Rostock. Meeresbiolog. Beitr.	Heft 17	91 – 109	Rostock 2007

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A method for classifying coastal marshes of the German Baltic Sea for the European Water Framework Directive (WFD)

Bewertungsverfahren für Salzrasen und -röhrichte der deutschen Ostseeküste nach der Europäischen Wasserrahmenrichtlinie

Abstract

Angiosperms are identified in the European Water Framework Directive (WFD) as one of the biological quality elements in the European Water Framework Directive (WFD) used to classify the ecological status of coastal waters. This comprises not only seagrasses, but also saltmarshes in the intertidal zone. We suggest including also coastal marshes at the non-tidal Baltic Sea in the WFD-classification, since they are relevant to the quality of coastal waters particularly regarding eutrophication.

We propose a classification method for Baltic coastal marshes that is based on vegetation and hydromorphological parameters. Vegetation parameters include quantity indicated by the areal extent of coastal marshes as well as coastal marsh quality indicated by zonation of the vegetation and species composition. Hydromorphological indicators such as creeks, ditches and dikes are used to support the vegetation parameters because they indicate anthropogenic alterations more directly and without any time lag. Since no negative impact of grazing on water quality is known, reference conditions include grazed marshes as well as ungrazed reed beds. While vegetation parameters such as zonation and species composition should be assessed in the field, areal extent and hydromorphological parameters are primarily based on existing GIS-based information, which must be complemented and verified in the field.

Finally, recommendations are given for a field trial to validate the classification method. Monitoring after a 6-year interval should be carried out further to comply with the requirements of the WFD and the Habitats Directive.

Keywords: Water Framework Directive, Ecological status, Classification, Saltmarsh, Brackish reed bed, Coastal waters

1 Introduction: Coastal marshes as part of the coastal water bodies?

The Water Framework Directive (WFD) of the European Union aims at achieving a “good ecological status” of all surface water bodies by 2015. This applies also to coastal waters, including the intertidal zone. The ecological status must be classified into 5 classes from “high” to “bad” using biological, physico-chemical and hydro-morphological quality elements. The classification of coastal waters is primarily

https://doi.org/10.18453/rosdok_id00005382

based on three "biological quality elements": benthic invertebrates, phytoplankton and macroalgae and angiosperms ("other aquatic flora"). These are supported by physico-chemical and hydro-morphological quality elements, *inter alia* "structure and condition of the intertidal zone" (WFD, European Commission 2000).

Only recently, the term "angiosperms" has been taken to include not only seagrasses, but also saltmarsh plants (CIS Coast 2003, CIS Wetlands 2003). As a consequence, several classification methods have been developed which consider saltmarshes as part of the coastal or transitional water bodies (e.g. Brys et al. 2005 for Belgium, Dijkema et al. 2005 for the Netherlands, and Best et al. 2007 for Great Britain). For the German North Sea coast, a common classification method is now under development (Stock pers. comm.), consulting the work of Arens (2006), Adolph et al (2007) and Stiller (2005a, 2005b).

However, all these approaches refer to tidal waters including the intertidal zone which is explicitly considered within the water body in the directive and in several guidance documents of the Common Implementation Strategy (CIS Coast 2003, CIS Wetlands 2003, CIS Monitoring 2003). So far, no WFD classification approach exists for non-tidal coastal marshes, nor has the relevance of non-tidal coastal marshes for the implementation of the WFD been discussed.

Thus, we will consider the questions if and why coastal marshes of the Baltic Sea should be regarded as relevant for the WFD. Further, we will present a draft outline of a classification method for coastal marshes of the German Baltic coast.

For non-tidal coastal waters such as the Mediterranean and Baltic Sea, the guidance document on Monitoring (CIS Monitoring 2003) proposes the term "mediolittoral zone" as an equivalent to the "intertidal zone", which comprises communities that are dependent on flooding by sea water.

At the Baltic Sea, coastal marshes form an important part of these irregularly flooded communities on shallow, wind-protected coasts. In this paper, "coastal marshes" is used as a generic term for both saltmarshes and brackish reed beds. Saltmarshes have developed in most areas due to centuries of grazing or mowing (Schmeisky 1974, Dijkema 1990), while brackish reed beds form without grazing. At the south-western Baltic, coastal marshes are largely developed as coastal peatlands.

The formerly extensive coastal marshes along the Eastern German Baltic Sea coast (federal state of Mecklenburg-Vorpommern) have been reduced by more than 80% due to diking and drainage (Herrmann & Holz 1997). Coastal marshes are not only sensitive to alterations of their flooding regime and morphology by drainage and construction of dikes, but also to eutrophication (Jeschke 1987, Krisch 1989, Adam 2002, Boorman 2003) and chemical pollution by heavy metals, organic substances or oil (Vestergaard 1979, 2002, Van Bernem et al. 1994, Boorman 2003, Schuldt & Borgwardt 2005). While eutrophication and chemical pollution are also indicated by other quality elements of the WFD classification (e.g. phytoplankton and seagrass, which are probably more sensitive to eutrophication than – naturally eutrophic – coastal marshes), hydro-morphological alterations of the coastal zone such as diking and drainage are more directly indicated by the status of coastal marshes.

