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TOWARDS A VEGETATION AND LANDSCAPE MAP OF THE DANISH, GERMAN, AND DUTCH WADDEN SEA ISLANDS AND MAINLAND COASTAL AREAS

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SUMMARY

An international Wadden Sea Working Group is compiling the ecological information, mainly derived from literature, on the Danish, German and Dutch Wadden Sea area. In this paper some results of the compilation and survey activities of the Terrestrial Botany section of this Working Group are presented.

In a special project the data on vegetation and landscape of the Wadden Sea islands and mainland coastal areas, combined with an interpretation of aerial photography, have been integrated in a map at scale 1:100,000. A brief survey of the mapping procedure is presented, followed by an enumeration of the map legend's landscape- and vegetation-units with their syntaxa and principal succession series in a schematic presentation. The (colour) map will be the first document to show the overall geographical distribution of the vegetation and landscape types of the – from a conservation point of view so important – Wadden Sea area.

1. INTRODUCTION

A "Wadden Sea Working Group", consisting of about one hundred researchers of the three Wadden Sea countries, The Netherlands, Germany, and Denmark, is currently preparing a management plan for the area (*fig. 1*). After compilation and processing of the basic information the results are now being presented in a series of reports dealing with the various ecological subjects. The report on terrestrial botany (DIJKEMA & WOLFF, in press) will include i.e. a bibliography of over 500 titles dealing with vegetation and landscape of the area, a description of major environmental conditions, inventories for the various flora groups, a detailed description of vegetation zonation and succession, a phytogeographical evaluation, recommendations for management, and a coloured vegetation and landscape map of the entire area.

For a coherent characterization of the vegetation a mere compilation of the basic information was not considered sufficient. An analysis and integrated presentation were required, presenting in one document the overall spatial distribution of the vegetation types of the islands and mainland coastal areas. It was decided that one map (in colour) with a consistent legend for the entire Danish, German, and Dutch Wadden Sea area should be produced.

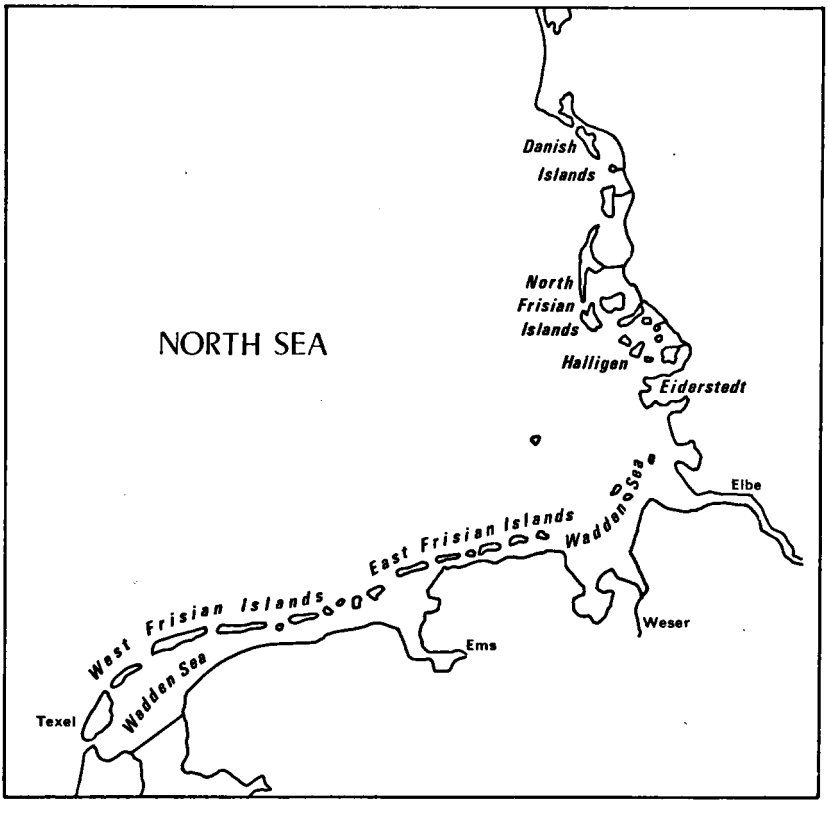

Fig. 1. The international Wadden Sea area.

