, activities are suggested to further improve on the comparability of seagrass monitoring data in the Wadden Sea.

2. SEAGRASS MONITORING IN THE WADDEN SEA

A detailed inventory of the existing seagrass monitoring is given in **Annex 2**. The following table provides an overview of these programs in the three countries.

Table 1: Seagrass monitoring in the Wadden Sea. NL: Dutch sector, NDS and SH: German sectors of Lower Saxony and Schleswig-Holstein respectively, DK: Danish sector (details in Annex 2)

	Title	Institute	Area	Period	Time	Frequency	Method
NL	Monitoring of seagrass in the Dutch Wadden Sea	RWS-RIKZ Middelburg RWS-Agi Delft	3 main areas (Hond+Paap, Groninger Kust, Terschelling), plus other areas (irregular frequency)	Since 1994 (Hond+Paap) and later	July - August	Main areas: annually, others: 1/2 yr- and 1/6 yr	Aerial photographs, field work
NDS	Seagrass monitoring	NLWKN, NPA Whv.	Whole area,	1993/94 and 2000-2002	July - October	Not fixed.	Field mapping
SH	Seagrass monitoring	AWI Sylt NPA Tönning	Whole tidal flats; Selected beds: field work since 2003 (biomass, species, GPS mapping)	Since 1991/95	June - August	Annually	Manual mapping (3 flights), field work
DK	NOVANA phytobenthos	Ribe Amt Sdjld. Amt NERI	Transect in the southern Danish Wadden Sea	Since 1991	August	Annually	Field mapping, aerial photograph in 2002

In Germany, the seagrass monitoring will be modified in conjunction with the WFD monitoring. In Lower Saxony, it is planned to monitor the seagrass stock every 6 years and to select about 5 sites where a monitoring is carried out every year in late summer. In Schleswig-Holstein, representative sites will be selected (about 1-3 per water body) where seagrass field work will be carried out.

3. REVIEW OF THE EXISTING SEAGRASS MONITORING

3.1 Monitoring strategy and methods (Task 1)

The monitoring programs in the different countries have been adapted to the regional situation. Different strategies and the applied methods reflect the uneven distribution of intertidal seagrass in the Wadden Sea.

Therefore the achievable accuracy of assessment in the Western Wadden Sea with few seagrass beds cannot be reached in the Northern Wadden Sea with plenty of seagrass beds.

However, this does not preclude consistent data sets from the sub-regions to arrive at reliable estimates of total seagrass area and the respective shares of the taxa, nor does it preclude to identify trends and deviations from a “potential area”.

A common definition of a seagrass bed including a definition of borders and minimum density has also not yet been attempted. Furthermore, a common method to calculate density (%-cover) and up-scaling has not yet been established and there is sometimes confusion between gross and net area coverage of *Zostera* beds.

Based on the existing monitoring programs, the expert group prepared a proposal for a TMAP guideline (see chapter 4).

3.2 Remote Sensing methods (Task 2)

The expert group discussed the various remote sensing methods applied in seagrass monitoring in the Wadden Sea. Examples of aerial photographs were presented to illustrate the specific methods, interpretation procedures and calculation of area and coverage. The results of the presentations and discussions were used as a basis for the proposed TMAP guideline.

Remote sensing (RS) provides a good area assessment of aquatic macrophytes in the intertidal zone but still cannot separate taxa sufficiently. In particular, the distinction between seagrass indicating generally good and green algae indicating potentially deteriorating ecological conditions in the Wadden Sea. Ground surveys provide good taxonomical resolution but are not feasible where aquatic macrophytes are spread over a very wide tidal area.

It is recommended to combine RS methods with other methods as appropriate in order to reach the objective:

- a. Application of RS techniques at irregular intervals (such as satellite and airborne sensors / aerial photographs),
- b. Airborne surveys (visual mapping of extensive occurrences of seagrass and green algae annually)
- c. Field surveys (all regions: transects, sampling plots, different methods applicable)

The results of the German remote sensing project “Operationalization of remote sensing methods in the Wadden Sea” (OFEW) and the experiences from the Dutch monitoring will contribute to further enhance the use of RS techniques in the TMAP.