Since coastal marshes are wetlands, they must be included in the coastal water body, if they "are directly influencing the status of the related water body" (CIS Water Bodies 2003) and if "the structure and condition of such wetlands is relevant to the achievement of the objectives for a surface water body" (CIS Wetlands 2003).

Coastal marshes (especially coastal peatlands) can affect the status of coastal waters, particularly relating to eutrophication. They have a potential for nutrient retention if intact and regularly flooded, whereas they can contribute to nutrient load if peat is mineralised due to drainage. However, quantitative studies on the function of coastal peatlands of the Baltic Sea are currently lacking (Trepel & Kluge 2001). The significance of coastal marshes as a nutrient sink or source depends on the ratio of water area and coastal marsh area. It can be particularly high for small, enclosed water bodies surrounded by large (former) coastal peatlands (such as the lagoons in Mecklenburg-Vorpommern or the Schlei fjord in Schleswig-Holstein). Hence, this area ratio should be taken into account when classifying the ecological status of the water bodies.

We conclude that coastal marshes can potentially influence the status of coastal waters and should therefore be generally considered as part of the coastal water bodies. Further, coastal marshes are particularly likely to reflect morphological alterations of coastal waters. Therefore they can complement the other quality elements in an integrated assessment of the ecological status of coastal waters.

2 Scale of classification: reference conditions

The scale for the classification of the WFD is related to the "reference conditions", that are defined in the Directive as "undisturbed conditions" with "no, or only very minor, anthropogenic alterations", under which "the values of the biological quality elements […] show no, or only very minor, evidence of distortion".

The term "disturbance" in this context is confined to "anthropogenic alterations". As mentioned above, anthropogenic alterations to coastal marshes may be changes of hydromorphology and hydrodynamics as well as input of nutrients and pollutants.

In general, (agricultural) grazing can also be considered an anthropogenic factor and at the Baltic Sea coast, large areas of saltmarshes have developed from brackish reed beds during the last 500 years as a consequence of grazing (Jeschke 1987: "anthropo-zoogenic saltmarshes", Dijkema 1990). So far, it is not known whether saltmarshes and brackish reed beds differ in their ability to retain nutrients or form coastal peat. Therefore the impact of grazing is not considered as either positive or negative in the sense of the WFD in this paper.

Thus, only anthropogenic alterations of hydromorphology and -dynamics will be defined as "disturbances" to coastal marshes in the context of the WFD. We define a coastal marsh under reference conditions as an area exposed to natural flooding regime where either saltmarshes or brackish reed beds have become established that are subject to no or only very minor anthropogenic alterations.

The classification method for coastal marshes of the Baltic Sea is based on vegetation parameters (as part of the quality element "angiosperms") and uses hydromorphological parameters further to support the assessment based on vegetation. Hydromorphological parameters reflect alterations of the flooding regime more directly than the coastal marsh vegetation. In some cases, halophyte species are known to persist in the vegetation for years or even decades after the construction of a dike and the cut-off from regular flooding.

The proposed draft classification method for coastal marshes results from a project that focused on coastal marshes at the Baltic Sea coast of the federal state of Schleswig-Holstein. Within the frame of the project, the present situation of coastal marshes in Schleswig-Holstein was analysed using existing (mainly digitally available) data. Results of this analysis were used to derive class boundaries for hydromorphological parameters. They should therefore not be in the same way applied to coastal marshes in Mecklenburg-Vorpommern without considering adaptations to local conditions. The general classification method, however, is designed to be applied for the whole German Baltic Sea coast. The consideration of local differences has to be one aspect of a field trial in the future (see “perspectives” below).

3 Hydromorphological parameters

Three hydromorphological parameters were selected: flooding dynamics, intensity of drainage and restriction of flooding.

To derive class boundaries, 10 coastal marsh sites along the Schleswig-Holstein Baltic coast were selected reflecting the whole gradient of degradation from natural flooding to completely diked and drained areas. GIS-based information, aerial photographs and site visits were used to assign these sites to the 5 WFD classes of ecological status for each of the three parameters separately. From this classification, class boundaries for the three parameters were derived.

Flooding dynamics

Creeks and salt pans are the products of natural flooding dynamics. The parameter is assessed by using GIS-available data of the most recent biotope mapping and is indicated by the total number of the biotope types “near-natural saline small water body” and “tidal creek/tideway” (LANU 2003) of a site per km² (see table 1). For the 10 sites in Schleswig-Holstein, the number of these biotope types ranged from 0 (Großer Binnensee) to 88/km² (Graswarder).

It remains unclear whether the indicator “creeks and salt pans” is applicable for sites totally covered by reed beds. Creeks are described as a characteristic feature of (mostly grazed) saltmarshes, but less of brackish reed beds. This may be a result of the fact that microrelief is facilitated by grazing and open vegetation, or that creeks may just not be visible in reed beds. Further, the existence and number of creeks, salt pans and other small water bodies also depends on the type and age of the site. Young sites of beach ridge systems have a more varied microtopography than older sites, especially than more uniform extensive coastal peatlands.

Further on, only larger creeks may have been mapped, while most creeks in Baltic saltmarshes are rather small. Therefore, during a field trial it must be determined whether it is necessary to complement the digital mapping results during field visits.