The purpose of this article is to discuss problems related to the production and presentation of this map as exemplified by the map of the Wadden Sea island Schiermonnikoog (*fig. 2*).

2. THE VEGETATION AND LANDSCAPE MAP

2.1. The mapping procedure

An overall picture of the entire Wadden Sea area can only be given on a small scale map (e.g. 1:100,000). Especially before the present era of satellite imagery such maps have often been based on a compilation of already existing vegetation maps of the component parts of the area under study. By transforming the legends these maps are then adapted to the desired legend-terminology of the new map (KÜCHLER 1967: chapter 18). For the present study another approach has been chosen. The base for the map units was an interpretation of aerial photographs. The already existing vegetation maps and vegetation descriptions served as reference material for the identification of the delineated units on the photo-

interpretation map. An important advantage of this method is its consistency, the boundaries being based on the same criteria throughout the area.

The map has been prepared in the following steps:

1. Collection of aerial photographs. In such a vast area in three different countries material with a wide variation in quality had to be processed. All images used were paperprints black and white panchromatic vertical aerial photography (scales 1 : 15,000 to 40,000), with stereo overlap and black en white panchromatic mosaics (scales 1 : 25,000 to 60,000).
2. (Stereoscopic) interpretation of sample areas to construct a provisional legend.
3. Systematic interpretation of the photographs with a mirror stereoscope. The smallest mappable unit for the final map was determined to be about 2 × 5 mm. At a map scale 1: 100,000 this equals 200 by 500 metres (10 ha) in the field. Smaller elements had to be shown as parts of complex mapping units or included in the more dominant vegetation types. In order to delineate in all cases more or less similar complexes of vegetation types the provisional legend and the collected literature were used for reference.
4. Transfer of the distinguished boundaries to a controlled photomosaic, serving as a base for the final map.
5. Identification of the distinguished units. For this purpose the vegetation classifications given in the references were incorporated in the new legend units. For "groundtruth" and confirmation of interpretations in addition experts on some particular areas were consulted and field visits made to selected areas.

3.2. Final map and legend

The 1: 100,000 map not only gives information on the geographical distribution of the vegetation types but also shows the types in their spatial arrangement and relations (see *fig. 2*). Local vegetation patterns are obscured on a map at this scale, but the main lines of landscape genesis throught the spatial pattern of the vegetation on the islands and mainland coast are clearly visible. The interdependence of the types in the Wadden Sea area is illustrated by the intricate pattern (ZONNEVELD & THALEN 1980).

The legend of the map consists at the highest hierarchical level of eight physiognomic landscape types. These types are subdivided into 21 natural vegetation types, while 19 other items are shown, such as planted woodlands, duck decoys, sand-dikes, salt marsh cliffs and -revetments and sedimentation fields. The vegetation types correspond by and large to syntaxonomic units. The types differ in spatial structure (physiognomy), vegetation composition and underlying geomorphology and soils.

The landscape and vegetation types with their corresponding syntaxa are listed in *table 1*. Wherever possible the syntaxonomic classification of WESTHOFF & DEN HELD (1969) has been followed, but in the list of *table 1* also use has been made of the following references: WIINSTEDT (1946), WESTHOFF (1947), MIKKELSEN (1949), BOERBOOM (1960), RAABE (1964), BEEFTINK (1965), HEYKENA (1965), TÜXEN (1966), WIEMAN & DOMKE (1967), RUNGE (1973), DOING (1974),

DIJKEMA (1975), TÜXEN & KAWAMURA (1975), BAKKER (1976), SLOET VAN OLDRUITENBORGH (1976), and DE SMIDT (1977).

In *fig. 3* the principal succession series of the vegetation on mud flats, salt marshes, beach plains, dunes and dune slacks in the Wadden Sea area have been summarized according to information derived from the compiled references, especially the ones mentioned above. This scheme was used to make a logical choice of colours for the map.