4. PROPOSAL MONITORING GUIDELINE (TASK 3 + 4)

The uneven distribution of seagrass on the tidal flats in the Wadden Sea requires different methods for an effective and efficient monitoring. No single monitoring method is available to meet all objectives.

The expert group developed common assessment methods which improves the comparability of the existing monitoring data and enhances the value of a trilateral assessment. The proposed monitoring guideline covers:

- monitoring objectives
- common definitions: seagrass bed, coverage categories, types of seagrass occurrence and areas,
- an estimation of a “potential area”
- description of suitable methods
- calculation and assessment tools

Based these common definitions, the available GIS data can now be combined in a common trilateral GIS database which gives information on:

- occurrence of seagrass beds (as in QSR 2004)
- coverage of seagrass beds (> 20%) (whole area) (new in QSR 2009)
- coverage of seagrass beds (e.g in steps of 10%) (selected areas) (new in QSR 2009)
- type of seagrass bed (*Z. noltii*, *Z. marina*, mixed, *Ruppia*) (new in QSR 2009)

5. FOLLOW UP ACTIVITIES

The expert group agreed to continue the cooperation on seagrass monitoring and to test and further develop the proposed seagrass monitoring guideline (including amongst others sampling methods, remote sensing techniques and coverage calculation):

- Preparation of an example booklet with photographs of cover densities to illustrate borders between TMAP seagrass categories 1, 2 and 3.
- Assessment of the SH long-term monitoring data (1994-2005) in order to define “permanent areas” and “ephemeral areas” of seagrass distribution (*remark*: analysis already done).
- Preparation of an intercalibration exercise in summer 2007 to test the proposed guidelines.
- Exchange of results from the German remote sensing project (OFEW) regarding monitoring of intertidal seagrass and macroalgae (*remark*: OFEW workshop on 11 – 12 September 2006 with international participation supported by Harbasins).

The aim of these activities is to further enhance the comparability and consistency of seagrass monitoring data for a trilateral assessment.

It is further recommended to adapt the TMAP guideline in 2007 in accordance with expected changes in seagrass monitoring for the Water Framework Directive (additional sampling stations and parameters, assessment methods).

ANNEX 1

TMAP Ad hoc working group SEAGRASS Terms of Reference (29.11.2005)

1. Introduction

The experiences from the QSR 2004 revealed that a harmonized assessment of Wadden Sea monitoring data of seagrass is still hampered because of limited comparability of monitoring methods and data.

The main objective of the TMAP expert group is

1. to support the TMAP revision process with regard to the implementation of monitoring for the Wadden Sea Plan Targets and the EC Habitats and Water Framework Directive monitoring requirements, also taking into account other relevant international conventions and
2. to enhance the comparability and consistency of Wadden Sea monitoring methods and data based on the experiences made during the preparation of the QSR 2004.

2. Tasks

1. to review the current monitoring program especially with regard to methods applied in the national monitoring programs, together with an indication of costs and priorities,
2. to assess cost-benefits on an integration of remote sensing techniques into national monitoring programs, especially in combination with other monitoring surveys in order to obtain comparable data sets for the whole Wadden Sea,
3. to prepare a proposal for complete and concerted surveys of seagrass and for inclusion of long-term monitoring stations with a higher frequency to better analyze population development, together with an indication of costs and priorities,
4. to prepare proposals for a common GIS database of seagrass occurrence based on the available monitoring data,

When having carried out tasks 1 - 4 the ad hoc group may also:

5. discuss possibilities in improvement of management and protection of seagrass,
6. exchange, as appropriate, results of research with regard to monitoring and management of seagrass in the Wadden Sea

3. Participation

The ad-hoc group will be attended by persons who are in charge of the national monitoring in organizational and technical aspects (Annex 1). The TMAG will nominate participants of the ad-hoc group and appoint a chairman. The CWSS will be responsible for the secretarial work.