Intensity of drainage

The density of ditches and the existence of pumping stations to lower the ground water table determine the intensity of drainage. To assess the density of ditches (km/km²), digital data of the local water boards was used. At the 10 selected sites, the density of ditches ranged from 0 (Schleimünde, Bottsand) to 7.85 km/km² (Reesholm). The proposed class boundaries are presented in table 1. For the class boundary between "good" and "moderate" status, information on the degree of ditch maintenance has to be requested from the local water boards.

Restriction of flooding

Flooding by salt or brackish water is an essential ecological factor for coastal marshes. Today, flooding is often restricted by dikes or dams. If a site is separated from the sea by a dike, some salt water influence may still be possible from saline ground or seepage water unless the site is additionally drained by a pumping station. Thus, the 5 classes are defined as given in table 1. The parameter can be classified using digital data of the nature conservation and coastal defence authorities (in Schleswig-Holstein: State Agency for Nature and Environment = Landesamt für Natur und Umwelt, Agency for Rural Areas = Amt für ländliche Räume).

Tab. 1 Hydromorphological parameters and indicators – Description of the five ecological status classes according to the WFD. The number of creeks and salt pans is derived from GIS-available data of the most recent biotope mapping (total number of the biotope types "near-natural saline small water body" and "tidal creek/tideway" (LANU 2003) of a site per km²). For assessing the density of ditches, digital data of the local water boards is used. Information on dikes is obtained from digital data of the nature conservation and coastal defence authorities (in Schleswig-Holstein: State Agency for Nature and Environment, Agency for Rural Areas).

Parameter	Flooding dynamics	Intensity of drainage	Restriction of flooding
Indicator / Status	Number of creeks and salt pans (no/km²)	Density of ditches (km/km²)	Dikes
high	Very many, > 10 /km²	No ditches	No dikes
good	Many, 7 < to ≤ 10 /km²	Only few old, not maintained ditches or ditches with impoundments, ≤ 1 km/km²	Dike removed
moderate	Existing, 4 < to ≤ 7 /km²	Only few maintained ditches, ≤ 1 km/km²	Dikes/dams with tubes (no regulation of water in-/outflow possible), dike with breach
poor	Few, 1 < to ≤ 4 /km²	Moderate length of ditch system, 1 < to ≤ 3 km/km²	Dike with sluice
bad	Very few to none, ≤ 1 /km²	Dense ditch system, > 3 km/km²	Dike with pumping station

4 Vegetation parameters

Normative definitions of the WFD for angiosperms

The WFD gives the following normative definitions for the ecological status of the quality element angiosperms (WFD Annex V, table 1.2.4):

High status: All disturbance-sensitive angiosperm taxa associated with undisturbed conditions are present. The levels of angiosperm abundance isare consistent with undisturbed conditions.

Good status: Most disturbance-sensitive angiosperm taxa associated with undisturbed conditions are present. The level of angiosperm abundance shows slight signs of disturbance.

Moderate status: A moderate number of the disturbance-sensitive angiosperm taxa associated with undisturbed conditions are absent. Angiosperm abundance is moderately disturbed and may be such as to result in an undesirable disturbance to the balance of organisms present in the water body.

Based on the definition of “disturbances” given above, “disturbance sensitive taxa” are defined here as all characteristic plant species adapted to natural flooding and natural (locally varying) levels of salinity of flooding water and soil (halophytes).

Quantity: coastal marsh area

„Abundance of angiosperms“, in this case coastal marsh vegetation, is dependent on the area of this habitat type. Therefore, areal extent is a basic parameter in all existing classification methods for salt or coastal marshes, and those being developed at present (Brys et al. 2005, Dijkema et al. 2005, Arens 2006, Adolph et al. 2007, Best et al. 2007, Stock for German North Sea coast, pers. comm.). The classification methods differ mainly in the way the value for the reference area is derived: either by predictive modelling or from historical data, and if the latter, the historical reference time differs.

We decided not to use a historical reference, because

- for times with “no anthropogenic alteration” (of hydromorphology), no adequate data or maps are existing
- any reference time based on data availability would be arbitrarily chosen
- such an approach would be too static: coastal dynamics and formation of new coastal marshes since a historical reference point would be ignored.

Instead, we developed a simple way of predictive modelling of the “**potential coastal marsh area**”. The most dramatic anthropogenic alteration of Baltic coastal marshes is the loss of area by diking and drainage. Therefore, the reference area is the area that would be covered by coastal marshes if today all these anthropogenic alterations of flooding dynamics were removed (“potential natural status”). The potential coastal marsh area includes coastal areas

- that would be regularly flooded if no dikes and other coastal defence structures existed (“potential flooding area“) and
- that are suitable for coastal marsh communities, i.e. the sites have to be sheltered (“potential coastal marsh area”).

At the German Baltic Sea coast, the mean high water is about 1.2 m at the outer coast (long-term mean for Schleimünde and Marienleuchte, Warnemünde, Sassnitz, Koserow) and occurs at 1.3 days/year on average (KfKI 2003). The elevation limit of halophyte vegetation was found at an average elevation of 0.7 m by Krisch (1990), but at 1 m by Paulson & Raskin (1998) and Seiberling et al (2004).