Some conclusions can be directly derived from the map image, e.g.:

1. Vegetation and landscape of the islands and coastal areas bordering the Wadden Sea have a great natural botanical diversity. Well developed natural communities of the xerosere, hygrosere and halosere and all sorts of transitions between these are occurring in a strong mutual coherence.
2. The pictures for the Danish and North-Frisian islands on the one hand and the East-Frisian and West-Frisian (= Dutch) islands on the other hand differ markedly, as follows:

– The West-Frisian and East-Frisian dry dunes are dominated by *Hippophaë*- and *Sambucus*-scrub (units B) and by dune grasslands (units G) with *Empetrum*-heath on the north exposures. In the slacks the succession goes from the *Schoenus nigricans*-community on a calcareous soil to wet heath (Hx) and *Betula*-brushwood (Wb).

– The Danish and North-Frisian dunes are almost limeless as a result of which the scrub (B) and the *Schoenus*-community (Ws) do not occur. The succession in the dunes and the slacks goes rapidly to dry (Hc) or wet heath (Hx). Succession to (brush-) wood as terminal stage (Wb) was not found on the North-Frisian and Danish dune islands. This may be due to a combination of exposition to wind and low soil fertility.

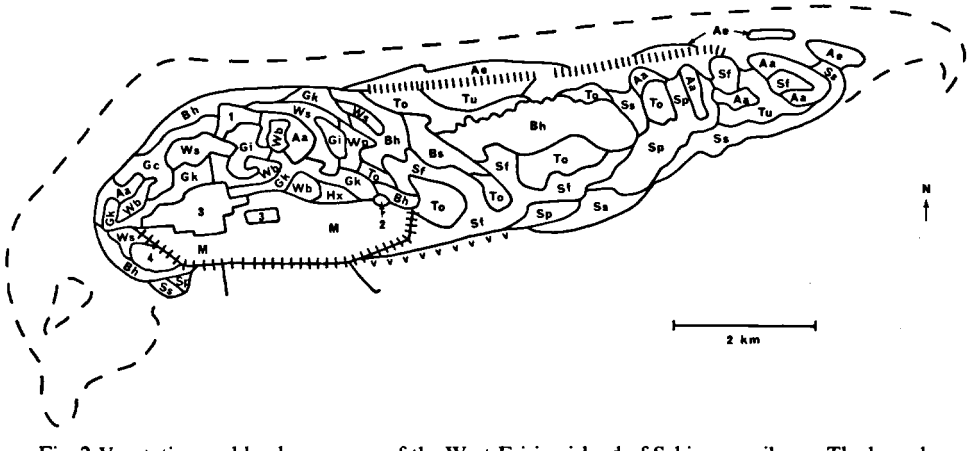

Fig. 2. Vegetation and landscape map of the West-Frisian island of Schiermonnikoog. The legend symbols used are the same as mentioned in table 2 and fig. 3. 1 = planted woodland; 2 = duck decoy; 3 = settlements; 4 = water; vvv = salt marsh cliff; III = sand-dike; ++++++ = sea-dike; --- = beach-edge at high tide.

Table 1. Landscape- and vegetation types and their corresponding syntaxa.