4. Mandate

The ad-hoc group is a TMAP expert group under the responsibility of the TMAG to carry out the tasks given above. The ad-hoc group will prepare a work program and report to the TMAG.

5. Time schedule

The ad-hoc group shall prepare a work program in order to carry out the above mentioned tasks within two meetings and to report to the TMAG until June 2006.

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ANNEX 2 INVENTORY

The Netherlands	
1. General	
1.1 Institutes	Rijkswaterstaat RIKZ Middelburg, Dick de Jong Rijkswaterstaat AGI Delft, A.H. Groeneweg; J Bergwerff
1.2 Title	a. Monitoring of seagrass in the Wadden Sea
1.3 Aim	<ul style="list-style-type: none"> a. Trend and spatial development of seagrass for habitat management, Waterframework directive, Habitatdirective, Management scheme of the Dutch Wadden Sea etc
2. Sites	
2.1 Area and frequency	<ul style="list-style-type: none"> program until 2005 Annual mapping in 3 main areas (in MWTL program since:): <ul style="list-style-type: none"> o Hond-Paap (since 1994) o Groninger Kust (Lauwersmeer – Eemshaven) (since 1998) o Terschelling (three sub-areas(since 1991) Sites mapped in irregular frequency or during projects: <ul style="list-style-type: none"> o Ameland, Schiermonnikoog, Rottumeroog, Griend, Balgzand, Mokbaai frequency and time of the year: annually, <ul style="list-style-type: none"> o 1 July - 1 September (may extend to 29 September) (aerial photographs) o 1 August – 25 September (fieldwork) o Program in 2006: <ul style="list-style-type: none"> - annual mapping Hond-Paap; - bi-annual mapping: Terschelling, 2 main parts coast Groningen, Voolhok (Ems), Balgzand (Den Helder); - once per 6 years rest of coast Groningen
2.2 Parameters	<ul style="list-style-type: none"> • Area and location, • Species composition, • Coverage (%) (vegetation density) • Surface of coverage classes (%) (0-5, 5-20, 20-40, 40-60, 60-80, 80-100) • Frequency of abundance,
2.3 Methods	<ul style="list-style-type: none"> • aerial surveys since 1991/1994 • aerial photographs (false color/infrared, scale 1:10,000, 60% overlap), (at Groninger Kust only fieldwork until 2002), • fieldwork: according “Standard procedure mapping macrophytes” (Koppejan et al., 2001), • Field work: GPS
2.4 Analyzing methods	<ul style="list-style-type: none"> • Interpretation aerial photographs: (to be described) • GIS: ArcGis, grid size 2x2m •
4 Data handling	<ul style="list-style-type: none"> • GIS (ArcGIS) •
5 Quality assurance	

Literature:

www.zeegrass.nl ; website (also in English) with monitoring data and additional information about seagrass in the Netherlands

Koppejan, H., Groeneweg A.H. & Jansen, B.J.M., 2001. Standaardvoorschrift macrophytobenthos kartiering in de Waddenzee en Oosterschelde. Ministerie von Verkeer en Waterstaat – Meetkundige Dienst, rapport MD-GAE-1002. 24 Juni 2001, 38 pp.