Therefore, we delimited the "potential flooding area" for Schleswig-Holstein as being at 1 m above sea level, being flooded several times a year and characterised by halophytic vegetation. This area was generated using GIS. With the elevation data of the digital terrain model (scale 1:25,000), 3D-models were constructed. By use of these models, 1-m-elevation lines were generated. From these "potential flooding areas", areas of lagoons and small water bodies as well as beaches and dunes – all unsuitable for coastal marsh formation – were subtracted to obtain the "potential coastal marsh area".

The "**present coastal marsh area"** was calculated for each water body from the digital results of the most recent biotope mapping for the Habitats Directive (habitat types: salt grasslands, salt and brackish reed beds, brackish tall forbs, other types of brackish grasslands, LANU 2003) and the HELCOM-mapping of coastal biotopes.

The metric for the classification is the ratio of present coastal marsh area to potential coastal marsh area for each water body. The class boundaries are preliminarily set as follows: High – 80-100 %, good – 60-79 %, moderate – 40-59 %, poor – 20-39 %, bad – 0-19 %.

Quality: zonation

Another parameter in all existing WFD-classification methods for saltmarshes is the zonation of the vegetation (Brys et al. 2005, Dijkema et al. 2005, Stiller 2005a, Arens 2006, Adolph et al. 2007, Best et al. 2007, Stock pers. comm.).

The background of the Dutch classification (Dijkema et al. 2005) is the model of a dynamic equilibrium of salt marsh zones under reference conditions. Pioneer, lower, middle and higher salt marsh zones are seen as a successional series, being built up by sedimentation, then destroyed by erosion and followed by new accretion.

The concept of cyclic processes and a dynamic equilibrium cannot be easily transferred to the Baltic Sea coast. Coastal peatlands cannot grow above certain heights (except under conditions of sea level rise), and hence are not subject to (cyclic) succession. Beach ridges are created by active coastal dynamics of abrasion and sedimentation, but abrasion takes place at nearby cliffs. Thus, a dynamic equilibrium exists not within a system of younger and older saltmarsh stages (= vegetation zones), but within a larger-scale coastal landscape system.

Still, zonation can be used as a characteristic feature and classification parameter for Baltic coastal marshes. The classification should be focused on the effects of anthropogenic alterations such as dikes in front of or behind the coastal marsh on the zonation. Since many factors (salinity, flooding frequency, moisture, local freshwater input, exposure, relief, substrate, grazing etc.) act together at the Baltic Sea coast, many species occur at differing elevations depending on local conditions. Thus species cannot generally be assigned to one elevational zone and lower and upper saltmarsh cannot in all cases be clearly delimited. The delimitation of elevational zones is further complicated by the small vertical range of the zonation (Dijkema 1990).

For these reasons, only two vegetation zones are distinguished here: The "**pioneer zone**" is characterised by active dynamics (by flooding, erosion, ice scouring, trampling etc.) and therefore colonized by pioneer species, often with a high percentage of open soil. These areas comprise, if existing,

- a zone around the mean water line, in transition from mud flat to coastal marsh, or
- areas strongly affected by flood water and other soil disturbances (such as trampling). They are often low-lying and salt accumulating areas as creeks, depressions, salt pans or their margins.

All higher elevations with halophyte vegetation are summarized as the "(**lower and upper) coastal marsh zone**".

Coastal marshes that are not anthropogenically altered are characterized by gradual transitions to terrestrial habitats such as dunes, dry or fresh grassland types, fens, swamps, coastal heathlands and forests. By diking, many coastal marshes are reduced in their extent and cut off, so that upper saltmarshes and natural transitions are missing. Therefore the existence or lack of such transitions is included in the classification.

Further, freshwater indicator species are also used since the occurrence of species like e. g. *Hippuris vulgaris* or *Ranunculus aquatilis* in the pioneer zone indicates that salinity is decreased by a dike that prevents flooding or reduces flooding frequency. However, these can be used as indicators only in sites with higher salinity of flooding water, i. e. west of the Darß sill (except for sites at the Inner Schlei or at oligohaline lagoons) and without natural structures that restrict flooding frequency (beach ridges etc.). At sites with low salinity, these species belong to the characteristic communities (Fukarek 1961).

Each site is classified by the lower value of the two criteria (zonation and freshwater indicators, see table 2). The assessment is carried out for each site separately.

Tab. 2 Zonation of the vegetation – Description of the five ecological status classes according to the WFD to be assessed in the field. "Pioneer zone" comprises a zone around the mean water line, in transition from mud flat to coastal marsh as well as other disturbed areas strongly affected by flooding water, trampling etc, as creeks, depressions and salt pans. All higher elevations with halophyte vegetation are summarized as the "(lower and upper) coastal marsh zone".