Landscape and vegetation types	corresponding syntaxa
YELLOW DUNES	
Ae Pioneer vegetation on embryonic dunes and nitrophilous vegetations with Elytrigia junceiformis, Elymus arenarius	Cakiletum frisicum (Hoquette 1927) R.Tx. 1950, Agropyretum boreoatlanticum (Warming 1909) Br. -Bl. et De Leeuw 1936 em. R. Tx. 1952 (synon.: Minuartio-Agropyretum juncei R. Tx. 1955 n.n.), Potentillo-Elymetum arenariae Raunkiaer 1935.
Aa Pioneer vegetation on the coastal dune ridge and on secondary windblown dunes with Ammophila arenaria	Elymo-Ammophiletum (Warming 1909) Br. - Bl. et De Leeuw 1936 em. R. Tx. 1952.
DUNE SCRUB	
Bh Pioneer scrub on young calcareous dunes and in the brackish zone with Hippophaë rhamnoides	Hippophaë rhamnoides-consociation Boerboom 1960
Bs Scrub on young calcareous dunes with Sambucus nigra, Hippophaë rhamnoides (, Crataegus monogyna)	Hippophao-Sambucetum Boerboom 1960.
GREY DUNES	
The NW- to NE- slopes sometimes have a vegetation of greater density with dwarf shrubs and Polypodium vulgare	Polypodio-Salicetum (R. Tx. 1955 n.n.) Boerboom 1960, Polypodio-Empetretum (Meltzer 1941) Westhoff 1947).
Gk Closed grasslands on dry dunes with Agrostis tenuis, Carex arenaria, Festuca ovina subsp. tenuifolia. Galium verum and various mosses	Tortulo-Phleetum arenarii (Massart 1908) Br. - Bl. et De Leeuw 1936, Festuco-Galietum maritimi (Onno 1933) Br. -Bl. et De Leeuw 1936 (synon.: Agrostio-Poëtum humilis R. Tx. et Preising 1951), Ario-Caricetum arenariae Westhoff, Van Leeuwen et Adriani 1962.
Ge Lichen steppe on dry dunes with Corynephorus canescens	Violo-Corynephoretum Westhoff (1943) 1947 (synon.: Corynephoretum maritimum (Westhoff 1946) R. Tx. 1962).
Gi Dwarf shrub vegetations on dry dunes with Salix arenaria	Polypodio-Salicetum (R. Tx. 1955 n.n.) Boerboom 1960, Thalictro-Salicetum R. Tx. 1937.
Gr Dwarf shrub vegetations on dry dunes with Rosa pimpinellifolia	Thalictro-Salicetum R. Tx. 1937 (synon.: Roso spinosissimae-Salicetum arenariae R. Tx. 1952). Tortulo-Phleetum arenarii (Massart 1908) Br. - Bl. et De Leeuw 1936, Festuco-Galietum maritimi (Onno 1933) Br. -Bl. et De Leeuw 1936.
DUNE HEATHS	
He Heath on dry and moist decalcified dune areas with Empetrum nigrum	Carici arenariae-Empetretum R. Tx. et Kawamura 1975 (synon.: Polypodio-Empetretum

	(Meltzer 1941) Westhoff 1947. Saliceto repentis-Empetretum R. Tx. 1955 n.n.. Empetro-Genistetum tinctoriae Westhoff (1947) 1968).
Hc Heath on dry and moist decalcified dune areas with Calluna vulgaris, Empetrum nigrum	Carici arenariae-Empetretum R. Tx. et Kawamura 1975 (synon.: Empetro-Genistetum tinctoriae Westhoff (1947) (1968).
Hx Heath in moist to wet acid dune slacks with Carex nigra, Oxycoccus macrocarpos, Erica tetralix	Caricetum trinervi-nigrae Westhoff 1947. Cirsio-Molinietum Siss. et De Vries 1942. Nardo-Gentianetum pneumonanthes Preising 1950 em. Westhoff, Empetro-Ericetum Westhoff (1943) 1947 (synon.: Saliceto arenariae-Ericetum tetralicis R. Tx. et Buchwald 1942).
DUNE SLACKS. REED MARSHES	
Wp Reed marshes in wet dune slacks, on desalinating ungrazed beach plains and marches and on brackish to fresh mud flats with Phragmites australis, Scirpus maritimus	Halo-Scirpion (Dahl et Hadač 1941) Westhoff & Den Held 1969. Phragmition (communis) W. Koch 1926 em. Balátová-Tuláčková. 1963.
Ws Marsh communities on desalinating beach plains and in moist calcareous dune slacks with Schoenus nigricans, Salix arenaria, Calamostis epigejos	Junco baltici-Schoenetum nigricantis (Westhoff 1943) Westhoff et Den Held 1969 (syon.: Salici repentis-Schoenetum nigricantis R. Tx. 1942). Ophioglosso-Calamagrostietum epigeji Westhoff et Segal 1961.
Wb Brushwood in moist dune slacks with Betula pubescens, (Myrica gale, Alnus glutinosa)	Querco roboris-Betuletum R. Tx. (1930) 1937, (Myricetum gale (Gadeceau 1909) Jonas 1935. Frangulo-Salicetum auritae (Malcuit 1929) Doing 1962 em. Westhoff, Alno-Salicetum cinereae (Allorge 1922) Doing 1962 em. Westhoff. Salicetum pentandro-arenariae Westhoff (1968 n.n.) Westhoff et Den Held 1969).
BRACKISH TRANSITION ZONES	
Carpets of dwarf plants with Sagina maritima, Cochlearia danica, Sagina nodosa weave through the communities in these zones.	Sagino maritimae-Cochlearietum danicae (R. Tx. 1937) R. Tx. et Gillner 1957. Centaurio-Saginetum moniliformis Diemot. Siss. et Westhoff 1940 (synon.: Gentiano uliginosa-Centaurietum vulgaris Br. -Bl et De Leeuw 1936).
Tu Open communities on beach plains and in young dune slacks with Spergularia marina, Glaux maritima, Agrostis stolonifera, Juncus anceps	Puccinellietum distantis Feekes (1934) 1943. Glaux maritima-sociation Beeftink 1962. Parnassio-Juncetum atricapilli (Westhoff 1947) Westhoff et Den Held 1969.
To Closed grasslands on transitions between salt marshes or beach plains and young dune slacks or dunes with Ononis spinosa. Lotus corniculatus, Agrostis stolonifera, Carex distans, Juncus maritimus, Scirpus rufus.	Community of Ononis spinosa and Carex distans Runge 1966 pro ass. (synon.: Ononido-Caricetum distantis R. Tx. 1955 n.n.). Community of Agrostis stolonifera subvar. salina and Trifolium fragiferum Westhoff 1947. Association of Juncus maritimus and Oenanthe lachenalii R. Tx. 1937 (synon.: Juncetum ma-