Schleswig-Holstein	
1. General	
1.1 Institutes	Alfred-Wegener-Institut, Wattenmeerstation List/Sylt National Park Agency Tönning,
1.2 Title	Sea grass Monitoring in the National Park Schleswig-Holstein Wadden Sea
1.3 Aim	Monitoring and assessment of the development and distribution of seagrass
2. Sites	
2.1 Area and frequency	<ul style="list-style-type: none"> • Annual mapping of tidal flats (from Elbe do Danish border) since 1991 (regularly and same methods since 1995) and ground truth, • Field mapping at selected sites (Lister Deep, Königshafen) • frequency and time of the year: <ul style="list-style-type: none"> ○ annually, 3 flights per year, June – August,
2.2 Parameters	<ul style="list-style-type: none"> • Area and location, • Coverage (%): <50% and >50% (half-schematically on maps 1:100,000) • Notes are made on unusual colour, green algal cover and visible disturbances • Biomass (selected sites since 2003) • Species composition (selected sites since 2003)
2.3 Methods	<ul style="list-style-type: none"> • Manual mapping by airborne surveillance (meandering flight during low tide at 300-500 m altitude) • Field mapping GPS (since 2003)
2.4 Analyzing methods	<ul style="list-style-type: none"> •
4 Data handling	<ul style="list-style-type: none"> • GIS: ArcGis
5 Quality assurance	

Literature:

Reise, K., 2001. Algen und Seegrass: grüne Matten und Wiesen im Watten. In. Wattenmeermonitoring 2000. Schriftenreihe des Nationalparks Schleswig-Holsteinisches Wattenmeer.

Niedersachsen	
1. General	
1.1 Institutes	Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz (NLWKN), Marc Herlyn National Park Administration Wilhelmshaven, Richard Czeck,
1.2 Title	Seagrass Monitoring in the Niedersachsen Wadden Sea
1.3 Aim	Monitoring and assessment of the development and distribution of seagrass
2. Sites	
2.1 Area and frequency	<ul style="list-style-type: none"> • Mapping of tidal flats in <ul style="list-style-type: none"> ○ 1993/94 (Kastler & Michaelis, 1997) ○ 2000-2002 (Adolph et al. 2003) • frequency and time of the year:, <ul style="list-style-type: none"> ○ July – October 2002 (1235 stations), plus 305 in 2000 and 2001
2.2 Parameters	<ul style="list-style-type: none"> • Area and location, • Species composition (<i>Zostera marina</i> and <i>Z. noltii</i>) • Cover and proportion (%) in five classes (<1, 1-5, 5-20, 20-60, 60-100) • <u>Cover</u> (%): area of seagrass-covered patches in relation to the total seagrass bed area • <u>Proportion</u> (%): area covered by seagrass within the patches in relation to the total area of the seagrass patches of a bed • Biomass: at selected sites: <ul style="list-style-type: none"> • to 6 samples per bed, each covering 181 cm² • fresh weight, dry weight and afdw • analysed separately for leaves and roots/rhizomes • - Sediment characteristics
2.3 Methods	<ul style="list-style-type: none"> • Field mapping, GPS • Complemented by aerial surveys in July and August 2002 (comparison with field mapping)
2.4 Analyzing methods	<ul style="list-style-type: none"> • GIS: ArcGis
4 Data handling	<ul style="list-style-type: none"> • GIS ArcGis
5 Quality assurance	

Adolph, W., S. Jaklin, M. Meemken & H. Michaelis, (2003): Die Seegrasbestände der niedersächsischen Watten (2000 – 2002), Dienstber. Forschungsstelle Küste 1/2003 -- 1-19 Norderney

KASTLER, T. & H. MICHAELIS (1997): Der Rückgang der Seegrasbestände im niedersächsischen Wattenmeer. Ber. Forsch.-Stelle Küste Norderney 41: 119 - 139.