Ecological status	Zonation[1]	Freshwater indicators[2] (e.g. *Hippuris vulgaris, Ranunculus aquatilis*)
high	Pioneer zone and coastal marsh zone developed completely consistent with relief. Gradual transition to terrestrial habitats.	No freshwater indicators in the pioneer zone
good	Pioneer zone and coastal marsh zone nearly developed completely consistent with relief, i.e. elevational gradient within the coastal marsh zone noticeable (but can also border on a dike)	No freshwater indicators in the pioneer zone
moderate	Pioneer zone and coastal marsh zone existing. No gradual transition to terrestrial habitats (e.g. upper part cut off by a dike).	Freshwater indicators in the pioneer zone
poor	Only one zone existing	Freshwater indicators in the pioneer zone (if pioneer zone existing)
bad	No zone existing	---

1: If sites are very small because of natural relief, the pioneer zone can be missing without negative assessment, especially at narrow margins along the coast line (< 10 m width)

2: Only for sites with higher salinity of flooding water (i.e. west of the Darß sill, not in the Inner Schlei or at oligohaline lagoons) and without natural structures that restrict flooding frequency (beach ridge etc.)

Quality: Plant species composition

Above, halophytes have been defined as „disturbance-sensitive taxa" in the context of the WFD. Reference conditions are described as "all disturbance-sensitive angiosperm taxa associated with undisturbed conditions are present." Since many ecological factors interact in determining which taxa could occur at a specific site without anthropogenic disturbances, it is not possible to prescribe a specific target species list for each individual site. This approach would also be too static and not allow for natural changes, and would be not practical with a high number of sites.

With our selective list of characteristic species (table 3), we allow for the diversity of site conditions. To keep the classification method as simple as possible, we present one list for the whole German Baltic Sea coast, differentiating between salinity levels for some species only. Whether more differentiation is necessary must be determined through a field trial in the future.

Tab. 3 Characteristic species of coastal marshes of the German Baltic Sea to be used for assessing the species composition as part of the WFD-classification method. Our own selection, compiled after: Jeschke (1987), Dijkema (1990), Berg et al. (2004).

Pioneer zone (including creeks, salt pans, depressions)	**Lower and upper coastal marsh zone**	**Restriction**
Agrostis stolonifera agg.		low salinity[2]
Schoenoplectus tabernaemontani		low salinity[2]
Aster tripolium	*Armeria maritima*	
Atriplex prostrata agg.	*Aster tripolium*	
Bolboschoenus maritimus	*Bolboschoenus maritimus*	
Cotula coronopifolia	*Carex distans*	
Juncus maritimus	*Carex extensa*	
Phragmites australis	*Centaurium litorale*	
Puccinellia distans	*Centaurium pulchellum*	
Salicornia europaea	*Festuca rubra*	
Spergularia media	*Glaux maritima*	
Spergularia salina	*Juncus gerardii*	
Suaeda maritima	*Juncus maritimus*	
	Leontodon autumnalis	
	Lotus tenuis	
	Phragmites australis	
	Plantago maritima	
	Puccinellia maritima	
	Spergularia media	
	Trifolium fragiferum	
	Triglochin maritimum	
	Artemisia maritima	only western part[1]
	Limonium vulgare	only western part[1]
	Agrostis stolonifera agg.	low salinity[2]
	Blysmus rufus	low salinity[2]
	Eleocharis uniglumis	low salinity[2]
	Elymus repens	low salinity[2]
	Hordeum secalinum	low salinity[2]
	Oenanthe lachenalii	low salinity[2]
	Triglochin palustre	low salinity[2]

1: The species *Limonium vulgare* and *Artemisia maritima* are only characteristic in the western part (up to the Wismar bight) and occur sporadically to the western part of Rügen.

2: These species are characteristic for coastal marshes of low salinity, i.e. east of the Darß sill and the inner coastal waters of Mecklenburg-Vorpommern, in the western part at lagoons and inner coastal waters (e.g. inner Schlei) or at sites where flooding dynamics is restricted e.g. by a beach ridge.

Tab. 4 Species composition – Description of ecological status classes (characteristic species of coastal marshes see table 3). The frequency of species has to be assessed in the field during "structured walks" using the "DAFOR scale" (JNCC 2004, see table 5).

Ecological status	**Pioneer zone** [1] (incl. Saltmarsh creeks, salt pans, depressions)	**Coastal marsh zone**	**Additional metric cover** [2]
high	At least 1 species abundant, 2 other frequent, 1 other rare	At least 2 species abundant, 3 other frequent, 2 other occasional	Species together sum up to at least 75% of cover
good	At least 1 species abundant, 2 other frequent	At least 2 species abundant, 3 other frequent	Species together sum up to 50-74% of cover
moderate	At least 1 species abundant, 1 other frequent	At least 1 species abundant, 2 other frequent	Species together sum up to 25-49% of cover
poor	At least 2 species frequent	At least 2 species frequent	Species together sum up to at least 10% of cover
bad	Less than 2 species frequent	Less than 2 species frequent	Species together sum up to 0-9% of cover

1: Especially in the pioneer zone the frequency may be (depending on the scale) dependent on the total cover which can be low – this has to be taken into account!

2: Whether an additional metric „cover" is necessary has to be proven in a field trial – in general we aim at using as few and simple metrics as possible. Also the numbers are preliminary.

The frequency of species should be estimated with a scale and a procedure that allows a simple, quick overview of large areas in the field and results in broad, but reproducible estimates that are independent of the person in charge. Based on the method described in the "Common Standards Monitoring Guidelines for Saltmarsh Habitats"(JNCC 2004) vegetation composition (presence of species + dominance > 50 %) should be recorded on at least 20 stops at 1 m²-plots during "structured walks" across the site. To avoid subjectivity when selecting stops, the route and stops should be selected in advance on a map or aerial photo. With these data, the frequency of the species can be estimated using the following scale (table. 5).