	ritimi Blik 1956), Junceto-Caricetum extensae blysmetosum rufi Westhoff 1947, Scirpetum rufi (G.E. et G. Du Rietz 1925) Gillner 1960.
Tl Brackish pastures on the highest (grazed) salt marshes, often protected by a low summer-dike, with Lolium perenne, Trifolium repens, Elytrigia repens	Poo-Lolietum D. M. de Vries et Westhoff n.n. apud A. Bakker 1965, Lolio-Cynosuretum (Br.-Bl. et De Leeuw 1936) R. Tx. 1937 em. Van Leeuwen et Westhoff apud A. Bakker 1965.
SALT MARSHES	
On marshes enriched with tidal drift material halo-nitrophilous communities develop with Suaeda maritima, Atriplex hastata, Atriplex litoralis, Elytrigia pungens. Usually they form narrow zones and cannot be mapped	Suaedetum maritimae (Conard 1935) Pignatti 1953, Atriplicetum littoralis (Warming 1906) Westhoff et Beeftink 1950, Atriplici-Agropyretum pungentis (Beeftink et Westhoff 1962).
Ss Halophytic pioneer communities within daily tidal range and on beach plains with Spartina anglica, Salicornia europaea	Spartinetum townsendii Corillon 1953, Thero-Salicornion Br.-Bl. 1933 em. R. Tx. 1950.
St pioneer community on mud flats with Aster tripolium	Aster tripolium-sociation Beeftink 1965.
Sp Halophytic grasslands and dwarf shrub vegetation on low saline salt marshes and beach plains with Puccinellia maritima. Limonium vulgare, Halimione portulacoides	Puccinellietum maritimae (Warming 1890) Christiansen 1927, Plantagini-Limonietum Westhoff et Segal 1961, Halimionetum portulacoidis Kuhnholtz-Lordat 1927.
Sf Halophytic grasslands on high salt marshes, brackish marshes and beach plains with Festuca rubra, Juncus gerardii, Agrostis stolonifera	Artemisietum maritimae (Hoquette 1927) Br.-Bl. et De Leeuw 1936, Juncetum gerardii Warming 1906, Junceto-Caricetum extensae pholiuretosum Westhoff 1947, Agrostis stolonifera salina-sociation Beeftink 1962.
MEADOWS (M)	

3. Another distinct difference is the one between island- and mainland salt marshes (the North-Frisian "Halligen" take up an intermediate position):
– Generally speaking the mainland salt marshes are terraced as a result of their exposed position and man induced development (land reclamation techniques). Island salt marshes often have a more differentiated morphology of creek banks and basins as a result of their natural development and more sheltered position.
–The vegetation of mainland salt marshes is determined by more clayey sediments (the *Halimionetum portulacoidis* is characteristic), heavier grazing (the *Puccinellietum maritimae*) and a gradient according to the decreasing salinity in estuaries (with the *Aster tripolium*-sociation, St, *Agrostis stolonifera*-sociation, Sf and reed communities, Wp). Island salt marshes are more sandy and less grazed, especially *Limonium vulgare*-communities are characteristic. Transitions to beach plains, dune slacks and dunes (Tu, To) can have an extremely high species diversity (THALEN 1971). Not only such transition zones, but in fact virtually the entire Wadden Sea area call for careful management aimed at conservation. The