	Denmark
1. General	
1.1 Institutes	Ribe Amt, Soenderjyllands Amt, Danmarks Miljøundersøgelser,
1.2 Title	NOVANA. Phytobenthos
1.3 Aim	Documentation of the development of phytobenthos (seagrass and macroalgae).
2. Sites	
2.1 Area and frequency	<ul style="list-style-type: none"> • Mapping of transects in the southern Danish Wadden Sea (Havneby, Ballum, Roemoe-Nord) <ul style="list-style-type: none"> ○ Yearly since 1991 • frequency and time of the year:, <ul style="list-style-type: none"> ○ annually, in August • Yearly annual surveys (combined with macroalgae survey)
2.2 Parameters	<p>Annually:</p> <ul style="list-style-type: none"> • Location of seagrass beds, • Coverage of seagrass-species • Total coverage of seagrasses • Coverage of eutrophication-related species • Coverage of macroalgae on hard substrate • Coverage of hard substrate incl. blue mussel beds <p>Every three years:</p> <ul style="list-style-type: none"> • Biomass of seagrass species • Number of shoots • Biomass of eutrophication-related algae (Chaetomorpha linum, • Cladophora sp., Enteromorpha sp., Ulva lactuca, Ulvaria fusca, Ectocarpus sp. , Pilayella sp. • Estimate of total area of seagrasses
2.3 Methods	<ul style="list-style-type: none"> • Field mapping, GPS • Aerial photographs in 2002
2.4 Analyzing methods	<ul style="list-style-type: none"> •
4 Data handling	<ul style="list-style-type: none"> •
5 Quality assurance	

Literature

Amterne Vadehavssamarbide, 2005. Vadehavet – Status og udvikling 1989 – 2004, NOVANA.

ANNEX 3 DRAFT TMAP GUIDELINE SEAGRASS MONITORING (VERSION 13.6.2006)

1. Introduction

In the Wadden Sea two seagrass species are found: the small and very narrow-leaved *Zostera noltii* is the most common. It grows in the intertidal and is usually perennial. It is often accompanied by a mostly annual, narrow leaved small morph of the large *Z. marina* particularly in puddles filled with water during low tide. Around low water line and deeper beds of large and perennial *Z. marina* once occurred in the Wadden Sea. In the course of the wasting-phenomenon in the 1930s these beds vanished and never came back. Under brackish conditions the related widgeon grass *Ruppia maritima* occurs in the Wadden Sea.

Seagrass beds have an important ecological function for coastal ecosystems. They provide habitats for several species such as fish, juvenile bivalves, crustaceans and a diverse range of other organisms. *Zostera* beds constitute a food for birds such as Brent geese and widgeon. With their dense growth, they also protect the sediment against erosion and facilitate deposition.

Both species *Z. marina* and *Z. noltii* show considerable interannual fluctuations in size and shape of local beds. Salinity and nutrient loading, separately and in combination, are important environmental factors for seagrass development. Local runoff of freshwater is considered advantageous for seagrass growth; these runoff points have been diminished by sea dike strengthening. Eutrophication, turbidity and hydrodynamics seem to be the major factors determining the distribution of seagrasses in the Wadden Sea, while shellfish fishery and land claim have negative effects on a more local scale (Reise et al., 2005).

In the southern and central Wadden Sea, a decline of seagrass was observed between the 1950s and 1990s which seems to have come to a halt, and some recovery is evident. In 2002/2003, intertidal seagrass beds were distributed rather unevenly. More than 80% of the beds occur in the northern Wadden Sea between Eiderstedt and Skallingen (Reise et al., 2005).

Due to divergent methods of assessment the total area of seagrass in the Wadden Sea is considered to be a rough estimate.

2. Objectives

Trilateral policy and management aims “to achieve, as far as possible, a natural and sustainable ecosystem in which natural processes proceed in an undisturbed way” (Guiding Principle).

With respect to the “Tidal Area” (intertidal and subtidal), the following Target applies (Wadden Sea Plan) to seagrass:

- An increased area of, and a more natural distribution and development of ... *Zostera* fields.

The monitoring of seagrass is carried out to support trilateral policy and management. It should

- assess changes in the distribution of seagrass,
- assess changes in species composition and abundance of *Zostera* and related aquatic phanerogams such as *Ruppia*,
- contribute to causal analysis of changes,
- enable an estimation of potential carrying capacity in the Wadden Sea for seagrass and assess deviation from it,
- prepare recommendations for management.