Tab. 5 Frequency classes „DAFOR scale" (JNCC, 2004)

Dominant	Species appears at most (>60 %) stops and it covers more than 50 % of each sampling unit
Abundant	Species occurs regularly throughout a stand, at most (>60 %) stops and its cover is less than 50 % of each sampling unit
Frequent	Species recorded from 41-60 % of stops
Occasional	Species recorded from 21-40 % of stops
Rare	Species recorded up to 1-20 % of stops

5 Water bodies for which coastal marshes should be considered in the WFD-classification

Coastal marshes should be included in the WFD-classification only if their potential impact is relevant to the quality of the coastal water body. This depends *inter alia* on the ratio of water area to coastal marsh area. Hence, we propose to assess the ecological status of coastal marshes for all water bodies in Schleswig-Holstein that are not heavily modified and in which the potential coastal marsh area (see above) comprises

- at least 10 % of the total area of the water body (total area = water area + potential coastal marsh area) or
- at least 250 ha.

These include eleven water bodies: all three water bodies of the Schlei fjord, three water bodies around Fehmarn island (Fehmarn Rund, Fehmarn Belt, Orther Bucht), the coasts of Ostholstein (Putlos, Grömitz, Neustädter Bucht) and the Probstei. Following this procedure, 11,027 of 12,085 ha of potential coastal marsh area (91.2 %) in Schleswig-Holstein would be integrated into the WFD-classification of the coastal waters.

6 Combining parameters to an overall assessment

When strictly interpreting the formal requirements of the WFD, hydromorphology of coastal marshes would account for a part of the hydromorphological quality element ("structure and condition of the intertidal zone"), while the coastal marsh vegetation would be summarized with seagrasses and macroalgae in the quality element "macroalgae and angiosperms". The hydromorphological quality element would only "support" the biological quality elements, i.e. would only be relevant for high status (European Commission 2000, CIS REFCOND 2003). Here we will refrain from this very formal interpretation to allow for a more integrative ecological understanding: because hydromorphology and vegetation of coastal marshes are closely linked and together indicate the same pressures on coastal waters, we recommend summarising both to an integrative classification. This would result in a coastal marsh classification indicating the pressure on and status of this zone of the coastal water body.

Two components are classified for each water body, hydromorphology and vegetation. The latter is composed of two aspects: quantity of vegetation (area) and quality of vegetation (zonation and species composition). In figure 1, an overview is given of how the single metrics are combined to an overall assessment.

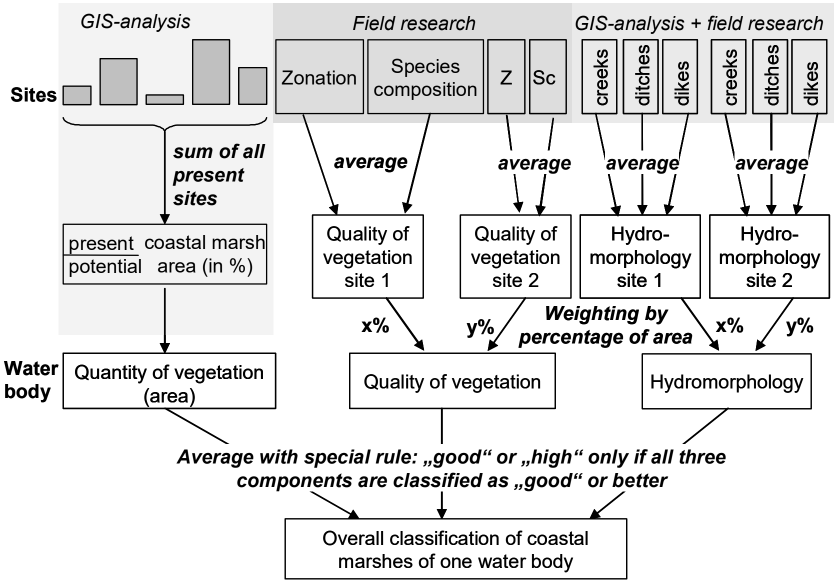

Fig. 1 Combination of all parameters to an overall assessment of the ecological status of coastal marshes per water body. x,y: Percentage of area of site 1 and 2 related to total area of present coastal marshes of a given water body.

The quantity of vegetation (area) is analysed using GIS for each water body as described above. Zonation and species composition are assessed in the field for each site separately, and the results are averaged to determine the "quality of vegetation" of the respective site. The classifications of all sites in a water body are combined by weighting the individual results by the areal percentage of the sites to the "quality of vegetation" of all coastal marshes of a given water body.

The same applies to the classification of hydromorphology: the values of all parameters assessed by GIS-analysis and/or in the field for a specific site are averaged to a classification of the hydromorphology of the site. In a second step, the classification of all sites in a water body are averaged weighted by the percentage of area to a classification of hydromorphology of all coastal marshes of a given water body.