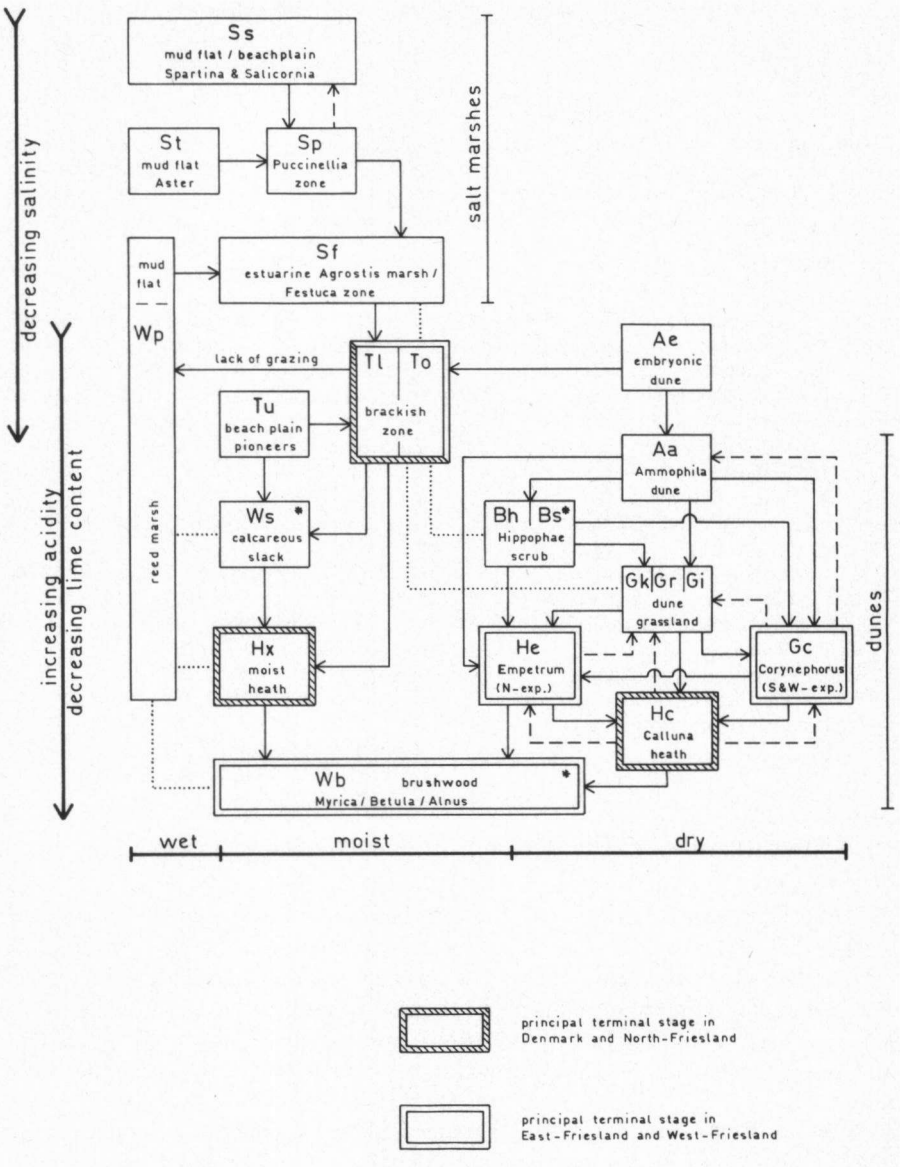

Fig. 3. Principal succession series on mud flats, salt marshes, beach plains, dunes and dune slacks in the wadden Sea area. → = succession; ←---- = regression (by overgrazing, erosion, manuring); ..... = examples of zonations; * = occurring on the East-Frisian and West-Frisian islands only.

compilation work and map discussed in this paper should particularly be judged in this context.

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