Monitoring of seagrass in the TMAP supports the reporting under the EC Habitats Directive and the EC Water Framework Directive:

- Habitats Directive: Habitat type 1140 “Mudflat and sandflats not covered by seawater at low tide”, (Favorable conservation status of habitats).
- Water Framework Directive: Biological quality element “Angiosperms” (Good ecological status of water bodies).

3. Status of seagrass in the Wadden Sea

For an appropriate seagrass monitoring strategy it is necessary to assess to which extent the trilateral Target “An increased area of, and a more natural distribution and development of ... *Zostera* fields” has already been reached and to which extent the current status relates to the “potential area” where seagrass could grow in the absence of anthropogenic disturbance.

This would be an expert estimation to compare the current situation with the maximum surface area of intertidal seagrass beds which could be reached under high quality conditions. This may give an indication whether the current situation has reached, is below or even far below the potential area.

For the Netherlands, the current surface area of seagrass beds was regarded as more or less the maximum which can be expected in the intertidal area. Only by intensive effort, esp. in the Groningen salt marsh works, a significant increase in area might be possible.

In Lower Saxony, the intertidal seagrass area is still at least 5 times lower compared to the situation in the 1950s/70s and is regarded as clearly below a potential which may be estimated to about at least 35 km².

In Schleswig-Holstein, the potential area of seagrass beds possible under no land claim and other mechanical disturbances, and continued decrease of nutrient input would be about 1 – 5% coverage in the Dithmarschen area (today 0.3%) and about 20% in the North Frisian Wadden Sea (today 10%), which includes a more or less continuous belt of seagrass along the mainland coast.

4. Definitions

Seagrass bed

Seagrass beds in the Wadden Sea comprise submerged phanerogame plants belonging to the genera *Zostera* (*Z. noltii* and *Z. marina*) and *Ruppia maritima*.

Three categories can be recognized based on occurrence of seagrass and the methods applied for their assessment:

1. Areas within the Wadden Sea may be entirely devoid of seagrass or may have a few isolated plants with coverage <5%.
2. Areas may show growth of scattered seagrass plants when at peak vegetation period average cover is between 5 and 20%.
3. In addition or instead, areas may show seagrass beds with >20% cover at peak vegetation period.

Beds have either a coherent coverage of >20% or are composed of clusters of patches (with >20% coverage) less than 25 m apart.

In ground surveys, area is preferably measured in a spatial resolution of 10x10 m and in airborne surveys in a spatial resolution of 100x100 m.

The area is given as gross area belonging to category 2 and/or 3 and, if available, also the seagrass net area by multiplying gross area with coverage (0.05 to 0.2 or >0.2 to 1).

Coverage categories

The available coverage data (ranges) will be combined for the TMAP as follows

TMAP Category	TMAP Density	Coverage %
1	Devoid or scarce	<5
2	Scattered	5-20
3	Beds	>20

More detailed coverage categories should be applied for sub-regions in the Wadden Sea if data are available.

Peak vegetation period

Time between mid of July to mid September.

Coverage

The average amount of living seagrass plants covering the bottom of the sea at low tide exposure during peak vegetation period from mid July to mid September.

At permanently submerged bottoms the coverage is measured as the shadow of seagrass plants cast onto the bottom when light shines vertically from above.

Ephemeral areas:

Areas with occasional occurrence of seagrass within a period of about 10 years.

Permanent areas:

Areas which are known as covered or can be assumed to have been covered with seagrass over 10 or more consecutive years.

Potential area of intertidal seagrass in the Wadden Sea

Surface area of intertidal seagrass beds which may be reached under the current conditions (e.g. continued decrease of nutrient inputs, maintenance of the present dike lines, no land claim or other mechanical disturbance) and the existing hydro-morphological regime (derived from historical data and expert knowledge. It may change with sea level rise, shifts in tidal range and with restoration measures.