In the last step, the three classifications of hydromorphology, quantity and quality of vegetation are combined to the overall classification of coastal marshes in a water body. This is done by calculating the mean of the three classifications with the restriction that the status "good" can only be achieved if all three parametersts are assessed as being of "good" or "high" status. This special rule makes sure that the coastal marshes of a water body cannot be at "good" status if one of the three parameters is not "good". On the other hand this special rule makes it still possible to improve the overall status, even in the case of the parameter "area" being in "bad" status, without creating large new coastal marshes. By reducing hydromorphological alterations in the present coastal marsh areas, the quality of vegetation as well as the hydromorphology could be improved, which could raise the overall classification from "bad" to, in the best case, "moderate". If in contrast the "one out – all out" rule were applied for the three parameters, the water body would remain in the class "bad" as long as the coastal marsh area was not enlarged to at least 60 % of the potential area. The present coastal marsh area must not be reduced in any case.

7 Monitoring

In contrast to the Wadden Sea area, no consistent monitoring data set exists so far on the status of coastal marshes at the Baltic Sea. Thus, an initial area-wide monitoring of all coastal marsh sites should be conducted to be used as a quantitative baseline for detecting future long-term changes (CIS Monitoring 2003). To limit the efforts of future monitoring cycles, a representative number of sites per water body should be sampled. Sites that are part of the Natura 2000 monitoring network should be included to use the data efficiently.

Since most coastal marshes are part of protected areas, they have to be included in the operational monitoring (WFD Annex V, 1.3.5). As a general rule of the WFD, the operational monitoring of angiosperms should be carried out at least every 3 years "unless greater intervals would be justified on the basis of technical knowledge and expert judgement." (WFD Annex V, 1.3.4). Coastal marshes largely consist of perennial plants, thus climatic between-year fluctuations are not very pronounced. Therefore, a greater monitoring interval of 6 years is considered to be sufficient. Only in cases where hydrodynamics have changed substantially should the monitoring be carried out more often, at least every 3 years. Generally, monitoring of vegetation should be carried out during the growing season between July and September.

All parameters proposed for the classification should be monitored. Some of the hydromorphological parameters (dikes, ditches) are classified according to GIS-based information. During a field trial or during the first monitoring cycle it should be determined whether these data are correct, up-to-date and detailed enough. For future monitoring cycles it should be sufficient to only check for changes.

8 Perspectives

Since the proposed classification method has been developed without any fieldwork, a field trial is needed as a feasibility test before applying it to the whole German Baltic coastline. After checking the results for plausibility, class boundaries and species lists may have to be modified. Coastal marshes of Schleswig-Holstein as well as Mecklenburg-Vorpommern should be included to make the method suitable for all varieties of coastal marshes along the German Baltic coast.

Further, "Atlantic saltmarshes" are listed in the Annex I of the EU-Habitats Directive as a habitat type of community importance (European Commission 1992). Thus, their status also has to be monitored according to the Habitats Directive. It should be examined how the classification of "ecological status" (WFD) and of "favourable conservation status" (Habitats Directive) could be combined and particularly how the monitoring procedure can be harmonized to use synergies in the best and most efficient way. This implies selecting monitoring sites, harmonizing monitoring intervals and timing, and developing common detailed monitoring methods.

To improve the knowledge on the relevance of coastal marshes for coastal water quality, studies on the nutrient balance of intact and drained coastal peatlands should be carried out. Further, the nutrient balance of grazed and ungrazed coastal marshes should be analysed to assess the impact of management on the capacity for nutrient retention.

Zusammenfassung

Die Wasserrahmenrichtlinie (WRRL) der Europäischen Union zielt darauf ab, bis 2015 alle Gewässer in einen „guten ökologischen Zustand“ zu versetzen. Der ökologische Zustand der Küstengewässer wird anhand der biologischen Qualitätskomponenten Phytoplankton, Makrozoobenthos sowie Großalgen und Angiospermen bewertet. Erst seit kurzem wurde der Begriff „Angiospermen“ nicht nur auf Seegräser, sondern auch auf die Vegetation der Salzrasen angewandt (CIS Coast 2003, CIS Wetlands 2003). In der Folge wurden Bewertungsansätze für Salzrasen der Küsten- und Übergangsgewässer der Nordseeregion entwickelt (Brys et al. 2005 für Belgien, Dijkema et al. 2005 für die Niederlande und Best et al. 2007 für Großbritannien). Auch für die deutsche Nordseeküste wird derzeit ein Bewertungsmodell erarbeitet (Stock mdl.), das Ergebnisse der Arbeiten von Stiller (2005a, 2005b), Arens (2006) und Adolph et al (2007) einbezieht.

Für die gezeitenfreie Ostsee wurde die Relevanz der Salzrasen für die WRRL jedoch bislang nicht diskutiert. In dem vorliegenden Beitrag wird geprüft, ob Salzrasen an der deutschen Ostseeküste sich generell für die Bewertung der Küstengewässer nach WRRL eignen. Nach WRRL und den Leitfäden der gemeinsamen Umsetzungsstrategie (CIS Coast 2003, CIS Wetlands 2003, CIS Monitoring 2003) sollte der Gezeitenbereich als Teil des Wasserkörpers aufgefasst werden. Auch für die gezeitenfreie Ostseeküste sind Feuchtgebiete wie Salzrasen und -röhrichte in den Wasserkörper einzubeziehen, wenn sie die biologischen Qualitätskomponenten der Küstengewässer beeinflussen und damit für die Qualität des Küstengewässers relevant sind. Zudem eignen sich Salzrasen besonders dazu, morphologische Veränderungen der Küstengewässer abzubilden und können damit die anderen Qualitätskomponenten in einer Gesamtbewertung der Küstengewässer sinnvoll ergänzen.