The potential area has to be defined taking into account the 3 different categories of seagrass beds.

Table 1: Surface area of seagrass beds (% coverage of intertidal area): Current situation and potential area.

Explanatory note: Areas with less than 5% coverage (Category 1) are not included. For Schleswig-Holstein, only areas with >20% coverage are given.

n.d. = no data

Region	Current situation		Potential area	
	Cat. 2 (5-20%)	Cat. 3 (>20%)	Cat. 2 (5-20%)	Cat. 3 (>20%)
Denmark			Not defined	Not defined
SH-Nordfriesland	n.d.	10%	n.d.	20%
SH-Dithmarschen	n.d.	0.3%	n.d.	1 – 5 %
Niedersachsen		[7.5 km ²]*		[About 35 km ²]*
Netherlands	[1 km ²]*	[0.2 km ²]*	[1 km ²]*	[0.2 km ²]*

*: to be converted into % and to be differentiated into category 2 (5-20%) and 3 (>20%)
 [Intertidal area: NL=1240 km², Nds=1440 km² (QSR 2004)]

Species composition

	Type of seagrass bed	Species composition:
1	<i>Z. noltii</i> bed	Consist of >75% <i>Zostera noltii</i>
2	<i>Z. marina</i> bed	Consist of >75% <i>Zostera marina</i>
3	Mixed <i>Zostera</i> bed	Percentage of <i>Z. noltii</i> or <i>Z. marina</i> between 25-75%
4	<i>Ruppia</i> bed	Consists of > 75% <i>Ruppia maritima</i>

5. Monitoring of species and areas

In the marine and brackish coastal waters of the Wadden Sea, the aquatic phanerogames comprise two genetically highly diverse seagrasses (*Z. marina*, *Z. noltii*) and restricted to brackish conditions the wigeon grass *Ruppia maritima*.

Seagrass should be monitored covering all intertidal flats in the entire Wadden Sea. Within the Wadden Sea regional assessments and analyses of spatial distribution should be carried out to fulfill the reporting commitments of the relevant EC Directives.

Selected monitoring areas should be assigned which are representative for a larger part of the Wadden Sea and where field surveys can be carried out with a high frequency. This should also include potential seagrass sites.

Additional surveys should be considered to include suitable subtidal areas for *Zostera marina* and brackish transitional water bodies for *Ruppia* spp.

6. Methods

No single monitoring method is available to meet all objectives.

1. Remote sensing (RS) provides a good area assessment of aquatic macrophytes in the intertidal zone but cannot separate taxa sufficiently. In particular, the distinction between seagrass indicating generally good and green algae indicating potentially deteriorating ecological conditions in the Wadden Sea.

Ground surveys provide good taxonomical resolution but are not feasible where aquatic macrophytes are spread over a very wide tidal area.

2. Seagrass occurrence is extremely uneven in the Wadden Sea. Therefore the achievable accuracy of assessment in the Western Wadden Sea with few seagrass beds cannot be reached in the Northern Wadden Sea with plenty of seagrass beds.

However, this does not preclude consistent data sets from the sub-regions to arrive at reliable estimates of total seagrass area and the respective shares of the taxa, nor does it preclude to identify trends and deviations from the “potential area”.

The following methods may be combined as appropriate in order to reach the objective:

- a. Application of RS techniques at irregular intervals (such as satellite and airborne sensors / aerial photographs),
- b. Airborne surveys (visual mapping of extensive occurrences of seagrass and green algae annually)
- c. Field surveys (all regions: transects, sampling plots, different methods applicable)

Remote sensing

The selection of the appropriate remote sensing (RS) techniques depends on:

- the overall monitoring strategy in which RS is an integrated part (combination of different methods and/or field surveys),
- the type of information to be delivered by RS (orientation, supporting information for field surveys, preparation of detailed seagrass maps).

There are different remote sensing techniques available which can be applied for monitoring of larger areas in the Wadden Sea.

Remote Sensing	Technique	Application	Remarks	Operation
Aerial photographs	IR ortho photographs (e.g. resolution 1:10,000)	Monitoring of distinct smaller areas	Seagrass beds with low coverage may be overlooked, discrimination between different <i>Zostera</i> species is difficult or not possible High costs	operational in NL (annually), applied also in Lower Saxony and Denmark for distinct years)
Other airborne sensors	Digital high resolution sensors e.g. HyMap	Synchronous monitoring of a large area	Objective automated analysis possible. High costs.	not yet operational (see OFEW project)
Satellites	Various optical sensors (by Landsat or Aster)	Synchronous monitoring of a large area	Objective automated analysis possible. Green macroalgae may not be discriminated from <i>Zostera</i> (see above). Limited data availability Low costs	not yet operational (see OFEW project)
Airborne surveys	visual mapping of seagrass beds	Monitoring of larger areas with high frequency	Seagrass may be overlooked. For seagrass beds >20% coverage. Discrimination between <i>Zostera</i> species is not possible but can mostly be separated from green macroalgae Low costs	operational in SH (annually, during peak season), applied also in Lower Saxony for distinct years)

OFEW = Operationalisierung Fernerkundungsmethoden für das Wattenmeer (Bockmann Consult, 2005-06)

Field surveys

Field surveys should be carried out

- as ground truth in conjunction with remote sensing
- to get more detailed information (quantitative and qualitative) to be able to characterize the ecological status of the seagrass beds.
- to monitor areas with scattered occurrence of seagrass (<20% coverage) including potential seagrass areas.

It is recommended to carry out these surveys at seagrass sites which are representative for a selected region during the peak vegetation period.

7. Parameters

The parameters currently monitored are sufficient to fulfill the objectives. Further adaptations may be required at a later stage if the comparability of results from different sub-regions should be enhanced.

TMAP Parameters (covering entire intertidal area)

- Area: size of seagrass beds (km²)
- Location: coordinates of seagrass beds (GIS polygon),
- Coverage: Seagrass coverage of the beds (%)

Optional parameters (if available from ongoing national programs and from selected field sampling sites):

- Species composition (*Zostera marina* and *Z. noltii*, *Ruppia maritima*, green macroalgae, others)
- Biomass,
- Sediment characteristics (such as: presence/absence of fossil clay or peat below sediment surface, accretion/erosion area, presence/absence of mobile sand ridges).
- Other

8. Frequency and time

The monitoring frequency has to be adapted to the situation in the sub-regions:

- NL: annual, biannual and every six years(selected sites)
- Nds: total area every 6 years, selected sites annually
- SH: every year aerial mapping / selected sites annually
- DK: every year at selected sites, areal cover two times in six years at selected sites

The surveys should be carried out during peak vegetation period (mid of July to mid September).

9. Reporting

All data obtained from aerial and field surveys should be transferred to a geographical information system (GIS) for the analysis and assessment of the data (spatial and temporal development) and in combination with other GIS based information.

The data should be reported as they were measured:

- area of the bed (and/or the single patches within a bed) (km²)
- seagrass coverage of the bed (or single patches) (%)

A description of the applied methods should also be reported. If available the accuracy of the data should be included in reporting.

10. Quality assurance

Appropriate monitoring protocols should be developed on national level. Intercalibration exercises should be carried out nationally and in the framework of the TMAP.

11. Monitoring authorities

Denmark

- Danmarks Mijoeundersøgelse (DMU, NERI),
- Sønderjyllands Amt
- Ribe Amt

Germany

- • Landesamt für den Nationalpark Schleswig-Holsteinisches Wattenmeer,
- • Nationalparkverwaltung Niedersächsisches Wattenmeer,
- • Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz

The Netherlands

- • Rijksinstituut voor Kust en Zee (RIKZ) Middelburg

12. Literature

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