Salzrasen und -röhrichte (insbesondere Küstenüberflutungsmoore) können die Eutrophierung der Küstengewässer beeinflussen. Im intakten Zustand tragen sie zur Nährstoffretention bei, während bei Entwässerung und Torfmineralisierung Nährstoffe freigesetzt werden. Der Beitrag der Salzrasen zur Be- oder Entlastung der Gewässer hängt dabei vom Verhältnis der Flächengrößen (Wasserkörper – Salzrasen-/-röhrichtfläche) ab. Er kann für kleine, austauscharme Wasserkörper mit großen (ggf. ehemaligen) Küstenüberflutungsmooren besonders groß sein. Daher sollte dieses Flächenverhältnis bei der Bewertung berücksichtigt werden.

Den Maßstab für die Bewertung nach WRRL bildet der „Referenzzustand“, der für Salzrasen und -röhrichte als „in Hydrodynamik und -morphologie nicht oder nur

sehr geringfügig anthropogen verändert“ definiert wird. Der Referenzzustand umfasst sowohl beweidete Salzrasen als auch unbeweidete Brackwasserröhrichte oder ein Mosaik aus beiden Vegetationstypen.

Die Bewertung nach WRRL basiert auf Parametern der Salzrasen- und -röhrichtvegetation als Teil der biologischen Qualitätskomponente der Angiospermen. Sie wird durch folgende hydromorphologische Parameter unterstützt: Überflutungsdynamik, Entwässerungsintensität und Überflutungseinschränkung. Dabei wird die Überflutungsdynamik durch Priele und Röten indiziert, die Entwässerungsintensität durch Gräben und die Überflutungseinschränkung durch Deiche. Diese Parameter werden im GIS für jedes einzelne Gebiet ausgewertet und sind ggf. durch Geländeerhebungen zu ergänzen.

Für die biologische Qualitätskomponente werden Quantität und Qualität der Vegetation bewertet. Als Referenzfläche wird die „potenzielle Salzrasen-/ -röhrichtfläche“ berechnet, die potenziell regelmäßig überflutet wird (d.h. unter 1 m über NN liegt) und für Salzrasen-/-röhrichte geeignet ist (d. h. Gewässer oder Strände werden abgezogen). Für die aktuelle Flächenausdehnung wird im GIS die Fläche aller salzbeeinflussten Biotoptypen berechnet und für jeden Wasserkörper summiert. Der relative Anteil der aktuellen an der potenziellen Salzrasen-/ -röhrichtfläche (in %) wird herangezogen, um die Ausdehnung aller Salzrasen eines Wasserkörpers einer der fünf ökologischen Zustandsklassen der WRRL zuzuordnen.

Die Qualität der Vegetation wird im Gelände für jedes Gebiet einzeln erfasst und anhand der Parameter Zonierung und Artenzusammensetzung bewertet. Die Vegetationszonierung wird anhand des Vorhandenseins der Vegetationszonen „Pionierzone“ und „untere/obere Salzrasen und -röhrichte“ sowie des Vorkommens von Süßwasserzeigern in der Pionierzone bewertet. Für die Artenzusammensetzung wird das Vorkommen charakteristischer Arten (Anzahl und Häufigkeit) in jeder der Vegetationszonen aufgenommen.

Für Schleswig-Holstein wird vorgeschlagen, Salzrasen und -röhrichte für diejenigen Ostsee-Wasserkörper in die Bewertung einzubeziehen, die nicht „erheblich verändert“ sind und in denen die potenzielle Salzrasenfläche mindestens 10 % des Wasserkörpers oder 250 ha ausmacht. Damit wären Salzrasen und -röhrichte für 11 der 19 küstenangrenzenden Wasserkörper relevant.

Das Monitoring nach WRRL sollte in einem 6-jährigen Intervall auf repräsentativ ausgewählten Flächen durchgeführt werden. In einem Praxistest sollte geprüft werden, ob die Parameter des WRRL-Bewertungsvorschlags sich im Freiland als praktikabel erweisen und ob die Qualität der Salzrasen konsistent bewertet werden kann. Um Synergien bestmöglich zu nutzen und Mittel effizient einzusetzen, sollte ein Monitoring gemeinsam für die WRRL und die FFH-Richtlinie durchgeführt werden. Dies wäre insbesondere bei der Präzisierung der Erhebungsmethoden und der Auswahl der Monitoringgebiete zu berücksichtigen.

Acknowledgements

We wish to thank the State Agency for Nature and Environment of Schleswig-Holstein for financial support of the project and the German Federal Environmental Foundation for the PhD-scholarship to the first author. We thank Martin Stock and Wolfgang Günther for fruitful discussions, Christof Herrmann and Jürgen Gemperlein for useful data, Amanda Prior for an article in press at the right time and John Burk for improving the English language.

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